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Evaluation of Mechanical Properties and Stability of Al 6061 with addition of ZrO_2 And Al_2O_3

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Abstract: *Newer materials with good specific strength, damage tolerance and corrosion resistance are needed for automotive industries. The research deals with the analysis of Zirconia on the mechanical and corrosion properties of Al6061. The Metal Matrix Composites (MMC) was prepared by friction stir welding. Three MMCs samples were prepared with 5%, 10% and 15% of zirconia. The mechanical properties such as seems to be increased due to the addition of zirconia in the composites. The plain strain fracture toughness increases slightly by increasing zirconia. But the wear studies shows the zirconia addition decreases the wear resistance of the composite in the Al 6061 matrix. This is due to the poor bonding of zirconia with the Al 6061 matrix. The selected combination of specimens proved that there are only minor changes in the properties due to zirconia additions.*

Keywords: Al6061; ZrO_2 & Al_2O_3; Mechanical behavior; Fracture Toughness; Thermal stability.

1. INTRODUCTION

Aluminum even though having high strength to weight ratio and it is widely used in automotive industries yet it suffers hardness and corrosion resistance. So we have to find a new alloying element which wills increases hardness, strength, wear and corrosion resistance. As we know many engineering ceramics have been widely used in making alloy of Al 6061. The addition of TiB_2 in Al6061 alloy results not only the increase of tensile strength without losing elongation percentage but also gives uniformity in microstructure. The type of fracture occurred is ductile in spite of adding TiB_2 [1]. On different reinforced material used in aluminum and explained the improvement in tensile strength, strain, fatigue, wear and hardness [3-5]. Many researchers found the increase in mechanical properties due to SiC than Al_2O_3 and therefore aluminum with SiC used in brake drums [2]

The processing of these nano powders are done by various methods can be compacted and sintered easily than the available commercial products [6]. However we have used commercial zirconia for our study. Formerly ZrO_2 is used for coatings in various metals for protection against corrosion and to improve hardness as the ceramics will act as crack fillers [7]. The wear mechanism in Al alloy was adhesive and when incorporating nano SiC it changed to abrasive. The composite has more wear and chemical resistant. It also has low friction coefficient [8].

MMCs are prepared by reinforcing zirconia grade aluminosilicate fiber by 15% and 20% by volumes increases wear resistance in high sliding speed. Also the MMC has improved CTE, hardness, compression and corrosion properties [9]. Alumina are used from 20% volume in in-situ powder metallurgy along with aluminium showed good wear resistance properties due to lower friction coefficient and shall be used in components exposed to wear [10]. Al 2618 grade also made good corrosion resistance by adding ceramics materials such as AlN, Si_3N_4, ZrB_2 produced by stir casting. The corrosion resistance is gradually improved in 3.5% NaCl by the results of polarization and AC impedance spectra [1].

Now a days hybrid composites are produced to enhance the strength of Al 6061. SiCp (CNT) reinforcements were used in different micron sizes improves the tensile strength largely [20]. Due to compression deformation behavior, increased energy absorption, sustain large strain at reduced level of stress, the metal matrix syntactic foams are widely used for Al-MMCs [21].

2. MATERIALS AND METHODS

2.1. Materials

Aluminium – 6061 grade was used in this study for base material. Zirconia and alumina with different weight percentages are added to the base material. The liquid metallurgy route was preferred during the research. The alumina and zirconia metal powder with 10 to 20 μm was used. Primarily the aluminum – 6061 was melted in a graphite crucible with a stirrer made up to steel coated with graphite. The chemical composition was given in the Table 1. The alloy was made to melt in the crucible. Zirconia and alumina was added gradually in the argon atmosphere at 5%, 10% and 15% by weight into the molten aluminium alloy. The stirrer speed was kept at 400 rpm. The temperature for the MMC were maintained above 720°C and poured into cast iron mold. The proportions of all the sample is listed in table 2. The density was found by using

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digital density measuring instrument – hydrometer. Both actual and theoretical was found. The hardness of the casted specimens were found by using Vickers Hardness by the load of 0 to 100 kgf. Wear test was carried out by using pin-on-disc experiment with ASTM G99 to found out the volumetric loss of the material [10-11]. The specimen size was set at 10mm and with the diameter of 25mm. The disc was made up of high chromium and high carbon steel which has R_C60. The sliding distance were kept for 540 m with the load variation 10 to 40N.

