WIRE ARC ADDITIVE MANUFACTURING

CASE STUDY

Wire Arc Additive Manufacturing (WAAM) minimises environmental impact for marine components

Gone are the days when companies used to give a nod to sustainability. Now it is an integral part of profitability and business success. In the marine industry, as well as setting emission reduction targets, many operators are looking to improve the sustainability credentials of the components that they source.

Alongside traditionally manufactured parts, another process for large-scale metal components - Wire Arc Additive Manufacturing (WAAM) – has been delivering significant environmental benefits. A case in point is a recent marine life cycle assessment carried out by leading wire arc additive manufacturer WAAM3D, that has demonstrated the potential of this technology for delivering sizeable environmental impact savings for component creation.

Project information:

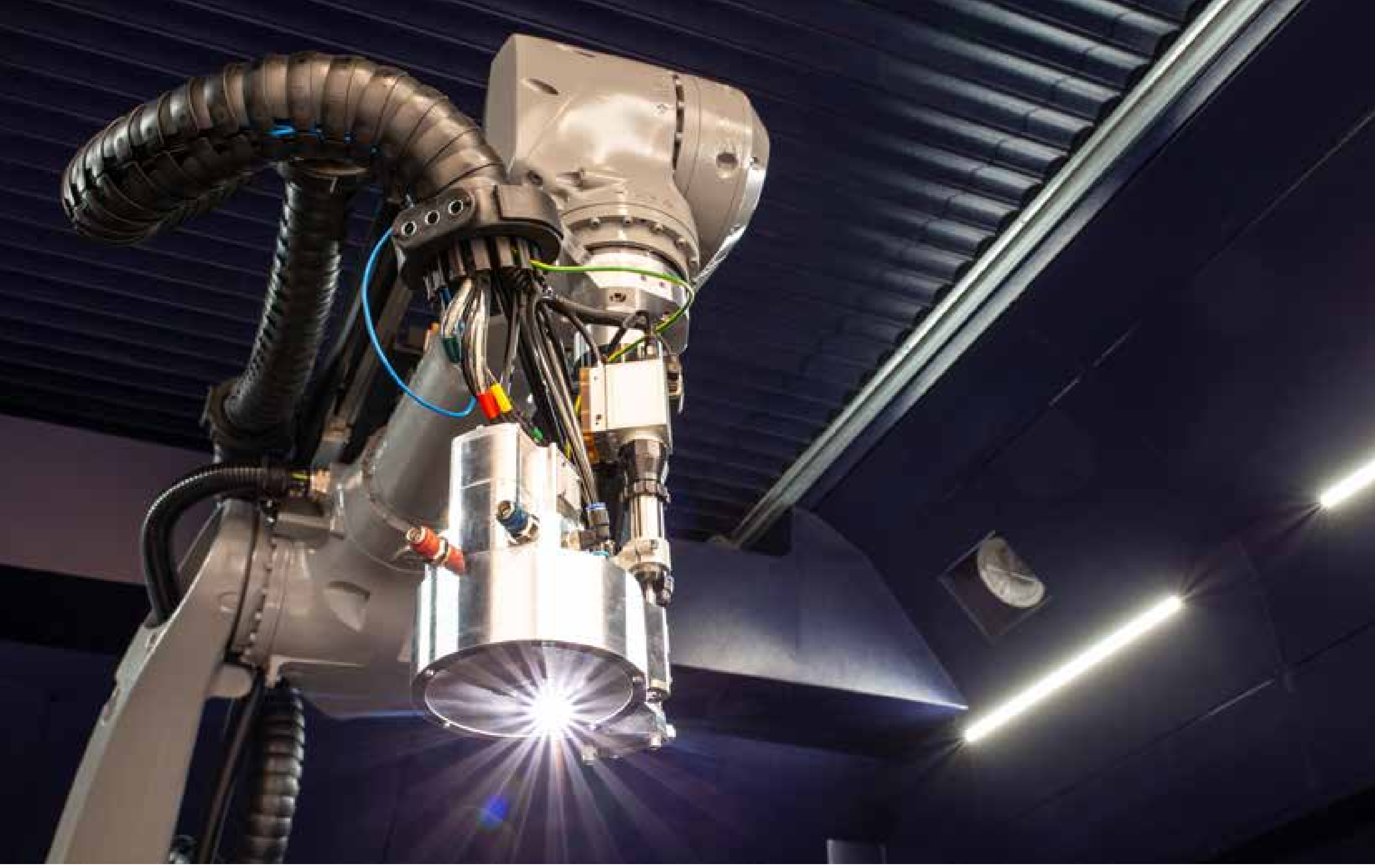
MARINE LIFE CYCLE ASSESSMENT

Objective:
To assess the environmental impact of a marine part made using traditional machining from billet compared to manufacturing via the WAAM process.

