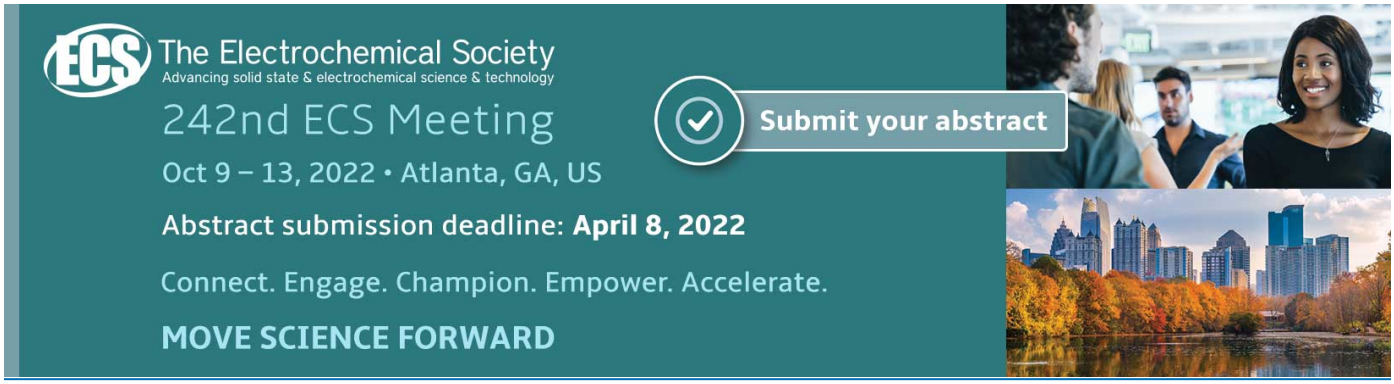
Framework for Sustainability Performance Assessment for Manufacturing Processes- A Review



Framework for Sustainability Performance Assessment for Manufacturing Processes- A Review

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Abstract. Manufacturing industries are facing tough competition due to increasing raw material cost and depleting natural resources. There is great pressure on the industry to produce environmental friendly products using environmental friendly processes. To address these issues modern manufacturing industries are focusing on sustainable manufacturing. To develop more sustainable societies, industries need to better understand how to respond to environmental, economic and social challenges. This paper proposed some framework and tools that accelerate the transition towards a sustainable system. The developed framework will be beneficial for sustainability assessment comparing different plans alongside material properties, ultimately helping the manufacturing industries to reduce the carbon emissions and material waste, besides improving energy efficiency. It is expected that this would be highly beneficial for determination of environmental impact of a process at early design stages. Therefore, it would greatly help the manufacturing industries for selection of process plan based on sustainable indices. Overall objective of this paper would have good impact on reducing air emissions and protecting environment. We expect this work to contribute to the development of a standard reference methodology to help further sustainability in the manufacturing sector.

1. Introduction

Sustainable manufacturing broadly implies the development of innovative manufacturing sciences and technologies that span the entire lifecycle of products and services to minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound [1].

Sustainable manufacturing plays an important role in the manufacturing of products, materials and processes. For sustainable manufacturing development, enhanced modeling techniques are needed to understand and predict the sustainability aspects through design and manufacturing where technologies can be applied to transform materials with reduced energy consumption, reduced emissions, reduced generation of waste products, and reduced use of non-renewable or toxic materials. The scope of this paper is to propose some significant findings for sustainable manufacturing assessment.

However, every manufacturing industry has always affected the environment and will continue doing so in one or the other ways, demanding a never-ending research for sustainability. Our goal will be continuous improvement making constant advances in manufacturing company's overall sustainability performance. To develop more sustainable societies, industry needs to better understand how to respond to environmental, economic and social challenges. Our motive is to develop framework and tools that accelerate the transition towards a sustainable system.

This paper is organized as follows, Section 2 describe the literature reviews on sustainable manufacturing assessment and identify the research gap based on various authors work in the field of sustainable manufacturing processes followed by some useful findings in this area. Section 3 propose some basic steps of methodology for sustainable product development. Section 4 present conclusions and future scope of work.

