OVERLAP BETWEEN MECHANICAL AND CIVIL ENGINEERING UNDERGRADUATE EDUCATION

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ABSTRACT

This paper presents a brief overview of the overlap between the mechanical and civil engineering professions. It discusses common undergraduate courses in their curricula. It illustrates with examples the practical applications of these courses in both fields of engineering. The paper explains the importance of understanding this commonality by the involved instructors. It also outlines the roles required from the instructors and the university in this regard.

1. INTRODUCTION TO ENGINEERING

In its broad definition, engineering is the practical application of science (Costello *et. al.,* 1993). Based on this fundamental definition, the engineering education in all of its branches requires a common scientific foundation. The first year of the engineering education is indeed identical for all students. With a few exceptions, the second year is also similar for all engineering students. These two years include necessary mathematics, physics, and chemistry courses besides other basic requirements like English, humanity, and art classes. Additionally, these first two years include a few introductory engineering courses, which vary between different engineering disciplines. Examples include Electric Circuits, Thermodynamics, Statics, and Strength of Materials. In other words, half of the education for all engineers is almost the same. The curricula change in the third and fourth years to fit the educational needs for each discipline.

2. ENGINEERING BRANCHES AND THE OVERLAP BETWEEN THEM

Engineering has various branches based on the specific means by which science is applied to practice, but almost all engineers interact with each other in various and interesting ways. For instance, mining engineering applies science to develop and use methods and techniques to extract natural minerals and metals. A part of the civil engineering profession is to design and construct structures made of steel, which is an alloy of iron, carbon, and other elements. Mining engineers however need the services of civil engineers in their line of work like building tunnels to extract such natural elements. As another example, petroleum engineers use science to develop techniques capable of making oil and gas available for human consumption. Mechanical engineers manufacture machines, which use oil like automobiles to benefit human beings as well. The petroleum engineering industry needs some of these machines, which are mechanical engineering applications, to properly function.

The boundaries between different engineering disciplines are in fact artificial. Occasionally, these boundaries are not well defined, and are even vague in some but rare cases. Often, two different engineering disciplines deal with the same application so much that each engineering branch claims it as one of its own. For instance, heat transfer is a major common area in the mechanical and chemical engineering disciplines, and the subject of site planning belongs to both of the civil and architectural engineering professions. Sometimes even more than two disciplines share the same application. As an example, the advanced theory of elasticity and its applications are well established in the fields of biomedical, civil, and mechanical engineering. The finite element method covers even a wider range as it fits the curricula of almost all engineering fields.

The above interaction manifests itself in the form of closely related engineering disciplines. Examples include, electrical and computer engineering, mining and geological engineering, agricultural and biological engineering, mechanical and aerospace engineering, and civil and architectural engineering. The curricula in these closely related engineering fields share several courses in their third and even in their fourth years. It is not surprisingly then to see many students opt to have one of the above combinations as a double major in their engineering education.

3. MECHANICAL AND CIVIL ENGINEERING

Mechanical engineering is the profession involved with the design of machines and devices used by the society like automobiles, manufacturing plants, and air-conditioners (Burghardt, 1995). It is the second largest engineering profession behind electrical engineering (Burghardt, 1995). Civil engineering, the oldest branch in our profession, is responsible for the design, construction and maintenance of the society's infrastructure. This infrastructure includes a variety of structures like buildings, roadways, bridges, irrigation systems, and dams. This description of these two specific engineering fields allows us to safely state that people use the services of mechanical and civil engineers all the time in their daily lives. It also shows that both civil and mechanical engineers design objects; machines and devices in the case of mechanical engineering, and buildings and other structures in the civil engineering case. Mechanical and civil engineering education have a lot in common. Specific details on the education aspects on this commonality are given later in this paper.

It is worthwhile to mention here that several national and international universities have one department of mechanical and civil engineering, or civil and mechanical engineering. The Department of Mechanical and Civil Engineering at the University of Evansville, and at Minnesota State University at Mankato are examples for the first case, while the Department of Civil and Mechanical Engineering at the United States Military Academy, and at the University of Missouri Kansas City are examples for the latter case. The Department of Civil and

Mechanical Engineering at the University of Tasmania in Australia serves as an international example. Some universities have this combination for engineering technology. A case in point is the Department of Civil and Mechanical Engineering Technology at South Carolina State University. Nonetheless, unlike the case with other popular double major options, students rarely obtain a combined civil/mechanical engineering degree.

