



Research Paper

EVALUATION OF CORROSION BEHAVIOR OF RETROGRESSION AND REAGED AL 7075 ALLOY REINFORCED WITH SiC_p COMPOSITE MATERIAL

Janardhana K^{1*} and D N Drakshayani¹

*Corresponding Author: Janardhana K, ✉ jk9013@rediffmail.com

The metal matrix composites offer a spectrum of advantages that are important for their selection and use as structural materials. A few such advantages are high strength, high elastic modulus, high toughness and impact resistance, low sensitivity to changes in temperature or thermal shock, high surface durability, low sensitivity to surface flaws, high electrical and thermal conductivity, minimum exposure to the potential problem of moisture absorption resulting in environmental degradation and improved machinability with conventional metal working equipment. The aim of the present study is to investigate the corrosion properties of Silicon Carbide particles (SiC_p) reinforced Aluminum matrix composite after retrogression and re-aging heat treatment. Aluminum 7075 alloy with 0%, 10%, 20% and 30% SiC_p were studied.

Keywords: Retrogression and re-aging, Corrosion, Aluminum 7075 alloy, Heat treatment

INTRODUCTION

Particulate reinforced aluminum alloy matrix composites have received attention over many years due to their excellent yield and tensile strengths, high specific elastic modulus and isotropic properties compared with the conventional alloy materials, which is very good candidate for structural applications in the field of aerospace, automotive and electronics.

The renewed interest in metal matrix composites has been aided by development of reinforcement material which provides

either improved properties or reduced cost when compared with existing monolithic materials (Bucci *et al.*, 2000; and Das, 2004).

7XXX series aluminum alloys are lightweight materials that are widely used in the aerospace industry because of their superior specific strength. The main strengthening mechanism for these alloys is artificial aging commonly known as T6 temper. Although T6 tempered 7XXX series alloys are satisfactorily used in many engineering applications, they suffer from stress corrosion

¹ Department of Mechanical Engineering, Sir M.VIT, Bangalore 562157, India.

cracking, especially when working in environments containing chloride. Another aging route known as T73 temper has been developed to overcome the drawback. However, T73 temper is accompanied by a loss in strength of about 10-15%. In Cina (1974) proposed new aging process known as retrogression and reaging to improve the Stress Corrosion Cracking (SCC) resistance of 7075 alloy without significance loss in strength when compared to the T6 temper state.

RRA is applied to T6 tempered 7XXX series alloys into 2 successive steps, namely, retrogression and reaging (Baruch Cina, 1974; Bruno Dubost and Jean Bouvaist, 1980; Melvin Brown, 1984 and 1989; and Janardhana and Drakshayani, 2014). Taguchi technique is used for design of experiments. The L18 array for each weight percentage of SiC(p) has been chosen and the factors for each specimen will be varied as required.

EXPERIMENTATION

The nominal composition of Al-7075 alloy is given in Table 1.

Stir casting method is used to obtain the Al 7075/ SiCp composite into fingers of specific dimensions. Preaging is carried out at

Table 1: Composition of Al-7075	
Elements	Wt (%)
Cu	1.2-2
Mg	2.1-2.9
Zn	5.1-6.1
Cr	0.18-0.28
Si	<0.4
Al	87.1-97.4
Fe	<0.5

temperatures of 125 °C, 135 °C and 145 °C for time periods of 12, 24 and 48 hr. Then Retrogression is carried out at temperatures of 200 °C, 220 °C and 240 °C for 5, 10 and 15 min followed by reaging at 125 °C, 135 °C and 145 °C for 12, 24 and 48 hr. The heat treatment is carried out in a Muffle Furnace.

These heat treated specimens are then immersed in 5% and 10% NaCl (by weight) solution for 12, 24 and 48 hr. The specimens were machined to the required dimensions (Figure 3) for the tensile test. The results are plotted in L18 arrays and Statistical Analysis Software MINITAB 16 by Taguchi method is used for analysis.

Stir Casting

Casting Process was carried out to prepare the samples as discussed in earlier paper (Janardhana and Drakshayani, 2014). All specimens were then coded as indicated in previous section.

Heat Treatment

Retrogression and reaging treatment can improve the stress corrosion behavior of the alloy while maintaining the mechanical

Figure 1: Furnace with Stirring Apparatus



Figure 2: Heat Treatment in Muffle Furnace



resistance of the T6 temper (Bruno Dubost and Jean Bouvaist, 1980; Melvin Brown, 1984 and 1989; Zhou and Xu, 1997; Viana *et al.*, 1999; Manabu Nakai and Takehiko Eto, 2000; Marko Tandler *et al.*, 2000; Peeler *et al.*, 2001; Andrzej Zieinski *et al.*, 2002; and Janardhana and Drakshayani, 2014a and 2014b).

