AC 2012-5384: INFUSING A SUSTAINABLE GREEN MANUFACTURING COURSE INTO MANUFACTURING/MECHANICAL ENGINEERING TECHNOLOGY PROGRAM

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Infusing A Sustainable Green Manufacturing Course into Manufacturing/Mechanical Engineering Technology Program

Abstract

Green manufacturing is an emerging field in recent years and is also the sustainable development model for modern manufacturing industries. Sustainable green manufacturing encompasses the concept of combining technical issues of design and manufacturing, energy conservation, pollution prevention, health and safety of communities and consumers. Many industries are directing their resources to reduce the environmental impact of their produced products and services. To remain competitive in the global economy, these industries need to train engineering and technology professionals to understand the impact of their decisions on the environment and society. It is important for universities to prepare these future engineering technologists to meet this need. Many technology programs do not offer this type of information to their undergraduate students. The goal of this paper is to assess the current undergraduate mechanical engineering technology program curriculum at Metropolitan State College of Denver (MSCD) with regard to sustainable green manufacturing predominantly metal working based manufacturing curriculum. In this paper we will discuss key topics that can be infused into manufacturing coursework at MSCD to include sustainability principles. Finally, the ABET process and the existing curriculum will be reviewed to indentify barriers and inclusion of sustainable green manufacturing course into current curriculum.

1. Introduction

Green manufacturing is an emerging field in recent years and is also the sustainable development model for modern manufacturing industries. The U.S. Dept of Commerce defines sustainable green manufacturing as “the creating of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities and consumers”[1]. There is a growing awareness among many manufacturing industries of the need to consider the economic, societal, and environmental performance. Demand for environmentally sustainable products and the advances in sustainable technology have become increasingly important components of engineering and engineering technology education. In order to be able to come up with environmentally sustainable products, sustainability issues need to be a part of the every engineering decision. This includes every step, from the design phase until the product reaches to its end-of life, and continues even after that, when the efforts to regain the material’s value may take place [2]. The engineering technology education program should reflect the needs and changes of today's manufacturing industry and prepare young engineer technologists to meet the challenges of the competitive world of manufacturing.

The need to integrate sustainability and green manufacturing subject matter into undergraduate curriculums in either engineering or engineering technology has become increasingly important over the last decade [3]. Given the increasing importance of sustainable green manufacturing, it is incumbent upon academia to educate future engineers and other decision makers on sustainability topics, i.e., incorporate sustainable thinking into engineering curriculum. Engineers, and thus engineering educators, need to be cognizant of how their specific disciplines interact with, and ultimately impact, the environment. This includes not only waste management practices, which traditionally fall into the domain of environmental engineering, but also green and sustainable courses as well [3]. The majority of undergraduate curricula in mechanical/manufacturing engineering technology have at least one course in manufacturing processes, while many of these courses cover the processes used in manufacturing industries but there has been little emphasis put on the associated environmental impacts resulting from these processes. The main objective of this paper is to introduce an interdisciplinary course on new technology, materials, or processes that encompass life cycle thinking, a focus on sustainability improvement, and the complexity within the principles of sustainability. The approach involves addressing green issues and sustainability, as a distinct course item by focusing on machining which produces lots of waste. This paper will discuss this idea by describing the general concepts of sustainable green manufacturing followed by mapping the needs in the current MSCD curriculum.

2. General Concepts in Sustainable Green Manufacturing

Manufacturing industries account for a significant part of the world's consumption of resources and generation of waste. It is widely recognized that industrial production inevitably results in an environmental impact. In 2006, the total output of the U.S. manufacturing sector in the form of a variety of products had a gross value of $\$5.3 \times 10^{12}$ and these products were responsible for about 84% of energy related carbon dioxide (CO_2) emissions and 90% of the energy consumption in the industrial sector [4]. Therefore, identifying the environmental footprints associated with these products has critical importance in the design and improvement for sustainability. Life cycle assessment (LCA) provides the common framework with science-based analysis methods for decision makers. LCA is an approach used to quantify the environmental impacts of a product by measuring the inputs, such as raw materials and energy, and outputs, such as aerosols, waste and greenhouse gases, associated with the entire supply chain of a product [5]. During Life cycle inventory (LCI), construction there is a clear flow chart of the whole manufacturing process, all entrance and exit flow of input and energy, and the balance between them, which means that a detailed map of the whole production process is obtained. Sustainable manufacturing practices adopted by manufacturers usually focus on manufacturing input materials, manufacturing processes, packaging and waste disposal, among others. Students should, upon entering the workforce, be able to assess a manufacturing process efficiently in terms of environmental impact. The manufacturing process consists of the inputs, process, and outputs of an operation. Each unit process is converting material/chemical inputs into a transformed material/chemical output. The unit process diagram of a machining process is shown in Figure 1.

