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Structure and properties of AA6061/$(Ti_3Al)_p$ composite materials obtained by mechanical milling and hot extrusion*

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The present work investigates the production of aluminium AA6061 matrix composite materials reinforced with Ti_3Al particles by powder metallurgy techniques and hot extrusion.

1. INTRODUCTION

Metal Matrix Composites (MMCs) are currently being investigated because of their superior properties as compared to those of most conventional materials. Two types of reinforcement (alumina and silicon carbide) have been extensively investigated by the scientific community. The introduction of new reinforcements such as intermetallics to aluminium alloys continues to be investigated in order to improve final behavior of AMCs as well as to avoid some drawbacks of using ceramics as aluminium alloys reinforcements. At present, the two major obstacles to the application of such materials are high cost and chemical reaction at reinforcement/matrix interfaces during materials processing and service at elevated temperatures [1, 2].

The synthesis of materials by high energy ball milling of powders however was developed to produce fine and uniform dispersions of oxide particles in nickel base superalloys presently is being used to produce numerous materials including metal matrix composites [3, 4]. The mechanical alloying process changes dramatically the powder characteristics, the more refined microstructure improved dispersion of the reinforcement particles and improved mechanical properties can be achieved with this process route compared with the same composite produced by conventional PM process and hot extrusions.

The present work investigates the production of aluminium AA6061 matrix composite materials reinforced with Ti_3Al particles by powder metallurgy techniques and hot extrusion.

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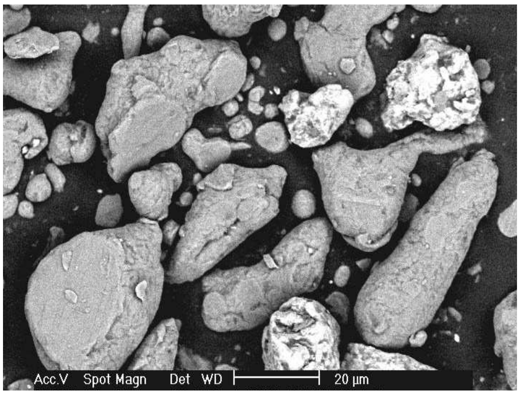
2. EXPERIMENTAL PROCEDURE

Aluminium matrix composites have been produced employing the atomised aluminium alloy AA 6061 as metal matrix when Ti_3Al intermetallics particles were used as reinforcement. Materials used were commercial powders with particles size less than 75 and 50 μm respectively. Three sets of samples with 5, 10 and 15 % (wt.) of reinforcement were prepared. To evaluate the effect of mechanical milling two types of ball mills were used: a low energy (horizontal ball mill) and a high energy one (planetary ball mill). Details of composite powders production were described in [5]. The powders were cold pressed in the cylindrical matrix 25 mm in diameter with 300 MPa pressure and then extruded at 500-510°C with graphite as lubricant without caning and degassing. To avoid the excessive grain growth due to high level of stored energy [6] in case of samples after mechanical milling annealing process were performed in 400 °C for 1 hour. Extruded bars of 5 mm diameter and theoretical density were obtained. To determine the ultimate tensile strength (UTS) tensile tests were performed on samples with 50 mm measuring length. To determine hardness Vickers tests were performed in the parallel plane related to the extrusion direction. Microstructure observations were made by optical microscopy and scanning electron microscopy SEM.

3. RESULTS AND DISCUSSION

In the contrary to conventional casting processes the PM route of composite materials production makes possible to obtain wide range of reinforcement particles percentage addition without typical for them segregation. Figure 1 shows morphology of powder mixture after low energy mixing and figure 2 show the microstructure of the composite powder reinforced with 15% wt after high energy mechanical milling. It can be seen that the mixing process do not change morphology of the initial particles, allows to better distribution of reinforcement particles but can not completely liquidate their agglomerates. Mechanical milling process has improved the reinforcement distributions throughout the whole particle. In the observed microstructures, the brighter particles are the intermetallic reinforcement, which has undergone plastic deformation as well as fragmentation what is not possible in case of low energy mixing processes.



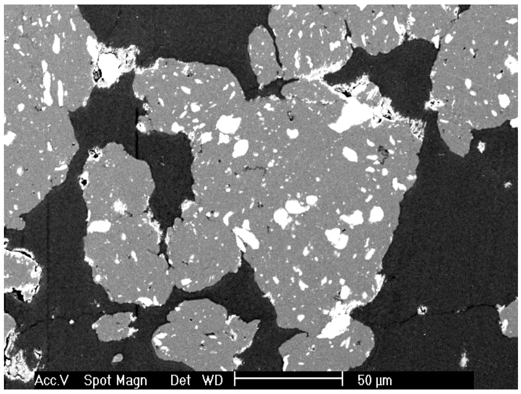


Figure 1. Mixture of powders particles AA6061+15% Ti_3Al after 2h of mixing process, SEM

Figure 2. Cross section of the composite powders particles AA6061+15% Ti_3Al after 18h of mechanical milling, SEM

In final products of composites materials, depending on the reinforcement size and shape, the density difference, a type of matrix material, agglomeration can occur. Although the extrusion processes tends to minimise this problem reinforcement particles agglomeration is the most appointed cause of low performance of this class of materials. To avoid this problem mechanical milling can be used to improve the distribution of the reinforcement particles through the matrix. Figure 3 and 4 show the microstructure of extruded composites reinforced with 15% wt after low energy mixing and 18 hours of mechanical milling respectively.

