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FPST

Fluid Power Systems & Technology Division Newsletter

Noah D. Manring, Editor *Spring 2001*

Chair's Message

Gabriel Silva

It is time to tell our members and associates what is going on with our Fluid Power Systems and Technology Division (FPST) through our common newsletter. The FPST Division series is accomplishing its goal of integrating office members with academia and industry. Our visibility keeps increasing through our new web page (www.asme.org/divisions/fpst/), through our growth in membership, and through our organization of industry forums, which have been successfully taking place over the last two Winters Meetings.

The collaboration among our members from different parts of the country and overseas has produced the contribution of 27 papers in combined sessions with the FPST Division and the Dynamic Systems, Measurement and Controls Division. The quality and innovation of the topics were very interesting for all the attendees. New ideas and approaches to solving control problems are a particularly attractive topic among our presenters. However, the majority of the papers are addressing current problems found in industries varying from the earth-moving equipment to injection molding machines to pump design, flow forces in spools and dissolved air and oil hydraulic systems. The Division has implemented a new way of promoting and increasing the participation of our members by creating a best paper award, which was first implemented this year (See FPSTD Best Paper Award" article below). The initial selection for the best paper award was done by the executive committee through voting over the internet and the winner was the paper titled "Control-Oriented Modeling of an Injection Molding Machine Including the Fill-to-Pack Transition" written by Danian Zheng, Andrew Alleyne, and Heather Havlicsek of the Mechanical and Industrial Engineering Department of the University of Illinois at Urbana-Champaign.

Two industry sessions have found a common theme for our Divisions during the Winter Meetings and they have received a lot of participation from the major industry speakers. The sessions titled, "Panel on Fluid Power Research Directions - An Industry Perspective" and "Panel on New Technologies in the Fluid Power Industry" were well attended and provided the opportunity for industry speakers from major hydraulic manufacturing companies to share ideas and concerns in areas where academia and industry could work together in solving current problems. The panel sessions helped to provide research direction for academia and discussed current trends within industry that demand effective, low-cost, analytical control solutions for the price-competitive market we are all facing.

Our Divisions face many challenges: we have to continue our cooperation among our members to provide a source of infor-

(continued on page 2)

Three Members of the FPST Group Elected to the Grade of Fellow of ASME

The 36th Division of ASME, the Fluid Power Systems and Technology (FPST) group, are pleased to announce the successful election of three of its members, the late Dennis Bowman, Arthur Akers and Bob Koski to the status of Fellows of ASME. These three persons have contributed significantly to the formation and progress of the FPST group of ASME.

Dennis Bowman became a member in 1981. He most recently was the manager of the Electrohydraulic Systems Engineering group, John Deere Products Engineering Centre in Waterloo, Iowa. He is well known for bringing electronics and electric controls into the agricultural machinery business. He has participated actively in ASME, the Society of Automotive Engineers (SAE), the National Fluid Power Association (NFPA) and American Society of Agricultural Engineers (ASAE) activities. He has been a member of the FPST advisory group since 1995 and Chair of the division in 1995. He has been organizer and Chair of numerous technical sessions at ASME and SAE meetings. His dream was to find ways in which the major fluid power organizations could come together in pursuing excellence in

(continued on page 4)

Chair's Message

(continued from page 1)

mation, a place to share ideas, a place to promote our developments, a place to stay in tune with academia and industry developments, a place where a focus on new technologies can be highlighted and discussed. How are we going to do this? The web page and the newsletter provide an open forum for our members to express their opinions. Our industry sessions are bringing our members together to discuss current demands in the fluid power market. We are also looking to expand our ties with the SAE organization with our common interest in fluid power. The Fluid Power Division is going to have a combined FPST Industry Session with SAE in our next Winter Meeting in November of this year in New York City. We expect to have a good exchange of ideas with the SAE members and speakers of industry during this session. However, there are many projects that are beginning to take place where we need member collaboration. We need to increase our membership and our visibility, not only in our Division, but through ASME and also in our industry. We need to increase our recruiting and find a way to promote our Division to schools around the country and around the world. Our Division has significantly contributed to the development of new technologies for the fluid power industry. A plan is in place to be able to provide a list of papers via our newsletter to attract attention to the current wealth of information provided by the papers.

