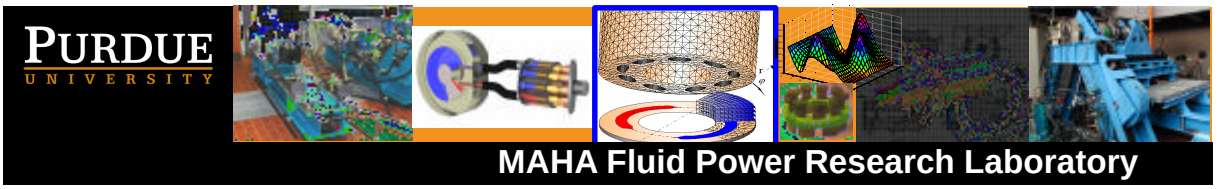


Annual Report 2004

Monika Ivantysynova
MAHA Professor Fluid Power Systems

West Lafayette, January 2005

Preface

The year 2004 was a really exciting one for our fluid power research group. Since its establishment at the Department of Mechanical Engineering of the University of Duisburg, Germany in 1996 and after five years of working at the Technical University of Hamburg–Harburg, Germany I have realized a second move of the entire lab and team in August 2004. This time a $ 3,000,000 worth fluid power research laboratory including three test machines have been moved over the Atlantic Ocean to Purdue University. I am especially proud that I can report that we could build and set up a complete new laboratory in only three month at Purdue University. I would like to thank all team members as well as all others involved in this big move for their excellent work. This move to Purdue and the establishment of the MAHA Fluid Power Research and Teaching Laboratory at Purdue confirms that our research results have earned international recognition and will give us an excellent platform for further growth. It is a great pleasure to present a survey of our activities and main achievements in the year 2004 within this annual report.

In spite of this unusual move of the whole team and laboratory from Germany to United States and in addition to setting up an entire new lab within three month our research activities continued extremely well. In 2004 the work on eight different larger research projects and several industrial sponsored smaller projects has been successfully continued and/or completed. I am especially proud to report that after more than two years of development a new and world wide unique test rig for measurements of dynamic pressure fields in the gap between piston and cylinder has been finally placed into operation. This is the first time that the dynamic pressure in the lubricating gap between piston and cylinder of an axial piston machine can be measured. The test rig is part of our research in modeling and simulation of elastohydrodynamic and other physical effects in narrow lubricating gaps to develop computer based optimization methods using micro and nanoscale surface design modification and adaptation. Our multi-domain simulation tool CASPAR, which has been developed over the last eight years by an excellent team work of researchers and students of my group, plays a central role in this research. In 2004 CASPAR has been successfully upgraded by the extension tool SUEZ, which has been developed by Sven-Kelana Christiansen within his master thesis. SUEZ allows an automatic design of the valve plate opening area based on a given cylinder pressure profile for axial piston pumps and motors and represents therefore a very important tool for the application of CASPAR in industry. Congratulations to Sven-Kelana for this excellent work. We are very happy that Christian Latinovic has completed the design of a new high pressure test pump for water, which should be used to support our ongoing research on micro and nanoscale surface optimization of tribological systems for high pressure displacement machines running with water.

The research work related to active oscillation damping of the machine frame of mobile machines applying our valveless linear actuator technology has made great progress and lead to several publications. Robert Rahmfeld and Bastian Eggers have completed an outstanding research study involving also measurements on a test machine. Among others we could place a review paper to the International Journal of Fluid Power analyzing the current state of art and discussing the ongoing research in this area world-wide. Also all other research projects in the system group have made very good progress. The control concepts developed for drive line control of off road vehicles with standard hydrostatic transmission could be successfully applied to a power split drive transmission. Our developed PSDD software for virtual prototyping of power split drives has been successfully used for different industrial sponsored research projects. The research activities concerning the de-

velopment of generic methods for prognostics of mechatronic systems installed in off-road vehicles have also made great progress. Robert Behr has completed an excellent research study about the application of structure borne noise measurement methods for this task. I am happy to report that Michael Oppermann could perform first field tests of the developed methods using an instrumented wheel loader here in Purdue.

I am very proud that the Purdue University Board of Trustees approved my appointment as the MAHA Named Professor in Fluid Power Systems on November 19, 2004.

On 20 December 2004 Jean Claude Ossyra successfully passed his PhD defence. Thus seven PhD theses have been successfully completed since the establishment of our fluid power research group. I hope we can continue with our excellent research work and I wish all members of the team a lot of success.

Monika Ivantysynova
MAHA Professor Fluid Power Systems

CONTENTS

2 RESEARCH ACTIVITIES

Our research activities focus on two major areas – advanced energy saving hydraulic actuators and drive systems and the investigation of physical processes in displacement pumps and motors especially modelling of flow phenomena in narrow lubricating gaps.

•Advanced energy saving hydraulic actuators

The aim of this research is to develop new valveless hydraulic actuator concepts, including necessary motion control strategies for different applications to avoid energy dissipation by resistance control. Recently, among others, a new valveless linear actuator has been developed and successfully tested on an off-road vehicle. For large mobile robots displacement controlled joint rotary actuator concepts have been developed and successfully tested using a large laboratory test rig. Current research activities include:

- Displacement controlled actuator technology for active roll stabilization
- Active oscillation damping based on displacement control for of off-road vehicles

• Computer based pump & motor design

This research focuses on the performance optimization and noise reduction of pumps and motors. These research efforts involve the design of special experimental facilities to develop a fundamental understanding of the complexity of physical effects taking place in displacement machines. One important result of this research on pumps and motors has been the development of the multi-domain simulation program CASPAR. CASPAR represents the first program worldwide, which allows the prediction of flow ripple, instantaneous cylinder pressure, oscillating swash plate forces, gap heights, friction forces and volumetric losses of piston pumps and motors. Current research activities concentrate on investigation of flow phenomena in micro and nano-scale area to improve existing mathematical models and to develop methods for surface optimization allowing a further increase of power density and improve of efficiency and reliability. Further research focuses on modeling of fluid and structure borne noise sources allowing the development of model based optimization methods for reduction of noise emission of pumps and motors.

• Drive line control of off-road vehicles

Research in this area centers on investigations concerning the feasibility and performance of alternative drive line technologies for off-road vehicles. The aim is to develop system concepts for minimizing exhaust emissions and fuel consumption without limiting the vehicles driving power. A special software tool called PSDD has been developed to support virtual prototyping of power split drives and complex multi-motor hydrostatic transmissions. The research activities are supported by performance measurements using motor and pump test rigs and a hardware-in-the-loop drive line test rig. Past and current studies include:

- Virtual prototyping of power split drives
- Vehicle drive line control towards optimized primary power consumption
- Advanced system and control strategies for multi-motor hydrostatic transmissions
- Development of generic methods for prognostics of mechatronic systems of off-road vehicles

In 2004 the work on the following research projects has been continued:

- Virtual prototyping of power split drives
- Development of elasto-hydrodynamic simulation model for advanced gap flow simulation
- Active vibration damping for off road vehicles using displacement controlled linear actuators
- Vehicle drive line control towards optimized primary power consumption
- Development of generic methods for prognostics of hydraulic systems in off-road vehicles
- Advanced gap design for displacement machines using tap water
- Displacement controlled actuator technology for active roll stabilization and other automotive applications
- Development of boom control strategies for excavators
- Online condition monitoring system for tractors and other agriculture machines
- Advanced system and control solutions for multi-motor hydrostatic transmissions

The described research activities have been accompanied by extensive experimental work. During the last eight years a comprehensive fluid power research laboratory with pump and motor test rigs, actuator test rigs, drive line control and transmission test rigs including test machines as well as several special test rigs for investigation of tribological systems of displacement machines, has been realized and is now available in the MAHA Fluid Power Research Lab @ Purdue University. It covers an area of 850 m^2 with an electric power supply totalling 700kW.

3 RESEARCH RESULTS & SOFTWARE TOOLS

Research Reports in 2004

Ivantysynova, M., Huang, Ch., Ossyra, J.-C. and Everth, H. 2004. *Development and Design of a Laboratory Test Rig for Measurement of Dynamic Pressure fields between Piston and Cylinder of an Axial Piston Pump*. Research report IV / 04 / 40F.

Ivantysynova, M. and Pinhel-Soares, L. 2004. Surface shape optimizations of piston - cylinder assembly of an axial piston pump using water. Research report. IV / 04 / 41F.

Ivantysynova, M. and Ossyra J.C. 2004. *Development of an open loop control concept for a two-motor hydrostatic transmission*. Research report IV / 04 / 42F.

Ivantysynova, M. and Krauss, Th. A. 2004. *Dynamic model for the controller design of a two motor transmission*. Research report IV / 04 / 43F.

Ivantysynova, M. and Krauss, Th. A. 2004. *Comparison of power split technology and hydrostatic multiple motor transmissions with respect to system efficiency*. Research report IV / 04 / 44F.

Ivantysynova, M. and Krauss, Th. A. 2004. *Design of a synchronization controller for a multiple motor transmission*. Research report IV / 04 / 45F.

Ivantysynova, M. and Rahmfeld, R. 2004. *Displacement Controlled Hydraulic Servo Drives for Wheel Loaders - "Valveless Technology"*. Research report IV / 04 / 46F.

Ivantysynova, M. and Oppermann, M. 2004. *Structure borne noise measurement at SONO test rig – comparison of results with healthy and failed load unit*. Research report IV / 04 / 47F.

Ivantysynova, M; Ossyra J.C. and Huang, Ch. 2004. *Elastohydrodynamic gap flow simulation – basis for surface adaptation. DFG – final research report*. Research report IV / 04 / 48F.

Ivantysynova, M. and Huang, Ch. 2004. *ANSYS based automatic influence matrix determination tool*. Research report IV / 04 / 49F.

Ivantysynova, M. and Ganesh Seeniraj 2004. *Actuator control for off-road vehicle incorporating cartidge valve technology. IBIS Progress Report.* Research report IV / 04 / 50F.

Ivantysynova, M. and Ganesh Seeniraj 2004. *Measurements for actuator control for off-road vehicle incorporating* cartidge valve technology. *IBIS Progress Report.* Research report IV / 04 / 51M.