Corrosion

- 5% and 10% NaCl solution (by weight) or 1 M and 2 M was prepared using distilled water.
- The heat treated specimens were immersed in the solution taken in glass jar for 12, 24 and 48 hours for respective trials.
- The weight of the specimens before and after corrosion was noted down.

METHODOLOGY

Experimental Design Using Taguchi Method

Eight factors and (one factor at 2 level and seven factors at 3 levels) levels for parameters have been chosen for each specimen composition as given in Table 2.

Table 2: Eight Factors and Levels for Each Parameter

Percentage of SiC, %	A-0	B-10	C-20
Preage temperature, °C	1-125	2-135	3-145
Preage time, hr	A-12	B-24	C-48
Retrogression temperature, °C	1-200	2-220	3-240
Retrogression time, hr	A-5	B-10	C-15
Reage temperature, °C	1-125	2-135	3-145
Reage time, hr	A-12	B-24	C-48
% NaCl (wt)	A-5	B-10	–
Soaking time, hr	A-12	B-24	C-48

The L18 array for each weight % fraction of SiC has been chosen and the coding of the specimen is done as follows.

If a specimen is labeled A2B3C1AAB, then the specimen condition is as indicated below:

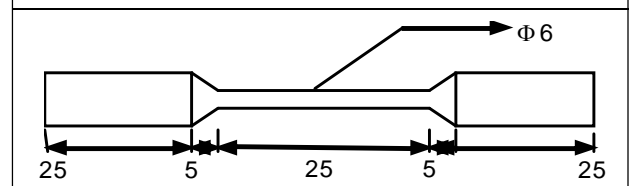
1. 0% SiC
2. Pre-aged at 135 °C
3. For 24 hr
4. Retrogressed at 240 °C
5. For 15 minutes
6. Re-aged at 125 °C
7. For 12 hr
8. Immersed in 5% NaCl
9. For 24 hr

Tensile Test

It was carried out as per ASTM standards E8-95A. All the samples were tested for strength.

The samples were loaded till fracture.

Figure 3: Tensile Test Specimen



RESULTS AND DISCUSSION

Taguchi Method

Taguchi technique using Minitab 16 Statistical Software was applied to analyze the L18 array for each of the specimens. Totally 4 arrays were used. In each 4 different percentages (0%, 10%, 20% and 30%) of SiC were considered. Main effects Graphs for means and S/N ratios were obtained showing relationships between the output result and the various factors.

For Tensile strength, the larger the better condition is selected.

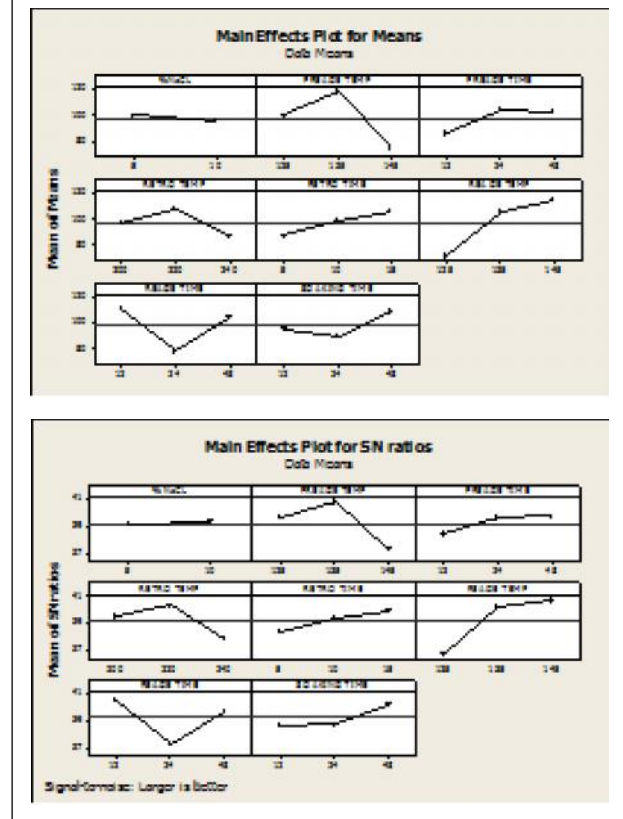
Tensile Strength

Regression Equations (0% SiC)

$$\begin{aligned} \text{TENSILE STRENGTH} = & -4 - 0.81\% \text{NaCl} - 1.24 \text{ PREAGE TEMP} + 0.380 \text{ PREAGE TIME} \\ & - 0.238 \text{ RETRO TEMP} + 1.83 \text{ RETRO TIME} \\ & + 2.12 \text{ REAGE TEMP} - 0.026 \text{ REAGE TIME} \\ & + 0.443 \text{ SOAKING TIME} \quad \dots(1) \end{aligned}$$

