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Life Cycle Assessment of Arc Welding and Gas Welding Processes

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Abstract

Welding is one of the important processes in most of the manufacturing process chains. In term of material and energy consumption, every welding process is different from each other and thus has different environmental impact. It is estimated that 0.5-1% of the consumables in arc welding are converted into particulate matter, gases and emissions. On global level, the pollutants released through welding process are in tons and a large amount of energy is consumed for the same. This study attempts to evaluate the environmental impact generated due to welding for training purpose. Material and energy flow modeling is carried out using software Umberto NXT universal with database Eco-invent version 3.0. Impact assessment has been carried out using midpoint (CML 2001) and end-point (Impact 2002+) assessment methods. It has been found that in the production of machine/equipment (manufacturing phase) copper and mild steel are major polluter; mild steel is dominant polluter in the use phase; and copper is the major contributor in the end of life phase. This study recommends use of simulation during training for advanced learning technologies for different welding processes

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Keywords: Welding process; Life cycle assessment; Environment impact; Energy consumption

1. Introduction

Increasing environmental concerns has got the priority in process development and these practices are gaining priority in present era of environmental consciousness. Green product and process development is a step towards the sustainability and life cycle assessment (LCA) is a useful tool to assess the environmental impact of products and processes. LCA helps the decision makers to identify the hotspots and take appropriate steps. In the past, the term sustainability was mainly environmentally oriented, i.e. sustainability as the quality to sustain the environment. However, in current literature, sustainability is defined with three dimensions: environmental, social and economical sometimes adding a fourth one, technology. LCA studies for various products and processes have been carried out nowadays to achieve the goal of green and sustainable production [1][2][3].

Welding is a process that can be carried out both indoors and outdoors. Whenever welding is carried out, ultimately the dust, fumes and pollutant gases will be emitted into the external environment. Several researchers and organizations have focused on the environmental consideration of welding emissions and their effect on the environment and workers who are involved in it [4] [5]. Three important factors in term of welding emission are – the volume of emission, the composition and the particle size. The fume emission during welding is commonly less and the symphony is normally nontoxic[6]. The size of particles that are formed due to welding varies from the nanometer scale to hundreds of micrometers with a mode diameter in the interval 0.1–1.0μm[4]. These particles have high chances of deposition in alveolar region of the lungs. Bureau of Labour Statistics approximates in 2008 shows that the number of welding workers are 369,610 [7]. In India, there are 1634596 engineering students intake seats for different streams of engineering at undergraduate level [8]. All the students undergo the basic training of welding in their first year of education. It shows the importance of the welding process in manufacturing sector and its environmental hazards and hence the motivation for this study. LCA can be utilized to visualize

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the environmental impact of product and process involved in welding process.

2. Welding and environmental impact

In last few of years some research on environmental impact assessment of welding processes has been carried out by some researchers. Finkbeiner et al. [9] presented a study of LCA of manual metal arc welding (MMAW), laser arc-hybrid welding (LAHW), gas metal arc welding (GMAW), and modified GMAW. The results of the study show that MMAW has the highest effect on global warming, acidification, eutrophication, and photochemical ozone depletion. LAHW has minimum environmental impact and the effect of modified GMAW is between MMAW and LAHW.

Chang et al. [10] presented a study incorporating environmental and social LCA of different welding technologies. It is found in this study that the manual welding process brings higher risk of welders to health over the automatic processes. The cause identified for the same are low productivity and speed of manual welding.

Sproesser et al. [11] presented a study to evaluate the energy efficiency of the gas metal arc welding (GMAW) by using a Tandem GMAW (TGMAW). It is found in the study that the high power TGMAW process decreased the electricity consumption and time required for welding by 23% and 55% respectively.

Vimal et al. [12] presented a study on sustainable SMAW (shielded metal arc welding) process. The research work addressed five important sustainable manufacturing strategies – energy modeling and optimization studies, waste minimization and disposal studies, process parametric optimization, process emission studies, and Employee skill training (green strategies) and involvement program – to study their effect on SMAW. Various disposal scenarios have been assessed using LCA.

Sproesser et al. [13] presented a research article for selection of sustainable welding process on the basis of weight space partitions. This study evaluates the two welding processes – manual and automatic GMAW) – on the basis of environmental and economical criteria. The weight space partitions approach used in the study provides opportunity to decision maker for assessment of sensitivity of selection problem. However, the motivation of this study is to show the environmental impact of simple arc welding and gas welding processes carried out by a large number of students in large parts of Asia and particularly in India.

3. Materials and Method

3.1. Life Cycle assessment

LCA is a tool that can be used to model the life cycle; and calculate, analyze and evaluate at every step in the life cycle various parameters in term of environmental impact [14]. It includes but not restricted to flow analysis, material and energy flows, cost accounting, outflows and inflows, and environmental impact. Regulated by the ISO 14040 [15] series standards, LCA studies comprise of four phases. Figure 1 depicts the relationship between these phases of the life cycle.

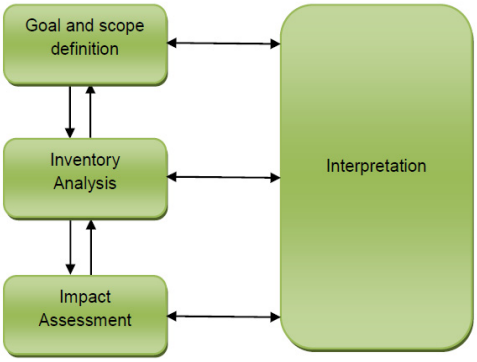

Fig. 1 Framework of LCA (Source: [15])

In this study life cycle assessment (LCA) methodology has been used to quantify the environmental impacts caused by training of a student in welding section of an Indian university's workshop per year. LCA has been performed from cradle to grave considering production of various raw materials starting from extraction till production of various tools/machines required for welding shop, their use phase and the end of useful life. Transportation of raw material, and processes for production of various tools and equipments have not been included in the LCA. The analysis was conducted using Umberto NXT universal software and Eco-invent v3.0 dataset [16]. In this study CML 2001 and Impact 2002+ valuation standards have been utilized to determine the environmental impacts. Attention has been focused on the calculation of masses of GHG expressed as CO_2 Kg equivalent emitted during entire life cycle. Hot spots have been identified and discussed in detail in results and discussions section of study.

3.2. Goal and Scope Definition

Every year 850 undergraduate students get training in different engineering shops and perform the respective practical and make demonstrable job for the purpose of learning and evaluation. Welding shop is one of the shops where student practice and make job using both gas and arc welding processes. Our goal is to assess impact on environment due these processes for training of one student per year at welding shop in the workshop. Product systems under the scope definition are gas welding and arc welding. The reference flow of the study is the arc welding and gas welding performed per student per year during training in the welding shop. The purpose of the study is to determine the impacts associated with this flow 0.5m arc welding and 0.5m gas welding per student per year.

3.3. System Boundary