4. SPECIFIC EDUCATIONAL OVERLAP BETWEEN MECHANICAL AND CIVIL ENGINEERING

Beyond the basic scientific and mathematical foundation required by all engineering disciplines, mechanical and civil engineering have their own inevitable educational overlap. This overlap occurs in both undergraduate and graduate education. Generally speaking, the overlap lies in the two vast and diverse areas of mechanics of solids and fluid mechanics. There is an array of common undergraduate courses within these specific areas. These undergraduate courses are listed next followed by some details and a few examples for the applications of each course in the two engineering fields at hand. This list and the subsequent detailed examples are needed to illustrate that knowing the overlap is important to improve the education process for theses two engineering disciplines. This discussion is deferred to Sections 6 and 7 of this paper.

Common undergraduate courses between mechanical and civil engineering are:

1. Engineering Mechanics-Statics
2. Engineering Mechanics-Dynamics
3. Strength of Materials (also known as: Mechanics of Solids, or Structural Mechanics)
4. Fluid Mechanics
5. Basics of the Finite Element Method (FEM)

Statics deals with external and internal loads on objects in equilibrium (Pytel and Kiusalaas, 1999a). It also deals with cross sectional properties like the centroid and center of gravity. Understanding the nature of and how to quantify loads, and how to find certain sectional properties are extremely critical to the mechanical engineering discipline in the design of machines and to the civil engineering field in the design of structures. Mechanical engineers need to know the loads acting on a sliding piston in the engine of an automobile, while civil engineers need to calculate the hydrostatic force exerted by the rising water on a levy protecting a community from dangerous flooding. Mechanical engineers need to know the concept of the moment of inertia, I, and how to find the polar moment of inertia, J_o, of a rotating circular shaft. Civil engineers need to learn the same concept of moment of inertia, and how to find the associated radii of gyration about the strong and weak axes, r_x and r_y, for a standard W shape.

Dynamics deals with the action of loads on bodies in motion. The fundamentals of dynamics are needed in both mechanical and civil engineering applications. In the automobile industry, mechanical engineers use the well-known Impulse-Momentum principle, $\mathbf{L}_{1\text{-}2} = \mathbf{P}_2\text{-}\mathbf{P}_1$, to reduce dangerous effects of collision accidents (Pytel and Kiusalaas, 1999b). In highway construction, using principles from the Force-Mass-Acceleration method (Newton's second law), $\mathbf{F}_n = m\mathbf{a}_\mathbf{n}$, civil engineers bank the pavement on a horizontal turn by a certain angle to overcome the normal force, created by the circular motion of a traveling vehicle (Tounge, and Sheppard, 2005). This is absolutely necessary to insure the safety of the vehicle and its occupants.

Strength of Materials is a prerequisite course for several advanced design courses in both mechanical and civil engineering fields. This includes machine design in mechanical engineering, and concrete, steel, and timber design in civil engineering. Strength of Materials defines the relationship between externally applied and the resulting internal loads (Hibbeler, 2005). Additionally, through the famous Hooke's law, it relates load to deformation, or stress to strain. Using concepts from this course, a mechanical engineer can calculate the shearing stress on a circular shaft, τ, due to rotation needed to transmit power in machines. He or she needs the value of this stress to safely design such a shaft. Similarly, a civil engineer needs the value of the critical normal stress, σ, developed in response to all possible kinds of externally applied loads to adequately design a beam in a building.

Fluid Mechanics, as its name suggests, deals with the mechanics of fluids. Fluids are defined as those substances which change shape if subjected to shear stress (Shames, 1992). In designing machines, mechanical engineers deal with all kinds of fluids ranging from water through oil to the air in the atmosphere, but civil engineers are mainly concerned with water in their applications. Accordingly, the terms hydrology and hydraulic are used routinely in civil engineering applications. Further, mechanical engineering applications involve closed channel flow while open channel flow dominates civil engineering applications. Drainage is extremely vital to highway systems. Civil engineers employ Manning's formula, $v= (1.486R^{2/3}S^{1/2})/n$, to design a drainage ditch (Garber and Hoel, 2002). Mechanical engineers utilize the hydraulic flow from a reservoir to generate power in a turbine. They use Bernouli's equation, $V^2/2g + p/\gamma + z = \text{constant}$, for this purpose (Shames, 1992).

Finite Element Method (FEM) is an advanced topic in engineering education. Many universities teach this course at the graduate level. Nonetheless, several universities offer its students an undergraduate version of it. A case in point is the undergraduate civil engineering course of CEVE 417 at Rice University, which is also offered in the undergraduate mechanical engineering curriculum as MECH 417 at the same institute. The Finite Element Method is basically a numerical approach to solve high order partial differential equations for various engineering applications. It is applicable to many engineering curricula including mechanical and civil engineering. This method is very suitable for computer implementation, and that made it very popular rather quickly compared to other numerical methods (Ugural and Fenester, 1977). Finite Element Method techniques are used in the analysis of pavement drainage in civil engineering applications. Mechanical engineers employ these techniques to study the flow of liquids and gases within components like turbines and compressors as well as air flow in large building atria.