Figure 1. Input-Output diagram of a machining process

3. Life Cycle Assessment in Sustainable Green Manufacturing

The main objective of sustainable green manufacturing is to conceive products which can be recycled, remanufactured or reused. The product lifecycle is divided in the four main phases: material production, manufacturing, use and end-of-life. The life cycle of a given product is made up of various linked processes or manufacturing plants that are each required in support of the production and use of a product, and all have inputs and outputs that impact the environment. This resulting database is the life cycle inventory (LCI) and provides a transparent description of a product. The life cycle inventory contains data that quantifies energy and raw material requirements i.e. emissions to air & water, solid waste, and other environmental releases that are included within the scope and boundaries of the systems. These data can be found in the literature, educational and industry manuals, or databases. The data can also be gathered experimentally. The proposed course will look at the environmental concerns of each individual process as shown below figure 2. Figure 2 shows an overview of the environmental-based factors for drilling operations as an example. The efficiency of energy utilization in manufacturing is an important indicator of performance. The focus of energy efficiency studies is changing from energy efficient products to energy efficient manufacturing [6]. Manufacturing processes consume resources directly and produce environmental pollution as well as being the main factors that affect sustainability. Therefore, innovative studies on green manufacturing processes are promising. Efforts to minimize the environmental impacts of manufacturing processes can be classified into the development of new processes and the improvement of existing processes based on the requirements of sustainability [7]. The life cycle approach addresses all phases of the product life cycle, including the design phase, the raw material production phase, the manufacturing phase, the distribution phase, the usage phase and the end of life phase, and it aims to maximize total product performances during the product lifetime [8].

Figure 2. LCI data for machining process

4. Mechanical/Manufacturing Engineering Technology Curriculum Concerns

The Engineering Accreditation Commission (EAC) of ABET program criteria for mechanical/manufacturing requires that programs demonstrate that students have proficiencies in five specific areas: 1) materials and manufacturing processes, 2) manufacturing systems design, 3) process, assembly and product engineering, 4) laboratory experience, and 5) manufacturing competitiveness [9]. Manufacturing engineering technology programs need to build on the manufacturing competitiveness criteria. Institutions pursuing accreditation must demonstrate that the program meets a set of general criteria. The students in the program must attain “an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability” (Criterion #3) [10]. ABET requirements already are addressing the issue of sustainability in Criterion #3 by listing the word “sustainability” as part of the general criteria for all engineering programs. This should also be considered for engineering technology programs. According to the National Academy of Engineering, the growing environmental crisis means that, “Engineering practices must incorporate attention to sustainable technology, and engineers need to be educated to consider issues of sustainability in all aspects of design and manufacturing” [11]. However authors are concerned for not including sustainable manufacturing in to engineering technology curriculum. The successful integration of sustainability into engineering technology requires that students achieve an understanding of how various courses relate to one another. The general course flow for the Manufacturing Engineering Technology program at Metropolitan State College of Denver Tech is shown in

Figure 3, and it is believed that MSCD curriculum is fairly representative of most other curricula. The total semester credit hours required for graduation in the school of technology are 128. Manufacturing engineering technology requirement consists of 51 credit hours in the major and 25 credit hours in an emphasis concentration (<http://www.mscd.edu/met/>). Students with sustainable green manufacturing emphasis option would substitute manufacturing upper division course (MET 4XX). In order to maintain the total 128 semester credit hours, they would use the remaining six of the proposed courses as their emphasis area. We recommend that the students begin with the course, Sustainable green manufacturing to learn basic principles of manufacturing processes and their environmental impact.