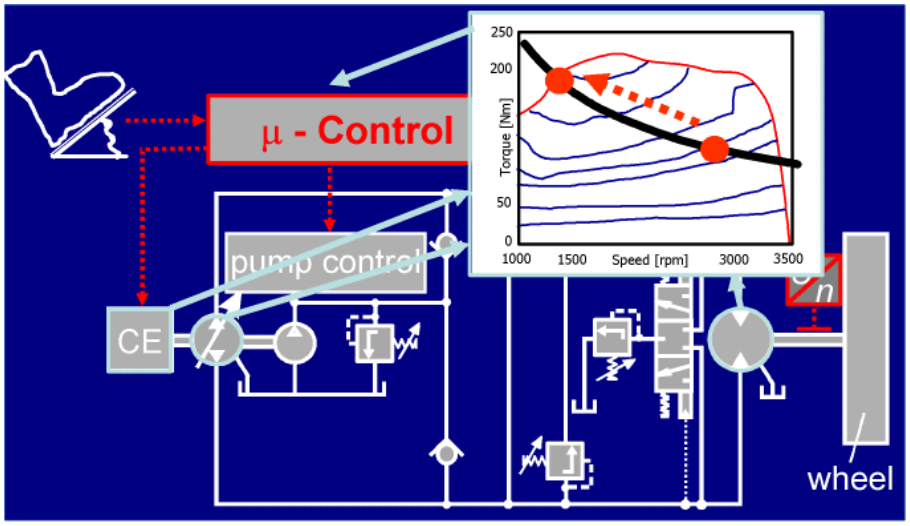
Ivantysynova, M., Oppermann, M. and Rahmfeld, R. et al. 2004. *IBIS Deliverable report - Finished Laboratory Test of Sub-Systems M5*. IBIS Research report M5-1004. Research report IV / 04 / 52F.

Ivantysynova, M. and Mikeska, D. 2004. *Analysis of the HVG-300-2Q Power Split Transmission*. Research report IV / 04 / 53F.

Brief Description of Research Projects in 2004

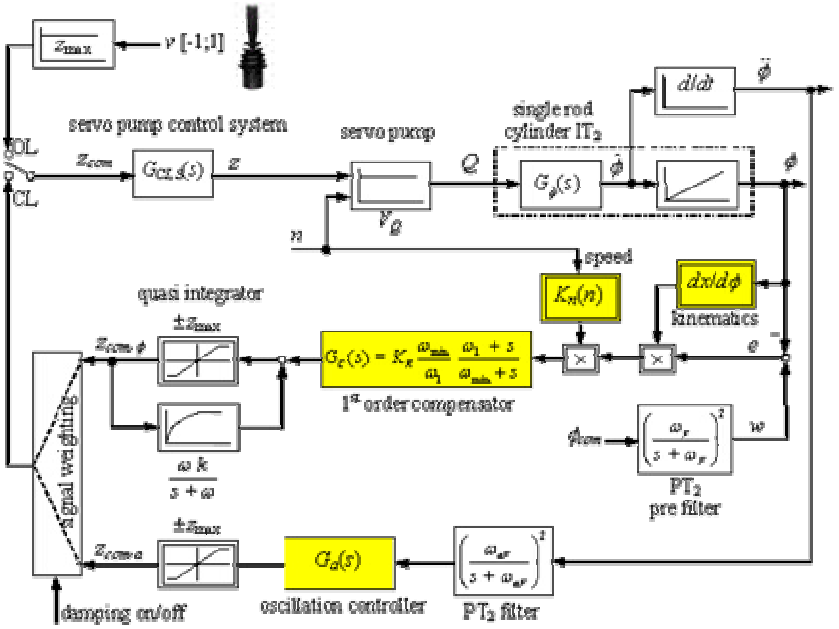
DRIVE LINE CONTROL OF OFF-ROAD VEHICLES

For off-road vehicles using hydrostatic transmissions a special drive line control concept for minimizing exhaust emissions (pollution) and fuel consumption has been developed. The control concept is based on two separate closed loop controls, one for the engine and another for the hydrostatic drive. It considers the steady state characteristics of the combustion engine and the loss behaviour of both displacement machines of the hydrostatic transmission. Therefore an optimization strategy and appropriate numerical methods have been developed to optimize the fuel consumption of the combustion engine. This concept allows the reduction of the fuel consumption of the combustion engine without limiting the vehicles driving power.



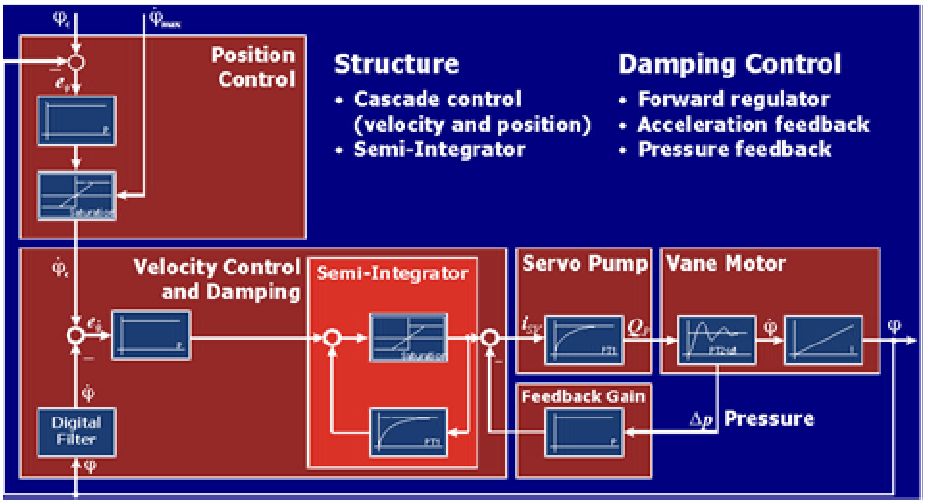
ACTIVE OSCILLATION DAMPING OF OFF-ROAD VEHICLES

Development of appropriate control concepts for actiave oscillation damping based on use of vlavless actuators is the main topic of this research. The basic idea is to use the boom actuator simulataneously for oscillation damping of the machine structure and the cabin.



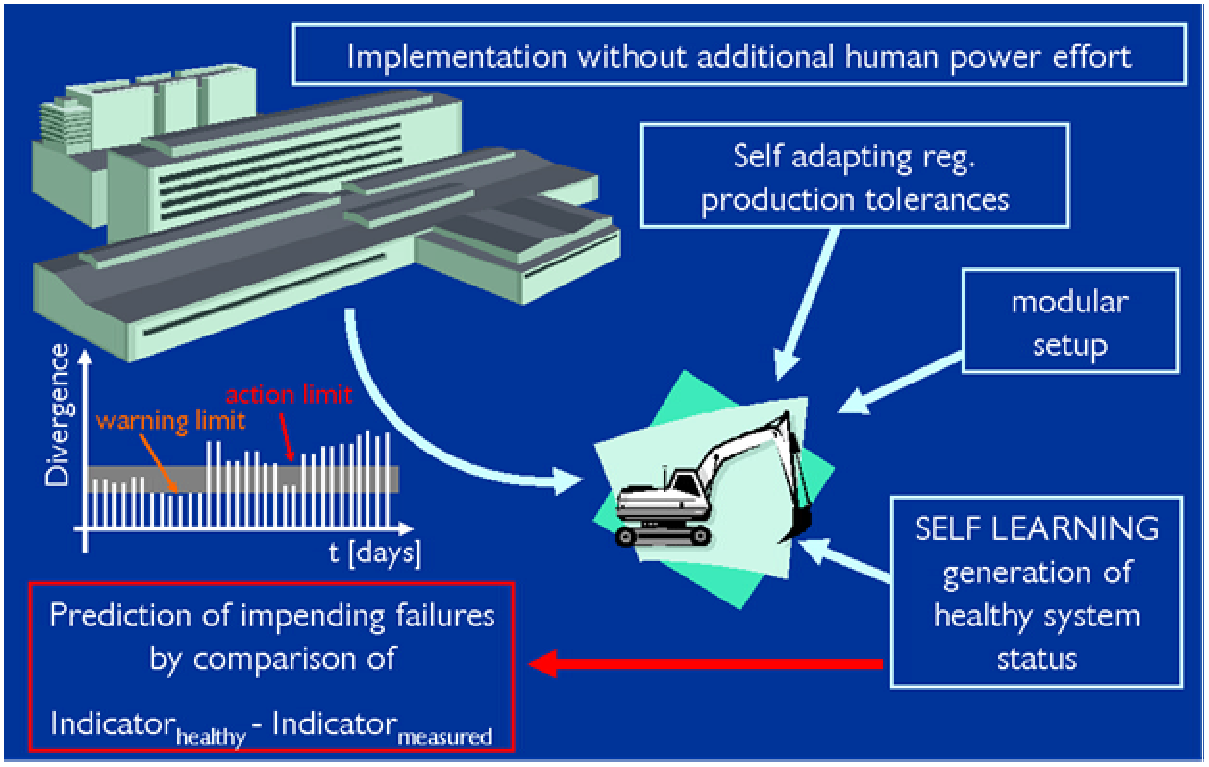
CONTROL CONCEPTS FOR ENERGY SAVING ACTUATORS

Robust control concepts for different pump controlled actuators have been developed and tested in the laboratory as well as in field tests of machines of alternative fluid power actuators. Among others a new actuator concept for pump controlled linear actuators with single road cylinder has been successfully tested. Hereby, non-linear machine influences are regarded by compensations e.g. for pump speed, kinematics, etc. The controller design basis ensures stability regarding the low damped pole movement of the main actuator. Further, robust control concepts for a pump controlled rotary actuator based on a swivel vane type motor have been developed and successfully tested.