This is just the beginning. We are busy and we expect to keep you informed through our newsletter and web page and we expect to hear from you!

Gabriel Silva, Ph.D., Chair

SAE Fluid Power Systems Group and ASME FPST Group Hold Joint Sessions

This year, a special fluid power session was held at the 2000 SAE Off highway conference held in Milwaukee. This session was entitled "Applications of Intelligent Hydraulic Systems" and was jointly sponsored by the Fluid Power Group of SAE and the Fluid Power Systems and Technology Division of ASME. Papers from Canada, USA, China and Denmark were presented. This was the first time such a session has been organized and given. It is clear indication that both organizations realize the importance of working together to disseminate technical information to the fluid power community. We are in fact, trying to attract the same audience to our conferences. In addition to increasing the attendance at conferences, it is important to encourage the fluid power community to support all fluid power organizations by have our libraries subscribe to our publications. We cannot survive without support of this kind.

The intention of the SAE session was to provide a forum for academics to present their research at a conference, which has a strong industrial presence. A similar session is now being planned for the 2001 ASME Conference in New York. A special panel session of industry experts is being organized which will bring an industry flavor to the academics who frequent the ASME conferences. Other organizations such as NFPA and Fluid Power Net (FPN) are also being contacted to join in expanding these co-sponsored sessions. Perhaps, in the future, a conference sponsored by all the major fluid power bodies might be possible.

The HUSCO/Ramirez Distinguished Chair in Fluid Power and Motion Control

The George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology in Atlanta, Georgia is pleased to announce the appointment of Dr. Wayne Book as the HUSCO/Ramirez Distinguished Chair in Fluid Power and Motion Control. Dr. Wayne Book joined the Woodruff School of Mechanical Engineering at Georgia Tech in fall 1974 as an assistant professor. He holds degrees from the University of Texas at Austin (B.S.M.E.) and the Massachusetts Institute of Technology (M.S., Ph.D). Dr. Book is a Fellow of ASME and the Institute of Electrical and Electronics Engineers. He is a registered Professional Engineer in Georgia, holds four patents, and served as the Technical Editor of the *Journal of Dynamic Systems, Measurement, and Control*. He received the Georgia Tech Faculty Research Award for Outstanding Leadership in Graduate Research Assistant Development in 1987 and was the founding director of Georgia Tech's interdisciplinary program in Computer Integrated Manufacturing Systems (1983-1987). Dr. Book's research in robotics and motion control improves the dynamics of intelligent machines, expanding design space to lighter, faster, more precise motion systems. He uses advanced control, dynamic modeling, sensing, and actuation by hydraulic, electric, and non-conventional means to gain improvements in autonomous and human-operated machines.

The Woodruff School of Mechanical Engineering is the oldest and second largest of the nine divisions in the College of Engineering at Georgia Tech. The School offers academic and research programs in mechanical engineering, nuclear and radiological engineering, and health physics. The enrollment includes approximately 1300 undergraduates and 540 graduate students. Studies are directed by 68 full-time, tenure track professors, 16 research faculty, three academic professionals, and a support staff of fifty. The George W. Woodruff School of Mechanical Engineering is the first educational institution to be designated a Mechanical Engineering Heritage Site by the ASME. For more information about the Woodruff School, please visit our home page at: http://www.me.gatech.edu.

