MODULARIZED CURRICULUM FOR AN UPPER LEVEL FLUID POWER COURSE

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***Abstract* – Nowadays it is difficult to add new materials in an existing curriculum or program due to the fact that, on one hand most programs are at the limit in terms of required credits, and on the other hand, the current tendency is to reduce the number of credits in a program. Therefore, there are very few options to insert the new material as anew full course, with the most usual approach - short of removing an existing course from the curriculum – is to somehow provide an overview of the material in an existing course already in the curriculum. Fluid power is a field that has gone through a cycle of being a staple in many technical programs primarily because of its wide use in industry as main option for power transmission, then having a substantial drop in its study and applicability, and lately becoming once again a preferred power transmission alternative. Hydraulic fluid power is a mature technology, and new applications present several new challenges, with significant benefits. Therefore, there is a growing need to have fluid power education in many engineering and engineering technology curricula.**

Curricular materials have been developed in order to offer advanced 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 a complete new course. The modules are at the application level, assuming that basic fluid concepts have been covered, and the development has the overall context of systems integration, with topics on controls, systems application, and energy efficiency. For this curricular development the learning outcomes were established with input from industrial constituents, with specific content, format of the modules, and integration topics being emphasized. This report includes the information used to define the actual content in the proposed modules. It is expected that this curricular 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.

Keywords: modularized curriculum, hydraulic fluid power, upper level course

I. INTRODUCTION

Hydraulic fluid power is a very alternative for power transmission systems due to the very high power density for most of its components and systems. However, hydraulic fluid power is a field that has gone through the cycle of being a primary option for power transmission, to having a substantial decline in its use, and now in becoming once again a primary technology. It is, without a doubt, that hydraulic fluid power is a mature technology, and the new applications present numerous challenges (e.g., compactness), at the same time that clearly offers substantial benefits. Therefore, there is a growing need to have fluid power education in existing engineering and engineering technology curricula.

Unfortunately, there is the challenge that most curricula are at capacity, which becomes even a bigger issue when the trend of reducing number of credits in a bachelor's degree is considered. Similarly, even when the basic concepts for fluid power technology are the same ones that were considered couple of decades ago, there are new approaches and factors that are utilized nowadays when using this technology. Topics such as energy efficiency, systems integration, and hybrid engineering need to be considered when fluid power technology is taught.

Towards this end, curricular development has taken place 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 complete new course(s). The modules are not introductory level material, and the development has the overall context of systems integration, with materials on controls, mobile, and energy efficiency. Learning outcomes were established, input from industrial constituents was requested to define specific topics, and the way the modules were defined and integrated.

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 development consists of lecture and lab materials, with proper linking and integration.

II. BACKGROUND

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]. 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]. 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]. Other 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]. Current pedagogical approaches should emphasize hands-on activities, particularly in engineering technology programs, there needs to be 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 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.

III. CURRENT OFFERING

The work focuses on solving the existing situation where most of current students in engineering or technology programs have limited exposure to the subject of fluid power. The Department of Engineering Design, Manufacturing, and Engineering Management (EDMMS) at Western Michigan University 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 'fluids' course, and 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 Parker Hannifin/NFPA sponsored Fluid Power Vehicle Design competition. This is a good example of the challenges that participating students face due to their limited exposure to fluid power. The existing course is a 3-credit one with a lab component, which has had a positive impact in the students' learning. This lab facility is also used at the graduate level to study the energy efficiency of industrial fluid power components, and is where the experimental aspect of the developed modules will take place.

IV. DEFINITION OF MODULES

The plan 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 performance, 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:

- 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 (Solidworks and/or Creo)
- 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, self-contained modules as possible. The goal is to make them transportable so that other people/institutions will be able to use/adapt them for existing courses. The initial plan is to offer this 3-credit course as an elective course during the Spring'19 session, which will allow for gathering of feedback from students and instructors on the materials. However, due to scheduling conflicts, it is only being done as dry-run this Spring semester. The plan now is to offer the course in the Fall 2019.

The development implied the following deliverables:

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

V. Development of Modules

The approach that was taken is to develop materials that will serve as self-study materials as well, which implies that background and new topics are covered. These materials are in PowerPoint files. It was decided as well to develop the materials in the context of specific systems out there, that students will relate to, and will be able to draw analogies to other situations. The two systems that were selected are (Figure 1):

a) garbage compactor
b) punching press

these are small and common enough 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, etc. so that at the end of the course the students can work on improvement of the given system.

Hydraulic systems diagrams are developed for the selected system. In these initial systems the important aspect is that they have the basic components and there is some type of control that is used. The systems are simple enough that only one control valve is needed, even when there might be other typical components that are missing (e.g., accumulators).

(a) garbage compactor

(b) punching press

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

In most of the modules the information was developed in MS PowerPoint files, with the use of some additional reference materials (e.g., video clips 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 variation that can be used when being assigned to the students. In the case of materials for exercises, it is usually presented in a Microsoft document (Word - text file, and Excel – tabulations), with some solution presented in pdf format. Regarding commercial software, the use of two possible ones is presented, even when development has been done for the use on only one of them (SolidWorks and Automation Studio).

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 is the use of computer-based tools given their greater acceptance nowadays within virtual engineering.

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 the National Fluid Power Association (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.

VI. Summary

This report presents the planning of the materials that are being developed for a modularized upper-level undergraduate course potentially titled "Design of Fluid Power Systems." This course will offer students the opportunity to expand their knowledge and skills in the field of hydraulic fluid power. The proposed modularized course can be considered an elective course that follows after introductory fluid mechanics course. The course is a 3-credit one, in six modules so that students can take either two modules at a time or the entire class as it suits their individual needs. The modules have a combination of theory and hands-on materials, and its content is standard fluid power topics.

Student learning and the overall impact of the modules/course will be assessed according to the current assessment cycle for regular courses. Dissemination of the course is planned through national educational associations (NFPA) and forums, and the university's e-learning system. It is expected that the modularized nature of the course will help in the transfer and implementation of the modules/course at other institutions.

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