CONDITION MONITORING OF MECHATRONIC SYSTEMS

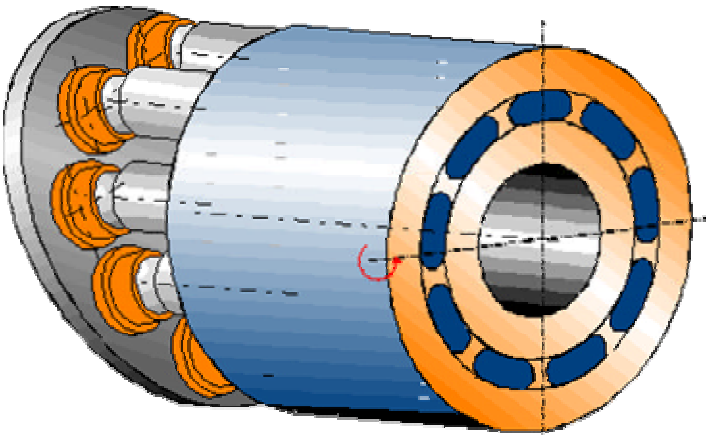
Generic methods for online and on-board condition monitoring of mechatronic systems of off-road vehicles are under development. These methods should be capable of indicating impending failures of the hydraulic and mechanical system of off-road vehicles. Different model and data based methods have been developed for the different submodules. The methods utilize the standard machine sensor information and for some methods additional sensors are required. The aim of these methods is to generate a condition monitoring system that allows the prediction of future failures in an early stage, to specify the residual terms of critical components and to keep the check intervals of the machine flexible.



The following special simulation software tools have been developed and are available for commercial use

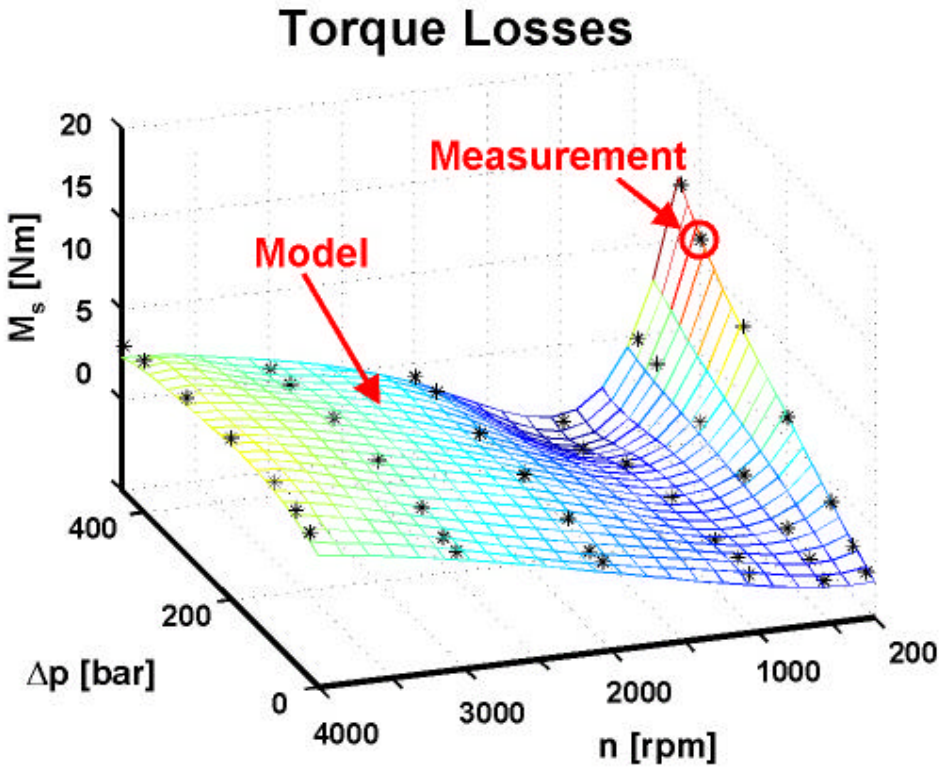
CASPAR

The prediction of pump and motor performance for a given design of a displacement machine requires a simulation model that describes the flow of a compressible and viscous fluid from the ports through the valve plate to the displacement chamber. It must further consider the gap flow through the lubricating gaps that seal the displacement chamber. The change of pressure in the displacement chamber resulting from the basic working process of the displacement machine causes fluctuating forces and moments leading to oscillating micro motion of moveable parts of the rotating group. The simulation program *CASPAR,* which has been developed at the Institute for Aircraft Systems is based on a non-isothermal gap flow model considering the change of gap heights due to micro motion of parts and due to surface deformations for the connected gaps of a swash plate axial piston machines. The program allows the calculation of real flow ripples at both ports, further the calculation of the instantaneous cylinder pressure, the internal and external volumetric losses, viscous friction forces, gap heights, oscillating forces and moments exerted on the swash plate. The program represents a powerful design tool for this kind of displacement machines. *CASPAR* is a stand alone tool developed using the C^{++} programming language. Models implemented and solved in *CASPAR* consider the time dependent change of gap heights due to oscillating forces, the interaction between machine parts, the dependency on design and operating parameters and the energy dissipation within the gaps. The updated relase of *CASPAR* includes the consideration of elasto-hydrodynamic effects due to surface deformation of parts forming the gaps. The mathematical description of the fluid flow from the ports to the displacement chamber and through the sealing and bearing gaps leads to a system of partial and ordinary differential equations. A new numerical method based on iterative coupling of separate solvers for fluid / solid domains has been developed to solve this transient nonlinear system consisting of the Reynolds equation and the energy equation for fluid domain, the equation of elasticity for the solid domain and the determination of gap heights by solving the motion equation of the multi-body system of the rotating group. The initial-boundary conditions such as instantaneous cylinder pressure are obtained by solving the fluid flow from displacement chamber to the ports.



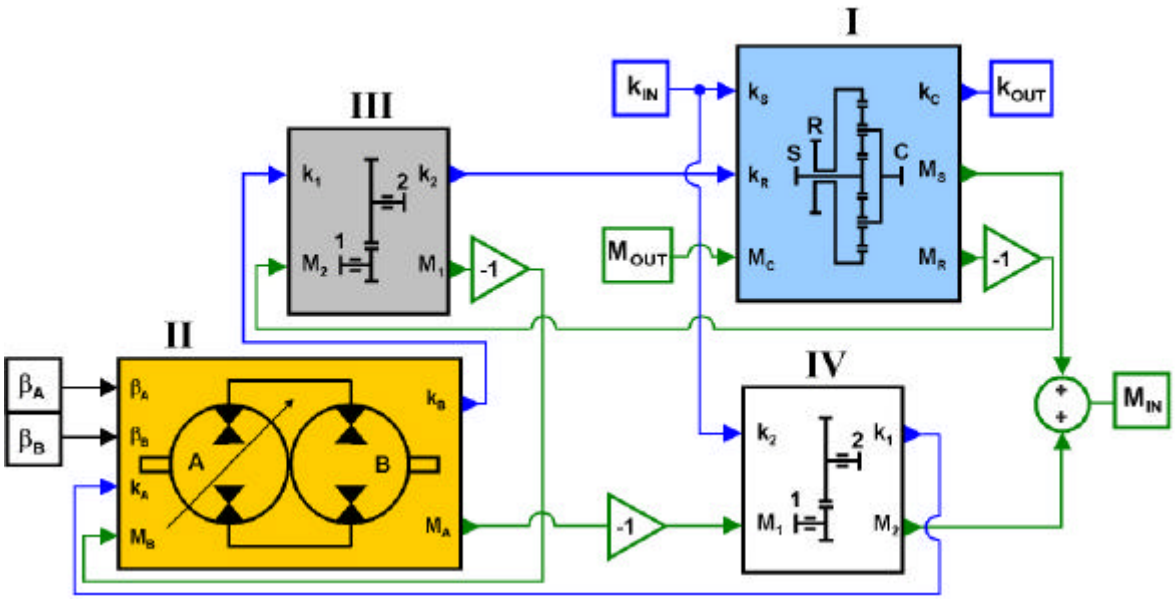
POLYMOD

The prediction of losses of fluid power systems by numerical simulation and the design of energy saving actuators and drive systems require a very high accuracy of steady state models of components especially of displacement machines. In the past a number of different mathematical models for the description of the loss behaviour of displacement machines were developed by many authors. Nearly all available models are based on measurements, but different methods are applied to obtain an analytical description. The limitation of achievable accuracy of most of these models is given by the use of relatively simple analytical expression, whereas a good fit with measured curves is usually obtained only in a limited area of operating parameters. The program *POLYMOD* uses a pure mathematical modelling approach by interpolation of measured steady state characteristics of displacement machines. The use of polynomial fitting of measurement points allows a higher accuracy of the model, especially in the range of boundary operating parameters. *POLYMOD* generates an analytical description of volumetric and torque losses of displacement machines for pump and motoring mode based on measured steady state characteristics. The dependency of all important operating parameters such as pressure difference, speed, displacement volume and temperature can be easily considered. *POLYMOD* can be applied for any kind of displacement machine. The software tool is Matlab-based.



