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REVIEW ARTICLE

A REVIEW ON THE MECHANICAL PROPERTIES OF ALUMINIUM BASED METAL MATRIX COMPOSITE VIA POWDER METALLURGY

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ABSTRACT

The present study deals with the aluminium metal matrix composite fabricated through different powder metallurgy process. This MMC's has wide application in aerospace, automobile, sports and industrial appliances due to their high strength to weight ratio, high temperature, better corrosion and wear resistance. This study will reveal the effect of different reinforcement in an aluminium matrix composite and review the technique that different researcher used to fabricating and estimating different mechanical and tribological properties.

Key words: Aluminium metal matrix composite (AMMC's), Powder metallurgy, Mechanical properties, Percentage amount of reinforcement.

INTRODUCTION

A Composite material is the combination of two or more material with different chemical property in order to form a stronger material. Aluminium metal matrix composite (AMMC) are formed by spreading reinforcement in the metal matrix. Reinforcement is usually done to improve the mechanical properties of the metal matrix like hardness, strength, temperature withstand capacity, wear resistance, environmental effect, density, porosity etc. In recent year stringent requirements of material quality in automotive and aerospace industries have necessitated the development of light weight aluminium alloys (Gaurang, 2016). The application of aluminium and its alloy are more in an industry in comparison to other metal alloys (Das, 2010). Silicon carbide, boron carbide, alumina, tungsten carbide, Titanium dioxide, graphite, carbon-nanotubes and silica are the basic reinforcement but silicon carbide and alumina are the most widely used reinforcement. Graphite are conductive, have an excellent combination of high modulus, high tensile strength and offer resistance to high temperatures. SiC reinforcement increases the hardness, tensile strength, wear resistance and density of Al alloys. The addition of Boron carbide increases the hardness exponentially while wear resistance doesn't increase significantly. Tungsten carbide as a reinforcement increase tensile strength and hardness of MMC (Habibur rehman, 2014). Basically MMC reinforcements are divided in four major categories: continuous fibre, discontinuous fibre, whiskers, wires and particulate (Rajesh purohit, 2012). The use of fly ash as a reinforcement is significant because of lower cost and availability as waste by product in thermal power plants (Aniruddha, 2015).

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In this paper we will be investigating the various methodologies for making different composite through the different reinforcement and their effects on the mechanical properties.

Silicon carbide as a reinforcement

Gaurang deep al (Gaurang Deep, 2010), investigated the mechanical properties of Al- SiC composite taking sample (400 grit) of commercial aluminium and SiC powder. In this work five different sample were fabricated by changing the quantity of SiC i.e. (5%, 10%, 15%, 20 %, and 25%). Fabricating these samples from the mixing, compacting and sintering process, the three major test were performed. The tensile test was carried out in on UTM, initially for the commercial aluminium the tensile strength was measured as 139.4 MPa which is 4.2% less than Al-5%SiC composite and from this test it was also observed and figure out that tensile strength of the Al-15% SiC was maximum i.e, 172.54 MPa. That showed for the sample of (15% of SiC) have maximum. The hardness test was performed the hardness value for the commercial aluminium was measured as 50.12BHN while the hardness was increasing for the 5%, 10% and 15% of SiC as 68.2%, 72.88% and 87.1 BHN respectively. This result showed that 15% of SiC reinforcement sample has maximum hardness. S.Das al (Das, 2010), fabricated and investigated the effect of reinforcement on the forge ability and mechanical properties of aluminium metal matrix composite. Here in this work four sample were fabricated that having (5%, 10%, 15%,20% of SiC) through powder metallurgy and calculated the theoretical and experimental density, forge ability, hardness and tensile strength. The result obtained from this experiment shows that a) forge ability decreases with increase in percentage of SiC, b) density increases with increase in SiC c) Hardness and the strength increases with increase in SiC. Rajesh Purohit al

