Development of Modules for Teaching Fluid Power Concepts

Dr. Jorge Rodriguez P.E., Western Michigan University

Professor in the Department of Engineering Design, Manufacturing, and Management Systems (EDMMS) at Western Michigan University's (WMU). Co-Director of the Center for Integrated Design (CID), and currently the college representative to the President's University-wide Sustainability Committee at WMU. Received his Ph.D. in Mechanical Engineering-Design from University of Wisconsin-Madison and received an MBA from Rutgers University. His B.S. degree was in Mechanical and Electrical Engineering at Monterrey Tech (ITESM-Monterrey Campus). Teaches courses in CAD/CAE, Mechanical Design, Finite Element Method and Optimization. His interest are in the area of product development, topology optimization, additive manufacturing, sustainable design, and biomechanics.

Dr. Alamgir A. Choudhury P.E., Western Michigan University

Alamgir A. Choudhury is an Associate Professor of Engineering Design, Manufacturing and Management Systems at Western Michigan University, Kalamazoo, Michigan. His MS and PhD are in mechanical engineering from NMSU (Las Cruces) and BS in mechanical engineering from BUET (Dhaka). His interest includes computer applications in curriculum, MCAE, mechanics, fluid power, and instrumentation & control. He is a Registered Professional Engineer in the State of Ohio and affiliated with ASME, ASEE, SME and TAP.

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Abstract

The subject of fluid power has gone through changes as modes of power transmission in transportation, industrial and aerospace application have evolved. Though this technology has matured over many decades, there is a growing demand for more compact and efficient systems in products. This requires integration of fluid power in traditional engineering and technology curricula. Considering the demand of knowledge and skill in program graduates, introduction of additional new subject in an existing program is a challenge. At the same time, a growing body of non-traditional and working students in undergraduate institutions demand flexibility in curriculum offering.

To incorporate fluid power in existing curriculum a flexible approach is utilized. In this paper, a modular form of an upper level fluid power curriculum is presented. The development consists of lecture and lab materials, with proper linking and integration. Technical topics are presented under the scope of energy efficiency, systems integration, and hybrid engineering, which will allow integration into existing curriculum in current programs without the need for additional new courses. Learning outcomes of the curriculum were established, and assessment of student learning based on input from industrial constituents will be conducted.

It is expected that the development of these six modules will address the limited exposure to fluid power that current students of engineering and engineering technology programs have, thus allowing them to consider careers in the hydraulic fluid power industry. The initial implementation of the proposed development will take place in the Fall semester of 2019.

Introduction

Fluid power industry has wide applications in the manufacturing segment across the globe, it is a $100 billion industry. This is an important component for the U.S. economy (i.e., roughly 25% of market share), with a ten-fold downstream economic impact for the top ten industries utilizing fluid power [1]. Its range of applicability has spanned many industrial segments for decades, and plays large roles 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 is required in order to have more efficient and higher productivity components and services [3, 4]. To regain their predominance in the field, the manufacturing sector needs better educated technical graduates trained in current technologies. These graduates are also expected to be equipped with generic engineering skills beyond their area of expertise [5]. Another aspect 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]. Current pedagogical approaches should thus emphasize hands-on activities, particularly in engineering technology programs, while maintaining a proper balance of theoretical and practical approaches.

Furthermore, for the target audience of the proposed work, an inductive learning methodology is considered, so that students can learn in a more organic environment [7]. Inductive learning emphasizes applied activities and experimenting with the concepts and components. Conventionally, engineering and technology classes are taught by using a combination of inductive and deductive learning, with emphasis based on student's content background and learning objectives. However 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 of this learning cycle 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, thus is the approach applied in this work.

Current Offering

The Department of Engineering Design, Manufacturing, and Management Systems (EDMMS) at Western Michigan University's College of Engineering and Applied Sciences 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 some topics in an introductory 'fluid mechanics' course, and student are not able to solidify this knowledge any further before graduation. 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 participated in the Parker Hannifin/NFPA-sponsored Fluid Power Vehicle Design competition. This is a great example of the challenges that participating students face due to their limited exposure to fluid power – need to learn as you go. The current 'fluid mechanics' offering is a 3-credit course with a lab component, feature that has had a positive impact in the students' learning based on their feedback. The lab facility is also used in other courses and projects to study the energy efficiency of industrial fluid power components and is where the experimental aspect of the developed modules will take place.

