ISSN (online): 2349-6010

Study of Ultrasonic Powder Consolidation Techniques and the Key Features of Aluminum Matrix Composites

Karan Singh
Assistant Professor
Department of Mechanical Engineering
Shri Ram College of Engineering and Management, Palwal (India)

Abstract

Ultrasonic powder consolidation (UPC) is a novel rapid, full-density powder consolidation process in which metal powders confined in a die under uniaxial loading is subjected to ultrasonic vibration at low temperature for a few seconds or less. In this research paper an overview of Ultrasonic Powder consolidation Techniques and the key fearures of Aluminium matrix composites are discussed.
Keywords: Ultrasonic, Powder, Technique, Loading, Matrix

I. INTRODUCTION

UPC is a novel new technique for the consolidation of metal powders. Intense vibrations break and displace surface oxide layers and contaminants, thus facilitate full metal contact between powder particles and metallurgical bonding thereof. The softening effect observed in the ultrasonic welding of sheets and wires [1] should also be promoting the deformation of metal powders, leading to high degrees of compact densification.

This Bonding must be preceded by the formation of nascent metal-to-metal contact of powder particles, which requires good compact densification. Thus, densification is only a necessary condition for bonding. For the copper compacts, metallurgical bonding, at a given temperature, increased with increasing consolidation time, indicating that bonding is a thermally activated (diffusional) process. Densification of dendritic powder produced more fresh metal surface and hence higher degrees of bonding. The bonding in the aluminum compacts, however, followed densification more closely, reflecting the higher homologuos temperatures [2]

II. THE KEY FEATURES OF ALUMINUM MATRIX COMPOSITES

The key features in the microstructure of a composite material resulting from the interaction between the matrix and the reinforcement usually include the type, size, and distribution of secondary reinforcing phases, matrix grain size, matrix and secondary phase interfacial characteristics. Two types of reinforcing materials have been investigated for Aluminum matrix composites [3]. The first and most widely used is ceramic. The other is metallic/ Intermetallic Ceramic particles are the most widely studied reinforcement for Aluminum matrix composites. Some common properties of ceramic materials make them desirable for reinforcements. These properties include low-density and high levels of hardness, strength, elastic modulus, and thermal stability .However, they also have some common limitations such as low wettability, low ductility, and low compatibility with a Aluminum matrix. Among the various ceramic reinforcements Al2O3 , SiC is the most popular because of its relatively high wettability and its stability in a magnesium melt, as compared to other ceramics [4]. The shape of reinforcement is another factor affecting the reinforcing effect. In a Aluminum matrix composite, the most commonly used reinforcements assume a shape of short fiber/whisker, or particle, or a mixture of these two configurations [5]. Short fiber/whisker reinforced Aluminum alloys usually show better mechanical properties than the particle reinforced Aluminum alloy with some degree of anisotropic behaviors. To overcome the barriers of relatively high cost and the anisotropic properties associated with fiber reinforcement, some recent efforts have been made to reduce the fiber cost by developing a new fibrous material and using hybrid reinforcements that incorporate particles into fibers. Because of metallic solids will generally have a much better wettability with liquid metals than ceramic powders, the reinforcing of a Aluminum matrix with metallic/intermetallic particulates has recently been examined [6]. The advantages of the metallic reinforcements lie in their high ductility, high wettability and high compatibility with the matrix as compared with ceramics, and their great strength and elastic modulus as compared to the Aluminum matrix. The interface between the matrix and the secondary reinforcing phase plays a crucial role in the performance of composite materials. The key features of the interface are the chemical reactions and the strength of bonding. Interfacial reactions in the Aluminum matrix composite are predominantly determined by the composition of the matrix and the reinforcement materials [7].

III. POWDER CONSOLIDATION TECHNIQUES

Powder metallurgy (PM) is a widely used technique to produce metal products and metal composites. Generally, it consists of four major steps:

1) production of powders,
2) blending or mixing,
3) pressing powders into green compacts which still contain porosity,
4) formation of a bulk material by a consolidation process.