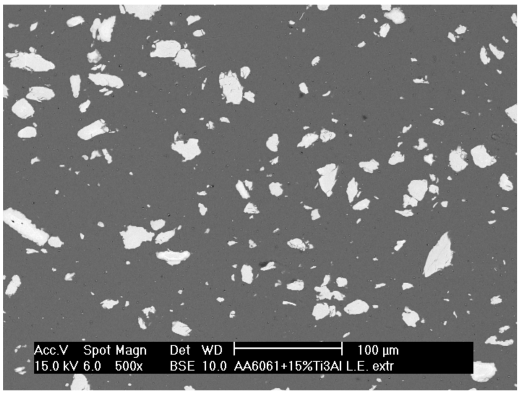


Figure 4. Microstructure of cross section of extruded composite AA6061+15% Ti_3Al after 2h of low energy mixing, SEM

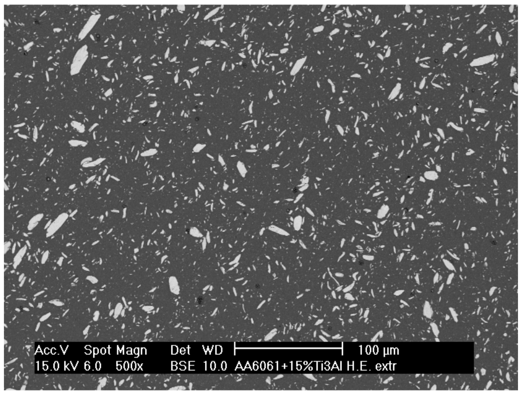
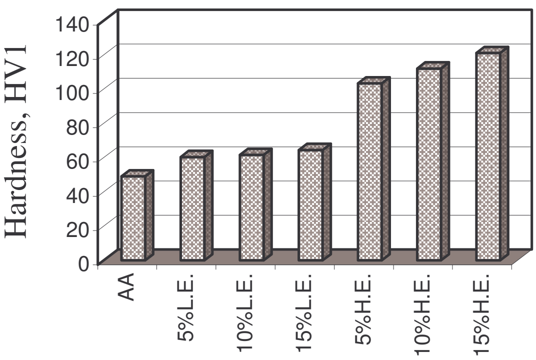


Figure 5. Microstructure of cross section of extruded composite AA6061+15% Ti_3Al after 18h of mechanical milling, SEM

It can be observed big difference between particle size and their distribution through the aluminium matrix. In the mechanically milled composites one can see very fine distribution of small reinforcement particles and absence of agglomerates however there is fraction of particles with elliptical or flattened shape.

Mechanical milling through the high degree of deformation, high density of dislocation, oxide and reinforcement particle dispersion in the matrix increase the hardness when the finer microstructure increase the mechanical properties of composites materials. Figure 5 and 6 show the hardness and ultimate tensile strength of extruded composites and aluminium AA 6061 alloy.



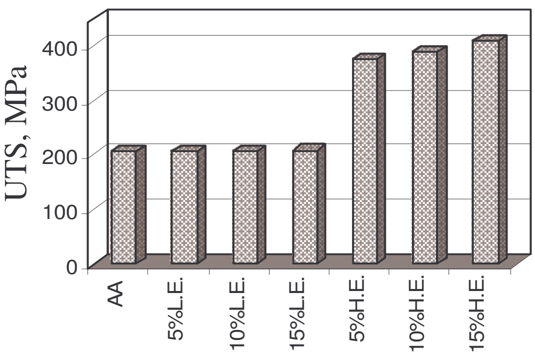


Figure 5. Hardness of the extruded composites

Figure 6. Ultimate tensile strength of the extruded composites

One can see the increase of the mechanical properties due to the mechanical milling process. Material designed as AA refers to aluminium matrix AA6061 alloy, L.E. refers to low energy mixing process, H. E. refers to high energy mechanical milling and for both of processes different concentration of reinforcement particles were used. As it can be seen hardness of composite materials is only slightly higher after mixing process and small increase of hardness value is observed when reinforcement contents increase. In a case of composites after mechanical milling hardness is more than twice of aluminium alloy. The same tendency can be observed for tensile properties however mixing process does not influence UTS value. Again mechanical milling change almost twice ultimate tensile strength of investigated composites. Moreover until 15 % of reinforcement particles contents UTS is growing indicating good interfacial bonding of matrix and reinforcement particles.

4. CONCLUSIONS

The mechanical milling can produce the composites powders with homogenous distribution of reinforcement particles.

The mechanically milled and extruded composites show finer and better distribution of reinforcement particles what leads to better mechanical properties of obtained products.

The hardness increases twice in case of mechanically milled and only 20 -25 HV1 for low energy mixed and hot extruded composites.

The finer microstructure increases mechanical properties of composites materials. The higher reinforcement content results in higher particles dispersion hardening. Composites reinforced with 15% of Ti_3Al reach about 400 MPa UTS.

The addition of intermetallic reinforcement particles to the low energy mixed and extruded composites do not influence their tensile properties.

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