Investigation of Heat Treatment on Al 6061- Al_2O_3 Composite & Analysis of Corrosion Behaviour

Rufin Rasheed.R[#1], Vishnu Deth.K.J[*2], Alphonse Mathew[#3]

Mechanical Engineering Department, St.Joseph's College of Engineering and Technology, Mahatma Gandhi University, Choondacherry, Pala, Kottayam 686579,India

Abstract — *Al 6061-Al_2O_3 composite materials are world widely known because of their better strength and reduced weight. In this work three (6,9&15) weight percentage of Al 6061-Al_2O_3 composite materials were made through stir-casting process and their mechanical properties were studied. Another set of Al 6061-Al_2O_3 composite materials having weight percentage 6,9&15 were under gone mechanical property testing after solution heat treatment and made a comparison with non-heat treated one. Corrosion behaviour of both heat treated and non-heat treated were evaluated in NaOH, H_2SO_4 and NaCl solution by using weight loss method. Solution heat treatment helped the improvement in strength and corrosion resistance but the addition of volume percentage of alumina particle did not show a consistent trend.*

Keywords— *Alumina particle, Corrosion, Solution heat-treatment, Stir-casting*

I. INTRODUCTION

Composite materials are made from two or more constituent materials having different chemical and physical properties [1].The constituent material remain separate and distinct with in the finished structure. Among the advanced composite materials ,particle reinforced metal matrix composites have large application due to their favourable mechanical properties[2].This composite materials show enhanced properties compared to the un reinforced composites. In this study a composite material was made through stir casting method by using Aluminium 6061 as base material and Al_2O_3 particle as particle reinforcement.

Al6061-Al_2O_3 composite materials are widely using in different engineering fields because of their improved strength compared to the non-reinforced Al606[3].In this study an investigation has made about the dependency of the amount of alumina particle on mechanical property and the influence of solution heat treatment on both mechanical property and corrosion resistant characteristics. Studies were carried out on three different composition of Al6061-Al_2O_3 composite such as 6, 9&15 weight percentages.

II. EXPERIMENTAL PROCEDURE

There are various types of metal-matrix composite material fabrication techniques in engineering like metallurgical melting method, gas or pressure infiltration method etc.[4].In this study investigations were made on the composite material which made by stir casting method. Al6061alloy having mass 3kg was cut in to three pieces of each having mass 1kg. Al_2O_3 particle having size 36µm was used. Three sets of Al_2O_3 particle were taken and in each set the amount of particle was 6 ,9&15 weight percentages respectively. Both Al6061 alloy and Al_2O_3 particle were pre heated in pre heating furnace for 15 minutes. For making a particular weight percentage composite material, mix Al6061alloy with corresponding amount of Al_2O_3 particle after melting the alloy in stir casting furnace at 800^0C with the aid of proper stirring. Then the mixture of molten alloy and Al_2O_3 particle was poured in to mould.

The purpose of the heat treatment over the composite is to improve the composite characteristics economically. Solution heat treatment involves heating an alloy to a suitable temperature, holding at the temperature long enough to allow one or more constituents to enter in to the solid solution and then cooling rapidly enough to hold the constituents in solution[5]. Solution heat treatment was done over the material by using muffle furnace and it was heated up to 520^0C for 6 hours and then allowed to cool in water at normal temperature. After reaching the desired temperature, the composite materials were maintained for definite holding time (6 hours) at 520^0C.

Mechanical property testings such as tensile, impact & hardness tests were carried out on both heat treated and non-heat treated specimens. For tensile testing cylindrical shaped specimens were used according to the ASTM standards .Tensile test of the fabricated specimens were conducted on the UTN40 type testing machine and tensile, yield &breaking strength and elongation of the specimens were measured[6-11]. Impact test was conducted in IT30 machine and energy absorbed during each impact was noticed. Vicker's hardness testing machine was used to find out the hardness of the material. Hardness values of each specimen were calculated by measuring the diameter of indentation produced.

