DEVELOPMENT OF FLUID POWER PROGRAM IN ENGINEERING & TECHNOLOGY

H. W. Shawn Kim
Department of Mechanical and Industrial Engineering
Youngstown State University

Abstract

This paper documents and presents successful efforts in developing a fluid power research and educational program in the College of Engineering and Technology at Youngstown State University. The main incentive of this documentation is to show the engineering community how a small to mid-size state assisted university that emphasizes undergraduate education has been developing a productive research and educational program through a strategic focus on technology development in areas that meets the need of local industries.

A series of initiatives and activities have been proposed and developed to accomplish short-term and long-term goals. Two main initiatives to facilitate the successful development, including the approval and funding of the strategic initiative proposing the Hydraulics Research and Education Center and the designation of the Center as one of the new PACER (Presidential Academic Centers of Excellence in Research) and subsequent funding for the next three years, have been taken and are well in progress. A number of collaborative research projects are being conducted, including a simulation project, a gear pump project, a fatigue testing project, and a virtual prototyping project with the above-mentioned industry. On the educational side, a new course in fluid-power and control has been proposed and will be offered in Spring 2004 to seniors and graduate students. Another course in advanced fluid power and control is to be developed and offered to graduate students next year.

It is expected that the fluid power program, by continuous development and successful operation in the coming years, can provide direct benefits to:

- Fluid-power industry by providing continuous technology support for new products and commercialization.
- Students by providing an exposure to the state-of-the art, real world engineering and technology, and the opportunity to co-op with fluid power industry and subsequent employment.
- The faculty by providing an opportunity to engage in cutting edge industrial research
- The programs by providing a strong foundation to develop a successful grant research program, and to participate in the cross-disciplinary research project.
- The College by contributing to the enrollment growth and enhancing the prestige.

I. Background information

A successful research program brings an educational organization not only prestige, but also a positive economic windfall to the institution and the community. Successful collaborative research between industry and academic institution may help in developing new technology for industry or creating new businesses. Throughout its existence of more than 100 years, personal care for excellent teaching and learning has been the trade mark of Youngstown State University. However, during the last several years, development of productive research programs, parallel with the outstanding teaching, has become an important educational goal [1] for the University. It is increasingly apparent that the College of Engineering and Technology is expected to lead the University, by both academics and the community, in achieving a high level of research, especially in the area of applied research in collaboration with industry. Establishment of such a research program became a high priority issue in the College. Unfortunately, there has been no sustaining infrastructure that motivates, promotes and assists the faculty to develop continuously successful research.

The need for the development of a successful partnership between YSU and industry is heightened by the past and current economic conditions of the metropolitan Youngstown-Warren area. Youngstown, Ohio, is located in the middle of the so-called rust belt of America, which bears a negative image of old smoke stack industries, closed businesses, and economic hardship. Youngstown was once a mighty steel town that produced a quarter of the national steel products. The economy fueled by steel industries started to decline in the late seventies and deteriorated further after several major steel mills, including the U.S. Steel and Youngstown Sheet and Tubes, closed their operation. The impact of the closing of mega steel mills and the subsequent massive layoffs was so great that, after more than twenty years, a full economic recovery has not been materialized and the unemployment rate of the Youngstown-Warren metro area has been among the highest in the nation.

In 2000, a new YSU administration put an emphasis on the University's role in the economic redevelopment for the area through collaborations between the University and the public and private sectors. Motivated and encouraged by the administration's new initiative, several faculty members from various programs and industrial counterparts have been working together to establish research centers that would facilitate such development. One of these efforts produced a successful launching of the Hydraulics Research and Education Center through the partnership between YSU and Parker Hannifin Corporation, a major fluid power industry with worldwide operation. Currently ten faculty members from six academic programs (Mechanical, Industrial, Electrical, and Chemical Engineering, Electrical and Mechanical Engineering Technology) are actively involved in research and administrative work to successfully establish the Center, including consultation with the engineers from the hydraulics industry to identify and develop possible research projects. Several industrial counterparts are participating in the research activities. All participants have expertise in the indicated research fields and have established good research records. However, due to lack of good supporting mechanism promoting grant research, they had limited success in bringing major external grants. It is expected that the Center will provide the faculty with opportunities in basic and applied research in fluid power, control, and other related areas and will play an important role in promoting a productive research environment in the College to the next higher level.

