The 10th International Conference on Fluid Power Transmission and Control
April 11-13, 2021, Hangzhou, China

Hosted by

Sponsored by
# Table of Contents

- Welcome Message ........................................... 1
- Conference Committees .................................. 2
- Program at a Glance ....................................... 5
- Keynote Speech List ....................................... 6
- Paper List of Sessions .................................... 7
- Keynote Speeches .......................................... 15
- Session Papers ............................................. 36
- Online Access (coming soon) ............................ 114
- Conference Venue .......................................... 115
- About Prevention of COVID-19 ........................ 117
- Exhibition .................................................. 118
Welcome Message

Since its inception in 1985, the international conference on fluid power transmission and control (ICFP) has been held consecutively and successfully in Hangzhou every four years. The conference has been offering great opportunities for fluid power researchers and participants all over the world to exchange their research ideas and show their latest research findings. Today, the 10th succeeding conference (ICFP 2021) is held on time. It is my great pleasure to express my warm welcome and sincere appreciation to all authors, attendees and guests for their valuable contributions to the conference.

With its glorious history, fluid power transmission and control technology is still making continual progress and getting new achievements to satisfy the increasing demand from development of modern industry and society. Therefore, the conference covers almost all of the most important and interesting research subjects of fluid power transmission and control. Besides conventional academic sessions, we also set an exhibit session for industrial partners to showcase their innovative technologies and a poster session for introducing the state key laboratory of fluid power & mechatronics systems. I believe this conference will further push forward the development of fluid power transmission and control technology.

Hangzhou is one of the seven ancient capitals and has always been the most attractive tourist city in China with the picturesque scenery of the West Lake located right in the heart of the city. I hope you could enjoy your stays here.

Chair: Prof. Huayong YANG
Honorary Chair
Lu, Yongxiang 
Zhejiang University, China

Chair
Yang, Huayong 
Zhejiang University, China

International Advisory Committee
Angue, Eric 
Festo (China) Automation Ltd., Germany
Fiebig, Wieslaw 
Wroclaw University of Science and Technology, Poland
Haack, Steffen 
Bosch Rexroth AG, Germany
Handroos, Heikki 
Lappeenranta University of Technology, Finland
Hong, Yeh-Sun 
Korea Aerospace University, Korea
Ito, Kazuhisa 
Shibaura Institute of Technology, Japan
Jiao, Zongxia 
Beihang University, China
Johansen, Per 
Aalborg University, Denmark
Juliano De Negri, V. 
Federal University of Santa Catarina, Brazil
Kagawa, Toshiharu 
Tokyo Institute of Technology, Japan
Kong, Xiangdong 
Yanshan University, China
Krus, Petter 
Linkoping University, Sweden
Lu, Daming 
Chinese Mechanical Engineering Society, China
Manring, Noah 
University of Missouri, USA
Mao, Ming 
China North Vehicle Research Institute, China
Mare, Jean-Charles 
INS A Toulouse, France
Mattila, Jouko 
Tampere University of Technology, Finland
Murrenhoff, Hubertus 
RWTH Aachen University, Germany
Plummer, Andrew 
University of Bath, UK
Ramfeld, Robert 
Danfoss Power Solutions, Germany
Rundo, Massimo 
Politecnico di Torino, Italy
Sanada, Kazushi 
Yokohama National University, Japan
Scheidl, Rudolf 
Johannes Kepler University Linz, Austria
Schmitz, Katharina 
RWTH Aachen University, Germany
Sha, Baosen  
China Hydraulics Pneumatics & Seals Association, China

Stelson, Kim A.  
University of Minnesota, USA

Su, Zimeng  
China Construction Machinery Association, China

Sun, Zongxuan  
University of Minnesota, USA

Tanaka, Yutaka  
Hosei University, Japan

Vacca, Andrea  
Purdue University, USA

Wang, Changjiang  
China Hydraulics Pneumatics & Seals Association, China

Wang, Qingfeng  
Zhejiang University, China

Wang, Yuming  
Tsinghua University, China

Xiang, Changle  
Beijing Institute of Technology, China

Yao, Bin  
Purdue University, USA

Zen, Guangshang  
China Academy of Launch Vehicle Technology, China

Zhao, Dingxuan  
Yanshan University, China

**Organization Committee**

**Chair**
Xu, Bing  
Zhejiang University, China

**General Secretaries**
Li, Xin  
Zhejiang University, China

Wang, Feng  
Zhejiang University, China

**Members**
Cao, Yong  
Shanghai Radk-Tech Hydraulic System Co., Ltd.

Ge, Yaozheng  
Zhejiang University, China

Gong, Guofang  
Zhejiang University, China

Jin, Bo  
Zhejiang University, China

Kimmich, Martin  
Festo (China) Automation Ltd., Germany

Kong, Xiaowu  
Zhejiang University, China

Ma, Qinghai  
SMC (China) Co., Ltd.

Lin, Yonggang  
Zhejiang University, China

Liu, Hao  
Zhejiang University, China

Liu, Hongwei  
Zhejiang University, China

Ouyang, Xiaoping  
Zhejiang University, China

Ren, Bingbing  
Linde Hydraulics GmbH & Co. KG
Tao, Guoliang  Zhejiang University, China
Wang, Liping   Jiangsu Hengli Hydraulic Co., Ltd.
Wei, Jianhua   Zhejiang University, China
Wang, Wei   Bosch Rexroth AG, China
Weng, Zhidan   Ningbo Hoyea Machinery Manufacture Co., Ltd.
Wu, Shijun  Zhejiang University, China
Xie, Haibo  Zhejiang University, China
Yang, Geng  Zhejiang University, China
Zhang, Junhui  Zhejiang University, China
Zhou, Hua  Zhejiang University, China
Zhu, Xiaocong  Zhejiang University, China
Zhu, Yi  Zhejiang University, China
## Program at a Glance

<table>
<thead>
<tr>
<th>Apr. 11</th>
<th>All day</th>
<th>Registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-8:30</td>
<td>Opening ceremony (3rd fl., Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>8:30-9:30</td>
<td>Keynote speeches 1-2 (3rd fl., Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>9:30-10:15</td>
<td>Group photo and tea break (3rd fl., Lobby)</td>
<td></td>
</tr>
<tr>
<td>10:15-12:15</td>
<td>Keynote speeches 3-6 (3rd fl., Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>12:15-13:30</td>
<td>Buffet lunch (2nd fl., Tianyu hall)</td>
<td></td>
</tr>
<tr>
<td>13:30-14:50</td>
<td>Parallel sessions 1-5</td>
<td></td>
</tr>
<tr>
<td>15:00-16:20</td>
<td>Parallel sessions 6-10</td>
<td></td>
</tr>
<tr>
<td>16:20-16:40</td>
<td>Tea break (3rd floor, Lobby)</td>
<td></td>
</tr>
<tr>
<td>16:40-18:20</td>
<td>Parallel sessions 11-15</td>
<td></td>
</tr>
<tr>
<td>18:00~</td>
<td>Buffet dinner (2nd fl., Tianyu hall)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Apr. 12</th>
<th>All day</th>
<th>Registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-10:00</td>
<td>Keynote speeches 7-10 (3rd floor, Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>10:00-10:20</td>
<td>Tea break (3rd fl., Lobby)</td>
<td></td>
</tr>
<tr>
<td>10:20-11:50</td>
<td>Keynote speeches 11-13 (3rd floor, Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>11:50-13:30</td>
<td>Buffet lunch (2nd fl., Tianyu hall)</td>
<td></td>
</tr>
<tr>
<td>13:30-15:10</td>
<td>Parallel sessions 16-20</td>
<td></td>
</tr>
<tr>
<td>15:10-15:30</td>
<td>Tea break (3rd fl., Lobby)</td>
<td></td>
</tr>
<tr>
<td>15:30-17:30</td>
<td>Parallel sessions 21-25</td>
<td></td>
</tr>
<tr>
<td>18:00~</td>
<td>Banquet (3rd floor, Shimao hall)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Apr. 13</th>
<th>All day</th>
<th>Registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-10:00</td>
<td>Keynote speeches 7-10 (3rd floor, Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>10:00-10:20</td>
<td>Tea break (3rd fl., Lobby)</td>
<td></td>
</tr>
<tr>
<td>10:20-11:50</td>
<td>Keynote speeches 11-13 (3rd floor, Shimao hall)</td>
<td></td>
</tr>
<tr>
<td>11:50-13:30</td>
<td>Buffet lunch (2nd fl., Tianyu hall)</td>
<td></td>
</tr>
<tr>
<td>13:30-15:10</td>
<td>Parallel sessions 16-20</td>
<td></td>
</tr>
<tr>
<td>15:10-15:30</td>
<td>Tea break (3rd fl., Lobby)</td>
<td></td>
</tr>
<tr>
<td>15:30-17:30</td>
<td>Parallel sessions 21-25</td>
<td></td>
</tr>
<tr>
<td>18:00~</td>
<td>Banquet (3rd floor, Shimao hall)</td>
<td></td>
</tr>
</tbody>
</table>
# Keynote Speech List

*All the keynote speeches will be carried out in Shimao Hall on 3rd floor.*

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 12</td>
<td>8:30-9:00</td>
<td>Future Mobile Machinery from Vision to Mission</td>
<td>Prof. Katharina Schmitz (RWTH Aachen University)</td>
</tr>
<tr>
<td></td>
<td>9:00-9:30</td>
<td>Piezo Technology and Application</td>
<td>Mr. Eric Angue (Festo (China) Automation Ltd.)</td>
</tr>
<tr>
<td></td>
<td>10:15-10:45</td>
<td>An Efficient Drive Technology for Electrified Off-road Vehicles</td>
<td>Prof. Andrea Vacca (Purdue University)</td>
</tr>
<tr>
<td></td>
<td>10:45-11:15</td>
<td>Recent Developments of Micro Hydraulic System Technologies</td>
<td>Prof. Kazuhiro Yoshida (Tokyo Institute of Technology)</td>
</tr>
<tr>
<td></td>
<td>11:15-11:45</td>
<td>Towards High-performance and Energy-efficient System of Systems Control of Heterogenous Heavy-duty Mobile Manipulators</td>
<td>Prof. Jouni Mattila (Tampere University of Technology)</td>
</tr>
<tr>
<td></td>
<td>11:45-12:15</td>
<td>Potential for Noise Reduction in Fluid Power Units</td>
<td>Prof. Wieslaw J. Fiebig (Wroclaw University of Science and Technology)</td>
</tr>
<tr>
<td>Apr. 13</td>
<td>8:00-8:30</td>
<td>Development of 3D technology from fluid power components to bioprinting</td>
<td>Prof. Huayong Yang (Zhejiang University)</td>
</tr>
<tr>
<td></td>
<td>8:30-9:00</td>
<td>Hydrostatic Machines for the Future</td>
<td>Dr. Robert Rahmfeld (Danfoss Power Solutions)</td>
</tr>
<tr>
<td></td>
<td>9:00-9:30</td>
<td>Artificial ventilation of the human respiratory system: modelling and optimization</td>
<td>Prof. Andrew Plummer (University of Bath)</td>
</tr>
<tr>
<td></td>
<td>9:30-10:00</td>
<td>Efficient and Precise Control of Fluid Power Systems</td>
<td>Prof. Zongxuan Sun (University of Minnesota)</td>
</tr>
<tr>
<td></td>
<td>10:20-10:50</td>
<td>Industrial Hydraulics: Now – Next – Beyond</td>
<td>Dr. Steffen Haack (Bosch Rexroth AG)</td>
</tr>
<tr>
<td></td>
<td>10:50-11:20</td>
<td>Why switching from hydraulic to electric actuation in Aerospace is not so simple?</td>
<td>Prof. Jean-Charles Mare (The French National Institute of Applied Sciences(INSA Toulouse))</td>
</tr>
</tbody>
</table>
# Paper List of Sessions

<table>
<thead>
<tr>
<th>Session 1: Intelligent Fluid Power</th>
<th>Apr. 12 13:30-14:50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Xiaoping Ouyang (Zhejiang University) and Prof. Yaoxing Shang (Beihang University), Wenlan hall, 2nd floor.</td>
<td></td>
</tr>
<tr>
<td>S0101 Hydro-Mechanical Closed-Loop Braking Torque Control - Experimental Investigation and Influence Analysis</td>
<td></td>
</tr>
<tr>
<td>S0102 Development Status of Connected Hydraulics</td>
<td></td>
</tr>
<tr>
<td>S0103 Research on Multi-Sensor and Multi-Level Information Fusion Technology for Fault Diagnosis of Directional Control Valve</td>
<td></td>
</tr>
<tr>
<td>S0104 Development of a Lumped-parameter Thermal Model for Electro-Hydraulic Actuator</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 2: Hydraulic Pumps</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Defa Wu (Huazhong University of Science and Technology) and Prof. Junhui Zhang (Zhejiang University), Shimao hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S0201 Optimal Design of Accelerated Life Testing for Hydraulic Piston Pump</td>
<td></td>
</tr>
<tr>
<td>S0202 Evaluation and Optimization of Axial Piston Pump Textured Slipper Bearings Based on Hybrid Genetic Algorithm</td>
<td></td>
</tr>
<tr>
<td>S0203 Dynamic Model Based Transfer Path Contribution Analysis of an Axial Piston Pump</td>
<td></td>
</tr>
<tr>
<td>S0204 Based on Amesim Simulation to Improve the Hysteresis Performance of Ultra-High Pressure and Large Flow Emulsion Pump Valve</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 3: Water Hydraulics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Hua Zhou (Zhejiang University) and Prof. Jiyun Zhao (China University of Mining and Technology), Wenjin hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S0301 Deep Sea Water Hydraulics: From 300 Meters to 11000 Meters</td>
<td></td>
</tr>
<tr>
<td>S0302 Research on the Friction and Wear Test and Lubrication Simulation of the Valve Plate Pair with Bionic Non-Smooth Surface in Water Hydraulic Motor</td>
<td></td>
</tr>
<tr>
<td>S0303 Numerical Simulation of Integrated Energy Recovery and Pressure Boost Device for Seawater Desalination</td>
<td></td>
</tr>
<tr>
<td>S0304 Separation Rate of Soft Tissue under High Speed Waterjet Impact: an Experimental Study on Gelatine Fracture Process</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 4: Mobile Hydraulics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Dr. Likui Zhai (Danfoss Power Solutions) and Prof. Feng Wang (Zhejiang University), Jiahe hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S0401 Matching Research on Self- Energy-Feed Heat Dissipation Hydraulic Auxiliary Brake System</td>
<td></td>
</tr>
<tr>
<td>Session 5: Renewable Energy</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>Chaired by Prof. Chao Ai (Yanshan University) and Prof. Hongwei Liu (Zhejiang University), Jianian hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S0501 Electrohydraulic Loading Technology for Simulating 5-DOF Loads of Large-Scale Wind Turbines</td>
<td></td>
</tr>
<tr>
<td>S0502 Dynamic Response Analysis of Energy Storage Hydraulic Wind Turbine</td>
<td></td>
</tr>
<tr>
<td>S0503 A Broadband and Frequency Up-converted Electromagnetic Vibration Energy Harvester</td>
<td></td>
</tr>
<tr>
<td>S0504 Effect of Accumulator on Dynamic Performance of a Hydraulic Wave Energy Conversion System</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 6: Hybrid Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Min Cheng (Chongqing University) and Prof. Tianliang Lin (Huaqiao University), Wenlan hall, 2nd floor.</td>
</tr>
<tr>
<td>S0601 Influence Study of the Different EDC and PC Control Layouts in Open Circuit Pump</td>
</tr>
<tr>
<td>S0602 Modeling of Hydraulic Hybrid Wind Turbine Transmission with Realistic Accumulator</td>
</tr>
<tr>
<td>S0603 Hydrodynamic Characteristics Research on Water-Jet Hybrid Glider’s Flying-Fish-Inspired Wings</td>
</tr>
<tr>
<td>S0604 Research on The Driving Characteristics of Hydraulic Excavator Boom Based on The Hydraulic-Electric Hybrid Driving Principle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 7: Sensors and Actuators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Liang Yan (Beihang University) and Prof. Liang Lu (Tongji University), Shimao hall, 3rd floor.</td>
</tr>
<tr>
<td>S0701 A Soft Actuator System for In-Bed Body Movement Assistant</td>
</tr>
<tr>
<td>S0702 Empirical Nonlinear Model Based Pneumatic Soft Bending</td>
</tr>
<tr>
<td>S0703 A New Type of Pneumatic Soft Actuator for Spiral Motion and Its Characteristics</td>
</tr>
<tr>
<td>S0704 A Novel Pneumatic Soft Actuator with Variable Stiffness Based on Extensor-Contractor Actuation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 8: Control Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 9: Mobile Hydraulics</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Chaired by Prof. Feng Wang (Zhejiang University) and Prof. Likui Zhai (Danfoss Power Solutions), Jiahe hall, 3rd floor.</td>
</tr>
<tr>
<td>S0901 On-Line Optimization Based on Pontryagin’s Minimum Principle for a Series Hydraulic Hybrid Wheel Loader</td>
</tr>
<tr>
<td>S0902 The Control and Performance Analysis of a Micro Excavator with Distributed Pump-Controlled System</td>
</tr>
<tr>
<td>S0903 Compound Control System Based on Minimum Differential Pressure for Electric Excavators Powertrain</td>
</tr>
<tr>
<td>S0904 Energy Consumption Analysis of Multi-Axle Steering System for Heavy Vehicle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 10: Renewable Energy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Hongwei Liu (Zhejiang University) and Prof. Chao Ai (Yanshan University), Jianian hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S1001 Research on an Electro-Hydraulic Independent Pitch System of Tidal Current Turbine</td>
<td></td>
</tr>
<tr>
<td>S1002 Study on Oscillating Float Wave Energy Generation Experiment Platform and Energy Harvesting System</td>
<td></td>
</tr>
<tr>
<td>S1003 Performance Characteristics of Horizontal Axis Tidal Turbine Considering Nose Shape, Angle of Inflow and Tower Structure</td>
<td></td>
</tr>
<tr>
<td>S1004 Effects of Different Air Turbines on The Operation Characteristics of Backward Bend Duct Buoy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 11: Modelling and Simulation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Lingxiao Quan (Yanshan university) and Prof. Xiaocong Zhu (Zhejiang University), Wenlan hall, 2nd floor.</td>
<td></td>
</tr>
<tr>
<td>Apr. 12 16:40-18:20</td>
<td>Model Predictive Displacement Control Tuning for Tap-Water-Driven Muscle by Inverse Optimization with Adaptive Model Matching</td>
</tr>
<tr>
<td>S1102 Dynamic Analysis of Hydraulic Pipeline Based on Substructure Method</td>
<td></td>
</tr>
<tr>
<td>S1103 CFD analysis of the leakages in external gear pump</td>
<td></td>
</tr>
<tr>
<td>S1104 System Diagnostic for an Electrohydraulically Actuated Controlled Trajectory Rapid Compression and Expansion Machine</td>
<td></td>
</tr>
</tbody>
</table>
### Session 12: Sensors and Actuators
Chaired by Prof. Liang Lu (Tongji University) and Prof. Liang Yan (Beihang University), Shimao hall, 3rd floor.

<table>
<thead>
<tr>
<th>Session 12</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1201</td>
<td>Electromechanical Actuator for Large Sized Directional Control Valves</td>
</tr>
<tr>
<td>S1202</td>
<td>Research on Jet Driven Water Hydraulic Rotary Actuator</td>
</tr>
<tr>
<td>S1203</td>
<td>Output Feedback Control for Electro-Hydraulic Servo Actuator Based on Levant Differentiator</td>
</tr>
<tr>
<td>S1204</td>
<td>Calibration Technology and Development of the Liquid Automatic Particle Counter</td>
</tr>
<tr>
<td>S1205</td>
<td>Highly Stable Stretchable Strain Sensors by Laser Processing</td>
</tr>
</tbody>
</table>

### Session 13: Control Systems
Chaired by Prof. Zheng Chen (Zhejiang University) and Prof. Jianyong Yao (Nanjing University of Science and Technology), Wenjin hall, 3rd floor.

<table>
<thead>
<tr>
<th>Session 13</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1301</td>
<td>A New Piecewise Linearization and Multi-Model Switching Control Method for The Hydraulic Transformer Control System</td>
</tr>
<tr>
<td>S1302</td>
<td>Precision Motion Control of An Electro-Hydraulic Actuator with Motor Pump Speed Dead Zone Compensation</td>
</tr>
<tr>
<td>S1303</td>
<td>Model Analysis on Vibration Characteristics of Hydraulic Shock Rotary Exciter</td>
</tr>
<tr>
<td>S1304</td>
<td>Performance Analysis of Double-screw Hydraulic Joint Based on Rolling Friction</td>
</tr>
<tr>
<td>S1305</td>
<td>Hydraulic Control System for an Asymmetric Cylinder Based on Dual-Constant Pump Driven by Dual-Servo Electric Motor Respectively</td>
</tr>
</tbody>
</table>

### Session 14: Light Hydraulics
Chaired by Prof. Jing Yao (Yanshan University) and Prof. Yi Zhu (Zhejiang University), Jiahe hall, 3rd floor.

<table>
<thead>
<tr>
<th>Session 14</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1401</td>
<td>A Novel Design Method for Hydraulic Manifold Blocks via Additive Manufacturing</td>
</tr>
<tr>
<td>S1402</td>
<td>Design of High-Speed 2D Piston Pumps for High Efficiency</td>
</tr>
<tr>
<td>S1403</td>
<td>The Modelling and Dynamic Characteristics of A Non-Metallic Pressurized Reservoir with Variable Volume</td>
</tr>
<tr>
<td>S1404</td>
<td>Design and Analysis on Light Weight Carbon Fibre-Reinforced Hydraulic Cylinder</td>
</tr>
<tr>
<td>S1405</td>
<td>Lightweight Design Method of Electro-Hydraulic Actuator Based on Rib Structure</td>
</tr>
</tbody>
</table>

### Session 15: Pneumatic Components
<table>
<thead>
<tr>
<th>Session 16: Intelligent Fluid Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Jianfeng Tao (Shanghai Jiao Tong University) and Prof. Tian Yu (Beihang University), Wenlan hall, 2nd floor.</td>
</tr>
<tr>
<td>S1601 A Passive Hydraulic System Increasing the Efficiency of Legged Robot</td>
</tr>
<tr>
<td>S1602 Attitude Adaptive Manipulation of Soft Dexterous Hand with Reinforcement Learning Method</td>
</tr>
<tr>
<td>S1603 Electro-Hydrostatic Actuators in Primary Flight Control – Lifetime and Reliability of Eha Piston Pumps</td>
</tr>
<tr>
<td>S1604 Development of Bendable and Twistable Electrohydrodynamic Pump with Improved Electrode Patterns</td>
</tr>
<tr>
<td>S1605 Neural Network-Based Robust Control of Hydraulic Systems with Partial Output Feedback</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 17: Valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Dr. Heng Du (Fuzhou University) and Prof. Haigang Ding (China University of Mining and Technology), Shimao hall, 3rd floor.</td>
</tr>
<tr>
<td>S1701 A Study on a MEMS Electro-Rheological Valve for Higher Pressure</td>
</tr>
<tr>
<td>S1702 Effects of Two-Stage Sleeves Deflection on Cavitation of High-Pressure Control Valve</td>
</tr>
<tr>
<td>S1703 Study on Characteristics of Two Dimensional Rotary Electromagnet</td>
</tr>
<tr>
<td>S1704 Numerical Analysis and Optimization of Ultra-clean Electric Valve with Magnetically Driven Poppet</td>
</tr>
<tr>
<td>S1705 Characteristic of Unsteady Cavitation Behaviour and Pressure Pulsation in Regulate Valve</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 18: Water Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Yinshui Liu (Huazhong University of Science and Technology) and Prof. Yongjun Gong (Dalian Maritime University), Wenjin hall, 3rd floor.</td>
</tr>
<tr>
<td>S1801 Design and Simulation on Pressure Difference and Flow Compound Control Valve for Water Hydraulic Artificial Muscle Joint</td>
</tr>
<tr>
<td>Session 19: Pneumatic Systems</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Chaired by Prof. Wei Xiong (Dalian Maritime University) and Prof. Tao Wang (Beijing Insititute of Technology), Wencong hall, 3rd floor.</td>
</tr>
<tr>
<td>S1901 Myoelectric Control of a Pneumatic Hand Rehabilitation Glove Using Pattern Recognition</td>
</tr>
<tr>
<td>S1902 A Low Friction Pneumatic Cylinder Based on Vibration Friction Reduction Theory and Its Motion Tracking Control</td>
</tr>
<tr>
<td>S1903 Research on Position Control of Friction Compensation Based on Improved Artificial Bee Colony Algorithm</td>
</tr>
<tr>
<td>S1904 The Simulation System Development of Bridge-Type Pneumatic Circuit and Its Experimental Verification</td>
</tr>
<tr>
<td>S1905 Research on the Application of Digital Pneumatics Control Technology in Industry4.0 Smart Manufacturing System Construction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 20: Industrial Hydraulics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Haibo Xie (Zhejiang University) and Dr. Wei Wang (Bosch Rexroth China), Jianian hall, 3rd floor.</td>
<td></td>
</tr>
<tr>
<td>S2001 Energy Saving Analysis of the Independent Metering System with Pressure Compensated Method in the Offside</td>
<td></td>
</tr>
<tr>
<td>S2002 Dynamic Characteristics Study of Electro-hydraulic Load-sensing Control System</td>
<td></td>
</tr>
<tr>
<td>S2003 A Mathematic Model for the Self-Rotation of the Slipper-Piston Assembly in Axial Piston Machines</td>
<td></td>
</tr>
<tr>
<td>S2004 Utilization of Gated Recurrent Units Combined with Attention Mechanism for Rock Mass Recognition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Session 21: Fundamentals and Fluids</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaired by Prof. Songjing Li (Harbin Institute of Technology) and Prof. Liang Hu (Zhejiang University), Wenlan hall, 2nd floor.</td>
<td></td>
</tr>
<tr>
<td>S2101 Analysis of Cavitation in Suction Channel of Pneumatic Drive Bellows Pump</td>
<td></td>
</tr>
</tbody>
</table>
Session 22: Hydraulic Pumps
Chaired by Dr. Chengxiang Wang (Bosch Rexroth China) and Prof. Wei Wu (Beijing Institute of Technology), Shimao hall, 3rd floor.

- S2201 Numerical Simulation of Churning Losses of Axial Piston Pump Using the Moving Particle Semi Implicit Method
- S2202 Investigation of Critical Inlet Pressure for Aerospace Hydraulic Pump with Boost Impeller Based on CFD
- S2203 A Numerical Model of Rotary Lip Seals Based on Non-Reverse-Pumping Mechanism
- S2204 Closed Circuit Solution for Concrete Pump
- S2205 Visualization of Fluid Flow Phenomena in a Single-Acting Vane Pump
- S2206 Analysis of Wear Degradation Process of Piston/cylinder Pair in Axial Piston Pumps

Session 23: Friction and Sealing
Chaired by Weifeng Huang (Tsinghua University) and Prof. Xudong Peng (Zhejiang University of Technology), Wenjin hall, 3rd floor.

