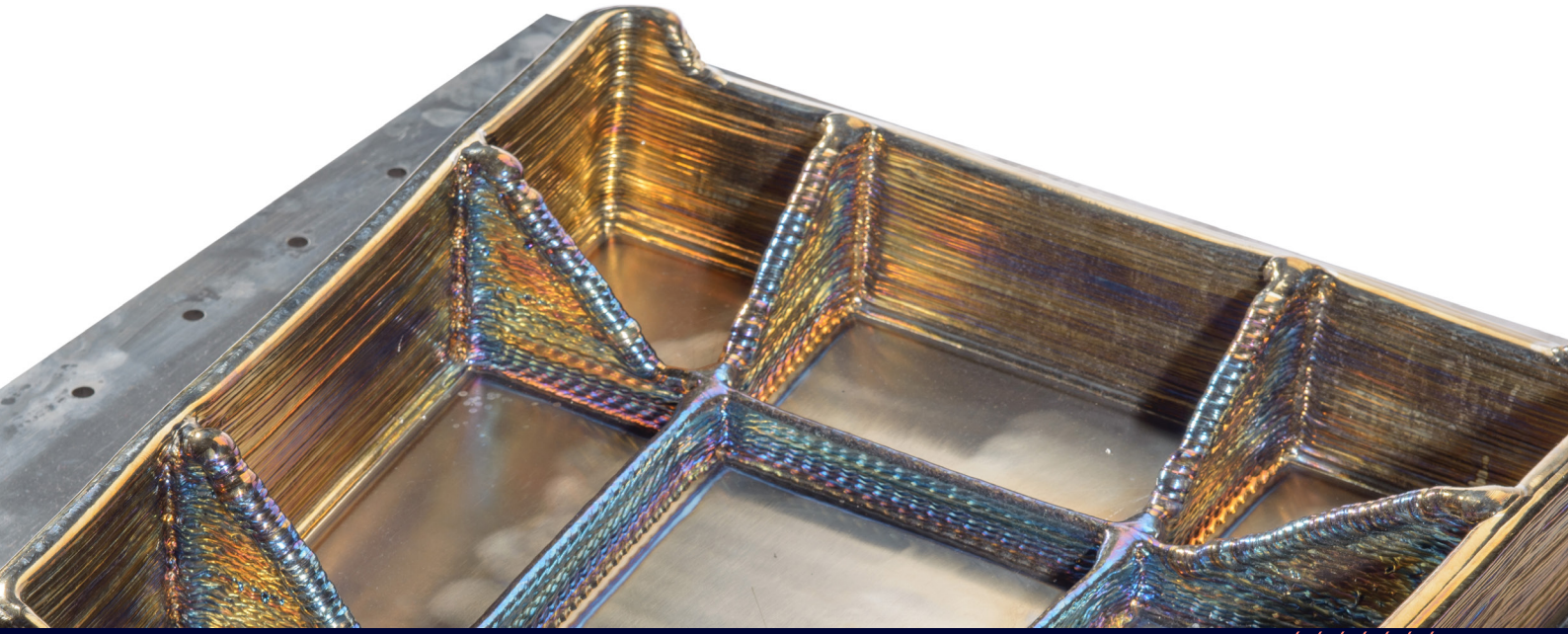
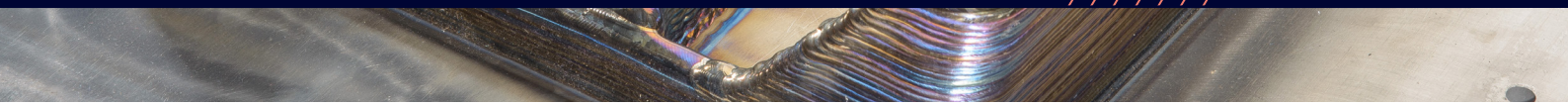


WIRE ARC ADDITIVE MANUFACTURING

Life Cycle Assessment for 3D Metal Printed Components



Growing use of 3D metal printing

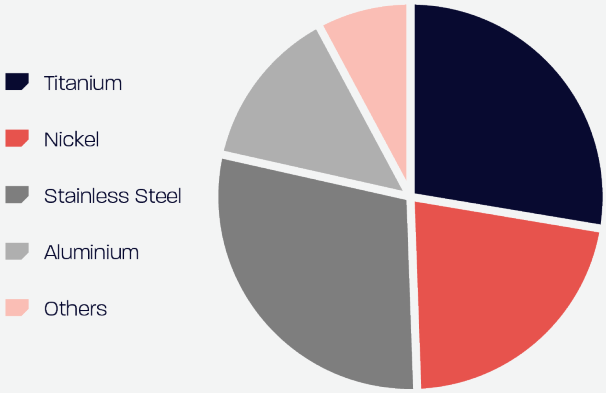
When 3D printing was introduced in the second half of the 20th century, there was no way to really understand its potential for healthcare, automotive, transportation, biotechnology and industrial applications. Since then, the global 3D metal printing market grew to USD 380.3 million by 2020 and is expected to expand at a staggering CAGR of 25.7% between 2021 and 2028[1].