II. The Center for Fluid Power Research and Education

Since the successful establishment of the Center is a key to the success of the development of the fluid power program, major efforts have been focused on the development of the Center. The following are the documentation of major events during the past two years in the development and a brief introduction of the Center.

1. Major Events in the Development

Partnership with Parker Hannifin

In Fall 2001, the Dean and the faculty of the William Rayen College of Engineering & Technology began to explore the possibility of developing a partnership program with local industry. An initial contact with the Vice President, Operations, the Hydraulics Group of Parker Hannifin, met with an enthusiastic response from the industry and provided a promising possibility of a successful partnership. A draft of a proposal regarding the development of hydraulics research and education program was presented by the author at the subsequent meeting arranged for Parker engineers and the faculty of the College. A planning committee was formed to include multiple disciplines in the development. After some consultation with the industry, a plan to establish a hydraulics research and education center was developed to facilitate the participating academic programs fulfilling the missions of the University and the College [2]. In August 2002, The Committee submitted to Parker Hannifin a proposal [3] that requests financial support from Parker Hannifin for an establishment of a Hydraulics Research and Education Center in the College. This proposal brought a donation of two hydraulic and a pneumatic trainers and a subsequent research grant supporting a simulation project. More equipment donations from Parker Hannifin, including hydraulic test stands, are expected.

Strategic Initiative Grant

In an effort to secure a matching fund, the Department of Mechanical and Industrial Engineering submitted a strategic initiative plan [4] requesting a fund for a permanent full-time faculty position and hydraulics laboratory equipment. Despite an increasing financial hardship encountered by many of state-assisted universities in Ohio, the YSU Board of Trustees approved the plan as one of the two initiatives successfully submitted by academic units. A full-time faculty position in the Mechanical Engineering Program was authorized and a faculty was hired in Fall 2002.

PACER Grant

In September 2002, the University announced a solicitation of proposals for the third and last award of the PACER (Presidential Academic Centers of Excellence in Research) that started in 1996 to promote a high level of research and give a moderate financial support for the initial three years to the selected centers. A successful proposal for the development of Hydraulics Research and Education Center [5] was submitted and awarded as a new PACER and an internal grant for the next three years.

NFPA Collaboration

From the outset, the College decided to develop a close relationship with the National Fluid Power Association and joined the Association as an Institutional Member. This non profit organization is mainly supported by hydraulic and pneumatic industries for promoting fluid power industry, supporting educational institutions for technology development, and facilitating information exchanges and communication among members. The collaboration brought a total of four grants for research projects for the faculty and students this academic year. NFPA is endorsing a major grant application that will be submitted to NSF by five core Universities (Illinois at Urbana Champaign, Missouri at Columbia, Georgia Tech, Minnesota, and the Milwaukee School of Engineering) [6]. The Center is working closely with NFPA to participate in a variety of research and professional activities that may lead to grant research [7]. This collaboration also prompted to include pneumatic technology and change the name of the center to the Center for Fluid Power Research and Education from the Hydraulics Research and Education Center.

2. Mission of the Center

Advancement of technology through basic and applied research and partnership with the community is an integral part of the mission and goals of Youngstown State University. The effects of technology development on teaching, learning, and scholarship are of vital importance to the enrichment and professional development of the faculty and students and equally important to the area industries. The development of this interdisciplinary collaborative research and education center is the culmination of an effort to accomplish these missions and goals, supports academic and educational activities of the participating programs, and fosters industrial research and new technology development in fluid power area.