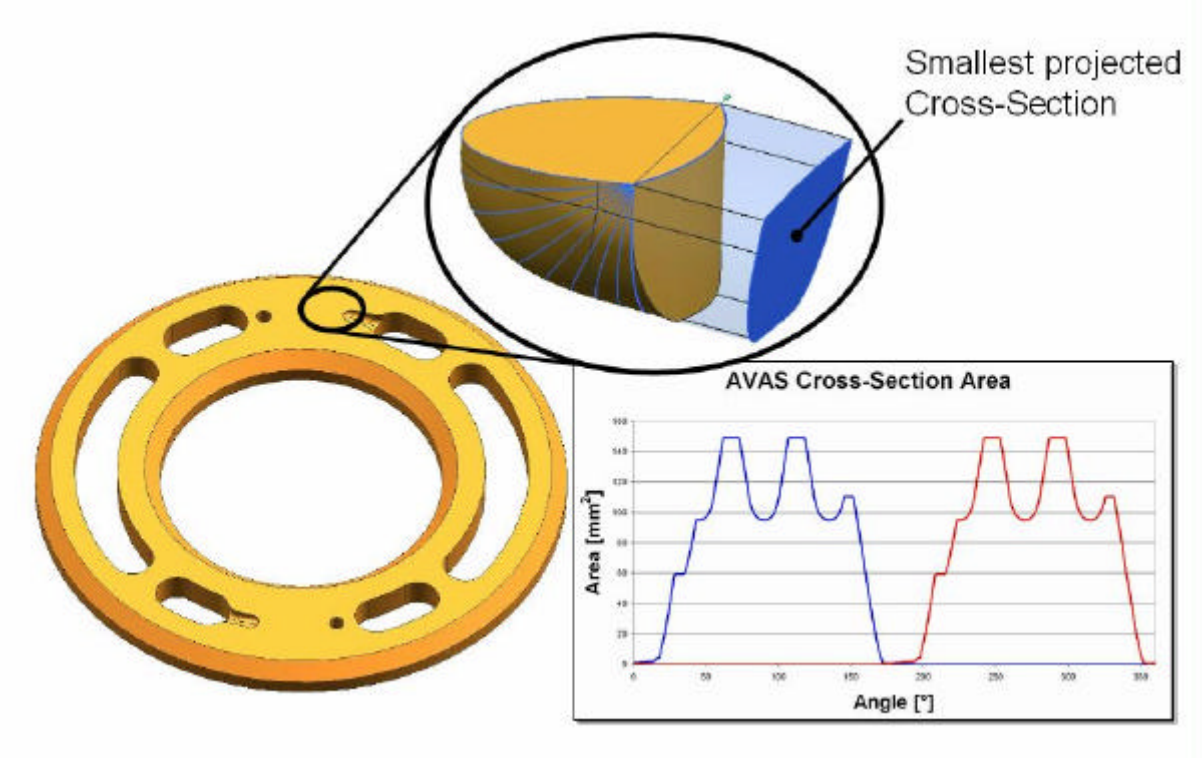
PSDD - POWER SPLIT DRIVE SIMULATION

One of the main reasons for the use of power split drives in many applications is the possibility to have a continuously variable transmission with simultaneously high efficiency in a wide range of operating parameters. This requires the consideration of real loss behaviour of all parts of the transmission. Due to the strong dependence of losses of displacement machines on operating parameters the integration of precise loss models is necessary. The *PSDD* software tool allows the calculation of system parameters including power losses in the whole range of operation for any kind of power split drive structure. This provides the design engineer with very good support during the design process and helps him to find an optimal structure of the power split drive. The tool has libraries for hydrostatic components, gears, clutches and planetary gear sets. These libraries can be extended and completed by the user easily. An open database of most common structures of power split drives is implemented in the CAE tool. The *PSDD* software tool is built in a modular way on Matlab and Simulink platform.



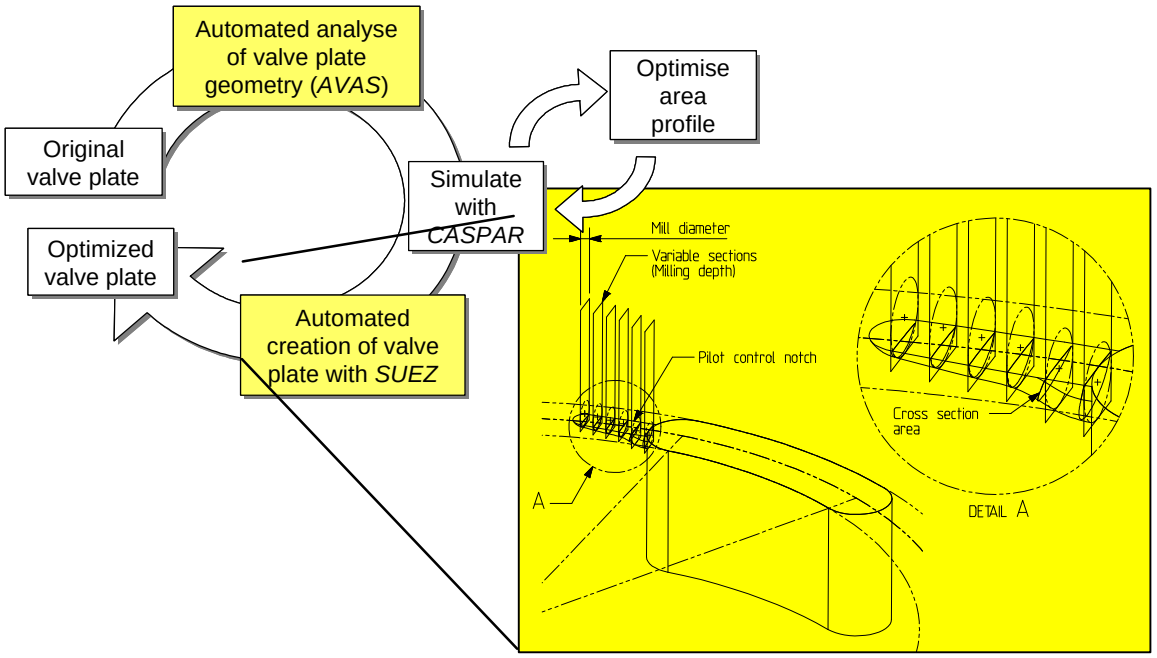
AVAS

The change of pressure in the displacement chamber of a displacement machine is greatly influenced by the smallest cross-section of the fluid flow which is formed by the valve plate and the rotating cylinder block. For simulation calculations, it is important to know the exact size of the flow passage opening to the high and low-pressure side, depending on the angle of rotation. Because of the complex geometric sectioning, an analytical description of the cross-section is not possible. In the past the cross-section was measured and interpolated manually to obtain the area profile. Using a 3D-model of the valve plate AVAS is able to compute the smallest cross-section of the fluid for a complete revolution of the cylinder block automatically. In the single-step mode every calculated passage area can be visualized. AVAS uses *Unigraphics* based routines to determine the smallest cross-section into the estimated flow direction. The program is written in C++ and uses the *UG/Open*++ interface to start as an internal application in *Unigraphics*. The 3D-model of the valve plate can be imported from any other CAD-System by the *STEP* interface.



SUEZ

SUEZ allows an automatic design of valve plate openings by reading a corresponding opening area file. SUEZ is based on the 3D CAD System Unigraphics. The pilot control notches of the valve plate are assumed to be manufactured by ball end milling. The cross section area, the length and the angle of the notches can be manipulated to obtain the desired instantaneous cylinder pressure for given operating parameters. The combination of the simulation tools CASPAR, AVAS and SUEZ allows optimizing swash plate axial piston machines in a very cost effective way. This method can also be used for other displacement machines.



4 MAHA FLUID POWER LABORATORY

The MAHA fluid power research laboratory @ Purdue University offers a unique well equipped laboratory for steady state and dynamic measurements on pumps, motors, hydrostatic transmissions and linear and rotary actuators. Different special test rigs are available for experimental investigations of tribological systems of pumps and motors. Two central hydraulic power supply nets using three pressure compensated pumps, which are independently controllable, are installed with a total power supply of 200 kW. The central pressure net is mainly used to supply hydraulic load units for the individual test rigs, where the load units are based on secondary control. The total installed electric power amounts 700 kW. The lab includes three mobile test machines allowing the test of new actuators and drive technologies as well as prognostic methods during practical field tests. The laboratory area amounts to 850 m^2.

This lab has been set up @ Purdue University since August 2004 and has been completed end of November 2004. The short period of setting up this new lab is documented by the following series of pictures taken during the three month of lab building.

Pictures documenting the installation of the MAHA Fluid Power Laboratory @ INOK building, 3601 SagamoreParkway North, Lafayette, IN 47904 August 16, 2004 – November 22, 2004

