Microstructural aspects of manufacturing composites based on aluminum and aluminum alloys reinforced with SiC particles

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Abstract

Statement of the Problem: Aluminium matrix composites (AMCs) reinforced with SiC particles exhibit desirable properties such as low density, high specific strength, corrosion resistance, high hardness, and abrasion resistance. These attributes make them suitable for a wide range of industrial applications, including components exposed to high temperatures (e.g., pistons, engine blocks), high-wear systems (e.g., brake discs, cylinders), and drive systems. Critical to the performance of composite materials is the interface between the matrix and reinforcing phase, where load transfer occurs, ultimately defining the composite's properties. Microstructural studies in this region are essential, focusing on the distribution of the reinforcing phase within the matrix and phenomena at the phase boundary. Factors like oxide behavior on powder surfaces and sintering atmosphere effects on potential phase formation must also be considered, especially in powder metallurgy. Various methods including spark-plasma sintering (SPS), cold pressed in a rigid die and sintering in different atmospheres, and friction stir processing (FSP) were employed to produce AMCs and aluminum alloys. Silicon carbide particles with differing grain sizes were utilized. The study emphasizes microstructural aspects influenced by manufacturing method, process parameters, reinforcing phase size, and matrix material type, alongside presenting select mechanical and tribological properties.

Conclusion & Significance: The utilization of traditional powder metallurgy techniques in producing SiC-AMCs allows for the fabrication of materials achieving densities exceeding 90% while maintaining satisfactory mechanical properties. Moreover, sintering under a nitrogen atmosphere facilitates the breakdown of the continuous Al_2O_3 oxide layer on the aluminum powder surface, thus aiding the sintering process. Additionally, nitrogen sintering encourages the creation of nitrides, which tend to accumulate in regions of heightened porosity. The SPS process, despite employing high vacuum, does not entirely eliminate Al_2O_3. Instead, this oxide undergoes partial reduction, leaving behind residues in the microstructure as nanoparticles situated near the original grain boundaries of the aluminum powder particles. Under conditions where the particle size of the reinforcing phase and aluminum matrix particles is similar, the SPS process enables the production of composites featuring a high content of the reinforcing phase with uniform distribution in the microstructure.

Image

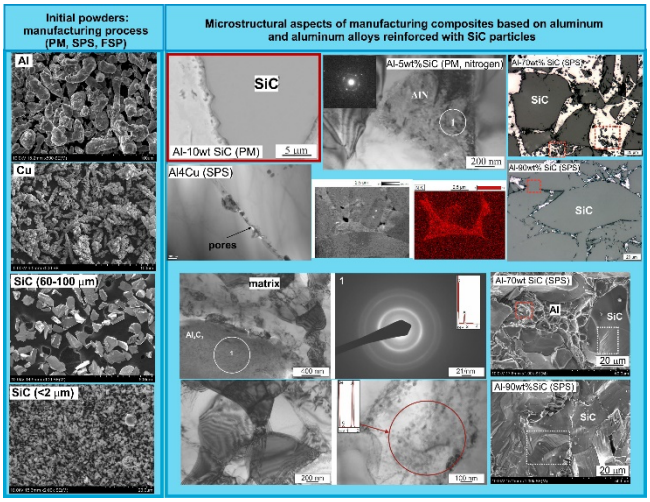

Figure 1. Microstructural aspects of manufacturing composites based on aluminum reinforced with SiC particles

Recent Publications

1. Leszczyńska-Madej B, Madej M, Wąsik A (2023) Analysis of sintering process of Alumix431-B4C Composites. Journal of Alloys and Compounds 965: 1–9.
2. Wąsik A, Leszczyńska-Madej B, Madej M (2023) Hot extruded Al5SiC-graphite composites: Effect of graphite on microstructure, flexural, compressive and wear resistance behavior. Journal of Manufacturing Processes 95: 266–274.
3. Leszczyńska-Madej B, Madej M, Wąsik A, Garbiec D (2023) Spark plasma sintering of Al–SiC composites with high SiC content: study of microstructure and tribological properties. Archives of Civil and Mechanical Engineering 23: 1–13.
4. Leszczyńska-Madej B, Madej M, Garbiec D (2020) Tribological properties of spark plasma sintered Al−SiC composites. Materials 2: 1–12.
5. Leszczyńska-Madej B, Garbiec D, Madej M (2019) Effect of sintering temperature on microstructure and selected properties of spark plasma sintered Al−SiC composites. Vacuum: Surface Engineering, Surface Instrumentation & Vacuum Technology 164: 250–255

Photograph

Biography

Beata LESZCZYŃSKA-MADEJ, PhD, DSc Eng., is a professor at AGH University of Krakow and works at the Faculty of Non-Ferrous Metals. Her primary areas of expertise include metal matrix composites reinforced with ceramic particles, heat treatment, non-ferrous metals and alloys, tribological properties, SPD methods, and surface engineering. She has authored and co-authored approximately 140 articles published in international and national scientific journals. Additionally, she is a member of the Polish Society for Microscopy, the European Microscopy Society, the International Federation of Societies for Electron Microscopy, the Academy of Engineering in Poland, and the Polish Materials Science Society.

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