- S2301 Performance Analysis of the Vl Seal Under Starved Conditions
- S2302 Influence and Selection of Numerical Model in Supercritical CO2 Dry Gas Seal
- S2303 Research On Leakage Characteristics of Metallic Seals Based On Soft/Hard Contact Theories
- S2304 Leakage Characteristics of Prototype Gasket Using Viscosity-Temperature Relation under Vibration Condition (Effects of Sealing Land and Viscosity Grade)
- S2305 Effect of Hydrostatic Pressure on the Tribocorrosion Behaviour of WC-10Co-4Cr Coupled to Si3N4 in 3.5 wt.% NaCl Solution
- S2306 Design of High-speed Large-scale Reciprocating Gap Seal Test Bench

Session 24: Fluid Media and Contamination
Chaired by Prof. Lipeng Du (Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.) and Prof. Hong Ji (Lanzhou University of Technology), Wencong hall, 3rd floor.

- S2401 Selective Separation of Air Bubbles from Working Oil by Bubble Elimination Device
<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2402</td>
<td>Application of Contamination Control In Super-Big Hydraulic System</td>
</tr>
<tr>
<td>S2403</td>
<td>Study of the Preparation of Filter Medium with Multilayer Structure and Its Impact on Oil Filtration Performance</td>
</tr>
<tr>
<td>S2404</td>
<td>Evaluation of Service Life of Filter Elements</td>
</tr>
<tr>
<td>S2405</td>
<td>Research and Practice of Contamination Tolerance of Hydraulic Components</td>
</tr>
<tr>
<td>S2406</td>
<td>Fluid Contamination Control Practice of Super Large Hydraulic System</td>
</tr>
</tbody>
</table>

**Session 25: Industrial Hydraulics**

Chair: Prof. Ruqi Ding (East China Jiaotong University) and Prof. Hu Shi (Xi’an Jiaotong University), Jianian hall, 3rd floor.

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2501</td>
<td>New Control Method of Active Absorption Wave-maker Based on Digital Twin-valve</td>
</tr>
<tr>
<td>S2502</td>
<td>Research on Performance of Biped Robot Hydraulic Drive System Based on Servo and Digital Control</td>
</tr>
<tr>
<td>S2503</td>
<td>Loss Optimal Control Strategy of Speed and Displacement Variable Electrohydrostatic Axes</td>
</tr>
<tr>
<td>S2504</td>
<td>Modeling and Analysis of a Novel Hydraulic Control Method for a Digital Hydraulic Actuator</td>
</tr>
<tr>
<td>S2505</td>
<td>Analysis of Vibration Characteristics of Intersecting Common-wall Pipeline</td>
</tr>
</tbody>
</table>
Keynote Speeches
Keynote Speech 1

Chaired by Prof. Huayong Yang (Zhejiang Univ.), 8:30-9:00, April 12, 3rd fl. Shimao hall

Future Mobile Machinery from Vision to Mission

Prof. Katharina Schmitz (RWTH Aachen University)

Brief Biography

Education and Scientific Career:
- since 2018 Director of the Institute for Fluid Power Drives and Systems (ifas), RWTH Aachen University
- 2015 Doctoral thesis and Dr.-Ing. certificate with the thesis: "Eindimensionale Hydrauliksimulation mehrphasiger Systeme"
- 2005 - 2010 Study of Mechanical Engineering, RWTH Aachen University, Specialization: Mechanical Process Engineering

Professional Background:
- 2016 - 2017 Technical Manager, Hunger Maschinen GmbH, Würzburg
- 2010 - 2015 Academic staff at IFAS of RWTH Aachen University
- 2013-2015 Deputy Chief Engineer

Abstract

In recent years, increasing efforts have been made in the automation of mobile machinery. While agriculture has made great strides in this area, automation in the construction industry, despite having made some progress, is still in its infancy. Nevertheless, the challenges faced by the construction industry - shortage of skilled workers in Europe as well as more efficient machine utilization, improved workplace safety, increased productivity - make automation necessary. For example, labor productivity in the construction industry has been stagnating for decades, while in agriculture or manufacturing it has increased rapidly.

Assistance systems - 2D and 3D digging assistants, fleet management systems - are already available on modern construction machines. With regard to a further development of automation, the recognition of the environment is indispensable. New types of sensors - LIDAR, stereo cameras are increasingly mastering the rough, dusty, and sometimes very dynamic environment of a construction site.
Therefore, approaches for automated digging or handling processes are increasingly an area of interest for research and development. For particularly hazardous environments - mining, demolition, chemical or radioactive contamination - remote-controlled machines are often used nowadays. The avoidance of latencies and process feedback for the driver are the subject of research. Besides that, the automation of sub-steps offers great advantages, as several machines can be operated in parallel and thus potentially increasing work productivity significantly. The networking of construction machines among themselves is necessary for automated working with several machines, like in a loading process. The construction process is composed of a large number of processes and participants. In order to optimize the entire process, it must be viewed as a whole, the construction machines must be networked for collaboration and increased efficiency, and machines and people must be integrated from planning to execution.

At RWTH Aachen University, an interdisciplinary scientific team, including the Institute for Fluid Power Drives and Systems (ifas), is researching in partnership with an industrial consortium on the construction site of the future. Beginning with the pre-production of construction elements and continuing with the automated and digitized construction site, research is conducted at the Reference Construction Site of RWTH Aachen University. The focus lies on optimization, automation, digitization and networking of the construction process and testing under real construction site conditions.

In the context of this keynote the state of the art in the automation of construction machines is shown and the Reference Construction Site is presented as a research approach of ifas and RWTH Aachen University.
Piezo Technology and Application

Mr. Eric Angue (Festo (China) Automation Ltd.)

Brief Biography

- Nov. 2019 till now, work at FestoESTO Production Ltd. in Shanghai (CN), Vice President, Head of R+D Greater China and Korea.

Abstract

As an innovation leader, for many years Festo has been providing impetus for factory automation and offers a wide product portfolio for advanced technology. That is why Festo makes use of intelligent components to facilitate and speed up the engineering process when it comes to configuring, commissioning and operating facilities. With all the benefits of compactness, lightweight, extremely precision, very durable and incredible fastness and above all save energy, Piezo technology offers a better alternative to conventional solenoid valves, especially in the areas of flow and pressure control and as directly controlled proportional valves. This speech provides you with answers to the following questions of how does piezo technology work, what is the principle behind it, and in which industry sectors and for which applications are piezo valves the technology of the future? For example, in the semiconductor industry with the accuracy and ability to quickly reach preselected setpoints ensure precise metering of even the smallest amounts of air or gas, and precise regulation of the pressure and vacuum used to press silicon wafers onto a polishing table.
An Efficient Drive Technology for Electrified Off-Road Vehicles

Prof. Andrea Vacca (Purdue University)

Brief Biography

Dr. Vacca completed his studies in Italy (Ph.D. from the University of Florence in 2005) and he joined Purdue University in 2010 after being an Assistant Professor at the University of Parma (Italy). He is chair of Fluid Power Systems and Technology Division of the American Society of Mechanical Engineers, and a former chair of the Fluid Power division of the Society of Automotive Engineers (SAE). Dr. Vacca is also one of the Directors of the Global Fluid Power Society (GFPS). Furthermore, he is also the Editor in Chief of the International Journal of Fluid Power.

His research interests include modeling and simulation of hydraulic systems, modeling and testing of pumps and motors for fluid power applications, hydraulic valves modeling and testing, reduction of noise emissions in fluid power systems.

Abstract

The recent electrification trend affecting off-road vehicles is pushing more than ever research towards more energy efficient solutions for mobile hydraulics. Several solutions have been developed affecting the individual components as well as the circuitual architecture of the hydraulic drive system. This presentation focuses on the solution currently under investigation at the Maha Fluid Power Research Center of Purdue University. The proposed solution aims at merging the advantages of both fluid power and electric technologies to implement a cost-effective and efficient hybrid solution. High energy efficiency is achieved by avoiding fluid throttling losses associated with the control of the hydraulic actuators, as well as allowing energy recuperations during instances of overrunning loads. Cost and simplicity of the hydraulic system is achieved through a solution that utilizes gear pumps in an open circuit configuration.

The presentation illustrates the main features of the proposed hydraulic circuit, giving emphasis to the design and the integration of the electric machine (a permanent magnet unit) and the hydraulic machine (a gear unit), to achieve maximum energy efficiency and high compactness. Considering
as reference the case of a compact wheel loader, the results show how the proposed solution permits to achieve energy savings higher that 50%, depending on the utilization cycle of the machine, when compared to the state of the art technology. The presentation is based on the results of a research supported by the US Dept. of Energy (award number: DE-EE0008334), which is performed in collaboration with Case New Holland Industrial and Bosch Rexroth.
Recent Developments of Micro Hydraulic System Technologies

Prof. Kazuhiro Yoshida (FIRST, IIR, Tokyo Institute of Technology)

Brief Biography

Professor Kazuhiro Yoshida received his B.E. degree in electrical engineering from Yokohama National University, Japan in 1984 and M.E. and Ph.D. degrees in control engineering from Tokyo Institute of Technology, Japan in 1986 and 1989, respectively. He is a member of the Japan Fluid Power System Society, the Japan Society of Mechanical Engineers, IEEE, and similar associations.

His research interests include microrobots using fluid power, functional fluids applications, and fluid power systems.

Abstract

Hydraulic systems are useful to microrobots due to their high power density. Using a functional fluid such as an electro-rheological fluid (ERF), the fluid power can be controlled with a simple micro device. In this speech, recent developments of micro hydraulic system technologies are introduced. As an example, a flexible electro-rheological microvalve (FERV) for soft microactuators is presented. The FERV having a simple and flexible structure controls the ERF flow with its viscosity change due to the applied electric field. Then, a multiple ER microactuator system using an alternating pressure source is presented (see the figure). The alternating pressure system rectifies the alternating flow by synchronous switching of ER microvalves and can realize small piping space for a multiple actuator system in a microrobot. Furthermore, a high power piezoelectric micropump using fluid inertia is presented. The pump is a piezoelectric diaphragm pump with replacing the outlet check valve by a small diameter pipe. By using the fluid inertia effect in the pipe, the simple pump can discharge larger volume than the displacement. By showing those case studies, the effectiveness of the micro hydraulic system technologies is demonstrated.
Towards high-performance and energy-efficient system of systems control of heterogenous heavy-duty mobile manipulators

Prof. Jouni Mattila (Tampere University of Technology)

Brief Biography

Professor Jouni Mattila received the M.Sc. Degree in 1995 and Dr. Tech Degree in 2000, both from the Tampere University of Technology. He has been the principal investigator (PI) in numerous national and European Union funded R&D-projects. Prof. Mattila is currently a Technical Editor of the IEEE/ASME Transactions on Mechatronics. His research interest includes machine automation, nonlinear model-based control system development for robotic mobile manipulators and off-highway machinery, and energy-efficiency of fluid power and hybrid systems.

Abstract

Europe has a strong focus on two key megatrends in twin transition R&D-programs that combine digital transformation with sustainability development. In terms of heavy-duty working machines, this twin transition strategy means more advanced autonomous functions and digital services at lower energy-consumption and emissions. Advanced control for hydraulic mobile manipulators has a high demand because of the robotization of heavy-duty working machines. Our research objective is to make a paradigm shift into heavy-duty mobile manipulator automation by developing a science-based control framework that would provide a modular, energy-efficient, yet high-performance solution with guaranteed stability for cooperating multi-mobile manipulator systems. Our main hypothesis is that even with such an extremely complex cooperating multi-mobile manipulator system, it is possible to design control components that can achieve a task-specific modularity and that would guarantee the stability and high performance of the system of systems. Modern mobile manipulators can be composed of complex energy-saving hydraulic and electric or hybrid actuator systems, making their system-level robotic control an extremely challenging task. These novel control-theoretic results are founded on advanced nonlinear modelling and our recently developed
control strategy called virtual decomposition control (VDC), which rigorously guarantees the stability of the system of systems (a system of interacting mobile manipulators as subsystems, each of which are virtually stable) without imposing additional approximations. In this talk, our recent research progress towards this ambitious objective is presented.
Potential for noise reduction in fluid power units

Prof. Wieslaw J. Fiebig (Wroclaw University of Science and Technology)

Brief Biography

Professor Wieslaw J. Fiebig received his Ph. D. degree in 1985 at Wroclaw University of Science and Technology. He is member of International Institute of Acoustics and Vibration IIAV.

He deals with machine dynamics, vibration and noise development and reduction in hydraulic machines and fluid power systems. He was one of the first authors in the field of modeling of dynamic phenomena in gear pumps and vane pumps as well as in fluid power units. His current additional interests include use of mechanical resonance in machines drive systems as well as the energy saving’s in machine drives.

Abstract

Fluid power units (FPU) determine often the noise development of many stationary industrial machines like hydraulic presses, machine tools, plastics molding machines, etc. Similar situation is also in the field of mobile hydraulics. Noise generated by FPU cannot be sufficiently decreased only with primary approaches towards single components and depends on mounting situation of the pumps, the mechanical structure and the layout of the hydraulic system. The noise behavior of FPU is therefore strongly system-dependent and is important in view of increased use of variable speed drives.

The total sound power level is given by the loudest source or sources of noise. Therefore, detection of the loudest noise sources has a key importance. The main noise sources and natural frequencies and mode shapes can be determined with an acoustic camera and by means Experimental Modal Analysis (EMA) and FEM.

The system approach is necessary to establish methods for noise reduction in fluid power drives. Avoiding of resonance phenomena for both fluid and structure borne vibrations has a great potential for noise reduction in fluid power drives. Knowledge of dynamic properties of fluid power drives is especially important in variable speed drives in which the frequency of excitations is
constantly changing. The methodology described in this paper has been used in many applications and its use leads to significant noise reduction of fluid power units.
Keynote Speech 7
Chaired by Prof. Bing Xu (Zhejiang University), 8:00-8:30, April 13, 3rd fl. Shimao hall

Development of 3D Technology from Fluid Power Components to Bioprinting

Prof. Huayong Yang (Zhejiang University)

Brief Biography

Professor Huayong Yang received his B.Sc. from Huazhong University of Science and Technology, China in 1982 and Ph.D. degree from University of Bath in 1988. He has been with Zhejiang University since 1989, and was made a full professor in 1996. He is currently the head of School of Mechanical Engineering Zhejiang University. He is a member of the Chinese Academy of Engineering. He was awarded Joseph Bramah Medal in 2017 and is a member in the board of directors in Global Fluid Power Society (GFPS) since 2018. He holds more than 290 invention patents and published authored over 380 peer reviewed journal papers.

His research interests are in motion control and energy saving of mechatronic systems, development of fluid power component and system, integration of electro-hydraulic system and engineering applications, 3D bioprinting machine and biofabrication applications.

Abstract

3D printing has been developing rapidly and widely used in various fields, such as fluid power and bio-manufacturing. In fluid power, 3D printing is efficient in increasing the fluid power components’ power density and part consolidation. In particular, fluid channels have experienced great design freedom using 3D technology. However, due to the layer-on-layer nature, fabricating defects and failures are found in specific regions, and moreover, a design approach still lacks. Here, we will show the influence of key parameters of 3D printed channels on fluid flow performance. General channel design criteria are developed. The first-version design tool of complex fluid channels based on 3D printing will also be presented, which takes weight, size, and fluid flow performance into account.

Metal 3D printing can also be used to fabricate customized dental implants. Based on gradient processing and surface roughness control, we are able to achieve consistent low roughness on a
dental implant surface with complicated geometries. In vitro and in vivo tests have indicated that the technology is promising for the future “immediate implantation”

In bio-manufacturing area, 3D bioprinting technology can be adapted to the dispensing of soft materials containing high-density cells in 3D space, which is a promising solution for the construction of functional tissues and organs in vitro. A novel designed high precision multi-nozzle bioprinter is presented, with a control algorithm for simultaneous control of up to 6 nozzles. Also, the fabrication methods for cell-laden skin and nerve conduit are introduced, both shown positive results for in vitro tests on animal models, with a full potential on future regenerative medicine.
Hydrostatic Machines for the Future

Dr. Robert Rahmfeld (Danfoss Power Solutions)

Brief Biography

Dr. Robert Rahmfeld is the Senior Director Engineering for Hydrostatics at Danfoss Power Solutions, being technically responsible for all axial piston units, including swash plate and bent-axis principle. He is with Danfoss over 15 years in various engineering positions, holds several patents, and is author or co-author of more than 40 scientific journal and conference papers. Before joining Danfoss, Dr. Rahmfeld completed his PhD on new displacement controlled hydraulic linear actuators at the Technical University of Hamburg in 2002, and his MSc in mechanical engineering at Duisburg University in 1996. He was also holding a postdoc position for 2 years at Technical University of Hamburg and Purdue University, Indiana, USA, before joining Danfoss Power Solutions.

Abstract

Simple continuous variability for rotary and linear drives as well robust reliability and efficient service concepts have enabled the powerful hydrostatic technology a continuous growth in the last decades, especially in mobile machine applications. The higher the power density requirements are, traditional central hydraulic system concepts powered by a combustion engine are still applied. However, it is well known that the total efficiency for hydraulic drives is in many cases relatively low, leading to corresponding exhaust and CO2 pollution. I.e. not improving this overall energy as well as heat balance, and/or not creating synergies between hydraulics and other technologies, will prevent even hybrid systems to enter this market segment. That is why a change usually starts as a combination or extension with somehow existing technologies, also to ensure the important robustness and reliability in the field. This overview lecture will therefore assess how those hydrostatic machines can fulfil these requirements for the market potential in the future, as mobile machines will be still required then.
Keynote Speech 9
Chaired by Prof. Bing Xu (Zhejiang University), 9:00-9:30, April 13, 3rd fl. Shimao hall

Artificial Ventilation of the Human Respiratory System: Modelling and Optimization
Prof. Andrew Plummer (Centre for Power Transmission and Motion Control, University of Bath)

Brief Biography
Professor Andrew Plummer received his PhD degree from the University of Bath in 1991. He has chaired the UK Automatic Control Council, the IMechE Mechatronics Informatics and Control Group, and is currently Chair of the Global Fluid Power Society. He is Associate Editor for IFAC Control Engineering Practice and the International Journal of Fluid Power.

His research interests are in the field of motion and force control, including inverse-model based control of electrohydraulic servosystems, hybrid hydraulic/piezoelectric actuation, wave energy converter power take off optimisation, active vehicle control, powered prosthetics, and active structures.

Abstract
With large numbers of COVID-19 patients requiring mechanical ventilation and demand outstripping supply in some parts of the world, rapid development of new safe and effective ventilation systems has been an important activity since early 2020. Fluid power expertise is required for the design and implementation of the pneumatic system which is usually used for ventilator actuation. In addition, the external breathing circuit in which the patient is a part can also be understood, modelled and optimized using techniques familiar to fluid power engineers. Some examples of modelling approaches for both the internal and external ventilator circuitry are presented in this talk. In particular, a case study will be discussed in which a configuration with optimized restrictor valves is proposed to allow two patients to be connected to a single ventilator. Both simulation and experimental results indicate that pressure and flow (tidal volume) parameters can be adjusted individually for the two patients in this scenario by tailoring the restrictor valve settings.
Keynote Speech 10
Chaired by Prof. Bing Xu (Zhejiang University), 9:30-10:00, April 13, 3rd fl. Shimao hall

Efficient and Precise Control of Fluid Power Systems
Prof. Zongxuan Sun (University of Minnesota)

Brief Biography
Professor Zongxuan Sun received his Ph.D. degree in Mechanical Engineering from University of Illinois at Urbana-Champaign in 2000. He is currently Director of the Center for Compact and Efficient Fluid Power (CCEFP). He was a Staff Researcher (2006-2007) and a Senior Researcher (2000-2006) at General Motors Research and Development Center in Warren, MI. His research interests include controls and mechatronics with applications to the automotive and commercial vehicle propulsion systems.

Abstract
Fluid power offers a unique way for power transfer with high power density and flexibility. It has been successfully applied to industrial and mobile applications. This talk will focus on the fundamental challenges on performance and efficiency faced by fluid power systems. Such challenges relate to the existing system architectures and fluid power components. We will also consider the influence on fluid power systems from the perspective of the whole powertrain system (energy generation, power transfer and motion control). System optimization and control that can significantly improve the efficiency and accuracy of fluid power systems will be discussed.
Industrial Hydraulics: Now – Next – Beyond

Dr. Steffen Haack (Bosch Rexroth AG)

Brief Biography

Dr. Steffen Haack has been a Member of the Executive Board of Bosch Rexroth AG since January 2021. He is responsible for Technology and in personal union for all divisions of Industrial Hydraulics. The main task is the electronification of all drive technologies for connected solutions in industrial and mobile applications. His technical background is Fluid Power and electrical Automation.

In addition to his professional activities, he is a member of the Executive Board of the Fluid Power Association of the German Engineering Federation (VDMA) and of the Advisory Board of the German Mechanical Engineering Summit.

Abstract

Industrial hydraulics is often perceived as an old fashioned technology at the end of its innovation cycle. Despite its indiscussable technical benefits as well as its economical importance it is not seen as a promising future technology so that influencing people like to talk about and to promote. This results in disadvantages when it comes to customer choices comparing solutions, bidding processes, and – maybe most important – in a difficult position concerning the war for talents in the long run.

Besides traditional challenges such as energy efficiency, environmental demands concerning material, oil, noise and safety related issues, new challenges are popping up such as functional integration and digitalization. But, especially the field of digitalization offers multiple opportunities for additional digital services along the product life cycle for both machine builders and end-users:

Users of industrial hydraulic products are increasingly expecting the same level of convenience they are accustomed to from the “IT consumer world”. This applies to the complete customer journey, from design via commissioning and production to maintenance.

Configurators will make the selection and sizing process easier or even automated dependent on the customers’ needs. Virtual commissioning allows plug and produce and start-up wizards with
auto-tuning algorithms reduce the on-site efforts to a minimum. The production in general is characterized by customer specific small batches with different requirements. Here online parameter adjusting of the industrial hydraulic equipment either via industrial Ethernet or via Bluetooth offers opportunities for the end-users facing changing customer demands on short notice. Continuous condition monitoring and predictive analysis reduces unplanned downtime. Digital service assistants and globally available AR supported remote services helps to keep high productivity if maintenance or repair is needed even for the robust and long lasting industrial hydraulics components and systems.
Keynote Speech 12
Chaired by Prof. Xiangdong Kong (Yanshan University), 10:50-11:20, April 13, 3rd fl. Shimao hall

Why switching from hydraulic to electric actuation in Aerospace is not so simple?

Prof. Jean-Charles Mare (The French National Institute of Applied Sciences(INSA Toulouse))

Brief Biography
Jean-Charles MARE, teaches Systems Engineering and Mechanics at Institut National des Sciences Appliquées de Toulouse, France. He conducts his research activity at the Institut Clément Ader in Toulouse. His current research deals with the model-based design of safety critical embedded actuation systems, in particular for architecting, preliminary design and virtual validation. In the last 15 years, his main activity has been related to the evolution toward more electrical solutions with numerous European or national research contracts in close relation with aircraft makers, systems and component suppliers. He is the author of 3 books and belongs to the steering committee of the Society of Automotive Engineers SAE A-6.

Abstract
The more electric aircraft is generally viewed as a target in itself, instead of one mean among others to make aircrafts safer, cheaper and greener. However, replacing well established "conventional" technologies by more electrical solutions is not so straightforward. This is particularly experienced for hydraulically powered actuation for flight controls, landing gear and engines. Although the shift has been engaged through impressive funding and research efforts since two decades, hydraulics remains extensively used onboard, including in the latest aircraft programs, whatever their use (military/commercial/private) and type (fixed/rotor wing). The keynote speech will review the needs, the expectations and the main issues encountered when hydraulic solutions are intended to be replaced by more electric ones. It will take the stock of the state of the art in aerospace actuation technology and recent research projects. Special consideration will be given to the remaining room for taking the best of hydraulics through innovative designs and hybridization.
The Impact of Digital- and Green transformation on Mobile Hydraulic Systems

Prof. Petter Krus (Linkoping University)

Brief Biography
Professor Petter Krus received the Ph.D. degree in hydraulic control systems from Linköping University, Sweden, in 1988. He became a Full Professor in machine design in 2001. Since 2010, he has been a Chaired Professor in fluid and mechatronic systems with Linköping University. His research interests include fluid power, mechanical, and mechatronic systems technology, specifically focusing on system dynamics, control, system simulation, optimization, system design, and design automation (system and geometric (CAD) design). Applications are in aircraft design, road vehicles and construction machines.

Abstract
The green transformation coupled with the digital transformation has profound implications for all technologies and businesses. In Europe there will be an almost complete transition from internal combustion engines to electric drives for all new vehicles within the next decade. The electrification means that the system architecture, in mobile machines, can be much more freely chosen in the full range, from centralized to fully decentralized hydraulic systems which means there is a much larger scope to explore energy efficient solutions than before.

To assist the development of these systems, simulation is an important tool. The Hopsan simulation package is an open-source simulation package that makes state of the art technology available to everyone, with component libraries that are making it highly useful for the development of next generation of system.

The logging of data from the use of machines in actual operation provides an excellent opportunity to analyze the use, and the work cycles in a way that has not been possible before. Here statistical methods are used for the characterization of work cycles. This means that the requirement for
systems becomes much more precisely known, and it makes it possible to optimize systems to a much higher degree.
Session Papers
Session 1: Intelligent Fluid Power

Chaired by Prof. Xiaoping Ouyang (Zhejiang University) and Prof. Yaoxing Shang (Beihang University), Wenlan hall, 2nd floor, 13:30-14:50, Apr. 12.

[S0101] Hydro-Mechanical Closed-Loop Braking Torque Control - Experimental Investigation and Influence Analysis

Philip Amos Merkel¹, Hubertus Murrenhoff¹, Olivier Reinertz¹, Katharina Schmitz¹
1 RWTH Aachen University

Abstract
A common problem of all friction-based brakes is their dependency on constantly fluctuating tribological conditions in the friction contact leading to effects such as brake fading. Typical counter measures take a purely passive approach, trying to optimize the tribological properties of the friction pairing. While noteworthy advances exit, the problem persists to limit brake performance. This paper proposes a completely different solution. A closed-loop braking torque control developed by the authors allows a higher utilization of the physical braking potential, an improved and more reliable braking process and the possibility to make use of cheaper, less optimized friction pairings. In this paper, the experimental investigation of the newly developed control system is presented. Here, an advanced brake test rig is introduced and an extensive experimental and theoretical investigation of the behaviour of the conventional brake system gives first insights into the possibilities and limitations of the novel closed-loop control system. The results of experiments with the novel controlled system prove the functionality of the control system and allow for a final evaluation of the concept.

