Mechanical Properties of SA508 Gr.3 Low Alloy Steel made by Laser Power Directed Energy Deposition

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1. Introduction

Small modular reactors (SMRs), notable for their compact size and superior safety features, have garnered significant interest in the nuclear energy sector. Specifically, pressurized water reactors (PWR), a category of SMRs, utilize reactor pressure vessels (RPVs) as a critical safety component. The evolving design complexities of RPVs necessitate enhancements in mechanical properties to leverage the full benefits of SMRs. Consequently, there is a growing emphasis on exploring advanced manufacturing technologies to fulfill these stringent requirements[1].

Laser powder directed energy deposition (LPDED), additive manufacturing (AM) technology, manufactures parts by spraying metal powder and melting and solidifying it using a laser beam. Recently, it has been reported that SA508 Gr.3 low alloy steel, the material comprising RPVs, can be used to control the heat accumulation characteristics using LPDED to achieve superior room temperature tensile and impact properties compared to conventionally made samples without heat treatment. However, RPVs are required to have excellent mechanical properties not only at room temperature but also at high temperatures, but no study has been reported to evaluate the mechanical properties at high temperatures.

Therefore, in this study, SA508 Gr.3 low alloy steel samples were fabricated using LPDED, and their mechanical properties at room temperature and high temperature were evaluated. The results of the tensile property evaluation showed that the tensile properties were relatively superior to those of conventionally made samples at high temperatures as well as at room temperature.

2. Experimental methods

For the experiments, spherical SA508 Gr.3 powder, with particle sizes ranging from 50 to 150 μm, was utilized to fabricate cuboid samples via LPDED. Tensile specimens, designed in a dog-bone shape to ensure uniform stress distribution, were extracted along different orientations relative to the build direction. Tensile tests were systematically conducted across a temperature range from ambient up to 650 ˚C to evaluate mechanical properties under varying thermal conditions.

3. Results

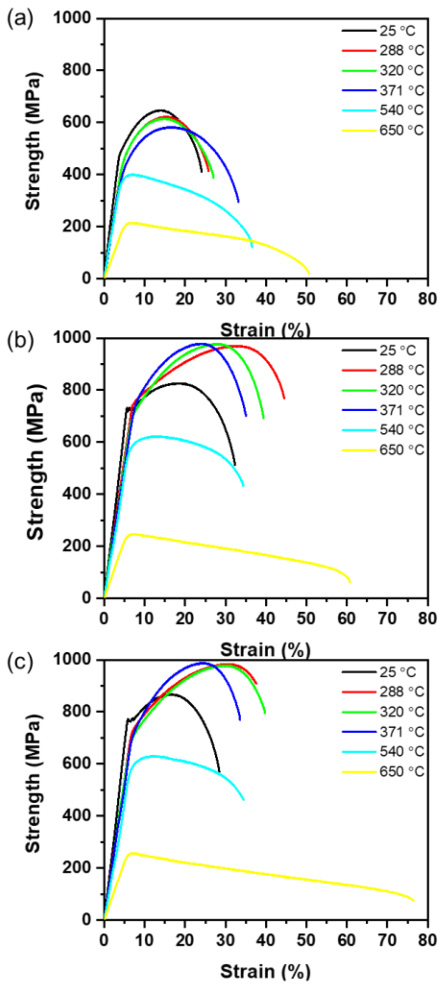

Figure 2 Tensile properties depending on test temperature. (a) Conventionally made samples, and LPDED printed samples extracted along (b) transverse and (c) longitudinal direction

Figure 3 presents the results from the tensile tests, illustrating the temperature-dependent mechanical behavior of both conventionally manufactured and LPDED-printed samples. Notably, the LPDED-printed samples exhibited an enhanced yield strength by 48% to 86% over their conventionally manufactured counterparts, across a broad temperature spectrum extending from room temperature to 540˚C. Furthermore, while the LPDED-printed samples demonstrated distinct anisotropic tensile properties at ambient temperatures, this anisotropy significantly diminished at temperatures exceeding 288˚C.

4. Conclusion

This investigation has quantitatively assessed the high-temperature mechanical properties of LPDED-printed SA508 Gr.3 low alloy steel, establishing a clear superiority over conventionally manufactured samples in terms of strength across a range of temperatures. Moreover, the study highlights a notable reduction in mechanical anisotropy at temperatures above 288˚C, underscoring the potential of LPDED technology in enhancing the performance and reliability of reactor pressure vessels.

REFERENCES

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