INOK building

MAHA lab September 10, 2004

MAHA lab September 20, 2004

MAHA lab September 22, 2004

MAHA lab September 22, 2004

MAHA Lab on October 1, 2004

MAHA Lab October 6, 2004

MAHA Lab October 6, 2004

October 28, 2004 – first test rig and three wheel loaders arrived from Germany

MAHA lab October 28, 2004-11-24

MAHA lab November 8, 2004 – 2nd lab equipment container arrived

MAHA lab November 8, 2004

MAHA lab November 9, 2004 – 3rd lab equipment container arrived

MAHA lab November 9, 2004-11-24

MAHA Lab November 22, 2004

MAHA lab November 22, 2004

MAHA lab November 22, 2004

MAHA lab November 22, 2004

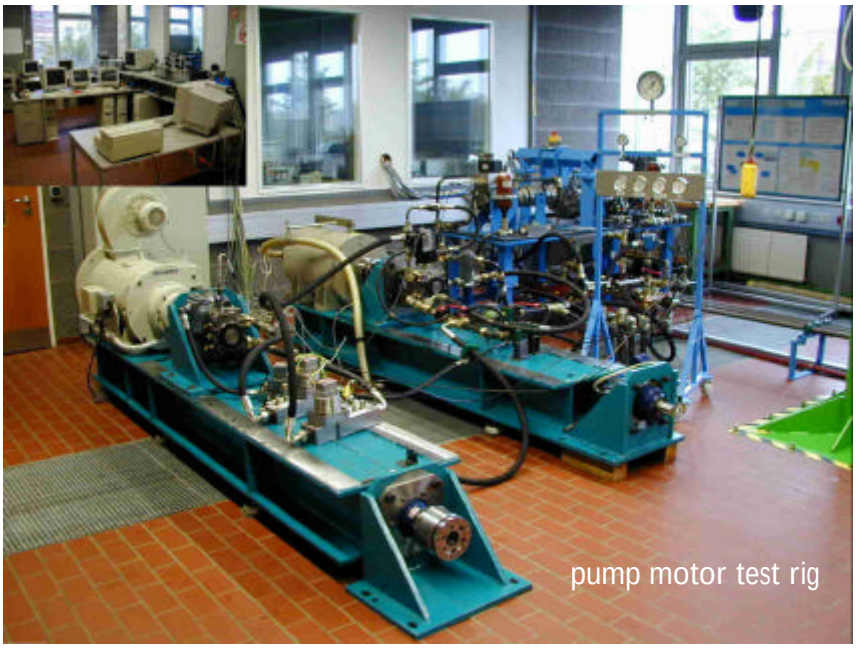
MAHA lab November 22, 2004

MAHA lab November 22, 2004

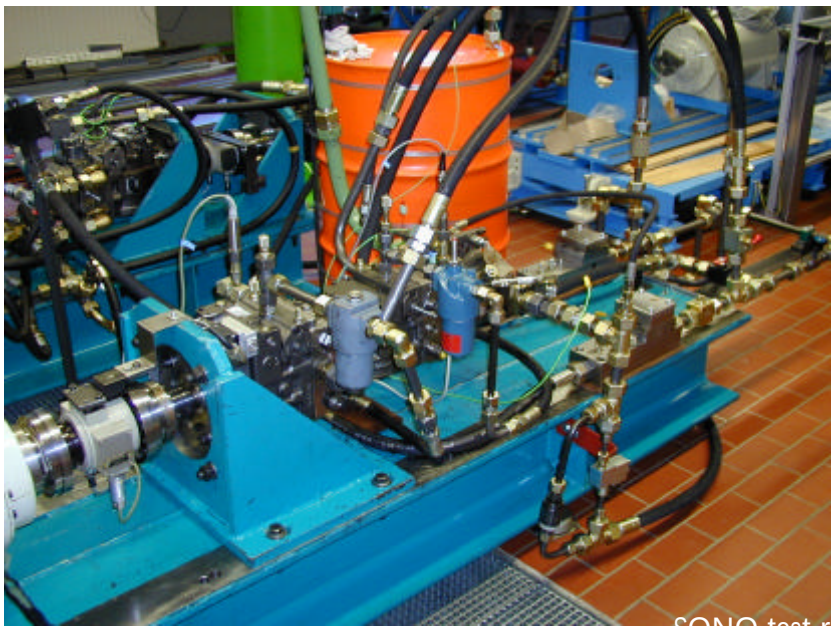
Test Rig Overview

The pump motor test rig allows steady state and dynamic measurements on pump and motors including 1 rpm tests. Using a high speed sensor telemetry in combination with piezoelectric pressure sensors among others the instantaneous cylinder pressure of pumps or motors can be measured.

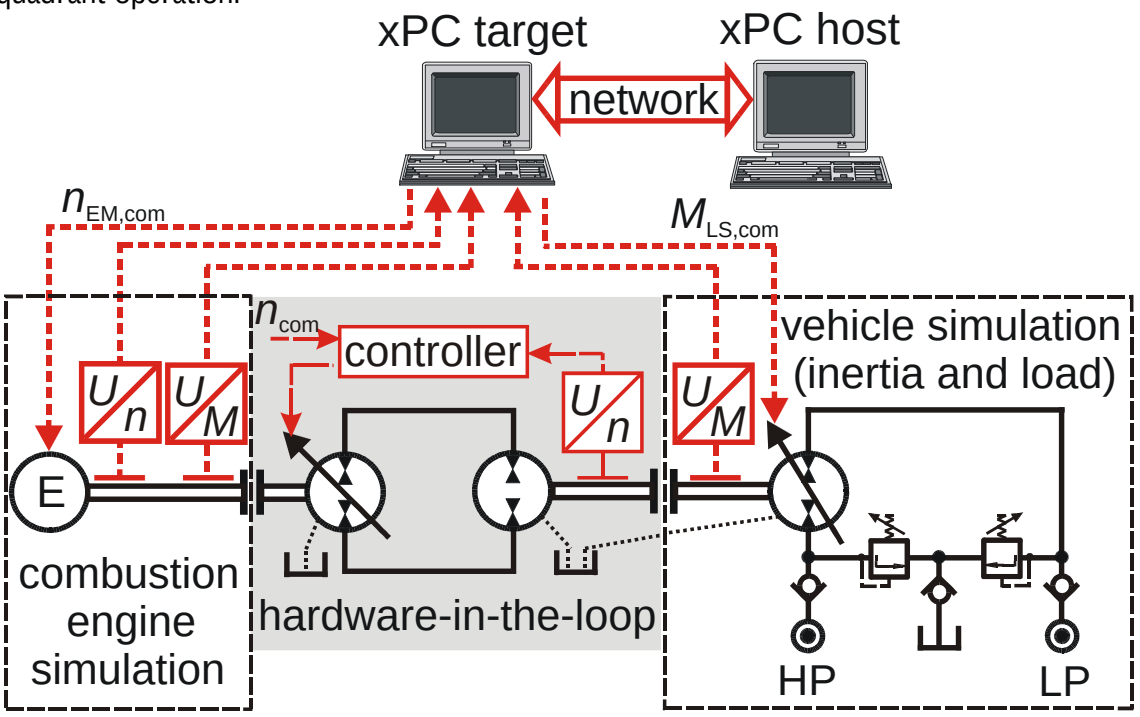
Test rig performance:
Max. installed electric power: 2 x 120 kW
Max. speed:
n_1 = 7000 rpm
n_2 = 3000 rpm
Max. pressure:
450 bar
Max. torque:
M_1 = 300 Nm
M_2 = 500 Nm

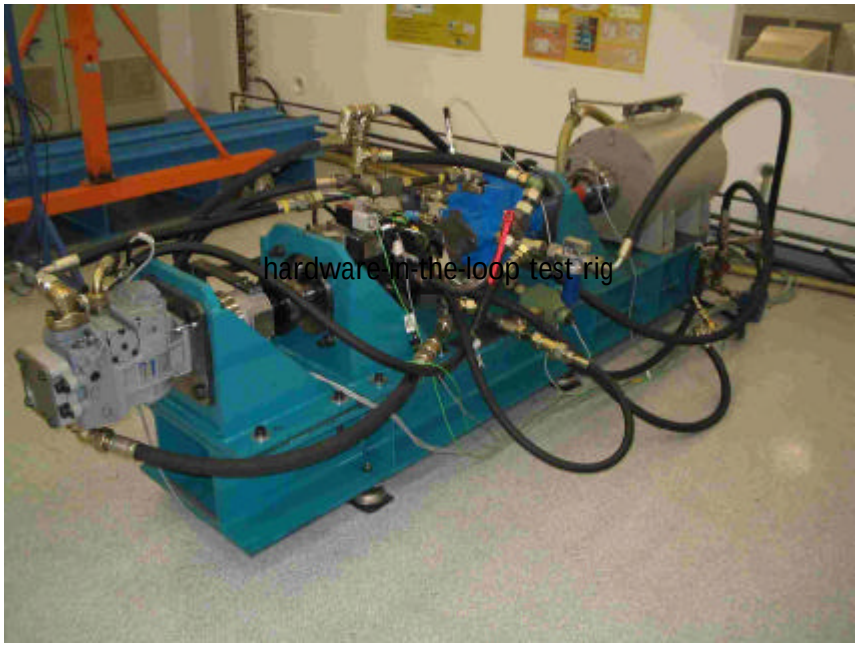

pump motor test rig

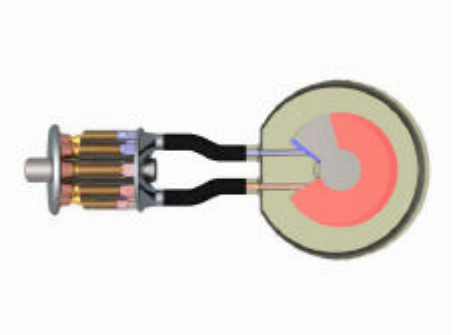
The SONO (Structure Borne NOise) test rig allows structure borne noise measurements to investigate and develop methods for the prediction of impending failures on drive lines of off road vehicles. Different methods for failure implementation can be realized.



A hardware-in-the-loop test rig serves for testing and developing drive line control concepts for off-road vehicles. The test rig allows the installation of hydrostatic transmissions up to 180 kW. A secondary controlled unit is used for load simulations including the vehicle inertia and allows a four quadrant operation.



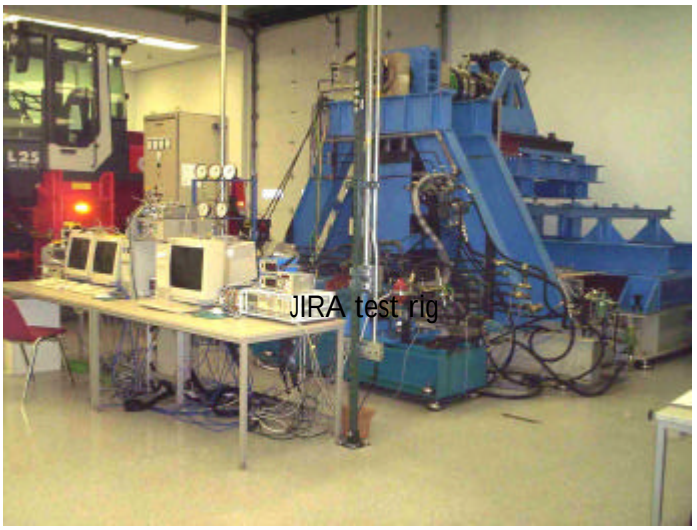




The joint rotary actuator test rig JIRA has been built for experimental investigations of displacement controlled rotary actuators for use as end effector drives in mobile robots and large manipulators. The developed system and control concepts can also be used for applications, e.g. stabilizers in cars or ships.

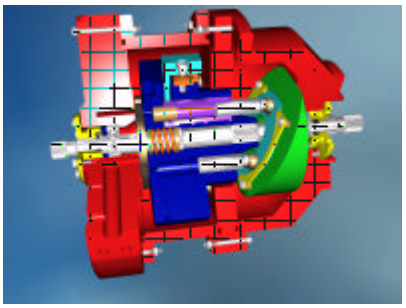
Test rig performance:

Max. Torque: 30000 Nm
Max. pressure: 350 bar
Max. power: 30 kW



JIRA test rig

The Tribo test rig allows friction force measurements on the piston / cylinder assembly of a special designed test pump. Measurements can be made on the rotating cylinder block using a telemetry and a piezoelectric force sensor installed in the cylinder block.



Tribo pump

Tribo test rig

A special test rig allows measurements of the temperature distribution in the gap between the piston and cylinder of a swash plate axial piston pump.