Mr. Agustin A. Ramirez is a graduate of Georgia Tech's School of Aerospace Engineering (B.S.A.E. 1968, M.S.A.E. 1969) and he has an MBA from Harvard University. He is the Chairman and CEO of HUSCO International, a major manufacturer of hydraulic and electrohydraulic controls for mobile equipment in the construction, materials handling, agriculture, and automotive markets. Mr. Ramirez is the past chairman of the NFPA, a past Wisconsin Entrepreneur of the Year recipient, and he serves on numerous nonprofit and public company boards. Mr. Ramirez's gift to Georgia Tech consists of the endowment for the chair in the Woodruff School of Mechanical Engineering and partial funding for a state-of-the-art fluid power laboratory.

Three FPST Members Attended ASME TEC 2001

In order to enhance the effectiveness of its Executive Committee, three FPST members, Prof. Dean Kim from Bradley University, Sanjay Mistry from John Deere Product Engineering Center and Dave Edeal from MTS Sensors, attended this year's ASME Technical Executives Conference (TEC) March 3-5 in Atlanta, GA. The annual event serves as an introduction to the varied aspects of the ASME organization as well as an opportunity for industry and academic professionals to network and gain valuable pointers for accomplishing division goals while minimizing headaches. All three FPST attendees felt that the conference was enjoyable, worthwhile and enlightening and look forward to utilizing concepts learned to help our division to thrive in the future. ASME is organization of impressive diversity that can seem intimidating at times. With this conference, the TEC committee has established useful tools to help us navigate the mazes. If you need any help, or have any questions about ASME policy or procedures - ASK - first your Executive Committee members, then

a staff person. Fred Goldfarb is the primary contact for the FPST and if he can't answer a question, he will know who can. During the conference, we were reminded that ASME is run by its membership and supported by its staff. When we work together as a team, we can accomplish just about anything. Refer to www.asme.org/tec for more information.

NSF Funds Research Supporting Fluid Power Technologies

The National Science Foundation (NSF) has recently awarded a $310k GOALI (Grant Opportunities for Academic Liaison with Industry) proposal entitled, "Analysis, Design, and Testing of Profiled Hydrostatic Thrust Bearings." The principal investigators on this project are: Noah D. Manring (University of Missouri - Columbia), Harischandra P. Cherukuri and Robert E. Johnson (University of North Carolina - Charlotte), and John Litherland (Caterpillar, Inc., Peoria, IL). This grant provides funding for improving the performance of a hydrostatic thrust bearing which are commonly used within fluid power machinery. It is well known that these bearings undergo both small and large scale deformations and that these deformations can significantly reduce the load-carrying capacity of the bearing. What has been less well known is that certain types of bearing deformation can actually increase the load-carrying capacity! In this research, these advantageous deformations will be investigated using analytical, numerical, and experimental techniques. The objectives of this work will be to develop design guidelines that may be used to ensure beneficial deformations while also guaranteeing that harmful deformations do not occur. The fluid-film thickness between the bearing and the thrust surface will be optimized based upon sliding speed, structural properties of the bearing, fluid conditions, and power source limitations. A method for conducting these investigations will be to study the impact of intentionally profiling the bearing surface to achieve optimal bearing performance. The optimized profile geometry, coupled with the expected passive deformation of the bearing, will be used to specify the design requirements for the advanced bearing design.

If successful, the work of this research will be used to significantly enhance the performance of hydrostatic thrust bearings that are widely used within hydraulic machinery. The improved performance will be demonstrated in higher load-carrying capacities and lower power requirements. A secondary impact will be to reduce wear and increase life expectancies by eliminating the potential for metal-to-metal contact between the bearing and the thrust surface. The design guidelines that are generated from this work may be used to update the classical textbook theory that exists for these widely used machine elements. By doing this, improved machine design practices will be disseminated among the engineering community and a significant reduction in waste and an increase in productivity will be realized. The description of this award can be accessed at the following web address:

https://www.fastlane.nsf.gov/servlet/showaward?award=0100279

Fluid Power Net International (FPNI)

Fluid Power Net International (FPNI) was formed late in 1997 as a multinational virtual engineering laboratory focused on active researchers in the field of motion control, specifically in fluid power technology. Over the last three years, there has been substantial progress in making FPNI a success. Some of these successes have been demonstrated by the following: 1) multiple fluid power laboratories in 22 countries have joined FPNI, 2) National Workshops and International Conferences sponsored by FPNI have been well-attended, and 3) two issues of the International Journal of Fluid Power were published in 2000 (three issues are planned for 2001).

