A Biomechanics Module Development in the Mechanical Engineering Curriculum

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Abstract - **Biomedical engineering has emerged as a discipline in universities with engineering programs due to the need to apply engineering theories and techniques to the medical field. Most universities having a separate biomedical engineering major are large scale research institutions. Primarily undergraduate institutions like Ohio Northern University (ONU) face a number of challenges when it comes to developing a vibrant biomedical engineering program, especially when the institution is not affiliated with a large research hospital. In this paper, a biomechanics module will be developed and incorporated in a mechanical engineering technical elective course to expose mechanical engineering students at ONU to the biomedical engineering topics. In this module, lectures will be offered focusing on the introduction of biomechanics concepts and the correlation between the human body and engineering systems. Application of engineering theories in the biomechanics field will be discussed through a review of research papers and a hands-on project, which requires the design of different structures simulating the human body using an Advanced Structures Set. The project will allow students to discover similarities between the human body and other constructions. This module will give engineering students an introduction to biomechanics principles. They will discover that similar principles of mechanics apply to different structures, including the human body; biomechanics can be part of mechanical engineering.**

Index Terms – Biomechanics module, mechanical engineering curriculum, Advanced Structures Set.

INTRODUCTION

Biomedical engineering has emerged as a discipline in universities with engineering programs due to the need to apply engineering theories and techniques to the medical field. Biomedical engineering is a wide field, including a variety of subdisciplines such as tissue engineering, genetic engineering and medical implants. Most universities having a separate biomedical engineering major are large scale research institutions. Primarily undergraduate institutions like Ohio Northern University (ONU) face a number of challenges when it comes to developing a vibrant biomedical engineering program, especially when the institution is not affiliated with a large research hospital. Ohio Northern University, established in 1871, has five colleges including Arts and Sciences, Law, Pharmacy, Engineering and Business Administration and an annual student population of approximately 3,600. The T. J. Smull College of Engineering at ONU, formally established in 1903, has five departments: civil, mechanical, electrical and computer engineering as well as computer science. There is no graduate program in the college. Given the small class sizes (~30 students) and the faculty focus on teaching responsibilities, it is impractical to create an entire track of courses for a specialized concentration in biomedical engineering. Hiring a faculty member with biomedical background to primarily teach biomedical courses is also unlikely. This fact, however, does not diminish the need for undergraduate engineering students at ONU to be exposed to biomedical engineering topics and concepts as part of an undergraduate mechanical engineering curriculum.

Due to the highly interdisciplinary characteristics of the biomedical engineering field, mechanical engineers are needed in many aspects such as medical implant and device design, material testing, and simulation for clinical applications. The mechanical engineering curriculum at ONU is strong in mechanics analysis, fluid mechanics, finite element analysis, and material testing. However, the traditional courses focus the application of the engineering principles on traditional industries such as automotive and aircraft industries. The human body, as a complicated living system, still seems esoteric to mechanical engineering students at ONU. In this paper, a biomechanics module will be proposed and incorporated in a senior technical elective course on biomechanics, biomaterial and medical devices. The course will be taught for students in the College of Engineering at ONU in the 2010 spring quarter.

The time duration for the biomechanics module will be three weeks. The objective of this module is to introduce the biomechanics topics to upper level mechanical engineering students. The module will focus on applying the engineering theories to the human body, such as the circulatory system. In this module, six lectures will be given on the basic concepts of biomechanics. Two lectures will be discussion and review of relevant research papers. Students will also finish a hands-on biomechanics project. In this project, models of the human arm, leg and back will be built and the forces exerted by muscles will be measured for different configurations. The project will allow students to discover similarities between the human body and other engineering structures. This module would bridge students' engineering

knowledge and problem solving skills using mechanics analysis on the human body.

DETAILED PLAN FOR THE PROPOSED MODULE

The biomechanics module will last three weeks including six lectures, two paper review sessions and one week of class time for a project. Details of this module will be described in the following sections.

Lectures

While the objective of this module is to get mechanical engineering students exposed to the application of engineering knowledge in the biomedical field, instead of teaching biomechanics theory systematically, only six lectures will be offered to introduce some basic concepts and topics in biomechanics. The major purpose is to let engineering students discover the similarities and correlations between human body (living) systems and engineering structures.

- Lecture 1: Overview of biomechanics, biomaterials, and biomedical devices.
- Lecture 2: Hemodynamics and the circulatory system
- Lecture 3: The respiratory system
- Lecture 4: Muscle and movement
- Lecture 5: Skeletal biomechanics
- Lecture 6: Terrestrial locomotion

As mentioned above, for each biomechanics topic, the application of engineering principles in the living system will be introduced and discussed. For example, fluid mechanics theory can be applied to the analysis of the circulatory system. In the lecture of skeletal biomechanics, the application of fracture and fatigue theories on bones will be discussed. Terrestrial locomotion will be introduced to show students how the statics and dynamics theories can be used to solve forces due to walking and running.

Paper review and discussion

After the first six lectures, students will be assigned biomechanics papers to review, summarizing and presenting the papers in class. Through the presentation and discussion of these papers, students will be aware of current trends in the biomechanics field. This review process will also help them to appreciate the application of mechanics theories in the field. For example, a paper "The effects of tibiofemoral angle and body weight on the stress field in the knee joint" will be adopted for this purpose [1]. This paper focuses on the study of how the tibiofemoral alignment affects the stress and strain distribution in the knee joint. Engineering mechanics analysis was applied to study the loading conditions on the knee joint and finite element analysis was used to study the local stress and strain distribution. The paper will help students understand how to solve a problem regarding a living system using statics and dynamics theories as well as finite element analysis.

