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reinforced with Aluminium glassy alloys

Engineering

The effects of mixing time, sintering temperature, sintering time and pressure on mechanical properties of a metal matrix composite (MMC) reinforced with Aluminium glassy alloys

Introduction

Metal Matrix Composites (MMCs) are an important class of engineering materials because they can continually be adapted to suit the needs of manufacturing and newly available technology. MMCs using aluminium as a basic ingredient can be designed to meet particular needs for high performance materials. Duralumin™ was the first aluminium alloy demonstrating the ability to result in a material with very high temperature strength after solution treatment and aging (STA). Duralumin™ or duraluminium was first developed in Germany by Alfred Wilm, a metallurgist in 1909; the trade name suggests the durability of the new aluminium alloyed with copper, magnesium or manganese compound which immediately became useful for aviation technologies starting with the German Zeppelin airships providing the rigid components for the aircraft.

Contemporary uses of Al-MMCs have been limited to Al-composite panels and Al-cans until the possibility of “ combining Al and carbon nanotube (CNT) materials. The attractiveness of combining Al and CNT is based on the complimentary properties; Al adds the property of super high temperature strength and the CNTs add “ their particularly high mechanical and electrical properties, chemical stability, and high thermal conductivity.” Priority

mechanical properties that are measured are “ strength, ductility, strain rate and temperature dependence, fatigue and tribological properties.”

Experimental research studies consider factors of MMC materials such as the “ high strength and considerable ductility, the compromise between enhance fatigue limit and reduced crack growth resistance, the stress-assisted dynamic grain growth during deformation, and the relation between rate sensitivity and possible deformation mechanisms.” Problems have been identified that must be solved before the MMC could be commercialized include dispersing the CNTs throughout the Al-matrix, an appropriate process design and control the interface of the Al and CNT. Although the ability to reduce grain sizes to the scale of nanometer improves material and “ intermetallic compounds.” mechanical properties and Therefore this research proposes to study the component of the process which requires dispersing agglomerated CNTs in Al powder with nano-SiC (nSiC) as the solid mixing agent; mechanical ball milling and hot pressing are proposed as the two processes used.

This research proposal is based upon current research which has experimented with the effect of milling time on the process of developing a dual nanoparticulate-reinforced Al-alloy MMC.

Research question

What are the effects of mixing time, sintering temperature, sintering time and pressure on mechanical properties of a metal matrix composite (MMC) reinforced with Aluminium glassy alloys?

Objectives of the Research

Background Literature

Highly dense Al-based MMC resulted in an experiment using glassy particles for reinforcement; no crystallization “ Pure Al powders reinforced with different amounts of ball milled Al₆₀Cu₂₀Ti₁₅Zr₅ glassy powders were produced by hot press at the temperatures within the supercooled liquid region under a high pressure of 5 GPa.” Ball milling is a process which enhances particle distribution homogeneity; which ameliorates the “ tendency of nanoparticles to agglomerate.” A study researching nanocrystalline metals’ mechanical behaviour concluded that the use of hot extrusion and mechanical milling resulted in the following positive impacts.

- Nanocomposite grain and particle size decreased as the reinforcement volume fraction increased.
- Compared to nanostructured-Al, an Al matrix incorporated with 2 and 4 wt. % B₄C increased in yield strength while decreasing in elongation.
- Hardness and wear performance were improved when 2 and 4 wt.% B₄C was incorporated into the Al-matrix.
- The problem of heavy deformation of the upper layer of the wear surface was ameliorated when the Al-matrix samples were incorporated with B₄C nanoparticles.

Microwave sintering is another process uses to fabricate MMCs. Ni MMCs reinforced with SiO₂. Researchers successfully applied a uniform nickel layer on SiO₂ powders using electroless plating technique. The best properties for σ_b and hardness were obtained at 1100°C. “ XRD studies revealed that NiO, SiO₂ and phases were formed between SiO₂ and Ni layers, suggesting that

microwave sintering of electroless Ni plated SiO₂ powders can be used to produce ceramic reinforced Nickel composites.”

Bulk nano-crystalline materials have successfully been prepared using the high pressure hot pressure pressing method using Al₆₀Cu₂₀Ti₁₅Zr₅ to reinforce Al-based metal matrix composites. Bulk glassy composites can also be synthesized using a viscous flow of the milled powders in the supercooled liquid region” (Yuan et al., 2014, 301). Glass alloys and glass alloy composites can also be prepared by Powder Metallurgy (PM). The critical part of the PM process is the consolidation step at high temperatures in order to accomplish satisfactory inter-particle bonding and porosity free bulk materials. High temperatures are used for other materials but glass alloys cannot withstand elevated temperatures. The consolidation of glass alloys from glassy powders must successfully crystallize the glass and during and allow for “ crystallization of glassy phase and extensive grain growth.” Spark plasma sintering has been found to work well for glassy powders’ consolidation for example good mechanical properties have been obtained when using MMC with CuZrNiTi- and Ni- based atomized powders.

