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Evaluation of Mechanical Properties of Retrogression and Reaged Al 7075 alloy reinforced with SiC_p Composite Material

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Abstract: **The metal matrix composites offer a spectrum of advantages that are important for their selection and use as structural materials. A few such advantages include the combination of 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 mechanical properties of Silicon Carbide particulate (SiC_p) reinforced Aluminum matrix composite after retrogression and re-aging. Aluminum 7075 alloy is chosen as the matrix. Al7075 alloy with 0%, 10% and 20% SiC_p were studied.**

Key words: Retrogression and Re-aging, Aluminum 7075 alloy, heat treatment.

1. 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 particulate-reinforced metal-matrix composites have emerged as attractive materials for use in a spectrum of applications such as industrial, military and space related. 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.[1-2]

Particulate reinforced metal-matrix composites have attracted considerable attention on account of the following aspects: 1. Availability of a spectrum of reinforcements at competitive costs. 2. Successful development of manufacturing processes to produce metal matrix composites with reproducible microstructures and properties. 3. Availability of standard and near standard metal working methods which can be utilized to produce these materials.

During the last decade, considerable efforts have been made to improve the strength of precipitation hardened aluminum alloy matrix composites, such as developing new preparation technologies with suitable heat-treatments. 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 cracking, especially when working in environments containing chloride. Another aging route known as T73 [3] temper has been developed to overcome the drawback. However, T73 temper is accompanied by a loss in strength of about 10-15%. In 1974, Cina [3] proposed new aging process known as retrogression and reaging to improve the Stress Corrosiom 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. In the first step (retrogression), the alloy is held at a temperature above the original aging temperature of the T6 temper and then air cooled. In the second step (reaging), it is reaged at the same temperature and time as that of T6 temper. 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.

2. EXPERIMENTATION:

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

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

Table 1: Composition of Al-7075

Stir casting method is used to obtain the Al 7075/ SiC p composite. Aluminum 7075 was introduced into the furnace at 660 ºC, so as to obtain its liquid phase. After obtaining a melt, silicon carbide powder pre heated at 300ºC for 30 minutes was added to it. Mechanical agitation was done to get a homogenous melt. This mixture is then casted into fingers of specific dimensions. Preaging is carried out at temperatures of 125 ºC, 135 ºC and 145 ºC for time periods of 12 hs, 24hs and 48 hs. Then Retrogression is carried out at temperatures of 200 ºC, 220 ºC and 240ºC for 5 minutes, 10 minutes and 15 minutes followed by reaging at 125 ºC, 135 ºC and 145 ºC for 12 hs. The heat treatment is carried out in a Muffle Furnace. These heat treated specimens are then machined to the required dimensions (Fig. 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.

2.1.1. Stir Casting

Casting Process was carried out through the following steps:

1. Aluminium 7075 of known weight was melted at 660ºC.
2. After obtaining a melt, pre heated (300 ºC for 30 minutes) silicon carbide particles were added to it.
3. Mechanical agitation was done to get a homogenous melt.
4. Silicon carbide reinforced Aluminium 7075 was obtained by Stir casting. At each casting operations, 4 fingers were obtained.
5. All specimens were then coded using the coding system as indicated in 2.2.

Fig 1. Furnace with stirring apparatus

2.1.2. Heat Treatment

Retrogression and reaging treatment can improve the stress corrosion behavior of the alloy while maintaining the mechanical resistance of the T6 temper [4-12]. The following are the steps involved in retrogression and re-aging:

- Specimens are placed in the muffle furnace for preaging. The temperature and time of heat treatment is decided by the specimen coding as that required by the Design of the Experiment
- Once the preaged specimens are naturally cooled to room temperature, they are retrogressed at the required temperature and time.
- Theretrogressed specimens are then cooled naturally to room temperature and then reaged as required

Fig 2. Heat treatment in muffle furnace

2.2. Methodology

Experimental design using Taguchi method.

Six factors and 3 levels for each parameter have been chosen for each specimen composition as given in Table 2.

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

Percentage of SiC,%	**A** - 0	**B** -10	**C** - 20
Preage temperature, ºC	**1** -125	**2** -135	**3** -145
Preage time, hs	**A** - 12	**B** - 24	**C** - 48
Retrogression temperature, ºC	**1** - 200	**2** - 220	**3** - 240
Retrogression time, hs	**A** - 5	**B** - 10	**C** - 15
Reage temperature, ºC	**1** - 125	**2** - 135	**3** - 145
Reage time, hs	**A** - 12	**B** - 24	**C** - 48

Table 2: Six factors and 3 levels for each parameter.

If a specimen is labeled A2B3C1A, then the specimen condition is as indicated below:

1. 0% SiC 2. Pre-aged at 135 ºC 3. For 24 hs
4. Retrogressed at 240 ºC 5. For 15 minutes
6. Re-aged at 125 ºC 7. For 12 hs

2.3. 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.

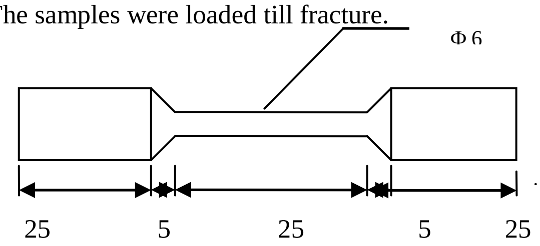

Fig 3: Tensile test specimen

3. RESULTS AND DISCUSSION

3.1. Taguchi Method

Taguchi technique using Minitab 16 Statistical Software was used to analyze the L18 array for each of the specimens. Totally 3 arrays were used. In each 2 different percentages (10% and 20%) 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.