3D printing, also known as Additive Manufacturing (AM), can be used to create a wide array of items: ranging from the smallest of dental crowns to large structural aerospace frames. It uses significantly less material than other forms of product creation, such as subtractive processes, and 3D printing is able to reduce the timeline from prototyping to production, further driving demand from producers.

Titanium on the rise

A range of metals are used for 3D printing and the one that is predicted to grow the fastest over the coming years is titanium, with stainless steel a close second[2]. Not surprisingly, the potential of titanium 3D printing technology is being actively explored in industries that are able to bear the high initial costs of implementation, such as aerospace and defence. With the significant material savings that can be achieved using AM technologies, it is no surprise that high-cost titanium is being prioritised for use in these processes.

Global 3D Printing Metal Market
share, by product, 2020 (%)



Source: www.grandviewresearch.com

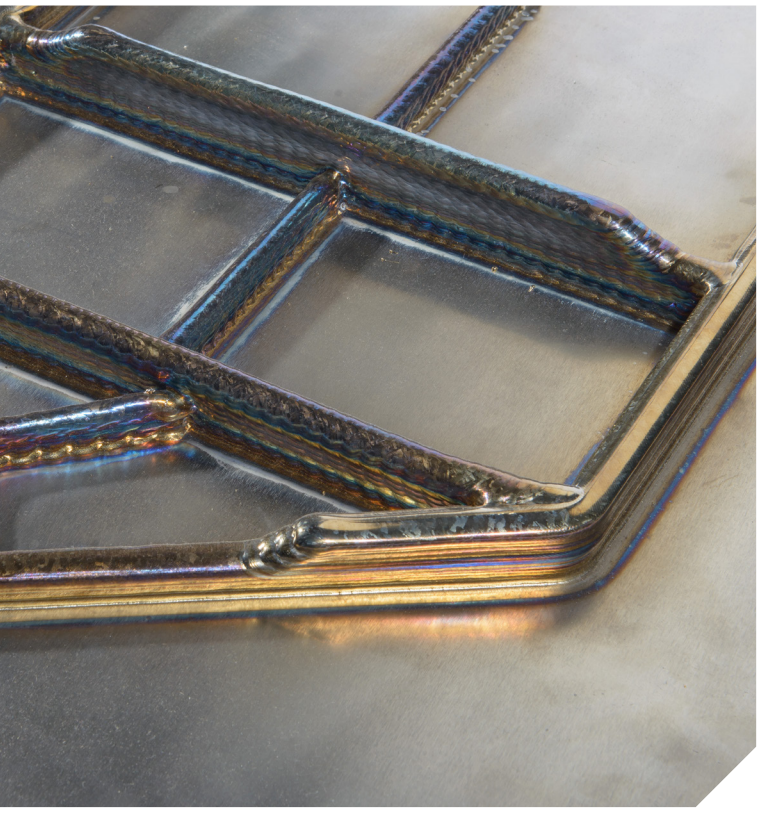
Consideration factors for 3D metal printing processes

Factors	Wire-feed technology (WAAM)	Powder-feed technology (LMD and PBF)
Raw material usage	Higher material efficiency of the process (90% -100%)[i], although finish-machining might be required[ii]	Lower material efficiency (~50%)[i]
Financial benefit	Low part cost[i, iii]	Very high part cost[i]
Accuracy	Lower accuracy achieved[iv]	Higher accuracy achieved[v]
Speed	Higher deposition rates[vi]	Lower deposition rates[vii]
Complexity	Lower to medium level of complexity achieved[vii]	Higher complexity levels achieved[vii]
Production safety	No powder handling required[viii]	Safety issues -Needs to be confined and presents fire hazards[ix]

i Colegrove 2010; D. Ding et al. 2015b
ii D. Ding et al. 2015a; S. W. Williams et al. 2016b
iii Busachi et al., 2017,Busachi et al., 2018
iv Szost et al. 2016; Zhang et al. 2016
v Gibson et al. 2015
vi Dilip & Ram 2012
vii Colegrove 2010
viii Zhang et al. 2016
ix Williams et al. 2017

3D metal printing saves resources

A key selling point for 3D metal printing in all its forms is its more precise use of the raw material to create the product, compared to subtractive manufacturing methods such as CNC milling and grinding. Depending on which 3D metal printing process is being used, more or less waste feedstock is achieved; with wire-feed technology such as wire-arc additive manufacturing (WAAM) showing higher material efficiencies of 80-90%, compared to powder-feed technologies (powder bed fusion (PBF) and laser metal deposition (LMD)) that are shown to be only 50% material efficient[3].



