IMPACT OF HEAT TREATMENT ON TRIBOLOGICAL PROPERTIES OF Al-0.5Si-0.35 Mg (wt. %) ALLOY

Jagadish Parida,
Lecturer,
Dept. of Metallurgical and Material Engineering,
Government College of Engineering, Keonjhar, India

Abstract: The heat treatments have high impact on hardness, microstructure, tensile properties and Tribological behavior of Al alloy. An experimental work has been carried out to check the impact of annealing, oil and water quenching on wear behavior of Al-0.5Si-0.35 Mg (wt. %) alloy. This experiment is done on a cylindrical shaped sample of 10mm radius and 30mm length, those samples are warmed up to 450^{0}C and after that permitted to cool in three distinctive conditions, few samples are cooled in the water, a couple are in oil and rest are left to cool in the furnace itself, duration for cooling samples are settled for 5 hours. After that each sample are experimented for various loading condition and speed on Pin on Disk equipment.

***Index Terms* - Al-0.5Si-0.35 Mg (wt. %) alloy, *Microstructure, Heat Treatment, Inter-metallic, Mechanical Testing, Tribological Properties*.**

I. INTRODUCTION

Aluminum is one of those metals which is found in the most plentiful amount in earth's outside layer (around 8% by weight) of the world's solid surface [1]. Aluminum has properties such as strength, light weight, and surface finish, which makes aluminum and its combinations to be utilized as an option for different metals (ferrous and non-ferrous), ceramics and wood [2]. Al-Si-Mg alloy represents gainful change in mechanical properties such as hardness, yield quality and elongation after heat treatment [3]. To verify the tribological behavior of heat treated alloy these are experimented on Pin on Disk equipment.

II. HEAT TREATMENT

The prime goals of the various types of thermal treatment are:

a) Soften the material consequently enhancing workability.
b) Enhance the strength, hardness and toughness of the material.
c) Improve the resistance to fracture.
d)Stabilize the internal and external properties like mechanical or physical changes due to various service conditions.

Annealing is a heat treatment process, where heating of samples is made up to a reasonable temperature and is permitted to hold for certain time and afterward it is cooled at moderate rate. If the state of surface isn't of critical significance or surface cleaning happens after heat treatment at that point, cooling can be possible in air. If the surface finish does matters then a defensive climate is used for cooling. Regularly this would be Nitrogen with a little addition of Hydrogen.

Quenching procedure can be accomplished from numerous points of view; it is a standout amongst the most basic advance in the arrangement of heat treating activities. The target of quenching is to safeguard the strong arrangement framed at the solution temperature in heat treating, by quickly cooling to a few bring down temperature, typically near room temperature. [5]

III. EXPERIMENTAL ANALYSIS

3.1 Sample preparation

A 10mm bar is considered and cut into pieces within the size of 2mm for machining resistance and after that surface turning activity is implemented on both circular appearances of cylindrical shaped samples. For steady and smooth surface each face is rubbed on the sand paper (320-grit paper) for each sample to have relatively same measurement and surface finish. Cylindrical shaped samples are set up of dimensions;

Diameter = 10mm
Length = 30mm

3.2 Heat treatment

Each of the specimen are heated to a temperature of 450^{0}C and cooled in various medium for distinct quenching process bringing about various kind of thermal treatment process. For annealing, specimens are allowed to cool in the furnace itself for 24 hours and when the furnace is cooled to room temperature specimens are carried out for testing [6]. For water quenching, the specimens subsequent to heating to 450^{0}C is drenched into typical water of 27^{0}C for the duration of 5 hours. Essentially, for oil quenching, the heated samples are drenched into the oil of same temperature as water again for 5 hours.

3.3 Tests on pin on disc machine

Typical framework comprises of a driven spindle and chuck for holding the rotating plate, a lever arm gadget to hold the pin, and connections to enable the pin example to be constrained against the spinning circle sample under a controlled load condition. The wear track on the circle is a circle, including various wear passes on a similar track. The system has a frictional force measuring framework, for instance, a load cell, that enables the coefficient of friction to be decided.

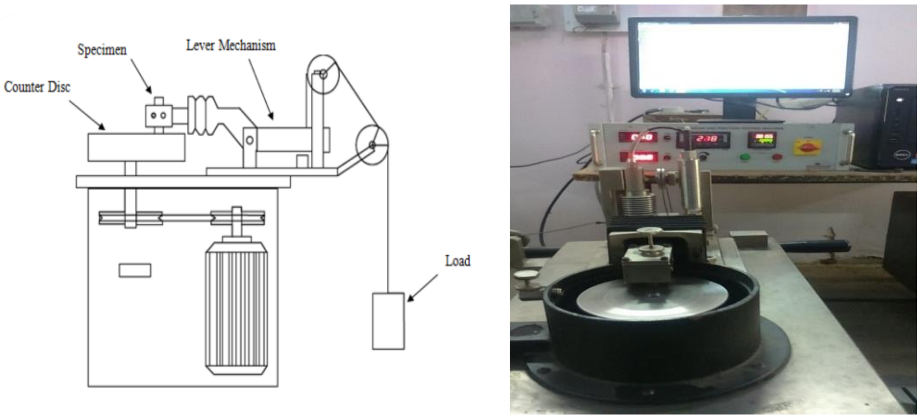

Figure 1: Schematic diagram of Pin on Disc Wear Testing Machine and its experimental setup