(Rajesh purohit, 2012), fabricated the six sample of aluminium composite taking (5%, 10%, 15%, 20%, 25%, 30% of SiC). During the powder mixing .5% of Mg was added in order to increase the wet ability of SiC particulate with aluminium powder and during milling process, 2% of stearic acid was added as a controlling agent in order to prevent the aluminium to get itself welded. Rockwell hardness was measured with the polished surface of Al-SiC composite samples using C scale on Rockwell hardness tester. A diamond indenter with fixed indentation load of 150kg was used for all tests. Porosity of sintered as well as un-sintered compacts was measured using archemidies principle. First calculate the theoretical and sintered density; these densities are used in order to calculate the porosity. For the compressive strength test was performed on UTM with load of 100KN and maximum failure load was recorded. The surface roughness on polished specimen was determined using Tally surf-6 roughness measuring instrument. Md. Habibur Rahman al (Habibur rehman, 2015). Fabricated silicon carbide aluminium metal matrix composite taking the (0, 5,10 and 20% of SiC) and obtained that 20% of reinforced AMC showed the maximum tensile strength and hardness. Clustering and non-homogenous dispersion were also observed in the microstructure and wear resistance were also increasing with increase in SiC content in Al matrix. Aniruddha V. Mulley al (Aniruddha, 2015), investigated that silicon carbide (5%,10% and 20% of SiC) reinforced aluminium composite. The study showed that increase in volume fraction of SiC will result in higher micro hardness of the AMC. This experiment also explained that Al-SiC has the higher thermal conductivity that's why this composite is used in microwave system, flat chip lid in networking, telecommunications system and intake and exhaust valve in Toyota Altezza. Y.Sahin al (Sahin, 2003), prepared and investigated some properties of SiC reinforced aluminium alloy. This study shoed that powder metallurgy is an accurate method of fabricat9ng alloy but costly one, that's why squeeze casting method is used to fabricate Al-alloy. Optical microscopic examination, density, hardness ad porosity measurement were carried out. The composite with 10% and 20% SiC as reinforcement was prepared using electric induction furnace, which is 2kw power under protected argon gas. Three methods were used for adding SiC in composite. Here we will bee discussing only one but most important method i.e by using tunnel pipe. Small amount of SiC is mixed into matrix during adding time by using this method some SiC particle distributed around and some remained at the bottom/ top of the furnace. After the mixing process, these blocks were put into crucible and held to be melted. After completion of melting process, the mixing started.

Approximately 5 to 8 gm of Silicon carbide were inserted on an aluminium foil by forming packet. The packet was added into molten metal of crucible when vortex was formed at every 5-25 sec. The packet of mixture melted and the particles started distributing in alloy sample. The different test was performed and got some important results. Micro structural examination showed that the SiC particles were distributed uniformly over the alloy and no interface porosity could be estimated. MMC' consisting of 10%, 20% of SiC can be fabricated easily through molten metal mixing process. Manufacturing of Al- alloy was done successfully by liquid metallurgy route through addition of SiC in the form of packets. T.G Nieh al (Nieh, 1988), investigated mechanical properties of SiC reinforcement based aluminium composite including 2024 and 6061 alloys matrices. Although SiC reinforcement increases the mechanical properties of Al- alloys at an elevated temperature but here in this study, strain rate energy and activation energy for the creep deformation are also investigated here. The three sample fabricated here were 20 vol-percent SiC-6061 Al, 30 vol percent SiC-6061 Al and 20 vol percent SiC-2124 Al though powder metallurgy method. The 2124 Al composite was tested under double shear stress configuration and 6164 Al composites were tested in tension under constant stress. The 20 vol percent SiC 2124- Al composite was tested at an elevated temperature of 643K under different values of shear stress. in most metal generally three major stages occurs: short primary stage, a long and reasonable secondary stage and then an increasing creep rate in tertiary stage. It has been observed that creep behaviour of discontinuous SiC reinforced aluminium composite is totally different from the metrics material. The minimum creep rate of composite however, strongly depends upon temperature and applied stresses.