From Figure 4 it is observed that, the specimens which are preaged at 135 °C for 48 hr, retrogressed at 220 °C for 15 minutes, reaged at 145 °C for 12 hr and immersed in 10% NaCl for 48 hr shows the improved tensile strength of the composite material. Also, the specimens which are preaged at 145 °C for 12 hr, retrogressed at 240 °C for 5 minutes, reaged at 125 °C for 24 hr and immersed in 5% NaCl for 12 hr exhibited the poorer tensile strength. The increase in the strength of the specimens are due to the formation of the more stable interphases like MgZn₂ (Andrzej Zieinski *et al.*, 2002; Es-Said *et al.*, 2003; and Grosvenor *et al.*, 2004) and also refinement of the grains at the said elevated temperature of retrogression for short interval of time. Whereas the specimens which are subjected to lower retrogressed temperature for short

Figure 4: Main Effects plot Pfor Means and S/N Ratios of 0% SiC



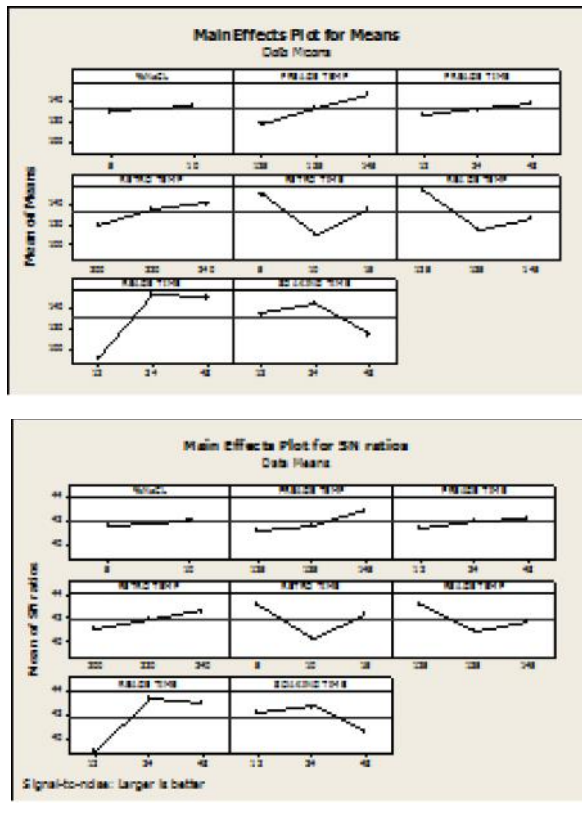
interval of time and higher reaging temperature for longer reaging time resulting in the coarsening of the interphases and formation of more unstable precipitates.

Regression Equations (10% SiC)

$$\begin{aligned} \text{TENSILE STRENGTH} = & -21 + 0.82 \% \text{NaCl} + 1.42 \text{ PREAGE TEMP} + 0.296 \text{ PREAGE TIME} \\ & + 0.554 \text{ RETRO TEMP} - 1.47 \text{ RETRO TIME} \\ & - 1.35 \text{ REAGE TEMP} + 1.43 \text{ REAGE TIME} \\ & - 0.654 \text{ SOAKING TIME} \quad \dots(2) \end{aligned}$$

From Figure 5 its observed that, the specimens which are preaged at 145 °C for 48 hr, retrogressed at 240 °C for 5 minutes, reaged at 125 °C for 24 hr and immersed in 10% NaCl for 24 hr improved the tensile strength of the composite material. Also, the specimens which are preaged at 125 °C for

Figure 5: Main Effects Olot for Means and S/N Ratios of 10% SiC



12 hr, retrogressed at 200 °C for 10 minutes, reaged at 135 °C for 12 hr and immersed in 5% NaCl for 48 hr exhibits poor tensile strength.

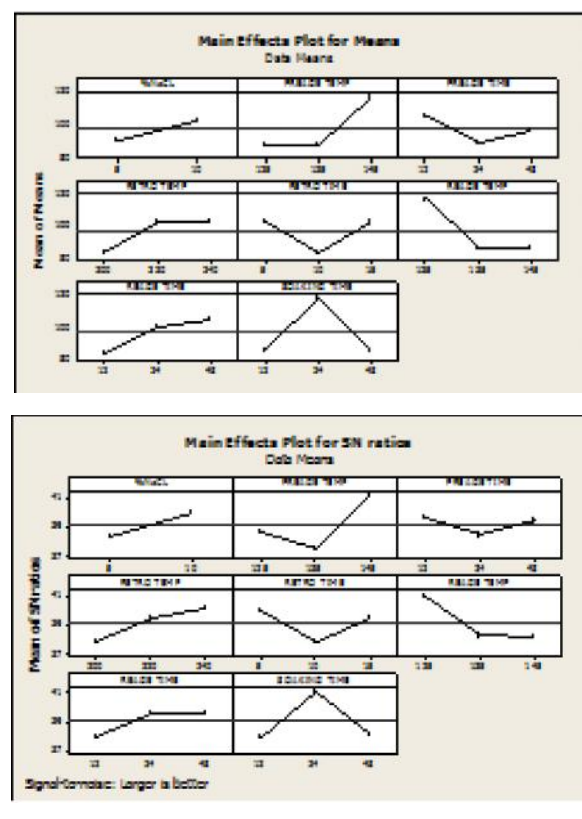
Regression Equations (20% SiC)

$$\text{TENSILE STRENGTH} = -33 + 2.32 \% \text{NaCl} + 1.46 \text{ PREGAGE TEMP} - 0.174 \text{ PREGAGE TIME} + 0.505 \text{ RETRO TEMP} + 0.02 \text{ RETRO TIME} - 1.49 \text{ REAGE TEMP} + 0.544 \text{ REAGE TIME} - 0.198 \text{ SOAKING TIME} \dots(3)$$

Regression Equations (30% SiC)

$$\text{TENSILE STRENGTH} = \text{RESULT3} = 747.645 - 5.09293 \% \text{ NACL} - 1.78372 \text{ PREGAGE TEMP} - 1.06103 \text{ PREGAGE TIME} - 1.1465 \text{ RTRO TEMP} + 0.00241111 \text{ RTRO TIME} \dots(4)$$

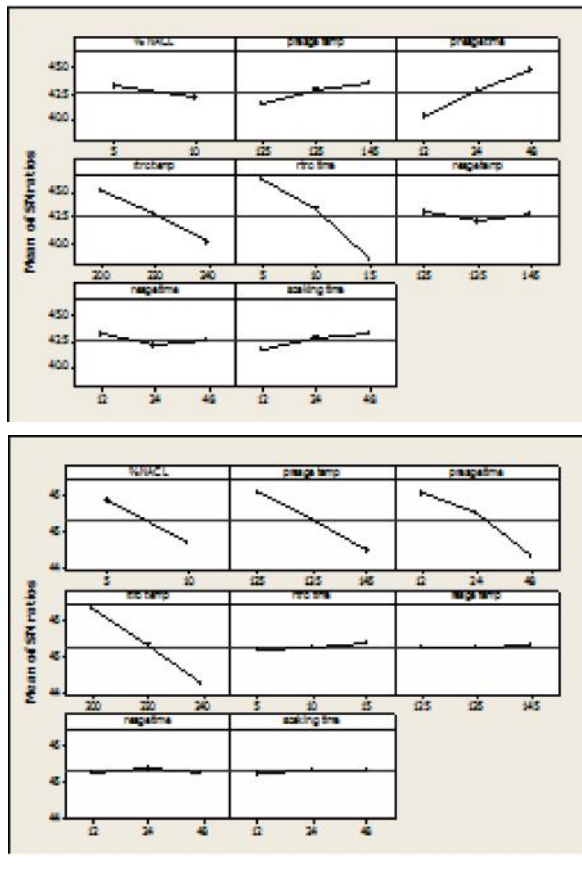
Figure 6: Main Effects Plot for Means and S/N Ratios of 20% SiC



From Equation 1, 2, 3 and 4 it's observed that the relationship between the stated parameters is established and also able to estimate the tensile strength for the different values of the parameters.

From Figure 6 its observed that, the specimens which are preaged at 145 °C for 12 hr, retrogressed at 240 °C for 5 minutes and reaged at 125 °C for 24 and immersed in 10% NaCl for 24 hr improved the tensile strength of the composite material. Also, the specimens which are preaged at 135 °C for 24 hr, retrogressed at 200 °C for 10 minutes, reaged at 125 °C for 12 hr and immersed in 5% NaCl for 12 hr exhibits poor tensile strength.

Figure 7: Main Effects Plot for Means and S/N Ratios of 30% SiC



From Figure 7 its observed that, the specimens which are preaged at 145 °C for 48 hr, retrogressed at 240 °C for 10 minutes, reaged at 145 °C for 48 hr and immersed in 10% NaCl for 24 hr improved the tensile strength of the composite material. Also, the specimens which are preaged at 125 °C for 12 hr, retrogressed at 200 °C for 5 minutes, reaged at 125 °C for 12 hr and immersed in 5% NaCl for 12 hr exhibit poor tensile strength.

CONCLUSION

From the present studies, the following conclusions were obtained.

1. With increase in temperature and time of all the three phases of RRA, pre-aging,

retrogression and reaging, the Tensile Strength increases generally.

2. At higher pre-aging and re-aging temperatures, increase in Tensile Strength can be due to the relieving of internal stresses within the material and refinement of the grains.
3. The effect of higher % of NaCl and longer soaking time on the composite material subjected to higher retrogression temperature for short duration is minimal. 🌀

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