In the field of fluid power there is a small number of large R&D laboratories, 3-4 in Europe and one or two in Asia, specializing in fluid power. However the bulk of fluid power research activities are widely spread around the world and is carried out in smaller research centers and institutes by researchers having highly specialized skills and experience in the development of fluid power technology. The Fluid Power Net was formed to achieve "critical mass" in resources and staff numbers, which would collectively enable these laboratories to develop and/or conduct large R&D projects/activities, consulting and educational projects. Furthermore FPNI was established with the main objective of providing the infrastructure to build an international network of researchers and facilities to carry out major projects. Other objectives are to:

1. Promote international research cooperation in the field of fluid power technology and related areas.
2. Provide information about worldwide research and industrial activities in the field of fluid power technology and related areas.
3. Promote engineering education in the field of fluid power technology and related fields.
4. Provide Technology Transfer to industry by way of Conferences, Workshops, Industrial courses and other news media as appropriate, including the Internet.
5. Publish scientific and educational books and monographs in the field of fluid power technology and motion control.
6. Publish a Scientific Journal in the field of fluid power technology.
7. Promote Postgraduate Study Programs in fluid power technology in member countries.
8. Develop education programs in fluid power technology, motion control and related areas.
9. Execute industrial research and development projects utilizing the resources of FPNI linked centers and institutes. (Commercial R&D projects will be undertaken by a separate legal entity in order to isolate any commercial risk from the members of FPNI.)

Though substantial progress has been made toward achieving these objectives, continued efforts must be put forth to insure the future success of FPNI. For instance, plans are being developed for greater involvement of colleagues from Industry and, specifically, the involvement of younger colleagues is being encouraged. An important issue, which was addressed during the last Convenor's meeting in Hamburg, is the funding of FPNI. The continuing success of the International Journal of Fluid Power, the only international refereed scientific journal on fluid power now in its third issue, will depend on a steady supply of quality papers and subscription level. One of the objectives of FPNI is to establish close links with national and international fluid power companies. An expertise of FPNI members, which covers practically every facet of fluid power technology, makes it possible to assist Fluid Power Industry in solution of R&D problems which cannot be handled by individual laboratories. A number of projects, teaming members in different countries, are currently under discussion with industry. Technology Transfer is an important activity of FPNI, thus FPNI organized a number of Conferences and Workshops and maintains WWW Virtual Library on Fluid Power website at http://www.fpni.net/fpn/wwwvl. The next conference, 2nd Workshop on Computer Software for Design, Analysis and Control of Fluid Power Systems will be held in September 2001 website at http://www.fpni.net/fpn/simula2001.

If you are interested in FPNI or would like to participate in their programs more fully, please contact Dr. Jacek S. Stecki (stecki@eng.monash.edu.au) or visit the FPNI website at http://fluid.power.net . The Journal website is at http://journal.fluid.power.net

Three Members of the FPST Group Elected to the Grade of Fellow of ASME

(continued from page 1)

the fluid power industry. That dream is now partially realized with the joint cooperation between the Society of Automotive Engineers (SAE) and ASME in sponsoring technical sessions at their annual conferences. Sadly, Dennis passed away last year and was awarded the Fellow posthumously. He will be missed.