Special temperature distribution test rig

In 2004 a new test rig for measurements of the dynamic pressure fields between piston and cylinder of a swash plate axial piston pump has been built. The test rig uses again a special test pump based on a single piston cylinder assembly.

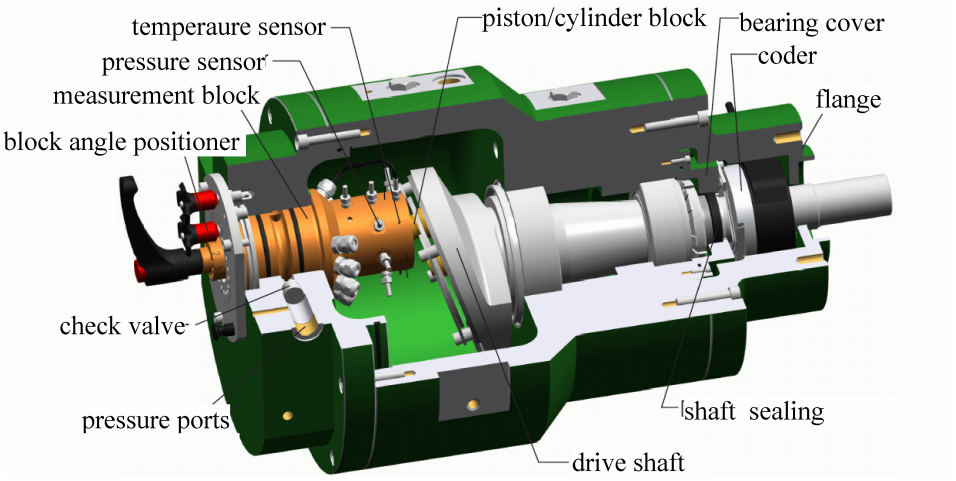
Test rig performance:

Max. power: 60 kW (electric asynchronous motor)

Pump Speed: 500...3000 rpm

Max. pump pressure: 400 bar

Max. torque: 200 Nm



5 RESEARCH GRANTS IN 2004

In 2004 we have applied for several research grants. Finally we obtained new industrial research awards with a total value of **$ 183 100**.

And the following public sponsored research grants:
Investigation of valveless actuator technology for active roll stabilization of cars, **German National Science Foundation 150 000 €**
Model based approach for noise reduction of axial piston machines, **German National Science Foundation 160 000 €**
Advanced multi-functional machinery for outdoor applications**, European Union**
293 000 €

The total value of public and industrial sponsored research grants in 2004 amounts **786 100 €**.

6 INDUSTRIAL PARTNERS & SPONSORS

Our research and consulting co-operation with industry has been successfully expanded in 2004. Finally, we could add some new partners in the list of our industrial partners and sponsors. We like to thank all our partners for a fruitful co-operation and support of our research:

Actia, Toulouse, France
Airbus Deutschland GmbH, Hamburg, Germany
Bosch-Rexroth AG, Elchingen, Germany
Bosch-Rexroth Corporation, Sturtevant, USA
B+V (Blohm+Voss) Industrietechnik, Hamburg, Germany
Case New Holland, Burr Ridge Chicago, USA
Caterpillar Inc., Preoria, USA
Centro Ricerche Fiat, Orbassano, Italy
Claas Industrietechnik GmbH, Paderborn, Germany
Cummins Inc., Columbus, USA
Deltrol Fluid Power, Milwaukee, USA
John Deere Product Engineering Center, Waterloo, USA
K. & H. Eppensteiner GmbH & Co. KG, Ketsch, Germany
Gates Corporation, Denver, USA
Hagglunds Drives Inc., Columbus, USA
Hense Systems, Bochum, Germany
Honda R&D Americas Inc., Raymond, USA
HYDAC International GmbH, Sulzbach / Saar, Germany

INNAS, Breda, Netherlands
Jungheinrich AG, Norderstedt, Germany
Linde AG, Aschaffenburg, Germany
Linde Hydraulics Corp, Canfield, USA
Mecalac, Annecy-le-Vieux, France
Moog GmbH, Böblingen, Germany
Moog Inc., East Aurora, USA
Adam Opel AG, Rüsselsheim, Germany
Oilgear Towler GmbH, Hattersheim, Germany
Orenstein & Koppel AG O&K, Berlin, Germany
Parker Hannifin GmbH, Kaarst, Germany
Parker Hannifin Corp., Cleveland, USA
Quality Control Corporation, Chicago, USA
ROSS Controls, Troy, USA
Sauer-Danfoss, Neumünster, Germany
Sun Hydraulics, Sarasota, USA
TRW Automotive, Lafayette, USA
ZF Luftfahrttechnik, Kassel, Germany

7 PUBLICATIONS

Dissertations

Ossyra, Jean Claude 2004. *Control Concepts for Vehicle Drive Line to Reduce Fuel Consumption.* Technical University of Hamburg-Harburg, Publication: VDI Verlag.

Journal Publications

Ivantysynova, M. and Lasaar, R. 2004. An investigation into Micro- and macro geometric design of piston/cylinder assembly of swash plate machines. *International Journal of Fluid Power* 5 (2004) No.1, pp. 23-36.

Ivantysynova, M. 2004. EHD-based simulation model for connected tribosystems of displacement machines (in German). *Tribologie und Schmierungstechnik No 05-04*.

Rahmfeld R. and Ivantysynova, M. 2004. An overview about active oscillation damping of mobile machine structure. (review paper). *International Journal of Fluid Power* 5 (2004) No.2, pp. 5-24.

Grabbel, J. and Ivantysynova, M. 2004. Advanced swash plate control for high dynamics of displacement controlled actuators. International Journal of Fluid Power (in review).

Refereed Conference Proceedings

Ossyra, J.C. and Ivantysynova, M. 2004. Application for a Direct Optimization Procedure for Drive Line Control. *Bath Workshop on Power Transmission and Motion Control PTMC 2004, Bath, UK*, pp. 53 – 69.

Ivantysynova, M.; Huang, C. and Christiansen, S.K. 2004. Computer Aided Valve Plate Design - An Effective Way to Reduce Noise. *2004 SAE International Commercial Vehicle Engineering Congress , Chicago, IL, USA, SAE Technical Paper 2004-01-2621.*

Krauss, A. and Ivantysynova, M. 2004. Power Split Transmissions versus Hydro-static Multiple Motor Concepts – A comparative analysis. *2004 SAE International Commercial Vehicle Engineering Congress , Chicago, IL, USA, SAE Technical Pa-per 2004-01-2627*.

Rahmfeld, R.; Ivantysynova, M and Eggers, B. 2004. Active Vibration Damping for Off-Road Vehicles using Valveless Linear Actuators. 2004 SAE International Commercial Vehicle Engineering Congress , Chicago, IL, USA, SAE Technical Paper 2004-01-2655.

Ossyra, J.-C. and Ivantysynova, M. 2004. Drive Line Control for Off-Road Vehicles Helps to Save Fuel. 2004 SAE International Commercial Vehicle Engineering Congress , Chicago, IL, USA, SAE Technical Paper 2004-01-2673

Rahmfeld, R.; Ivantysynova, M and Weber, J. 2004. Displacement Controlled Wheel Loader – a simple and clever Solution. *Proc. of the 4th International Fluid Power Conference (4. IFK), Dresden, Germany, Vol. 2*, pp. 183 - 196.

Huang, C. 2004. CASPAR based slipper performance prediction in axial piston pumps. Proceedings of 3rd FPNI-PhD symposium on Fluid Power, Terassa, Spain, pp.229- 238.

Oppermann, M. 2004. Condition Monitoring of Mechatronic Systems of Off-road Vehicles. Proceedings of 3rd FPNI-PhD symposium on Fluid Power, Terassa, Spain, pp. 381-390.

Ossyra, J.-C. 2004. Optimization of power losses in off-road vehicles using drive line control. Proceedings of 3rd FPNI-PhD symposium on Fluid Power, Terassa, Spain, pp. 391-400.

Invited Lectures

Perspectives on New Directions in Research. 3rd NFPA Educators Summit, September 30, 2004. Cammelback Inn, Scottdale Arizona.

Posters presented

Krauss, A. 2004. System concepts and control strategies for multiple-motor transmission
@ 3rd FPNI-PhD symposium on Fluid Power, Terassa, Spain

Three posters @ 3rd NFPA Educators Summit, September 30, 2004. Cammelback Inn, Scottdale Arizona.

1. Poster: *New energy saving actuator technology*
2. Poster: *Drive line control for off road vehicles online processing*
3. Poster: *Computer based design & optimization of pumps and motors*

System Concepts and Control Strategies for Multiple-Motor Transmissions

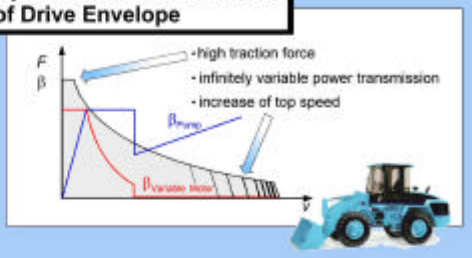
Goals

Continuously Variable Transmission for heavy machines with

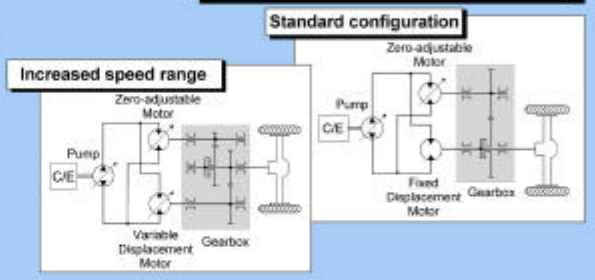
- simple and cost effective structure
- high efficiency
- enlarged speed range
- high traction force
- open / closed loop control

to replace hydrodynamic converters

Optimization and Extension of Drive Envelope



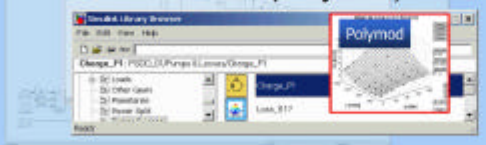
Development of System Structures



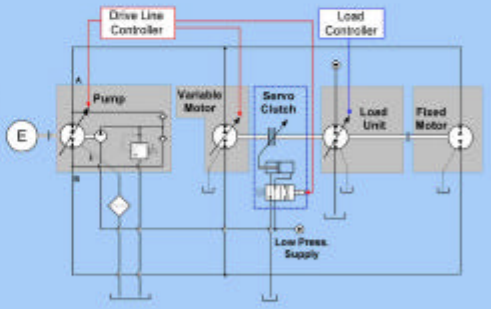
Methods

Modeling and Simulation of

- Dynamic behavior (Simulink & PSDD)
- Precise loss models (Polymod)