Curriculum Modules

The objective is to develop an upper-level modularized *fluid power system design* course. The goal is to ensure student learning outcomes consistent with the Accreditation Board of Engineering Technology (ABET) 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 topics were divided into six modules, each running for a period of two weeks. Specific topics to be covered in each module, after consultation with regional industry, are as follows:

- Module 1: Fluid Power System
  - Review of basic theory, Application
  - Components and General circuitry
- Module 2: System Design - Components
  - Energy equation applied to individual components
  - Performance data for individual components
  - Solid modeling (Creo and/or SolidWorks)
- Module 3: System Design - Analysis
  - CFD for individual components
  - Small systems (2-3 components) – definition and performance
- Module 4: System Design – Simulation
  - System modeling (Matlab and/or Automation Studio)
  - Performance simulation – complete systems
- Module 5: Control System (Final Project I)
  - Control methodologies
  - Valves/Sensor - component selection
  - PLC
- Module 6: Prototyping and Comparison (Final Project II)
  - System development in the lab
  - Performance testing and comparison
  - Improvement and/or change system design

The modules have been developed as independent and self-contained as possible in order to make them transportable so that other institutions or individuals will be able to adapt them for existing courses. The initial plan is to offer this course as a 3-credit technical elective course during the Fall 2019 semester (not during Spring'19 as originally planned, due to scheduling conflict). The first offering of the course will allow for gathering of feedback from students and instructors on the materials offered and the sequencing. The development implied the following deliverables:

- Course syllabus, including topics in each module
- Lecture materials, including theoretical basis, presentations and exercises
- Manual for hands-on labs for each module
- Evaluation and assessment materials applicable to student learning

Development of Modules

The goal was to develop materials that will serve as well as adequate self-study materials, which implies that some background is provided for all new topics are covered. The materials were also created in the context of specific examples of real-world system that will also conjure analogies to other situations. The two systems selected are (Figure 1): garbage compactor [11], and b) punching press. These are relatively commonplace and simple systems that students will be able to relate to their operation, and more important to be able to have good discussion about capabilities, specifications, options, and provides opportunity for potential improvements of the systems.

(a) garbage compactor (b) punching press

Figure 1. Systems used for development of materials on fluid power.

The corresponding hydraulic systems to be used as the base for the materials and further development are the ones shown below in Figure 2. In these systems, the important takeaway is that they have the basic components and there is some type of control that is used [12]. The systems are simple enough that only one control valve is needed, even when there might be other typical components that are utilized (e.g., accumulators).

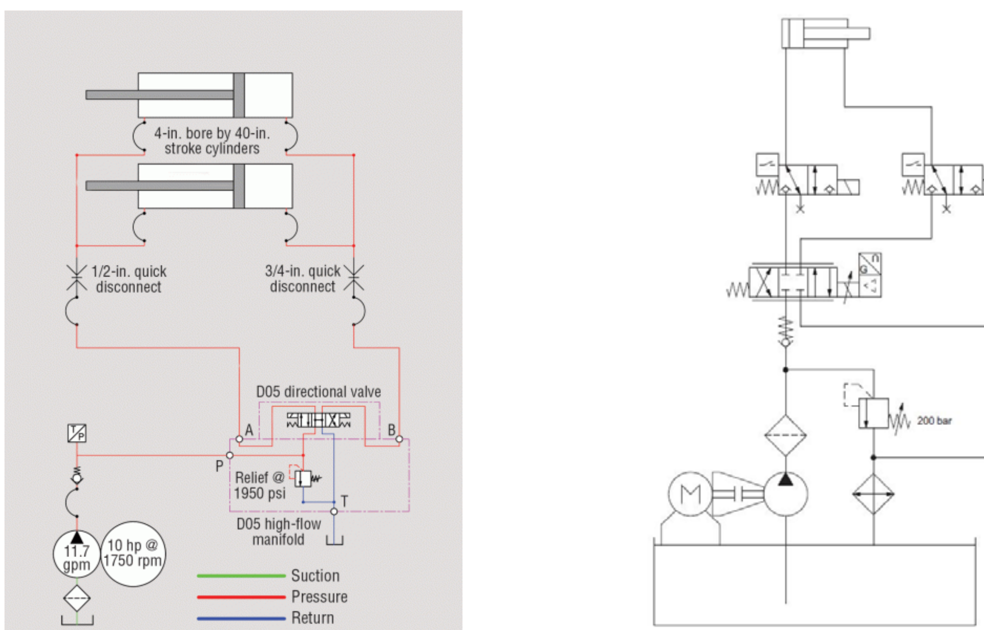


Figure 2. Fluid power diagrams for systems used to develop materials.

Most module material will be provided in MSWord and PowerPoints format, depending on the content, with the availability of additional reference materials (e.g., videoclips and websites) where the student can look for more information and additional coverage of the topic. Selected items from the reference list are assigned as required viewing. Whenever there is an exercise, it is presented, to the instructor, with the possible variations that can be used when being assigned to the students. In the case of materials for exercises, it is usually presented in MS files (Word - text file, and Excel – tabulations), with some materials (e.g. solutions) presented in PDF format. Regarding commercial software, the use of two software packages in Module 3 and 4 is presented. The development has been completed for the use of one set of commercial software packages (Solidworks and Matlab), with plans to develop for Creo and Automation Studio.

Specifically, for Module 1 (Fluid Power System), most of the material is in PowerPoint (Figure 3), and there is no actual numerical or experimental work to be done. For Module 2 (System Design – Components), there are several items that are provided as PDF files since it implies equations and several industry-supplied materials. Modeling software is used, with the actual CAD model being provided to the students (Figure 4), with enough information for modification(s) to be done by students.