2. Related work

Earlier, researchers have investigated performance evaluation and improvement for manufacturing process variable consumption. This section describes previous research efforts related to sustainable manufacturing assessment and sustainability indicators of various manufacturing processes. Lee et al. [2] introduces MAS2, which is an integrated modeling and simulation-based life cycle evaluation approach for sustainable manufacturing. This work has provided a way to assess the sustainability performance by combining sustainability concepts with engineering technologies using mathematical modeling. Zhang et al. [3] developed process-oriented Information Model (PIM) to integrate the relevant information regarding the sustainable manufacturing with the product design information. Seow et al. [4] developed an approach to model energy flows within a manufacturing system with an aim of representing the amount of energy attributed for manufacturing a product. They applied the concept of direct energy, indirect energy and auxiliary energy. Ciceri et al. [5] proposed a tool to estimate materials and manufacturing energy based on the bill of material for a product. The mechanism proposed by them determines the energy estimate by compiling available data from material embodied figures, empirical and bill of material. Kellens et al. [6] proposed a life-cycle analysis (LCA) oriented methodology for systematic inventory analysis of the use phase of manufacturing unit processes providing unit process datasets to be used in life-cycle inventory (LCI) databases and libraries. The methodology has been developed as a framework of the CO2PE! and comprises two approaches namely, screening approach and the in-depth approach with different levels of detail. Kellens et al. [7] presented two case studies, one for both the screening approach and the in-depth approach, demonstrating the application of the life cycle assessment-oriented methodology for systematic inventory analysis of the machine-tool use-phase of manufacturing unit processes. Methodology is explained with the help of machining and laser cutting processes. Jeswiet and Kara [8] proposed a method that connects the electrical energy used in manufacturing directly to the carbon emissions generated during production of that electrical energy. The developed methodology was implemented in machining operations, such as turning and milling. Taha et al. [9] presented a methodology that links design features of a product to the environmental impact. The study determines the specific energy consumption for the turning operation experimentally, which is in turn interpreted into CO2 emissions. Jayal et al. [10] presented an overview of present tools and methodologies for evaluating sustainability contents at the product, process and system levels. The authors consider dry, near-dry and cryogenic machining as examples for optimization of sustainable manufacturing

processes. Feng and Juong [11] proposed a framework for quantitative measurement of sustainability for machining operations. They take into consideration carbon emission and energy use in their study. Gutowski et al. [12] studied the environmental impact of different manufacturing processes, which accounts for the exergy used during the manufacturing process. Krajnc et al., [13] proposed a method to measure sustainability indicators and a strategic set of metrics for assessing the sustainability level of a company. The choice of the sustainability indicator for a company is left at the option of the user. Madan et al. [14] develop the needed measurement science, standards and methodologies to evaluate and improve sustainability of manufacturing processes. Authors present a science-based guideline to characterize energy consumption for a part manufactured using the injection molding process. Companies use these indicators to set targets and monitor progress for sustainability in manufacturing. A survey of the corporate sustainability reports demonstrated that environmental and social impact assessment has received less attention as a whole to evaluate sustainability of a manufacturing process. Furthermore, comparison and assessment of production systems demand quantitative measures for sustainability. Such quantitative measurement requires environmental indicators. For simplicity, environmental indicators are classified into input and output indicators. Input indicators for sustainability include energy use, material use, and water use indicators. Output indicators include product, solid waste, liquid waste, and air emission indicators. It is identified that some indicators do affect the performance of the other indicators. For example, electrical energy affects indicators like the Co^2 emission or renewable of energy. In the following section, we discuss the research gap followed by objectives of present work.

2.1. Research gaps

Despite very useful work presented in the literature, there are still gaps that need to be addressed, the prominent ones are mentioned below:

- Available approached do not satisfy the need for early estimation of sustainable manufacturing indicators that are useful for decision support to identify the most efficient manufacturing/process plans.
- Few researchers have made efforts in selecting indicators effecting environmental, economic and social aspects of manufacturing sustainability at the factory level. However, the use of specific methodologies and tools to measure and evaluate such indicators based on data collection from the industry shop floor or LCI database.
- Focus of most of the research papers is to collect life cycle inventory data for the database. This database is later used in the various inventory databases, such as Ecoinvent. The process of this data collection takes long time. Furthermore, such databases only represent average sustainability information and does not represent specific improvements made by the manufacturing.
- The manufacturing industry is more interested in knowing sustainability assessment of their product manufacturing in terms of
  - inter-process sustainable manufacturing comparisons
  - comparing alternative process plans for manufacturing a product
- Therefore, a deeper science based study to further carry on the sustainability assessment research to the process level is required.
- In demand-driven manufacturing scenario, estimation of sustainability assessment is very important and available systems do not support it.

- There has been a very limited work on sustainability information with integrating product design, which is essential for achieving overall sustainability. Therefore, further research is needed to address how to evaluate product sustainability using economic and environmental factors.
- Pre-and post-operations, such as joining, coating which are closely associated with the processes, have not been given much attention.
- Providing a computer-aided approach would help generate better sustainability evaluation and inter-process sustainability comparison for selected manufacturing processes.

