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A Study on Wear Characteristics after Ultrasonic Nano-Crystal Surface Modification for High-Manganese Steel Built by Directed Energy Deposition

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High-manganese steel has been used as a wear -resistant material in excavator buckets because of its high wear resistance and work-hardening characteristics. However, the manufacturing method of high-manganese steel (HMS) is limited to casting owing to its plastic deformation sensitivity. The wear properties of the mechanical parts are significantly affected by the surface conditions. Therefore, improving the performance and lifespan of a part by changing only the surface properties is an efficient method. This study aims to improve the surface properties of parts by depositing high-manganese steel powder on a substrate using directed energy deposition (DED) process. The DED process continuously generates a molten pool by irradiating a laser while supplying metal powder, and the molten pool rapidly solidifies to form a metal layer. Ultrasonic nano-crystal surface modification (UNSM) is a technology that uses ultrasonic vibration energy to cause rapid plastic deformation on the surface to improve surface properties. In this study, UNSM process was applied to improve the surface performance of the built HMS. The surface quality and wear characteristics of HMS built using DED were observed to be changed by UNSM treatment.

The specimens were additively manufactured under DED conditions with a laser power of 850 W, powder feed rate of 3 g/min, and scanning speed of 1105 m/s. After grinding the deposited surface, the specimen was treated using UNSM under a static load of 80 N, an interval of 10 μm, and a scanning speed of 2000 m/s. The ball-on-disc method for the wear test was performed using a WC ball with a diameter of 12.7 mm. The wear test was conducted under a load of 250 N and 300 RPM for 150 min.

After UNSM treatment of the deposited specimen, the microhardness and microstructure near the surface were observed. The surface hardness of the specimen not treated with UNSM (As-built HMS) was 298 HV and that of the specimen treated with UNSM (UNSM-treated HMS) was 598 HV. This was because the grains near the surface were refined owing to UNSM treatment. As shown in Fig.1 (d) indicating the Electron Backscatter Diffraction (EBSD) GND map, it appears as a black region near the UNSM-treated HMS surface. This is because the grains were refined (the refined grain size exceeded the EBSD resolution). In addition, the dislocation density on the surface of the As-built HMS was 1.8 × 10-2 μm-1 whereas that of the UNSM-treated HMS was 2.2 × 10-2 μm-1. Therefore, compared with the As-built HMS, the UNSM-treated HMS exhibited less weight loss after the wear test; the width of the wear track was narrow, and the depth of the wear track was shallow. This was because the hardness and dislocation density near the surface increased owing to the UNSM treatment. These results suggest that wear resistance can be effectively improved by applying the UNSM process after depositing high-manganese steel with high work-hardening characteristics only on the surface. In the future, the wear resistance of UNSM-treated HMS under various wear conditions (abrasion load and speed) should be studied.

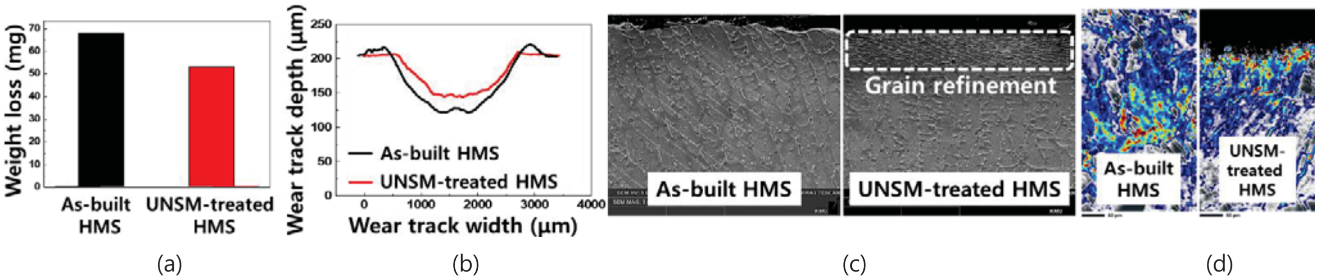

Fig. 1 (a) Weight loss, (b) 3D profiles of wear track, (c) microstructure near surface and (d) G.N.D maps of As-built HMS and UNSM-treated HMS