Project

The hands-on project is to design different structures simulating the human body using an Advanced Structures Set (ASS) [2]. The ASS includes many components that can be assembled to represent different kinds of structures for structure and force analysis. Engineering students can be divided into groups to investigate and design typical engineering structures such as:

- Bridges
- Teeter totters (as shown in Figure 1)
- Suspension bridges
- Catapults

Structures based on the human body would then be investigated. These include:

- Human back models (as shown in Figure 2)
- Human leg models
- Human arm models

The project involves students in the study of geometric configurations and structural analysis, as well as force measurement for structural members. Student teams will build the assigned structures, analyze forces in structural members according to different loading and structural variables such as angles, and present their work. The project will allow students to discover similarities between human body and other engineering structures. They will observe that similar principles of mechanics apply to different structures, and that the human body and biomechanics can be part of engineering.

FIGURE 1
TEETER TOTTER ASSEMBLED USING ASS (REPRINTED FROM PRODUCT MANUAL 012-10657D.PDF OF PASCO SCIENTIFIC COMPANY WITH THEIR PERMISSION) [2]

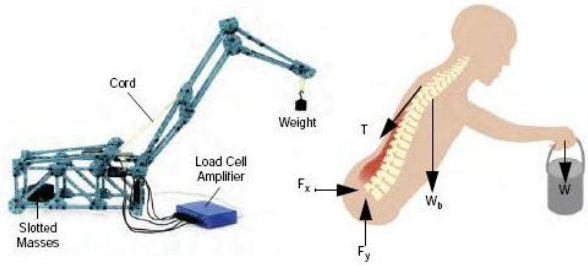

FIGURE 2
HUMAN BACK MODEL ASSEMBLED USING ASS (REPRINTED FROM PRODUCT MANUAL 012-10657D.PDF OF PASCO SCIENTIFIC COMPANY WITH THEIR PERMISSION) [2]

It should be mentioned that the use of projects to teach courses is ideal pedagogy for the proposed curriculum program development. Students can remember more from practicing and teaching others than passively listening to lectures. Using projects also gives students opportunities to practice their engineering thinking and problem solving skills that they already have in the biomedical field.

EXPECTED OUTCOMES

A number of positive outcomes are expected from this proposed effort. While the proposed module will expose engineering students to the application of engineering problem solving skills in the biomedical field, this effort will expand the career path of mechanical engineering students at ONU. The midwest healthcare industry is an emerging industry field while the Midwest healthcare startups have received large investment during recent years [3-4]. Ohio ranked second in the Midwest for investment in Biomedical start-ups by the Midwest Health Care Venture Report 2008 [5]. Adapting the focus of engineering education to emerging new industries and technologies nationwide and in the local area should give students a broader application of the engineering theory and skills.

Both anecdotal information [6] and quantitative research [7] indicate that the current generation of students is more interested in social and environmental issues than was the case in the past. Female students in particular are attracted by careers that offer social and environmental impact [8-9]; female students traditionally receive a high percentage of the total number of bachelor degrees awarded in Environmental (44.2%) and Biomedical (40.7%) Engineering. Few bachelor's degrees in traditional engineering programs, such as Mechanical Engineering (13.1%) are awarded to women today [10]. Only 10% of female high school students are interested in engineering majors because they see engineering as a purely technical field with no relevance in society [11]. The relation between engineering and healthcare and the potential for a career in the healthcare industry can be used to attract prospective students, especially female students, who otherwise might not consider a degree in a traditional field within engineering.

The project developed in this module will be used as a demonstration for outreach programs at ONU such as Camp GEMS (Girls in Engineering, Math and Science). It is hoped that this early exposure to the biomedical projects will spark the interest of some of these students, especially female, in engineering majors.

The measurable expected outcomes for the module are the following:
1. Students are to be more proficient at interpreting requirements of biomedical analysis.
2. Students are to be more confident at solving problems at a biomedical engineering field.
3. Students, especially women, find increased motivation to pursue engineering.
4. The curriculum developed can be disseminated to engineering programs at other teaching-focused undergraduate institutions.
5. The model can be easily implemented by engineering instructors with strong traditional engineering backgrounds such as mechanics but limited background in biomedical field.

ASSESSMENT

A summative evaluation will be performed for the module to assess the assignments and projects. The results of this evaluation will be used to improve the assignments and project portion of the module before it is taught for the second time. Students will also be asked questions regarding their perception of students' ability to apply engineering problem solving skills in the biomedical field. That is, students' perceptions of the module will be measured to evaluate satisfaction and obtain suggestions for future revisions. In addition, the on-line instruments called AWE (Assessing Women & Men in Engineering) for assessing self-efficacy will be used for outreach activities. These tools were developed by Pennsylvania State University and the University of Missouri with funding from the National Science Foundation (HRD 0120642 and HRD 0607081) and the Henry Luce Foundation [12].

CONCLUSIONS

A biomechanics module in a senior technical elective course for mechanical engineering students will be developed in the college of engineering at ONU. The module will last three weeks, containing lectures, paper discussion sessions, and a hands-on project. This module will expose mechanical engineering students at ONU to biomedical engineering topics and concepts. It will help to expand mechanical engineering students' career paths. The hands-on project in the module will be used as a demonstration in the existing outreach program at ONU to attract more students, especially female students to the engineering program at ONU. Because this is the first biomechanics module to be offered in the college of engineering at ONU, there might be unanticipated difficulties related to its content and format. For example, it is not easy to judge the appropriate amount

of technical content to provide to students. The author will modify the module based on students' feedback.

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