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Planning of Curriculum Modules for Teaching of Fluid Power Concepts

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Abstract

Hydraulic fluid power is a technical field that has gone through the cycle of being a primary option for power transmission, to having a substantial drop in its use, and now in becoming once again a preferred technology. There is no doubt that hydraulic fluid power is a mature technology, and the new applications present numerous challenges, but it is evident that there are significant benefits. Therefore, there is a growing need to have fluid power education in many engineering and engineering technology curricula.

Towards this end, curricular development is being planned in order to offer fluid power technology education in existing programs. This development has the main characteristic that is modularized, thus presenting the opportunity to be included in existing programs without the need for new courses. The modules are not introductory level material, and the development will have the overall context of systems integration, with topics on controls, mobile, and energy efficiency. Learning outcomes have been established, and at this point the input from industrial constituents is being requested in order to define specific content, and how the modules should be developed and integrated. This report will include all the information used to define the topics, and the actual content in the proposed modules. It is expected that such development will address the limited exposure to fluid power subject that current students of engineering and engineering technology programs have, thus allowing them to consider careers in the hydraulic fluid power industry.

Introduction

Fluid power, hydraulic and pneumatic, is an industry that has had multiple applications in the manufacturing segment all across the globe, being close to $20 billion industry. This industry is particularly an important component for the U.S. economy (i.e., basically 25% of market share), with a ten-fold downstream economic impact for the top ten industries utilizing fluid power [1]. There might be some specific industrial segments where fluid power is a predominant technology, but its range of applicability is something that has spanned many industrial segments for decades, and it is something that has a bright future because of the role it will play in current initiatives, such as IoT, Industry 4.0 and others [2].

For U.S. economy, and particularly for the state of Michigan, manufacturing is a critical component that has declined due to globalization and competition. Innovation in order to have more efficient and higher productivity components and services is required [3, 4]. The workplace of engineering and engineering technology program graduates is changing due to increasing global competition, changing demographics and technology, integration of engineering and business function, shrinking product life cycle and environmental awareness. To regain their predominance in the field, the manufacturing sector needs better educated technical graduates trained in current technology. These graduates are also expected to be equipped with generic engineering skills beyond their area of expertise [5].

Another aspects that needs to be considered when dealing with curriculum development is the constantly changing classroom environment. Students in the classroom nowadays have different expectations and faculty needs to be prepared for technology savvy, multitasking, and socially connected student body [6]. These students are different from the traditional ones (i.e., more passive), and the pedagogical approach should emphasize hands-on activities. Therefore, any curricular development, particularly in engineering technology programs, needs to include a good balance of theoretical and practical approaches.

Furthermore, for the target audience of the proposed work, an inductive learning methodology will be considered, so that students learn in a more natural fashion [7]. Inductive learning emphasizes hands on activities and experiencing with the concepts and components.

Most engineering and technology classes are taught by using a combination of inductive and deductive learning, with emphasis based on student's background and learning objectives. For advanced courses, where the learning objectives are not easily realized, Kolb's experiential learning cycle [8] is one of the most widely utilized. This methodology has four steps: abstract conceptualization, active experimentation, concrete experience and reflective observation. A key aspect is to define the activities that complete the learning cycle without burdening the students in the process. The inductive learning process has been previously applied to fluid mechanics and heat transfer [9, 10] with positive results, and it is the approach to be followed in the proposed work.

Background

The proposed work focuses on solving the current situation where most of the students in engineering or technology programs have limited exposure to the subject of fluid power. As a result, graduating students are not well prepared to pursue a professional career in the fluid power industry. The Department of Engineering Design, Manufacturing, and Engineering Systems (EDMMS) in the College of Engineering and Applied Sciences (CEAS) at Western Michigan University (WMU) offers BS programs in Engineering Design Technology (EDT), Manufacturing Engineering Technology (MFT) and Engineering Management Technology (EMT). There are over 250 undergraduate students in these programs. The programs are designed to provide students a strong theoretical and practical foundation in their respective subject areas. Currently, student exposure to fluid power is limited to a single junior level course. Due to the lack of any follow up course, student are not able to solidify this knowledge any further at the senior level. As a result, very few of these students are able to pursue successful careers in the fluid power industry. Over the last ten years, the students have been participating in the Fluid Power Vehicle Design competition, currently sponsored by the National Fluid Power Association (NFPA) Foundation, and previously by Parker Hannifin. This is a good example of the challenges that participating students face due to their limited exposure to fluid power. The existing course was revamped in 2012, with the inclusion of lab experiments, and being transformed from a sophomore level course to a junior level. The course was converted from a two credit hour class with a 2 hour lecture component per week to a three credit hour course with a 2 hour lecture component and 3 hour labs per week. It resulted in a distinct and positive impact in the students' learning. The lab is also used at the graduate level to study the energy efficiency of industrial fluid power systems. The developed laboratory will also be used to support the proposed senior level fluid power system design course.