5. THE IMPORTANCE OF UNDERSTANDING THE OVERLAP BETWEEN MECHANICAL AND CIVIL ENGINEERING IN THE EDUCATION PROCESS

As seen from the above detailed section, there are many common courses between mechanical and civil engineering. These courses are taught in general by either an instructor with a mechanical engineering background, or by a faculty member with civil engineering education.

In fact, many mechanical engineering departments include faculty with civil engineering background, and vice versa. In advertising for a faculty position, the clause of: "an advanced degree in mechanical engineering or a closely related field is required," supports the above statement. Occasionally though, instructors with other backgrounds teach such courses. This includes faculty from other engineering departments like engineering mechanics.

Despite the above variety, only one instructor with a specific background teaches a group of students majoring in civil, mechanical, and possibly other engineering fields in a given class. Unfortunately, it is a fact that such an instructor is bound to be biased towards his or her own field in his or her teaching for two major reasons. First, he or she is much more comfortable using applications from his or her own field because he or she understands them very well and perhaps has industrial experience on them. Second, he or she is not as confident or even does not know how to apply such concepts to applications outside his or her field. Many educators may not agree with this statement, and many will not even admit it.

An instructor with a civil engineering background tends to use beams, columns, and other similar components to illustrate examples in Statics, while machine parts dominate the applications used by an instructor with a mechanical engineering background. Strength of Materials instructors focus on steel and concrete if they are civil engineers because these are the main materials in their industry. The industry of mechanical engineering does not use concrete at all, and steel is not dominant in it either. Metals and their alloys are used frequently in class applications taught by a mechanical engineer. This shows that mechanical engineering students have an advantage over civil engineering students if the course is taught by an instructor with a mechanical engineering background. Similarly, civil engineering students benefit more than mechanical engineering students if the course is taught by an instructor educated in civil engineering.

This situation also occurs even within a discipline itself. For example, an instructor with a hydrology background teaching a Finite Element Method course to civil engineering students tends to use hydrology applications frequently in his or her class. This is very beneficial to civil engineering students who are concentrating on hydrology in their education, but it might be an unpleasant class for structures, transportation, or geotechnical civil engineering students. This is the same case with mechanical engineering subdivisions as well.

Another unavoidable part in this process lies in the fact that each of the above common courses contains parts, which belong to only one of the two engineering disciplines under consideration here. For instance, mechanical engineers do not deal at all with trusses in their professional practice. Nonetheless, the subject of trusses is always included in the Statics course because it is vital to the civil engineering discipline. Similarly, the topic of kinematics and kinetics of mechanisms in the Dynamics course is essential to mechanical engineering students, but it has little value to civil engineering students. Again, it is an integral part of the Dynamics course for both groups of students. The Fluid Mechanics course contains both open and closed channel flows. Civil engineering applications are mainly open channel flow, while mechanical engineering applications are closed channel flow. Nonetheless, like the above examples, both groups learn both topics because they sit next to each other in the same class.

6. WHAT SHOULD OR CAN BE DONE

The ideal situation is to have an instructor with a mechanical engineering background to teach these courses to mechanical engineering students, and the same for the civil engineering counterpart. The decision in this case is not made by the instructor. Rather, it is made at the department, college, or university level. Economics play a major part in this situation.

The instructor's role in all of this is nonetheless extremely important. An instructor with a mechanical engineering background teaching these courses must exert extra efforts to learn the applicability of his or her courses in the civil engineering discipline. It is not enough simply to flavor the course with sporadic superficial examples from civil engineering. This is not fair to his or her civil engineering students. By the same token, an instructor with a civil engineering background should learn about the extent of his or her courses in the mechanical engineering field. If needed, he or she should seek help from other faculty in the mechanical engineering discipline at his or her institute.

The administration should encourage the above activities. Neither group of students should have a disadvantage in comparison to the other simply because of the instructor's background.

7. CONCLUSIONS

Instructors teaching common mechanical/ civil engineering courses need to have an acceptable level of understanding of the applications of their courses in both fields of engineering to insure the integrity of the engineering education process. It is extremely detrimental to limit the applications in any of these courses to just one of these two engineering disciplines. Administration and faculty members have great responsibilities in this regard.

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