[S0102] Development Status of Connected Hydraulics

Wei Wang¹, Dapeng Yang¹, Zihang Huang¹,Yongbo Chen¹
1 Bosch Rexroth China

Abstract
With the maturity level of electronics, control/software and sensor technology increasing, hydraulic scope is extended. Related industrial market requirement is also re-defined under I4.0 revolution, the I4.0 features for hydraulics are investigated, and one overview of connected hydraulics from component level to compact system is introduced. Multi-Ethernet valves, Hydraulic Motion
Controller, compact and energy saving pump system/servo hydraulic actuator are showed as component or modular samples, also new solutions in Hydraulic Pump Unit are developed, besides that, with data mining and data analysis technology, Online Diagnostics Network (ODiN) system which are targeting on condition monitoring and predictive maintenance is introduced with application sample.

[S0103] Research on Multi-Sensor and Multi-Level Information Fusion Technology for Fault Diagnosis of Directional Control Valve
Shi Jinchuan¹, Ren Yan¹, Tang Hesheng¹, Xiang Jiawei¹
1 Wenzhou University

Abstract
The hydraulic valve plays an important role in controlling the oil circuit in the hydraulic system. However, the lag in the development of hydraulic valve fault diagnosis has seriously affected the in-depth development and wide application of hydraulic systems. Therefore, it is necessary to implement state monitoring and fault diagnosis. This paper presents a multi-sensor multi-level information fusion fault diagnosis method for directional control valves. The method is mainly divided into three steps. First, the integrated empirical mode decomposition (EEMD) and target energy operator (TEO) are used to denoise the vibration information collected by multiple acceleration sensors to highlight the fault characteristic information. Then extract multiple types of features from the preprocessed signal and form the original feature set. Secondly, combined with the feature ranking and subset selection based on Euclidean distance (FRSSED) and the maximum correlation minimum redundancy feature selection method, the statistical features extracted from multiple sensor signals are optimized to form the optimal feature subset (first stage Information fusion). Finally, combining Dempster-Shafer evidence theory (DS) and convolutional neural network (CNN), a decision fusion diagnosis framework is constructed to realize the second stage of decision information fusion to complete the fault diagnosis of the directional control valve. Experimental results show that this method not only overcomes the shortcomings of a single sensor that cannot accurately express the health status of the directional control valve. In addition, it reduces the loss of fault information caused by a single preprocessing method, and improves the diagnostic accuracy under low signal-to-noise ratio conditions.

[S0104] Development of a Lumped-parameter Thermal Model for Electro-
Hydraulic Actuator
Shaoyang Qu¹, David Fassbender¹, Andrea Vacca¹, Enrique Busquets²
1 Purdue University
2 Bosch Rexroth Corporation

Abstract
This paper describes a thermal-hydraulic modeling method of a closed-circuit electro-hydraulic actuator (EHA). Despite the high energy efficiency of EHAs, it is always important to assess their cooling requirements, to guarantee that the operating temperature remains within an acceptable range. The method proposed in this paper is based on a lumped parameter approach and simplifies some of the complex heat transfer processes by introducing empirical correction factors. The model is validated by means of temperature measurements on an EHA architecture developed by the author. The good match between the simulation results and experiments confirms the capability of the proposed methodology to predict the temperature performance of the reference EHA under different drive cycles. The paper presents a detailed analysis of the power losses and passive heat dissipation for the reference system. Based on this analysis, the cooling requirements of the EHA are studied.
Session 2: Hydraulic Pumps

Chaired by Prof. Defa Wu (Huazhong University of Science and Technology) and Prof. Junhui Zhang (Zhejiang University), Shimao hall, 3rd floor, 13:30-14:50, Apr. 12.

[S0201] Optimal Design of Accelerated Life Testing for Hydraulic Piston Pump
Zhonghai Ma¹, Songlin Nie¹, Shaoping Wang², Chao Zhang²
1 Beijing University of Technology
2 Beihang University

Abstract
As a key power component of hydraulic system, hydraulic piston pumps have been developed with high reliability. However, due to their long lifetime and high cost, it is hard to collect failure time data of such pumps for reliability analysis, even using accelerated life testing (ALT). Nowadays, the biggest challenge is to accurately evaluate the lifetime of hydraulic piston pump under the condition of limited test samples and test time. This research will focus on the ALT optimal design method of hydraulic piston pump. Based on the ALT model of hydraulic piston pump and V-optimality criteria, determine the number of units allocated in ALT, and introduce degradation data to expand the small sample size. An ALT case of hydraulic piston pump will be presented to illustrate the use of the proposed method, and show its significance in improving the estimation accuracy.

[S0202] Evaluation and Optimization of Axial Piston Pump Textured Slipper Bearings Based on Hybrid Genetic Algorithm
Hesheng Tang¹, Yan Ren¹, Jiawei Xiang¹
1 Wenzhou University

Abstract
In this study, the structure parameters of textured slipper bearing are investigated to obtain minimum friction coefficient as well as maximum loading capacity. Optimization of the geometry parameters of dimple texture by the integration of a hybrid evolutionary optimization method based on the sequential quadratic programming and genetic algorithm. Parametric analysis is applied for the evaluation of the impact level of geometry parameters on lubrication performance. The results shows that hybrid genetic method can be used for the optimization of slipper bearing with spherical dimple textures to generate lower friction coefficient and greater capacity of load carrying. The carrying
capacity and friction coefficient of slipper bearing demonstrate a 64.8% and 4.5% improvements after multi-objective optimization. When the texture radius and depth are set to 18 μm and 0.8 μm, there exists the greatest load carrying force and lowest friction coefficient. This work presents a key designing guide for axial piston pump textured slipper bearings.

[S0203] Dynamic Model Based Transfer Path Contribution Analysis of an Axial Piston Pump
Shaogan Ye¹², Junhui Zhang², Bing Xu², Liang Hou¹, Yuhui Liu³, Shoujun Zhao⁴, Huixiang Liu⁴
¹ Xiamen University, Xiamen
² State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
³ Sichuan Aerospace Fenghuo Servo Control Technology Corporation
⁴ Beijing Institute of Precision Mechatronics and Controls
Abstract
A dynamic model based transfer path contribution analysis of an axial piston pump is proposed. The pump is modelled with a dynamic system with four masses and 19 degree of freedoms (DOFs), and then the model is validated using experimental tests. The transfer paths in the pump are systematically analyzed. The power-based path ranking algorithm is proposed. The contributions of transfer paths to the targeted vibration are obtained and analyzed. The findings show that the vibrating powers at the frequencies of 2900, 2400, 2100, 3000 and 1800 Hz are far larger than those at other frequencies, and the vibrating power of the rotational movement around the XF- direction of the assembly of the swash plate and housing generated by the operational forces transmitted via the four bolts between the housing and end-cover has the largest contribution. This study contributes to the design of quieter axial piston pumps.

[S0204] Based on Amesim Simulation to Improve the Hysteresis Performance of Ultra-High Pressure and Large Flow Emulsion Pump Valve
Qunjie Ouyang¹, Yinshui Liu¹, Defa Wu¹, Hao Pang¹, Wenshu Wei², Ran Li²
¹ Huazhong University of Science and Technology
² Beijing Tiandi-Marco Electro-Hydraulic Control System Company Ltd
Abstract
This paper takes the emulsion pump with a flow rate of 1200L/min and a pressure of 40MPa as the research object. A simulation model of the emulsification pump was established by using AMESim
software to analyze the dynamic characteristics of the opening and closing process of the port valve of the original model. Then through the design and improvement of the relevant parameters of the port valve, the lag of the opening and closing process of the port valve is optimized and improved. The research results show that the lag time of the valve is related to the basic parameters of the spring, the quality and cone angle of the spool, the opening of the valve, the clearance volume, the backing pressure and so on. By changing the maximum opening of the spool, adjusting the spring parameters and reducing the clearance volume, the opening and closing lag time of the suction valve was reduced by 44.4% and 38.4% respectively, and the opening and closing lag time of the discharge valve was reduced by 30.9% and 43.95% respectively. At the same time, the negative pressure duration when the suction valve is opened is shortened by about 0.2ms, and the pressure pulsation value in the plunger cavity during the discharge phase is reduced from 64MPa to 40.5MPa, also the average output flow of the entire pump is also increased by 19.12%.
Session 3: Water Hydraulics

Chaired by Prof. Hua Zhou (Zhejiang University) and Prof. Jiyun Zhao (China University of Mining and Technology), Wenjin hall, 3rd floor, 13:30-14:50, Apr. 12.

[S0301] Deep Sea Water Hydraulics: From 300 Meters to 11000 Meters
Yinshui Liu¹, Qian Cheng¹, Defa Wu¹, Ziwei Guan¹, Yunxiang Ma¹, Yulong Wang¹
1 Huazhong University of Science and Technology

Abstract
Seawater hydraulic system directly uses seawater as the working medium, which eliminates the pollution caused by oil leakage, can realize the depth adaption and so has natural advantages in the deep-sea. With the breakthrough of the extreme working depth from 300m to 11000m, the seawater hydraulic technology is facing huge challenges. Firstly, the physical and chemical properties of seawater will change significantly, such as density, temperature and composition. Then, the hydraulic components will be subject to an environmental pressure of up to 110MPa, which will cause serious deformation or even jamming, and will also affect the efficiency of the hydraulic components. The friction and wear characteristics between the moving pairs will also change significantly with the change of the sea depth, so it is necessary to select the matching friction pair material according to the depth. The cavitation characteristic of valve port is obviously different from that on land, so special material and structure should be used to improve the service life of valve port. These factors have severely restricted the improvement of the working depth of seawater hydraulic technology. This article will focus on the above problems and find the solutions for deep-sea seawater hydraulic technology.

[S0302] Research on the Friction and Wear Test and Lubrication Simulation of the Valve Plate Pair with Bionic Non-Smooth Surface in Water Hydraulic Motor
Zongyi Zhang¹, Dianrong Gao¹, Hao Ma¹, Yanan Sun¹
1 Yanshan University

Abstract
In order to improve the self-lubricating and anti-wear and drag reduction performance of valve plate pair in high-torque seawater hydraulic motor, different types of bionic non-smooth units are processed on the surface of CF/PEEK specimen using precision machining technology. The friction
coefficient and wear loss of friction pairs with 316L stainless steel are measured on MMD-5A multi-function friction and wear tester under different normal loads. The anti-wear of different types of bionic non-smooth surface is tested. The worn surface morphology is observed by OLS3100 laser confocal microscope. Computational fluid dynamics (CFD) method is employed to calculation the hydrodynamic lubrication model, combined with the simulation analysis result of ANSYS Fluent, the influence mechanism of the bionic non-smooth pit on the tribological performance of the hydraulic motor valve pair under water lubrication is explored. The results show that under the condition of seawater lubrication, the lower sample (CF/PEEK) mainly occurs the furrow effect and abrasive wear during the friction process. The pits on the bionic non-smooth surface can effectively store abrasive particles, reduce abrasive wear and friction coefficient.


Fangli Lou¹, Wei Ge², Songlin Nie¹, Fanglong Yin¹, Hui Ji¹, Zhonghai Ma¹
1 Beijing University of Technology
2 Hubei Institue of Aerospace Chemical Technology

Abstract
Energy recovery device is a key component of reverse osmosis seawater desalination system. This paper introduces a new type of integrated energy recovery device, which is composed of a rotary pressure exchanger and a swash plate axial piston booster pump. When the end gap leakage happened in the energy recovery device, the flow ripple of the high-pressure outlet was affected by many factors. Therefore, a computational fluid dynamics (CFD) method was applied to study flow characteristics and mixing process in the energy recovery device. The simulation results show that the outlet flow ripple of the device was simultaneously affected by the gap leakage and the number of cylinder holes. When the silencing groove was set on the port plate, the high-pressure outlet flow ripple was significantly reduced. This research lays the foundation for the integrated energy recovery device to further achieve high-quality output flow.

[S0304] Separation Rate of Soft Tissue under High Speed Waterjet Impact: an Experimental Study on Gelatine Fracture Process

Chao Cao¹, Jiyun Zhao¹, Di Huang¹, Liangchen Song¹
1 China University of Mining & Technology
Abstract

The non-rigid separation effect of soft tissue is the result of the nonlinear coupling of fluid dynamics and biomechanics within the field of physics. In clinical applications, the separation rate of medical waterjet separating soft tissue is the most intuitive indicator of the separation effect. According to the fracture characteristics of different biological soft tissues, studying the change law of the separation rate is the prerequisite for mastering the dynamic adjustment method of medical high-speed waterjet. In order to distinguish the separation rates of different biological soft tissues under different impact conditions, this study measured the separation depths of gelatin samples with three mass fractions under different impact distances, impact pressures and waterjet moving speeds. According to the characteristics of water hammer action and the relation of energy conversion in the separation process, the variation trend of dynamic separation rate is explained. A high-speed camera was used to observe the dynamic separation rate of the gelatin samples under fixed waterjet force. The results show that the constant waterjet force increases the separation rate within a certain impact depth. The invariable waterjet force and fixed operation mode are not conducive to accurate clinical application. Adjusting the waterjet force according to the characteristics of dynamic separation rate will make clinical control easier.
WANG Xin¹, ZHU Ziqiang¹, CHEN Rui¹, WANG Zeng-xiang², LIU Xin-hui¹
¹ Jilin University;
² Jiangxi Yuanbang Collaborative Innovation Co., Ltd.

Abstract
A self-energy-feed heat dissipation system is proposed in this paper, which solves the problem of brake heat fade caused by the increase of component temperature when the vehicle is braked for a long time. The action mechanism and function relationship of system parameters on hydraulic oil temperature are analyzed. The adaptive weight particle swarm optimization is used to optimize the matching of the main parameters of the system. The optimized parameters are matched according to the actual component specifications. And the rationality of the system parameters is verified by simulation analysis of the AMESim. The simulation results show that the matching system can greatly reduce the use frequency and intensity of the friction braking system under the premise of controlling the oil temperature.

[S0402] Research on of Operation Law and Reversing Sequence Matching of Concrete Pumping System
Haigang Ding¹,², Yanbin Zhao², Jiyun Zhao¹, Yongzhuang Liu¹, Chao Cao¹, Ziwen Sang²
¹ China University of Mining and Technology
² Jiangsu Province and Education Ministry Co-Sponsored Collaborative Innovation Center of Intelligent Mining Equipment

Abstract
The concrete pump truck is a special type of construction machinery to realize the rapid transportation and pouring of concrete, which is widely used in transportation, energy, construction, national defence engineering and other fields. The pumping system is the core of concrete pump trucks. Two parallel delivery cylinders are used to transport concrete alternately, and their suction
and pumping functions are realized through the swing of a distribution valve. At present, there is a lack of clear understanding of the operation law of the pumping system, and the reversing sequence of the pumping circuit and the distribution circuit does not match, which results in low pumping efficiency, large impact and serious erosion wear. In this paper, the structure and working principle of the hydraulic control concrete pumping system is clarified, and the simulation model is established based on the AMESim software; the dynamic characteristics of the pumping circuit and distribution circuit and their coupling relationship is analysed, and the hydraulic sequential operation law of the pumping system is revealed, and the reversing sequence diagram of the signal valve-swing valve-main valve-main cylinder – swing cylinder is drawn, and the matching method of reversing sequence of pumping system is put forward, that is, the delivery cylinder reverses later, while the distribution valve accelerates the reversing process; the structure and parameters of the pumping system, especially the buffer structure of the swing cylinder, are optimized. Finally, the reversing time of the distribution valve is greatly shortened and sequence matching of pumping and distribution is realized. Through the reversing sequence matching, the pressure impact of the system could be reduced, the erosion wear between the spectacle plate and cutting ring can be reduced, the amount of leakage could be reduced also, and the pumping efficiency of the conveying cylinder could be improved. This study will provide technical reference for the structure and parameter optimization of concrete pumping systems.

[S0403] A Novel Hydraulic Fan Drive For Off-Road Engine Cooling With a Power Split Hydraulic Transmission

Feng Wang¹, Junyi Hong¹, Bing Xu¹ and Wieslaw Fiebig²

¹ State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University
² Division of Off-Highway Vehicle Engineering, Department of Mechanical Engineering, Wroclaw University of Science and Technology

Abstract

The engine fan drive is crucial for engine cooling as it ensures safe and efficient engine operations. In heavy duty construction machinery, the engine fan drive system consumes considerable amount of engine power. To meet high cooling power requirement, a hydraulic fan drive is usually employed owe to its high torque and power density. One type is to employ two fixed displacement hydrostatic units and a pressure relief valve to adjust fan shaft speed. Another type is to employ a variable
hydrostatic pump and a fixed hydrostatic motor. The former has severe valve throttling losses while the latter is more efficient however has relatively slow response due to pump displacement control. Therefore a more efficient cooling fan drive solution with a power split hydraulic transmission was proposed for off-road diesel engine. The hydraulic transmission is a compact design with pump and motor function in a single component. By adjusting the transmission outlet pressure, fast-response fan shaft speed control is achieved. The system mathematical model was developed and system controller was designed. The dynamic characteristics of the hydraulic fan drive system was analyzed through simulation study. To evaluate the system design, a hydraulic fan drive test bench was developed. Finally experimental study was conducted to compare the analysis and simulation results with test results.

[S0404] Research on Ride Comfort of Hydropneumatic Suspension for High-Speed Wheeled Excavator

Yu Gao¹, Zhiqi Liu¹, Zhanlong Li¹ and Shantie Gao²
1 Taiyuan University of Science and Technology
2 Guizhou Jonyang Kinetics Co., Ltd.

Abstract
At present, high-speed construction machinery is not equipped with suspension system, which makes the vehicle intolerable when walking at high speed or road conversion. Hydropneumatic suspension has nonlinear spring and damping characteristics, which can satisfied with the requirements of high-speed construction machinery. Simultaneously, it is absolutely necessary to development a special hydropneumatic suspension system for the high-speed construction machinery, because its complicated working conditions also makes higher demands on suspension system. This paper performs a mathematical model for the specific type of single-chamber hydropneumatic suspension, and makes a detailed study on its nonlinear characteristics. The result of parameter study provides some theoretical reference for the design of special hydropneumatic suspension.
[S0501] Electrohydraulic Loading Technology for Simulating 5-DOF Loads of Large-Scale Wind Turbines
Danyang Li¹, Yonggang Lin¹, Hongwei Liu¹, Jinglong Ding¹, Wei Li¹, Xiangheng Feng¹
¹ State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

Abstract
This paper introduces electrohydraulic loading technology to simulate 5-DOF loads for large-scale wind turbines. Combined with dynamic structural analysis and foreign loading information, three main non-torque loading (NTL) structural schemes are summarized: symmetrical loading scheme, radial eccentric loading scheme and parallel six-hydraulic-cylinder loading scheme. Each loading scheme is loaded with multiple hydraulic cylinders in different arrangements to reproduce realistic 5-DOF turbine loads under various working conditions. An NTL testing prototype has been carried out based on the symmetrical loading scheme. The hydraulic system of the prototype is presented and its basic loading unit is a servo valve controlled (SVC) cylinder. Moreover, to solve the problem of the control accuracy caused by the increment of loading force, this paper proposes a multi-cylinder electrohydraulic digital loading (MEDL) technology. The basic unit is converted from a traditional SVC cylinder into a hydraulic cylinders group that includes N cylinders at each point, in which one is controlled by the servo valve and the others (N-1) are controlled by on-off valves. The force of the SVC cylinder can be regulated continuously, and the on-off valve controlled (OVC) cylinders have only two states of no loading force or maximum loading force. Thus the error of the OVC cylinder is so small that can be ignored. With a case of N = 4 for MEDL, AMESim simulation and experiment results illustrate that the accuracy of the 4-cylinder digital loading can be substantially increased. The NTL technology and MEDL technology build a theoretical and technical foundation for the drivetrain testing system of large wind turbines.

[S0502] Dynamic Response Analysis of Energy Storage Hydraulic Wind Turbine
Wei Gao¹, Zengrui Han¹, Xuan Wu¹, Pengfei Zheng¹, Chao Ai¹
¹ Yanshan University
Abstract
Wind has been admitted as one of the most promising renewable energy resources in multinational regionalization policies. However, with the increase of the wind power proportion in the electrical grid, the intermittent and fluctuating wind energy will reduce the inertia of your system, which is not conducive to the frequency control of the power grid. Therefore, the hydraulic energy storage system (HESS) is introduced into the original hydraulic wind turbine (HWT). The working principle of energy storage hydraulic wind turbine is analyzed. Secondly, the mathematical models of wind turbine, hydraulic main transmission system and hydraulic energy storage subsystem are established, and the inertia constant and moment of inertia of hydraulic energy storage system are obtained. At the same time, the response characteristics of the hydraulic energy storage system are analyzed based on the 24kW energy storage hydraulic wind turbine semi-physical simulation experimental platform. The energy storage hydraulic wind turbine proposed in this paper will help to improve the stability of wind turbine output energy, and it is of great significance to enhance the proportion of wind turbine in the power grid and maintain the stability of power grid.

[S0503] A Broadband and Frequency Up-converted Electromagnetic Vibration Energy Harvester
Fang Lu¹, 2, Dong Han¹, 2, Yi Liu¹, 3, 4, Guofang Gong¹, 2, Huayong Yang¹, 2
1 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
2 School of Mechanical Engineering, Zhejiang University
3 NingboTech University
4 Ningbo Research Institute, Zhejiang University

Abstract
In the past few decades, the capture of vibration energy has been a research hotspot. And the existing vibration energy harvesters (VEHs) are able to generate considerable output power under suitable conditions. However, the narrow bandwidth remains a significant challenge with respect to linear VEHs. To address this issue, we propose a broadband, frequency up-converted electromagnetic VEH utilizing dual magnetic springs. Under the excitation with low acceleration, two spring-mass systems composed of cylindrical magnets and ring magnets, respectively, reciprocate synchronously and their nonlinear stiffness help broadband. When the excitation acceleration exceeds a certain threshold, the cylindrical magnet separates from the ring one and their interacted magnetic pull realizes the cylindrical magnet’s frequency up-conversion. Firstly, a simulation analysis is carried out and the results show that the nonlinear magnetic spring mechanism is superior to linear one in
broadening the response bandwidth of VEHs. Afterward, the broadband of the proposed architecture under the excitation of small acceleration is validated by simulation.

[S0504] **Effect of Accumulator on Dynamic Performance of a Hydraulic Wave Energy Conversion System**

Hong Gao¹,², Jie Xiao¹

¹ Shanghai Jiao Tong University
² Zhejiang University

Abstract

Dynamic model of an oscillating floating body and wave energy conversion system under irregular waves are established. The effect of accumulator parameters on dynamic performance of a hydraulic wave energy conversion system are investigated. The motor speed and output power become relatively stable through stabilization of accumulators. As the high pressure accumulator prechange pressure increases, the peak values of high pressure accumulator pressure, the motor speed and output power reduce, and the harvested power decreases, while the motor mean speed and output power, the hydraulic conversion efficiency increase. As the high pressure accumulator initial volume increases, the pulse amplitudes of the motor speed and output power decrease, the mean harvested power increases and the motor mean output power reduces. It is due to the energy stored in the high pressure accumulator increases. As the low pressure accumulator pre-change pressure increases, the motor speed and output power peaks become sharp, the motor mean speed, mean output power, the harvested power and the hydraulic conversion efficiency reduce. As the low pressure accumulator initial volume increases, the peak and valley values of high pressure accumulator pressure reduce, and fluctuation amplitudes of low pressure accumulator pressure, motor speed and output power decrease. When the low pressure accumulator initial volume is small, the energy storage function of the low pressure accumulator is greater than that of stabilizing pressure. The mean values of motor speed, output power, harvested power and hydraulic conversion efficiency increase as the low pressure accumulator initial volume increases.
Session 6: Hybrid Hydraulics
Chaired by Prof. Min Cheng (Chongqing University) and Prof. Tianliang Lin (Huaqiao University), Wenlan hall, 2nd floor, 15:00-16:20, Apr. 12.

[S0601] Influence Study of the Different EDC and PC Control Layouts in Open Circuit Pump
Qiang Sun\(^1\), Likui Zhai\(^1\), Xiujian Lv\(^1\), Xin Zheng\(^1\)
1 Danfoss Power Solutions (Zhejiang) Co. Ltd

Abstract
Open circuit pumps are widely used in both mobile and industrial applications. To meet various requirements of system control, different control options have been developed, e.g. EDC (Electronic Displacement Control), PC (Pressure Compensator), TC (Torque Control), and LS (Load Sensing). EDC and PC control are very often combined together to run direct displacement control, with PC to limit the system maximum pressure. However, the positioning of EDC and PC with respect to the servo chamber would have much influence to the control performance. This paper first builds the dynamic model of EDC and PC control valves. Then the two different positionings of EDC and PC w.r.t. servo chamber are simulated. The result shows EDC+PC has smaller flow drop, while the PC+EDC has better performance on hysteresis. Moreover, the EDC+PC performance is verified by experiment, with closer study on the impact of control spool overlap, clearances, and oil temperature, the test result show the same tendency with Simulation at same condition.

[S0602] Modeling of Hydraulic Hybrid Wind Turbine Transmission with Realistic Accumulator
Eric Mohr\(^1\), Daniel Escobar\(^1\), Deborah Ajagbe\(^1\), Kim A. Stelson\(^1\)
1 University of Minnesota

Abstract
Wind turbines require cost-effective, highly-power dense, and reliable drivetrains to operate efficiently over long periods of time. Hydrostatic Transmissions (HSTs) are an attractive option to meet these conditions. The potential of using hydraulic systems in a wind turbine goes beyond the drivetrain itself. Conventional gearbox turbines intentionally limit energy extraction above the rated wind speed. Extra energy from high-speed wind transients can be captured and reused by hybridizing a HST wind turbine. We propose a method to hybridize HSTs by adding an accumulator to store the
extra energy and reuse it for multiple purposes. In this paper, we will present the dynamic model of the hybrid transmission and compare its effectiveness when using an adiabatic, an isothermal or a heat transfer model of the accumulator. Realistic turbulent wind data samples are used to evaluate the simulations and prove the concept.

