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Stress Corrosion Behaviour of Aluminium7075/Beryl Composites

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Abstract: Composites are finding applications in recent days with a huge demand in aircraft, automobile and marine engineering due to their increased resistance towards corrosion and improved mechanical properties. This research paper is the work on stress corrosion behaviour of Aluminium 7075 alloy reinforced with 2, 4 and 6 weight percentages of beryl particulates. Composites containing 2, 4 and 6 weight percentage of beryl particulates are manufactured. Composites are manufactured by stir casting technique using vortex method. Specimens are machined from the bar castings according to ASTM standards. Three point loaded specimens, typically flat strips of dimension 8mm thickness, 40mm wide and 150mm long were machined from the composites by adopting standard metallographic procedure for the stress corrosion testing. Matrix alloy was also casted in the same way for comparison. Microstructures of matrix alloy and composites are taken using scanning electron microscope. Stress corrosion tests were conducted using a stainless steel auto clave by weight loss method for different exposure time, normality and temperature of the hydrochloric acid medium. Ultimate tensile strength of the composites increased after subjecting them for stress corrosion. The corrosion rates of composites were lower than those of Aluminium 7075 matrix alloy under all conditions. Hence composites can be preferred in place of metal or alloy in applications mentioned above.
Keywords: Aluminium 7075, Beryl, Autoclave, Vortex method

I. INTRODUCTION

Metal matrix composites (MMCs) reinforced with ceramic particulates, whiskers, has received increasing attention due to their potentially high fracture toughness and strength [1-5]. Particle reinforced aluminum MMCs find potential applications in several thermal environments, especially in the automobile engine parts, such as drive shafts, cylinders, pistons, and brake rotors[6], and in space applications. With the exception of noble metals, no metal and alloy is stable in air at room temperature, which tend to form oxides. Most of the metals in the solid or liquid state are morphologically unstable in air at any temperature. An investigation relating to the temperature profiles of the piston area in a diesel engine has shown that the temperature can reach as high as 200-600°c in certain regions of the piston [7]. As the piston and cylinder areas are exposed to high temperature environment, the MMCs used here should have sufficient stability as well as good mechanical properties like withstanding stress and strain at high temperatures.[8-10]. Therefore, in high-temperature applications, it is essential to have a thorough understanding of the behaviour of the aluminum MMCs reinforced with beryl particulates. Jayaparakash and Krupakara[11] studied the stress corrosion behaviour of ZA-27/red mud particulate composites in different concentrated solutions of hydrochloric acid at different temperature and exposure time. They report that composites showed improved corrosion resistance and tensile strength. Hence composites are more suitable for different applications. Ashok. S. D et al [12] report in their research paper related to stress corrosion behaviour of Aluminium 7075 / red mud metal matrix composites in different concentrated solutions of hydrochloric acid. They report that composites exhibited excellent stress corrosion resistance when compared with matrix alloy. Hence this work with respect to stress corrosion behaviour has been taken up.

II. MATERIAL SELECTION

The raw material selected is aluminium 7075 alloy as matrix and it is commercially available in the market. Its composition is given in the table.1 The reinforcement used is Beryl particulates of 50-80 micro meter size. Beryl is the commercial name for Beryllium-Alumina-Silicate. Its formula is $Be_3Al_2(SiO_3)_6$. It contains other salts also. Its correct composition is given in table 2. The stress corrosion studies were conducted in different concentrated solutions of hydrochloric acid at different exposure time and temperature.

Table 1: Composition of Aluminium 7075

Element	Cu	Cr	Mn	Mg	Si	Ti	Zn	Fe	Al
Percentage	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	Bal

Table2: Chemical composition of Beryl Particulates

SiO_2	Al_2O_3	BeO	Fe_2O_3	CaO	MgO
68.01	16.74	12.01	1.91	0.86	0.08

Beryl has hardness of 7.5 – 8 in Mohr scale. It has specific gravity 2.6 to 2.9.Beryl often crystallizes in perfect, six-sided hexagons. Crystals are usually as individual prismatic hexagons. Crystals may be enormous in size; some 30 foot long (8 meter), well-crystallized examples have been found. Beryl may also be short, stubby crystals, and occasionally in tabular crystals and plates.

A. Composite preparation

Composites containing Aluminium 7075 alloy and beryl particulates are prepared by stir casting method used by P.V.Krupakara[13]. Pre heated but uncoated beryl particulates of size 50-80 micro meters are added to vortex created in molten melt of Aluminium 7075 alloy. Mechanical impeller coated with aluminite is used to create the vortex. Aluminite coating prevents the release of ferrous ions from the mechanical impeller made up of iron in to the aluminium melt. Beryl particulates are added in to the melt at a rate of 120 grams per second. The mixture is stirred well and degasified by adding degasification tablets made up of hexa chloro ethane, Then the melt is poured into pre heated cast iron moulds to get cylindrical bar castings. Aluminium 7075 containing 2, 4 and 6 weight percentage of beryl particulates are casted in the above mentioned method. Aluminium 7075 alloy was also casted in the same way for comparison.

