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TO STUDY THE DRY SLIDING WEAR RESISTANCE OF HEAT TREATED Al 6061 USING TAGUCHI METHODOLOGY

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Abstract-*Aluminum 6061 is used in wide range of applications such as in the automotive components and construction of aircraft structures. Heat treatment process helps in improve the mechanical properties and strength of aluminum. The objective of this study is to identify the effect of heat treatment process on Hardness of 6061 aluminum alloy, also to determine weight loss on pin on disc set up using L9 OA with Taguchi approach. The heat treatment process involves the Solution Heat treatment, quenching, aging at same temp. with change in aging time. The specimens were solutionized at 530°C and quenched in water. The specimens were aged at 170°C for the time period of 4 hours, 5 hours, 6 hours 8 hours. The natural aging behavior of specimen was studied using aging curves determined at difference in Hardness. The aging period for high hardness was identified. The high hardness was found to increase with increase with aging time and the highest hardness was observed 47.16 HRB at 170ºC with aging time of 8 hours.. After this weight loss of heat treated 6061 has been determine on pin on disc setup. Three parameters are selected to investigate the weight loss i.e. Load, Speed and Sliding Distance. The design of experiments (DOE) approach using Taguchi method (L9 Orthogonal Array) was employed to analyze the wear behavior of heat treated Al 6061 Alloy Signal-to-noise ratio, analysis of variance (ANOVA)and regression equation were used to investigate the influence of parameters on the weight loss.*

Key Words: *Al-Si composite, Aging curve, Rockwell B hardness, T4 Treatments. Pin on disc*

1. INTRODUCTION

Heat treatment is defined as an operation or combination of operations, involving heating and cooling of metal or alloy in its solid state with the object of changing the characteristics of the material. Heat treatment is generally employed for the following purposes:

1. To improve machinability .
2. To change or refine grain size
3. To improve mechanical properties, eg., Tensile strength, hardness, ductility, shock resistance, resistance to corrosion etc.
4. To improve magnetic and electric properties.
5. To increase resistance to wear, heat and corrosion.
6. To produce a hard surface on ductile interior.

Solution heat treatment and Natural aging are common processes in metallurgy to improve the mechanical performance of metals. The process parameters employed during these treatments are shown to play an important role in the mechanical properties of alloys .Solution heat treatment involves the heating of an alloy to a suitable temperature, holding at that temperature for sufficient time and then cooling rapidly. After that specimen are heated to aging temperature which is lower than the heating temperature and are hold that that temperature for long time depending upon the thickness of specimen.

2. METHODOLOGY

The Taguchi method involves reducing the variation in a process through robust design of experiments. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. In the present investigation weight loss of samples is calculated to analyze the influence of parameters like Load, Speed and Sliding Distance.

3. SPECIMEN'S DETAILS

6061 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminium for general purpose use. It is commonly available in pre-tempered grades such as 6061-O (annealed) and tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged. Composition

Table 1. Typical composition of aluminium alloy 6061

Component	Amount (wt. %)
Aluminium	Balance
Magnesium	0.8-1.2
Silicon	0.4 – 0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

The specimens with dimensions (30x7x7) each in mm were prepared. To ensure a reproducible initial surface condition, samples were polished with 600 grit emery polishing paper followed by degreasing in propanol and rinsing with distilled water.

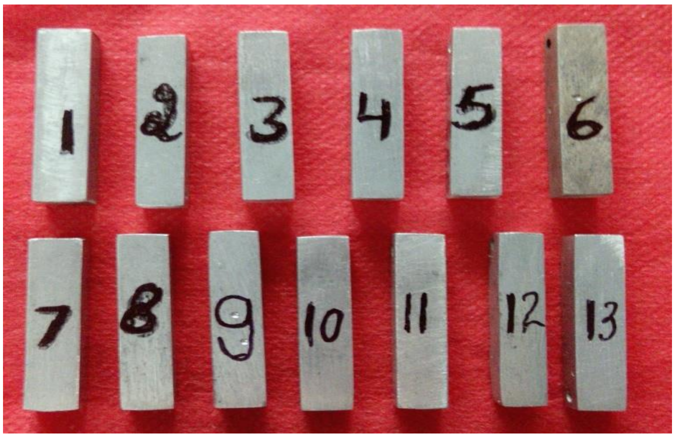


Figure 1.Specimen's Detail

4 .EXPERIMENTAL WORK

The heat treatment process involved the Solution Heat treatment, quenching, aging at same temperature with change in aging time. The specimens were solutionized at 530°C and quenched in water. The specimens were aged at 170°C for the time period of 4 hours, 5 hours, 6 hours 8 hours. The natural aging behavior of specimen was studied using aging curves determined at difference in Hardness. The aging period for high hardness was identified. The following graph shows the heat treatment cycle i.e. Time Vs Temp