3. RESULTS AND DISCUSSION

3.1. Density

The density of the 4 specimens where evaluated by both theoretically and experimentally. The experimental values are taken by using digital density measuring device. As per the result obtained, the density increases for the MMCs with the addition of alumina and zirconia filler content. The theoretical and experimental density values show less variations.

3.2. Vickers Hardness

Vickers Hardness test was considered for the present study. The hardness of the material increases with the addition of hard phase nano particles – ceramics (Al_2O_3 and ZrO_2). The hardness values increases due to the addition of more weight percent of the ceramics into the matrix. This is due to the uniform dispersion of the reinforcements into the matrix of Al6061 and due to the addition of hard materials as a reinforcements into the soft metal matrix.

3.3. Tensile Strength

The tensile strength was performed as per ASTM – E8/E8M-08 in room temperature. The graph was plotted based on the experiment done on 4 different samples with the average of 5 readings. The tensile strength increases with the additions of reinforcement's particulate in the MMC [15]. The ceramics bonding is good and due to which the tensile strength has increased than the Al6061 and reached maximum in 15% weight additions. The ceramics act as barrier to the dislocation in the matrix during the application of load. Also the strengthening mechanism occurs due to the addition of nano particles [16-19].

3.4. Percentage elongation

The table 6 shows a decreasing trend in the percentage elongation with an increase in quantity of Al_2O_3 and ZrO_2. The local stress concentrated on the reinforcement and matrix interface reduces the ductility monotonically. The decrease in ductility is one of the disadvantage in MMCs.

3.5. Plain Strain Fracture Toughness

Linear elastic plain strain fracture toughness was conducted on the materials according to ASTM E 399. It is important test for material damage as it shows resistance to crack propagation [12, 13]. In order to conduct the test, the specimens were polished and maintained at 3μm surface roughness. The 3 point bend test was initiated until the propagation of crack occurs in the specimen. The cross head speed was maintained at 5mm/sec with the load of 250KN. The fracture toughness increases gradually due to addition of ceramics in the matrix shown in Table 7. The crack growth initiated on the specimen become less when the reinforcements are added. The crack as propagated are not elastic and due to the harder reinforcements it become fracture. This is evident from the poor ductility in the elongation percentage. Many small cracks are observed shows the crack propagation in all directions. The specimen which has more % of ceramics in the matrix shows higher KIC. The specimen 4 which has higher KIC of 19.3 Mpa.

3.6. Wear test

The effect of alumina and zirconia amount and its size in the matrix were considered during the wear of specimen. The volume loss for the sliding distance of 540 m for all the 4 specimens were calculated. It is observed that the wear of specimens with the addition of ceramics into the matrix of Al6061 decreased greatly. By Archard theory, wear resistance is proportional to the hardness of the specimen. Thus by adding ceramics into the matrix, the hardness as well as wear resistance increased. It is compared that the volume loss in 15% alumina and zirconia is less and found to be more wear resistant than Al 6061. This is due to harder phase of the reinforced material.

3.7. Thermo Gravimetric Analysis (TGA)

The TGA study of the samples are presented in the figure 1. The % weight loss gets reduced due to the addition of Al_2O_3 and ZrO_2.

Table 1. Chemical composition of Al 6061 Alloy

Element	Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Be	V	Al
%	0.92	0.76	0.28	0.22	0.10	0.07	0.06	0.04	0.03	0.01	Bal

Table 2. Composition of the samples

Sample	Composition
Specimen 1	100% Al6061
Specimen 2	Al 6061 + 5% ZrO_2 +5% Al_2O_3
Specimen 3	Al 6061 + 10% ZrO_2+ 10%Al_2O_3
Specimen 4	Al 6061 + 15% ZrO_2 +15%Al_2O_3