Boron carbide as a Reinforcement

Yusof Abdullah al (Yusof Abdullah, 2012), fabricated and analysed the mechanical properties by making two sample of AL/B_4C with (5, 10 wt% of B_4C) reinforcement. In this experiment Al and B_4C powder were mixed by ball milling, dried and sintered at 850^0C for 2 hours. In this work milling time of 8 and 16 hours were the controlling parameter. The hardness test was conducted in these two different milling times and came to the result that showed, increased in hardness of Al/B_4C composite on increasing the amount of boron carbide in the composites. The hardness of Al/10%B_4C and Al/5%B_4C was 81.72 and 78.68% respectively. The density was also calculated in both 8 and 16 hours and the result indicated that the density increases with increase in milling time but decreases with increase in amount of B_4C reinforcement in Al-composites. Jinkwan jung al. (Jinkwan jung, 2004), fabricated Al-B_4C composite via powder metallurgy and investigated the mechanical properties. Reinforcement boron carbide have some advance properties such as extremely high hardness (H_v=30GPa) and low specific density (2.5 gm/cm^3). In addition it has distinct advantages for an application involving wear resistance and impact resistance. In this study Titanium and its alloy were used as additive in order to enhance the wet ability of the liquid aluminium on boron carbide skeletons. Four sample of boron with its additive were formed taking aluminium (99.9%) rest B_4C:TiB_2, B_4C:TiN are taken in weight ration of 5:1 and B_4C:Ti of 10:1 or 20:1 weight percentage. The mixtures were magnetically stirred with acetone for uniform mixing, drying at 100^oC. Now after mixing it was compacted under uni-axial load of 100MPa. A pressure of 200MPa was used when bimodal mixtures were formed. XRD result showed the presence of Al_4C_3 phase. Different mechanical properties were calculated using the different instruments like hardness value was $88H_{RA}$ by heat treatment of samples at 1100^oC at 8h. fracture toughness of 9.2 MPa*$m^{1/2}$ was obtained by heat treatment of sample at 600^oC for 20 h. the compact density of specimens was ≈85%.Ibrahim at (Ibrahim, 2014), investigated all the mechanical properties of Al-15%B_4C based metal matrix composite. The researcher observed that ductility of composite sample decreased on increasing vol% B_4C and fracture of B_4C occurred by cleavage process. Baradeswaran. A al (Baradeswaran, 2013), investigated the mechanical and tribological properties of Aluminium alloy (6061)-Boron carbide. In his study specimen was fabricated through powder

metallurgy by taking 5, 10, 15 and 20% volume of reinforcement(B_4C). Methods of fabricating the specimen were same as discussed earlier. The composite samples produced were characterized by hardness and compression tests. The result of this test showed that on increasing the vol percentage or amount of B_4C, the harness of composite increases accordingly because of the increase in ceramics phase of metal alloy. Compressive strength of the composite also increases with increase in B_4C content. Wear resistance of composite increases with increase in amount of B_4C, the coefficient of friction decreased on increasing content of boron carbide with minimum of .3 at 10% vol and remain steady between.3 to .4. Pradeep V. Badigar al (Pradeep, 2015), investigated mechanical properties of aluminium alloy 6061 with reinforcement of B_4C. the researcher observed that hardness is increased due to addition of B_4C content remarkably and an improvement of 17% and 38% in ultimate tensile strength was observed over aluminium alloy 6061 on addition of 7% and 9% of B_4C.compressive strength was achieved over aluminium alloy on addition of 7% and 9% of B_4C were 330 N/mm^2 and 355 N/mm^2.

Aluminum Oxide as a reinforcement

Dewan Muhammad Nuruzzaman al (Dewab Muhammad nuruzzaman), fabricated the three sample of alumina-aluminum matrix (Al-Al_2O_3) having 10%, 20% and 30% of Alumina (Al_2O_3) and calculated the effect on different mechanical properties. These specimens were fabricated under the different load of 15 and 20 ton. Basically in this study effect of volume fraction of Al_2O_3 and compaction load on the properties of Al/Al_2O_3 was calculated. Now taking different samples, it was observed that increasing the load from 15 ton to 20 ton, increases the density of Al-composite. On increasing the volume fraction of Alumina, the density increases but after sintering process it was observed that for the compaction load of 20 ton , the increase in density of composite was somehow less than that of the composite under the load of 15 ton. It was calculated through the Rockwell hardness tester that average hardness under the 20 ton compaction load is greater than that of composite under 15 ton compaction load and densities of composite under 20 ton load is higher than the specimen under 15 ton. Bhaskar Raju al (Bhaskar raju, 2014). Aluminum matrix have enhanced properties such as elastic module, Hardness, tensile strength at room and elevated temperature over the unreinforced alloys. Hybrid composite are relatively new and obtained by using two or more different kind of reinforcement materials in metal matrix. Hybrids have a better all around properties than a composite containing only single phase. In this study fabrication of Al-4%Cu/ Alumina was done by in-situ reaction to form alumina during fabrication.