Corrosion characteristics of the aluminium composites were tested in three different solutions such as NaOH, H_2SO_4 and NaCl [12&13] .The solutions were prepared in the manner, one molar NaOH solution was prepared by dissolving 40gm NaOH in one litre water, half molar H_2SO_4 solution was prepared by dissolving 60 ml H_2SO_4 in one litre water, NaCl solution was prepared by dissolving 30gm NaCl in one litre water. The specimens for the tests were cut to size 20x20x 5 mm, after which the sample surfaces were mechanically polished with emery paper starting from 120 grit down to 640 grit size. Specimens as per the above dimensions were also cut from solution heat treated composite materials, to carry out the immersion test. Then specimens from each weight percentage of composites, before and after solution heat treatment, immersed in to the solution by hanging at the top of the vessel containing the solution. The results of the corrosion tests were evaluated by mass loss method. Weight of each specimen was measured after 10 days by four decimal digit electronic weighing balance.

III.RESULTS AND DISCUSSION

A. *Mechanical properties*

Mechanical properties of the composite material were investigated by conducting corresponding mechanical property evaluation tests. The tests carried out were tensile, impact and hardness. The tensile test results shows that the addition of Al_2O_3 particle does not support the increase in yield, ultimate and breaking strength of the composite material. Tensile tests were conducted once again on the composite material, after allowing it to undergo solution heat treatment process. The results are shown in the Table 1. From the results we can conclude that the yield, ultimate and breaking strength are decreasing with the addition of Al_2O_3 particles in to the metal matrix. But when we compare the results with the values obtained before heat treatment, there exists a drastic increase in yield, ultimate and tensile strength

Like in the case of tensile strength the addition of Al_2O_3 particles did not increase the impact strength. But the solution heat treatment process influenced on the impact strength of the composite material. A hardness test result shows that, the addition of Al_2O_3 and solution heat treatment process much influenced to increase the hardness of the material. Al-Al_2O_3 (15wt%) has the highest value of hardness. Elongation of each weight percentage composites were calculated before and after heat treatment. The results show that 9wt% material has better elongation before heat treatment.

The results obtained after heat treatment reveals that the elongation of each weight percentage composites were found to be decreased. This is due to the intermetallic precipitation occurred during heat treatment.

Examination of the composite materials on scanning electron microscope Fig1,2&3, before heat treatment made it possible to reveal occurrence of intermetallic phases precipitations. Examinations of these materials in the heat treated state indicate to the reduction of the presence and size of the intermetallic precipitations. This shows the Fig 4,5&6. Due to the heat treatment performed the precipitations get dissolved in the solid solution in the hyper quenching process.

B. *Corrosion behaviour*

The mass loss profile in NaCl solution reveals that the mass gain occurred due to the formation of passive films on the surface of the composite material. The mass gain is very high for 6 weight percentage material. Mass loss profile after heat treatment indicates that solution heat treatment process decreases the mass gain of the material. The corrosion rate result shows that, corrosion rate of 15 weight percent materials were decreased because of the improved dispersion of the alumina particles in the matrix.

In NaOH solution the mass of the specimens were observed to decrease. Mass loss observed very greater for 6 weight percent material and lower for 9 weigh percent.15 weight percent material had moderate mass loss. Corrosion rate was very high initially then after it decreased. Solution heat treatment helped to decrease the corrosion rate of 15 weight percent material

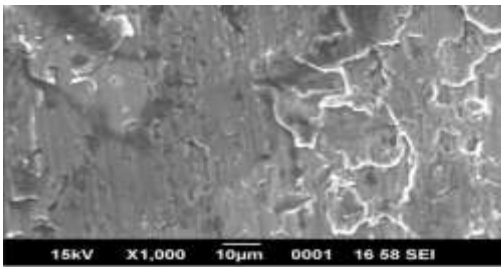

Fig.1 SEM Image of 6 wt% material

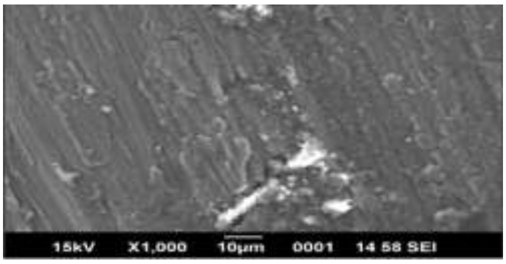

Fig.2 SEM Image of 9 wt% material

TABLE. I

	Before Heat -treatment			**After Heat- treatment**		
Composition	**Yield Strength (N/mm^2)**	**Ultimate Strength (N/mm^2)**	**Breaking Strength (N/mm^2)**	**Yield Strength (N/mm^2)**	**Ultimate Strength (N/mm^2)**	**Breaking Strength (N/mm^2)**
6%	59.43	105.94	103.36	112.86	119.06	117.83
9%	51.6	99.79	98.19	86.82	103.36	99.22
15%	41.3	94.5	93.02	77.5	98.1	98.1