Table 3. Density of the samples

Specimen	Specimen			
	1	2	3	4
Densities (g/cm^3)	2.7	2.948	3.127	3.45

Table 4. Vickers hardness of samples

Specimen	Specimen			
	1	2	3	4
Vickers Hardness	69	72	85	89

Table 5. Tensile strength of samples

Specimen	Specimen			
	1	2	3	4
Tensile Strength (MPa)	118	124	143	157

Table 6. Percentage Elongation of samples

Specimen	Specimen			
	1	2	3	4
Percentage Elongation (%)	9.3	7	5.4	3.8

Table 7. Plain strain fracture toughness of samples

Specimen	Specimen			
	1	2	3	4
Fracture Toughness ((KIC) Mpa√m)	13.5	15.5	17.8	19.3

Table 8. Wear test of samples

Specimen	Specimen			
	1	2	3	4
Volume Loss (mm^3/min)	3.633	2.165	1.054	0.288

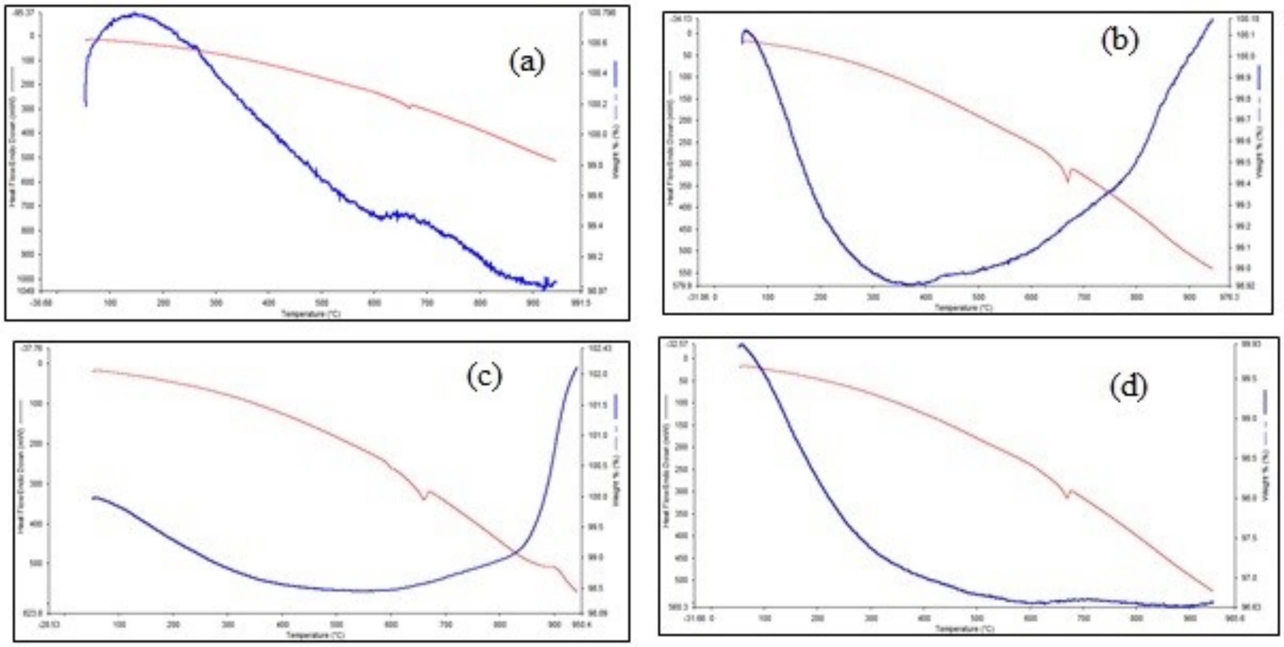

Figure 1. Thermo Gravimetric Analysis of the samples

The MMC is maintaining a solid state structure and exhibit an endothermic nature by being thermally stable. The amount of heat absorbed during the endothermic process represents almost similar trend after the melting point of about 650℃. The weight loss occurs over a wide range of temperature between 300℃ - 800℃ without melting.

4. CONCLUSION

•Al 6061 with 5%, 10% and 15% weight increased hardness, tensile strength along with decreased % elongation i.e. low ductility of the material.

•The plain strain fracture toughness is shows moderate increase due to the addition of ceramics into the matrix of Al 6061.

•The wear of the material seems to be decreased due to alumina and zirconia combined additions in Al 6061. The more wear resistant material is 15% zirconia and alumina additions.

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