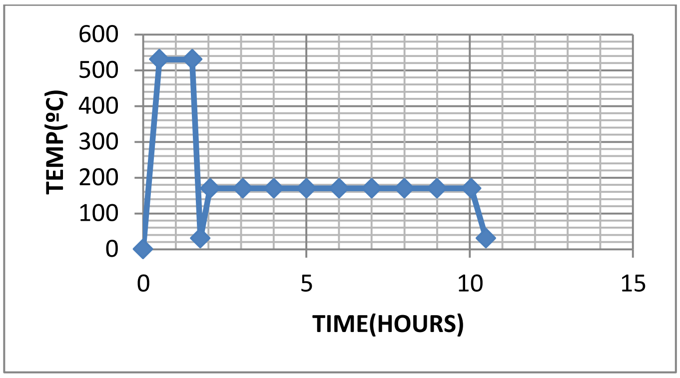


Figure 2-Heat Treatment Cycle

Hardness was observed as per following manner with respect to change in aging time. The various Rockwell scales and their applications are shown in the following table.

Table 2. Testing application of Rockwell Hardness

Scale	Indenter	Minor load (kgf)	Major Load (kgf)	Testing Application
HRB	1/16"ball	10	100	Copper alloy , Aluminium alloys,

Table 3. Heat treatment Parameters

Heating Temp. (Specimen1)	Heating Temp. (Specimen2)	Heating Temp. (Specimen3)	Heating Temp. (Specimen4)
520°C	520°C	520°C	520°C
Soaking Time	Soaking Time	Soaking Time	Soaking Time
1 hr	1 hr	1 hr	1 hr
Aging Temp	Aging Temp	Aging Temp	Aging Temp
170°C	170°C	170°C	170°C
Aging Time	Aging Time	Aging Time	Aging Time
4 Hr	5 Hr	6 Hr	8 Hr
Hardness after Heat treatment	Hardness after Heat treatment	Hardness after Heat treatment	Hardness after Heat treatment
39 HRB	40.5 HRB	43 HRB	47.16 HRB

Table 4- Average hardness values

Sr.No	Aging Temp. (ºC)	Aging Time (Hours)	A (HRB)	B (HRB)	C (HRB)	Average HRB
1	170	4	39	38	40	39
2	170	5	40	40.5	41	40.50
3	170	6	43	42	43	43
4	170	8	47	46.5	48	47.16

Fig 3 shows the Rockwell B hardness values of natural aging and aging curve. It shows the hardness increases with increase in aging time. The hardness measurement for T4 treatment shows a sharp rise after the solution treatment and aging

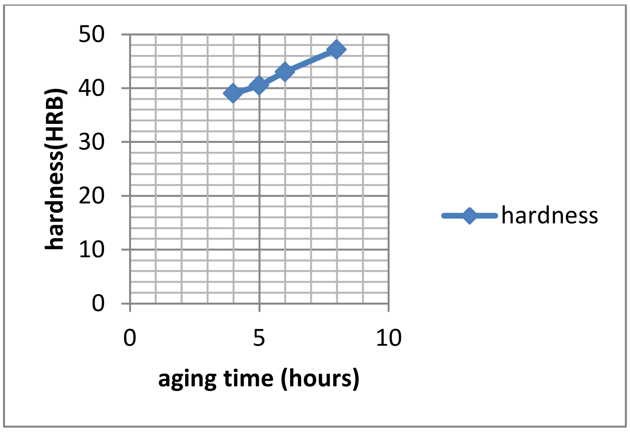


Figure 3. Aging curve i.e. Aging time Vs Hardness

For the further experiment the maximum hardness specimen was taken to perform the wear test. i.e

Table-5.Optimum hardness value parameter

Solution temp	Soaking time	Aging temp.	Aging time
530°C	1 hour	170°C	8 hours

A pin on disc test (DUCOM TR-20) was performed to determine the sliding wear characteristics of the Heat treated Al 6061. The contact surface of the sample (pin) has to be flat and will be in contact with the rotating disk. During the test, the pin is held pressed against a rotating EN8 steel disc (hardness of 65HRC) by applying load that acts as counterweight and balances the pin. Once the surface in contact wears out, the load pushes the arm to remain in contact with the disc. This movement of the arm generates a signal which is used to determine the maximum wear and the coefficient of friction is monitored continuously as wear occurs. Weight loss of each specimen was obtained by weighing the specimen before and after the experiment by a single pan electronic weighing machine with an accuracy of 0.0001g after thorough cleaning with acetone solution.