[S0603] Hydrodynamic Characteristics Research on Water-Jet Hybrid Glider’s Flying-Fish-Inspired Wings
Yanzhi Wu¹, Jianxing Zhang¹, Gang Yang¹, Baoren Li¹
¹ Huazhong University of Science & Technology
Abstract
Water-jet hybrid glider (WJHG) integrates the advantages of traditional AUG and AUV, having three types of motion pattern, with long-distance movement ability and good manoeuvrability. As WJHG’s different motion patterns corresponds to multiple optimal hydrodynamic shape, a conventional fixed wing cannot meet the changing hydrodynamic requirement. In the ocean, the flying fish can maintain different motion characteristics in different configurations of wing. Inspired by flying fish’s motion characteristic, we proposed a flying-fish-inspired wing to adjust the hydrodynamic shape of WJHG in this paper. To research the hydrodynamic characteristics of flying-fish-inspired wing, we adopt the verified numerical calculation method. The work indicates the better layout (configuration) scheme for flying-fish-wing-inspired wing on WJHG. In addition, we carry out the evaluation towards hydrodynamic performance under various wing configuration of flying-fish-inspired wing WJHG.

Yunxiao Hao¹, Long Quan¹, Shufei Qiao¹, Zepeng Li¹, Lei Ge¹, Yunwei Li², Zhongyi Quan²
¹ Taiyuan University of Technology
² University of Alberta
Abstract
Due to the shortage of fossil energy and the implementation of strict environmental regulations, electrification has become an important development direction of hydraulic excavators. However, the existing excavator hydraulic systems have low energy efficiency due to large throttling loss of hydraulic valves and waste of large amount of working device potential energy, which has a negative
impact on the development of the pure electric hydraulic excavator. Therefore, a hydraulic-electric hybrid drive system with distributed independent driving function was proposed and applied to the boom of pure electric drive hydraulic excavator. The proposed system adopts a new type of electro-mechanical-hydraulic linear actuator (EMHA) which integrates electro-mechanical actuator (EMA) and hydraulic cylinder. The permanent magnet synchronous motor (PMSM) in the EMHA controls the speed and position of the boom through ball screw. The non-rod chamber of the EMHA is connected with a hydraulic accumulator to efficiently reutilize the gravitational potential energy. The working principle of the hydraulic-electric hybrid drive system of the boom is analyzed firstly. The control scheme of the hydraulic system and the PMSM are designed. Finally, a test rig is built to test the feasibility and characteristics of the proposed system. The results show that the hydraulic-electric hybrid drive system of the boom has good operation characteristics and energy saving effect. The total reutilization efficiency of the working device gravitational potential energy can reach 72.1%. Compared with the traditional hydraulic excavator system, during the individual operation of the boom, the proposed system can reduce the boom system energy consumption by 66.1%; during one excavation cycle, the proposed system can reduce the energy consumption of the whole machine by 16.8%.
Session 7: Sensors and Actuators

Chaired by Prof. Liang Yan (Beihang University) and Prof. Liang Lu (Tongji University), Shimao hall, 3rd floor, 15:00-16:20, Apr. 12.

[S0701] A Soft Actuator System for In-Bed Body Movement Assistant
Xiaofeng Zou¹, Tao Liu¹
1 State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University

Abstract
Pressure ulcer (PU) or decubitus ulcer is a condition of insufficient blood flow caused by pressure on the body surface. PU is one of the most frequent hazards for patients who are bedridden for a long time. Clinically, turning over regularly is the main nursing method to prevent pressure ulcers. With the growth of aging population, the number of disabled and semi-disabled elderly people who have been bedridden for a long time is increasing. There is a serious shortage of professional pressure ulcer caregivers and flexible turning equipment for pressure ulcer prevention in clinical nursing. In order to improve the effect of preventing PU for the elderly with long-term bed rest and disability, and reduce the burden of daily nursing staff, a set of pneumatic turning mattresses based on clinical nursing methods have been developed. The mattress is divided into a turnover area and a support area. The tpu film airbag is used to drive the turnover. Through the linkage of the turning airbags and the support airbags to provide a comfortable turnover experience for the patients. The turnover range and interval can be adjusted to provide personalized experience.

[S0702] Empirical Nonlinear Model Based Pneumatic Soft Bending
Cong Chen¹, Jun Zou¹
1 State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University

Abstract
The inherit compliance brought about by soft materials suggests that soft fluid-driven robots are capable to adapt to complex and unpredictable environments, which describes a good prospect in safe interaction with humans. The respective customized structures and massive use of nonlinear and viscoelastic soft materials enrich the functions and applications of soft fluid-driven robots, yet pose
a great challenge to system modeling and dynamic control of soft fluid-driven robots and impose restrictions on further applications. In this study, a unified modeling strategy is utilized to establish the complete dynamic model of pneumatic soft bending actuators. Meanwhile, the inner pressure dynamic model of the pneumatic soft bending actuator is also established by introducing the quasi-steady mass flow rate model of the unbalanced pneumatic proportional valves. Then, a backstepping-based sliding mode controller is designed to handle the nonlinear and uncertain system. Finally, the comparative trajectory tracking experiments demonstrate the effectiveness of the proposed modeling method and designed controller.

[S0703] A New Type of Pneumatic Soft Actuator for Spiral Motion and Its Characteristics
Chenghao Ji¹, Zhonghua Guo¹, Peng Qin¹
¹ Nanjing University of Science and Technology
Abstract
In this paper, a kind of pneumatic soft actuator is proposed to realize spiral motion. It provides bending and rotation deformation with a specific angle between the air chamber and the axis direction. By using finite element simulation software, the deformation characteristics and motion trajectory of the soft actuator under variable input pressures are analyzed by changing the angle of the air chamber, as well as the length of the actuator. 3D printing fabrication and liquid silicone rubber pouring method is adopted to make the physical model of soft actuator. The deformation of the physical model is tested by experiments and the data are compared with the simulation results. Furthermore, the force provided by the new type of soft actuator is measured experimentally and compared with bending type actuator. With all these work the actuator can be designed well and they are the basis for the further design of the blooming type gripper.

[S0704] A Novel Pneumatic Soft Actuator with Variable Stiffness Based on Extensor-Contractor Actuation
Yinglong Chen¹, Junhao Zhang¹, Zengmeng Zhang¹ and Yongjun Gong¹
¹ Dalian Maritime University
Abstract
The soft actuator possesses the characteristics of flexibility, environmental adaptability, and human-machine interaction. Firstly, aiming to resolve the limitation of variable stiffness performance of a
traditional pneumatic artificial muscle (PAM) actuator, based on the antagonistic mechanism of extensor and contractor muscles, a novel pneumatic soft actuator coupled of extensor and contractor muscles is proposed in this paper. The actuator can perform the compound action of elongation/contraction, and the stiffness of it can be controlled by adjusting the elongation and contraction forces. Secondly, based on the deformation principle of woven and elastic fabric layers, the mechanical characteristics model of the actuator is established and simulated. The mechanical properties of the actuator are tested under different pressures and deformation displacement and the variable stiffness characteristics of the actuator are verified. Finally, actuators are utilized to manufacture a soft mechanical manipulator, which can achieve variable stiffness in a fixed bending attitude.
Session 8: Control Systems

Chaired by Prof. Jianyong Yao (Nanjing University of Science and Technology) and Prof. Zheng Chen (Zhejiang University), Wenjin hall, 3rd floor, 15:00-16:20, Apr. 12.

[S0801] A Simple Nonlinear Robust Control of Single DOF Support System of Magnetic-Liquid Double Suspension Bearing

Jianhua Zhao¹,²,⁴, Ziqi Wang¹, Sheng Li¹, Dianrong Gao¹,²,⁴ and Guojun Du¹,²,⁴

1 Fluid Power Transmission and Control Laboratory, Yanshan University
2 College of Civil Engineering and Mechanics, Yanshan University
3 LiRen College, Yanshan University
4 Jiangsu Provincial Key Laboratory of Advanced Manufacture and Process for Marine Mechanical Equipment

Abstract

The support system of MLDSB is composed of electromagnetic suspension as the main and hydrostatic as a supplement. Which can greatly improve the bearing capacity and stiffness, It is more suitable for the occasions of medium speed heavy load and frequent starting. Due to both the magnetic-hydraulic bearing systems are nonlinear systems, and they are coupled and interfered with each other, the nonlinear characteristics of MLDSB are intensified, and the operation stability and reliability are reduced. Therefore, in this paper, MLDBS is controlled through the combination of accurate feedback linearization and closed-loop gain formation Firstly, the structure characteristics and regulation mechanism of MLDSB are introduced, and then on linear dynamic model of the single DOF bearing system is established. Secondly, exact feedback linearization is used to the mathematical model, and the magnetic-liquid double suspension bearing controller is designed based on the closed-loop gain forming control theory. Finally, the influence of traditional PID control strategy and simple nonlinear robust control strategy on the control performance of magnetic-liquid double suspension bearing are compared by using Matlab\Simulink software. The results show that the single DOF support system with the simple nonlinear robust control strategy has excellent dynamicquality, robust stability and vibration suppression ability. A theoretical basis for the stable suspension and control of themagneto-liquid double suspension bearing system is provided in this paper.
Abstract
A terminal sliding mode control (TSMC) strategy is used in the velocity control of Electro-Hydraulic Actuator (EHA) to improve the output response performance. Based on the terminal sliding mode technique, a disturbance observer is designed to estimate the lumped uncertainty of EHA including hydraulic parametric uncertainty and unknown external load. Different from asymptotic convergence controller, the TSMC guarantees the system state error and observer estimation error converge to zero in a finite time. The effectiveness of the proposed controller is verified by simulation results with comparisons the other controllers.

Active Control Method for Pipe Support with Vibration Absorber
Zirui Zhao¹,², Yuanzhi Xu¹,²,³, Yufeng Qu²,³, Qiyang Yu⁴, Zongxia Jiao¹,²,³
1 School of Automation Science and Electrical Engineering, Beihang University
2 Ningbo Institute of Technology, Beihang University
3 Research Institute for Frontier Science, Beihang University
4 Shanghai Aerospace Control Technology Institute

Abstract
The impact and pulsation of the fluid can cause mechanical vibration and noise in the hydraulic pipeline, which may lead to serious fatigue problems. In this paper, an active pipe support with a vibration absorber is investigated, and an adaptive vibration control method is proposed. The control algorithm can track the vibration frequency and cancel the vibration by driving the vibration absorber. An anti-saturation unit in the control scheme is used to improve the convergence speed. The simulation results indicate that the vibration reduction effect by the active pipe support is more than 90%.

Two DOF Point Absorber Power Take-off System with Flow Phase Control
Zijian Zhou¹, Hao Tian¹, Jiaoyi Hou¹, Yongjun Gong¹
1 Dalian Maritime University

Abstract
Small-scale wave energy conversion devices may be a potential solution to the distributed ocean monitoring network, but it faces the problems such as poor sea state adaptability and low output power in comparison with the shore-based permanent conversion facilities. In order to solve such problems, a new two degrees of freedom point absorber power take-off system based on electro-hydraulic circuit with actively controlled accumulator and twin cylinders in parallel to capture the heaving energy of the wave is proposed. A numerical model of the system is setup based on the previously validated single degree of freedom system parameters. In this paper, the phase differences caused by incident waves are studied. Using the phase differences, the cylinder displacement, the motor displacement as the simulation variables, a numerical search over the maximum energy output of the system is carried out. Initial results show that the displacement ratio between the twin cylinders and the motor play an important role, and when the ratio is near 1 and with active accumulator control, the output work of the energy conversion system can be significantly improved.
Session 9: Mobile Hydraulics

Chaired by Prof. Feng Wang (Zhejiang University) and Prof. Likui Zhai (Danfoss Power Solutions), Jiahe hall, 3rd floor, 15:00-16:20, Apr. 12.

[S0901] On-Line Optimization Based on Pontryagin’s Minimum Principle for a Series Hydraulic Hybrid Wheel Loader
Qi Zhang¹, Feng Wang¹, Bing Xu¹, Zongxuan Sun²
¹ State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University
² NSF Engineering Research Center for Compact and Efficient Fluid Power, Department of Mechanical Engineering, University of Minnesota

Abstract
Owing to its high power density, the hydraulic hybrid powertrain has great potential for reducing fuel consumption and emission of off-road vehicles, such as wheel loaders. The energy management strategy is the key to hybrid powertrain and currently there are many well-developed strategies. Of which the Pontryagin’s Minimum Principle is of research interest since it is a global optimization method while less computational burden than dynamic programming. However, it requires full cycle information to calculate co-state value in the principle, making it not implementable. Therefor in this study, an implementable Pontryagin’s Minimum Principle is proposed for a series hybrid wheel loader, where the optimal co-state value in the principle is trained through repetitive wheel loader duty cycle. The Pontryagin’s Minimum Principle formulations of hybrid wheel loader are developed. The online co-state training algorithm is presented. A dynamic simulation model of hybrid wheel loader is developed. To validate proposed method, the fuel consumption of hybrid wheel loader is compared to dynamic programming. Results show the fuel consumption results with proposed method is close to dynamic programming. Finally, the influence of pressure level of hybrid powertrain on fuel consumption is studied.

[S0902] The Control and Performance Analysis of a Micro Excavator with Distributed Pump-Controlled System
Shuzhong Zhang¹,², Su Li¹, Fuquan Dai¹,³, Haojie Huang¹
¹ Fujian University of Technology
Abstract
Due to the low energy efficiency and environmental pollution of the construction machinery, energy-saving researches of them has attracted increasing attention. The variable speed pump controlled system driven by the electric machine has the advantages of high efficiency and zero-emission. Therefore, a micro hydraulic excavator equipped with distributed pump-controlled systems is proposed. The operating principle of the proposed system is illustrated. Further, the multi-discipline model of the front working set is built, including the multibody dynamics model of the front attachment mounted with the pump-controlled unit, hydraulic system model, permanent magnet synchronous motor, velocity control based on active disturbance rejection control. The profile of a typical simulated digging cycle is created and used as an input to the system. The simulation results show that, under the typical digging cycle, the control performance of the pump-controlled system and the valve-controlled system is equivalent, but the distributed pump-controlled system saves energy 14.3kJ and improves efficiency by 46.2%.

[S0903] Compound Control System Based on Minimum Differential Pressure for Electric Excavators Powertrain

Qihuai Chen¹, Tianliang Lin¹, Yuanzheng Lin¹, Cheng Miao¹, Shengjie Fu¹, Tong Guo¹
1 College of Mechanical Engineering and Automation

Abstract
Load sensitive system is widely used in construction machinery. But the load sensitive system valve differential pressure is usually fixed and relatively conservative, and the throttling loss is big. To further improve the energy saving, based on the displacement adaptive-variable speed control of load sensitive system with variable pressure difference control characteristics, combined with the pilot control system of electric control, a compound control strategy based on the minimum differential pressure of the pump-valve on the basis of hierarchical differential pressure control is proposed. The working principle of this compound control strategy is introduced and the switch rule between different working mode is created. AMESim is used to establish the simulation model of the proposed system. The simulation results show that the minimum pressure differential control can reduce the maximum throttling loss by 76% compared with the hierarchical pressure differential control. And the control performance is basically consistent with the hierarchical differential pressure control strategy which has the good performance.
Energy Consumption Analysis of Multi-Axle Steering System for Heavy Vehicle
Du Heng¹, Hong Yue¹, Liu Xiaoyang¹, Shu Yue¹, Li Yuzheng¹
¹ Fuzhou University

Abstract
The electro-hydraulic steering system commonly used in traditional heavy vehicle has a significant energy consumption due to its large and widely variable steering load. An in-depth analysis of the energy consumption for multi-axle steering system has important reference significance for the design of new energy-saving schemes. In order to explore the energy consumption characteristics of multiaxle steering system in driving conditions, a single-axle energy consumption model is established in this paper. By analyzing the corner relationship of each steering axle based on Ackerman principle, the energy consumption model of multi-axle steering system is derived. In addition, a new test cycle for energy consumption is innovatively designed to analyze the energy consumption characteristics of multi-axle steering system for heavy vehicle in driving conditions, and the main factors that affect its energy consumption and average efficiency during driving. Through the study of the key factors, the potential direction of reducing the energy consumption of multi-axle steering system is proposed, which provides a new idea for designing the energy-saving scheme of the steering system.
Session 10: Renewable Energy

Chaired by Prof. Hongwei Liu (Zhejiang University) and Prof. Chao Ai (Yanshan University), Jianian hall, 3rd floor, 15:00-16:20, Apr. 12.

Hongwei Liu¹, Pengpeng Zhang¹
1 Zhejiang University

Abstract
Pitch-regulated mechanism is an important component of horizontal axis tidal current turbine, which is used for power control, orientation with inflow direction and hydrodynamic emergency stop of the turbine. Compared with an electric motor pitch actuator, hydraulic pitch system has good robustness to the working environments, which will reduce the requirements for sealing. This paper presented an independent hydraulic pitch scheme based on electro-hydraulic (EH) proportional control. With load characteristics being considered, the research focus of this pitch system was the design of valve-controlled hydraulic motor pitch mechanism and synchronization of pitch actuators which occurred due to the asymmetric loads on three blades. A method of pressure compensation before proportional directional valve was used. In order to verify the proposed method, its model was constructed and simulated in Amesim, and its prototype was manufactured and tested in the factory. Results show that proposed pitch system has good response characteristic, and synchronization of three blades was well achieved in spite of the blade asymmetric loads.

[S1002] Study on Oscillating Float Wave Energy Generation Experiment Platform and Energy Harvesting System
Feixue Wang¹,², Baiqiang Han¹,², Tianyi Zhang¹,², Zicong Li¹,², Longfei Yao¹,², Xiangdong Kong¹
1 Yanshan University
2 Hebei Innovation Center for Design and Preparation technology of Lightweight Structural Equipment

Abstract
Through laser melt district (Selective Laser Melting, SLM) increased 316L stainless steel material manufacturing technology for preparation of the material tensile and compression standard
specimen, and experimental research, the comparison of the SLM under the preparation process of 361L metal materials and ordinary 316L metal material mechanics performance difference. Several four-pyramid lattice model specimens with different aspect ratios were prepared, and static compression and tensile experiments and simulation calculations were carried out. The experimental results and simulation results were in good agreement. The mechanical properties of four-pyramid lattice with different aspect ratio and inclination angle are verified by theory, experiment and simulation, and some reasonable suggestions are put forward to enhance the tensile and compressive properties of four-pyramid lattice.

[S1003] Performance Characteristics of Horizontal Axis Tidal Turbine Considering Nose Shape, Angle of Inflow and Tower Structure

Man-Woong Heo¹, Dong-Hwan Kim¹ and Jin-Hak Yi¹
1 Korea Institute of Ocean Science and Technology

Abstract
In this study, three-dimensional Reynolds-averaged Navier-Stokes equations were solved to analyze the performance characteristics of a horizontal axis tidal turbine (HATT) with the shear-stress-transport turbulence model. The computational domain for flow analysis was composed of hexahedral grids, and the grid dependency test was performed to find the optimum grid size considering computational cost. The effects of the nose shape, inflow angle and the tower affecting on the hydrodynamic performances of the HATT were studied. It was found that the loss of power output was reduced as the ratio of hub diameter to hub nose length (aspect ratio of hub nose) increased, the loss of output power is more than 10% when the inflow angle was larger than 15 degrees, and the loss of power output due to the existence of the tower is about 1% when the flow was reversed, i.e. downstream generation was considered.

[S1004] Effects of Different Air Turbines on The Operation Characteristics of Backward Bend Duct Buoy

Wu Rukang ¹, Wu Bijun ², ³, ⁴, Li meng ¹, Zh1ng Yunqiu ², ³, ⁴
1 Nanjing Institute of Technology
2 Chinese Academy of Science Guangzhou Institute of Energy Conversion
Abstract

In this paper, the effects of two different turbines (one is a straight blade turbine and the other is a twisted blade turbine) on the energy conversion characteristics of backward bend duct buoy (BBDB) are studied experimentally. The experimental results show that the twisted blade turbine reduces the capture width ratio (CWR) of the BBDB due to the unreasonable damping coefficient provided by the twisted blade turbine. However, the twisted blade turbine has higher conversion efficiency, which can improve the secondary conversion efficiency converting from pneumatic energy to electrical energy. Totally, the total conversion efficiency of the BBDB equipped with the straight blade turbine is higher than that of the BBDB equipped with the twisted blade turbine. But if the BBDB equipped with twisted blade turbine can maintain the same CWR, the total conversion efficiency could be higher.
Session 11: Modelling and Simulation

Chaired by Prof. Lingxiao Quan (Yanshan university) and Prof. Xiaocong Zhu (Zhejiang University), Wenlan hall, 2nd floor, 16:40-18:20, Apr. 12.

[S1101] Model Predictive Displacement Control Tuning for Tap-Water-Driven Muscle by Inverse Optimization with Adaptive Model Matching
Satoshi Tsuruhara¹, Ryo Inada², Kazuhisa Ito³
1,3 Shibaura Institute of Technology
2 Graduate School of Shibaura Institute of Technology

Abstract
The tap-water-driven McKibben muscle has many advantages and is expected to be applied in mechanical systems that require a high degree of cleanliness. However, the muscle has strong asymmetric hysteresis characteristics that depend on the load, and these problems prevent its widespread use. This study proposes an asymmetric Bouc-Wen model and model predictive control with servomechanism. In addition, inverse optimization with adaptive model matching achieves the desired response by obtaining the optimal weight in the evaluation function of the model predictive control. Experimental results show that the proposed approach achieves a high tracking performance at a reference frequency of 0.3 Hz with a mean absolute error of 0.13 mm in the steady-state response, and easier controller tuning could be made.

[S1102] Dynamic Analysis of Hydraulic Pipeline Based on Substructure Method
Qing-Jun Yang¹, Ri-Zhi Dong¹, Rui Zhu¹, Xiao-Mei Luo², Qing-Jun Lv²
1 Harbin Institute of Technology
2 China North Vehicle Study Institute

Abstract
The vibration problem of hydraulic system is related to the normal operation of vehicles. The research methods of hydraulic system mainly include finite element simulation and vibration test. The vibration test is not repeatable because of the great influence of the environment, and the computer simulation provides the possibility for the analysis of the complex hydraulic system. However, in the process of local refinement design of the system, the simulation calculation of the
whole structure is still needed to modify the local parameters, and the simulation time is long. Based on the substructure method in structural analysis, the substructure method for fluid structure coupling is derived to reduce the time cost in the simulation process of hydraulic system. In this paper, pointing at the particular vibration region of the pipeline, the structure is divided into substructures. The dynamic characteristics of each substructure are obtained by dynamic analysis, and the overall characteristics of the system are obtained according to the boundary coordination.

[S1103] CFD analysis of the leakages in external gear pump

Abstract

---

[S1104] System Diagnostic for an Electrohydraulically Actuated Controlled Trajectory Rapid Compression and Expansion Machine

Hao Sun¹,³, Yongsoon Yoon², Abhinav Tripathi³, Zongxuan Sun³

1 Southeast University
2 Oakland University
3 University of Minnesota-Twin cities

Abstract

In order to overcome limitations of the state-of-the-art rapid compression machines (RCM), an electrohydraulic actuator with precise motion control was designed for piston actuation of a new combustion instrument: controlled trajectory rapid compression and expansion machine (CT-RCEM) in our previous work. Considering typical faults in electrohydraulic systems, such as the pump fault, viscous friction change, oil contamination, and internal or external oil leakage, a recursive spectral analysis-based diagnostic method is applied to the CT-RCEM to improve its durability and reliability. The diagnostic method is motivated by parametric nonlinear frequency domain analysis with the inverse generalized frequency response functions (iGFRF). The diagnostic consists of two steps: 1) reference tracking control; 2) recursive harmonic analysis. And then the diagnostic decision is made based on the distribution of the Fourier transforms at different harmonics. Finally, the effectiveness of the proposed diagnostic is illustrated with numerical simulations for the CT-RCEM.

Weifei Hu\textsuperscript{1,2}, Jinyi Shao\textsuperscript{1,2}, Chuxuan Wang\textsuperscript{1,2}, Zhenyu Liu\textsuperscript{1,2}, Jianrong Tan\textsuperscript{1,2}

1 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
2 School of Mechanical Engineering, Zhejiang University

Abstract

Robotic grasping plays an important role in achieving the intelligent manufacturing nowadays. This paper develops a digital twin technology to carry out virtual grasping experiments, avoiding the expensive cost and time required for actual robot testing. To improve the grasping accuracy and efficiency, a new architecture optimization method is proposed to optimize the convolutional neural network which is implemented to predict the best grasping location of unknown objects in the digital twin technology. Different from existing neural networks optimization methods, the proposed architecture optimization method not only consider the performance accuracy, but also incorporate the computational latency into the optimization process. The computational and experimental testing results show that the proposed optimization method enables the optimal convolutional neural network to perform robotic grasping with improved accuracy.
Session 12: Sensors and Actuators

Chaired by Prof. Liang Lu (Tongji University) and Prof. Liang Yan (Beihang University), Shimao hall, 3rd floor, 16:40-18:20, Apr. 12.

[S1201] Electromechanical Actuator for Large Sized Directional Control Valves
Tobias Vonderbank¹, Prof. Dr. Katharina Schmitz¹
1 RWTH Aachen University

Abstract
Large sized valves commonly are pilot operated, due to high necessary forces. In hydraulic systems, in which the pressure in the main supply can drop below a critical value of around 4 bar, the internal supply of the pilot valve is not feasible and the system needs to be extended by a hydraulic pilot system. Thus, increasing the system complexity and its cost. By applying electromechanical valve actuation systems, the valve can be switched when low pressure in the hydraulic main line occurs. Consequently, a new electromechanical valve actuation system based on a steep threaded rod and a stepper motor has been designed. The dynamic behaviour, as well as the behaviour in the case of a power outage is investigated and presented in the following paper. The actuator is designed for valves of nominal size NS 25 and for a high volume flow system application. Tests with a representative high volume flow valve have been carried out to validate the concept and show various advantages over commonly used hydraulic operated valves with external pilot supply.

[S1202] Research on Jet Driven Water Hydraulic Rotary Actuator
Yousheng Yang¹, Hao Li¹, Yunkai Zheng¹, Hongyu Qi¹, Richmond Polley¹
1 Ocean University of China

Abstract
Based on the physical and chemical characteristics of water and jet propulsion theory, a novel jet directly driven water hydraulic rotary is developed. The driver uses water of a specific pressure to form a water jet through the nozzles which is uniformly distributed on the inner rotor in the circumferential direction, impacting the outer rotor, forming the impact torque on the outer rotor and the reverse thrust torque on the inner rotor, which then drives the dual rotor to rotate, The closed synthesizing mechanism is used to synthesize the reverse rotary motion and which drives the rotary tool to work. Through the application of Fluent software to establish the corresponding simulation
model, and simulating the jet impact moment and reverse thrust moment under different target distances, inlet pressures, and impact plate inclination angles, etc., the influencing factors of jet impact moment and reverse thrust moment are analysed, and gradually, a limited space jet hydraulics theory is established. The research results show that: when other relevant factors are determined, the jet impact moment increases with the increase of the nozzle inlet pressure; decreases with the increase of the impact plate inclination angle; increases first and then decreases with the increase of the target distance. The optimal target distance is 20mm. The jet reverse thrust moment is less affected by the jet inclination angle, target distance and impact plate inclination angle, and only increases with the increase of the nozzle inlet.