In a conventional method, green compaction is normally achieved by cold pressing, while consolidation is obtained by sintering at an elevated temperature. Another widely used method is hot isostatic pressing in which powders vacuum-encapsulated in a metal container is held under isostatic pressure at an elevated temperature for a sufficient amount of time which depend on the material and selected temperature. Generally, a complete cycle of HIP takes 12 to 24 hours for full consolidation at 80% of the absolute melting temperature [8]. Since the compaction and subsequent sintering processes are time consuming, there is a vast amount of research in the field of high strain-rate processes [9] conducted to minimize the processing time. However, these methods still require the powder to be compacted prior to deformation processing. The most commonly employed high strain-rate powder consolidation techniques are powder forging, rolling and extrusion, equal channel angular pressing (ECAP), and shock wave consolidation. Although, materials produced by these techniques can generally achieve more than 99% density, they may still need to be further processed in order to improve mechanical properties. Extrusion is generally a two-step process where the powders are first cold pressed into a can and subsequently extruded at room temperature or an elevated temperature after evacuation and sealing. The shock wave consolidation process produce a bulk material by passing a shock wave through the powder and the necessary shock wave is generated by detonating an explosive [10]. Prinz [11] summarized various studies covering this techniques. Jin Yuan et al. [12] consolidated Al-Li alloy powders by this method and they concluded that the shock wave could break up the surface oxide layer and resulted in compacts with densities above 98% while preserving the initial microstructure of the powders. However, they also stated an abnormal softening in comparison with the original powders.

IV. CONCLUSION

UPC provides a viable route for the rapid consolidation of metal powders at low temperature under low pressure. Dendritic copper powder specimens exhibited better densification and metallurgical bonding than spherical ones above 450 because they had to deform to a higher degree to fill the space between particles, hence creating more metal-to-metal contacts for bonding formation. The metallurgical bonding occurs almost as quickly as densification proceeds indicates that the rate of metallurgical bond formation is limited by the rate of creating fresh metal-to-metal contact in the compact. This research focused on study of ultrasonic powder consolidation techniques and the key features of Aluminium composites are discussed .

REFERENCES

[1] Zhang, Z.; Chen, D.L. Contribution of Orowan strengthening effect in particulate-reinforced metal matrix nanocomposites. Mat. Sci. Eng. A 2008, 483–484, 148–152.
[2] Zhang, Z.; Chen, D.L. Consideration of Orowan strengthening effect in particulate-reinforced metal matrix nanocomposites: A model for predicting their yield strength. Scripta Mater. 2006, 54, 1321–1326.
[3] Sanaty-Zadeh, A. Comparison between current models for the strength of particulate-reinforced metal matrix nanocomposites with emphasis on consideration of Hall–Petch effect. Mat. Sci. Eng. A 2012, 531, 112–118.
[4] Luo, P.; McDonald, D.T.; Xu, W.; Palanisamy, S.; Dargusch, M.S.; Xia. K. A modified Hall–Petch relationship in ultrafine-grained titanium recycled from chips by equal channel angular pressing. Scripta Mater. 2012, 66, 785–788.
[5] Uddin, S.M.; Mahmud, T.; Wolf, C.; Glanz, C.; Kolaric, I.; Volkmer, C.; Höller, H.; Wienecke, U.; Roth, S.; Fecht, H. Effect of size and shape of metal particles to improve hardness and electrical properties of carbon nanotube reinforced copper and copper alloy composites. Comp. Sci. Technol. 2010, 70, 2253–2257.
[6] Bakshi, S.R.; Lahiri, D.; Agarwal, A. Carbon nanotube reinforced metal composites-a review. Int. Mater. Rev. 2010, 55, 42–64.
[7] Trojanova, Z.; Lukac, P.; Ferkel, H.; Riehemann. W. Internal friction in microcrystalline and nanocrystalline Mg. Mat. Sci. Eng. A 2004, 370, 154–157.
[8] Deng, C.F.; Wang, D.Z.; Zhang, X.X.; Ma, Y.X. Damping characteristics of carbon nanotube reinforced aluminum composite. Mater. Lett. 2007, 61, 3229–3231.
[9] Shehata, F.; Fathy, A.; Abdelhameed, M.; Mustafa, S.F. Preparation and properties of Al2O3 nanoparticle reinforced copper matrix composites by in situ processing. Mater. Design 2009, 30, 2756–2762.
[10] Ferkel, H.; Mordike, B.L. Magnesium strengthened by SiC nanoparticles. Mat. Sci. Eng. A 2001, 298, 193–199.
[11] Prinz , V.C.; Prewo, K.M. On the strength of discontinuous silicon carbide reinforced aluminum composites. Scripta Metal. 1986, 20, 43–48.
[12] Jin Yuan , Bacon, D.J. Introduction to Dislocations, 4th ed.; Butterworth Einemann: Oxford, UK, 2001.
[13] Smallman, R.E.; Ngan, A.H.W. Physical Metallurgy and Advanced Materials, 7th ed.; Butterworth Einemann: Oxford, UK, 2007.
[14] Hull, D.; Clyne, T.W. An Introduction to Composite Materials, 2th ed.; Cambridge University Press: Cambridge, UK, 1996.
[15] Casati, R.; Amadio, M.; Biffi, C.A.; Dellasega, D.; Tuissi, A.; Vedani, M. Al/Al2O3 nano-composite produced by ECAP. Mater. Sci. Forum. 2013, 762, 457–464. Metals 2014, 4 79