A Quanta 200i 3D FEI scanning electron microscope (SEM) with a energy-dispersive SEM attachment provided images used to interpret micro-structural fractures in an Al-SiC MMC providing in a better understanding of the “ considerable adhesion of selected aluminium matrix alloys at matrix-filler interfaces and the high mechanical strength of the material under study.” The images and resulting data interpretation demonstrated that “ only silicon and carbon were found in regions of the fracture of silicon carbide grains (within the device’s limit of detection).” (See fig. 1)

Figure 1 (a) SEM image of Al-SiC (x3500) and (b) Distribution in reference to the line profile in (a)

The mechanical properties of MMCs vary depending upon how the powder mixture was prepared. Al₂O₃-Cr composites which demonstrate “ resistance to thermal shocks and to oxidation at high temperatures (even to 1500°), have a high mechanical strength and a high hardness . . . are chiefly produced by the sintering technique.” Research was conducted to compare two preparations, firstly a conventional ball-mix (mechanical) and secondly, a high energy attritor-type mill (mechanical alloying). The sintered Al₂O₃-Cr composites were prepared with differing volumetric shares of the starting powders a range from 25 to 75 vol. %. The research concluded that density did not depend on the method of preparation whereas the hardness was dependent on the shape and composition of the starting materials. Higher bending strength was measured in mechanically alloyed prepared powders (approximately 350 MPa) than when conventional milling was used for the preparation (305 MPa). Both the powder mixture’s composition and the preparation methodology influenced the resistance of the Al₂O₃-Cr although wear resistance was high in general. For the three bend stress test a load was repeatedly be placed at the centre of the upper surface of the sample (the specimen) in order to cause a bending tensile stress at the sample’s bottom. The bending stress (σ_b) will be calculated using the following equation.

Bending stress = $\sigma_b = \frac{6PL}{wt^2}$ Eqn. 1

Where

P = load

L - span

w = sample width, and

t = sample thickness.

Research on the bending fatigue of Al-SiC alloy composite material due to casting imperfections was carried out using the three-point bending fatigue tests. Comparison was made of MMC castings consisting of 30 vol. % SiC particles and Al-9mass % Si alloy. The fatigue test was carried out by fixing the samples to “ a device with span between the lower supports of 60 mm, and a three-point bending fatigue test was carried out at a frequency of 10 Hz and a stress ration of 0. 1 (tension-tension type).” (See fig 2) The research concluded that as a result of the three-point bending fatigue test the “ frequency of cavities decreased with increasing cavity size.” Also the fracture toughness of the MMC casings and the Al-Si alloy casting are similar possibly due to the similar size of the fatigue fracture region in both of the specimens when the shapes were flat and the specimens were notched.

Figure 2 Instrument used for the fatigue testing (a) and specimen placement for the three-point bending fatigue test (b)

A premixed commercial Al-Zn-Mg-Cu powder was used prepare cold pressed powder compacts in order to evaluate direct hot extrusion processing of 7075 Al. The purpose of the research was to “ produce a bulk alloy with homogeneous microstructure and superior mechanical properties from the employed premixed powder.” The experimental procedure started with the preparation of 2. 5 mm diameter by 15 mm thick cylindrical compacts by “

uniaxially subjecting them to cold pressing at 600 MPa. Green compacts were selected so that a portion underwent delubrication (from the 1.5 wt% lubricant in the commercial premix) or to presintering. A 425° C extrusion process was then carried out on the powder compacts. Graphite was added to some of the compacts in order to investigate how the microstructure developed during heating. The conclusions reached included interestingly that “ the pre-sintered powder compacts showed a fine, recrystallized microstructure” and the result was “ a superior combination of mechanical properties for the consolidated material.”

A MMC consisting of carbon nanotube reinforced copper matrix using powder metallurgy used different 1 - 2% volume of the carbon nanotubes which were then compacted at 80 kN. The purpose of the research was to compare the green density and the sintered density of the specimens. Sintering took place in Argon gas at a temperature of 900°C to ensure the same temperature while the sintering time ranged from 45 to 90 minutes. The microstructures of the sintered samples were studied under an optical microscope and with an SEM. The researchers found that the “ sintered and the theoretical densities showed 98% of the theoretical densities” whereas the 90 minutes duration at the 900°C sintering temperature with “ about a 17 ton load (was) sufficient to produce near full density copper-fibre composite.”