[S1203] Output Feedback Control for Electro-Hydraulic Servo Actuator Based on Levant Differentiator

Yunfei Wang¹, Jiyun Zhao¹, He Zhang¹, Xiaochun Zhang¹

¹ China University of Mining and Technology

Abstract

An output feedback controller based on Levant differentiator is proposed to track the desired trajectory with only position signal available. The typical modal of electro-hydraulic asymmetric cylinder system is transformed into Brunovsky form which is more suitable for the introduction of Levant differentiator. Modified sliding mode control is adopted to avoid complex calculations in the process of solving control input. Besides, the robust term of the sliding mode control is changed to a continuous switching function to reduce the inherent chattering of the system. The stability of the whole system is proved by Lyapunov method. Finally, simulations and experiments are constructed to verify the performance of proposed controller. The results demonstrate that the designed output feedback controller combining differentiator and modified sliding mode control has an excellent tracking performance with a simple structure.

[S1204] Calibration Technology and Development of the Liquid Automatic Particle Counter

Xinyou Hao¹

¹ Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.

Abstract
The liquid automatic particle counter is key equipment in the field of hydraulic contamination control technology, and calibration is the basis of its measurement accuracy. This paper describes the principle, method, application range and main characteristics of the liquid automatic particle counter calibration technology, at the same time, the development and application of calibration technology in improving the accuracy of calibration results, calibrating on-line application instruments and multi-pass on-line particle counting system are analyzed.

[S1205] Highly Stable Stretchable Strain Sensors by Laser Processing
Kaichen Xu¹
1 Zhejiang University

Abstract
In wearable electronics, to acquire stability and simultaneously preserve stretchability, sensitivity, as well as scalability are of high significance yet challenging for practical device applications. In this work, a kirigami-structured graphene-polymer hybrid nanocomposite is proposed for strain sensors by a laser direct writing technique on a polyimide sheet. Using such kirigami structures, strain in the sensor material can be drastically reduced in the circumstances of highly stretching conditions. To protect the device, ecoflex polymer is applied as the passivation layer. Depending on the applications, ecoflex grid-wrapped and film-encapsulated devices are realized with high stretchability (>200 % strain) and sensitivity (>80 % resistance change at 60 % strain), respectively. Significantly, this sensor platform presents almost no performance degradation even after >60,000 stretching cycle tests due to less strain within the sensor. Furthermore, as proof-of-concepts for the human-interactive applications, motion detection and perspiration monitoring with a breathing period of 3-4 s for comparatively long duration (>2 hours) are successfully demonstrated. These facile, scalable, highly stable and stretchable strain sensors afford a new route towards next-generation reliable skin-inspired wearable electronics.
Session 13: Control Systems

Chaired by Prof. Zheng Chen (Zhejiang University) and Prof. Jianyong Yao (Nanjing University of Science and Technology), Wenjin hall, 3rd floor, 16:40-18:20, Apr. 12.

[S1301] A New Piecewise Linearization and Multi-Model Switching Control Method for the Hydraulic Transformer Control System

Wei Shen¹, Jinli Liu¹, Chao Shen¹

¹ University of Shanghai for Science and Technology

Abstract

The hydraulic transformer control system is a promising energy-saving architecture due to its low throttling loss and four-quadrant characteristic. However, the strong nonlinearity because of the unique structure and work principle of the NHT becomes the key issue to be solved for application. In this paper, the mathematic model of the NHT system is provided. Additionally, the method of piecewise linearization with multi-model switching is proposed to address the nonlinear issue caused by trigonometric function. Then the control quantity of the system is transformed into a linear problem to be solved through linearization. The backstepping control algorithm and the filter are combined to the design of the robust controller. Finally, the simulation is performed to validate the effectiveness of the proposed algorithm.

[S1302] Precision Motion Control of an Electro-Hydraulic Actuator with Motor Pump Speed Dead Zone Compensation

Xiaoping Ouyang¹

¹ Zhejiang University

Abstract

xxxxxx


Qichao Ren¹, Ziming Kou¹, Juan Wu¹, Tengyan Hou¹, Peng Xu¹

¹ Taiyuan University of Technology
Abstract
According to the mechanism of hydraulic impact phenomenon, a rotary differential vibration exciter with trapezoidal throttle area is optimized. The rotating motor drives the shaft to rotate, so as to realize the switching of the connection state of the hydraulic system, and finally realize the vibration output of the piston connecting rod of the vertical differential hydraulic cylinder. The simulation model of the excitation system was established on the Simulation X platform, and the validity of the model was verified by comparison with physical experiments. The simulation and calculation of the output characteristics of the excitation system under different pressures and different speed of the drive motor. The results show that: When the throttle opening of the hydraulic vibration exciter is switched, hydraulic impact will occur. Hydraulic shock waves can effectively improve the vibration force and amplitude output of the system, and the extreme value of impact waves increases with the increase of supply pressure and excitation frequency. The excitation frequency of the excitation system has a linear relationship with the speed of the motor, and the excitation force and amplitude have good periodicity. The excitation force and amplitude of the system are positively correlated with the oil source pressure. With the increase of the excitation frequency, the excitation force also presents an upward trend and the amplitude decreases.

[S1304] Performance Analysis of Double-Screw Hydraulic Joint Based on Rolling Friction
Yongming Bian¹, Jie Shao¹, Meng Yang¹, Liang Lu¹,²
1 Tongji University
2 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
Abstract
Hydraulic joint is the key driving component of robot. The traditional double-screw hydraulic joint has large volume and weight, and the screw pair is in surface contact, so the friction resistance is large, and the motion has large nonlinear characteristics. In order to reduce the joint size of the hydraulic robot, improve the control accuracy and dynamic response performance, this paper proposes a new joint structure form of ball double-screw hydraulic robot. Using ball and circular arc spiral groove transmission, the friction coefficient is small, the whole joint structure is compact, the volume is small, and the transmission accuracy is high. According to its structure and working principle, the force analysis of the hydraulic joint was carried out, the mathematical model of the hydraulic joint was established, and the static and dynamic response simulation experiments were carried out. The experimental results show that compared with the traditional double-screw hydraulic
joint, the ball double-screw hydraulic robot joint has the advantages of smaller starting pressure, larger output torque and faster speed response under the same specification. It provides a new structure idea for precise and efficient control of hydraulic joint.

[S1305] Hydraulic Control System for an Asymmetric Cylinder Based on Dual-Constant Pump Driven by Dual-Servo Electric Motor Respectively
Shijun Chen¹, Guanglin Shi¹, Xiaofu Zhang¹
¹ Shanghai Jiao Tong University

Abstract
In this paper, a hydraulic control system for an asymmetric cylinder based on dual-constant pump driven by dual-servo electric motor respectively is proposed. According to the designed hydraulic schematic diagram, the system has the characteristics of small power loss and high efficiency. Since the independent "servo electric motor + constant pump" is used to supply oil to the two chambers of the asymmetric cylinder, there is no solenoid valve used and no need for the servo electric motor to reverse to realize the two-way line motion. This is realized by two position three-way valves directly controlled by the outlet pressure of the constant pump, so the system response speed is high, so is the control accuracy. The overall structure design of the system and the design of the hardware control system are completed based on the hydraulic schematic diagram. Secondly, the mathematical model of the control system is established, and the steady-state and dynamic characteristics of the system are preliminarily analyzed. Then, through the co-simulation of AMESim and MATLAB Simulink, the feasibility of the system is verified, its mechanism is further studied, and the parameters of major hydraulic components are determined, which provides theoretical support for the test. On this basis, the control strategy and control method are studied. At last, the prototype is completed, and the test results are analyzed. Through the combination of theory, simulation and experiment, it is proved that the hydraulic control system for an asymmetric cylinder based on dual-constant pump driven by dual-servo electric motor respectively is feasible. The results of the three supports each other. The parameters of hydraulic components obtained by theory and simulation have achieved good results in the experiment. Through simulation and test, it is also proved that the system designed in this paper can achieve high-precision positioning control under PID control, and show the characteristics of fast response and good stability.
Session 14: Light Hydraulics

Chaired by Prof. Jing Yao (Yanshan University) and Prof. Yi Zhu (Zhejiang University), Jiahe hall, 3rd floor, 16:40-18:20, Apr. 12.

[S1401] A Novel Design Method for Hydraulic Manifold Blocks via Additive Manufacturing

Cong Zhao†, Zhiyang Liu†, Chao Zhang†, Huayong Yang†, Yi Zhu†
†State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University

Abstract
Additive manufacturing (AM) can be used to make hydraulic components light and compact. However, an AM-enabled design methodology of complex hydraulic manifolds, which considers both lightweight and pressure loss, still lacks. This paper presents a simple and efficient design method for selective laser melting (SLM) fabricated hydraulic manifolds. SLM process boundaries are firstly developed. An algorithm using depth-first search (DFS) is presented to determine the relative positions of installed hydraulic components through comparisons among typical bends in a simplified fluid network. Bionic structure shaped like a tree leaf is introduced to reduce the local pressure loss. A case study was also performed to validate the feasibility and efficiency of the method. Results indicated that a great lightweight and pressure loss reduction are simultaneously achieved.

[S1402] Design of High-Speed 2D Piston Pumps for High Efficiency

Jian Ruan†, Sheng Li†, Bin Meng†, Chuan Ding†, Yu Huang†, Chenchen Zhang†
†Zhejiang University of Technology

Abstract
Axial piston pumps are widely used in various fields for advantage of high power-weight ratio. In order to further increase its advantage, many researchers have focused on the mechanical losses generated by the three sliding friction pairs in such pumps and attempted to diminish them through new structural designs of the pump’s components. In this paper, high-speed 2D piston pumps are redesigned through changing its rotational sets and increasing the size of the rolling bearing installed in the cone roller for the decrease of the churning losses of the rotational sets and the
mechanical losses that the cone roller rolling on the guiding rail. This new high efficiency 2D piston pump is researched on the mechanical efficiency by mathematical modelling and compared with the high-speed 2D piston pump. The experimental results measured by building a new experimental rig for verifying its working principle and measuring its mechanical efficiency show its mechanical efficiency is higher to that of the high-speed 2D piston pump and not decreases in high load pressure. It is conclusion that the high efficiency 2D piston pump has the potential to load with greater pressure.

[S1403] The Modelling and Dynamic Characteristics of a Non-Metallic Pressurized Reservoir with Variable Volume
Jing Yao\(^1\), Pei Wang\(^1\), Baidong Feng\(^1\), Mandi Li\(^1\), Dingyu Wang\(^1\)
1 Yanshan University

Abstract
With increasing demands for reducing emissions and energy saving, hydraulic reservoirs need new architecture to optimize their weight, space and volume. The traditional open reservoirs are considerably larger and weights, easy polluted, which threatens to the operation of hydraulic systems. While the closed-reservoir provides small volume and light-weight advantages versus open reservoir. In this study, a non-metallic pressure reservoir with variable volume is designed and manufactured for closed-circuit hydraulic systems. The reservoir housing is made of rubber, and Mooney-Rivlin model is chosen based on the rubber strain properties. The FEA simulation for the reservoir was done on ANSYS Workbench to obtain the structural stiffness. The major contributions are the establishment of the mathematical models for this reservoir, including the volume equation changing with height, the flow equation, as well as the force balance equation, to explore the output characteristics of this reservoir. Based on these, the simulation models were built to analyse the output characteristics of the reservoir. Moreover, the test rig of traditional hydraulic system is transformed as a closed-circuit asymmetric hydraulic system for the reservoir, and preliminary verification experiments are carried on it. Results demonstrates that the designed reservoir can absorb and discharge oil, and supercharge pumps inlet to benefit system operation. The changes in volume and pressure with displacements under different volume ratios and frequencies were obtained, which verified the correctness of the mathematical models. By virtue of its light-weight design and small volume, the reservoir has the ability to replace traditional open reservoirs, which would lay foundation for future theoretical research of this reservoir.
[S1404] Design and Analysis on Light Weight Carbon Fibre-Reinforced Hydraulic Cylinder
Yao Li¹, Yeshuo Wang¹, Yaoxing Shang¹, Tian Yu¹
1 Beihang University

Abstract
Hydraulic cylinder is widely used in aerospace vehicles, construction machinery. Its weight accounts for a large proportion in the hydraulic system. The lightweight of hydraulic cylinder is beneficial to improve the mobility, bearing capacity, and energy efficiency. In this paper, the hydraulic cylinder tube with aviation actuator (double output rod) is taken as the research object. Carbon fiber reinforced plastics (CFRP) composite material is used to replace part of metal material, which can reduce the weight of hydraulic cylinder on the premise of meeting the performance requirements of hydraulic cylinder.

According to the requirement that the seal of hydraulic cylinder allows deformation, a new calculation method of CFRP layer of composite hydraulic cylinder is proposed. The structure suitable for forming hydraulic cylinder of heterogeneous composite structure is designed. A simulation platform of heterogeneous composite structure was built by finite element software, and the stress and deformation were analyzed. The simulation results show that the CFRP hydraulic cylinder tube can not only guarantee the performance of the original all metal hydraulic cylinder tube, but also has great weight reduction potential. With the increase of the internal temperature of the hydraulic cylinder, the proportion of the CFRP layer carrying the cylinder tube load increases.

[S1405] Lightweight Design Method of Electro-Hydraulic Actuator Based on Rib Structure
Huang Zhipeng¹, Kong Xiangdong¹, Yu Bin¹, Ba Kaixian¹, Fu Kangping¹, Fu Chengwei¹
1 Yanshan University

Abstract
Compared with other robots, the hydraulically driven legged robot has larger power-to-weight ratio, higher load capacity and faster response speed, but the weight of its single leg affects the motion performance. If the one-leg lightweight design can be realized, it will greatly improve the motion performance of the robot. To realize the lightweight of the one-leg hydraulic system, it is necessary to focus on the lightweight of the electro-hydraulic actuator, which is the key driving component. Considering the problems caused by the lightweight, the rib structure design is carried out. To
lighten the electro-hydraulic actuator, the first step is to make the hydraulic cylinder thinner, and the thinning of the cylinder wall will reduce the safety factor, increase the deformation and affect the performance. A lightweight design method of electro-hydraulic actuator based on rib structure is presented in this paper. First, the inherent mechanism of the traditional hydraulic cylinder design method is studied, and it is concluded that the radial stress of the force unit of the hydraulic cylinder wall is twice as much as the axial stress. The physical constraint model of wall thickness and the quality optimization model are established, and the cylinder wall thickness that meets the requirements is obtained. It provides a theoretical reference for the follow-up lightweight design of hydraulic cylinder. The auxiliary rib structure can effectively reduce the deformation of the thin-walled cylinder and improve the reliability. Therefore, under the condition of the same quality, the influence of the closed area of different size and shape of the rib on the local deformation is studied, and the optimal size and closed shape are obtained. The theoretical reference for the design of thin-walled hydraulic cylinder is provided. Through the stress analysis of the hydraulic cylinder by the finite element analysis software, it is concluded that the deformation in the middle area is the largest and the deformation at both ends is small. A compact transverse and longitudinal rib structure is designed in the middle area of the cylinder to reduce the deformation, and a sparse rib structure is designed at both ends of the hydraulic cylinder to improve the safety factor and reliability of the cylinder. Through the simulation analysis, it is proved that the electro-hydraulic actuator based on the rib structure can be lightweight while meeting the performance requirements.
Session 15: Pneumatic Components

Chaired by Prof. Tao Wang (Beijing Institute of Technology) and Prof. Yan Shi (Beihang University), Jianian hall, 3rd floor, 16:40-18:00, Apr. 12.

[S1501] Finite Element Modeling and Optimal Design of Electromagnet Pneumatic Proportional Servo Valve
Yan Shi¹, Luyu Xu¹, Yixuan Wang¹, Shuai Ren¹, Maolin Cai¹, Weiqing Xu¹
¹ Beihang University

Abstract
The electromagnet type pneumatic proportional servo valve has the advantages of simple working structure, large output power, and large working frequency response. It is widely used in industrial pneumatic servo control systems that require precise adjustment of high-pressure air sources. It has control performance in actual use. The shortcomings of poor output and easy to be interfered by working conditions. Based on the practical electromagnet-type pneumatic proportional servo valve, this paper conducts finite element analysis on the electromagnet magnetic field in the valve, based on the finite element dynamic mathematical model, and studies its dynamic characteristics to optimize the performance of the valve.

Xubo YU¹, Xin LI¹
¹ State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

Abstract
Bernoulli grippers, which are widely employed in automated production lines, are pneumatic manipulators capable of noncontact adsorption that utilize the decelerating inertial effect of the radial air flow to generate negative pressure and a suction force. This paper proposes an innovative design for the Bernoulli grippers in which divergent flow is formed through a tiny-inclination cone structure between the gripper and the workpiece, and the inertia-enhancement effect of the divergent flow is exploited to greatly increase the negative pressure and suction force (hereafter, this is referred to as a divergent-flow gripper). First, a theoretical model of the divergent flow between the divergent-flow gripper and the workpiece was formulated. The theoretical formulas for calculating the pressure distribution and suction force were then derived. Suction force measurement experiments were then
conducted, whose results indicated that the proposed divergent-flow gripper can increase the suction force by several factors compared with that of an unmodified gripper with a flat surface. The influence of the divergent flow on the inertial and viscous effects of the gripper was examined both theoretically and experimentally and the main factors leading to the increase in suction force were analyzed. These findings serve as important theoretical and experimental references for the design of the Bernoulli gripper.

[S1503] Optimal Trajectory and Design for Piston Expander
Qihui Yu¹, Xiaofei Li¹, Qianchen Wang¹, Xin Tan¹
¹ Inner Mongolia University of Science & Technology

Abstract
Energy efficiency and output power are critical to air expander which limit the development of the piston expander. Piston trajectory will influence on the expansion ratio which affects the expander efficiency and output power. Under the conditions of the fixed total cycle time and compressed air consumed per cycle, the optimal piston motion trajectories for maximizing the output power are derived on each stroke by applying optimal control theory. Based on the trajectory, the new mechanical structure of piston expander are designed. And then the output power and efficiency characteristics of the new piston expander are obtained. Results show that, the performances of the new piston expander are better than that of the traditional piston expander. This research can be referred to in the design of the piston expander.

[S1504] Modeling and Experimental Validation of the Basic Characteristics of an Air Conveyor Using Inclined Air Jet
Rongyue Wang¹, Wei Zhong¹, Chong Li¹, Jiwen Fang¹
¹ Jiangsu University of Science and Technology

Abstract
Transport in a contact status is likely to cause defects on the surface of orkpieces. Transport by means of pneumatics technology is widely used in practical applications. In this paper, a modular two-dimensional air conveyor using inclined air jet is developed. The inertial force and viscous force generated by air jet are theoretically modelled and simulated, and the experiments are performed to verify the model. The results indicate that the inertial force of tilted air-jet is much larger than the viscous force, and the actuating force increases with the raise of the floating height of the object in a certain range of floating height.
[S1601] A Passive Hydraulic System Increasing the Efficiency of Legged Robot

Wu Fan¹, Tao Liu¹, Jingang Yi¹, Xinyan Huang¹, Bin Zhang¹ and Shuoyu Wang¹
¹ State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

Abstract
Load-carrying capability is an essential criterion in legged robots’ practical application. This paper proposes an unpowered hydraulic auxiliary system to improve the legged robot’s loading capability and energy efficiency. For humans, it has been widely hypothesized that intra-abdominal pressure can reduce potential injurious compressive force imposed on spinal discs when a person lifts heavy objects. Inspired by this human biomechanical phenomenon, we design a novel load-carrying strategy using hydraulic cylinders, valves and accumulators. Different from ordinary powered hydraulic systems, this design provides continuous support force to share the load applied on knee joint actuator without consuming extra energy. The bent-leg theoretical model is constructed to validate the design and analysis. A bipedal hydraulic-assisted electric leg prototype (HyELeg) is fabricated and tested for squatting with a load of 125% of its own body weight, and the walking performance is enhanced by 16.9% in energy efficiency with carrying a load of 67.5% of its own body weight.

[S1602] Attitude Adaptive Manipulation of Soft Dexterous Hand with Reinforcement Learning Method

Yinglong Chen¹, Xinyan Tan¹, Zengmeng Zhang¹ and Yongjun Gong¹
¹ Dalian Maritime University

Abstract
In this paper, a soft dexterous hand with soft bionic joints is designed with soft finger matrix and composite elastic fabric. The proposed soft dexterous hand has 15 independently controlled finger joints similar to the human hand in skeletal structure, which greatly improved its dexterity. In order to realize the grasping of special objects in special scenes, this paper proposes a grasping method based on the reinforcement learning method the deep deterministic strategy gradient DDPG. In
addition, we have created a virtual simulation environment with collision function in MATLAB, which can calculate the contact force between the soft dexterous hand's fingertips and surrounding environment and verify the dexterity of the soft dexterous hand. In the virtual environment, we carried out simulation of the designed soft dexterous hand, and tested the dexterous manipulation of the dexterous hand to grasp objects with the adaptive attitude control method. The simulation results indicate that the proposed attitude adaptive method is effective for the soft dexterous hand to grasp and manipulate the object dexterously, which improves the success rate of grasping.

[S1603] Electro-Hydrostatic Actuators in Primary Flight Control – Lifetime and Reliability of Eha Piston Pumps
Amos Merkel¹, Yannick Duensing¹, Katharina Schmitz¹
1 RWTH Aachen University

Abstract
More electric Aircrafts require electrically powered yet highly dynamic and robust linear flight control actuators. Electro-Hydrostatic Actuators (EHA) combine the advantages of both, the electric and the hydraulic domain. Hence, they are a highly favoured solution for the application to actuate ailerons, rudders and elevators. However, the lifetime of existing systems is limited due to early pump failure, limiting the use to backup-actuators in present systems. This paper gives an overview of the EHA technologies in primary flight control. From the special operating conditions in primary flight control application, the sources of pump failure are derived. The authors highlight the challenges and characteristics in pump design for EHA applications. Furthermore, possible countermeasures are discussed. In order to find the dominant damage relevant operating conditions and areas of wear of specific systems, the experimental design for a sequential endurance test campaign is presented. This test campaign aims to allow the distinction of wear contribution to specific areas and operating modes in future. Finally, the authors highlight possible optimization strategies for reducing wear and increasing reliability by focusing on understanding and predicting pump failure in aerospace EHAs.

[S1604] Development of Bendable and Twistable Electrohydrodynamic Pump with Improved Electrode Patterns
Zebing Mao¹, Yumeta Seki¹, Yota Asai¹, Ardi Wiranata¹, Ayato Minaminosono¹, Shingo Maeda¹
1 Shibaura Institute of Technology
Abstract

Soft electrohydrodynamic (EHD) pumps are a promising enabling technology for a wide range of emerging applications, e.g., robotics, microfluidics, and muscles, etc. The previously reported soft EHD pumps generated limited pressure and flow rates, which restricts their applications. Aiming to improve the performance of EHD pumps, we focus on the optimization of pairs of electrodes with different patterns. The planar EHD pumps consist of four parts: a pump base, a top cover, fluidic channels, and electrodes. We designed two patterns of electrodes for the EHD pumps. The EHD pumps were verified to be bendable and twisted according to the fabricated results.

[S1605] Neural Network-Based Robust Control of Hydraulic Systems with Partial Output Feedback

Xianglong Liang\textsuperscript{1}, Zhikai Yao\textsuperscript{1}, Yaowen Ge\textsuperscript{1}, Jianyong Yao\textsuperscript{1}

1 Nanjing University of Science and Technology

Abstract

This paper proposes an asymptotic tracking controller for hydraulic systems without velocity measurement. Although velocity signal can be approximately obtained by numerical differentiation operation based on position measurement, it usually contains strong noise effect which will extremely deteriorate the tracking performance. In order to deal with this issue, a neural network (NN) based robust control scheme is developed for hydraulic systems. First of all, a NN-based observer is designed to estimate the velocity information. And then a robust control approach is effectively integrated to dealing with the matched and mismatched disturbances. As a result, theoretical analysis reveals that the proposed controller guarantees a semiglobal asymptotic stability with partial output feedback. Extensive simulation results are provided to verify the performance of the proposed control strategy.
**Session 17: Valves**

Chaired by Dr. Heng Du (Fuzhou University) and Prof. Haigang Ding (China University of Mining and Technology), Shimao hall, 3rd floor, 13:30-15:10, Apr. 13.

[S1701] A Study on a MEMS Electro-Rheological Valve for Higher Pressure

Daichi Sugauchi¹, Kazuhiro Yoshida¹, Sang In Eom¹, Joon-wan Kim¹

¹ Tokyo Institute of Technology

**Abstract**

For an advanced microrobot, a MEMS electro-rheological valve with higher pressure was investigated. In the microrobot, simple ER microvalves control the electro-rheological fluid (ERF) flows with its apparent viscosity change when subjected to an electric field. High pressure can reduce the diameter of the pipes with low flow rate and the sectional area of the actuator. First, the adhesive strength of MEMS devices was measured at 1.7 MPa. Second, a three-port MEMS ER valve was fabricated and characterized. It was found that the pressure control range is decreased with increased supply pressure, however, the valve can control 10 kPa level pressure even at 0.5 MPa. Then a rubber-tube microactuator constrained with a coil spring was fabricated and characterized for the system.

[S1702] Effects of Two-Stage Sleeves Deflection on Cavitation of High-Pressure Control Valve

Long-jie YU¹, Cong-wei HOU¹, Chang Qiu¹, Zhi-jiang JIN¹, Jin-yuan Qian¹

¹ Zhejiang University

**Abstract**

Cavitation is serious problem when the liquid flows through control valves under high-pressure difference working conditions. The control valve with multi-stage sleeves is widely used for the advantages of cavitation reduction during the high-pressure reducing process. The geometric structure of sleeves plays a significant role in reducing cavitation. Thus, the effects of the deflection angle of the two-stage adjacent sleeves are analysed in this paper. Results indicate that adjacent sleeves deflection can reduce cavitation effectively, especially under high pressure, and the more energy will be lost inside adjacent sleeves. This work can provide a reference for the design of sleeves in high-pressure control valves.
[S1703] Study on Characteristics of Two Dimensional Rotary Electromagnet
Mingzhu¹, Dai, Bin. Meng¹, Tao. Pu¹, Hao. Xu¹, and Deng. Wang¹
1 Zhejiang University of Technology

Abstract
The spiral groove structure of two-dimensional valve feedback mechanism is difficult to be machined, and the cost is high. A novel rotary electromagnet with negative feedback mechanism (RENFM) is proposed in this paper in order to replace the feedback mechanism of spiral groove. Prototypes of RENFM with different mover oblique angles were designed and machined, and a special experimental bench was built. The FEM simulation and experimental approaches were performed to study the driving and feedback performance. The mover oblique angle has crucial influence on both driving and feedback performances. It is expected that two-dimensional valve driven by RENFM has very economical machining cost.