Growing importance of the triple bottom line

In years gone by, businesses focused purely on the financial bottom line to discern their success. However, with the growing environmental and societal agenda demanding that businesses become more accountable to a wide variety of stakeholders, measuring success via a triple bottom line – as coined by John Elkington almost 25 years ago - is becoming an essential, not a 'nice to have'.

The Triple Bottom Line - Business Success has Evolved

As part of the triple line argument, it has become clear that the people, the planet and prosperity are all interconnected. If financial success is to be long-term, then the other two factors need to be built into a company's processes. When it comes to 3D metal printing however, how can producers accurately measure its environmental impact and make more sustainable decisions?

More sustainable 3D metal printing decisions

With the triple bottom line increasingly driving manufacturing decisions, life cycle assessment is becoming ever more important to gauge the environmental performance of 3D metal printed products. Afterall, 3D metal printing technologies may use less raw material and produce less scrap than conventional production techniques, but an assessment of potential environmental impact cannot be based on this data alone.

To achieve the best possible conclusion of the environmental impact of the 3D metal printing process, as wide a technological context as possible needs to be used. This includes assessing the details of raw material extraction, the production material manufacturing technology chosen, the service life of the final product and the environmental impact of any waste produced[4].

Life Cycle Assessment includes:

- Initial material sourcing phase - recovery of non-renewable raw materials, energy sources from the environment and essential renewable materials (eg. crude oil, ore extraction, water usage).
- Material production phase - use of fuels, electric energy, and other resources.
- Product manufacturing phase - conversion of materials for manufacturing, creation of the product, including its packaging.
- Consumer use phase – repairs, maintenance, storage, any energy and raw material requirements to use the product.
- Disposal phase – energy to dispose of the product, re-use it or recycle it.
- Transportation – needs to be considered between each of the phases too.

WAAM3D Consult in practice

In the recent development of an advanced marine platform, the defence contractor was tasked with delivering value as well as showing the environmental footprint of key components. WAAM3D Consult worked in close partnership with the supplier of 3D printed parts to deliver accurate environmental footprint data for these components compared to their forged equivalents.

- Environmental impact assessment of the product completed, 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”).
- **The WAAM component demonstrated a 40% reduction compared to the demonstration part.**

Improving environmental footprint through accurate modelling

With the lifecycle of a product interacting with the environment in many ways, accurately assessing a 3D metal printed component’s environmental impact can be a complex task. That is why WAAM3D has created its environmental assessment service. WAAM3D Consult is aimed at helping 3D metal printers deliver accurate environmental footprint data to their customers - enabling the end purchaser to make well-grounded ethical and cost decisions.

As a company, WAAM3D was created following years of collaborative academic research between experts at Cranfield University, who were tasked with exploring the potential of WAAM for medium- and large-scale component manufacturing. As well as offering wire-arc additive manufacturing component production to customers, its WAAM3D Consult environmental modelling consultancy service enables a wide range of 3D metal printing companies to make the most of the latest in environmental modelling intelligence.

The accuracy of environmental modelling is based on the quality of the data that has been inputted and how well it aligns with the actual process being carried out on site. WAAM3D has access to proprietary, in-depth models, process and environmental footprint data to help deliver highly accurate assessments.

When it comes to 3D metal printing it is now possible for producers to accurately measure the environmental impact of their products, and make more sustainable decisions, thanks to the advanced modelling solutions available with WAAM3D Consult.

Sources:

1 3D Printing Metal Market Size, Share & Trends Analysis Report By Product (Titanium, Nickel), By Form (Filament, Powder), By Application (Aerospace & Defense, Medical & Dental), By Region, And Segment Forecasts, 2021 – 2028, Grand View Research, October 2021
2 ibid
3 Colegrove 2010; D. Ding et al. 2015b
4 Jan Vŷtisk et al. Current options in the life cycle assessment of additive manufacturing products. Open Engineering, 20 Dec 019

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