Maha Fluid Power

RESEARCH CENTER

affiliated with the Energy Center

- Computer based Design of Pumps and Motors
- Noise Control and Acoustics
- Pump Control System Design

- Advanced Energy Saving Actuation and Drive Systems
- Hydraulic Power Trains and Hybrid Systems
- Machine Diagnostics and Prognostics
One of our primary research areas, the focus is on discovering the physical effects influencing energy dissipation in pumps and motors and to develop appropriate models describing these effects. Custom, in-house models are being extensively used and developed to predict the behavior of the lubricating fluid film interfaces. The ultimate goal is to find new methods for pump and motor design allowing for a decrease in development time and cost.

**Fluid Structure Thermal Interaction Model for Tribological Interfaces**

- Considers solid body micro-motion, dynamic loading, surface deformation due to temperature and pressure, and fluid and material properties
- Calculate leakage, friction losses, and energy dissipation
- Predict load carrying ability and fluid film stability
- Determine heat transfer and temperatures within the rotating group
- Predict operating condition limits
- Enable design studies, improvements, and optimization

**Thermodynamic Model**

- Predict case and port temperatures
- Couples with gap lubrication models to provide accurate boundary conditions for analysis of novel designs
Experimental Investigation

The Maha Research Center has several special test rigs to support their research in the field of pump and motor development.

- Measure friction forces between piston and cylinder
- Measure temperature and pressure fields between piston and cylinder
- Measure fluid film thickness between slipper and swashplate
- Measure the temperature distribution between the block and valve plate
- Measure instantaneous displacement chamber pressure

Advanced Methods for Pump Design for Tap Water

- Computer aided simulations for optimized micro-surface shaping
- Smart structures, new materials, and coatings to improve properties
Modeling and Analysis of Noise Generated by Pumps and Motors

The goal for this area of research is to understand the sources of noise in pumps, motors, and the noise generated within hydrostatic transmissions. The use of sophisticated yet complex hydraulic systems has led to the demand for a more comprehensive understanding of audible noise emissions. The utilization of axial-piston based hydraulic systems by numerous industries with a wide range of operating conditions has motivated our research to focus on the design of those pumps and motors. The Airborne Noise (ABN) emitted by hydraulic system can be attributed to two main energy pathways, Fluid Borne Noise (FBN) and Structure Borne Noise (SBN). It is critical that all noise control designs consider both sources of noise.

Noise Reduction Techniques of Pumps/ Motors and Systems

- Modeling of fundamental pump and motor noise sources
- Hydrostatic transmission line pressure/flow modeling
- Valve plate design optimization
- Active vibration damping methods

Experimental Investigation of Noise Sources

- Semi-anechoic sound chamber
- Automated robot to spatially sample the sound field
- Capability to measure sound pressure, sound intensity, sound power, sound quality metrics, case vibrations, and modal parameter estimation

Pump Control System Design and Optimization

- Modeling and simulation
- Optimization of dynamic performance response and system stability
- Dynamic performance measurements
- Advanced control concepts
Advanced Energy Saving Actuation and Drive Systems

Displacement controlled actuators are proposed and investigated as solutions for substantial energy reductions in fluid power systems. The research focuses on new circuits, advanced control concepts, and power management strategies for multi-actuator, displacement controlled systems. Along with nearly eliminating throttling losses while allowing for the possibility of energy recovery, feedback control, path coordination, and path optimization can further increase machine productivity, effectively saving even more fuel to accomplish the same task.

- Novel architecture based on displacement control
- Actuator switching techniques for multi-actuator DC systems
- Multi-domain models for complex machines to predict performance and energy consumption
- Advanced controls for actuation and drive systems
- Novel dynamic system sizing techniques utilizing dynamic programming
- System implementation in prototype machines and machine testing
- Thermodynamic modeling of complex hydraulic systems predict local temperatures and cooling capacity
- Machine field testing
- Novel concepts for machine power management

Steer-by-Wire Systems Based on DC actuation

- Energy efficient
- Variable steering ratio
- Variable steering effort
- Autonomous operation
Hydraulic Power Trains and Hybrid Systems

The focus is on new transmission concepts including advanced power train control strategies for off-road and on-road vehicles. The goal of this research is to investigate ways to drastically reduce fuel consumption and emissions for different kinds of vehicles.