Experimental Proof



Controller Development

- Integrated Control of Pump, Variable Motor, Clutch and Combustion Engine
- Easy operation and high comfort
- Investigation of safety critical issues

TUHH Technical University of Hamburg-Harburg — Alexander Krauss — Institute for Aircraft Systems Engineering — Prof. Dr.-Ing. Monika Ivantysynova

Study and Master Theses completed

Ahlers, Florian 2004. *Mapping* Non-Linear Flow Characteristics of a Proportional Hydraulic Valve Using Artificial Neural Networks. (Study Thesis in co-operation with University of Saskatchewan, Canada, jointly supervised by Richard Burton)

Bauer, Dorothee 2004. *Investigation of simultaneous working ability of the primary flight control drives mainly consisting of an electro-hydrostatic actuator with electric motor as final control element (EHA) and a standard hydraulic actuator.* (Study Thesis)

Behr, Robert 2004. *Design and laboratory test of an online diagnose system for off road vehicles based on structure borne noise measurements.* (Study Thesis)

Christiansen, Sven-Kelana 2004. *Automatic generation of valve plate geometry basd on an optimized pressure profile.* (Master Thesis)

Eggers, Bastian 2004. *Controller Design for active damping of a wheel loader based on displacement control boom actuators.* (Study Thesis)

Eggers, Bastain 2004. *Extended Control Concepts and Energetic Aspects for Active Oscillation Damping with Displacement Controlled Linear Actuators.* (Master Thesis)

Everth, Henning 2004. *Design, Installation and Controller Development for a Brake-By-Wire HIL System.* (Master Thesis)

Hermann, Rene 2004. *Investigation of alternative system solutions for valveless actuators for active roll stabilization of cars.* (Study Thesis)

Kikker, Arnd 2004. *A comparative study of approach to simulation of a vehicle power train.* (Study Thesis in co-operation with Monash University, Australia, jointly supervised by Jacek Stecki)

Latinovic, Christian 2004. *Design of an axial piston pump for water based on special design of tribological systems.* (Study Thesis)

Rahman, Muhammed Saidur 2004. Investigation of measurement methods for the determination of gap flow parameters for an axial piston pump using tap water. *(*Study Thesis)

Subramanian, Saravanan 2004. *Dvelopment ofa nonlinear mathematical model of the boom actuation system of an excavator using Matlab/Simulink.* (Study Thesis)

Tews, Tjerk Christoph 2004. Development of an orifice scaling software tool for the G&T / CAE system of the airbus A3456 family and the CAX system of the A380. (Study Thesis)

Ziemen, Lars 2004. *Advanced displacement control system of a modified axial piston machine.* (Study Thesis)

8 INTERNATIONAL CO-OPERATION

Our successful international co-operations with fluid power research centres world wide could be strengthen by using our membership in the international network "Fluid Power Net International" (FPNI), which is currently joined by members from 26 countries, see http://fluid.power.net

The FPNI network has allowed establishing an individual student exchange programme. In 2004 three of our students have used this opportunity for performing a research study abroad:

- Florian Ahlers at University of Saskatchewan, Canada
- Arnd Kikker at Monash University, Australia
- Dorothee Bauer at Airbus, France

We would like to thank the following colleagues for their fruitful collaboration:

- Prof. Jacek Stecki from Monash University, Australia
- Prof. Jean-Charles Mare from INSA Toulouse in France
- Prof. Richard Burton from University of Saskatchewan, Canada

Our co-operation with the Department of Mechanical Engineering at the Technical University of Ostrava, Czech Republic, within the ERASMUS program has been successfully continued from last year.

Since February 2003 our research group became a member of European Centre of Fluid Power Laboratories (ECFP), see http://www.fpce.net

In 2004 the following students and researchers have worked in our team:

Juraj Gulas , Technical University of Bratislavea – 6 month @ TUHH

Bastian Eggers, Technical University of Hamburg - 4 month @ Purdue

Edat Kaya, Technical University of Hamburg - 2 month @ Purdue

Robert Behr, Technical University of Hamburg - 4 month @ Purdue

Jan Radtke, Technical University of Hamburg - 2 month @ Purdue

9 AWARDS AND HONOURS

PURDUE UNIVERSITY News

OTHER LINKS

News Archive (searchable) Recent releases News Service home page

November 19, 2004

Purdue trustees approve appointments for 4 professors

WEST LAFAYETTE, Ind. – The Purdue University Board of Trustees today (Friday, Nov. 19) approved the appointment of designated professorships.

The board approved the appointments of the following professors: Monika Ivantysynova as the Maha Named Professor in Fluid Power Systems, Philip Nelson as the first Scholle Chair in Food Processing, Herbert Ohm as a Purdue Distinguished Professor, and Vladimir P. Shalaev as the Robert and Anne Burnett Professor of Electrical and Computer Engineering. With these appointments, the Purdue faculty has 102 named or distinguished professors.

"These scholars are pre-eminent in their fields, attracting major research grants as well as the very best students and faculty," said Purdue Provost Sally Mason. "They are essential to our strategic plan."

Monika Ivantysynova

Ivantysynova, a professor within the School of Mechanical Engineering and the Department of Agricultural and Biological Engineering, came to Purdue in August. She specializes in computer-based pump and motor design, modeling and simulation of hydraulic systems, motion control with advanced hydraulic actuators, and the development of design algorithms.

Her current research efforts also include the development of new energy-saving hydraulic actuators for heavy-duty manipulators and robots, drive-line control and active oscillation damping of off-road vehicles, virtual prototyping of power split drives, as well as condition monitoring and prognostics of mechatronic systems. In addition to the book "Hydrostatic Pumps and Motors," published in German and English, she has published about 80 papers in technical journals and at international conferences. She is editor-in-chief of the

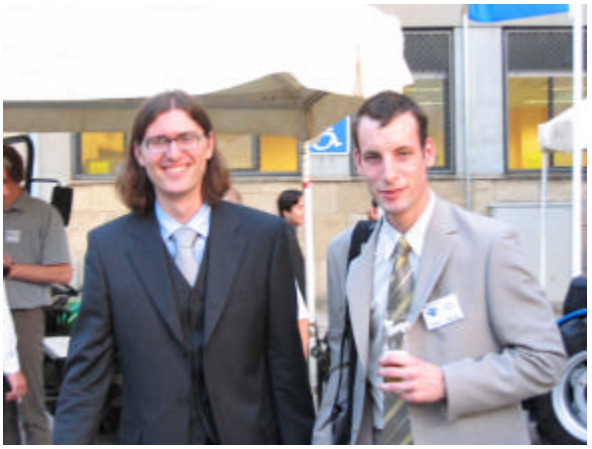
International Journal of Fluid Power.

A native of Polenz, Germany, she earned a doctoral degree in 1983 from the Slovak Technical University of Bratislava, Czechoslovakia. She then worked for seven years in the fluid power industry. She was a professor of mechatronic systems at the Institute for Aircraft Systems Engineering at the Technical University of Hamburg in Germany from 1999 to 2004, a professor of fluid power and control at Duisburg University in Germany from 1996 to 1999, a senior researcher and manager at the Institute for Aircraft Systems Engineering from 1992 to1996, and a project leader at the Institute for Machine Design at the Technical University of Hamburg from 1990 to1992.

10 OTHER EVENTS

3 rd FPNI PhD Symposium in Terassa, Spain

The 3rd FPNI PhD symposium in Terassa was a great event for young researchers coming from more than twenty countries world wide. We were participating with 11 people.




02.07.2004 22:18

Purdue trustees approve appointment of Monika Ivantysynova as the Maha Named Professor in Fluid Power Systems on November 19, 2004

First international guest visits the Fluid Power Laboratory of Purdue University:

Prof. Sobczyk
on November 15th

11 EDUCATIONAL ACTIVITIES

The following courses have been prepared and offered in 2004:

Design of Mechatronic Systems I (30 hours)

(Prof. Dr.-Ing. Monika Ivantysynova)

Goals:

Introduction to the design process of complex mechatronic systems. The course gives an overview about components, sub-systems and control strategies of actuators and drive systems including the basic computational methods, which are necessary for the design and analysis of mechatronic systems. The main focus of this course lies on modelling of fluid power systems.

Content:

- Classification of mechatronic systems
- Fundamentals of modelling based on physical laws
    - physical properties of fluids
    - transient response models of transmission lines
    - turbulent and laminar flow of viscous fluids
    - modelling of tribological systems
- Components and sub-systems of resistance controlled systems
    - pressure and flow control valves, proportional and servo valves
    - dynamic and steady state models
    - experimental methods to determine component and system properties
- Components and sub-systems of displacement controlled systems
    - displacement machines, flow pulsation and pressure ripple
    - pump control systems, classification, design and modelling
    - experimental methods to determine pump and motor performance
    - steady state models of displacement machines
    - dynamic models of displacement controlled actuators
- Classification of energy supply systems, load sensing systems
- Secondary controlled actuators

Grading: Oral exam

Design of Mechatronic Systems II (45 hours) - PC classroom required!

(Prof. Dr.-Ing. Monika Ivantysynova, Dipl.-Ing. Jean-Claude Ossyra, Dr.-Ing. Robert Rahmfeld)

Goals:

This second course gives an overview on computer aided system design methods using different engineering tools and provides the ability of application of computer aided design methods using MATLAB / SIMULINK in combination with multi-body-simulation tools for complex mechatronic systems.