Process:
Completed an environmental impact assessment of the product based on the life cycle assessment methodology according to the guidelines of ISO 14044:2006.

Following a "cradle-to-gate" approach, the project evaluated all the main product life cycle phases from the extraction of the necessary raw materials ("cradle") to the shipment of the final product to the customer ("gate").

Learnings & outcomes:
The WAAM component demonstrated a 40% reduction in environmental impact.



Comparing WAAM and traditional machining

WAAM3D, in conjunction with a maritime supplier, and Cranfield University, wanted to assess the environmental impact of a part made using traditional machining from billet, compared to a part made using WAAM. They undertook a Life Cycle Assessment (LCA) of a demonstrator part from a maritime supplier and compared to this to a part made using WAAM technology.

Both parts were made from Ti-6Al-4V. The demonstration part had a final mass of 49.8 kg and if machined traditionally, it would have had a Buy-To-Fly (BTF) ratio of 10. The preform made by WAAM was built on three different substrates. The mass deposited was 75 kg. After machining, the three sections were butt-welded together..

Environmental impact assessment

The environmental impact assessment of the product was based on the life cycle assessment methodology according to the guidelines of ISO 14044:2006. In particular, the scope of the study followed a “cradle-to-gate” approach, evaluating all the main product life cycle phases from the extraction of the necessary raw materials (“cradle”) to the shipment of the final product to the customer (“gate”). Material flows were evaluated for each manufacturing route – conventional and WAAM - modelling the chain of life cycle phases using a mathematical graph that was topologically sorted.

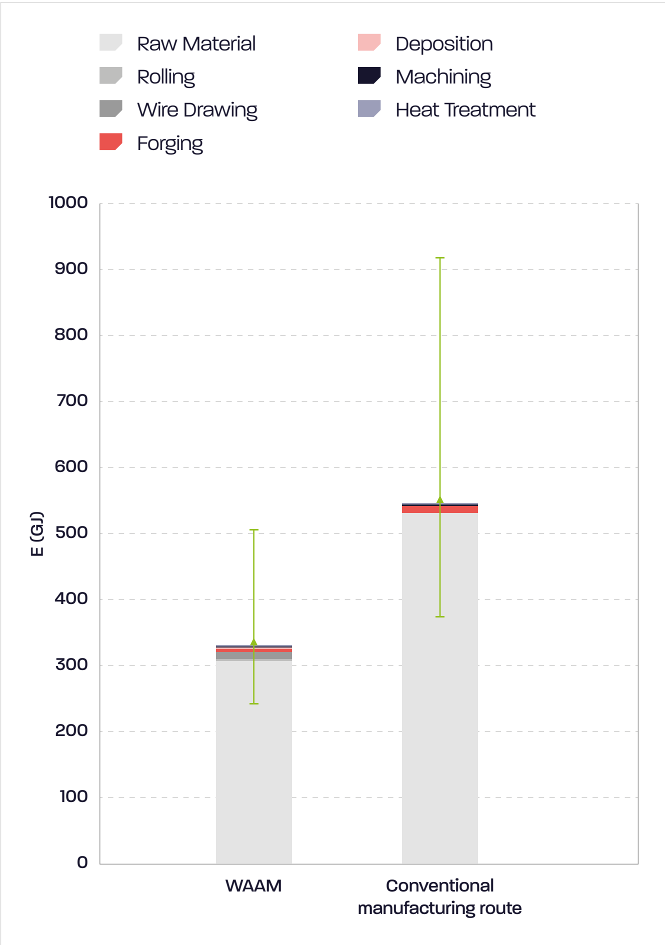
Input data allocation and aggregation were obtained from the commercial database Granta Edupack 2021. The only exception was the WAAM deposition and heat treatment phases. The characterisation factors and process material efficiency were estimated for the metal deposition by laboratory measurements, and the heat treatment phase by first principles combined with regression models, based on the manufacturer’s data of vacuum furnace systems.

For these two phases, assumptions were made to convert the electric energy consumption to primary energy and to carbon dioxide equivalent emissions. The former was done using a primary energy factor, to contribute to the product embodied energy. The latter used the carbon intensity of the electric grid, to contribute to the embodied carbon dioxide equivalent emissions. Assumptions were made to quantify the impact of transportation of the final alloy in the supply chain.