3.2. Tensile strength

REGRESSION EQUATIONS (0% SiC):

Tensile strength = - 324 + 2.48 preage temp + 0.109 preage time + 0.476 retrogression temp - 0.53 retrogression time - 0.239 reage time ………………………… 1

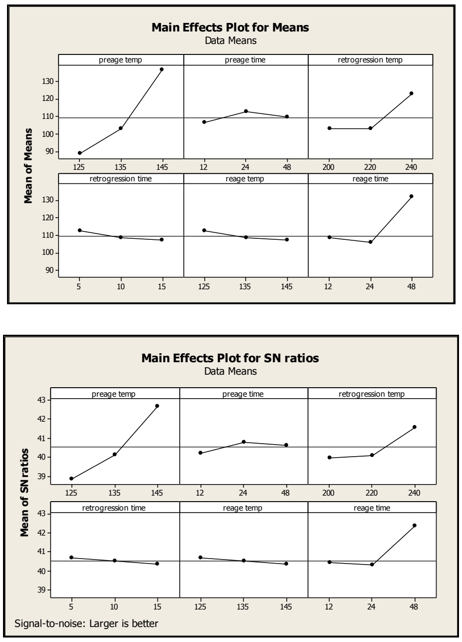

Fig. 4: Main effects plot for Means and S/N ratios of 0% SiC

From Fig.4 its observed that, the specimens which are preaged at 145°C for 24 hs, retrogressed at 240°C for 5 minutes and reaged at 125°C for 48 hs improved the tensile strength of the composite material. Also, the specimens which are preaged at 125°C for 12 hs, retrogressed at 200°C for 15 minutes and reaged at 145°C for 24 hs exhibits poor tensile strength.

The increase in the strength of the specimens are due to the formation of the more stable interphases like $MgZn_2$ [12-14] 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 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):

Tensile Strength = 140 - 0.237 preage temp - 0.616 preage time + 0.109 retrogression temp + 4.12 retrogression time - 0.200 reage time ..………………. 2

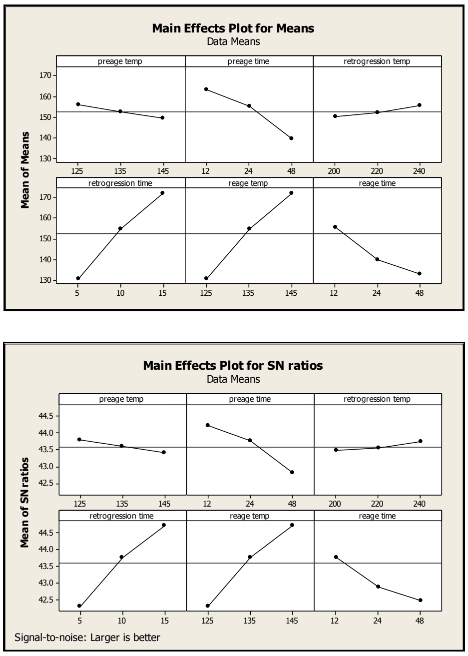

Fig. 5: Main effects plot for Means and S/N ratios of 10% SiC

REGRESSION EQUATIONS (20% SiC):

Tensile Strength = - 957 + 1.16 preage temp - 0.173 preage time + 4.18 retrogression temp + 6.43 retrogression time + 0.0088 reage time ……………… 3

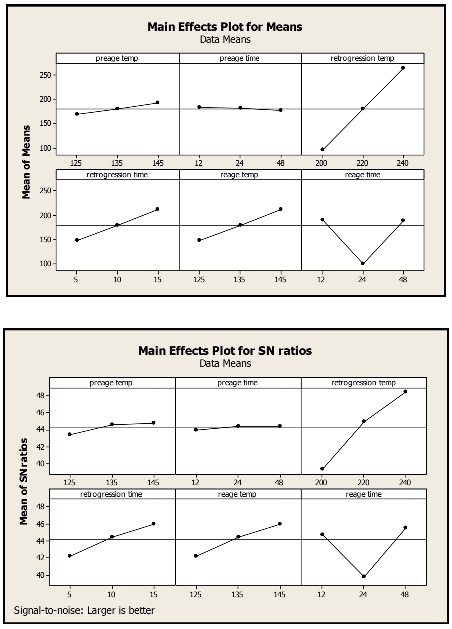

Fig. 6: Main effects plot for Means and S/N ratios of 20% SiC

From Equation 1, 2 and 3 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 Fig.5 its observed that, the specimens which are preaged at 125°C for 12 hs, retrogressed at 240°C for 15 minutes and reaged at 145°C for 12 hs improved the tensile strength of the composite material. Also, the specimens which are preaged at 145°C for 48 hs, retrogressed at 200°C for 5 minutes and reaged at 125°C for 48 hs exhibits poor tensile strength.

From Fig.6 its observed that, the specimens which are preaged at 145°C for 12 hs, retrogressed at 240°C for 15 minutes and reaged at 145°C for 48 hs improved the tensile strength of the composite material. Also, the specimens which are preaged at 125°C for 48 hs, retrogressed at 200°C for 5 minutes and reaged at 125°C for 24 hs exhibit poor tensile strength. The increase in the strength of the specimens is due to the formation of the more stable interphases like $MgZn_2$ [12-14], dissolution of the unstable precipitates and also refinement of the coarser grains at the said elevated temperature of retrogression for short interval of time. Whereas the specimens which are subjected to lower retrogressed temperature for longer interval of time and higher reaging temperature for longer reaging time resulting in the coarsening of the interphases and formation of more unstable precipitates resulting in the increase of dislocation density as the percentage of SiC particles increased.

4. CONCLUSIONS

From present studies, the following conclusions were obtained.

1. With increase in temperature and time of all 3 phases of RRA, pre-aging, retrogression and reheating, the Tensile Strength generally increases.
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.

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