[S1704] Numerical Analysis and Optimization of Ultra-clean Electric Valve with Magnetically Driven Poppet
Mingxiao Liu¹, Dong Yang¹, Tianyi Ge¹, Liang Hu¹, Xiaodong Ruan¹, Rui Su¹
1 The State Key Laboratory of Fluid Power & Mechatronic Systems, Zhejiang University

Abstract
To meet the needs of ultra-clean flow control in the fields of semiconductor and biomedicine, a new permanent magnet embedded ultra-clean electric valve (PMEV) was proposed. By embedding the PM into the poppet, which is made by ultra-clean material (such as ultra-pure perfluororesin), and controlling the poppet through magnetic field contactless, the PMEV has excellent reliability and safety. In this paper, the working principle and application of the ultra-clean electric valve were described firstly. Then, the reason for poppet vibration was investigated through force analysis of poppet. Based on the numerical calculation of the magnetic force and the transient simulation of the fluid impact force on the poppet, the vibration characteristics of the poppet were obtained. By improving the driving magnetic structure and optimizing the geometry of poppet, the vibration of the poppet was reduced. Furthermore, the feasibility of using ultra-clean electric-valves as actuators of high precision flow control systems was guaranteed.

[S1705] Characteristic of Unsteady Cavitation Behaviour and Pressure Pulsation in Regulate Valve
Yongwei Xie, Beibei Li, Xiumei Liu, Jie He
1 China University of Mining and Technology

Abstract
The unsteady flow in a regulating valve and pressure pulsation were numerically studied based on a computational fluid dynamics (CFD) method. The spectrum analysis is used for processing the pressure signal, and the correlation between the unsteady cavitation behaviours and the pressure fluctuations was discussed. The results show that a typical quasi-periodic process is characterized by the process of attached cavity growth, attached cavity shedding, and the growth and collapse of cloud cavities. The periodic frequency of cavitation is 565Hz. The reverse pressure gradient at the end of the attached cavity near the wall is the main cause of the reverse jet, and then the vortex is formed to make the attached cavity shedding. At the same time, the development of shedding also has influence on the pressure pulsation in the flow passage. The average pressure variation in different sections of the valve has the same dominant frequency, and the frequency is basically consistent with the unsteady quasi-periodic breaking and shedding frequency of the shedding. This study analyses the behaviour of the unsteady cavitation correctly, and this results is significant for the optimized design and stable operation of control valves in engineering applications.
[S1801] Design and Simulation on Pressure Difference and Flow Compound Control Valve for Water Hydraulic Artificial Muscle Joint

Zengmeng Zhang\textsuperscript{1,2}, Yong Yang\textsuperscript{1}, Jinkai Che\textsuperscript{1}, Yunrui Jia\textsuperscript{1}, Yinglong Chen\textsuperscript{13}, Yongjun Gong\textsuperscript{13}
1 Dalian Maritime University
2 Key Laboratory of Rescue and Salvage Engineering Liaoning Province
3 Dalian Maritime University

Abstract
The water hydraulic artificial muscle joint (WHAMJ) compound control valve is composed of a pressure control valve and two flow compensation valves. The pressure control valve is used to control the pressure difference of the water hydraulic artificial muscles (WHAMs). The flow compensation valves are used to improve the response speed of the WHAMJ. The model of the compound control valve is established in AMESim and the simulation analysis is carried out. The results show that the compound control valve has the advantages of high control accuracy and fast dynamic response, which can meet the requirements of the WHAMJ.


Ruihao Zhao\textsuperscript{1,2}, Yaoyao Liao\textsuperscript{1,2}, Zisheng Lian\textsuperscript{1,2}
1 Taiyuan University of Technology
2 Shanxi Key Laboratory of Fully Mechanized Coal Mining Equipment

Abstract
The widely used high-pressure, large-flow water based electro-hydraulic on/off valve can no longer meet the automatic, precise and smooth action of the actuators of hydraulic powered support in the coal mine, for the improvement of intelligent coal mining level. An effective way to achieve this is electro-hydraulic proportional flow control. However, there is no electro-hydraulic proportional flow valve suitable for the hydraulic powered support due to the high-pressure, large-flow system and the
low-viscosity of the water based fluid. In this paper, A high pressure, large flow water based
directional flow valve, with both manual and automatic controlling functions is proposed. The paper
establishes the mathematic model of the new valve, investigating the effects of duty ratio, width of
feedback groove, area ratio on the displacement characteristics through some simulations. The work
provides an important reference for the design of high-pressure, large-flow water based electro-
hydraulic flow control valve.

[S1803] Optimization Design of The Anti-Cavitation Structure in the High
Pressure Water Electro-Hydraulic Unloading Valves with Large Flow Rate
Rui Yu¹, Siyu Ma¹, Haochen Qi¹, Kamal Upadhyay¹, Hua Zhou¹, Huayong Yang¹
1 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

Abstract
High pressure water electro-hydraulic unloading valves with large flow rate are important parts of
emulsion pump station system. These valves are the core components of unloading system for
pressure control and overload protection. However, the cavitation often occurs in the main valve port
due to the sudden drop of pressure under circumstances of large flow rate (1200 L·min⁻¹) and high
pressure (50MPa), which affects the safety and reliability of the whole pumping station system. To
improve the cavitation resistance of water electro-hydraulic unloading valve, a double-row-hole
valve sleeve structure was proposed to improve the pressure and flow distribution of flow field based
on the combination of two-step throttling and high-pressure jet orifice structure. Using a CFD
approach, the pressure, flow velocity and vapor phase distribution of main valve with different size
of valve opening were obtained under actual conditions. The results showed the effectiveness of the
proposed method.

[S1804] Simulation Research on Dynamic Characteristics of Check Valve of
Reciprocating Pump (CVRP) for High Pressure and High Flow Water Medium
Jie Dong¹, Yinshui Liu², Wenbin Cao¹, Qingzhen Dong¹, Hong Ji¹
1 Lanzhou University of Technology
2 Huazhong University of Science and Technology

Abstract
The check valve is the key component of the water hydraulic reciprocating pump. The working state
of the check valve of the reciprocating pump directly affects the efficiency of the pump. In this paper,
the inertial force of the valve movement and the volume elastic modulus of the medium were considered. The mathematical model of the suction and discharge valve of water hydraulic reciprocating pump with ultra-high pressure and large flow is established, and the fluent simulation software was used to simulate the coupling characteristics of the transient flow field change in the valve cavity and the valve movement under the liquid pure water medium, and the pressure velocity distribution of the flow field were obtained. The flow coefficient of the check valve port and its changing law were identified, and the influence of spring stiffness and limit height on valve performance was also discussed. The research results show that in different stages of valve lift, the valve port flow coefficient has different changing laws. When the valve opening is at its maximum, the flow coefficient is stable, between 0.6 and 0.7. In addition, the spring stiffness and limit height will affect the response, opening, and impact stress of the valve. Changing the spring has advantages over changing the limit height, so a reasonable value should be selected.

[S1805] Design and Simulation of Water Hydraulic Digital Valve
Qingtong Liu¹, Wei Ge², Songlin Nie¹, Hui Ji¹, Fanglong Yin¹ and Zhonghai Ma¹
1 Beijing University of Technology
2 Hubei Institute of Aerospace Chemical Technology

Abstract
In order to achieve the high-precision flow control requirements of the water hydraulic system, a water hydraulic digital valve driven by voice coil motor is designed. The valve is composed of six array-type single valves, which realizes the flow characteristics of digital output by controlling the switch combination of different single valves. The characteristics of flow coefficient are related to valve opening and system pressure. To design accurately the flow output under different single valves, the CFD simulation technology is employed to calculate the flow rate under different valve openings and system pressure, and the curve of flow rate with valve opening and system pressure is fit through Design-Expert software. And each single valve spool was designed according to flow output requirements. The output flow rate characteristics of the digital valve are simulated. The simulation results show that the digital valve has good output flow characteristics, which can meet the requirements of the flow digital output.
Session 19: Pneumatic Systems

Chaired by Prof. Wei Xiong (Dalian Maritime University) and Prof. Hao Liu (Zhejiang University), Wencong hall, 3rd floor, 13:30-15:10, Apr. 13.

[S1901] Myoelectric Control of a Pneumatic Hand Rehabilitation Glove Using Pattern Recognition
Ningte Chen¹, Zhongsheng Sun¹
¹ Nanjing University of Science and Technology

Abstract
An EMG control method of pneumatic rehabilitation gloves was studied to realize the myoelectric control of rehabilitation training for stroke patients. Firstly, the surface EMG signals of finger flexors and extensors at the front arm were collected and were subjected to three-scale wavelet packet decomposition. The energy and variance feature of wavelet packet coefficients were extracted with the data sliding window method and composed of 32-dimensional vectors. The 32-dimensional feature vector was reduced to 3 dimensions by Principle component analysis. Furthermore, a BP neural network pattern recognition classifier was designed, which used the minimum deviation of output vector to judgment gestures. The average recognition accuracy of the optimal scheme for offline training of five motions was 97.09%. Finally, the average online recognition accuracy of real-time gesture control was 87.43%.

[S1902] A Low Friction Pneumatic Cylinder Based on Vibration Friction Reduction Theory and Its Motion Tracking Control
Peng-fei Qian¹, Pan-song Lv¹, Yang Liu¹, Peng Xia¹, Bing Zhang¹
¹ Jiangsu University

Abstract
Pneumatic cylinders are widely used in fields such as automated production and robotics, but nonlinear factors such as friction have brought control difficulties to pneumatic servo systems. In order to improve the friction characteristics of the cylinder and improve the tracking accuracy of its trajectory, this paper based on the principle of vibration reduction to propose a low-friction cylinder that realizes the longitudinal vibration of the cylinder through the inverse piezoelectric effect of the piezoelectric stack, and builds the cylinder friction test system, experiments show that: in the
longitudinal vibration mode of the resonance frequency of 3050Hz, the static friction of the cylinder is reduced by up to 25%, and the dynamic friction is reduced by up to 20%. Subsequently, in order to study the impact of vibration on the tracking accuracy of the cylinder motion trajectory, the PID algorithm and the sliding mode algorithm were selected in the controller design. When tracking the sinusoidal reference signal, it was found that the tracking performance of the sliding mode algorithm was significantly better than the PID algorithm; in addition, the introduction of high-frequency vibration can reduce the maximum tracking error of the cylinder, especially in the commutation phase, the tracking accuracy is improved by about 23%.

[S1903] Research on Position Control of Friction Compensation Based on Improved Artificial Bee Colony Algorithm
Yeming Zhang¹, Zhiyu Yang¹, Hongwei Yue¹, Kaimin Li¹, Weiqing Xu², Maolin Cai²
1 Henan Polytechnic University
2 Beihang University
Abstract
Compared with the driving force of compressed air, the friction force of the pneumatic end effector in motion is relatively large, and the friction force changes nonlinearly during the motion, which seriously affects the precise positioning of the cylinder position. In order to reduce the influence of friction and improve the positioning accuracy of the pneumatic system, this paper proposes a friction feedforward compensation control strategy based on the improved artificial bee colony algorithm (IABC) based on the research on the cylinder friction mechanism, and combines the control strategy. The results are compared with those of the general PD control strategy. The experimental results show that when the input signal frequency and amplitude are 0.5Hz and 40mm respectively, the maximum tracking steady-state error of the traditional PD controller is 6.88mm; the maximum tracking steady-state error of the IABC-friction compensation-PD device is 1.08mm, verification. The feasibility of the friction feedforward compensation control strategy based on the improved artificial bee colony algorithm (IABC) and the good tracking performance of the system are discussed.

[S1904] The Simulation System Development of Bridge-Type Pneumatic Circuit and Its Experimental Verification
Zhong’ai Jiang¹,², Changle Sun¹, Wei Xiong¹, Hongwang Du¹, Zhiwen Wang¹
1 Dalian Maritime University
2 Dalian Ocean University

Abstract
In order to save experimental cost, during the process of energy-saving research of bridge-type pneumatic circuit, simulations are needed for verifying the accuracy and applicability of theoretical research instead of a plenty of actual experiments. In this paper, a simulation system based on VB and ActiveX controls of NI Measurement Studio is proposed, which can describe the running state parameters of bridge-type pneumatic circuit through system modeling and programming. The simulation system can take a variety of the hardware parameters and experimental conditions as input variables, so as to achieve better applicability and wide application range. The actual experiments were carried out according to the same conditions of simulation variables, the comparison of experimental results and simulation results show that the simulation system can accurately describe the real running state of the bridge-type pneumatic circuit under different virtual experimental conditions, so the simulation results can used for the validation of the theoretical research results, and provide reference for actual experiment design.

Wenjun Zhang
1 Business Unit, Pneumatic Control, FESTO

Abstract
Digitalisation (Digitalization) is the first key step for us to build Industrie 4.0 (Industry 4.0) System. Automation operation technology OT (e.g. Pneumatic / Fluid / Mechanical / PLC / Robot Control, etc.) and all kinds of physical assets must go through a comprehensive and thorough digital transformation and upgrading, through the Industry 4.0 system all levels communication technology CT (e.g. Quantum Communication / 5G / Internet of Things / OPC UA TSN Industrial Internet / PROFINET Industrial Ethernet / IO-Link, etc.), establish and run the information model of the complete automation Digital Twin Asset Administration Shell, so as to thoroughly integrate with information technology IT (e.g. Artificial Intelligence / Big Data / Cloud Computing / VR / AR / MR / XR / Blockchain, etc.), truly realize various functional application scenarios of Industry 4.0, and build the Industry 4.0 Smart Manufacturing and Smart Business System, which throughout the whole value chain ecology, so that Human Beings would reach an unprecedented strong and reliable survival and development ability and civilization. This paper analyzes the realization method of
Digital Pneumatics control technology in actual products, and analyzes the application method of Digital Pneumatics control technology in the construction of Industry4.0 Smart Manufacturing System, so as to provide a pneumatic automation reference solution for the market, which not only create Industry4.0 innovation value, but also optimize the total cost of ownership (TCO) for all users.
Session 20: Industrial Hydraulics

Chaired by Prof. Haibo Xie (Zhejiang University) and Dr. Wei Wang (Bosch Rexroth China), Jianian hall, 3rd floor, 13:30-15:10, Apr. 13.


Zeng Yishan¹, Huang He¹, Liu Changhai¹, Hu Min¹, Liu Wang¹, Liu Rui¹
1 Hefei University of Technology

Abstract
Aiming at solving the problems of large power loss of the traditional load sensing system and high difficulty of the electro-hydraulic pressure compensation control in the research of flow-saturated resistant, this paper combines the independent metering technology and mechanical-hydraulic pressure compensation method in the offside, to design a new independent metering system that resists flow saturation. The energy saving model of the system is established, and the energy saving characteristics are compared with those of the traditional load-sensing system. The results show that the energy saving effect of the proposed system is better than that of the traditional load-sensing system, and the energy saving rate can reach 16.97% when the actuators both work in power retract mode.


Jiaming Wu¹, Feng Wang¹, Bing Xu¹ and Zongxuan Sun¹
1 Zhejiang University

Abstract
Hydraulic load-sensing control system is an efficient system solution to working function of mobile machines. It is a pressure feedback control typically achieved by a hydro-mechanical load-sensing pump. However, it is a solution with poor dynamic performance and flexibility. An electro-hydraulic load-sensing control system where the pressure feedback control is achieved electronically and only a simple displacement controlled pump is needed, offers better system performance and larger flexibility. The existing studies focus on system application and control strategies. The system dynamic characteristics have not yet been researched. Therefore in this paper the dynamic
characteristics of the electro-hydraulic load-sensing control system were studied. These include: the
influence of pump displacement control dynamics on the load-sensing control performance, the
influence of preset pressure margin between system pressure and load pressure on the load velocity
control etc. A hydraulic load-sensing control test rig capable of simulating different pump
displacement control dynamics was developed. The system dynamic characteristics were verified
through both simulation and experimental results.

[S2003] A Mathematic Model for the Self-Rotation of the Slipper-Piston
Assembly in Axial Piston Machines
Junjie Zhou¹, Chongbo Jing¹, Qianqian Bao¹, Zhihui Wang²
1 Beijing Institute of Technology
2 The 18th Institute of China Academy of Launch Vehicle Technology
Abstract
Whether it spins or not has important effects on the lubrication and wear of the slipper and piston in
axial piston machines. Previous studies focus more on the experimental study with few attempts on
the theoretical side. In this paper, a mathematic model for this issue based on the torque balance
exerted on slipper-piston set is presented. A pump prototype with a transparent casing is designed
and the slipper and piston are marked. The self-rotation is observed with high speed camera. Results
show that both the slipper and piston rotates along with the cylinder in the same direction, and the
slipper rotates faster than the piston. It is concluded that the cause of self-rotation is the friction
imposed by the swash plate.

[S2004] Utilization of Gated Recurrent Units Combined with Attention
Mechanism for Rock Mass Recognition
Zhe Zheng¹,², Dong Han¹,²*, Fei Wang³, Guofang Gong¹,², Huayong Yang¹,²
1 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
2 School of Mechanical Engineering, Zhejiang University
3 Beijing Institute of Space Launch Technology
Abstract
Rock mass recognition domain attracts researchers due to its key role in guiding the operation of
tunnel boring machine (TBM), where mainstream existing models are based on operational data in
mile to discover the mapping relationship between TBM and rock mass, which ignores that the
operational data is time correlation. In this paper, an intelligent recognition model was proposed based on gated recurrent units (GRU) combined with attention mechanism to realize rock mass recognition. First, some data preprocessing methods were used to improve the operational data quality, and the extreme gradient boosting (XGBoost) was introduced to select the operational parameters which have greater impact on rock mass recognition. On this basis, the GRU excavates the time correlation among operational data and combines the attention mechanism which realize automatically concentration on the relationship between input sequence and output sequence to further improve the recognition performance. In the end, the practical engineering data was used to estimate the performance of several proposed models, and was evaluated by some widely used metrics. The results show that the designed intelligent rock mass recognition model achieves an accuracy of 76.81% on rock mass recognition.

Zhang Fengrui¹, Hou Jiaoyi¹, Ning Dayong¹, Gong Yongjun¹
1 Dalian Maritime University

Abstract
Twin barges lifting salvage is a salvage method for large-tonnage shipwreck, by the synchronously work of multiple hydraulic strand jacks, it has good load capacity and applicability. While, the motions of lift barges like heave, roll and pitch caused by the sea waves will make the sling tensions imbalance and the shipwreck unstable. To reduce such tension surges in slings and weaken the shipwreck’s motion, the passive heave compensation hydraulic systems are added. In this article, the mathematical model of passive heave compensation hydraulic systems, shipwreck motions and sling tensions are developed. The load performances like sling tensions and shipwreck motions under the 2-level sea state are simulated by MATLAB. The research results provide a theoretical basis for the actual salvage operation for a heavy shipwreck.
Session 21: Fundamentals and Fluids

Chaired by Prof. Songjing Li (Harbin Institute of Technology) and Prof. Liang Hu (Zhejiang University), Wenlan hall, 2nd floor, 15:30-17:10, Apr. 13.

[S2101] Analysis of Cavitation in Suction Channel of Pneumatic Drive Bellows Pump
Tianyi Ge¹, Zhijian Gao¹, Liang Hu¹, Xiaodong Ruan¹, Rui Su¹
1 The State Key Laboratory of Fluid Power & Mechatronic Systems, Zhejiang University

Abstract
The pneumatic drive bellows pump is widely used in many industries, on account of its outstanding performance. However, the cavitation phenomenon in the bellows pump is not sufficiently understood. In this paper, cavitation in the suction channel of the pneumatic drive bellows pump is investigated utilizing both experimental and numerical methods. High-speed camera measurements were performed with the pump model actuated by different air supply pressure under the same external load. The occurring position and time series of the cavitation were described based on high-speed sequences. To better understand the internal flow field of the pump, a detached eddy simulation turbulence model and a transport equation based cavitation model were used to simulate the cavitating flow. High shear stress, high vorticity, and flow separation were observed in cavitating regions.

[S2102] Design of Combustion Controller in Thermal Desorption
Yunhua Li¹, Liman Yang¹, Hui Jiang¹, Dongkai Shen¹, Dong Li², Xv Yang¹ and Yuan Ye³
1 School of Automation Science and Electrical Engineering, Beihang University
2 School of Aeronautic Science and Engineering, Beihang University
3 CENTER International Group Company Limited

Abstract
Nowadays, the problem of soil pollution in abandoned chemical factories and product warehouses has become more and more prominent. More and more attentions have been paid to soil remediation. Soil thermal desorption is widely used to treat volatile organic compounds (VOCs) in the soil. Thermal desorption soil remediation system is related to fluid control, combustion, and thermal science. Thermal desorption is a combustion system with large lag. For the problem of
large temperature overshoot, large one-way temperature rise and large lag in this control system, the traditional temperature PID control law has a large overshoot and poor anti-interference. In this paper, a control algorithm based on traditional PID control algorithm combined with Smith predictor compensator is proposed, and it can effectively deal with the impact of large hysteresis in combustion system and significantly improve the stability by regulating flow rate of the gas in the combustion system. The simulation result and the practical application in-situ show that the proposed control method and the developed controller can significantly enhance system stability and effectively decrease the volatile organic compounds in the soil.


Speed Modulation: a CFD Study
Chu-chen Wang ¹, Feng Huang ¹,², Xiao-dong Ruan ²
¹ China Jiliang University
² Zhejiang University

Abstract
Lavare Cycle is a new speed modulation method for rotary blood pumps. By periodically adjusting pump speed, it increases flow pulsation through the blood pump, which is thought to help the pump washing and reduce the risk of adverse complications such as thrombosis. In order to verify the pump washing effectiveness, the method of computational fluid dynamics was adopted to investigate the flow field of a rotary blood pump during the Lavare Cycle operation. The inlet and outlet dynamic pressures of the blood pump were set as the boundary conditions, which were obtained by systemic simulation with a lumped parameter cardiovascular model when a blood pump model was run under the Lavare Cycle mode. The flow pulsating index, velocity vector and Scalar Shear Stress distribution diagram before and after Lavare Cycle operation were obtained and compared. The results show that, Lavare Cycle operation can effectively increase the blood flow pulsation, and reduce blood stagnation in the pump. In addition, Lavare Cycle operation almost will not affect the volume of non-physiological regions in the pump. In general, it will be a feasible way to improve blood washout of the rotary blood pump.

[S2104] A New Method for Generating and Controlling Freak Waves in Laboratory
Jintao Lu¹, Chengwei Xiong¹, Tao Wang¹, Yi Liu¹,², Heng Jin¹, Dong Han²
1 NingboTech University
2 Zhejiang University
3 Ningbo Shenglong Automotive Powertrain Systems Co., Ltd

Abstract
The generation of waves in the lab and their potentially devastating impacts on coastal and offshore engineering structures are hot topics in the current wave research field. This paper mainly introduces the principle of electro-hydraulic rotary valve (EHRV) driven wave-making system, establishes its theoretical numerical model, builds a piston type/flap type wave-making experimental device, and carries out the generation tests of regular waves and freak waves respectively. The research results show that the EHRV driven wave-maker can generate various expected regular waves. The errors between theoretical and experimental of regular waves generated by the EHRV driven wave-maker are mostly within 10%. In the (piston-type / flap-type) wave-making mode, the generation effects of freak waves in the wave’s frequency configuration (1 Hz+1.5 Hz) are better. In the piston-type wave-making mode, the maximum waves height abnormality index can be obtained, but the overall generation effects of freak waves under the flap-type wave-making mode is better than that of the piston-type. This study indicates that the new method has a certain rationality and feasibility, which offers a useful design guideline for further generating the high-power controllable freak waves.

[S2105] Influence of Pulsating Flow Conditions on the Results of Multiple Pass Tests
Hongnan, Lyu¹
1 State Key Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.

Abstract
This document is based on the ISO/PWI 23369 "Hydraulic fluid power Multi-pass method of evaluating filtration performance of a filter element under cyclic flow conditions" Round Robin, The Round Robin organized by the Technical committee of fluid power systems contamination control in 2018. Through comprehensive comparison and analysis of the test results of many laboratories under the condition of pulsating circulating flow, some influence rules of the pulsating circulating flow condition on the filter element filtration ratio and dirt holding capacity are summarized.
Session 22: Hydraulic Pumps

Chaired by Dr. Chengxiang Wang (Bosch Rexroth China) and Prof. Wei Wu (Beijing Institute of Technology), Shimao hall, 3rd floor, 15:30-17:30, Apr. 13.

[S2201] Numerical Simulation of Churning Losses of Axial Piston Pump Using the Moving Particle Semi Implicit Method
Wei Chunhui¹, Wu Wei¹, Yuan Shihua¹
1 Beijing Institute of Technology

Abstract
The power losses of swash plate axial piston pump are mainly divided into mechanical losses, volume losses and churning losses. With the continuous improvement of the rotating speed of the piston pump, the churning losses can’t be ignored. This paper creatively uses moving particle semi-implicit (MPS) method to calculate the churning losses of piston pump. The churning losses of the cylinder block, slippers, retainer, swash plate and pistons at different speeds, and the density distribution of oil particles in the pump body are analyzed. It provides a new method to calculate the churning losses of axial piston pump.

[S2202] Investigation of Critical Inlet Pressure for Aerospace Hydraulic Pump with Boost Impeller Based on CFD
Hongkang Dong¹, Yan Wang¹, Jianfeng Chen¹, Yongling He¹
1 Beihang University

Abstract
In order to avoid or release the cavitation damage caused by insufficient suction, the inlet pressure should be higher than the fluid's vapour pressure and outgassing pressure. The resulting pressure for practical purposes is designated as the “Critical Inlet Pressure (CIP) of the Pump.” Currently, most pump manufacturers define the CIP by observing the steep decrease in outlet flow that results from altering inlet conditions. However, the pump already has severe cavitation when the flow decreases drastically. In addition, experimental means are sometimes limited to the specific hydraulic fluids, which cannot provide reference values for wider applications. Aiming to accurately predict the CIP of aerospace hydraulic pump, this paper proposed a numerical approach based on Computational Fluid Dynamics (CFD) for cavitation and takes into account the effects of compressibility of both

101
the liquid phase and gaseous phase, related to aeration and fluid vaporization. Instead of observing the discharge volumetric flow, this paper focuses on the mass flow into the suction chambers, which can reflect the suction performance instantaneously. Verification tests prove that the model is reliable for determining the inflection of effective discharge flow and predicting the CIP for piston pumps. Further simulation results show that the boost impeller can be effective to lower the CIP and improve the anti-cavitation performance of aerospace hydraulic pumps.

