Aluminum Alloy Metal Matrix Composite Processing and Properties

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Abstract— For the last few years there has been a rapid increase in the utilization of aluminum alloys, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, and high strength, wear resistance. Among the materials of tribological importance, Aluminum metal matrix composites have received extensive attention for practical as well as fundamental reasons. Aluminum alloys and aluminum-based metal matrix composites have found applications in the manufacture of various automotive engine components. Compound work pieces are developed to combine favorable properties of different materials. Many composite materials are used in home and industrial production. Weight reducing in rapid moving parts of automobile engines such as Crankshaft, connect rod. to a reduction of the weight and wear reduction purpose. For this review paper discussed with recent composite technology and performance behavior and also we discussed MMC. the material mixed with non metal and analyzed in this mechanical properties and fabrication technique

I. INTRODUCTION

From the last few years in much industrial application the important parameter in material selection is specific strength, weight and cost. Before going study about the paper we must know the difference between the composite and MMC. The composite defined as the made of several part or element but only combined different material not a non-metal whereas the non-metal is mixed with material this called MMC. Clearly we had seen the review paper. the main mixed material most probably like aluminum alloy, silicon carbide, fly ash, graphite, boron carbide, fly ash cenosphere, silicon nitride, silicon carbide, etc, in this material we fabricated by using different method with respected to the grain size the generally we go for the stir and GPIT technique were check the material distribution by using SEM analyzed with FEA model. Finally we are going to study about the properties.

Composites

The possibility of taking advantage of particular properties of the constituent materials to meet specific demands is the most important motivation for the development of composites. A composite is a material made with several different constituents intimately bonded. This definition is very large, and includes a lot of materials such as the Roman ways (constituted of different layers of stones, chalk and sand), wood, human body etc... A more restrictive definition is used by industries and materials scientists: a composite is a material that consists of constituents produced via a physical combination of pre-existing ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties. This definition distinguishes a composite from other multiphase materials which are produced by bulk processes where one or more phases result from phase transformation ("in-situ" composites).

Aluminum Matrix Composites (AMCs)

Aluminum is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminum matrix composites (AMCs) have been widely studied since the 1920s and are now used in sporting goods, electronic packaging, amours and automotive industries. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. They are usually reinforced by Al2O3, SiC, C but SiO2, B, BN, B4C, AlN may also be considered. The aluminum matrices are in general Al-Si, Al-Cu, 2xxx or 6xxx alloys. As proposed by the American Aluminum Association the AMCs should be designated by their constituents: accepted designation of the matrix / abbreviation of the reinforcement’s designation / arrangement and volume fraction in % with symbol of type (shape) of reinforcement. For example, an aluminum alloy AA6061 reinforced by particulates of alumina, 22 % volume fraction, is designated as "AA6061/Al2O3/22p".
In the 1980s, transportation industries began to develop discontinuously reinforced AMCs. They are very attractive for their isotropic mechanical properties (higher than their unreinforced alloys) and their low costs (cheap processing routes and low prices of some of the discontinuous reinforcement such as SiC particles or Al2O3 short fibers). Among the various and numerous applications [10, 11], a few arbitrary examples, are given in Fig. brake rotors for high speed train automotive braking systems automotive pushrods corss for HV electrical wires etc.

Some industrial AMCs applications: brake rotors for high speed train automotive braking systems automotive pushrods corss for HV electrical wires.

A. Fabrication of the AMCs

There are many processes viable to fabricate AMCs; they can be classified in: solidstate, liquid-state and deposition processes. In solid-state processes, the most spread method is powder metallurgy PM; it is usually used for high melting point matrices and avoids segregation effects and brittle reaction product formation prone to occur in liquid state processes. This method permits to obtain discontinuously particle reinforced AMCs with the highest mechanical properties. These AMCs are used for military applications but remain limited for large scale productions. In liquid-state processes, one can distinguish the infiltration processes where the reinforcements form a perform which is infiltrated by the alloy melt (1) with pressure applied by a piston or by an inert gas (gas pressure infiltration GPI) and (2) without pressure. In the last case, one can distinguish (a) the reactive infiltration processes using the wetting between reinforcement and melt obtained by reactive atmosphere, elevated temperature, alloy modification or reinforcement coating (reactive infiltration) and (b) the dispersion processes, such as stir-casting, where the reinforcements are particles stirred into the liquid alloy. Process parameters and alloys are to be adjusted to avoid reaction with particles. In deposition processes, droplets of molten metal are sprayed together with the reinforcing phase and collected on a substrate where the metal solidification is completed. This technique has the main advantage that the matrix microstructure exhibits very fine grain sizes and low segregation, but has several drawbacks: the technique can only be used with discontinuous reinforcements, the costs are high, and the products are limited to the simple shapes that by obtained by extrusion, rolling or forging.