In this trial, the wear of pin is experimented and circular plate is made up of high carbon, quenched and tempered steel. It is well realized that stainless steel is significantly harder than Al-alloy so it won't experience wear process as of being disc. The path of pin on the disc having radius of 40mm and each experiment is carried out for 30 minutes. [7]

The samples are marked in understanding to heat treatment and cooling strategy implemented. In first step, the specimens are measured and their individual weights are noted down. In second step, after successful experimentation, the similar process is carried out for calculating the weight loss of material. therefore, loss of material shows the wear of tested specimens.

IV. RESULTS AND DISCUSSION

Table 4.1: Annealing Treatment

Sl No.	Load (kg)	Time (min)	RPM	Coefficient of Friction	Weight Loss (mg)	MRR (mm^3/min)
1	1	30	1500	0.171	187.4	2.313
2	1	30	1000	0.175	166.7	2.058
3	1	30	500	0.185	194.9	2.406
4	0.75	30	1500	0.189	98.2	1.212
5	0.75	30	1000	0.193	92.4	1.140
6	0.75	30	500	0.195	26.6	0.328
7	0.5	30	1500	0.204	29.2	0.360
8	0.5	30	1000	0.203	55.6	0.686
9	0.5	30	500	0.203	9.3	0.114

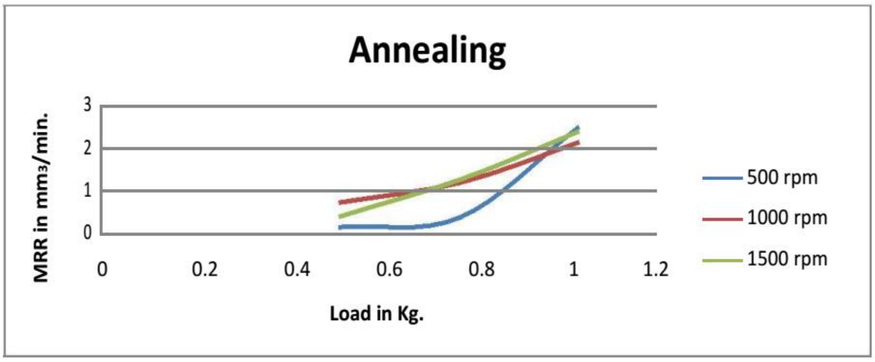

Figure 2: Graphical analysis of annealing at various rpm

In Figure 2, it is shown that since increasing load is applied, removal rate of material increases and after a certain limit it starts increases at a faster rate. From the Figure, it is also observed that, higher the rpm value, higher is the value of removal rate of material. However, in some cases it decreases rather than increasing.

Table 4.2: Oil Quenching Treatment

Sl. No.	Load (kg)	Time (min)	RPM	Coefficient of friction	Weight loss (mg)	MRR (mm3/min)
1	1	30	1500	0.187	190.4	2.351
2	1	30	1000	0.194	150.1	1.851
3	1	30	500	0.198	112.7	1.391
4	0.75	30	1500	0.195	29.9	0.370

5	0.75	30	1000	0.191	30.9	0.381
6	0.75	30	500	0.191	15	0.185
7	0.5	30	1500	0.208	19.7	0.243
8	0.5	30	1000	0.200	19.5	0.241
9	0.5	30	500	0.202	5.7	0.070

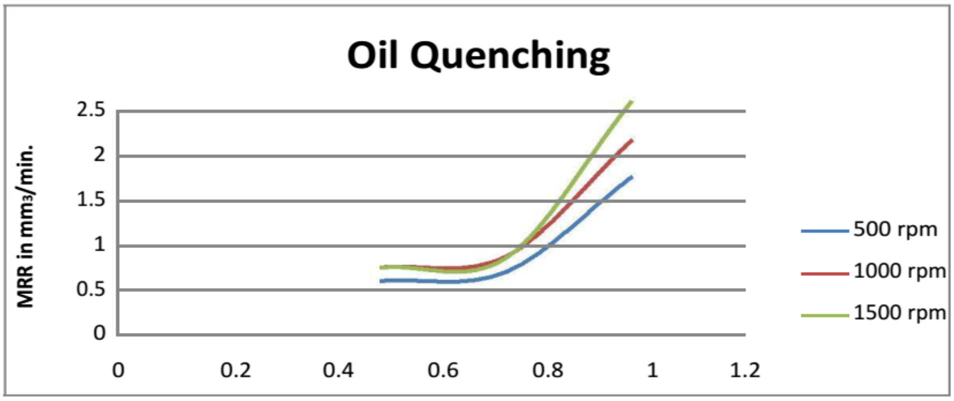

Figure 3: Graphical analysis of annealing at various rpm

From Figure 3, it depicts that in oil quenching process, the wear rate increases at a very low rate since load is associated however after a certain point, the wear rate rapidly improves. The impact of rpm is analogous to annealed specimen. Typically, wear rate increases with increase in rpm but in some cases wear rate decreases rather than increasing.