Content:

Design and Analysis of steady state and dynamic properties of mechatronic systems of an Aircraft Cargo Robot using advanced computer based design methods.
Students are divided into small design groups with maximum three students. Each group has to develop its own system solution and to proof the system performance by computer simulation using a co-simulation of the mechanical and hydraulic model. In 2003 a co-simulation between MATLAB and ADAMS was required. The task includes a design report with complete project documentation. Different actuator principles had be used by different design groups. Finally an evaluation of advantages and disadvantages of the chosen design solution for the given task was required.

Grading:

Written report plus oral exam

System Simulation (30 hours) - PC classroom required!

(Prof. Dr.-Ing. Monika Ivantysynova, Dipl.-Ing. Jean-Claude Ossyra)

Goals:

This course contains an introduction into MATLAB / SIMULINK and provides an insight into problems of modelling and simulation of fluid power systems.

Content:

- Controller design with MATLAB / SIMULINK
- Simulation of dynamic systems with MATLAB / SIMULINK

- Simulation of dynamic behaviour of a valve controlled linear drive with double acting cylinder
- Position controlled linear drive based on resistance control
- Simulation of dynamic behaviour of a pressure compensated pump
- Simulation of dynamic behaviour of a electrohydraulic pump control system
- Simulation of dynamic behaviour of a pump controlled rotary drive
- Integration of steady state characteristics into the dynamic model of a servopump

Grading:

No exam, only active participation required!

Practical Course of Instrumentation - taught in English: (5 hours)
(Prof. Dr.-Ing. Monika Ivantysynova, Dipl.-Ing. Michael Oppermann)

Goals:

This course aims to provide an overview about measurement methods of pressure and flow for applications in mechatronic systems. The course includes a practical laboratory course, where students are divided in groups learn the installation of sensors, the use of PC based data acquisition and the evaluation of measured data for pressure and flow rate.

Content:

- Application of pressure and flow measurement devices and typical applications in mechatronics
- Types of pressure to be measured
- Common methods for measuring pressure and classification of sensors
- Electrical pressure sensors
- Flow measurement methods and devices
- System installation and measurement accuracy
- Steady state and dynamic measurements – some examples

Grading: Written exam

Seminar Aircraft Engineering (30 hours)

(Prof. Dr.-Ing. Monika Ivantysynova, supervisor)

Goals:

The seminar aims to train presenting skills including literature study, graphical and oral presentation.

Content:

Each student has to prepare an oral presentation on a certain topic. In 2004 the following topics were chosen:

Topic 1: The fin stabilizer – a hydraulic rotary drive for less sea disturbance
Topic 2: Strategies for private retirement ar-rangement
Topic 3: Aerodynamic in everyday life – about golf balls and bees
Topic 4: Stirling Motor - an forgotten machine
Topic 5: German Lloyd – a traditional classification society
Topic 6: Crash of Columbia Space Shuttles – cause and impact
Topic 7: Sun fire – Energy from plasma
Topic 8: 3-Liter-car – Ideas and concepts
Topic 9: Robots in households – dream or reality?
Topic 10: Vehicles between air and water – flying boats and swimming airplanes

12 INTERNATIONAL JOURNAL OF FLUID POWER

The fifth year of successful publication of the *International Journal of Fluid Power* draws to its close. The 14th issue was printed and sent to our readers end of November. I would like to express my grateful thanks to you all for your continuous support of the *Journal,* especially for reviewing papers and submitting manuscripts. On behalf of the Editorial Board I would like to thank all Associate Editors for their great help.

I am happy to inform you that the Journal's position could be strengthened again in 2004. Here some facts confirming this positive development. Since 2004 the Journal is abstracted and indexed also by *Elsevier Compendex Engineering Information*. The ASME Fluid Power Systems and Technology Division has proposed an agreement for a non-exclusive participation of ASME in the Journal's publication. Unfortunately the first version of the agreement was not approved by ASME board. As Editor-in-Chief I believe that this co-operation will contribute to an enhancement of our readership as well as to an increase of submitted papers, which supports the Journal's mission in offering a unique platform for high quality information about ongoing research in fluid power technology world-wide. Therefore we will continue this effort in 2005.

We have also successfully continued our co-operations with our partners in several countries, e.g. the Journal of the Japan Fluid Power System Society *"Fluid Power System*", the Italian "*Oleodinamica Pneumatica Lubrificazione*" and "*Go –Fluid"* and the USA "*Fluid Power Journal*". In December 2004 we agreed a new co-operation with the German "Ölhydraulik und Pneumatik O+P", which gives researchers from Germany the possibility to publish their results after publication in the *International Journal of Fluid Power* also in German language in the O+P. The Journals website has been continuously improved and has become a very good source of information.

This year was accompanied with my move to Purdue University in August 2004. I am proud that we finally could manage this move without big troubles for the Journal publication. In this regard I would like to express my warmest thanks to Robert Rahmfeld, who did a great and so excellent job as technical Editor of the Journal. He was able to handle for free an enormous workload by running the journal review process, including communication with authors and reviewers as well as the proof reading process and the communication with the printing office. In addition he was responsible for the journal website. Unfortunately Robert will leave my team January 15, 2005. I offered him to continue his job as Technical Editor on a reduced work load basis. This has to be approved by his new employer. On behalf of the Editorial board I would like to thank Robert for his outstanding work and continuous support of the Journal.

Let me add some other important facts to inform you about the Journal's progress. In 2004 totally 30 papers were submitted to the *International Journal of Fluid Power,* which means an increase of 3,4%. Until now authors from 28 countries have submitted papers to the *International Journal of Fluid Power*. All papers are peer reviewed by at least two experts. Very often three independent reviewers are involved to make sure that the review process is fair and ensures a high level of Journals final publication. The rate of successfully approved papers is 48%.

We have continued our effort to become indexed by the Scientific Citation index. Our first approach failed because of the too low number of citations. Please do not forget to put references to

your and other publications in the *International Journal of Fluid Power.* We will continue to apply for this important index.

In spite of the relatively low price of the Journal (the annual subscription rate is 98€) we have still an insufficient number of subscribers. And therefore I would be grateful if you could implement this *Journal* in your university library and please help to get it also in other university libraries in your country. I need your help to strengthen our advertisement activities.

Monika Ivantysynova

Editor-in-Chief

13 TEAM MEMBERS

JANUARY 1ST- AUGUST 15TH @ TUHH

We are pleased to welcome the following new members of our team:

Dipl.-Ing Sven-Kelana Christiansen started his research work in May 2004.

Professors

Prof. Dr.-Ing. Monika Ivantysynova email: m.ivantysynova@tuhh.de

Secretary

Marlies Schäfer email: schaefer@tuhh.de

Technicians

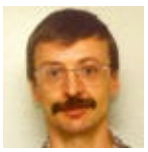
Dipl.-Ing. Detlef Lehmann email: d.lehmann@tuhh.de

(Laboratory)

Dipl.-Ing. Todd Parry email: t.parry@tuhh.de

(IT area)

Georg Schindler email: schindler@tuhh.de



(Electrics)

Scientific Employees

Dipl.-Ing Sven-Kelana Christiansen email: s.k.christiansen@tuhh.de

M. Sc. Changchun Huang email: c.huang@tuhh.de

Dipl.-Ing. Alexander Krauß email: krauss@tuhh.de

M. Sc. Dusan Mikeska email: d.mikeska@tuhh.de

Dipl.-Ing. Michael Oppermann email: m.oppermann@tuhh.de

Dipl.-Ing. Jean-Claude Ossyra email: ossyra@tuhh.de

M. Sc. Leonardo Pinhel-Soares email: pinhel-soares@tuhh.de

Dr.-Ing. Robert Rahmfeld email: r.rahmfeld@tuhh.de

M. Sc. Ganesh Seeniraj email: seeniraj@tuhh.de

Dipl.-Ing. Elmar Wulf email: e.wulf@tuhh.de

Student Assistants

Robert Behr
Christian Bruhn
Fu Jie
Anna Grubinski
Susan Hanke
Edat Kaya
Igor Kolchin
Matthias Mohr
Jan Radtke

MEMBERS OF THE FLUID POWER RESEARCH TEAM @ PURDUE UNIVERSITY SINCE AUGUST 15TH

Dr. Monika Ivantysynova,
MAHA Professor of Fluid Power email: mivantys@purdue.edu

Robert Behr email: robert.behr@tuhh.de

Bastian Eggers email: bastian.eggers@tuhh.de

M. Sc. Changchun Huang email: huang31@purdue.edu

Edat Kaya email: ekaya@purdue.edu

Dipl.-Ing. Detlef Lehmann email: d.lehmann@tuhh.de

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Jan Radtke email: radtke@purdue.edu

Dr.-Ing. Robert Rahmfeld email: r.rahmfeld@tuhh.de

M. Sc. Ganesh Seeniraj email: gseenira@purdue.edu

14 VISITORS & GUESTS

Andrzej Sobzyk, Technical University of Cracow, Poland

Marcus Kliffken, Thomas Kunze, Gerold Müller, Gerhard Geerling, Mel Maynard, David Saaski, Bosch Rexroth Group

Hans Heinrich Harms, Torsten Lang, Technical University Braunschweig, Germany

Michael Djurovic , Technical University Dresden, Germany

Hubertus Murrenhoff, Michael Deeken, RWTH Aachen, Germany

Bodo Voß, B+V Industrietechnik, Germany

Oliver Kunze, ZF Luftfahrttechnik, Germany

Juergen Weber, CNH

Eckhard Skirde, Dean Jones, Jeff Herrin, Sauer-Danfoss GmbH Neumünster, Germany & Aims, USA

Joe Kovach, Lew Kasper, Rich Kimpel, Howard Zhang, Lawrence Schrader, Ken Gorski, Sandy Harper, Duane Crockrom, Parker Hannifin Corporation, USA

Gary L. Dostal, John Deere, Tractor Hydraulics Systems, Waterloo, USA

Ng Gorman, Linde Hydraulics Corporation, USA

Dan Williams, Phil Peterson, TRW Commercial Steering Systems, USA