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Effect of Hatch Distance on Mechanical Properties of SA508 Gr.3 made by Powder Bed Fusion

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1. Introduction

Reactor pressure vessels (RPVs) are critical components of nuclear reactors, as they contain the coolant and the reactor core, ensuring the safe and efficient operation of the entire system. The materials used in RPVs must exhibit exceptional mechanical properties, including high strength and a low ductile-to-brittle transition temperature (DBTT), to withstand the demanding conditions within a reactor. However, traditional manufacturing techniques such as welding and forging, while effective, present significant limitations in fabricating complex geometries. These conventional methods often require substantial time and financial resources, making them less ideal for modern, intricate designs.

Additive manufacturing (AM) offers a transformative approach to component fabrication by enabling the layer-by-layer construction of parts directly from digital models. Metal AM techniques, such as directed energy deposition (DED) and powder bed fusion (PBF), have already demonstrated significant potential in industries like aerospace, automotive, and medical devices due to their ability to process high-performance alloys. Despite its widespread success in these fields, the application of AM in the nuclear industry is still in its early stages. However, it holds considerable promise, particularly for the production of RPV materials. For example, recent studies, such as those conducted by Jeong et al[1]., have shown that DED can enhance the strength and reduce the DBTT of SA508 Gr.3, attributing these improvements to factors such as refined grain structure and the formation of dislocation cell structures under controlled thermal conditions.

Building on this foundation, our research investigates the impact of process parameters on RPVs composed of SA508 Gr.3 using the PBF technique. Specifically, we focus on controlling the hatch distance to achieve rapid cooling rates, leading to smaller grain sizes. Comprehensive mechanical testing, including Charpy V-notch impact and tensile tests, was conducted to compare the performance of PBF-manufactured samples with those produced through conventional fabrication methods. Our study aims to further enhance the mechanical properties of RPV materials, contributing to safer and more efficient nuclear reactor designs.

2. Experiment

The chemical composition of the SA508 Gr.3 powder met the required range of particle sizes, ranging from 15 to 53 μm (Table 1). The specific process parameters included a laser power of 180W, a layer thickness of 30 μm, a rotational scan strategy of 67˚ , and a hatch distance of 0.04-0.06 mm.

Table 1 Chemical composition of SA508 Gr.3 used in this study

Chemical composition	ASME Requirements	Measured composition
Fe	Bal.	Bal.
Mn	1.2-1.5	1.36
Mo	0.45-0.6	0.49
Ni	0.4-1.0	0.47
Cr	<0.25	0.21
Si	<0.4	0.12
C	<0.25	0.21

3. Result

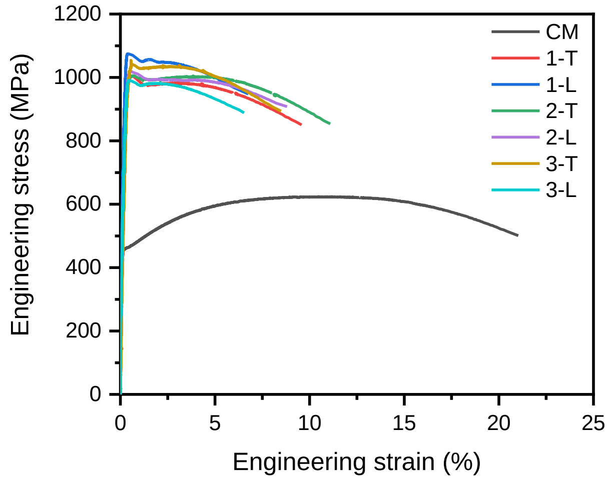

Fig. 1 Stress-strain curves as a function of hatch distance and build direction. 1, 2, and 3 represent hatch distances of 0.04 mm, 0.05 mm, and 0.06 mm, respectively. T and L denote the transverse and longitudinal directions, respectively. CM indicates conventionally manufactured samples.

Figure 1 shows the representative stress-strain curves as a function of hatch distance and build direction. Compared to conventionally manufactured samples (CM), the PBF-printed SA508 Gr.3 samples exhibit more than 100% higher yield strength, regardless of hatch distance and build direction. However, in terms of elongation, all the PBF samples demonstrate lower values than the CM samples.

4. Conclusion

The effect of hatch distance on the mechanical properties of SA508 Gr.3 produced by powder bed fusion was investigated. The tensile properties of SA508 Gr.3 fabricated by powder bed fusion are consistent regardless of build direction and hatch distance, with yield strength exceeding that of conventionally manufactured samples by more than 100%. This result suggests that additively manufactured SA508 Gr.3 can enhance the mechanical properties of reactor pressure vessel components.

REFERENCES

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