Proposed Plan

The proposed plan is to develop an upper level modularized fluid power system design course. The goal is to ensure student learning outcomes consistent with ABET (previously known as Accreditation Board of Engineering Technology) criteria involving knowledge, skill, tools and techniques practices in the subject area. Specific learning outcomes are:

- Understanding of fluid power theory, application, circuit, and function
- Ability to analyze behavior, simulate function of a fluid power system
- Understanding of engineering design process with system approach
- Ability to implement and test a laboratory prototype of a designed fluid power system
- Understanding of process sensor and data acquisition method in performance testing

The proposed course will be developed in modules, each running for a period of two weeks. Specific topics to be covered in each module, after consultation with regional industry, are:

- Module 1 (Fluid power system): Application, components and circuit.
- Module 2 (System design): Modeling (Creo or SolidWorks) and measurement of performance analysis of components.
- Module 3 (Analysis): Theory and problem solving on component and system performance. Comparison numerical and experimental results.
- Module 4 (Simulation): System modeling and performance measurement (lab setting) and simulation (Matlab or Automation Studio)
- Module 5 (Control system): Control methodology, PLC (Programmable Logic Controller), servo valve and component selection.
- Module 6 (Prototyping): System development in the lab and performance testing.

The proposed modules will be developed as independent, self-contained modules, so that transportability is possible whenever one of them needs to be offered as a complement in an existing related course. For the proposed plan all six modules will be offered as a three credit hour senior level class (Fluid Power System Design) that will end with the completion of a semester project. In this project, students will develop and test their own prototype system e.g., emulation of a backhoe or a stamping device duty cycle.

The reason for the modularization is to offer the option that each module can be offered as a topic in any existing application-based course. Courses with, for example, design, energy, sustainability content can benefit from the use of any of the proposed modules. Under this development plan all modules are offered in a single course in order to test and refine them, but it is well known that the trend nowadays is to reduce the number of total credits in existing BS programs. Therefore, individual modules can be offered as complementary modules, either at existing related courses or at for-credit independent study course. Students will be able take individual modules in a sequence for one to three credit hours at their own convenience. Completion of module 5 and 6 will require finishing a final project.

The development plan considers the following deliverables, again, thinking about mobility of the modules:

- Course syllabus, including details of subject by topics of the modules
- Documented lecture materials, including theoretical basis, presentations and exercises
- Manual for hands on labs for each module, including the final project
- Evaluation and assessment materials applicable to student learning

Detailed lecture materials of the course will be selected from standard fluid power topics (component and systems) together with topics related to control logic, simulation, integration and documentation. For experimental learning, the lab exercises will be developed for the corresponding topics in each module.

The pre-requisites for the proposed modules are fluid mechanics/power and electrical/electronic concepts, which will ensure students are familiar with the use of sensors, data acquisition tools, and basic control components (PLCs). An important aspect in the proposed development of this course is the use of computer-based tools given their greater acceptance nowadays within virtual engineering. Thus, the use of software tools will be implemented for component selection (PARTsolutions), control logic (Rockwell Automation), circuit simulation (Automation Studio), and documentation and integration (CAD package – Creo or SolidWorks).

Going beyond the typical design of a mechanical system (i.e., solid mechanics concepts), this proposed course will allow students to benefit from learning specific methods and tools used in the design of fluid power systems. This will enhance the overall quality of the undergraduate programs available at adopting institutions and will prepare students to pursue future careers within the fluid power field. The impact of the course will be at both the university level and regional level by graduating qualified students ready for entry-level positions in this field. Additionally, dissemination and replication of the model at other universities will have a discernably positive effect at the national level.

