Wear Behavior of Additive Manufactured Stainless Steels 304L for Nuclear Applications

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Guide card (GC) is the key component of a guide tube in pressurized water reactors (PWRs), which is housed inside a guide tube and designed to provide guidance for the movement of rod control cluster assemblies (RCCAs). In recent days, GC wear becomes an emerging issue in a PWR industry, which can cause a problem of rod insertability. It will be challenging to fabricate the GC with improved design and performance through additive manufacturing (AM) method. In this study, two types of laser-based metal additive manufacturing processing were employed to fabricate stainless steel (SS) 304L, including Powder Bed Fusion (PBF) and Directed Energy Deposition (DED) methods.

Prior to parts making, we investigated microstructure and evaluated the mechanical properties of AM steels made by two methods. Besides, pin-on-disk wear tests were conducted to examine the wear resistance of the AM samples since the GC wear is linked to metal-to-metal contacts with RCCAs due to flow-induced vibrations. High porosity was found in the AM samples from the optical microscopy observation. Especially, the PBF sample includes higher porosity and larger pores than the DED one. Both AM samples exhibited an anisotropic non-equilibrium microstructure depending on the material build direction. Along the build direction, highly elongated grains were observed in the AM samples, which are known to result from the high thermal gradient associated with laser solidification processing. The hardness values for the PBF and DED sample were measured to be 218 HV and 246 HV, respectively, which were higher than that of wrought sample (204 HV). The tensile tests for the AM samples at room temperature showed higher strength than wrought ones. The DED sample was found to exhibit not only superior tensile strength but also higher elongation as compared to the wrought and PBF sample, which needs in-depth investigation for clarification. Wear tests on the AM and wrought samples were carried out according to the ASTM standard G99. Generally, the AM samples revealed a lower weight loss and the highest wear resistance was obtained from the DED sample.

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