There is considerable possibility for debate and experiment about incorporating sustainability into an engineering technology curriculum. Sustainable green manufacturing requires the same basic mathematical and scientific competence as engineering for any other purpose. Also, the general skills such as communication, life-long learning and functioning in multi-disciplinary teams that are now imparted by good engineering technology programmes will be equally necessary in a curriculum that addresses sustainability. Every engineering technology graduate should have a major design experience that accounts for a range of realistic constraints, including sustainability. The most common method of introducing green manufacturing has been through a senior level elective course on manufacturing/mechanical engineering, with emphasis on end of the process treatment. Green Manufacturing has been used as an alternative of sustainable manufacturing. “Green” technologies are often understood as those capable of meeting product design requirements and minimizing environmental impact simultaneously. However, minimizing impacts is a necessary but not sufficient condition for sustainable manufacturing. Three most important components of a sustainable manufacturing system are (i) the selection and application of appropriate metrics for measuring manufacturing sustainability; (ii) the completion of comprehensive, transparent, and repeatable life-cycle assessments (LCA); (iii) the adjustment/optimization of the system to minimize environmental impacts and cost based on the chosen metrics and the LCA [12]. Authors are considering doing literature review to scrutinize current sustainable manufacturing courses from different universities in engineering technology field as future work. Moreover, the importance of embedding the concepts of sustainability principles in all relevant courses will also be highlighted in future. To put this idea into practice, more detailed mapping is required and an insertion plan for each course has to be drawn further.

Figure 3. Course flow for BSMET degree at Metropolitan State College of Denver.

5. The plan for insertion

Many opportunities currently exist to infuse mechanical/manufacturing engineering program curricula with sustainable green manufacturing concepts, and the benefits are not only in terms of curricular augmentation alone, but they also provide a chance for faculty to develop new, innovative teaching materials. This course should be introduced at 4th year assuming that students have acquired enough manufacturing knowledge to adopt green manufacturing with sustainable principle into the previous concepts, approaches, and techniques they have been studying. The course should not be an elective course but a mandatory one to ensure that all Mechanical/manufacturing students have the understanding of sustainability. In the second plan, the concepts and approaches of environmentally benign manufacturing are blended and embedded into courses along the curriculum from the first semester to the end. For example, the necessity of sustainability is introduced in the MET 1000 Introduction to Mechanical Engineering Technology course at the first semester.

Description of Proposed Course for Sustainable Green Manufacturing

After thorough review of the literature, authors identified the following course learning objectives:

- 1) Analyze manufacturing processes with intent to point out areas of adverse environmental impact and how this impact could be minimized or prevented by emphasizing on machining.
- 2) Alternate processes incorporating these environmentally based improvements. These improvements take advantage of recycling, substitution of environmentally favorable materials and redesign of processes.
- 3) Evaluate life cycle analyses of products and/or processes and propose strategies for minimizing environmental impact while still meeting design and economic requirements.
- 4) End-of-use strategies include design for recycling tools will be demonstrated and practiced on real products.
- 5) Conduct a material selection with the goal of reducing the environmental impact of a product and/or process while simultaneously reducing material costs.
- 6) Design the rules and processes to meet the current market need and the green manufacturing requirements by selecting and evaluating suitable technical and supply chain management schemes.

This course focuses on the life cycle concepts and assessment by presenting students with the notion that environmental impact extends beyond production to include material extraction, product use, and end-of-use strategies. Students will discuss life cycle stages for a variety of example products.

6. Conclusion

Engineering technology education strives to produce graduates who are ready to perform at a high level immediately after receiving their degrees and who can achieve strong professional growth throughout their careers. There is no doubt that sustainable green manufacturing will

continue to be developing, be a benefit to society and improve the environment in various ways. We recognize the need for incorporating an environmental conscious course into our manufacturing curriculum. This paper has highlighted the importance of infusing sustainability into current mechanical/manufacturing engineering technology curriculum in order to address current unsustainable practices in industry and society. The introduction of sustainable green manufacturing as a separate course has been discussed and a review of the current curriculum at MSCD has been presented. Our interaction with local manufacturing industries indicates that they welcome the addition of this course.

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