The proposed modularized form of course is based on the objectives and goals of NFPA curriculum developments. The work will benefit students, has direct involvement of faculty and industry, and will be disseminated with potential for replication. The most important features of the course are integration of previous materials from existing courses and incorporation of new knowledge regarding the system approach to design. It will also prepare students for a final capstone project in the fluid power arena.

Project Timeline

The proposed work will be performed during the 2018-19 academic cycle, with some planning activities during the 2018 summer months. Actual development of course materials (lecture and lab) will take place during Fall 2018, with further development and pilot offering/assessment of specific topics (module 1 and 2) during Spring 2019, followed by complete development over Summer 2019. The proposed course will be offered in the Fall 2019, and student outcomes assessment data will be acquired at the end of the semester. The curriculum will be ready for dissemination once the course is taught and curriculum improvement measures are implemented.

Assessment and Impact

Two assessment activities will be performed, one for the initial offering of the first two modules (1 and 2), and one for the offering of the full course. In both cases, there will be an assessment of the curriculum content and learning/engagement by students. Each module will have specific learning objectives and assessment tools will be developed accordingly. These assessments are a single survey at the end of the corresponding offerings (i.e. modules and full course).

The assessment of the curriculum will focus on quality of the course materials for lecture and lab practices. The assessment of the learning and engagement of the students will be done with the use of a comparative instrument. Learning assessments before and after the will be conducted with quizzes and an adapted (i.e., shorter) motivation survey (i.e., IMI – Intrinsic Motivation Inventory). These assessments will be used mainly for improvement of the pedagogical and learning aspects of the subject.

Students and faculty are an integral part of the project and are directly involved in all aspects. Analysis of the data collected in the learning and engagement surveys will serve as the main indicators of the impact of the proposed materials. An additional indicator will be the transfer of know-how through the course's implementation at other institutions. Materials developed in the process, such as lecture notes, presentations, exercises, lab experiments and corresponding lab booklets can be used to replicate the course at other institutions as a turn-key task; therefore promoting fluid power education beyond the scope of any academic institution. Additionally, showcasing student work (namely their semester projects) during open houses and poster fairs will generate awareness of fluid power among middle and high school students and parents. In the past, our "Hydraulic Bike" has always drawn attention of young people in the area and has served as a successful promotional tool for the use of fluid power.

Sustainability and Dissemination

The proposed modularized course on Design of Fluid Power Systems is an elective course that will be initially offered as Special Topics course. Students have four spots for elective courses in their study programs, so that they are able to select courses that interest them. In recent years, fluid mechanics and hydraulics course have been improved by incorporating fluid power in the curriculum. The proposed new course is a natural continuation of this improvement effort, and it is expected that there will be an enrollment of about 8 to 10 students in that first offering of the proposed course. This number is expected to increase to 12-15 students in subsequent offerings. Development and implementation will be through this grant and matching departmental contribution. There are no major requirements of resources once the project is implemented and the course is approved for offering. All software, including Matlab, Automation Studio, Creo, SolidWorks and others are already available though some may require an annual renewal cost. Maintenance and improvement of experimental equipment are expected to be covered by college funds.

Outcomes of this project will be disseminated through both external and internal venues. For external dissemination, there will be a conference presentation and journal publications of the work and its impact. These are similar to efforts in the past for other curriculum developments by the faculty involved in this proposed work. Internal dissemination will be done through NFPA by publicizing accomplishments in their website and newsletters, as well as allowing marketing with its academic programs.

Summary

This paper presents a plan to develop an upper-level undergraduate course titled "Design of Fluid Power Systems", and it will offer students the opportunity to expand their knowledge and skills in the fluid power field. The proposed course will be a continuation of a previously revamped fluid mechanics and hydraulics course, and it will be a complement to the typical mechanical design aspects currently offered to students. The course will be developed in six modules in which students can take either two modules at a time or the entire class as it suits their individual needs. The course will have a mix of theory and hands-on materials, and its content is standard fluid power topics based on input from regional industry and advisory board members. It will have a set of linked modules that will follow a system approach with fluid power components, control logic, and functional integration, with the requirement of a final comprehensive project. Starting with the initial modules, student learning and the overall impact of the course will be assessed according to the current assessment cycle for courses. Dissemination of the course will be through national educational forums and the departmental website. The modularized nature of the course will help in the transfer and implementation of the modules/course at other institutions.

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