The material obtained in starting was having silica, copper and aluminum. In this experiment firstly sintering of the mixture was done at an elevated temperature of 650^{o}C and then hot forging was done at an elevated temperature range of 590^{o}C to 650^{o}C after this process it was observed that the chemical reaction between silica and aluminum took place during the long heating above the 590^{o}C. Microstructure showed, reacted areas consisting the gamma- alumina. done at an elevated temperature of 650^{o}C and then hot forging was done at an elevated temperature range of 590^{o}C to 650^{o}C after this process it was observed that the chemical reaction between silica and aluminum took place during the long heating above the 590^{o}C. N.parvin al[15] investigated the effect of aluminum oxide on the mechanical properties of pure aluminum. The powder metallurgy technique was used to fabricate the powder. In this study three sample of different size (3, 12 and 48μm) but with the same percentage of aluminum oxide (10%) were prepared and effective properties were calculated. Firstly sample were cold pressed under 440MPa and then sintered at 550OC for 45 min. the result showed that the relative density increased initially with decrease in particle size, however, decreased with further particle size reduction and also pointed out that mechanical properties was increased with decrease in particle.G.B veeresh kumar al[16] investigated properties of aluminum alloy (Al-7075) with reinforcement of Al_2O_3. In this study composite specimens were prepared using liquid metallurgy technique (already discussed in…). Here some of the important results were estimated that include increase in hardness with an increase of percentage of Al_2O_3. The wear resistance was also estimated that showed the superior wear resistance properties of composite.

Titanium Oxide as Reinforcement

Ravichandran et al. (Ravichandran, 2014), synthesized Al+TiO_2+Gr composite through powder metallurgy. Aluminum metal matrix is mostly used as a design material for the bearing because of its good porosity. In all the reinforcement SiC, Alumina, Boron carbide , the titanium dioxide posses high hardness , modulus with superior corrosion resistance and wear resistance. In this study three sample of Al+TiO_2+Gr, the first sample consisting 2.5% TiO_2 and rest of aluminum, Al-2.5% TiO_2. 2% Gr and last sample having Al, 2.5%-TiO_2 , 4% Gr. The blending was done with balls and the powder weight ration of 5:1 and sintering was done at higher temperature of 590^{o}C. The XRD analysis for Al-2.5% TiO_2. 2% Gr was carried out in XRD, Diffractometer , C_u ka target with the wavelength of 1.5418 A^o. The XRD results confirmed the presence of graphite and TiO_2 reinforcement in the aluminum matrix. Different pattern of composite showed that the peak broadening of Al increases with increasing addition of Al and Gr reinforcements. The result of this study also include that on 2.5 weight of increases the hardness of performs and addition of 4% of Gr to the Al+2.5% AlO_2 decreases the hardness of Al- composite. M. Ravichandran et al (Manickam Ravichandran, 2014). investigated the Al- TiO_2 through the liquid powder metallurgy technique. This is special type of study there the researcher fabricated the Al- composite with presence of 5% weight of TiO_2 through the liquid powder metallurgy technique. Basically the liquid powder metallurgy technique is more economical in nature with discontinuous fibre and particulates. In this study first an Al- was first superheated above the melting point and then temperature was cool down to the liquid us temperature to keep the matrix alloy in semi-solid state, the TiO_2 particle were introduced in the slurry and mixed using graphite stirrer.

After the sintering process the different tests i.e hardness and SEM test was performed and calculated the hardness and tensile strength of the Al-5%weigth TiO_2 composite. After performing these tests it was observed that the hardness increases with addition of TiO_2 in the Al- composite in comparison to the pure Al. tensile strength test was done using electron microscope. From thus test it was observed that the failure was ductile-brittle failure and it was caused due the presence of Hard and brittle TiO_2. Sumanth H.R al (Sumnath, 2015), investigated mechanical properties of Aluminum alloy

(Al6061) with reinforcement of Titanium oxide. In this study the specimen by taking the different percentage of TiO_2 as (5%, 10% and 15%) in weight. From the experiment it is observed that for 5% of TiO_2 reinforcement the hardness of the sample were maximum as compare to the other samples consequently the compressive strength is recommended for the 5% TiO_2 metal matrix composite. wear resistance increases with increase in percentage of TiO_2 till 15%.SEm test gives uniform distribution of reinforcement over the metal matrix.

Conclusion

The present study deals with the fabrication of Al-metal matrix composite with the different reinforcements of SiC, B_4C, AlO_2 and TiO_2 and calculated the mechanical properties and perform different test like Rockwell hardness text, tensile test, compression test, XRD test, SEM etc.

Following major facts are drawn from the above study

- Powder metallurgy is an easy, accurate method of fabricating aluminum composite.
- The percentage increase of reinforcement increases the hardness, wear resistance of the composite.
- Improved tensile strength, compressive strength and impact are obtained on adding the different reinforcement.
- Liquid powder metallurgy is also an effective method fabricating the composite.
- Apparent density, tap density, green density and sintered density were calculated successfully and an increment of these densities was observed on addition of reinforcement.

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