Metal Matrix Composites Via PM Routes

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Abstract:
The demand for metal matrix composites (MMCs) is increasing dramatically as more applications require higher performance lighter weight materials. Powder Metallurgy (PM) is an ideal method of fabrication for MMCs because of the ability to produce near net shapes and little material waste associated with the process. Due to the increased strength associated with the part after fabrication, machinability of the part can be difficult. This research examines the best type of reinforcement fiber to be used with aluminum matrixes via PM routes, and the effect that these fibers have on green strength of the part. The results show that alumina fibers should be used in the form of either continuous or discontinues fibers to produce the highest mechanical properties, whereas silicon carbide should be in the form or particulates and whiskers.

Introduction:
Powder blending and consolidation, a solid state method of fabrication, consistently produces superior mechanical properties distributed evenly throughout the material [2]. The increase in strength observed after the sintering process decreases the machinability of the material creating new challenges. Each MMC fabrication process varies in nature, resulting in
unequal costs and properties associated with the final components. Although the fabrication method plays a role in the mechanical properties of the MMCs, the materials chosen for the matrix and reinforcement fibers play an equally important role. Numerous metals including aluminum, titanium, magnesium, and copper have been used as matrix materials in MMCs [3]. Aluminum is the most widely used matrix material in structural components as it provides relatively high strength and toughness, while still remaining lightweight. In an effort to increase the strength of the aluminum matrix while still maintaining the low density and moderate ductility of the aluminum, reinforcement fibers of either alumina or silicon carbide are distributed throughout the matrix.

When selecting materials for a MMC, it is critical that the materials selected for the matrix and reinforcement fibers are not only evaluated on their individual properties, but also on their reactivity with each other during the forming process. Often times the interactions between matrix and fiber materials impose restrictions on the type of constituents that can be combined [3]. In an attempt to reduce the reactivity of the constituents, a barrier coating is often applied to the reinforcement. This barrier surrounds the reinforcement fibers preventing any contact between the unstable constituents during the high temperature forming process [3]. It is also critical to evaluate the temperature that MMCs will be subjected to in service in an effort to prevent any potentially dangerous reaction between unstable constituents.

**Results and Discussion:**

Reinforcement fibers are produced in four forms: continuous, discontinuous, whiskers, and particulates as seen below in Figure 1 A-D [4]. Aluminum matrix composites (AMCs) can be
enhanced with any of the above fiber types; however, not all reinforcement materials can be fabricated into a specific fiber form. For example, in an aluminum matrix, alumina fillers produce the highest mechanical properties when they are in the form of a continuous or discontinuous fiber, whereas silicon carbide produces superior properties in the form of particulates and whiskers [3].

Figure 1: Types of reinforcement fibers used in MMCs A) Continues Fibers B) Discontinuous Fibers C) Whiskers D) Particulates

In comparison with the matrix material, particulate reinforced MMCs often show a large increase in strength, but also a reduction in ductility and fracture toughness resulting from the addition of brittle particulates within the matrix [3]. Isotropic behavior is also characteristic of particulate reinforced MMCs, since particles are distributed evenly throughout and cannot align in any particular direction to provide increased strength. In opposition of particulate reinforced MMCs, the mechanical properties associated with whisker reinforced MMCs is strongly dependant on their orientation. Randomly oriented whiskers will essentially act as large particulates dispersed within the matrix, resulting in isotropic behavior. Unlike particulates
though, extrusion can be used to align the whiskers resulting in anisotropic behavior [4]. It is important to not only consider the filler fiber and its orientation within the matrix, but also the effect that the matrix material has on the overall composite behavior. Stress–strain curves generated from MMCs often display non-linear behavior resulting from the yielding of the matrix before the reinforcement.

Although there are many other methods of MMC fabrication, it is clear that powder metallurgy (PM) produces a product with exemplary strength and toughness. Although this increase in strength is highly coveted and necessary for the materials intended application, it presents a new challenge. After the sintering process, the MMCs have such high strength that they are extremely difficult to machine to final specifications [5]. Although PM produces net or near-net shapes, over 60% of the parts will still need to undergo some form of machining that cannot be achieved by die pressing [6]. This additional machining leads to additional production costs since it is more difficult to machine porous PM parts than pore-free material. Machining costs can easily add up to 20% of the overall production costs of a part [6]. In order to be competitive in industry, it is critical to reduce these costs either by optimization of the machining process or modification to the production process.

Green machining of the parts has the potential to reduce costs associated with machining due to their decreased strength. Warm die compaction and advanced lubrication systems with binding agents have resulted in an increase in green strength by 10 N/mm² over traditional die pressing technology [6]. In response to this increase in strength of the green compact, it is now possible to perform machining operations before the sintering process. Although the material is strong enough to withstand machining, the quality will not be as high
as if completed post sintering. The green compacts flake and disintegrate around the edges where the tool enters and exits the compact. However, minor surface defects are produced [5].

As a result of this, it is recommended that green machining only occurs in applications with medium quality demands. Despite the fact that the green strength obtained by new technologies is higher than previous methods, the materials are still extremely brittle. In order to successfully machine the compacts the cutting forces must be reduced as much as possible, which can be achieved by using sharp tool geometries and lowering the feed rate [6].

**Conclusion:**

The formation of MMCs via PM routes was investigated in this research. The following conclusions can be made:

1. PM is suitable for the production of MMCs that require high strength while maintaining low density.

2. The type of reinforcement fiber will affect the mechanical properties of the part. Alumina should be in the form of continuous or discontinuous fibers, silicon carbide in form of particulates or whiskers.

3. Increase in green strength associated with MMCs allows for green machining, but only produces mid-range quality products.

**Acknowledgements:**

The author would like to thank Dr. Wojciech Z. Misiolek, Loewy Professor in the Institute for Metal Forming at Lehigh University for his advice throughout this course of study. Also many
thanks to the Center for Powder Metallurgy Technology and Arlan J. Clayton for their financial support, which made this project possible.
Literature:


