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Stress Corrosion Behaviour of Advanced Materials Like Al1100/Sic Nano Composites

Abstract

The stress corrosion resistance of AL1100/SiC Nano Composites metal matrix composites (MMC's) in high temperature acidic media has been evaluated using an autoclave. The liquid melt metallurgy technique using vortex method was used to fabricate MMC's. SiC Nano Composites particulates of 50-80 μm in size are added to the matrix. AL1100 containing 2,4,6 weight percentage of SiC Nano Composites are prepared. Stress corrosion tests was conducted using weight loss method for different exposure time, normality and temperature of the acidic medium. The corrosion rates of composites was lower to that of matrix AL1100 alloy under all conditions.

Keywords: SiC Nano Composites, MMC's, Vortex method, Stress corrosion, Autoclave

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1. Introduction

Metal matrix composites (MMCs) made of AL1100 offer the designer with many added benefits, since they are particularly suitable for application requiring their combined high strength,[1] better wear resistance [2], thermal conductivity[3], damping properties [4], and low coefficient of thermal expansion with lower density[5]. These properties of MMCs enhance their usage in automotive and tribological applications. The trend is towards safe usage of MMC parts in the automobile engine, which works particularly at high temperature and pressure environments.[6-7] Particle reinforced MMC's has been the most popular over the last two decades. Among them ceramic reinforced AL1100 are very popular in the recent days. The addition of the ceramic particle not only enhances the mechanical and physical properties, but also it change the corrosion properties significantly.

Particle reinforced AL MMC's find number of applications in several thermal environments especially in the automobile engine parts such as brake drum, brake rotors, cylinders and pistons. MMC's used at high thermal conditions should have good mechanical properties and resistance chemical attack in air and acidic environment. It is necessary that the detail corrosion behaviour of AL composites must be understood thoroughly for high temperature applications. Several authors [8-10] point out that the extent of pitting in SiC-AL1100 MMC increased with increase in SiC volume fraction which may be due to the preferential acidic attack at the matrix –reinforcement interface.[11] The corrosion behaviour of MMCs is influenced by the nature of matrix alloy, a type of reinforcement and alloying elements[12], in spite of these factors the corrosion behaviour in AL1100 MMCs is a complex nature.[13] The objective of the present investigation is to understand the role reinforcement on the stress corrosion behaviour of AL1100/SiC Nano Composites MMCs at high temperature in varied normalities of Hydrochloric acid solutions. High temperature and pressure in an autoclave is an excellent test for stress corrosion.

2. Experimental procedure

Material selection

Here the matrix alloy used in AL1100 and its composition is given in Table1.

Table 1: Composition of AL110

	Copper	Magnesium	Zinc
26-28%	2-2.5%	0.01-0.02%	Balance

SiC Nano Composites, which is used as reinforcement in the form of particulates, contains 37.8% silicon dioxide and 67.2% of SiC Nano Compositesica. It has got hardness of 6.0 on the Mohr's scale.

Preparation of composites

The liquid metallurgy route using vortex technique[12] was employed to prepare the composites. A mechanical stirrer was used to create the vortex. The reinforcement material used was SiC Nano Composites particulates of size varying 50-80 μm. The weight percentage of SiC Nano Composites used was 2-6 weight percentages in steps 2%. Addition of SiC Nano Composites in to the molten AL1100 alloy melt was carried out by creating a vortex in the melt using a mechanical stainless steel stirrer coated with alumina (to prevent migration of ferrous ions from the stirrer material to the zinc alloy). The stirrer was rotated at a speed of 450 rpm in order to create the necessary vortex. The SiC Nano Composites particles was pre heated to 200°C and added in to the vortex of liquid and melted at a rate of 120 g/m. This composite melt was thoroughly stirred and subsequently degassed by passing nitrogen through the melted at a composite rate 2-3 l/min for three to four minutes. Castings were produced in permanent moulds.

Specimen preparation

Three point loaded specimens, typically flat strips of dimension 8mm thickness, 40mm wide and 150mm long was 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. It was 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.

Corrosion studies

Autoclaves are often used for high temperature and pressure applications. The Teflon coatings protect the autoclaves from severe aggressive environments.

Fig 1 shows 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 was used and stressed to the same level. In a three point loaded specimen the maximum stress that 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 was used.

After loading the specimen in to the holder and placing the same in autoclave. Then the required normality acid solution of 2 litres was added as corrodant. Then autoclave was closed and heated to test temperature with increase in inside pressure. Different composites with varying percentages of reinforcement were subjected to test with 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]

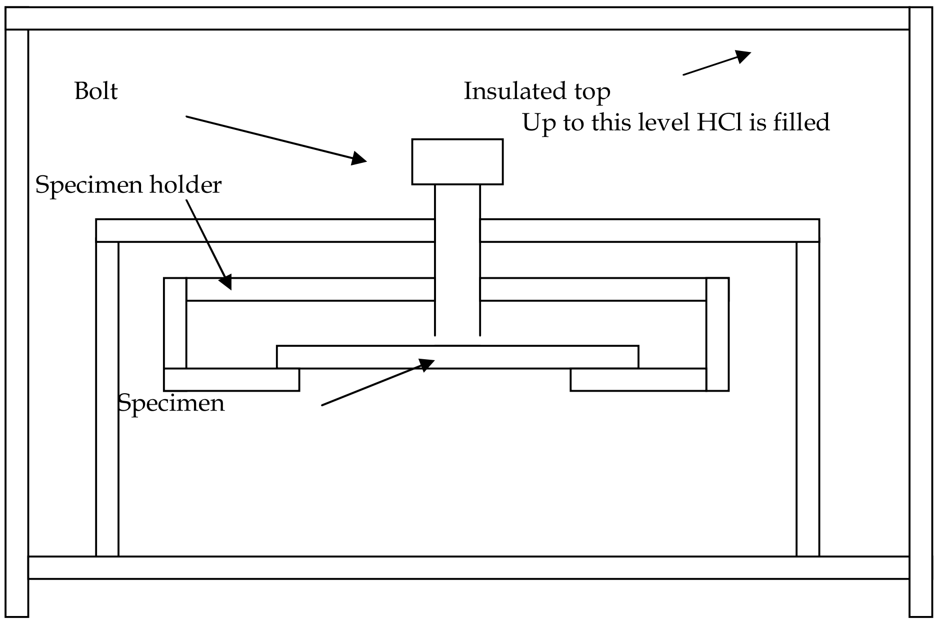

Figure 1: Autoclave

3. **Results**

Corrosion test

Figure 2 shows corrosion rate and fig 3 shows the ultimate tensile strength vs. percentage of the SiC Nano Composites reinforced AL1100 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 4 shows stress corrosion rate vs. exposure time of AL1100 and AL1100/SiC Nano Composites MMC's at 100^0C in 1N HCl. The corrosion rates of both matrix alloy and composites increase with increase in exposure time.

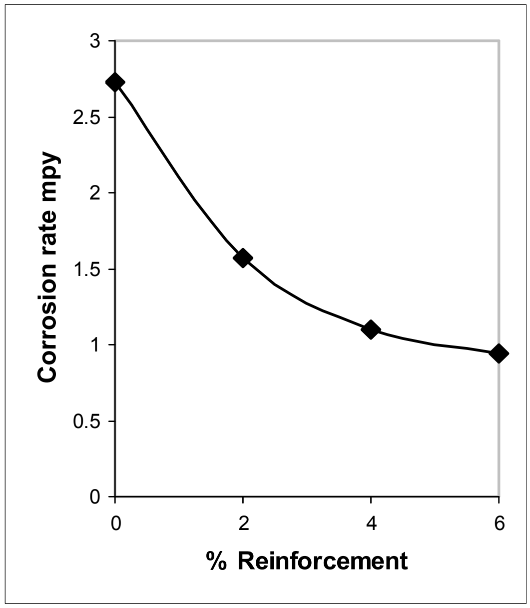

Figure 2: Stress corrosion rates of MMCs in 1 N HCl (5% error)

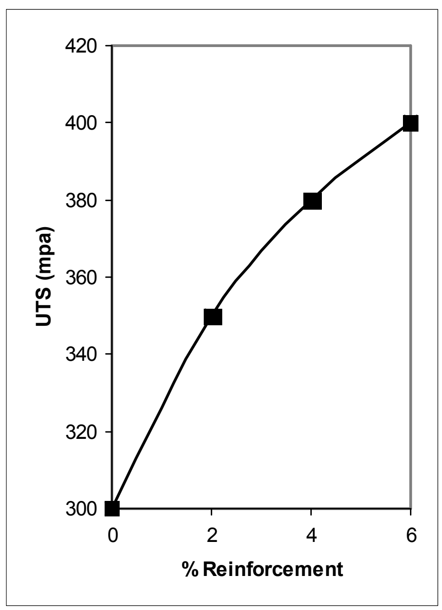

Figure 3: UTS of MMCs (2% error)

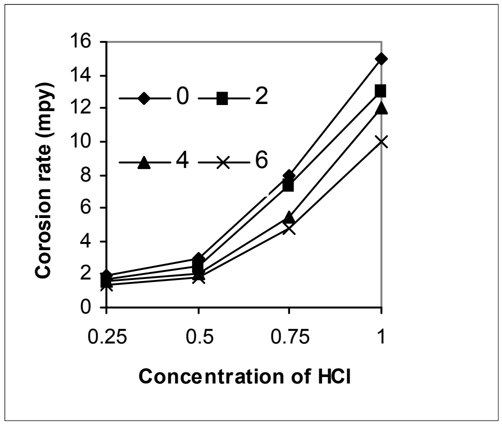

Figure 4: Corrosion rate vs. concn. Of HCl at 100^0C (3% error)