Table 6. Different Values and Parameters On Pin On Disc

Sr.No	LOAD(N)	SPEED(m/s)	DISTANCE(m)
1	5	0.5	400
2	5	1	800
3	5	2	1600
4	10	0.5	800
5	10	1	1600
6	10	2	400
7	20	0.5	1600
8	20	1	400
9	20	2	800

Figure 4. Pin On Disc Machine

5. RESULTS AND DISCUSSION

The Wear process parameters were analysed using Minitab 18 software (Trial Version)

5.1. S/N Ratio Analysis The influence of control parameters such as load (L), speed (S), and sliding distance (D) on weight Loss was evaluated using S/N ratio response analysis. Process parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance. The sliding wear quality characteristic selected was smaller is the better type and same type used for signal to noise ratio which is given below of response was

$S / N = -10\log 1/n \Sigma y^2$------------ (1)

The S/N ratio response was analyzed using the above Equation (1) for all 9 tests and presented in Table 9. Figure 5 and Figure 6 show the main effects plots of S/N ratios and main effects plots of means for wear of heat treated aluminium alloy. From the figure it is evident that the average mean weight loss of aluminium is 0.00398 grams. The response table for SN ratio depicts the rank of

Process parameters with Delta as static criteria, From Table 7, it has been observed that Load has significant impact on weight loss followed by Speed and Sliding Distance. The main effects plot for Means shown in figure 6 infers that weight Loss increase for increase in load from 5N to 20N.

5.2. Analysis of Variance

The analysis of variance (ANOVA) was used to analyze the influence of wear parameters like sliding speed, load and sliding distance. The ANOVA establishes the relative significances of factors in terms of their percentage contribution to the response. This analysis was carried out for a level of significance of 5% (*i.e.*, the level of confidence 95%). **Tables 10 shows** the results of ANOVA analysis of heat treated Al 6061. The last column of Table shows the percentage of contribution (P %) of each parameter on the response, indicating the degree of influence on the result. It can be observed from the results obtained that Load was the most significant parameter having the highest statistical influence (90.72%) on the dry sliding wear of heat treated Al6061 followed by Speed (3.78%) and Distance (2.23)

Table-7: Response Table for Signal to Noise Ratio (Smaller is better)

Level	Load	Speed	Sliding distance
1	55.47	49.40	50.18
2	5076	50.91	49.95
3	42.85	48.76	48.94
Delta	12.62	2.14	1.24
Rank	1	2	3

Table 8: Response table for Means

Level	load	Speed	sliding distance
1	0.001700	0.004167	0.003433
2	0.002900	0.003300	0.004200
3	0.007333	0.007333	0.007333
Delta	0.005633	0.005633	0.000867
Rank	1	2	3

Table-9: Orthogonal array (L9) of Taguchi for wear test

Sr.No	LOAD	SPEED	DISTANCE	Wt.Loss (grams)	SNRA1
1	5	0.5	400	0.0018	54.8945
2	5	1.0	800	0.0014	57.0774
3	5	2.0	1600	0.0019	54.4249
4	10	0.5	800	0.0027	51.3727
5	10	1.0	1600	0.0030	50.4576
6	10	2.0	400	0.0030	50.4576
7	20	0.5	1600	0.0080	41.9382
8	20	1.0	400	0.0055	45.1927
9	20	2.0	800	0.0085	41.4116

Table-10: ANOVA Analysis for SN Ratio-weight Loss

Source	DF	Adj SS	Adj MS	F-Value	P-Value	%age
Load	2	0.00005	0.000026	29.1	0.031	90.72
Speed	2	0.000002	0.000001	1.21	0.474	03.78
Sliding Distance	2	0.000001	0.000001	0.74	0.468	2.23
Error	2	0.000001	0.0000009			3.09
Total	8	0.000058				

5.3 Multiple Linear Regression Model Analysis

A multiple linear regression analysis attempts to model the relationship between two or more predictor variables and a response variable by fitting a linear equation to the observed data. Based on the experimental results, a multiple linear regression model was developed using MINITAB 18.

