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A Study on the Characteristics of Intermetallic Compound and Nanoindentation in ZrH_2-Reinforced Aluminum Matrix Composite Layered by Directed Energy Deposition

Hwajeong Kim[1,2], Gwangyong Shin[3], and Dosik Shim[1,2,#]
1 Department of Ocean Advanced Materials Convergence Engineering, Korea Maritime and Ocean University, 727, Taejong-ro, Yeongdo-Gu, Busan, 49112, Republic of Korea
2 Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime and Ocean University, 727, Taejong-ro, Yeongdo-Gu, Busan, 49112, Republic of Korea
3 Automotive Materials& Components R&D group, 9 Chemdanventure-ro 108 beon-gil, Buk-Gu, Gwangju 61007, Republic of Korea
Corresponding Author / Email: think@kmou.ac.kr

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Aluminum alloys are widely used in aerospace and automotive industries owing to their low density, high specific strength, and ease of processing. In recent years, there has been an increasing demand for lightweight materials with higher strength, toughness, and wear resistance for use in aerospace, weapons, and ship transport. Therefore, studies on high-strength aluminum alloys and aluminum matrix composites are being actively conducted. Directed energy deposition (DED) is an additive manufacturing process that involves the formation of a molten pool by laser irradiation on the surface of a substrate and simultaneous deposition of powder materials to produce a three-dimensional part through a layer-by-layer method. In this study, AlSi10Mg and ZrH2 powders were mixed and deposited using DED. The intermetallic compounds formed in the deposited layers and their nanoindentation properties were characterized. The main process parameters of DED included laser power, powder feed rate, scanning speed, and shielding gas. A laser power of 1100 W, powder feed rate of 1.5 g/min, scanning speed of 1050 mm/min, and coaxial/powder gas of 8/5 ℓ/min were selected considering the powder flowability and surface quality from the preliminary experiments.

By observing the cross-section of the deposit, Al3Zr and Zr particles were observed. Al3Zr particles were formed by the reaction of aluminum and ZrH2, and they diffused simultaneously with the growth around the Zr particles. As the Al3Zr particles grew, Kirkendall voids were formed, which formed micropores in the deposited region. The Al3Zr particles were expected to improve their mechanical properties. The Vickers hardness of the composite was 123.5 HV, which was higher than that of the deposited AlSi10Mg (89 HV) without reinforced ZrH2. This was because of the presence of the Al3Zr particles and the remaining Zr particles. The Zr particles were embrittled by H, N, and O; thus, the hardness increased and the ductility decreased. As a result of nanoindentation, the hardness of the deposited AlSi10Mg was 105 HV, that of the foamed Al3Zr was 149 HV, and that of the Zr particles was 330 HV. In the load-displacement curve, the curve of the Zr particles is located to the left compared with that of the deposited AlSi10Mg and Al3Zr particles. This means that the Zr particles effectively reduced the displacement owing to reinforcement and load sharing. This indicates that particle-reinforced aluminum matrix composites (PRAMC) comprising an aluminum matrix with ductility and reinforced particles with high stiffness can be manufactured using the DED process. In the future, we plan to study the performance of the vibration and shock absorption.

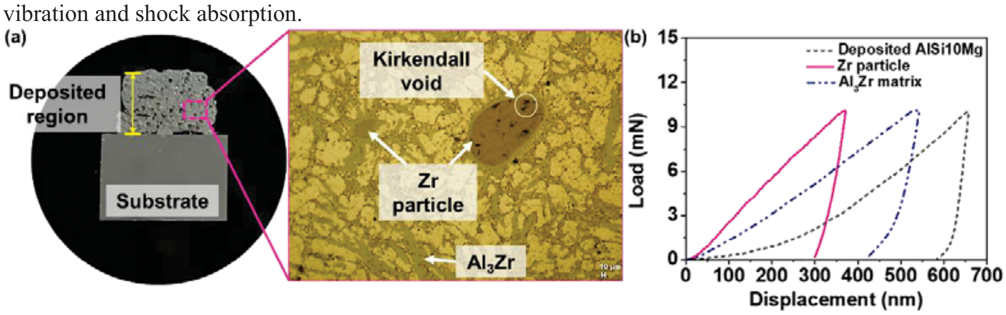

Fig. 1 (a) Image of the deposited sample and OM images of the cross section of the deposited AlSi10Mg and ZrH_2 and (b) load-displacement curves of Zr particle, Al_3Zr, and deposited AlSi10Mg