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Distribution Effect of Nanostructure Reinforcement in Al/Ni Aluminides Composite on Homogenization and Mechanical Properties

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Introduction

Aluminum base composites (AMC) reinforced with Ni-aluminides have been proposed as substitutes for ceramic reinforced composites [1] because they have sufficient mechanical properties.
In metal matrix composites blending or mixing, is just as important, because it controls the final distribution of reinforcement particle and porosity in green compacts after compaction, which strongly affects the mechanical properties of PM materials produced. Segregation and clustering are the common problems associated with the present state-of-the-art blending or mixing methods. The phenomenon of segregation is inherent to any loose powder configuration which is subjected to mechanical blending [2]. The reason for segregation and clustering includes different flow characteristics between metal powders and reinforcement particles and the tendency of the agglomeration of particles to minimize their surface energy [3].The segregation and clustering during blending can be overcome by a technique developed during the 1960s called mechanical alloying (MA) [4]. Mechanical alloying is a dry, high-energy ball-milling process for producing composite metal powders with a fine controlled microstructure [5].
This process consists of the repeated fracturing and rewelding of a mixture of particles and metal powders by high-energy compressive-impact forces to yield a uniform distribution of particles and metal powders with a satisfactory microstructure after compaction[4,6], also contribute to the strengthening of these MMCs. In this paper the effect of mixing condition and distribution of nanostructure reinforcement on the homogenization and mechanical properties of AMC has been investigated.

Experimental procedure

Aluminum matrix composites were produced employing pure aluminum as metal matrix when nanostructure Ni_3Al intermetallics particles were used as reinforcement. Aluminum powder from The Merck Co. (Germany) was used as a matrix material. Reinforcement particles used were the nanostructure Ni_3Al Nickel aluminide (particles size less than 100 nm) produced in mechanical alloying process with the conditions given in Table 1. As well as XRD pattern of nanostructure reinforcement is shown in Fig. 1.
In order to evaluate the effect of mixing conditions, blending and high energy ball milling (planetary ball mill) were used as methods to obtain different levels of mixing and distribution of 5.0 vol.% nanostructure Ni_3Al particles in 95.0 vol.% Al powders. Blending process was done in a tumbling mixer for 30 min. and the condition of ball milling is given in Table 2.
The obtained mixed powders were cold compacted uniaxially in a pressing tool with floating die, and compacting pressure was chosen equal to 400 MPa. The compacted test specimens, was sintered at 625ºC in a vacuum furnace for 30 min followed by furnace cooling. Densities of the sintered parts were determined using Archimedes principle (DIN ISO 3369).
To determine macro-microhardness Vickers tests were performed in the carefully sectioned and polished specimens. Microstructure observations were made by optical microscopy and scanning electron microscopy

Table1
Parameters of mechanical alloying

Speed of milling	550rpm
Milling time	15h
Weight ball/powder ratio	20:1
Ball diameter	15mm
Ball material	stainless steel
Process control agent	stearic acid(2% wt) Merck Co. (Germany)
Atmosphere	air

Table 2
Parameters of mechanical milling

Speed of milling	200,300 rpm
Milling time	18h
Weight ball/powder ratio	6:1
Ball diameter	15mm
Ball material	stainless steel
Process control agent	stearic acid(1%wt) Merck Co. (Germany)
Atmosphere	argon

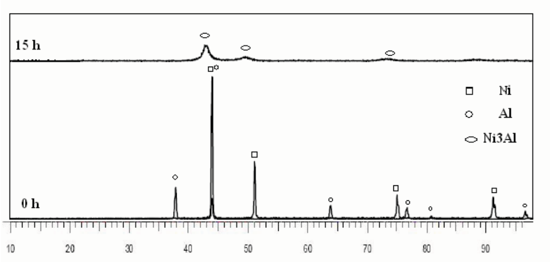

Fig1. XRD pattern of nanostructure reinforcement

Results and discussion

Observations of mixed powder morphology after mixing process and after high energy mechanical milling process explain that the mixing process cannot completely liquidate agglomerates. Mechanical milling process improved the reinforcement distributions throughout the whole particle. However, Fig. 2 shows the morphology of the composite powder reinforced with 5% vol. Ni_3Al after 18 h of mechanical milling at 200 and 300 rpm, respectively in an Ar atmosphere. At 200rpm particles are generally laminar. In the microstructure, the brighter laminates are the nanostructure intermetallic reinforcement; the observed morphology indicates that mechanical milling is still at the early stages, it can be seen that higher speed of milling has improved the reinforcement distributions throughout the whole particle, and has produced equiaxial morphology.

Metallographic study on microstructure of sintered parts shows agglomeration of nanostructure intermetallic particles under blending process however mechanical milling and increasing speed of milling improve the distribution of the nanostructure reinforcement particles through the matrix.

Mechanical milling through the high degree of deformation, high density of dislocation, reinforcement particle dispersion in the matrix increase the hardness when the finer microstructure increase the mechanical properties of nanostructure composites materials. By the way using of mechanical milled powder results more homogenization in sintered microstructure.

(a) 200rpm (b) 300rpm

Fig.2. Backscattered image of Al/5vol.%Ni_3Al nanostructure powders ball milled at different speeds.

Conclusions

The mechanical milling can produce finer composite powders with homogenous distribution of nanostructure reinforcement particles therefore mechanical properties are improved.

References

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