B. Specimen preparation

Three point loaded specimens, typically flat strips of dimension 8mm thickness, 40mm wide and 150mm long were prepared from the composites and the matrix alloy by adopting standard metallographic procedure for the stress corrosion testing. Before subjecting the specimens for the stress corrosion test they were ground with silicon carbide paper of 1000 grit and then polished in steps of 15 to 3 μm diamond paste to obtain a fine surface finish and degassed in acetone then dried. The samples were weighed up to fourth decimal place using electronic balance.

C. Stress corrosion studies

Stress corrosion studies are conducted in autoclaves. These are often used for high temperature and pressure applications. The Teflon coatings protect the autoclaves from severe aggressive environments. A bracket used to load corrosion specimen to be placed in autoclave. The specimen was supported at both ends and bending stress was applied using a screw equipped with a ball to bear against specimen at a point midway between the end supports. For calibration a prototype specimen of same dimensions were used and stressed to the same level. In a three point loaded specimen the maximum stress occurs at the mid-length of the specimen, decreases linearly to zero at the ends. The specimens were subjected to one third of matrix alloy's ultimate tensile strength. For each test two litres of different normalities of HCl solution, prepared were used. After loading the specimen in to the holder and placing the same in autoclave the required normality acid solution of 2 litres was added as corrodant. Then autoclave is closed and heated to test temperature with increase in inside pressure. Different composites with varying percentages of reinforcement were subjected to test at different temperature, different normality and corroded for various duration of 10,20,30, 40, 50 and 60 minutes respectively. After the corrosion test the specimen was immersed in Clark's solution for 10 minutes and gently cleaned with a soft brush to remove adhered scales. Then after drying the specimens were accurately weighed again. Weight loss was calculated and converted to corrosion rate expressed in mils penetration per year (mpy) [14].

III.RESULTS AND DISCUSSION

Fig 3 shows corrosion rate and Fig 4 shows the ultimate tensile strength vs. percentage of the beryl particulate reinforced Aluminium 7075 MMC's. The ultimate tensile strength increases with increase in the percentage of reinforcement with respect to matrix alloy [15]. Corrosion rate decreases with increase in the percentage of reinforcement with respect to matrix alloy[16]. Fig 5 shows stress corrosion rate vs. exposure time of Aluminium 7075 and Aluminium 7075/beryl composites at 100^0C in 1N HCl. The corrosion rates of both matrix alloy and composites increase with increase in exposure time.

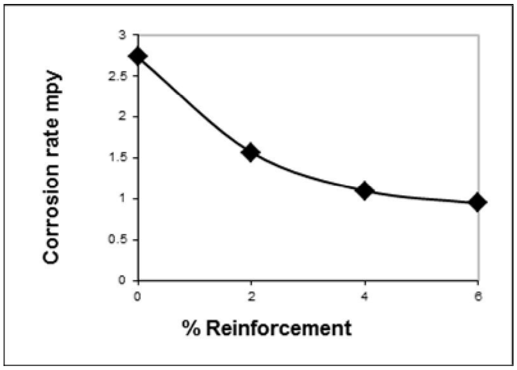

Fig 3: Stress corrosion rates of MMCs in

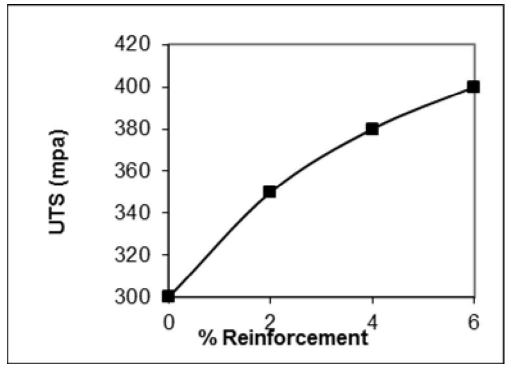

Fig 4: Ultimate tensile strength1 N HCl

Fig 6 shows the plot of stress corrosion rate vs. different concentrations of HCl at exposure temperature of 100^0C and exposure time of 30 minutes. The stress corrosion rates of specimens increase with the concentration of HCl. Fig 7 shows the stress corrosion rates of matrix alloy and composites in 1N HCl at different temperatures. All figures clearly show the decrease in corrosion rate monotonically with increase in quartz content. In other words greater the quartz particle addition, greater will be the corrosion resistance.