2.2. Objectives of the present work

To address the research gaps, there is a need to develop a methodology, which can be used to evaluate and improve the sustainability of manufacturing processes. In this paper, we try to develop a guideline specify to several manufacturing processes. The objectives of this paper are mainly:

- Study the manufacturing processes with an objective to develop a sustainability assessment methodology for manufacturing processes
  - Step 1: Study taxonomies and structure of manufacturing processes
  - Step 2: Select representative manufacturing processes.
- Identify key performance indicators (KPIs) for manufacturing sustainability assessment
- Analyze the selected unit manufacturing processes and their structure/sub-processes.
  - For example, Heating and melting, casting, cooling, machining and finishing process.
- To propose a science based approach for sustainability assessment of the manufacturing processes with respect to identified KPIs.
- To develop a framework that helps assess sustainability for product manufacturing with selected manufacturing processes and process plans.
  - provide a basis for comparison and selection of the most sustainable process plan.
- Optimize product manufacturing for sustainability by selecting appropriate process parameters
- Verify the proposed methodology, compare the developed model by comparing results with the actual shop floor data obtained from the manufacturing industries.

3. Methodology for Sustainable manufacturing assessment

Methodology for proposed work is listed below.

- To review the literature related to Sustainable assessment of manufacturing processes, key performance indicators and various techniques to solve above said problem.
- After that this project proposes a structure for manufacturing processes and identification of representative manufacturing processes with an objective to develop a sustainability framework for manufacturing processes.
- Structured information models for seamless flow of information across design and manufacturing domains for selected manufacturing processes will then be defined.
- The proposed work also intends to identify key performance indicators (KPIs) for manufacturing sustainability assessment and perform analysis of selected unit manufacturing processes and their sub-processes aiming to propose a methodology for determining science based measurements of the manufacturing processes affecting the KPIs.

The below figure 1.1 chart shows the methodology of proposed system.

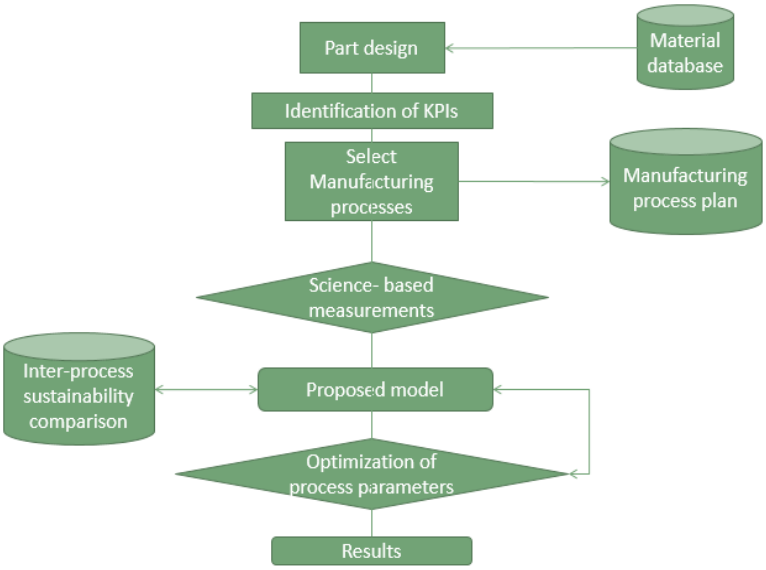

Figure 1. Methodology of proposed system

- The theoretical foundations determined will be used to develop a model that could evaluate sustainability of selected manufacturing processes and their respective process plans providing a basis for inter-process comparison and selection of the most sustainable process plan.
- The framework aims to consider different influencing factors such as product information, manufacturing process plan, part geometry, material related physical and processing properties and the manufacturing equipment information.
- Optimize product manufacturing for sustainability by selecting appropriate process parameters.
- Obtaining best compromising results.
- The proposed methodology will be verified with actual shop floor data obtained from the industry.

4. Conclusion

Since In recent years, the concepts of sustainability have gradually evolved and has begun receiving international attention. In addition, companies are under pressure to have environmental friendly manufacturing and service sectors, hence, this paper provides an attempt to have a brief overview towards the sustainability and related issues. Sustainability in manufacturing is considered as an important tool strategy similar to other manufacturing tools and systems for example lean production, supply chain management etc. This concept helps organization to have economically improvement but not only this, but also, environmentally and sociality. In the other words, environmentally friendly product and totally sustainable manufacturing system helps organization to reduce use of material, minimize environmental impact and make product economical sustainable. Although there are lots of researches which have been done on the area of sustainability, there are few works on sustainability of early product development and inter-process sustainable comparison, therefore, these issues need more investigation in future research.

Acknowledgements

The authors sincerely extend their appreciation to Federation University Australia for their support of this research project.

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