Densification and Conolidation of Powders by Equal Channel Angular Pressing

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Abstract

In this study, bottom-up type powder processing and top-down type SPD (severe plastic deformation) approaches were combined in order to achieve both full density and grain refinement of metallic powders with least grain growth. ECAP (Equal channel angular pressing) was used for the powder consolidation. We investigated the consolidation, plastic deformation and microstructure evolution behavior of the metallic powders during ECAP using an experimental method. It was found that high mechanical strength could be achieved effectively as a result of the well bonded powder contact surface during ECAP process of gas atomized Al-Si powders.

1. Introduction

Recently, bulk nanostructured materials processed by several methods of severe plastic deformation (SPD), such as equal channel angular pressing (ECAP), high pressure torsion straining, accumulated roll bonding, equal channel angular rolling, groove rolling, equal channel multi-angular pressing etc., were developed [2-7]. The main advantage of SPD processed materials, compared to other nanostructured materials processed by gas condensation or ball milling with subsequent consolidation, is the possibility of overcoming a number of difficulties connected with residual defects and powder contaminations in the compacted samples. Among the various SPD processes, ECAP is a convenient procedure for obtaining ultrafine grained materials by extruding metallic materials through specially designed channel dies without a substantial change in geometries.

In a separate development, studies of rapidly solidified alloy powders have suggested the possibility of producing new alloys having metastable microstructures, e.g. amorphous and nanostructured phases, characterized by superior mechanical properties. Generally, it is necessary for powder consolidation to be performed by solid-phase diffusion at temperatures far below the melting points of the raw material powders, in order to ensure that the structural features obtained by rapid solidification are not lost. Indeed, grain growth, which was considered as a bottle neck of the bottom-up method using the conventional powder metallurgy of compaction and sintering. In addition, the surfaces of metallic powders are usually covered by an oxide layer, which prevents powder bonding. Unless this oxide film is ruptured and the fresh powder particle surfaces are allowed to come into contact with each other, it is not possible to obtain good bonding by diffusion. Therefore, the powder particles should be bonded together by plastic deformation during powder compaction step as well as forging step, and so imposing shear stresses as well as hydrostatic pressures during powder compaction is very important to achieve good powder bonding. From this point of view, the ECAP process was confirmed to be effective for consolidation of gas atomized metallic powders at a relatively low temperature [8].

In this study, bottom-up type powder processing and top-down type SPD approaches were combined in order to achieve both full density and grain refinement of metallic powders with least grain growth. ECAP was used for the powder consolidation. In the ECAP process of not only solid but also powder metals, knowledge of the density as well as internal stress, strain and strain rate distribution is important for understanding the process. We investigated the consolidation, plastic deformation and microstructure evolution behavior of the metallic powders during ECAP using an experimental method.

2. Experimental and Results

Al-Si alloy powders were studied. Al-20 wt% alloy powders were N_2 gas atomized. The gas atomized Al-Si powders with +25 μm in diameter and commercial copper powders were put into pure copper can and/or cold isostatically pressed to a sample size of 6 mm x 6 mm x 50 mm. In the ECAP process, samples were pressed through a die having two channels, equal in cross-sectional area, that intersect at a channel angle Φ of 90° and a corner angle Ψ of 0° at room temperature. The ECAP processing was conducted up to eight passes at 200 ℃, following Route C, that is, rotating a workpiece by 180° around the longitudinal axis between the passes, respectively. The die parameter used, *viz*. the channel angle (Φ= 90°), the outer corner angle (Ψ_o=0°) and the inner corner angle (Ψ_I=0°) yield a maximum effective strain of 1.155 for a single pass, which decreases with increasing strain hardening coefficient. The pressing speed was 1 mm/min, which is slow enough to keep the temperature rise during ECAP to less than several K. A mixture of MoS_2 powder and commercial oil was used for lubrication between the can and the channel surfaces. The starting powders were characterized by scanning electron microscopy (SEM). The density of the compacts was measured by the Archimedes method.

3. Summary

The ECAP process was applied to metallic powders in order to achieve both powder consolidation and mechanical alloying. Various general phenomena, such as densification, plastic deformation and microstructure evolution behavior of the metallic powder compact were investigated. By using the powder ECAP process with an adequate sheath metal, almost full densification could be achieved at room temperature. In particular, it was shown by FEM that almost full densification is achieved in the entry channel. Hence, the powder ECAP proceeds in consecutive steps of densification by hydrostatic pressure, simple shear and elastic unloading. The SPD processing of powders is a viable method to achieve both fully density and good particle bonding in CNT-metal matrix composites. The effects of CNT/matrix interface and CNT alignment will be the focus of our future work.

4. References

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