[S2203] A Numerical Model of Rotary Lip Seals Based on Non-Reverse-Pumping Mechanism
Bingqi Jiang\(^1\), Fei Guo\(^1\)
1 Tsinghua University

Abstract
The reverse pumping mechanism is currently the most widely accepted sealing mechanism of rotary lip seals. However, the experimental results showed that the reverse pumping mechanism cannot describe the sealing behavior well when the radial force is in a wide range. In this work, a new numerical model of rotary lip seals based on non-reverse-pumping mechanism was presented by using a deterministic surface topography method. The friction force, pumping rate, pressure distribution and oil film thickness were calculated to compare the differences between the new numerical model and the elder ones.

[S2204] Closed Circuit Solution for Concrete Pump
Qingwu Qiu\(^1\), Likui Zhai\(^1\)
1 Shanghai Danfoss Hydrostatic Transmission Co., Ltd.

Abstract
Concrete pumping may use both open circuit and closed circuit solution. Closed circuit solution has the advantages of higher pressure, higher speed and valveless control. But on the other hand there is higher requirements on the response speed of swashplate, and higher tendency of block tipping. This paper studies the response performance of swashplate under fast switching of HDC (hydraulic displacement control). It is shown that a severe high swashplate angle acceleration can break the cylinder block equilibrium and the block tend to tipping. Accordingly, a detailed theoretical analysis and experimental verification are carried out. Finally an optimization direction is discussed for future work.
[S2205] Visualization of Fluid Flow Phenomena in a Single-Acting Vane Pump

Paulina Szwemin¹, Wiesław Fiebig¹, Piotr Antoniak¹, Feng Wang²
1 Wroclaw University of Science and Technology
2 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

Abstract

Vane pumps are widely used in many different positive displacement applications and often are the source of flow in different hydrostatic power transmission systems. The paper deals with the visualization methods of fluid flow inside a single chamber vane pump. In this article a stand for investigating flow phenomena in vane pumps with the use of a high-speed camera was presented. Due to the complex nature of the flow and limitations of visual experimental method a numerical model of chosen pump was prepared. CFD flow simulations were performed for different values of suction pressure, discharge pressure and rotation speed. Comparison of the results of visual experimental investigation and computer simulation proved that CFD modeling can be successfully used for prediction of fluid flow inside different vane pumps.


Fei Lyu¹, Junhui Zhang¹, Ciying Liu², Bing Xu¹, Weidi Huang¹, Haogong Xu¹, Xiaocheng Huang¹
1 State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University
2

Abstract
Session 23: Friction and Sealing

Chaired by Weifeng Huang (Tsinghua University) and Prof. Xudong Peng (Zhejiang University of Technology), Wenjin hall, 3rd floor, 15:30-17:30, Apr. 13.

[S2201] Performance Analysis of the VL Seal Under Starved Conditions
Chao Peng¹,², Xiaoping Ouyang², Katherina Schmitz¹
¹ RWTH Aachen University
² Zhejiang University
Abstract
Hydraulic seals play critical roles for the cylinder. During the reciprocating motion, the lubrication oil in the instroke comes from the leaked oil in the outstroke. The leaked oil is sometimes not enough for the construction of the hydrodynamic film in the instroke, and the starved lubrication condition occurs along. This paper focuses on the sealing performance of VL seals under insufficient oil for the lubrication in the instroke. The whole simulation is based on the coupling method of the macro FEA model and mixed lubrication model, and the hydrodynamic length is changed due to the limited lubrication oil in the instroke. Sealing characteristics of different velocities in the instroke are discussed to obtain the critical velocity for the starved lubrication condition. Different from the sufficient lubrication condition where the friction decreases with the velocity, the friction force increases with the velocity rising under the starved working condition.

[S2202] Influence and Selection of Numerical Model in Supercritical CO₂ Dry Gas Seal
Zhang Cong¹, Jiang Jinbo¹, Peng Xudong¹, Meng Xiangkai¹, Li Jiyun¹
¹ Zhejiang University of Technology
Abstract
Supercritical carbon dioxide (SCO₂) Brayton cycle system is a promising energy conversion system in the future, while the dramatic changes in thermodynamic properties of SCO₂ near critical points make the design of dry gas seals (DGS) for compressors challenging. This paper analyses the results of SCO₂-DGS based on isothermal fluid, isothermal wall and coupling model respectively. The temperature and pressure distribution on seal face under different operating conditions are studied, the law of opening force and leakage rate under different models is obtained, and the differences and
selection schemes of the models under different operating conditions are further explored. The results show that temperature distribution of SCO2-DGS and air is completely different, and pressure distribution of the two is basically the same. The difference of pressure calculated by the three models is not significant, while the temperature calculated by coupling model deviates significantly from ambient temperature, followed by isothermal wall model. However, they all increase with the increase of rotating speed in the simplified models, opening force decreases and leakage rate increases with the increase of film thickness. The leakage rate is obviously different from the actual result under the condition of small film thickness with high speed and large film thickness with low speed, at which point a coupling model should be adopted.

[S2203] Research on Leakage Characteristics of Metallic Seals Based on Soft/Hard Contact Theories
Felix J. Fischer¹, Chao Peng¹, Hubertus Murrenhoff¹, Katharina Schmitz¹
¹ RWTH Aachen University

Abstract
The fluid leakage of metallic ball seat valves is simulated using the method developed by Persson et al. To do so, the contact pressure distribution and contact area are needed. In this work, four different methods are used to calculate these values. Two of these methods assume a hard contact model and the other a soft one. The resulting leakages are compared with each other and with experimental measurements, as well. It is found, that a soft contact model leads to more accurate results and that simplified analytical calculations deliver comparable results to the more sophisticated FEA approach.

[S2204] Leakage Characteristics of Prototype Gasket Using Viscosity-Temperature Relation under Vibration Condition (Effects of Sealing Land and Viscosity Grade)
Song Gao¹, Toshiharu Kazama¹
¹ Muroran Institute of Technology

Abstract
Gaskets are widely used as static sealing elements in industry, machinery, and living ware. Generally, gaskets are composed of metals such as rubber, copper alloy, or plastic, which is placed between two planes to strengthen sealing material in order to prevent leakage between static surfaces.
Theoretically, the leakage is directly proportional to the cube of gap height and inversely proportional to liquid viscosity. However, it is difficult to reduce leakage because there are roughness and waviness on the solid surface. It is possible to lose the sealing function when the stress is insufficient while strong clamping may also lead to surface damages. In this report, a flange-type gasket is modelled by using the inversely viscosity temperature dependence of hydraulic oils by cooling and heating the seal parts. The viscosity of fluids, particularly oil, is strongly depended on temperature, as lower temperatures correspond to higher viscosities. Besides, different types of oil correspond to different viscosity grades, and the size of sealing land is also one of the factors that affects leakage. Using the viscosity-temperature relation of fluids, a gasket to reduce leakage further is proposed. The principle of thermo-hydrodynamic is applied to the gap flow. The experiment was conducted under a wide range of conditions in terms of temperature, oil viscosity grade, sealing land size, and vibration meters. The basic equations include the Reynolds equation, simple harmonic vibration equation and other equations concerning the physical characteristic of oil.

[S2205] Effect of Hydrostatic Pressure on the Tribocorrosion Behaviour of WC-10Co-4Cr Coupled to Si₃N₄ in 3.5 wt.% NaCl Solution
Defa Wu¹, Ziwei Guan¹, Hao Min¹, Qian Yu¹, Yinshui Liu¹
¹ Huazhong University of Science and Technology

Abstract
The tribopair composed of high oxy-fuel (HVOF) spraying WC-10Co-4Cr coating and sintering Si₃N₄ is started to be used in modern underwater equipment due to its excellent wear and corrosion resistance, while the effect of hydrostatic pressure on its tribocorrosion behaviour has been poorly investigated. In this paper, the effect of hydrostatic pressure on this tribopair was studied on a customized test rig, and hydrostatic pressure was 0, 20, 40, 60 and 80 MPa, respectively. The scanning electron microscopy was used to observe the worn surfaces to study the friction and wear mechanism. Results suggested that the effect of hydrostatic pressure on tribological properties was not significant. Friction inhibited corrosion under different pressures and the minimum corrosion-only rate occurred at 0 MPa. The main friction and wear mechanism of WC-10Co-4Cr coating was the removal of binder followed by carbide pull out due to the surface undermined, while the wear mechanism of Si₃N₄ was mechanical wear resulting in pits.

[S2206] Design of High-speed Large-scale Reciprocating Gap Seal Test Bench
Shendan Zhao¹², Yinshui Liu¹², Zhuang Niu², Hao Pang¹, Cheng Qian¹, Chuanmin Wang²
1 State Key Laboratory of Digital Manufacturing Equipment and Technology, Huazhong University of Science and Technology
2 Wuxi Research Institute, Huazhong University of Science and Technology

Abstract
The plunger of high-pressure and large-flow mining pumps is generally sealed with packing. With the development of high-pressure and large-scale of the plunger pump, the pv value of the friction pair can easily exceed the capacity limit of the packing seal, and its sealing life will drop sharply. With the development of modern sealing technology, gap sealing, a novel sealing method, has been more widely used. In order to study the leakage characteristics of large-scale gap dynamic seals, a high-pressure and large-flow reciprocating gap sealing performance test bench with a pressure balance structure with symmetrical arrangement of double plungers was designed and built, which can greatly reduce driving power and experimental costs. This test bench uses a hydraulic system to drive the plunger to reciprocate, and with the coordinated work of a proportional servo valve and a displacement sensor, the motion amplitude and reciprocating frequency can be precisely controlled. The leakage characteristics of three plunger pairs with different seal clearance were measured under four pressure conditions. The results show that the performance index of the sealed test bench meets the design requirements, the coordination of each system is good, and the test results are accurate and reliable. In this paper, the relationship between annular gap flow pattern and pressure, sealing gap and sealing length is explored by comparing the test results with theoretical calculation values. The test data can be used as the basis to evaluate the performance of gap dynamic seal and lay a foundation for the theoretical design and product development of high pressure and large flow plunger pump.
Session 24: Fluid Media and Contamination

Chaired by Prof. Lipeng Du (Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.) and Prof. Hong Ji (Lanzhou University of Technology), Wencong hall, 3rd floor, 15:30-17:30, Apr. 13.

[S2401] Selective Separation of Air Bubbles from Working Oil by Bubble Elimination Device

Yutaka Tanaka, Yusuke Kishi, Sayako Sakama
1 Hosei University
2 National Institute of Advanced Industrial Science and Technology

Abstract

The bubble elimination device using the swirling flow can selectively separate the bubbles mixed in the hydraulic oil from the working oil according to the diameter of the bubbles depending on the shape parameter of the device. Its separation performance has been analytically clarified by CFD analysis. In this paper, using this bubble elimination device, we experimentally verify the possibility of selectively separating the bubbles contained in the hydraulic oil according to the bubble diameter.

[S2402] Application of Contamination Control in Super-Big Hydraulic System

Miao Yang1, Bingwang Lei2, Yabin Zhou3, Jingbo Wang4, Haijun Li5
1 Beijing all-of Filtration Technology Development Co., Ltd.
2 Inner Mongolia North Heavy Industry Group Co., Ltd.
3 PetroChina Lanzhou Lube Institute
4 Inner Mongolia North Heavy Industry Group Co., Ltd.
5 Beijing all-of Filtration Technology Development Co., Ltd.

Abstract

Super large hydraulic system in process industry has the characteristics of high system pressure, high control precision, high maintenance cost and high reliability requirements. In this paper, Proactive Maintenance(PAM) has been taken as the equipment management strategy and controlled fluid contamination by comprehensive solution. A series of measures, such as TPM, RCA, RCM, four
standards point inspection and oil monitoring were used to strengthen the quality control, improve the cost-effect and ensure the long-term healthy equipment operation.

[S2403] Study of the Preparation of Filter Medium with Multilayer Structure and Its Impact on Oil Filtration Performance

Min Tang¹, Yun Liang¹, Jian Hu¹
1 South China University of Technology

Abstract
To achieve high reliability and longevity for hydraulic system, contaminants in the hydraulic oil must be removed through filtration process before damage ensues. The filtration system needs an effective filter medium with high filtration efficiency and service life. This study developed a novel filter medium with multi-layer structure through wet-laid method, and its oil filtration performance was evaluated by multi-pass test. It was found that the dust holding capacity of multi-layered filter medium can be significantly improved without compromising filtration efficiency compared to single layer medium. The gradient structure was beneficial for deep capture inside the filter medium. With close filtration efficiency, the dust holding capacity of multi-layered medium was 52.9% higher than that of single-layered medium. This study proposed a strategy to design filter medium with both high filtration efficiency and dust holding capacity.

[S2404] Evaluation of Service Life of Filter Elements

Lan Feng¹
1 Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.

Abstract
This paper reviews the main methods of evaluation of filter service life at home and abroad. The actual service life cannot be predicted for laboratory evaluation results, the time interval of replacing and cleaning filter elements has long been a problem of manmade compulsory regulation. Time interval of compulsory regulation lacks scientific verification, this can lead to increased maintenance costs or equipment failure due to delayed filter maintenance. Based on the principle of equal limit differential pressure of filter element, the corresponding relationship between the test life and service life is established by combining test data of filter with the data in use, the idea and method of evaluating the service life of filter element by using the measured receiving capacity are discussed.
[S2405] Research and Practice of Contamination Tolerance of Hydraulic Components

Lipeng DU¹
1 Aviation Industry (Xinxiang) Metrology and Test Science Technology Co., Ltd.

Abstract
The wear law of solid particles on hydraulic components and its influence on working performance are revealed by conducting contamination sensitivity test of hydraulic components based on the analysis of the principle of contamination tolerance evaluation of hydraulic components. The evaluation method of contamination tolerance of hydraulic components is described completely. The correctness and feasibility of the existing contamination tolerance theory and method are verified by comparing the measured curve with the standard curve.

[S2406] Fluid Contamination Control Practice of Super Large Hydraulic System

Miao Yang¹, Bingwang Lei², Yabin Zhou³, Jingbo Wang², Haijun Li¹
1 Beijing all-of Filtration Technology Development Co., Ltd
2 Inner Mongolia North Heavy Industry Group Co., Ltd.
3 PetroChina Lanzhou Lube Institute

Abstract
The super large hydraulic system in process industry has the characteristics of high system pressure, high control precision, high maintenance cost and high reliability requirements. In this paper, Proactive Maintenance (PAM) has been taken as the equipment management strategy and controlled fluid contamination by comprehensive solution. A series of measures, such as TPM, RCA, RCM, four standards point inspection and oil monitoring were used to strengthen the quality control, improve the cost-effect and ensure the long-term healthy equipment operation.
Session 25: Industrial Hydraulics

Chaired by Prof. Ruqi Ding (East China Jiaotong University) and Prof. Hu Shi (Xi’an Jiaotong University), Jianian hall, 3rd floor, 15:30-17:10, Apr. 13.

[S2501] New Control Method of Active Absorption Wave-Maker based on Digital Twin-Valve

Xxx, xxx, xxx (xxxx University)

Abstract

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

xxxxxxxxxxxx.

[S2502] Research on Performance of Biped Robot Hydraulic Drive System Based on Servo and Digital Control

Pengyu Zhao¹, Anhuan Xie¹,², Wei Song¹,², Shiqiang Zhu¹,², Dan Zhang¹,³
1 Zhejiang Lab
2 Zhejiang University
3 York University

Abstract

Based on the biped robot experimental platform of Zhejiang Lab, the hydraulic drive systems controlled by servo valves and digital valves are proposed respectively. The structure of the biped robot experimental platform is introduced. The schematics of the hydraulic drive systems are designed. The parameters of the key hydraulic components are calculated according to the motion and force of the robot. Finally, the simulation models are built and the performance assessments of the hydraulic drive systems controlled by servo valves and digital valves are analysed. The simulation results show that the trajectory tracking accuracy of servo valve control system is higher. But the digital valve control system shows an advantage on system efficiency.

[S2503] Loss Optimal Control Strategy of Speed and Displacement Variable Electrohydrostatic Axes

Tim Reidl¹, Philippe Schraft¹, Jürgen Weber¹, Steffen Ihlenfeldt¹
1 Technische Universität Dresden
Abstract

Electro-hydrostatic axes certainly outrun traditional throttle based solutions in terms of efficiency. However, electromechanical axes set a high standard with their low energy consumption. In order to increase the efficiency of an electro-hydrostatic axis somewhat further to the state of the art, we developed an dynamic optimization algorithm based on dynamic programming to compute a loss optimal displacement trajectory for a given duty cycle. Simulation results show that varying the pump’s displacement and velocity in an optimized way, can achieve an average loss reduction of up to 29 % on all drive train components. The most crucial and complex model in the approach is the one for the radial piston pump which is represented by a trained neural network which respects the actual fluid’s viscosity over a brought range of input values. Five different viscosities are feed into the optimization algorithm and lead to varying optimal displacement trajectories. The developed approach guarantees decent computation time and offers the possibility to make use of high order and non-analytic functions in the loss descriptions.

[S2504] Modeling and Analysis of a Novel Hydraulic Control Method for a Digital Hydraulic Actuator

Shuang Peng
1 School of Mechanical & Mechatronic Engineering, Wuhan University of Technology

Abstract

In this paper we develop a dynamic Zero-Flowrate-Switching (ZFS) control method for digital hydraulic/pneumatic systems that apply switching valves and high frequent PWM controller. The proposed control strategy is to actively make the flowrate through the valve close to zero and then switch off the valve. To realize it, we build an accessory line paralleled by the main control line for flowrate regulations. A RLC oscillator is used in the accessory line to generate sinusoidal flowrate; pressure with high-frequent and small-amplitude waves output from a regular piston pump is used as the drive of the RLC oscillator. Dynamic models regarding to the capacitance of the cylinder chamber are built to make the ZFS controller feasible for the systems with dynamic loads. The simulation results indicate that the system applying dynamic ZFS controller consumes only 16% energy of that consumed by a normal Hard-Switching (HS) system; moreover, pressure pulses in a ZFS system are much minor than those in a HS system.

[S2505] Analysis of Vibration Characteristics of Intersecting Common-Wall
Pipeline
Ying Li¹, Yuying Zhang¹, Jiafang Zhang¹, Xing Chen¹, Jin Zhang¹
¹ Yanshan University

Abstract
Based on additive manufacturing, the original hydraulic valve block can be transformed into intersecting pipe-network structure. However, The fluid interaction in the pipe-network causes the fluid-structure interaction vibration of the pipeline. It is necessary to study the fluid-structure interaction vibration characteristics of pipeline when designing pipeline structure. In this paper, the intersecting common-wall pipeline formed by additive manufacturing is taken as the research object. Based on fluid-structure interaction, the stress and deformation of the intersecting common-wall pipeline under different working conditions are analyzed firstly. Secondly the influence of fluid pressure and velocity on vibration response and the prediction of resonance peak frequency are analyzed when the straight pipe is high-pressure and the bent pipe is low-pressure. The results show that: The stress deformation is small when the straight pipe is high-pressure and the bent pipe is low-pressure. The fluid pressure has little influence on the natural frequency of the pipeline. When the excitation frequency is close to the first-order natural frequency, the displacement response in Y direction reaches the resonance peak. The stress responses in X, Y and Z directions reach resonance peaks. And the peak value in Z direction is the largest, the peak value in X direction is the smallest. These analyses can provide theoretical basis for the design and optimization of common-wall pipelines.
Online Access

Coming soon.

Online Participant

Access Link

Keynote Speech Parallel Session Parallel Session Parallel Session Parallel Session Parallel Session

录制、可以下载无交互操作流程和界面说明，待补充
Conference Venue

Zhejiang Narada Grand Hotel
浙江世贸君澜大饭店

About the hotel

Zhejiang Narada Grand Hotel Located at the center of financial, business and culture in Hangzhou, sits at the foot of the Precious Stone Hill and is beside the Yellow Dragon Cave. Given the two spots of the Ten Scenes of the West Lake, Precious Stone Hill Floating in Rosy Cloud and Yellow Dragon Cave Dressed in Green, near at hand, the location of the hotel is a perfect place for its quietness in the noisy downtown. The hotel, comprising the five-star hotel, international exhibition center and first-rate office building, covers an area of 4.5 hectares and its overall floorage is 132,000 m², in which there are 403 guest rooms, various Chinese Western restaurants and more than conference rooms of all sizes. There are not only hairdressing salon, indoor swimming pool and indoor tennis court, but large green lawn of 15,200 m² and a large underground parking lot of over 8,000 m².
Address: 122 Shuguang-road, Xihu-district, Hangzhou, Zhejiang, China  
中国浙江省杭州市西湖区曙光路 122 号

Phone: +86-571-87990888

- Being close to the West Lake scenic spots, at the foot of the Precious Stone Hill and beside the Yellow Dragon Cave, it is quiet in the noisy downtown
- 2 km from the West Lake
- 35 km from Xiaoshan International Airport, about 40-minute drive
- 8 km from Hangzhou Railway Station (Chengzhan), about 20-minute drive
- 10 km from Hangzhou Railway Station (East Railway Station), about 40-minute drive about 10 minutes from Wulin commercial district
About Prevention of COVID-19

Please take anti-epidemic measures during the ICFP conference.

✓ Please cooperate with the organizing team to carry out epidemic prevention and control works, and show the personal health code and itinerary records when required.

✓ Anti-epidemic materials such as masks and disinfectant alcohol are available in the bags in the venue.

✓ If you have suspect fever, cough and other uncomfortable symptoms, please stay in your hotel room and report to the organizing team in time.
   Tel. 13588749435, Qiaomei Dong (Zhejiang University).

✓ Participants from an area with high epidemic risk should notify the organizing team in advance.
Exhibition
I. Overview

1.1 Venue

Date: April 11, 2021 - April 13, 2021
Address: 3/F, Zhejiang Narada Grand Hotel, 122 Shuguang Road, Hangzhou
Contacts: Liu Hongwei, 15868186005

1.2 Exhibits and areas of expertise

- Hydraulic and pneumatic components
  Various new hydraulic pumps, hydraulic motors, hydraulic valves, hydraulic cylinders and other hydraulic and pneumatic components
- Hydraulic power station
  Intelligent standard hydraulic power station, compact hydraulic power station;
- Festo Motion Terminal and Intelligent manufacturing training bed.
- Mobile hydraulics and intelligent hydraulics
  Hybrid drive and control, industrial robots, construction machinery and hydraulic equipment, mobile machinery, etc.

1.3 Booth layout
II. Introduction of exhibitors

State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University

About the Lab

The State Key Laboratory of Fluid Power and Mechatronic Systems of Zhejiang University (the Lab), formerly known as the State Key Laboratory of Fluid Power Transmission and Control, was among the first batch of open laboratories approved by the former State Education Commission in 1985. The construction of the State Key Laboratory of Fluid Power Transmission and Control began in 1989, and completed and passed the inspection and acceptance in 1995. In 2018, the Lab was rated as "Excellent". In 2010, it was renamed as the State Key Laboratory of Fluid Power and Mechatronic Systems. Currently, Xu Bing from Zhejiang University serves as the director of the Lab, Lin Zhongqin from Shanghai Jiaotong University as the director of the academic committee, and Lu Yongxiang as the honorary director of the academic committee. The Lab has been committed to achieving the national strategic goals and carrying out the frontier research on subject basics as its priority. After two decades of development and adjustment, the Lab has formed 5 strategic research directions: applied fluid mechanics, fluid transmission and control, innovative design of mechatronic systems, perception and control of mechatronic systems, and advanced manufacturing of mechatronic systems. With significant achievements in scientific research, talents training, team building, and open exchanges, the Lab has gradually emerged as a first-class teaching and research base in the field of fluid power and mechatronic systems in China and a research institution with significant global presence.

Representative research topics

(1) Independent design and manufacture of full-face tunnel boring machines (TBMs)

To meet the requirements of major national projects for tunnel boring machines (TBM), the Lab has solved three major international problems: ground collapse caused by the instability of the tunneling interface, failure of key components due to sudden load changes, and deviation of tunnel from design axis caused by misalignment; invented sealed chamber pressure dynamic balance control and multi-system coordinated control technologies, load compliance design and cutter head drive system integrated design technology, and TBM attitude-based prediction propulsion control and pressure/flow combined correction technology; and created the theoretical and technical systems including coordinated multi-system control of pressure balance of sealed TBM chamber, and catastrophic load compliance design of electro-hydraulic drive system. To tackle the three international challenges of hard rock tunneling equipment, i.e. insufficient capability, low speed, and inaccuracy, the Lab invented the hob rock-breaking technology under free surface and combined dynamic and static loads, stiffness matching design theory for efficient power transmission and supporting and propelling coordinated control technology, combined driving method for the motor-flywheel-hydraulic motor, multi-inclinometer filter data fusion algorithm, and intelligent correction control and geological adaptability control based on geological prospecting. These achievements have laid the foundation for the development of the full-face TBM design technology with independent intellectual property rights in China.
(2) **Key technology of high-performance hydraulic components**

To satisfy the R&D needs of core hydraulic components such as axial piston pumps/motors, large flow electro-hydraulic control valves, and large flow balance valves, the Lab has cooperated with leading enterprises in the Chinese hydraulic industry and achieved breakthroughs in international challenges in industries such as multi-field strong coupling design tools, high-speed and heavy-duty friction pair interface micro-parameter test methods and equipment, strong impact hydraulic components vibration and noise reduction technology, and dynamic and static hydraulic nonlinear compensation control, and established a high-performance hydraulic component design system consisting of design software, testing methods, invention patents and technical standards, contributing to solving the "bottleneck" problem of high-end hydraulic components in China's equipment manufacturing industry.

(3) **Immersion system of lithography machine**

As one of the four core components of an immersion lithography machine, the immersion system is used to prepare ultra-clean immersion liquid and control it to fill as a liquid lens between the objective lens and the silicon wafer, thereby improving the numerical aperture and exposure resolution of the lithography machine. Regarding the progress of solving the three major technical challenges in immersion systems that directly affect the exposure resolution, productivity and yield of lithography machines: scanning and pulling residual droplets/liquid film, exposure flow field pollution and stress, and two-phase recovery induced vibration, the Lab has achieved a series of original results in many areas including interface behavior of immersion fluid and its control, detection of submerged flow field distribution and pollutant
control, and gas-liquid two-phase flow regime modulation and vibration suppression. The Lab has become the third institution in the world to master the technology of immersion system of lithography machine.