Arthur Akers is a long-standing active member of ASME (1976). He is a retired (Emeritus) professor from the Department of Aerospace Engineering and Engineering Mechanics at Iowa State University. He has lived a very colorful life and perhaps will be best remembered (from a research perspective) for his studies on axial piston pumps. His work has appeared in almost every significant Journal or Conference proceedings in the world. Arthur has also been a strong and active participant in the FPST group. He has been on the advisory board for the FPST group since 1995, and was chair of the division in 1994. He was associate Editor, ASME Journal of Dynamic Systems, Measurements and Controls from 1989 to 1993. Perhaps, of most importance to our Division, Arthur was responsible for the formation of the FPST group and really can be credited with the success it has today. Arthur was presented with his award at the November ASME IMECHE conference in Orlando. Well-done Arthur. Have a great retirement.

Bob Koski is the founder and chairman of Sun Hydraulics, a company that employs over 500 people at plants in Sarasota, Florida, Coventry, England and a distribution facility near Aachen, Germany. Bob is well known for his promotion of Fluid Power Education around the world. He was also instrumental in the formation of the FPST group and has served as Member-at-Large, on the Council of Members. He has been Vice Chair of the Systems and Design Group and has been on the Advisory Board of the FPST division. His forward thinking and interest in design as opposed to analysis has resulted in his being in demand as a guest speaker for many different occasions. His talks on design have attracted the attention of many audiences all over the world. Bob has been actively associated with NFPA and IEEE and was instrumental in establishing a contest oriented towards University and College students to design and compare mechanical, electrical and fluid actuation systems. We thank you Bob for the support you have always given to the Fluid Power Systems and Technology Group.

University of Bath Receives the Queen's Anniversary Prize 2000 for Higher and Further Education

The University of Bath received an award at Buckingham Palace February 15, 2001 at the honours ceremony The Queen's Anniversary Prize 2000 for Higher and Further Education. A prize was given to mark the University's contribution to teaching, research, and knowledge transfer in the field of power transmission and motion control.

At the prize ceremony Her Majesty The Queen personally presented a Gold Prize Medal to the University's Chancellor, Lord Christopher Tugendhat; Vice-Chancellor, Professor David VandeLinde (formerly Dean of Engineering at Johns Hopkins); and Hebron and Medlock Dean of Engineering and Design, Professor Cliff Burrows. The Duke of Edinburgh also presented them with an illuminated Prize Certificate before he and The Queen talked to staff and students about their work.

> *'Our visit to Buckingham Palace to receive the Queen's Prize crowned a year of success for the Centre for Power Transmission and Motion Control. It was less than a year ago that we received an announcement of funding to erect a new building for the Centre. We will be proud to house in that building the Gold Medal and Certificate presented to us by Her Majesty The Queen and His Royal Highness The Duke of Edinburgh. The day was made even more special by the presence of colleagues and students who also had the pleasure and honour of meeting our Royal hosts.' (Cliff Burrows)*

The Centre for Power Transmission and Motion Control was established at the University in 1968. The work at the Centre has earned them a place as the UK's leading institution in the area of fluid power systems engineering and has won international acclaim for their strategic and applied research. Fluid power is used in many commercial applications, including anti-lock braking, aircraft simulators for pilot training and aircraft flight controls.

In the Power Transmissions area, more efficient vehicles may result from the Centre's research into vehicle driveline control, where various types of continuously variable transmissions are being studied with the aim of reducing fuel consumption and harmful emissions. Work at the Centre has also led to the development of quieter products, achieved through a greater understanding of the way that noise is generated and transmitted through hydraulic machinery and has led to new test procedures, which have been adopted as International Standards.

Life-saving developments in intensive care and improvements in safety for divers are among the benefits springing from the Centre's research into the human respiratory system. Researchers crossed conventional disciplinary boundaries, working in multi-disciplinary teams to gain an improved understanding of life support systems.

FPSTD Best Paper Award

At the ASME Winter Annual Meeting (2000), Danian Zheng and Andrew Alleyne (University of Illinois at Champaign-Urbana) and Heather Havlicsek (Motorola Inc.) were awarded the Best Paper Award for a paper entitled, "Control-Oriented Modeling of an Injection Molding Machine Including the Fill-to-Pack Transition." In this paper, an effort has been made to establish a feasible model of both machine and polymer systems from a control-oriented viewpoint. The motivation is to provide a simulation tool for eventual design of injection molding machine (IMM) control algorithms in order to achieve better accuracy of filling speed and holding pressure as well as the fill-to-pack transitions.

