ME - PhD Thesis Defense

Microstructure, mechanical behavior, and thermal stability of in-situ polymer-derived ceramic reinforced Al-based composites

Mr. Abhishek Pariyar, PhD Student, Department of Mechanical Engineering, IISc

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ABSTRACT

Al-based metal matrix composites (MMCs) show a high strength-to-weight ratio which makes them attractive for the aerospace and automobile industries. The reinforcements for the same have conventionally been micron-sized ceramic particles (ex-situ MMCs). These MMCs show high strength, elastic modulus, and resistance to wear. However, there is also a severe reduction in their ductility. These MMCs also do not possess strong particle-matrix interfaces which adversely affect the ductility. If the particle-matrix interface is strong, ceramic nanoparticles, when used as ex-situ reinforcements, have shown improvement in strength and relatively lower loss in ductility as compared to using micro-particles. However, these nanoparticles, tend to agglomerate which deteriorates the mechanical properties. Additionally, they are also expensive and can be hazardous to health during handling. Polymer Derived Ceramics (PDCs) based composites can potentially overcome these shortcomings. Such ceramics are obtained from the preceramic polymers after pyrolysis. These polymers are inexpensive, can be fragmented to the nanoscale, and pyrolyzed in-situ within the matrix.

Initially, friction stir processing (FSP) was used to fragment and disperse the polymer within an Al-Mg alloy. The PDC particles pinned the dislocations and grain boundaries. The composite exhibited a microstructure resulting from continuous dynamic recrystallization aided by the PDC particles. It also exhibited both high strength (96% and 24% improvement in the yield and ultimate tensile strength (UTS), respectively) and good ductility (18%). Interestingly, the amplitude of the serrations in the tensile curves commonly observed in Al-Mg alloys due to the Portevin-Le Chatelier (PLC) effect was reduced in the composite. This composite also exhibited a stable grain structure with minimal loss in strength (represented through hardness) when exposed to 450°C and 550°C for 1 hour due to the particle pinning of the grain boundaries by the Zener mechanism.

In order to fabricate PDC-based MMC in the bulk scale, accumulative roll bonding (ARB) was used. Detailed through-thickness microstructural investigation of this composite revealed that in the central/mid-section region, both large elongated and fine equiaxed grains were present. The latter were recrystallized grains. Some of the large grains were also comprised of subgrains with low angle boundaries. However, in the region near the surface, the fine equiaxed grains were dominant, which were also recrystallized grains. The composite exhibited a large improvement in strength (~8 and ~5 times improvement in the yield and UTS, respectively) as compared to the parent material. However, the loss in the ductility of the composite was induced by the ARB process itself and not by the addition of PDC particles, as it exhibited values similar to a specimen prepared under the same conditions but without the PDC particles. Additionally, this composite exhibited stability in the grain size and strength when exposed to 250°C for 1 hour.

ABOUT THE SPEAKER

Abhishek Pariyar is a Ph.D. student in the Dept. of Mechanical Engineering, IISc. His research interests include the mechanical behavior of metallic materials, severe plastic deformation, materials characterization, crystallographic texture, and tribology. He works with Prof. Satish V. Kailas in the Surface Interaction and Manufacturing Lab, IISc.