(4) Fluid power system of marine mechatronic equipment

The Lab conducts systematic research in the fields of ocean current power generation, abyssal water bodies series airtight sampling, and seabed observation network connection technology. The 5kW~650kW series products were integrated into the State Grid for the first time and set China's records such as the largest single-unit actual power generation and the largest cumulative power generation. The ocean current energy island independent and stable power supply system developed by the Lab offers a new solution for the power supply for China's island and reef construction, offshore instruments, and coastal defense facilities. The Lab has developed a series of deep-sea fluid in-situ network observation connection boxes, making China the fourth country capable of building large-scale seabed observation networks following the U.S., Canada, and Japan. The deep-sea intelligent operation and propulsion control system developed by the Lab is an important part of China's Haima and Jiaolong vehicles. The installed power per unit thrust of the 4500m deep-sea operation propulsion system is 20% lower than that of its international peers, and the operating blind zone of the 11,000m deep-sea Jiaolong's manipulator has been reduced by 38%. The whole-deep sea airtight sampler developed by the Lab has become an important operational equipment of China's "Jiaolong" HOV. For the first time, it has brought back precious airtight fluid samples for scientists from the 10,000m abyss of the Mariana Trench, achieving the breakthrough from zero to one in obtaining pressure-preserving airtight water samples at a depth of 10,000m in the world. The technological breakthroughs in the whole-deep sea (shallow sea-deep sea-abyss) mechatronic equipment can substantially promote the development of China's marine economy and national security.

(5) Key technologies and process equipment for automated aircraft assembly

Aircraft assembly technologies are the most indicators of a country's aviation manufacturing industry competitiveness. The Lab has systematically overcome three recognized technical challenges in the field of aviation manufacturing: connection failure, hole-making misalignment, and positioning deformation, and developed 5 automated aircraft assembly process equipment series: horizontal dual-machine combined automatic drilling and riveting system, 360° circular track five-axis linkage hole making system, 5+X axis special CNC machine tool hole making system, robot precision hole making system, and dynamic reconfigurable automatic positioning system, completely breaking the blockade of military technology and the monopoly of civil aircraft equipment in the field of aircraft automated assembly established by Western developed countries on China. The 17 partial assembly systems and 2 final assembly production lines developed by the Lab have achieved full coverage in China's five major aircraft manufacturers and provided a full set of process, technology, equipment and system support for the successful development and mass production of 9 key models, making huge contributions to national security.
(6) **Innovation and systematic application of pneumatic high-performance basic components**

Continuous research has been conducted on high-performance pneumatic control, actuating and detection components. Through innovation in theory, design, method, and test method, the Lab has developed high-performance basic components such as passive solenoid valve energy-saving modules, precision pressure reducing valves, high-performance pneumatic valve terminals, frictionless cylinders, and multi-range composite gas dynamic flow testing modules, the key technical indicators of which have reached or exceeded the world class. On this basis, the Lab has developed a series of pneumatic control units and systems including a zero-gravity environment simulation pneumatic suspension system, a pneumatic muscle parallel joint position control system, a 3D pneumatic dynamic seat position control system, climbing robots, flexible manipulators, and combinable robots. The Lab assisted the local government to establish the only National Pneumatic Product Quality Supervision and Testing Center in China, and took the lead in the establishment of the Zhejiang University-Fenghua Pneumatic Technology Transfer Center to comprehensively serve the product development and industrial upgrading of local industrial clusters.

The Lab has offered various technical services for enterprises:

1) Simulation analysis, design optimization, test evaluation, prototype development, etc. of hydraulic components;
2) Configuration design, motion control, energy-saving technology, etc. of electro-hydraulic control systems;
3) Problem tackling and research and development of key technologies of high-end mechanical-electric-hydraulic equipment;
4) Technical consultation, technical training, industry-university-research cooperation, etc.
Jiangsu Hengli Hydraulic Co., Ltd.

- **Company Profile**

Committed to independent innovation, Hengli Hydraulic (stock code: 601100) has developed from a hydraulic cylinder manufacturer into a large-scale comprehensive enterprise integrating hydraulic components, precision castings, pneumatic components, hydraulic systems and other industries, and is capable of providing efficient, safe and precise transmission and control technologies for various machines, systems and equipment. Thanks to the four hydraulic R&D centers and nine manufacturing bases in China, Germany, the United States, Japan, and India, Hengli is the world's industry leader in terms of R&D and production capabilities. Currently, Hengli serves more than 2,000 top customers around the world, as our main markets cover more than 20 countries and regions and our product range involves many industries such as construction machinery, ports and ships, energy mining, tunnel machinery, and industrial manufacturing. Hengli Hydraulic is committed to providing more energy-efficient solutions in a wide range of markets, and working with customers to achieve global sustainable development.

- **Product series and introduction**

<table>
<thead>
<tr>
<th>Hydraulic cylinders</th>
<th>Hydraulic valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hengli's technology and R&amp;D center serves the complex and diversified development and innovation of hydraulic cylinders. Hengli has established a full series of professional and scientific design processes, and imported world's leading five-axis linkage special processing center, surface treatment equipment, automatic monitoring equipment, etc. to ensure the reliability of design and products.</td>
<td>The hydraulic valves for Hengli's mobile machinery include multi-way control valves and pilot control devices with outstanding quality and superior performance. Hengli has continued innovating and integrating functions into control components, setting new standards for the performance, control accuracy and service life of such products.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hydraulic pumps</th>
<th>Hydraulic motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hengli has been committed to innovation, R&amp;D and optimization of products, following a customer-centered principle. The open-circuit axial piston pumps developed by Hengli have won recognition and praise from customers around the world thanks to their outstanding performance.</td>
<td>Designed with a swash plate, Hengli's piston motor can integrate a variety of control valves. It is suitable for medium- and high-pressure scenarios, and can be used in traveling and rotating occasions. Thanks to its solidity, reliability, long service life, low noise, high efficiency and other advantages, it has been widely applied in a range of fields.</td>
</tr>
</tbody>
</table>
### InLine piston pumps
With seven decades of mature experience in the development of heavy-duty piston pumps, InLine Hydraulics has created innovative pump series such as V30G, V30D, V30E, V80M, V60N, etc., and is well-known worldwide for its high power-to-weight ratio and multiple control methods.

![InLine piston pumps](image)

### Industrial hydraulic valves
Focusing on independent innovation, Shanghai Lixin Hydraulics has mainly developed three types of standard industrial hydraulic valves for pressure, flow, and direction control, as well as customized hydraulic integrated systems. The product quality and service have been widely recognized by customers.

![Industrial hydraulic valves](image)

### Hydraulic castings
Hengli's hydraulic casting series cover various fields including hydraulic cylinders, valves, pumps, motors, and reducers, and can meet strict requirements of wind power, high-speed rail, automobiles, agricultural machinery, maritime and offshore industries for hydraulic castings.

![Hydraulic castings](image)

### Precision parts of pumps and valves
In 2018, Hengli acquired Hattori Seiko, a Japanese high-precision parts manufacturer mainly engaged in the processing and manufacturing of ultra-precision parts for hydraulic machinery. With excellent quality, the products can meet the needs of customers in the industries of construction, industrial machinery, ship building and power plants.

![Precision parts of pumps and valves](image)

### Pneumatic components and system integration
Hengli mainly produces pneumatic actuating, control, processing components and various auxiliary components, which have been widely used in automotive engines, engineering machinery, metallurgy, electronic technology, textile machinery, high-speed rail, medical equipment, food packaging and other automated industries.

![Pneumatic components and system integration](image)

### Hydraulic system integration
Hengli Hydraulic System Division focuses on the R&D of customized electro-hydraulic control systems, and has made a series of achievements in various fields. Hengli is capable of independently designing and manufacturing high-performance hydraulic test benches, which can be applied in a wide range of fields.

![Hydraulic system integration](image)
Festo (China) Co., Ltd.

- **Company Profile**

  Founded in 1925, Festo is a global leader in automation technology and a global player of basic and advanced technical training. Headquartered in Esslingen, Germany, Festo is an independent family business. The Festo Group runs businesses in 200 industries around the world, providing leading pneumatic and electric drive technologies and comprehensive solutions to over 300,000 customers. In addition, Festo Didactic has provided advanced engineering training equipment and courses to more than 40,000 customers around the world. In 2019, the Festo Group recorded sales revenue of approximately EUR 3.2 billion, and hired 20,100 employees in 250 countries and regions around the world.

  Festo began its operations in China in 1985. Currently, it is operating more than 100 sales offices and dealer outlets in Greater China. Festo Asia Pacific Technical Centre and the Greater China Solution Engineering Centre in Shanghai provide customers in the region with products and solutions tailored to their applications, while the global production centres in Jinan and Shanghai, the Regional Service Centre-China in Jinan, and the South China Distribution Centre in Guangzhou provide guarantee for improving the supply and service to the Chinese market. Festo provides the Chinese market with pneumatic and electric technologies and comprehensive solutions for factory automation and process automation, which mainly serve automotive, rubber and plastics, electronics and light assembly, food and beverage packaging, water/sewage treatment, and biotechnology/pharmaceutical industries. Festo Experience Centre is a motion control laboratory that stimulates innovation. Festo joins hands with Chinese customers to develop valuable cutting-edge industrial automation solutions. Meanwhile, Festo Didactic (industrial training) has supported more than 600 education partners, universities, vocational colleges and industrial training centers in the Greater China region, with training content ranging from basic knowledge to turnkey equipment for technical learning centers. Festo has approximately 2,000 employees in China currently.

- **Product series and introduction**

  ![Product Series and Introduction Diagram]

  * **Novel products**
    - **Factory automation**
    - **Process automation**
    - >32000 products
  *

  * **Focus on industry**
    - automotive
    - solar
    - electronics
    - biotechnology
    - food
    - beverage
    - pharmaceutical
    - water/sewage
    - >300,000 customs

  **2019年销售额 30.7亿欧元**

  Festo – 助您取得长期成功的合作伙伴
Festo - one-stop supplier of factory automation

- Pneumatic actuators
- Pneumatic servo actuators
- Electric actuators
- Controllers
- Grippers and vacuum technology
- Sensor technology
- Diagnostics/Vision
- Plug and Work® system

>950 experts

Teaching and trainings

Festo - one-stop supplier of factory automation

- Process automation solutions
  - Front displays
  - Valve terminals
  - Actuators

- Controllers
- Solenoid valve
- Process and media valves

- Remote I/O
- Sensors and positioners
- Accessories
Focus on industry segmentation

通过跨界的方式，从工厂自动化和过程自动化的丰富经验中获益

协同增效
Ningbo Hoyea Machinery Manufacture Co., Ltd.

- **Company Profile**

Since its inception in 1993, Ningbo Hoyea Machinery Manufacture Co., Ltd. has been committed to the R&D and manufacturing of hydraulic valves. With solid technical foundation and the advantages of hydromechatronics, Hoyea has established its reputation with three knock-out products: conventional hydraulic valves, proportional valves, and explosion-proof valves. Through the industry-university-research cooperation with Zhejiang University, Zhejiang Sci-Tech University, etc., Hoyea has developed a series of high-end hydraulic valves. After nearly three decades of development, Hoyea has emerged as a fluid transmission and control leader and expert in China. Hoyea runs the Ningbo branch of the National Electro-hydraulic Control Engineering Technology Research Center and the Ningbo Electro-hydraulic Control Technology Provincial High-tech Enterprise R&D Center, and has strong R&D capabilities in the field of electro-hydraulic control.

Over the years, Hoyea has cooperated closely with Zhejiang University and other domestic well-known universities, jointly developed new products, and undertaken many trial production tasks under national innovation fund projects, national torch plan projects, 863 projects and national major scientific research projects. Hoyea will continue providing customers with advanced electro-hydraulic control solutions and highly cost-effective products, help them win the fierce market, enhance their competitiveness, and create more value for customers.

- **Product series and introduction**

(1) **Intrinsically safe solenoid directional valve (HY-E-3SE6)**

The HY-E-3SE6 intrinsically safe electromagnetic directional valve is an intrinsically safe device used in explosive gas environments, and an explosion-proof hydraulic component. The electric spark or thermal effect energy that may be generated during the operation is limited to a level that cannot cause ignition, so that it will not ignite the surrounding explosive environment. It can be used in intrinsically safe monorail cranes, roadheaders and other equipment for mines.

Parameters of HY-E-3SE6 intrinsically safe solenoid directional valve

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>12V</td>
</tr>
<tr>
<td>Rated current</td>
<td>120mA</td>
</tr>
<tr>
<td>Maximum working pressure</td>
<td>31.5MPa</td>
</tr>
<tr>
<td>Maximum flow</td>
<td>4L/min</td>
</tr>
<tr>
<td>Intrinsic safety parameters</td>
<td>Ui: DC12.6V</td>
</tr>
<tr>
<td></td>
<td>Ii: 2A</td>
</tr>
<tr>
<td></td>
<td>Ci: 0μF</td>
</tr>
<tr>
<td></td>
<td>Li: 0mH</td>
</tr>
</tbody>
</table>
(2) Proportional threaded cartridge valves

Proportional threaded cartridge valves include multiple types (pressure, direction, and flow) and sizes. The hydraulic parameters of the valves are proportional to the electrical control signal. Designed with a universal plug-in hole installation form, the valves feature compact structure, simple connection, flexible interchangeability, light body, etc., which realize the miniaturization, modularization and integrated design of proportional hydraulic systems. Thanks to our advanced design and manufacturing of proportional control components, the performance of the proportional threaded cartridge valve series is comparable with the world's leading performance, providing customers great cost performance.
Linde Hydraulics (China) Co., Ltd.

Company Profile

Linde Hydraulics was founded in 1904, headquarter located in Aschaffenburg Germany. It’s a global leader in high pressure hydraulic system, and devoted to the design and developments of high-level hydraulic products. The products spread above 50 countries. Linde Hydraulics (China) Co., Ltd. was founded in 2014, located in Weifang Shandong, which is a joint venture company between Weichai Power and Linde Hydraulics. It’s a base of Linde Hydraulics in China for R&D, manufacture and sale.
**Product series and introduction**

(1) *Hydraulic components*

- 高压泵 (High pressure pump)
- 液压马达 (Hydraulic motor)
- 高压多路方向阀 (High pressure multiple directional valves)
- 中压泵 (Medium pressure pump)

(2) *Drive assembly*

- 回转马达 (Rotary motor)
- 斜轴马达 (Inclined shaft motor)
- Caterpillar drive
- Wheel drive

(3) *Control system WISE 40*

- 控制器 (Controller)
- 人机接口 (HMI)
- 传感器 (Sensors)
Core Technology Advantages of Linde Hydraulics (China) Co., Ltd.

- Stable performance at constant rotation speed up to 2 rpm
- Customized design of components
- Quick delivery and reliable service
- Control of pressure
- Control of flow
- 6000 bar working pressure
- Flow rates up to 9000 l/min
- High reliability
- Superior efficiency

Main industry sectors in China

- Construction machinery
- Earthmoving machinery
- Excavator
- Material handling machinery
- Agricultural machinery
- Sanitation machinery
- Sea and oil machinery
- Special equipment

Combining the actual needs of domestic customers and the product characteristics, Linde hydraulic products are widely applied in road machinery, earthmoving machinery, excavators, material handling machinery, agricultural machinery, sanitation machinery, sea and oil machinery, and special equipment.
SMC (China) Co., Ltd. & SMC Automation Co., Ltd.

### Company Profile

SMC China is a joint venture established in 1994, with operations in Beijing, Shanghai, and other major cities in China. SMC China offers a wide range of pneumatic components, air compressors, and other industrial equipment. The company operates in the automotive, power, and other industries, providing comprehensive solutions to meet diverse customer needs.

### Product series and introduction

12,000 basic component types

Multitude of 700,000 specifications, adaptable to various applications.

---

**Company Name:**

SMC (China) Co., Ltd. & SMC Automation Co., Ltd.

**Date Established:**

September 2, 1994

**Capital Investment:**

240 million yuan

**Company Nature:**

Wholly Foreign Invested

**Employees:**

592 people (as of April 2020)

**Headquarters:**

Beijing, Shanghai, Guangzhou

**Business Scope:**

Production and sales of pneumatic components, air compressors, and other industrial equipment.

**Corporate Purpose:**

- Use advanced technology and management techniques to provide high-quality products.
- Dedicate to serving customers with the highest standards.
- Aim to become a world-class enterprise.

**Corporate Philosophy:**

- Professional
- Quality
- Customer-oriented
- Continuous improvement
**Featured products**

SMC一直致力于为客户提供全面满足其需求的高品质产品。我们将自己定为一家“以客户为中心”的公司，而我们所取得的成就在很大程度上取决于这一准则。无论您需要的是对现有标准产品的简单型注塑，还是专门为您的设计、生产的定制产品，SMC将与您合作每一步。

SMC丰富的产品可以满足各种自动化领域并可向您提供最先进的、综合的“气动/电动解决方案”的能力。

现如今，SMC作为气动元件和电动执行元件的主要供应商，积极开展技术和技术集成，使我们成为客户工程部门的有效延伸。

**Featured products**

---

**Automobile Industry**

CK1, CKZT, CKZ3T, X2734, CLK2, MGGM, MHHM-X6400, MXS, MWB, MWPU, D-M9*S*PC, D-P3DWA, LEBH-X3, EX245, EX260, EX500, EX600, EX600-W, PCA/EX9, SY, VQC, VP542-X536, VP544-X538, VG342-X87, VHS, ASR, AS-Q, AS-X737, ASS, ASD, ASP, KQB-X1124, AV, AR-T6, ZK2, ZL, ISE20, ISE40A, ISE80

---

**Electronics Industry**

## Featured products

- Featured products:
  - CG5, CJ5, CG1, CQ2, HYB, HVC, HWG, HYQ, MQQ, MQM, MGP, MY3, MXQ, EX260, EX600, S10, SY5000-X500, VQZ, VR51, VBA, VFN2120N-X23/-X36, VP542-X536, VP544-X538, VG342-X87, VHS, AV, AC, IZS, IZF, IZN, ISE30A, ISE40A, ISE80ASS, ASD, AS-R, AS-Q, ASP, PFM, PF3W, IBG, AP

## Technical services

- Technical services:
  - Service center
  - Energy saving service center
  - Chiller service center

## Service centers

- Service centers:
  - Energy saving service center
  - Chiller service center
Company Profile

As one of the world's leading suppliers of transmission and control technologies, Bosch Rexroth has extensive project service experience in mobile machinery application, mechanical application and engineering, and factory automation. With smart components, customized solutions and services, Bosch Rexroth has been committed to creating a perfect application environment for the realization of interconnected industries. In addition, Bosch Rexroth provides customers with a large variety of hydraulic, electronic transmission and control, gear, linear transmission and assembly technologies, as well as software and Internet of Things interfaces.

Product series and introduction

1. Hydraulic components for mobile machinery
   Bosch Rexroth provides components and solutions for mobile machinery applications, which help manufacturers increase productivity and reliability while meeting the most stringent emission regulations. New functions have been integrated into our control software to reduce complexity and develop regional design, manufacturing and customer-specific versions.

2. Industrial hydraulics
   The connected hydraulic technology makes full use of the powerful functions and intelligence of Bosch Rexroth's advanced hydraulic technology to break through the limits and set new standards for the performance, function and service life of related products.

3. Gear technology
   A variety of planetary gearboxes are available and applicable for various mobile machinery applications. A planetary gearbox can be used as a propulsion drive in a tracked vehicle, a wheel drive in a wheeled vehicle, a swing drive for rotary motion, and a winch drive for
lifting and lowering loads. A planetary gearbox may have two, three or more planetary stages. It can be equipped with different Rexroth hydraulic motors.

4. Automation and electrical control
Powered by the CNC system and motion control technology with the best performance on the market, we can maximize the performance of your machines. In addition, we have set the standard for servo drives. At Bosch Group, we have implemented systematic solutions to connect your machines to the future Internet of Things. Our 24/7 service will guarantee the maximum productivity of your application. With many years of experience and enthusiasm in the automation industry, we can develop more Factories of the Future for you every day.

5. Linear motion technology
We have carefully developed and produced the linear components and systems, which have laid the foundation for you to manufacture first-class machines and automation systems. Our linear motion technology with high quality and long service life maximizes the system availability. With more than 1,000 standard components and products and modular principle, we can tailor solutions to meet your needs. As a leading user and supplier of Industry 4.0, we can get you prepared for the future. We provide users with reliable support throughout the product life cycle, from searching for proper solutions, to consulting and using electronic tools, and to on-site services all over the world. Rexroth's linear motion technology offers you with a variety of solutions including ball screw drive systems, and special-shaped or linear guide rail systems. Please contact our partners for more information.

6. Assembly technology
Customizing the working environment to meet the production requirements will increase working efficient. Bosch Rexroth's assembly technology has been applied in many occasions from turnover racks and frames made of aluminum profiles, partitions, ergonomically assembled workbenches to fully automatic production lines and conveying systems. With decades of practical experience, Bosch Rexroth's cutting-edge and unique multi-functional assembly technology has been developed and optimized continuously. With modular and finely
coordinated components, Bosch Rexroth helps you customize production solutions to respond to future challenges.

7. Tightening technology
Rexroth provides precise tightening technologies for all critical tightening tasks in various industries - tools, control systems and relevant accessories: from the smart wireless tightening machine - Nexo, the ergonomic handheld tightening machine - ErgoSpin, the multifunctional tightening spindle, even to the complete automated tightening system.

8. Welding technology
The welding process in the automotive and household appliances industry requires the highest reliability and quality. Rexroth's welding controllers and transformers provide users with quick commissioning, optimized programming, and control and monitoring functions, and feature simple operation and super-high flexibility. 80% of the auto manufacturers in the world trust the performance of Rexroth's spot welding controllers.

9. Production assistants (APAS)
The production assistants (APAS) can help manufactures realize Industry 4.0 in all aspects
As the core of a smart factory, flexible production systems and mobile auxiliary systems are no longer a single process in production.
The smart and automated APAS provided by Bosch Rexroth meets these requirements and enables the perfect collaboration between human and machines. From fast, high-precision image processing assistants to high-safety collaborative robots, these products will accompany us to enter the highly flexible i4.0 era.

10. Components for mobile robotics
As a software module, Bosch Rexroth's Locator provides reliable positioning and orientation in various changing environments and can be deployed in various types of vehicles, such as automated guided vehicles (AGVs) and automated mobile robots (AMRs).
Precise positioning is achieved through high-performance algorithms and the use of laser sensors on the vehicle to automatically detect the natural environment and draw a map. Bosch Rexroth thus provides a laser positioning software solution that can provide powerful and reliable simultaneous localization and mapping (SLAM) functions. The software solves the problem of precise positioning of mobile robots with maximum flexibility and usability.
Shanghai Radk-Tech Hydraulic Controls Co., Ltd.

Company Profile

Shanghai Radk-Tech Hydraulic Controls Co., Ltd. is a high-end hydraulic valve leader in China's hydraulic industry. Radk-Tech has been focusing on the field of high-end servo proportional hydraulic valves for 15 years and has won the honorary titles such as Shanghai High-tech Enterprise, Shanghai Little Giant Enterprise, Shanghai Specialized, Refined, Special, New Enterprise, Shanghai Intelligent Manufacturing Demonstration Enterprise, etc. Radk-Tech has also been listed among the top 15 Advanced Manufacturing Brands in Shanghai, and is a key enterprise supported by the Shanghai Municipal and Minhang District Governments. Radk-Tech insists on independent innovation and continuous precipitation of process technologies. Currently, Radk-Tech's product series can completely satisfy 80% of the imported products needed for domestic industrial, mobile equipment and main engine applications. More than 500 customers have adopted Radk-Tech's products. Radk-Tech provides industry-leading high-end hydraulic valves in China in terms of both market share and technologies. The independent brand Radk-Tech has built an excellent reputation in the global hydraulic industry.

Product series and introduction

Load-sensitive proportional multi-way valves

The load-sensitive proportional multi-way valve series developed by Radk-Tech consist of Series 2, 3, and 5. The flow range is 1-200L/min and the max pressure is 42MPa. The valves have been widely used in pump trucks, wet spraying machines, rotary drilling rigs, coal equipment, petroleum equipment, sanitation vehicles, aerial work vehicles, flatbed trucks, mining equipment, etc. The control modes include CAN bus, coal explosion-proof, petroleum explosion-proof, spool displacement detection, switching, manual, hydraulic control, and proportional control, which can be combined as required. Up to 13 working groups can work in collaboration at the same time.

Servo valves

Radk-Tech's servo valve series RT661, RT7625M, RT6313E, and RT6225M are widely used in metallurgy, electric power, railway, die-casting, injection molding, machine tools, testing and other industries. The flow range is 5-200L/min, and the max pressure is 35MPa. Customization is accepted.

Hydraulic valve groups

Radk-Tech invests in advanced flexible processing and assembly lines, and specializes in R&D, manufacturing, and sales of various hydraulic valve groups, which are used in agricultural machinery, aerial work platforms, sanitation vehicles, excavators, truck-mounted cranes and other mobile equipment and can be customized according to customers' needs.
Hannover Milano Fairs Shanghai Ltd.

■ Company Profile

Deutsche Messe established a subsidiary in Shanghai, China in 1999. In January 2008, Deutsche Messe and Fiera Milano reached agreement on a collaboration, establishing a joint venture of future foreign expansion - Hannover Milano Fairs Shanghai Ltd. Hannover Milano Fairs organizes more than 20 domestic exhibitions every year, and Chinese companies have been invited to participate in and visit the exhibitions held by the head office in Europe and around the world. With years of exploration and development in the Chinese market, Hannover Milano Fairs has gained a wealth of experience in successfully running various exhibitions, and has established close cooperative relations with Chinese industry associations and exhibition organizations, and maintained a successful track record in venue planning, design, construction and operation. With advanced exhibition idea and professional exhibition services, Hannover Milano Fairs provides an excellent platform for enterprises to explore business opportunities.

■ Product series and introduction

The Asian International Power Transmission and Control Technology Exhibition (PTC ASIA) was formerly known as China International Power Transmission and Control Technology Exhibition (PTC China), the first session of which was held in China World Trade Center in Beijing in 1991. As the scale of the exhibition expanded, the exhibition was moved from Beijing to Shanghai in 1999. In 2002, in order to further enhance its international influence, the exhibition was officially renamed PTC ASIA, which has been held once a year instead of once every two years in the past. In 2005, the number of exhibitors exceeded 1,000. In 2018, the number of professional visitors exceeded 100,000. To celebrate its 30th birthday in 2021, the organizer will hold a series of special events. We sincerely invite all guests to participate in this grand gala. The PTC ASIA will set up 11 major themed exhibition areas for hydraulics, pneumatics, seals, gears, motors, chain drives, belt drives, springs, bearings, transmission couplings, and industrial subcontracting. In recent years, the exhibition has attracted exhibitors and visitors from Germany, Italy, Russia, Turkey, the United States, Canada, Brazil, Japan, South Korea, Indonesia, Malaysia, Singapore and other countries and regions, and has greatly promoted the international exchanges in the power transmission and control technology market and the development of the trade market.
Contact details:
Hannover Milano Fairs Shanghai Ltd.
301 B&T Pudong Office Tower, 393 Yinxiao Rd, Pudong, Shanghai
Contact: PTC ASIA Project Team
Tel: 021-2055 7000
Email: ptc-asia@hmf-china.com
Website: www.ptc-asia.com