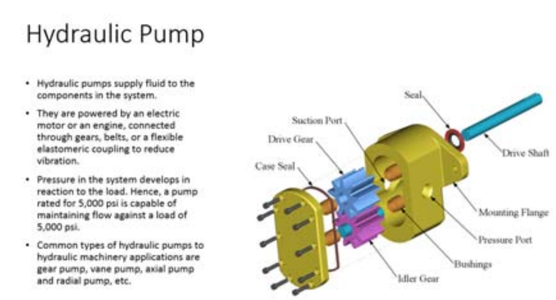
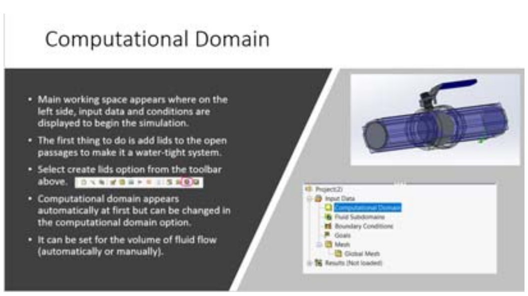


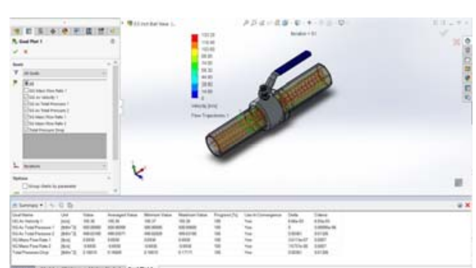
Figure 3. Powerpoint shot for Module 1.

Figure 4. Solid model for relief valve (M2).

The analysis material is based on SolidWorks Simulation; at the component level, the objective is to get students exposed to numerical analysis techniques to obtain performance information (Figure 5). Most of the calculations are CFD simulation for pressure drops (e.g., efficiency) as a function of operational conditions. Tutorial on software use have been developed, and basic components like valves, pipes, and gear pumps are used in this module. Students work on connecting the needed components to implement a complete circuit for the system, which is then analyzed and evaluated.



(a) Tutorial on CFD



(b) Pressure drop calculation

Figure 5. Performance of CFD analysis on a valve (M3).

For the Control System (Module 5), the lab setup has been implemented with the use of LabView, which basically communicates with the PLC (Figure 6), and in Module 6 students perform testing of the complete the fluid power system in the lab, either on one of the trainer benches (Figure 7) available, or in the testbench in the fluids lab. The lab already has the proper LabView (Figure 8) interfaces for instrumentation, and most students have been exposed to these test benches in the fluid mechanics course.

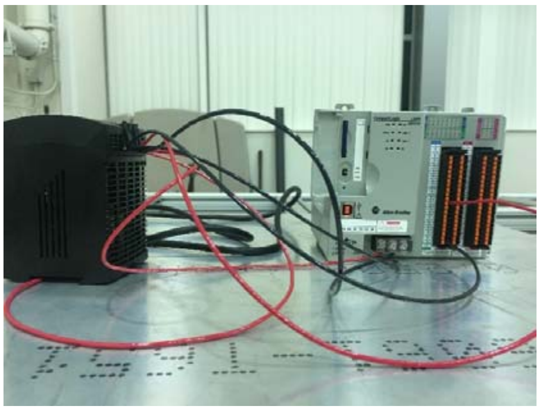


Figure 6. PLC in the system.

Figure 7. Trainer bench in the lab.

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 this development is the use of computer-based tools given their greater prevalence within virtual engineering.

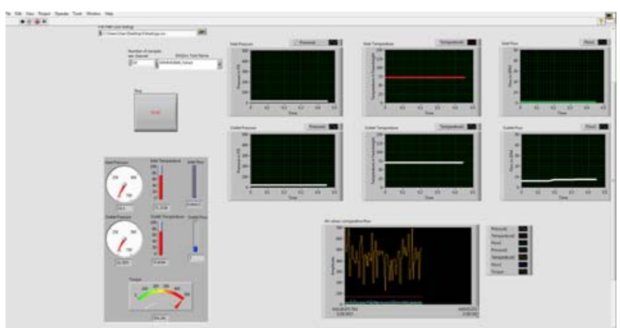


Figure 8. LabView interface for test bench.

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 format of the 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 senior capstone project in the fluid power field.

Conclusions

This paper presents the definition of technical topics, and development of lecture/lab materials that are needed for a modularized upper-level undergraduate course potentially titled "Design of Fluid Power Systems", which offers to students the opportunity to expand their knowledge and skills of the fluid power field in a practical and hands-on setting. The proposed course requires basic knowledge of fluid mechanics and instrumentation, therefore, it can be considered as a second course in the field.

The course is for a total of 3-credit, and due to its modular format can be offered/taken as three one-credit courses, meaning two modules at the time. Alternatively, based on resources it can be taken as an ongoing independent study, suiting individual students' needs. This course will be offered as a 3-credit course in the Fall'19 session, and 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 professional societies and departmental website. It is expected that the modularized nature of the developed course will help in the transfer and implementation of the modules/course at other institutions.

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