# Mechanical Properties of Dissimilar Metal Weld Joints made by Laser Power Directed Energy Deposition

Lee Tae Yang, Wonjong Jeong, Ho Jin Ryu*
*Nuclear & Quantum Engineering, KAIST, Daejeon, Daejeon 34141*
*Corresponding author: hojinryu@kaist.ac.kr

***Keywords : Dissimilar metal weld joint, reactor pressure vessel, laser powder directed energy deposition, additive manufacturing**

## 1. Introduction

Multi-material components, such as safe-end joints, are crucial in nuclear power plants for their adaptability to diverse loads and operational conditions. These components enhance efficiency through regionally tailored features. Dissimilar metal welds (DMWs), typically joining austenitic steel pipes (SUS 316) to ferritic reactor pressure nozzles (SA508 Gr.3) with nickel-based filler metal (Inconel 52), exemplify such technology [1]. The conventional fusion welding method, multi-pass gas tungsten arc welding (GTAW), requires significant heat input [2]. This process modifies the microstructure at the low alloy ferritic steel and austenitic Ni alloy interface, resulting in a large heat-affected zone (HAZ) and compromising quality. High heat input also induces substantial residual stress and the formation of brittle intermetallic phases due to excessive dilution. Consequently, electron beam or laser beam joining techniques are emerging as preferred methods to reduce the thermal impact on dissimilar materials, thereby preserving the structural integrity of nuclear components.

Laser Powder Directed Energy Deposition (LPDED), an additive manufacturing approach, offers advantages for creating large or heterogeneous parts. Its ability to deposit specific metal powders in targeted areas makes it promising for DMW joint production. However, the application of LPDED for manufacturing DMW joints and evaluating their mechanical properties remains unexplored.

This study investigates the use of LPDED to fabricate and analyze the microstructural and mechanical properties of heterogeneous material parts. We aim to assess the viability of LPDED for DMW joint manufacturing, marking a novel exploration in the field.

## 2. Experimental methods

Samples were manufactured using gas-atomized powders of SA508 Gr.3, SUS 316, and Inconel 52 (supplied by HANA AMT) via LPDED as shown in Fig. 1. The powders' particle size distribution, measured with a laser particle size analyzer, ranged from 54 to 150 µm. An Insstek Mx-4 metallic LPDED system equipped with a Yb fiber laser (IPG Photonics, 1070 nm wavelength) with a 1 kW maximum output was used for fabrication.

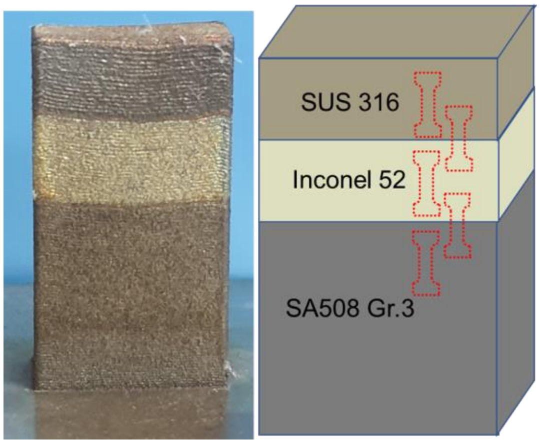

Figure 1 LPDED-printed dissimilar metal weld joints

## 3. Results

### 3.1 Microstructural characteristics

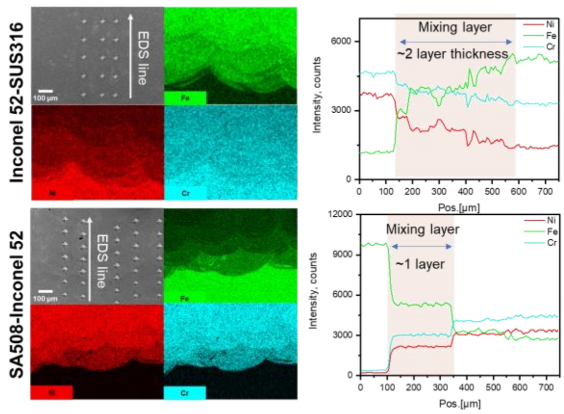

Figure 2 EDS results and chemically mixed layer on dissimilar metal weld joint

Energy Dispersive Spectrometer (EDS) analysis and the examination of the chemically mixed layer of LPDED-printed samples for DMW joints are presented in Fig. 2. The thickness of the chemically mixed layer at the SA508 Gr.3-Inconel 52 interface was approximately 260 µm, similar to that at the Inconel 52-SUS 316 interface. This uniformity is attributed to the differing thermal conductivities between SA508 Gr.3 and Inconel 52.

### 3.2 Mechanical properties

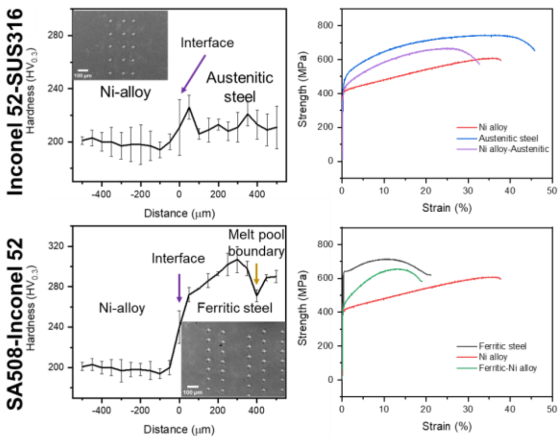


Figure 3 Mechanical properties on each interface

Hardness and tensile properties at the interfaces were also assessed as presented in Fig. 3. The hardness values were intermediate between those of the constituent materials, while the tensile properties, including yield strength and elongation measured at the interface.

## 4. Conclusion

This study represents the first attempt to fabricate dissimilar metal weld joints using LPDED, followed by an evaluation of their microstructural and mechanical properties. The EDS analysis confirmed a chemically mixed layer up to 520 μm. The mechanical testing results demonstrated intermediate properties between those of the dissimilar materials. This investigation underscores the potential of LPDED in producing DMW joints, paving the way for future research in this domain.

## Acknowledgments

This work was supported by the National Research Foundation of Korea(NRF) funded by the Ministry of Science and ICT(RS-2023-00257279)

## REFERENCES

[1] Zuback JS, Palmer TA, DebRoy T. Additive manufacturing of functionally graded transition joints between ferritic and austenitic alloys. J Alloys Compd 2019;770:995–1003. https://doi.org/10.1016/j.jallcom.2018.08.197.

[2] Hytönen N, Ge Y, Que Z, Lindqvist S, Nevasmaa P, Virkkunen I, et al. Study of fusion boundary microstructure and local mismatch of SA508/alloy 52 dissimilar metal weld with buttering. J Nucl Mater 2023;583. https://doi.org/10.1016/j.jnucmat.2023.154558.