It is observed that Al (6061)- Al_2O_3 composites exhibited excellent corrosion resistance in NaCl medium than NaOH and H_2SO_4 .Solution heat treatment resulted in improved corrosion resistance of 15 weight percentage composite material in NaOH and H_2SO_4solution.While the effect of volume percent alumina on corrosion resistance did not follow a consistent trend.

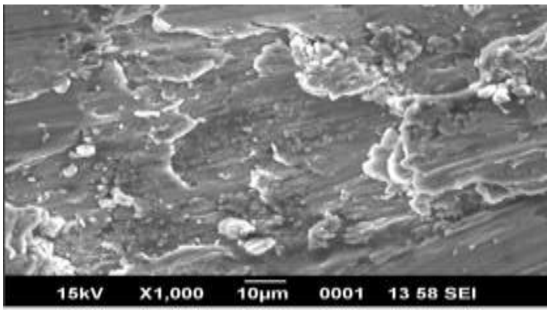

Fig.3 SEM Image of 15 wt% material

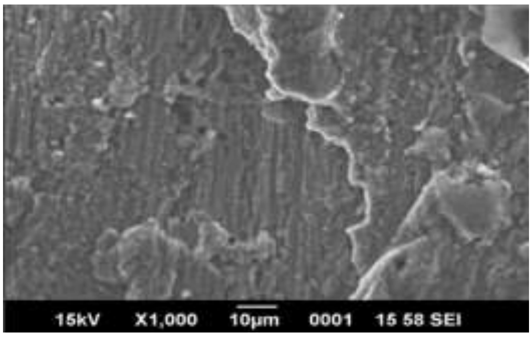

Fig.4 SEM Image of 6 wt% material

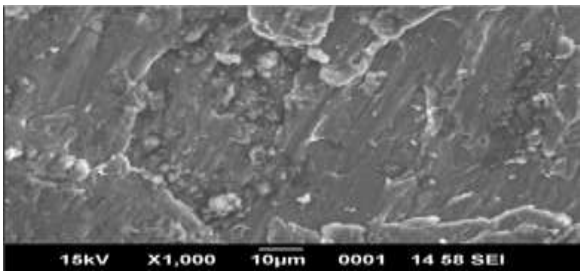

Fig.5 SEM Image of 9 wt% material

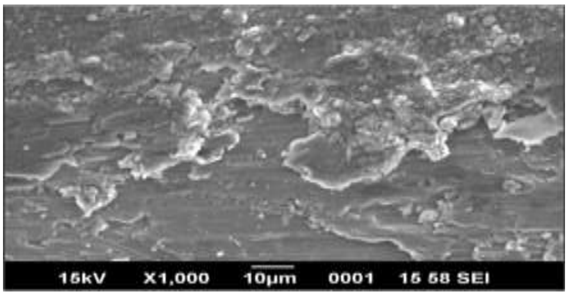

Fig.6 SEM Image of 15 wt% material

IV.CONCLUSIONS

In the earlier sections mechanical properties of different weight percent alumina reinforced aluminium composite material, before and after heat treatment were discussed .Also their corrosion resistant characteristics in different environment were investigated. The important conclusions from the present research work are summarized here:

•Increase in weight percentage of Al_2O_3 doesn't help the improvement in yield, ultimate and break stress.
•But the results show that there exists some improvement in stress after heat treatment.

TABLE.II

	Before Heat -treatment			After Heat- treatment		
Composition	**Impact strength (KJ/m^2)**	**Hardness**	**Elongation (mm)**	**Impact strength (KJ/m^2)**	**Hardness**	**Elongation (mm)**
6%	55.5	39.86	2	112.2	73.86	1
9%	44.4	43.61	5	111.1	78.81	3
15%	44.4	48.54	2	155.5	91.96	1

•Impact test of the fabricated composite revealed an improvement in impact strength of 15 weight percent material after heat treatment.