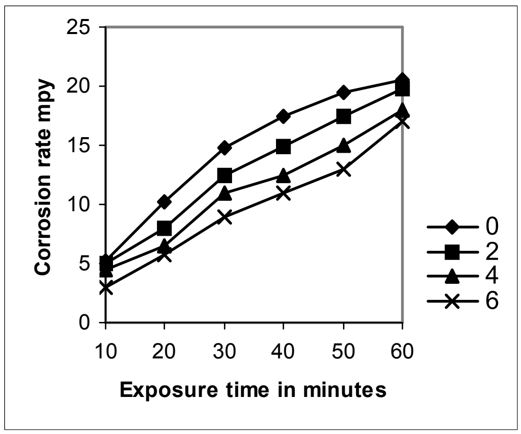

Figure 5: Corrosion rate vs. exposure time at 100^0C in 1N HCl (4% error)

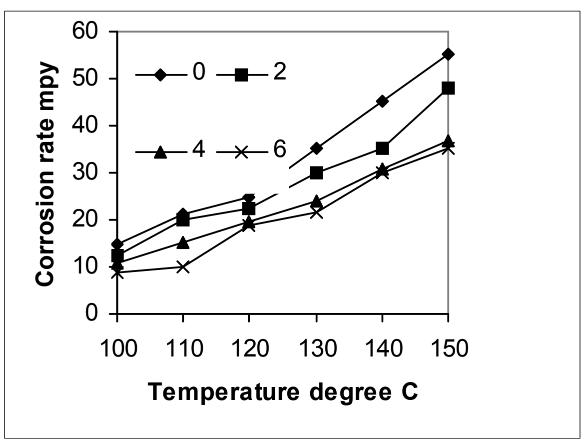

Figure 6: Corrosion rate vs. exposure temperature for 30 minutes exposure in 1N HCl (2% error)

Fig 5 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 6 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 SiC Nano Composites content. In other words greater the SiC Nano Composites particle addition, greater will be the corrosion resistance.

Corrosion Morphology

Visual examinations of the specimens after the stress corrosion experiments has shown few deep pits, flakes and cracks formed on the unreinforced matrix alloy and the cracks was perpendicular to the axis of the specimen. Whereas more wide spread superficial pitting was observed and few or no cracks were seen on the surface of the reinforced composites. However few cracks on 2% SiC Nano Composites reinforced matrix composites and no cracks on 4% and 6% SiC Nano Composites reinforced matrix composites specimens was observed.

4. Discussion

Hydrogen has been found to evolve when aluminium, was exposed to boiling water.[17] If the alloy alike AL1100 was 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.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2 \uparrow \quad (1)$$

$$Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2 \uparrow \quad (2)$$

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

$$2Al + 6H_2O \longrightarrow 2\,Al(OH)_3 + 3H_2 \uparrow \quad (4)$$

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] has reported in their papers on static corrosion that the corrosion rate of the matrix aloy 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. However the percentage of aluminium was only between 26-28% But in the case of Zinc formation of oxide layer was ruled out. Hence the corrosion takes place and increases with the increase in temperature, normality of HCl and exposure time. Corrosion rates for matrix alloy and reinforced composites increased with increase in the normality of corrodant like HCl. The corrosion rates in 1N HCl was 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 corrodant. Temperature also plays an important role in the corrosion properties. Two factors with respect to temperature, which influences on corrosion factor. These energy of activation of hydrogen ions and the temperature variation of hydrogen gradient.

SiC Nano Composites 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 SiC Nano Composites increased in the composites. This shows the direct or indirect influence of SiC Nano Composites particles on the corrosion properties of the composites. Several authors[20-22] point out that the extent of pitting in SiC-AL1100 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 AL1100 MMCs was 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.[16] To support this it was observed that when SiC Nano Composites particle content was increased, and there is a reduction in corrosion.

5. Conclusion

Corrosion rate increases with solution temperature. SiC Nano Composites is a ceramic material and hence it is not involved in galvanic corrosion with matrix alloy. Normality of HCl plays significant role in the corrosion of AL1100/SiC Nano Composites MMC's. 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 is reduced with increasing reinforcement. Which may be due to increase in tensile strength and bonding strength of the MMCs. Material loss from corrosion is significantly higher in the case of AL1100 than in the AL1100/SiC Nano Composites MMCs.

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