The IMM used in this research is a typical Reciprocating Screw type IMM consisting of a mold, a barrel, a ram screw in the barrel, and the electro-hydraulic system that controls the screw movement and mold opening. The hydraulic system driving the ram screw has a hydraulic pump with an electrically controlled proportional valve and pressure relief valve to control the 2 hydraulic cylinders that move the ram screw. The ram screw moves to inject the polymer melt into the mold. When the mold is full, the ram screw holds the polymer in the mold at a pressure to compensate for the shrinkage that occurs during mold cooling. In each of these IMM cycle phases, there are the following distinct control requirements:

1. Mold filling phase: Position or velocity control to ensure the correct melt front velocity;
2. Packing phase: Pressure control at a higher boost pressure to ensure correct part weight.

In the presented work, the interest is on the filling and packing phase as well as the critical transition between the two phases. A schematic of a typical cycle is shown in Figure 1 that depicts the fill-to-pack transfer location in the IMM cycle.

Building upon the model tested in Havliseck and Alleyne, (1999), the current model takes into account both the detailed mechanical system components as well as polymer characteristics. The model of Havliseck and Alleyne, (1999) considered only the mechanical components of the machine without considering the polymer loading; therefore the current paper's goal was to improve upon the previously presented model. The model consists of 8 major components consisting of both machine dynamics and polymer dynamics. These are:

1. a proportional flow control valve which regulates the flow of high pressure hydraulic fluid from the pump to cylinder,
2. a length of hose containing a significant volume of hydraulic fluid which includes several restrictions as well as a proportional pressure relief valve,
3. 2nd order hydraulic line dynamics for fluid between the valves and cylinder,
4. a reducing orifice through which flow must pass from the line to the actuator,
5. the hydraulic actuator that generates necessary force for ram motion,
6. the ram inertia itself which includes stick-slip friction,
7. the polymer melt viscosity as a non-Newtonian viscous friction.
8. the mold cavity as a fixed control volume with nonlinear leakage.

Previous modeling work has usually concentrated on either the filling phase or packing phase of the IMM cycle. Since the system dynamics, particularly the polymer characteristics, are totally different before and after the change, this transition is one of the most challenging in IMM system modeling. When the mold is fully filled by polymer melt, the pressure within the mold and at the nozzle will rapidly increase. At the same time, the ram screw speed decreases dramatically and comes almost to a stop. After the transition phase both the machine and polymer behaviors change enormously. Very little is available in the literature as a procedure for dynamically describing this changeover. Therefore, a suitable model that combines both phases of the IMM cycle would be extremely valuable for overall IMM control design. A primary goal of this paper was to develop such a a model capable of capturing the transition dynamics. In addition, the overall model should be able to represent the pressure dynamics after the mold is full. Changes of the model during the packing phase are made accordingly as following.

For polymer melt flow dynamics, we can no longer assume the polymer to be incompressible and isothermal. The polymer part will shrink during the packing phase because of the heat being transferred from polymer to the mold wall. Also because of the high holding pressure, the polymer begins to become compressed by the pressure. Therefore, from a force balance, the ram will slowly move forward to inject more material and compensate for the pressure drop. For the purpose of our model we assume that the compression and shrinkage of the polymer occurs as a relatively steady process because the movement of the ram is relatively slow. Therefore, we model the shrinkage using a leakage flow with a power relationship to nozzle pressure.