Figure 3 Green copper compact (a) and sintered copper compact (b) Test samples at 900°C

Abrasive wear was compared between SiCrFe, CrFeC and Al₂O₃ reinforced Al₂O₂₄ MMCs by evaluating the effects of particulate volume fraction and

particulate size. Stirring speed, stirrer position and stirrer diameter were found to affect diffusion between the matrix and particulates. The researcher found that “ the abrasive wear rate was decreased by an increase in the particulate volume fraction of CrFeC and SiCrFe intermetallic reinforced composites over 80 grade SiC abrasive paper. Overall the conclusion was made that “ fabrication of composites containing soft particles as copper favours a reduction in friction coefficient.” The following equation was used to calculate the wear rate.

$$\text{Wear rate} = W \text{ (mm}^3 \text{ m}^{-1}\text{)} = \frac{\text{Mass loss (g)}}{\text{Density (g mm}^{-3}\text{)} \times 320 \text{ m} \times 160 \times 10^{-3}}$$

Eqn. 2

Methodology

A qualitative and quantitative research project on MMCs is proposed for this research project. The qualitative portion of the project consists of a thorough literature review including academic articles from peer reviewed journals and industry white papers. Design plans or specifications from manufacturers and specification sheets will be used when helpful for understanding the theory of the instrumentation design. Engineering results and tables published in the literature and handbooks will be used for reference. Articles have been compiled using research terms including “ Al-SiC” “ MMC” “ Metal Matrix Composites” “ nanotube MMC” “ effects of mixing time” “ sintering temperature” “ sintering time” “ sintering pressure” “ mechanical properties of Metal Matrix Composites” “ Green Density Measurements” “ Sintered Density Measurements” “ Volume Shrinkage Measurements” “ three point

bending test” and “ Scanning Electronic Microscope.”

Figure 4 Methodology Flow Chart for study of MMCs

Preparation

An adaption of the experimental methodology of Yuan will be used. Al, Cu, Ti and Zr elemental powders of the highest purity (99.5%) will be mixed to prepare Al₆₀Cu₂₀Ti₁₅Zr₅ (atom) in a glove box with a high purity atmosphere of Argon. Stainless steel balls will be added with the mixture into a 250 ml stainless steel vial and mixed with stainless steel balls. Al powders will be mixed with the resulting Al₆₀Cu₂₀Ti₁₅Zr₅ powders in predetermined volume fractions. Consolidation of green compacts will be carried out at two temperatures but for the same amount of time. The following tests will be carried out.

- Green and Sintered Density Measurements will be taken in order to determine the degree of porosity in each of the samples. By measuring both the pre-sintered green density and the post sintered density of the samples the degree of porosity can be compared.
- Volume Shrinkage Measurements will be taken so any dimensional changes can be accurately evaluated based on whether or not diameter expansion and grain growth are observed.
- The three point bending test will be carried for an analysis of the bending tensile strength of the samples.
- Scanning Electronic Microscope will be used in order to determine the microstructural properties of the MMC such as particle size distribution and the particle shapes.

Generally speaking the mechanical properties of sintered MMCs are dependent upon the process parameters of the sintering: the temperature, the process duration and the pressure. And the mechanical properties of sintered MMCs are also dependent on the measurable geometrical factors of the starting powders including “ grain size and roughness of the grain surfaces, type and form (particles, fibres) of the reinforcing phase, distribution of the reinforcing phase within the matrix, and the type of the bonds at the reinforcing phase / matrix interface.” The effects of mixing time, sintering temperature, sintering time and pressure on mechanical properties of MMCs will be measured, evaluated and compared.

References

Alizadeh, A. and E. Taheri-Hassaj. ‘ Mechanical properties and wear behavior of Al-2wt.% Cu alloy composites reinforced by B₂C nanoparticles and fabricated by mechanical milling and hot extrusion’, *Materials*

Characterization, 67, 119-128

Chmielewski, M., Pietrzak, K. and W. Wlosinski. ‘ Properties of sintered Al₂O₃-Cr composites depending on the method of preparation of the powder mixture’, *Science of Sintering*, (2006), 38, 231-238, p. 232.

Clyne, T. W. and P. J. Withers. *An Introduction to Metal Matrix Composites*. Cambridge Solid State Science Series. Cambridge, UK: Press Syndicate of the University of Cambridge. 1993, Print.

Dao, M., Lu, L., Asaro, R. J., De Hosson, J. T. M. and E. Ma. ‘ Toward a quantitative understanding of mechanical behavior of nanocrystalline metals’, *Journal of Acta Mater* (2007) 55, 4041 – 4065.

