A comprehensive framework for sustainability assessment in a shielded metal arc welding (SMAW) process

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Abstract: The shielded metal arc welding (SMAW) is undoubtedly a popular metal fabrication process owing to its widespread applications in heavy constructions involving welding of steel structures, building materials, ships, bridges etc. in addition to various types of repair and maintenance works. The process is, however, considered as environmentally vulnerable owing to its energy intensive nature, pollution issues and susceptibility of human hazards. The deployment of sustainable manufacturing practices can surely enhance the sustainability of the welding processes. Although various tools for ensuring sustainability in SMAW exist, but there is still a need to visualize sustainability aspects within a broad perspective. This paper reviews the salient sustainable practices and methodologies in the welding processes with focus on SMAW and thereby proposes a comprehensive and quadruple framework for sustainability assessment by amalgamation of four factors namely technical, environmental, social and economic. Finally, the study also steers directions for future research and recommendations towards sustainable welding processes.
Keywords: *Shielded metal arc welding (SMAW), sustainability, assessment, framework*

1. Introduction

Implementation of sustainable manufacturing practices has become increasingly imperative for industries owing to the factors such as government legislation, competitive business environment, economic benefits, green image, social responsibility etc. In addition, the sustainable development concepts have witnesses a favorable shift from product oriented approach to process-oriented practices encompassing a dedicated methodology for sustainable manufacturing based on cradle to grave philosophy.

Shielded metal arc welding (SMAW) and other welding processes can be attributed as one of the most popular joining methods with their widespread applications in building structures, ship and aircraft manufacturing, automotive,

electronic, nuclear, chemical, oil and gas industries, etc. However, they attract unhealthy environmental image due to enormously high temperatures, toxic gases and fumes, ultraviolet and infrared radiations, energy intensive nature, process wastes and related reasons. This makes it extremely necessary to design, devise and implement sustainable manufacturing measures (SMSs) for the welding processes with a particular focus on SMAW.

Yeo and Neo (1998) highlighted the need and relevance of establishing effective environmental performance in welding process selection using the Analytic Hierarchy Process (AHP) and computer based health hazard score. A characterization model was developed by Zimmer and Biswas (2001) for SWAW and fluc cored arc welding (FCAW) which helped to ensure a steady state arc with suitable manipulation of process parameters. Favi et al. (2019) employed a life cycle assessment (LCA) tool for comparing different traditional metal arc welding technologies. In another study by Amza et al. (2010) environmental assessment of the gas welding process was undertaken and the based on a work environment of the welding process, a pollution coefficient was defined. This helped to characterize and mitigate the fumes of the welding process. Various researches in the past have contributed sustainability assessment (Yeo and Neo, 1998), characterization studies (Zimmer and Biswas, 2001) environmental assessment (Amza et al., 2010), however, a holistic approach to present a clear picture of the environmental impact and sustainable criteria of welding technologies is still missing.
This paper attempts to propose a four-point sustainable approach for achieving sustainability in a SMAW. In particular, the triple bottom line (economic, environmental and social) sustainability approach has been amalgamated with technical factor to present a comprehensive framework for ensuring sustainability in a SMAW.

2. Proposed Framework for Sustainability

As mentioned above most of the existing literature focus on triple bottom line approach (Alkahla et. al, 2017) encompassing social, economic and environmental aspects neglecting the technical and engineering aspects. The proposed four-point framework (Fig. 1) has been conceptualized by incorporating the technical considerations also as they play a vital role in ensuring sustainability in manufacturing using SMAW.

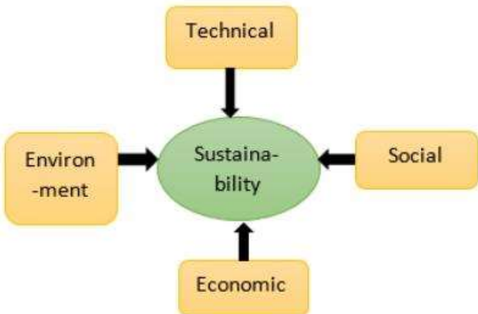

Fig: A four-point framework for sustainability

2.1 Social Aspects

This aspect primarily includes reducing the risk involved towards health hazards due to enormously high temperatures, toxic gases and fumes, ultraviolet and infrared radiations etc. A number of cases of eye-nose-throat (ENT) infection, bronchitis, chest congestion pneumonitis, chronical asthma and lungs cancer have been reported in literature. Various welding processes such as metal arc welding, manual / automatic gas metal arc welding, laser arc hybrid welding, were investigated for their environmental and social impact using life cycle analysis (LCA) approach by. Salary based social aspects can also be seen in literature wherein welder's salary has been proposed to be sufficiently high to sustain a good life (Chang et. Al, 2015).

2.2 Economic Aspects

Welding operation is an expensive process because it involves several types of resources. Undoubtedly, performing parametric optimization using different experimental setups can be a very expensive solution. This has motivated the researchers to employ various cost effective approaches such as Taguchi method, Genetic Algorithms and other metaheuristic based optimization techniques. Vimal et al. proposed the graph theory approach to model different sustainable measures for the assessment of sustainable strategies using employee skill training and waste reduction. The study showed that both economic and environmental benefits. Can be achieved through waste reduction through the proposed optimization method. The concept of labour and material related cost reduction for the arc welding operation has been explored by Patrick and Newell. As observed, the costs related to material consumables is only 10 – 20% of overall welding cost, whereas the remaining 80 – 85% of the total cost can be attributed to the labour and overheads. The productivity can be increased by reducing the labour man-hour.

2.3 Environmental Aspects

It is a known fact that welding process increases air pollution due to generation of hazardous fumes and particulate matter. The literature reveals the idea of reducing current intensity to lower the emissions from welding fumes. The environmental performance of the SMAW process can be increased by lowering the energy consumption in the process. Sproesser et al. [15] employed the life cycle analysis (LCA) to analyse the environmental impact of different welding processes.

2.4 Technical Aspects

The technical aspects have not been focussed in sufficient details during sustainability studies in the triple bottom line approach. However, by giving a substantial weightage to these factors the model can be holistic to ensure sustainability in a SMAW. These factors may include electrode position, arc length, arc travel speed, temperature, power input etc. The proper selection of these factors may surely augment in ensuring sustainability during a SMAW.

3. Conclusions

The proposed four-point framework has been conceptualized to ensure sustainability in a SMAW and other allied welding processes. The available literature has been explored and it was proposed that if technical and engineering factors are also augmented in triple bottom line approach, one can achieve a holistic sustainability during SMAW. As future recommendation, it is proposed to conduct more studies based on numerical models involving multi-physics such as heat transfer, fluid flow and electromagnetics to ensure holistic sustaibility in the SMAW.

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