•Hardness of the composite material increased with increase in content of the reinforcing material in the metal matrix.

•Heat treatment helped to improve the hardness and decreased the elongation.

•Solution heat treatment resulted in improved corrosion resistance but the effect of volume percent alumina on corrosion resistance did not follow a consistent trend.

•SEM analysis reveals that heat treatment helped the reduction of the presence and size of the intermetallic precipitations.

REFERENCES

[1] Shang-Nan Chou , Horng-Hwa Lu , Ding-Fwu Lii , Jow- Lay Huang, "Processing and Physical Properties of Al_2O_3/Aluminum Alloy Composites",Ceramics International 35 (2009).

[2] Wenlong Zhang, Mingyuan Gu, Jiayi Chen, Zhengan Wu, Fan Zhang, Herve, E. Deve,"Tensile and Fatigue Response of Alumina-Fiber-Reinforced Aluminium Matrix Composite",Materials Science and Engineering A341 (2003).

[3] Nardone and Prewo "Modified Shear- Lag Theory to Describe the Strengthening of the Composites" Procedia Engineering 88 (2012).

[4] M.Wegmuller Mohammed.K.Hassan,Y.Mohammed,Abu El- Ainin H. "Improvement of Al -6061 Alloys Mechanical Properties by Controlling Processing Parameters". International Journal of Mechanical &Mechatronics Engineering IJMME-IJENS (2013)

[5] K. Rajkumar P. Rajan and J. Maria Antony Charles. "Microwave Heat Treatment on Aluminium 6061 Alloy-Boron Carbide Composites". Procedia Engineering 86 (2014) 34 – 41.

[6] Baradeswaran, A. Elaya Perumal, "Study on Mechanical and Wear Properties of Al7075/Al_2O_3/Graphite Hybrid Composites" Composites: Part B 56 (2014) 464–471.

[7] Devaraju Aruri, Kumar Adepu, Kumaraswamy Adepu, Kotiveerachari Bazavada, "Wear and Mechanical Properties Of 6061-T6 Aluminum Alloy Surface Hybrid Composites [(Sic + Gr) And (Sic+Al2o3)]Fabricated by Friction Stir Processing", (2014)

[8] H. Huang, M.B. Bush, "Finite Element Analysis of Mechanical Properties in Discontinuously Reinforced Metal Matrix Composites with Ultrafine Microstructur", Materials Science and Engineering A232 (1997) 63-72..

[9] S.A. Sajjadi, H.R. Ezatpour, H. Beygi, "Microstructure and Mechanical Properties Of Al–Al_2O_3 Micro And Nano Composites Fabricated by Stir Casting", Materials Science and Engineering A 528 (2011) 8765–8771.

[10] M.B. Karamıs, A.AlperCerit, BurhanSel, Fehmi Nair, "The Effects of Different Ceramics Size and Volume Fraction on Wear Behavior of Al Matrix Composites" (For Automobile Cam Material), Wear 289 (2012) 73–81.

[11] Guo-Zheng Kang, Qing Gao, "Tensile Properties of Randomly Oriented Short Al_2O_3fiber Reinforced Aluminium Alloy Composites": II Finite Element Analysis for Stress Transfer, Elastic Modulus And Stress-Strain Curve‖, Composites Part A 33 (2002) 657-667.

[12] K. K. Alaneme* and M. O. Bodunrin . "Corrosion Behavior of Alumina Reinforced Aluminium (6063) Metal Matrix Composites" Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.12.

[13] Aprael S. Yaro, Anees A. Khadom, Rafal K. Wael,"Apricot Juice as Green Corrosion Inhibitor of Mild Steel in Phosphoric Acid", Alexandria Engineering Journal(2013)52, 129–135.

[14] Rosenberger MR, Florlerer E, Schvezov CE, "Wear Behavior of AA1060 Reinforced with Alumina Under Different Loads", Wear 2009;266:356–9.

[15] L.J. Yang, "The Transient and Steady Wear Coefficients of A6061 Aluminium Alloy Reinforced with Alumina Particles", Composites Science and Technology 63 (2003) 575–583.