The mission of the Center is:

- to support the missions of the University and the College of serving its major constituents and striving to create a teaching and learning environment that promotes academic excellence and fosters intellectual growth and scholarship.
- to promote and develop fluid power technology.
- to develop a productive partnership between the University and the fluid power industry through cutting edge research and innovative educational programs

3. Structure of the Center

The Center consists of four functional units that include two laboratories and two programs. The laboratories are a hydraulics laboratory and a computational laboratory. The two programs are a technical assistance program and an educational assistance program. The laboratories provide the faculty and students with facilities and software, and allow them to generate actual research and educational projects in the Technical Assistance and Educational Assistance programs.

Hydraulics Laboratory

This laboratory will provide state-of-the-art educational experience to engineering and engineering technology students in the areas of hydraulics, pneumatics, controls, and instrumentation. The long-term goal is to expand the capability of the lab to provide applied research and testing resource to Parker Hannifin through active partnership between the company's engineers and the faculty of the University. The laboratory is equipped with hydraulic and pneumatic trainers, a liquid level system, a multi-purpose data acquisition system, and other instrumentation for measurement. A customized industrial-size fluid power hydraulic test stand will be installed soon to facilitate the investigation of capacity, power, and efficiency of a variety of hydraulic cylinders, pumps, motors, actuators, valves, and pneumatic systems. The lab will also have a variety of control devices to investigate manual, eletromechanical, and computer control techniques and ultimately develop cutting edge technology in control of hydraulic and pneumatic systems utilizing such modern control devices as micro/nano circuits and sensors.

Computational Laboratory

Computational analysis and simulation of hydraulic and pneumatic systems will be performed utilizing the College of Engineering and Technology's state-of-the-art computing facility. The College has maintained, since 1996, a centralized computer complex that includes the CADD (AutoCAD, SolidWorks, and SolidEdge), motion study software (Working Model), and finite element analysis software (Algor), and control-simulation software (MATLAB). New software was added to include FLUENT, MSC NASTRAN, ADAMS, and PRO E. This proposal calls for an expansion to the current computing capability by purchasing additional computers and related software to augment the modeling, analysis and simulation of complex fluid power systems. The fully functioning computational laboratory will include the additional software, Working Model 3-D, CFD-RC for interactive analysis, Easy Five for modeling and system simulation, and Coventor for simulating micro and nano systems.

Technical Assistance Program

This is a program to facilitate and coordinate special projects that are initiated between the YSU faculty and fluid power industry. This function of the Center is vitally important to fulfill the original objective of establishing the Center, which intends to develop sustained collaboration between Parker Hannifin and YSU. This will provide Parker Hannifin and other fluid power industries with prompt, efficient access to the expertise and knowledge offered by academic programs and faculty members. An example of this would be a special project arising from a need by the hydraulic industry to have assistance in analyzing a manufacturing process. Other examples are basic and applied research projects developed by the faculty and the Parker Hannifin technical staff, using the aforementioned laboratories.

Educational Assistance Program

The Center assists academic programs to offer students with additional courses related to fluid power and motion control and, ultimately, an option to add a fluid power specialization to the traditional degree in Mechanical Engineering, Electrical and Computer Engineering, Chemical

Engineering, Mechanical Engineering Technology, and Electrical Engineering Technology. In general, this would require a student to take two or three key existing courses and labs in the thermal fluid area, as well as additional fluid power and control-specific courses. The Educational Assistance Program helps the faculty develop these new courses in conjunction with the appropriate programs by providing needed resources. A faculty member was awarded a full-year sabbatical for development of the hydraulics laboratory and the author was awarded a University Research Professorship for the 2003-04 academic year for the development of a Senior/Graduate level course. The course, MECH 5836 Fluid Power and Control, will be offered in Spring 2004. A graduate course, MECH 6937 Advanced Fluid Power and Motion Control, will also be developed in the near future. Utilizing the Center in this manner would enhance the possibility of the successful development of such an option. The Center also assists the faculty and students to engage in student design projects, hands-on experience, field trips, and co-op/internship programs.

