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Effect of Scan Strategy of SA508 Gr.3 Constituting Reactor Pressure Vessel on Mechanical Properties in Directed Energy Deposition

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1. Introduction

As interest in small modular reactors (SMRs) increases, the research interest in advanced manufacturing that can produce complex shape while maintaining performance is also growing. Additive manufacturing, one of these promising technologies, involves forming parts by depositing materials layer by layer. Directed energy deposition (DED) is a type of additive manufacturing methods suitable for producing large parts by melting a metal material at a desired location to create a specific shape [1].

In this study, we evaluated the possibility of using additive manufacturing to produce samples with SA508 Gr.3, which is a constituent material of the reactor pressure vessel. As a result of mechanical property evaluation, it was confirmed that the parts manufactured using appropriate process conditions met the required mechanical properties of conventionally manufactured parts, without additional heat treatment processes. Therefore, DED offers the possibility of manufacturing small modular reactor parts.

2. Methods

The spherical SA508 Gr.3 powder, with the composition as provided in Table 1, was used to fabricate samples through additive manufacturing by changing the scanning strategy. The fabricated resulting samples were etched using 2 % Nital solution to observe their microstructural characteristics. The samples were processed along the stacking direction, and their mechanical properties were evaluated using tensile tests, which were conducted with digital image correlation.

Table 1 Chemical composition of the powder

Element	Mn	Mo	Ni	Cr	C	Fe
Content	1.36	0.49	0.92	0.21	0.21	Bal.

3. Results

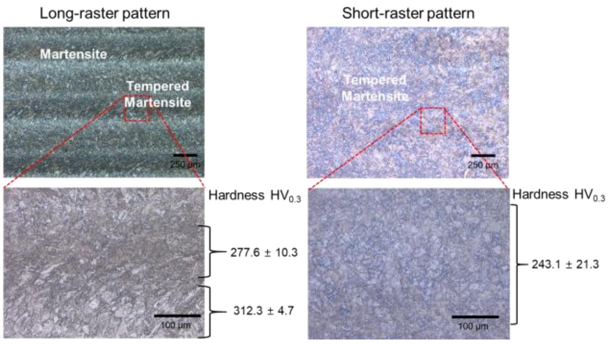

Fig. 1. The optical microscope images of the samples, fabricated depending on the scan strategy, were etched using Nital solution.

Figure 1 presents the sample fabricated using the different scanning strategies and etched with Nital solution. The long raster sample displayed a band structure in which martensite and tempered martensite appeared repeatedly, while the short raster samples mainly exhibited tempered martensite, with a small amount of martensite. Vickers hardness measurements revealed that the long raster sample had a hardness of about 312 ± 5 HV in the martensite region, which was approximately 10 % higher than the tempered martensite region's hardness of 277 ± 10 HV. However, compared to the short raster sample's hardness value of 243 ± 21 HV, it had a higher average hardness value.

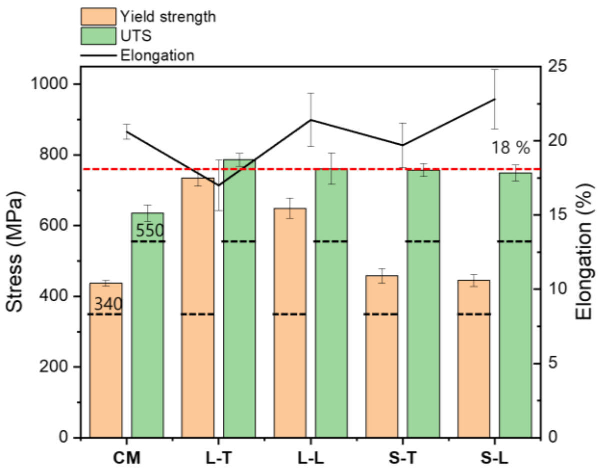

Fig. 2. The average tensile properties, depending on the build direction and scan strategy, are indicated, as well as the ASME requirements.

Figure 2 presents the tensile properties of the samples manufactured with different scanning strategies and build directions. The conventionally manufactured sample is labelled as CM, while the first letters L and S indicate the scanning strategy, and the second letters T and L denote the build direction. The long raster samples displayed relatively higher yield strength than the short raster samples. However, the long raster sample exhibited anisotropic behavior with varying tensile properties depending on the stacking direction. In contrast, the short raster sample displayed reduced mechanical anisotropy compared to the long raster sample and had elongation characteristics similar to those of the conventionally manufactured sample.

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. The short raster scan strategy produced mechanical properties comparable to those of conventionally manufactured parts, without requiring additional heat treatments. These findings demonstrated that selecting appropriate process conditions in DED can yield components with mechanical properties similar to those of conventionally manufactured parts.

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