II. MECHANICAL PROPERTIES OF THE AMCS.

In this section, the basic mechanical properties are succinctly introduced: yielding, fracture. The mechanical models and concepts presented in this section will be used to show that the mechanical behavior of the WFA/Al2O3/sf and WFA/SiC/p composites cannot be completely understood without deeper micro structural investigations.

A. Yielding / Flow.

The ideal AMC stress-strain curve for continuous unidirectional fiber composites (with stress in the fiber direction) is presented in Fig. . Generally, this curve consists of two stages. During the stage I, both fiber and matrix remain elastic, during stage II, the matrix deforms plastically and fibers remain elastic. There is possibly a stage III where both matrix and fibers deform plastically, but generally the fibers break before their plastic deformation. In the case of short fiber composites, the three stages are degenerated in one, and there is no definable linear region in the composite due to the existence of micro plasticity at the fiber ends and to the random fiber orientation. The yield stress is defined as the stress at a plastic strain of 0.2% and represents the limit of the elastic behavior of the composite. Flow stresses are stresses at greater plastic strains. In general the yield stress increases with the fiber volume fraction and a better orientation of the fibers along the tensile axis. The yield stress in compression is in general larger than
in traction due to the residual stress caused by the CTE mismatch between the alloy and the fibers. The prediction of yielding and flow behavior is quite complex. During tensile loading, at a given strain, the stresses in the matrix are expected to be lower than in the unreinforced alloy due to the load transfer to the reinforcements, and therefore the matrix yielding is delayed in comparison with the unreinforced alloy (work hardening caused by the composite structure). The distribution of the reinforcements (orientation and homogeneity) plays a key role in this work hardening. Local plasticity occurs at fibers ends during the deformation (an effect accentuated by the thermal residual stresses). This stress concentration can lead to relaxation effects as dislocation motions, diffusion, recrystallization or to more catastrophic effects such as inclusion fracture, interfacial deboning and matrix cavitations. However, these models remain not very accurate to predict the yield and flow stresses of composites (underestimation of the predicted yield stress), particularly for the misoriented short fiber composites. The underestimation can be explained by a matrix hardening as detailed by Taya. The matrix hardening is mainly the consequence of three effects:

(1) smaller grain sizes in the AMC matrix than in the alloy due to the reinforcement tangle. The hardening follows the Hall-Petch law:

\[ \Delta \sigma_m^y \propto 1/\sqrt{D} \]

where D is the grain size.

(2) higher dislocation density generated by the CTE mismatch between matrix and reinforcements. Arsenault showed that the dislocation density \( \rho \) increases by

\[ \Delta \rho = \frac{BV_\varepsilon}{b(1-\nu_\varepsilon)} \times \frac{1}{t} \]

where B is a geometric constant \( b \) the Burgers vector and t the smallest dimension of the inclusion. The matrix yield stress enhancement follows the dislocation forest hardening:

\[ \Delta \sigma_m^y = \beta \mu b \sqrt{\rho} \]

where \( \mu \) is the shear modulus of aluminum, and \( \beta \) a constant estimated at 1.25 for aluminum.

(3) another aspect has not been considered yet. Considering that \( \sigma_Y = 20 \text{MPa} \) for pure aluminum and \( \sigma_e = 400 \text{MPa} \) for 2xxx alloys, both alloys being cast in the same conditions, it is clear that any possible change of the precipitation state of the alloy when it is reinforced can have a great influence on the final AMC mechanical properties. It is often reported in literature that a change of the density or of the spatial distribution of the precipitation occurs due to the increased dislocation density.

III. CONCLUSION

The matrix hardening does not influence the stiffness of the alloy and therefore of the discontinuous AMCs, but significantly improves the yielding behavior and tensile properties. A fine precipitation homogeneously distributed in the matrix is required to obtain good mechanical properties for the matrix alloy and therefore also for the composite. Moreover, precipitation free zones PFZ near the reinforcements must be avoided since they are favorable to crack propagation.

REFERENCES


