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Effect of Scan Strategy in Directed Energy Deposition of SA508 Gr.3 on Charpy V-notch Impact Energy

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1. Introduction

As the drive to enhance the features of small modular reactors grows, there is a trend towards designing reactor pressure vessels with intricate shapes made of SA508 Gr.3. Such vessels not only have compact volumes but also offer superior safety features. These requirements necessitate excellent mechanical properties, which are challenging to achieve with traditional manufacturing processes.

Additive Manufacturing (AM), on the other hand, stands out as a method that can address this challenge. AM builds components by stacking material layer by layer. Its rapid cooling rate and ability to craft intricate parts with impressive mechanical strength have earned AM significant attention. A recent study on AM's capability to manufacture low alloy steel, such as SA508 Gr.3, has indicated that variations in thermal conditions influence the microstructure and phase fraction, subsequently affecting mechanical properties [1,2].

In light of these findings, our objective was to craft samples under different thermal conditions, using a scan strategy that modulates these conditions. We then intended to analyze the Charpy-V notch energy characteristics of these samples across a temperature spectrum. We employed Directed Energy Deposition (DED) for the AM process, which involves melting metal powder with a laser during its spray. DED's rapid production rate makes it ideal for large component manufacturing. Our research underscores that, with tailoring thermal conditions, it's possible to achieve Charpy-V notch impact energy levels comparable to traditionally made samples without necessitating any additional heat treatment.

2. Experimental methods

The spherical SA508 Gr.3 powder with a range of 50~150 μm in size was used to manufacture cuboid samples through DED by changing the scanning strategy called long raster and short raster scan strategy. The samples with long raster have experienced relatively rapid re-heating between the track formation. The fabricated samples were etched using 2% Nital solution to observe their microstructural characteristics.

The Charpy V-notch samples were processed based on build direction and tested over a temperature range of -196~50℃. The transverse direction and longitudinal direction indicate perpendicular and parallel to the build direction.

3. Results

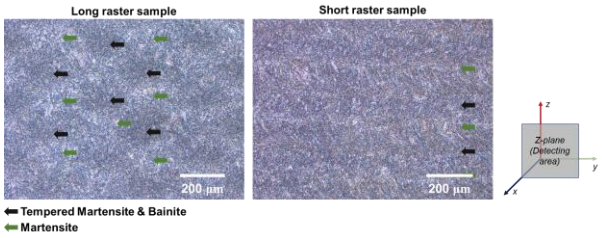

Fig. 1 Effect of scan strategy on microstructure constituting martensite, tempered martensite, and bainite

Figure 1 depicts the Nital etched surfaces of samples fabricated with diverse scanning strategies along the build direction. The long raster sample distinctly displayed a band structure with brighter regions indicating martensite and darker areas suggestive of bainite or tempered martensite. The martensite phase, with an arc shape, forms at the melt pool boundaries due to its high rate of thermal heat extraction into the previous layers. Similarly, the short raster sample has martensite regions, but the fraction is small, indicating relatively low thermal heat extraction. This indicates that thermal conditions vary based on the scanning strategies employed.

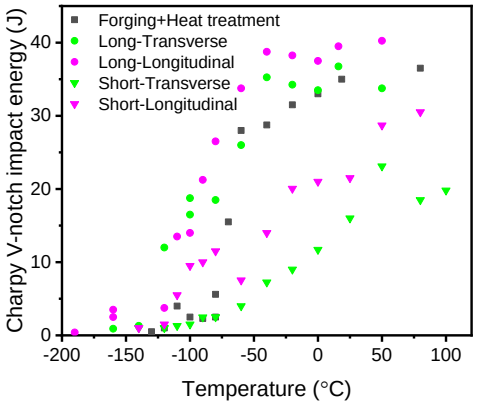

Fig. 2 Charpy V-notch impact energy depending on temperature and samples.

Figure 2 illustrates the Charpy-V notch impact energy of DED-crafted samples with varied scan strategies, contingent upon temperature. The long raster sample shows isotropic Charpy V-notch energy with 35~39 J as upper shelf energies depending on build direction, and the values are comparable to that (34 J) of conventionally made samples. However, the short raster sample represents anisotropic Charpy V-notch energies with 18~30 J as upper shelf energies depending on build direction.

3. Conclusions

SA508 Gr.3, an essential component alloy of the reactor pressure vessel (RPV) was fabricated using directed energy deposition (DED) with different scanning strategies. SA508 Gr.3, a core component of the reactor pressure vessel, was fabricated using directed energy deposition by varying scan strategies. The resultant Charpy V-notch energy, contingent upon temperature, was evaluated. Samples produced using the long raster scan strategy showed promising results, rivaling conventionally made counterparts. This suggests that with apt thermal condition modulation, DED-produced samples might be viable for use in reactor pressure vessels, eliminating the need for additional heat treatments.

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