The previously developed model was tested against data taken from the actual machine. Two separate PID controllers are used to control the filling and packing phase. There is also an open loop controller to handle the transition between the filling and the packing phases. From the figures we can see the simulation predicts the behavior well enough to be valid for controller development. Comparing the current model to previous work, this model resolves the problem of a lack of an accurate representation for the polymer viscous friction as well as the pressure underestimation due to the exclusion of the polymer flow dynamics through the nozzle. These modeling improvements give simulation more accuracy for comparison with actual experimental results. For future optimal IMM control design, this model would serve as a good testbed.

Havlicsek, H. and A. Alleyne, "Nonlinear Control of an Electrohydraulic Injection Molding Machine via Iterative Adaptive Learning," IEEE/ASME Transactions on Mechatronics, Vol. 4, No. 3, pp. 312-323, Sept. 1999

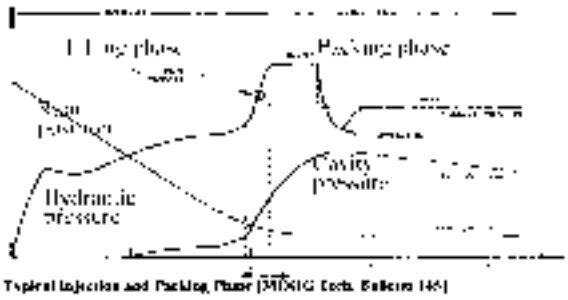

Figure. 1. Injection cycle phases (Thayer & Davis, 1980)

Figure 2. Comparison between Simulated and Experimental Pressure. For whole injection cycle of both phases

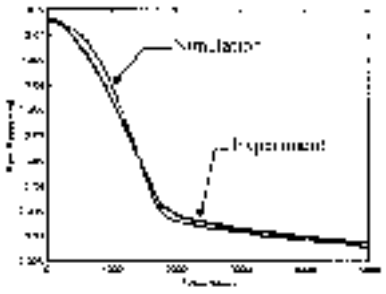

Figure 3. Comparison between Simulated and Experimental Position. For whole injection cycle of both phases

FPST DIVISION

EXECUTIVE COMMITTEE, 2000-2002

Chair
Dr. Gabriel Silva
Young & Franklin Inc.
T: 315-457-3110 F: 315-457-9204
gsilva@yf.com

Vice-Chair:
Dr. David Edeal
Moog Technology Center
T: 716-687-5520 F: 716-687-4504
dedealinc.@moog.com

Members:
Mr. Robert E. Koski
Sun Hydraulics Corporation
T: 941-362-1200 F: 941-355-4497

Prof. Satish S. Nair
University of Missouri
T: 573-882-2974 F: 573-884-5090
nair@ccsl.mae.missouri.edu

Prof. Richard Burton
University of Saskatchewan
T: 306-966-5427 F: 306-966-5473
burton@engr.usask.ca

Woong-chul Yang
Ford Motor Company
T: 313-323-0894 F: 313-845-4495
wyang@ford.com

Past Chair:
Ram S. Chandran
Kettering University
T: 810-762-7839 F: 810-762-7860
rchandra@kettering.edu

COMMITTEE CHAIRS:

Member Affairs:
Dr. Sanjay I. Mistry
John Deere Product Engineering Center
T: 319-292-8080 F: 319-287-1348
re39771@deere.com

Honors:
Prof. Richard Burton

Journal of Dynamic Systems, Measurement and Control, Associate Editor:
Noah D. Manring
Satish S. Nair

Publications Chair (Newsletter):
Noah D. Manring
University of Missouri-Columbia
T: 573-882-7539 F: 573-884-5090
manringn@missouri.edu

2001 Congress Program Representatives:
Dean H. Kim
Bradley University
T: 309-677-3142 F: (309) 677-3453
deankim@bradley.edu

Motion Control Contest Liaison
Donald Margolis
Univ of California
T: (530) 752-1446 F: (530) 752-4158
dlmargolis@ucdavis.edu

Advisor:
Arthur Akers
Iowa State University
Ames. IA 50011
T: 515-294-5782 F: 515-294-8584
aakers@iastate.edu