4. General Operation

The functions of the Center will be such that a single department or an individual will be unable to achieve these objectives and goals of the Center. The Department of Mechanical and Industrial Engineering provides the Center with the administrative and clerical support. The College of Engineering and Technology is asked to support the Center by providing three faculty members with 12 SH release time per year per each member during the initial three years. In addition, the participating members are encouraged to apply for Research Professorship and sabbatical leave, whenever possible. The Director of the Center has administrative authority and is responsible for the day-to-day operation. The Director should consult with the Dean of the College for pertinent decision-making, including administering and generating grant proposals.

III. Areas of Research Focus

The educational and research objectives of the Center are inherently interdisciplinary. A variety of traditional disciplines in engineering and engineering technology are needed to design and manufacture fluid power systems. The faculty participants have been working closely with the engineering staff of Parker Hannifin Corporation and were able to identify and develop the initial phase of industrial research projects. The Center is developing these projects in an appropriate sequence depending on the faculty resources and will seek external grants whenever possible. In addition, the Center will focus on the development of basic and applied research projects that will bring ongoing activities and sustain the operation of the Center beyond the initial phase of three years. Listed below are several research projects that are grouped together in the same general areas of mobile cylinders, gear pumps and valves, and hydraulic control systems for the next three years.

The participation of student assistants is considered essential in conducting technical research. The Center will heavily depend on the service of outstanding undergraduate students who are capable of helping the faculty in many areas of research. The students will also assist the faculty in developing experimental projects and work as laboratory technicians. Currently three graduate and six undergraduate students assist the faculty in making finite element modeling, computing and design analysis, coating technology, manufacturing processes, and control systems.

1. Mobile Cylinders Projects

Mobile cylinders are hydraulic devices that are mostly used for transportation and construction equipment. These devices deal with very high-pressure hydraulic fluids and often operate in harsh environmental conditions. A number of challenging problems associated with the performances of mobile cylinders provide engineers with abundant opportunity to improve the design, manufacturing, and operating performance of these cylinders. After consultation with engineers, several possible projects were identified. They are fatigue testing of cylinders for improvement of the design, computational and experimental analysis of buckling of telescoping cylinders, and corrosion and coating technology.

2. Gear Pump Projects

Gear pumps and hydraulic valves are utilized over a wide spectrum of applications such as excavators, skid loaders, shovels, dump trucks, braking systems in automobile engines, fork-lift trucks, and aircraft controls to name a few. Gear pumps develop extremely high pressures to overcome large forces while providing accurate motion in the pistons. The pump casing, valves, and other components must withstand very large forces and heat generated during operation as a result of high pressures (of the order of thousands of psi). The pumps must also endure long hours of operation experienced during a hostile environment such as soil and dirt. A number of engineering problems, including CFD, coating analysis, port analysis, sealing technology, filtering, environmentally friendly material, have been considered. However, only a limited number of research projects such as the test stand development, CFD analysis of Series 505 pumps and hydraulic valves are described here.

3. Hydraulic Control Systems

Many hydraulic and pneumatic systems are used to control the motion of other mechanical systems or devices. The required precision and quick response time in the control systems present another challenging problem. The limiting factor in most hydraulic control systems is the response time of the cylinder itself. The cylinder moves at a much slower rate than the electronics that control its motion. Thus, the biggest impediment to increasing the speed (and ultimately profitability) of a process is the cylinder response time. This is particularly true in metal processing where hydraulic screw-downs are used to reduce the metal to its final gage and hydraulic cylinders are used to control the shape of the metal. An improved cylinder response would translate into faster line speeds for all metals manufacturers. Metals producers would also see a quality improvement by a more consistent cylinder response. The standard deviation of the final gage is often what determines a company's market share and whether or not their product can be sold at premium rates. A critically damped cylinder response helps to minimize this gage deviation. The potential market for cylinder retrofits in the metals industry alone makes this a very quick payback project.

Linear encoders are frequently used to provide cylinder position feedback to the controller in a hydraulic system. These encoders must be rugged to withstand the dirt, heat, and vibration of industrial environments. They must also be carefully calibrated with the cylinder to provide

accurate position measurement. Typical current encoder technology can achieve resolutions of 0.000003" at stroke lengths of 4" to 48".