<https://assignbuster.com/free-research-proposal-about-the-effects-of-mixing-time-sintering-temperature-sintering-time-and-pressure-on/>

Dwight., J. Aluminium Design and Construction, Routledge, 1999

Goudah, G., Ahmad, F. and O. Mamat. ‘ Microstructural studies of sintered carbon nanotubes reinforced copper matrix composite”, Journal of Engineering Science and Technology, (2010), 5(3), 272-283, p. 272.

Griffin, Richard B. An experiment in powder metallurgy: Sintering of Cu. Materials Education, [http://www. materialseducation.](http://www.materialseducation.org/educators/new/2006/docs/Griffin%20Paper%20Exp%20In%20PM06_08-11-06.pdf)

[org/educators/new/2006/docs/Griffin%20Paper%20Exp%20In%20PM06_08-11-06. pdf.](http://www.materialseducation.org/educators/new/2006/docs/Griffin%20Paper%20Exp%20In%20PM06_08-11-06.pdf)

Kaczmar The production and application of metal matrix composite materials [http://www. sciencedirect. com/science/article/pii/S0924013600006397](http://www.sciencedirect.com/science/article/pii/S0924013600006397)

Krasnowski, M., Antolak, A. and T. Kulik. ‘ Nanocrystalline Ni₃Al alloy produced by mechanical alloying of nickel aluminides and hot-pressing consolidation’, Journal of Alloys and Compounds, (2007), 434-435, 344-347

Kato, H., Otsuka, s. and A. Nonaka. ‘ Influence of casting defects on fatigue properties of SiC particulate dispersed aluminium alloy composite castings’,

Kwon, H., Saarna, M., Yoon, S. Weidendkaff, A., and M. Leparoux. ‘ Effect of milling time on dual-nanoparticulate-reinforced aluminum alloy matrix composite materials’, Materials Science and Engineering, (2014) 590, 338-345

Laparoux, Susanne. Influence of SiC-particle size on microwave sintering of mixed metal composites. [http://www. empa.](http://www.empa.ch/plugin/template/empa/*/22843)

[ch/plugin/template/empa/*/22843](http://www.empa.ch/plugin/template/empa/*/22843)

Nishchev, K. N., Nvopoltsev, M. I., Mishkin, V. P. and B. V. Shchetanov. ‘

Studying the microstructure of AlSiC metal matrix composite material by scanning electron microscopy’, Bulletin of the Russian Academy of Sciences,

<https://assignbuster.com/free-research-proposal-about-the-effects-of-mixing-time-sintering-temperature-sintering-time-and-pressure-on/>

Physics, (2013), 77(8), 981-985

Rosso Ceramic and metal matrix composites: Routes and properties.

<http://www.sciencedirect.com/science/article/pii/S092401360500419X>

Saheb, Nouari Zafar Iqbal, Abdullah Khalil, et al., ' Spark Plasma Sintering of Metals and Metal Matrix Nanocomposites: A Review', Journal of Nanomaterials, (2012) Article ID 983470, 13 pages, doi: 10.

1155/2012/983470 <http://www.hindawi.com/journals/jnm/2012/983470/cta/>

Scott, M. L. Proceedings of the 11th International Conference on Composite 1997 books. google. gr/books? isbn= 1855733528

Srikanth ' Finite element based energy dissipation studies of Al-SiC composites', Journal of Composite Materials,(2003), 37(15), 1385-1410 <http://ac.els-cdn.com/>, doi: 10. 1177/0021998303034362,

Yilmaz, S. O. ' Comparison on abrasive wear of SiCrFe, CrFeC and Al₂O₃ reinforced Al₂O₃ MMCs', Tribology International (2007) 40, 441-452, p. 441

Yuan, M. Zhang, D. C., Tan, C. G., Luo, Z. C., Mao, Y. F. and Lin, J. G. ' Microstructure and properties of Al-based metal matrix composites reinforced by Al₆₀Cu₂₀Ti₁₅Zr₅ glassy particles by high pressure hot pressing consolidation', Materials Science & Engineering A, (2014) 590, 301-306

Zhang, W. L., Wang, J. X., Yand, F., Sun, Z. Q. and M. Y. Gu. ' Recrystallization Kinetics of Cold-rolled Squeeze-cast Al/SiC/15w', Composites Journal of Composite Materials, (2006), 40(12), 1117-1131 <http://jcm.sagepub.com/content/40/12/1117.full.pdf+html>

APPENDIX

ABBREVIATIONS AND ACRONYMS

<https://assignbuster.com/free-research-proposal-about-the-effects-of-mixing-time-sintering-temperature-sintering-time-and-pressure-on/>

AlAluminium

CuCopper

NiNickel

SiCSilicon Carbon

STASolution Treatment and Aging

TiTitanium

ZrZirconium

CNTCarbon Nanotube

GRAGlass Formation Abilities

MMCMetal Matrix Composites

ncnanocrystalline