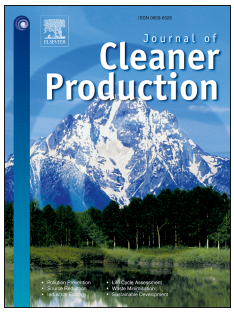
Accepted Manuscript



Life Cycle Assessment of Wire + Arc Additive Manufacturing compared to green sand casting and CNC milling in stainless steel

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PII: S0959-6526(17)33107-4

DOI: 10.1016/j.jclepro.2017.12.148

Reference: JCLP 11543

To appear in: *Journal of Cleaner Production*

Please cite this article as: Anne C.M. Bekker, Jouke C. Verlinden, Life Cycle Assessment of Wire + Arc Additive Manufacturing compared to green sand casting and CNC milling in stainless steel, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2017.12.148.

LIFE CYCLE ASSESSMENT OF WIRE + ARC ADDITIVE MANUFACTURING COMPARED TO GREEN SAND CASTING AND CNC MILLING IN STAINLESS STEEL

Abstract

Wire and Arc Additive Manufacturing (WAAM) is a metal 3D printing technique based on robotic welding. This technique yields potential in decreasing material consumption due to its high material efficiency and freedom of shape. Empirical measurements of WAAM, using a deposition rate of 1kg/h, were performed on site of MX3D. The measured power consumption per kg stainless steel is 2.72 kW, of which 1.74 is consumed by the welder, 0.44 by the robotic arm, and 0.54 by the ventilation. The material loss was 1.1%. A 98% argon 2% CO2 welding gas was used with a flow of 12 l/min.

A cradle-to-gate Life Cycle Assessment (LCA) was performed. To give this assessment context, green sand casting and CNC milling were additionally assessed, through literature and databases. The purpose of this study is to develop insight into the environmental impact of WAAM. Results indicate that, in terms of total ReCiPe endpoints, the environmental impact of producing a kg of stainless steel 308l product using WAAM is comparable to green sand casting. It equals CNC milling with a material utilization fraction of 0.75. Stainless steel is the main cause of environmental damage in all three techniques, emphasizing the importance of WAAM's mass reduction potential. When environmentally comparing the three techniques for fulfilling a certain function, optimized designs should be introduced for each manufacturing technique. Results can vary significantly based on product shape, function, materials, and process settings.

Keywords: LCA; additive manufacturing; wire + arc additive manufacturing; metal 3D printing; environmental impact

1 INTRODUCTION

The fabrication of metal parts and products is a significant contributor to multiple aspects of environmental damage (Norgate et al. 2007). The impact of the metal industry is especially high in the aircraft sector due to high buy to fly ratios that result in high waste volumes. Furthermore, the requirement of spare parts in automotive and aerospace industries implies a large volume of unused stock that cannot be repurposed (Rossetti & Choi 2005). Such requirements also lead to a conservative innovation strategy. In the last decades, additive manufacturing (AM) or 3D printing techniques have been developed. AM is a means of building up a 3D shape by 'printing' (depositing, solidifying, or fusing), layer on top of layer (Gibson et al. 2010). Although AM is typically slower than conventional manufacturing technologies, it enables one-off products, customization, makes the supply chain redundant and lead times shorter. AM is often seen as a disruptive technology, which does not only offer production flexibility and customization, but also material and resource efficiency (Huang et al. 2013).

It is important to assess the full environmental impact of new manufacturing techniques, to enable others to make a well-informed choice environmentally-wise. At this moment, there is limited research on the environmental impact of AM techniques, specifically for metal production (Bekker et al. 2016). While such techniques may be more efficient in material consumption, its energy use per produced part is considerable (Baumers et al. 2016). (Huang et al. 2016) on the other hand, highlights the energy savings potential in the case of lightweight aircraft components.