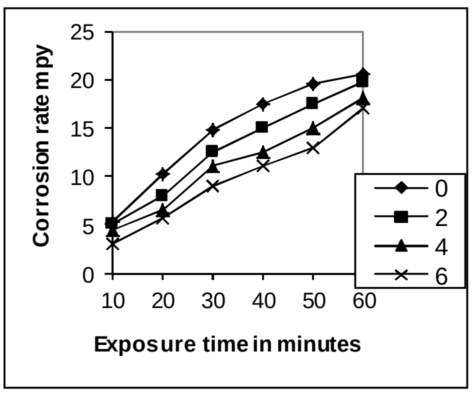

Fig 5: Corrosion rate vs. concentrations. of HCl at 100^0C

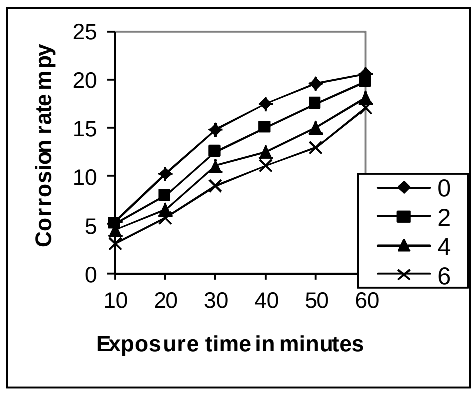

Fig 6: Corrosion rate vs. exposure time at 100^0C in 1N HCl

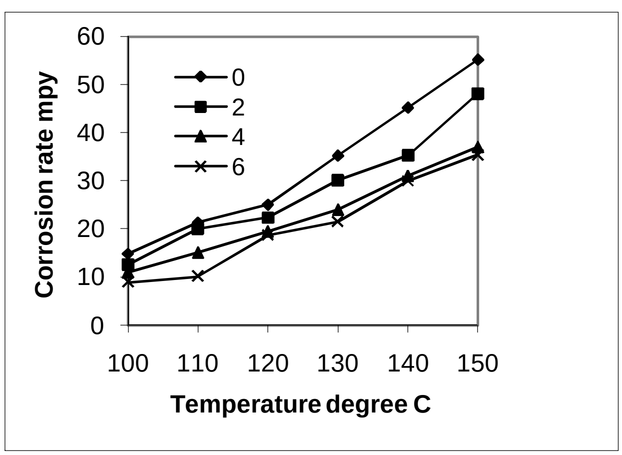

Fig 7 Corrosion rate vs. exposure temperature for 30 minutes exposure in 1N HCl

Hydrogen has been found to evolve when aluminium exposed to boiling water [17]. If the alloy like Aluminium 7075is taken in acid solution like HCl then there will be liberation of hydrogen due to the slow dissolution of alloy. It may be due to the chemical reactions shown below.

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2\uparrow$$

$$2Al + 6H_2O \longrightarrow 2\,Al(OH)_3 + 3H_2\uparrow$$

The reaction rates for the above reactions are directly influenced by external variables such as exposure temperature of acidic solutions, exposure area of the specimen, concentration of hydrogen in solution, specimen exposure time and area of specimen exposed. Various researchers [18-19] have reported in their papers on static corrosion that the corrosion rate of the matrix alloy and the reinforced composites decrease with increase in exposure time. There may be possibility of conversion of hydroxide of aluminium into non-porous oxide layer, which prevents further corrosion. Hence the corrosion takes place and increases with increase in temperature, normality of HCl and exposure time. Corrosion rates for matrix alloy and reinforced composites increased with increase in the normality of corrodent like HCl. The corrosion rates in 1N HCl were more when compared to the corrosion rates in 0.25N. 0.5N and 0.75N HCl solutions. This is due to the increase in concentration of hydrogen in corrodent. Temperature also plays an important role in the corrosion properties. Two factors with respect to temperature, which influence on corrosion factors, are energy of activation of hydrogen ions and the temperature variation of hydrogen gradient.

Beryl particles are inert and not expected to affect the corrosion mechanism of composites. The corrosion results indicate the improvement of corrosion resistance as the percentage of quartz increased in the composites. This shows the direct or indirect influence of quartz particles on the corrosion properties of the composites. Several authors [20-22] point out that the extent of pitting in SiC-ZA-27 MMC increased with increase in SiC volume fraction which may be due to the preferential acidic attack at the matrix –reinforcement interface [23]. The corrosion behaviour of MMCs is influenced by the nature of matrix alloy, type of reinforcement and alloying elements [24], in spite of these factors the corrosion behaviour in Aluminium 7075 MMCs is a complex nature [25]. But nature of bond between reinforcement and matrix plays an important role in the corrosion property. Since the composites developed show improved mechanical properties it can be claimed that the interface between the matrix alloy and reinforcement is quite strong [26].To support this it was observed that when beryl particle content is increased there is a reduction in corrosion.