- Novel circuit solutions for continuously variable transmission concepts
- Models for vehicle powertrain including engine and vehicle dynamics
- Thermodynamic models for advanced transmission and hybrid systems
- Novel control concepts for transmission and hybrid drives
- Performance prediction including fuel consumption
- Hardware in-the-loop testing
- Drive cycle testing utilizing a dynamometer test rig
- Maha hydraulic hybrid SUV test vehicle
- Virtual prototyping for power split transmissions and hybrids
- Dynamic programming for system sizing and system optimization
- Energy recovery concepts

Modeling Approach

- Transmission models built in MATLAB Simulink
- Based on governing equations
- Contains empirically derived component models
- Dynamic programming applied directly to high fidelity Simulink models

Active Vibration Damping and Machine Diagnostics/Prognostics

Machine diagnostics and prognostics focuses on generic methods for online and on-board condition monitoring of hydraulic systems of off-road machinery. The methods will indicate impending failures of complex hydraulic systems, even those that are properly maintained. The research also includes new concepts for active vibration control of off-road vehicles through the use of energy saving displacement controlled actuators, providing:

- Improved ride comfort and additional fuel savings
- Increased operator productivity and decreased fatigue
- Flexible maintenance intervals due to online monitoring
- Increased machine productivity and reliability, leading to more on-the-job hours
Optimal Control Strategies for Valve- and Metering-Controlled Systems

- Integrated AMESim-Simulink models for accurate modeling and control studies
  - Detailed valve modeling
  - Interaction between hydraulic components
  - Sizing and design optimization

Control Techniques for Structure and Payload Oscillation Reduction

- Self-tuning techniques for online oscillation reduction
- General and low control-effort approaches for oscillation damping through pressure and acceleration feedback
- Suitable for both traditional and independent metering valve controlled systems

Advanced Traction Control Systems

- Ground-tire interaction modeling
- Strategies for reduction of tire slip in mobile applications through braking and engine control
- Integration with active machine oscillation reduction systems
HYGESim (HYdraulic GEar Machines Simulator) drives current research on external gear machines for both high pressure and low pressure applications. It consists of several submodels which run in co-simulation. HYGESim can be used for pump/motor design and virtual prototyping purposes. It can be used for studying the effects of different tooth profile, porting grooves, axial balance compensation methods. HYGESim also permits the prediction of the actual airborne noise emission. The integration within AMESim permits also complete system simulations.

Gerotor Units

A multi domain simulation model for Gerotor and orbit unit is now available to perform design and optimization studies. The model accurately predicts the displacing actions accounting for the main sources of power loss and the actual geometry of the rotors.

- Flexible rotor geometry, imported from CAD
- Prediction of actual contact points and contact stresses
- Accurate prediction of the gap flows
- AMESim integration for system simulation
- Analysis of main flow
- Effects of porting grooves
- Aeration and cavitation

- Fluid-dynamic module

- Evaluation of instantaneous shaft forces and torque

- Loading module

- Axial gap module

- Fluid-structure and thermal interaction

- Noise FEM/BEM module

- Fluid-borne noise
- Structure-borne noise
- Air-borne noise

- Design of new solutions

- Miniature gear pumps

  0.1 cm^3/rev pressure compensated pump for compact EHA

- Variable displacement gear pumps

  Variable delivery flow pump for high pressure applications (flow range 60-100%)

- Micro-surface shaping

  Surface shaping of gears to reduce power loss and extend the speed range of operation

- Pump/motor geometry imported directly from CAD files
- AMESim icon for complete system simulation
- Effect of material properties and surface roughness
- Effect of geometric tolerances
- Prediction of gear micromotions
- Prediction of flow pulsation, volumetric and torque efficiency
- Estimation of possible casing wear
- Effect of fluid cavitation
- Simulation of non-Newtonian fluids
Test Facilities

- Measure steady state and dynamic performance of pumps and motors
- Measure instantaneous displacement chamber pressure
- Measure acceleration of the swashplate
- Measure sound intensity of pumps/motors and hydraulic circuits utilizing an automated measurement robot
- Measure micro-surface shaping and wear inside hydraulic pumps and motors
- Parallel job computation across 40 computers for virtual prototyping and design studies
- Investigate powertrain architectures and controls through dynamic driving cycles
- Investigate displacement controlled rotary actuators, pump switching for sequential operation of multiple actuators, and new control concepts
- High versatility to measure steady-state and transient performance of pumps and valve, according
- Dedicated test station to test hydraulic components in presence of oil aeration or cavitation
- Measure temperature and pressure distribution of the lubricating film between the piston and cylinder
- Measure axial and circumferential piston friction forces on a hydrostatically supported bushing
- Measure the temperature behavior in the cylinder bore
- Measure fluid film thickness between slipper and swashplate
- Measure temperature distribution between the block and valve plate
• Implementing advanced control strategies for active vibration damping algorithms, bucket self leveling, and smooth speed shifting between the two displacement modes of the drive motors.

• Demonstrates displacement control and hydraulic hybridization showing engine downsizing while maintaining performance.

• Experimental set up to test counterbalance valves, standard and independent metering control architectures.

• Mobile application for testing hydraulic control systems for optimal traction control.

• Hydraulic hybrid vehicle demonstrating real world testing of hybrid architectures and control strategies.

• Platform for diagnostics and prognostics on hydraulic systems.

• Test vehicle for investigating displacement controlled steer-by-wire system.

Test Machines
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