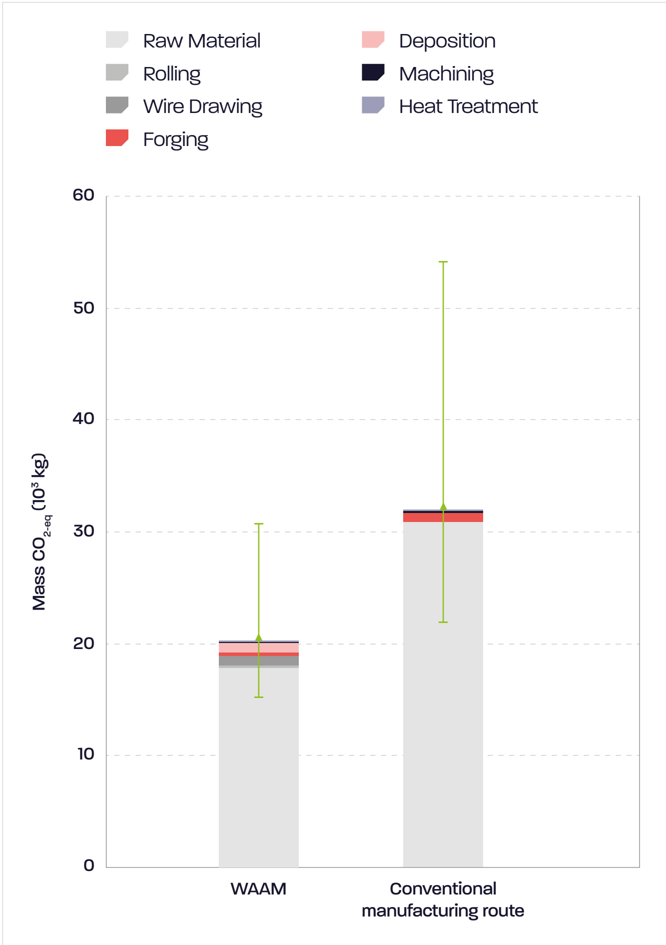
Table 1: Source and specifications of life cycle phases

Life cycle phase	Source	Specifications
WAAM deposition	Laboratory measurements	**Heat source:** CMT **Deposition rate:** 1.2 kg/hr **Shielding:** local
Heat treatment	First principles and regression models	**Furnace:** electric vacuum **Temperature set point:** 700°C **Time:** 3 hours **Cooling:** with air **Electric to primary energy factor:** 0.4 **Carbon intensity of the electric grid:** 425 gCO_2-eq/kWh (world average in 2021)
Transportation of final alloy in the supply chain	Granta Edupack 2021	**Total distance:** 500 km **Mode:** 32-tons capacity, 4-axle truck
All remaining	Granta Edupack 2021	**Material:** Ti-6Al-4V alloy

With this information, output error bars were constructed that cumulatively combined "pessimistic" and "optimistic" estimates for all input data available in the ranges (e.g. for different geographical locations or technological level of processes).



Embodied energy consumption of the main product life cycle phases from the extraction of raw materials until the shipment to the customer for the two manufacturing routes considered.



Embodied carbon dioxide equivalent emissions of the main product life cycle phases from the extraction of raw materials until the shipment to the customer for the two manufacturing routes considered.

Significant environmental impact reduction using WAAM

The results of this life cycle assessment have shown a significant reduction of environmental impact - according to the selected characterisation factors - when traditional, subtractive fabrication approaches are substituted with WAAM. In fact, the WAAM component demonstrates a 40% reduction in environmental impact compared to the demonstration part.

Dr Filomeno Martina, co-founder and CEO of WAA3D concludes: "It is no surprise that WAAM came out so well in this life cycle assessment of marine components. Raw material production is by far the major contributor to a product's environmental impact and forging, wire production and wire deposition are relatively small contributors compared to traditional billet. This shows that as well as enabling cost savings, WAAM can be preferrable to traditional approaches when environmental impact is of importance to the operator."

Note: Credit for the research goes to Dr Emanuele Pagone, a Research Fellow in Sustainable Manufacturing Modelling at the Sustainable Manufacturing Systems Centre, Cranfield University.

info@waam3d.com
+44 (0)1234 754693
WAAM3D.COM

WAAM3D Limited
5 Thornton Chase
Milton Keynes
MK14 6FD
United Kingdom