Lastly, as some engineering products continue to miniaturize, the control systems must also become smaller. However, the fluid power industry has not fully embraced the technology, although there should be definite demands on micro and nano sensors in fluid power control systems in the future. In order to meet the challenge, the Center plans to develop expertise on micro and nano technology, while seeking collaboration with individuals from other colleges and even from other institutions.

IV. Timeline for the Projects

Most of the faculty participants teach a full load every semester. Although some faculty will have release time for this research endeavor, it is neither possible nor prudent to initiate all projects at the same time. Thus, the Committee decided to prioritize the above mentioned research projects, although some adjustments could be made later depending on the faculty resource and other development. The tentative timeline are presented as follows:

Project Title	Research Period	Funding Source
Hydraulic valves	Fall 2003 – Spring 2004	NFPA
Fatigue testing	Fall 2003 – Spring 2004	PACER
Virtual modeling of pumps	Fall 2003 – Spring 2004	Parker Hannifin
Hydraulic test stand	Fall 2003 – Spring 2005	Parker Hannifin
FPP development	Fall 2003 – Spring 2005	NFPA
Data acquisition system	Spring 2004 – Summer 2004	NFPA
Pneumatic machine	Spring 2004 – Summer 2004	NFPA
Gear pump analysis	Fall 2004 –Spring 2005	PACER
Buckling of cylinders	Fall 2004 - Spring 2005	Parker Hannifin
Linear encoder	Fall 2004 – Spring 2005	PACER
Response time	Fall 2004 – Spring 2005	PACER
Corrosion and coating	Fall 2005 - Spring 2006	PACER
Micro-nano sensors	Fall 2005 - Spring 2006	PACER

V. Outcome

Several criteria have been selected to measure the outcome of the Center. The success of the Program and the Center will be judged by meeting the minimum requirement for the criteria that is tentatively set by the Committee as follows:

- Research productivity – one peer-reviewed journal article or conference presentation per year per participant in research project.
- External funding – one major grant per year during 2003-2006, self supporting after 3 years.
- Student research – one presentation at student or professional conference per project.
- Educational program – fluid power option in undergraduate engineering and technology by Fall 2007, fluid power certificate in graduate program by Fall 2006.

VI. Conclusion

The development of fluid power research and educational program at Youngstown State University is presented. The collaborative development through partnership with industry has been successful so far and its progress has generally been on time. Although the long-term success of the Program can neither be guaranteed nor predicted, the development of the Program has been very productive and made tangible impacts on the faculty and academic programs. The Program dramatically increased the amount of internal and external grants to the faculty for research and helped the Mechanical Engineering Program directly for enrollment growth. The most important contribution by the success of this Program, however, is positive changes of perception and attitudes of the faculty and students on grant research. Despite still heavy teaching loads, the faculty finds their research meritorious and are willing to participate in funded research and produce more, which means better scholarship and expert knowledge that will be passed on to students.

Creating an environment for sustained research at a teaching institution with limited resources and a predominantly undergraduate population is a difficult task. Maintaining and advancing the research program conducive to excellent teaching and learning is even more difficult. However, concentrating and developing niche area through a partnership with local industry makes a start-up development possible. The ultimate success of this development will depend on the commitment of the faculty to continue engagement in research and professional development, as well as the commitment of the University administration regarding the faculty resources.

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H. W. Shawn Kim

H. W. Shawn Kim is a Professor of Mechanical Engineering and Chair of the Department of Mechanical and Industrial Engineering at Youngstown State University. He has been developing the fluid power program for the past two years and currently serves as the Director of the Center for Excellence in Fluid Power Research and Education. He is currently developing a course in fluid power and motion control. He is a registered Professional Engineer in Ohio and is conducting applied research in fluid power and micro gas turbines. He helps the local industry with his expertise in heat transfer and thermal sciences. Dr. Kim received a B.S.E. degree from Seoul National University, a M.S.E. from the University of Michigan, and a Ph.D. from the University of Toledo.