IV. CONCLUSIONS

Corrosion rate increases with solution temperature. Red mud is a ceramic material and hence not involved in galvanic corrosion with matrix alloy. Concentration of HCl plays significant role in the corrosion of Aluminium 7075/beryl composites. The increase in hydrogen evolution results in higher corrosion rate. Corrosion rate increases with increase in time of exposure and temperature. The extent of corrosion damage was reduced with increasing reinforcement. Which is due to increase in tensile strength and bonding strength of the MMCs. Material loss from corrosion was significantly higher in case of Aluminium 7075 than in the Aluminium 7075/ bryl composites.

V. ACKNOWLEDGMENT

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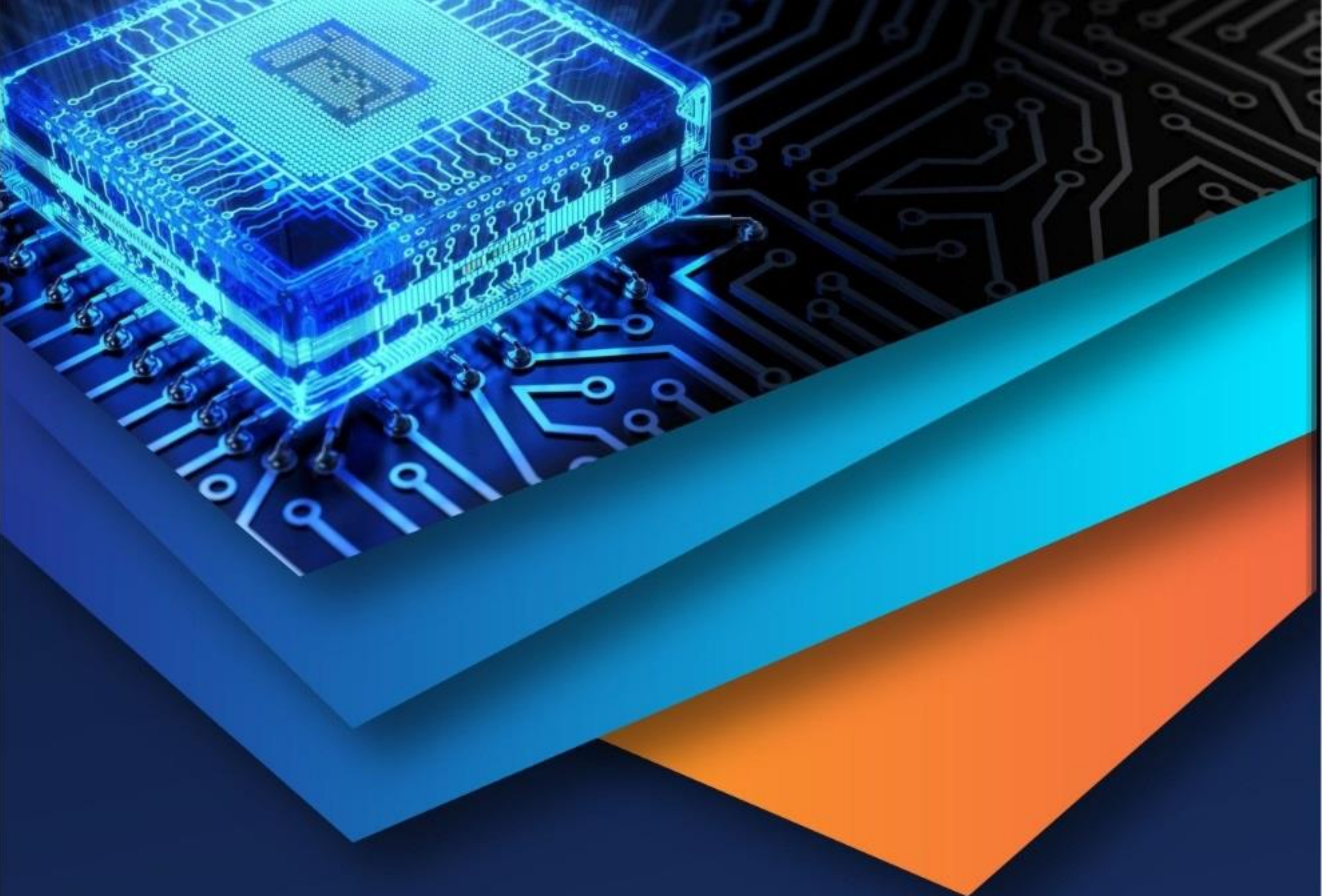

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