Regression Equation

WT. LOSS = - 0.00151 + 0.000385 LOAD + 0.000338 SPEED + .000001 SLD. DISTNT

The above equation can be used to predict the weight loss of the heat treated Al 6061. The constant in the equation is the residue. From the above regression equation it is found that weight Loss of Al 6061 is inversely proportional to load, speed and distance. From the above regression equation it is found that weight Loss of Al 6061 is directly proportional to load, speed and distance

Fig 5-Mean essect plot for SN ratio

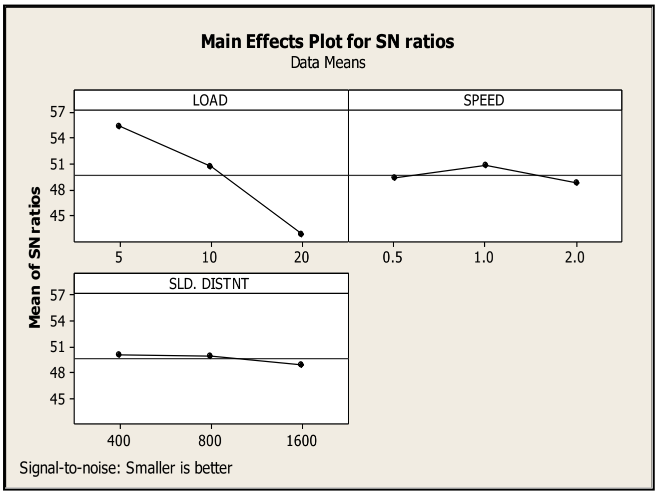
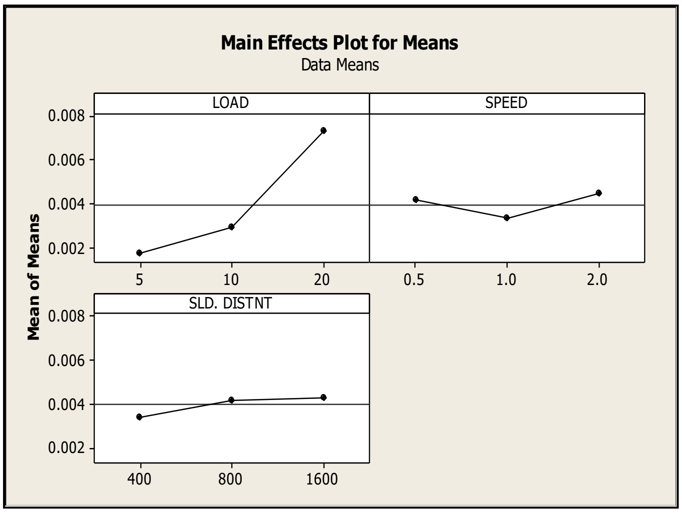


Fig-6. Main Effects Plot for Means



6. CONCLUSIONS

1) It was found that optimum hardness value 47.16 HRB came with the aging time of 8 hours.

2) The analysis of variance shows that weight Loss/wear was highly influenced by applied load (90.72%) followed by sliding speed (3.78%) and sliding distance(2.23%) respectively.

3) The optimum Parameters were found to be with high signal to noise ratio from response Table 3 i.e.Load-5N,Speed-1m/s and Sliding Distance-400m

4) From the regression equation it was found that weight Loss increases with increase in load, speed and distance

VII. REFERENCES

1. ASTME G-99-03"Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus"

2. Aytekin Polat, Mustafa Avsar, Fahrettin Ozturk, "Effects of the artificial-aging temperature and Time on the mechanical properties and spring back Behavior of aa6061" , Materials and technology 49 (2015) 4, 487–493

3. Halil Demir, Süleyman Gündüz, "The effects of aging on machinability of 6061 aluminium alloy", Materials and Design 30 (2009) 1480–1483

4. C., Montgomery, Douglas "Design and analysis of Experiments", Wiley India edition.

5. Chee Fai Tan, Mohamed R. Said, 2000. Effect of hardness test on precipitation hardening aluminum alloy 6061-T6. Chiang Mai J. Sci., 36: 276-286

6. Cheng L.M., Poole W.J., Embury J.D. and Lloyd D.J., "The Influence of Precipitation on the Work-hardening Behaviour of the Aluminium alloys AA6611 and AA7030", Journal of Metallurgical and Materials Transactions A, 2003; 34A: 2473-2481

7. Christy, T.V., Murugan N. and Kumar, 2010. A Comparative study on the microstructures and mechanical properties of Al 6061 alloy and the MMC Al 6061/TiB2/12P. J. of Minerals & Materials Charac. & Engin., 9: 57-65

8. Demirci, E.E., Arslan, E., Kadri. E, Vefa, B., Özlem,T.Y., and Efeoglu, İhsan (2013) "Investigation of wear, corrosion and tribocorrosion properties of AZ91 Mg alloy" Thin Solid Films, Vol. 528,pp. 116–122

9. Devaraju, A., Kumar A., Adepub, K., andKotiveerachari, B.(2013) "Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC + Gr) and (SiC + Al2O3)]fabricated by friction stir processing" Journal of Material Science Research and Technology,Vol.2,No.4,pp.362-369

10. Dong, H.(2010)"Surface Engineering of Light Alloys: Aluminium, Magnesium and Titanium Alloys"Elsevier

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