Table 4.3: Water Quenching Treatment

Sl. No.	Load (kg)	Time (min)	RPM	Coefficient of friction	Weight loss (mg)	MRR (mm3 /min)
1	1	30	1500	0.201	93.1	1.150
2	1	30	1000	0.198	117.2	1.447
3	1	30	500	0.197	12.8	0.158
4	0.75	30	1500	0.200	48.9	0.604
5	0.75	30	1000	0.197	15.6	0.193
6	0.75	30	500	0.199	15.7	0.194
7	0.5	30	1500	0.194	41.7	0.515
8	0.5	30	1000	0.197	5.6	0.069
9	0.5	30	500	0.195	4	0.049

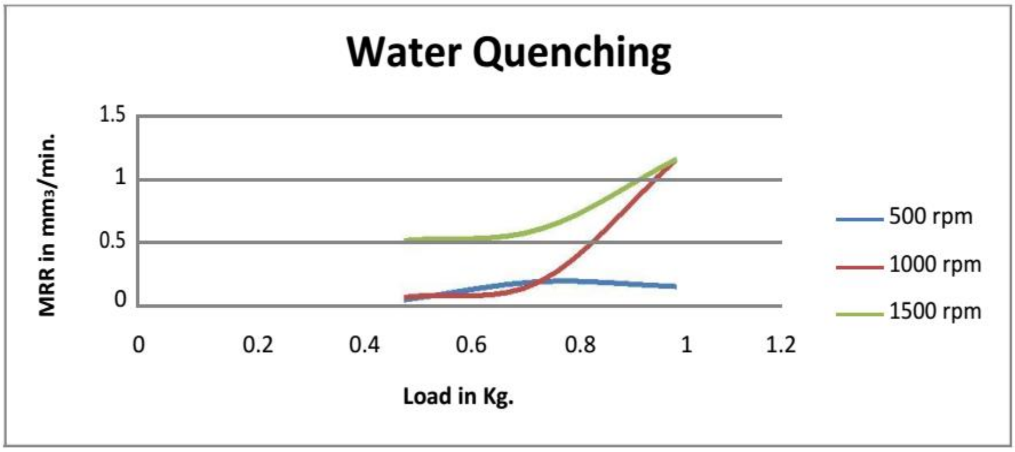

Figure 4: Graphical representation of Water Quenching for different rpm

In the above Figure 4, it is represented that the behavior of water quenched samples uniformly indicates the variation for different wear rate at different rpm. From Figure, it is shown that at 500 rpm, the wear rate gradually increases and remains almost constant, while in case of 1000 rpm, the parameter increases with connected load and rapidly increases after a certain limit. At 1500 rpm and low load, wear rate is high and also increases as the connected load increases.

V. COMPARISION OF HEAT TREATMENTS

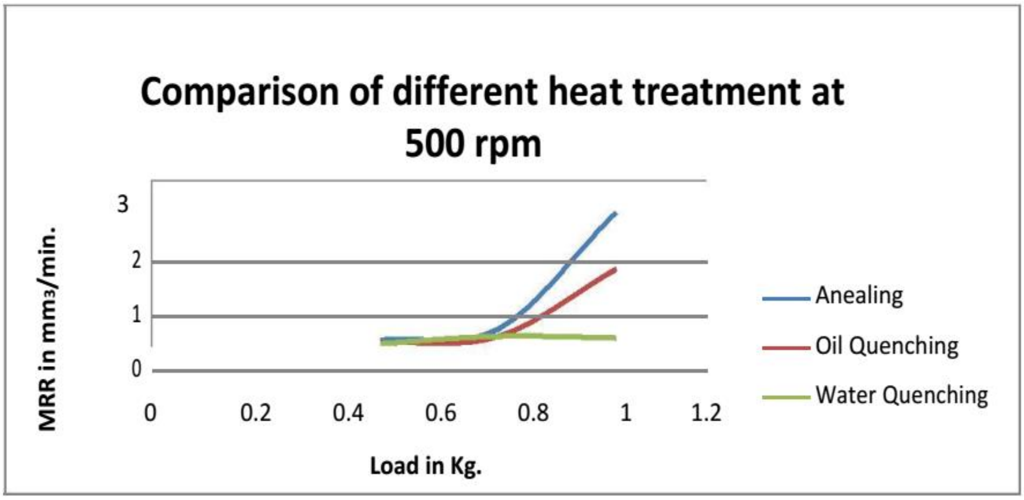

Figure 5: Comparison of wear behavior of different heat treatment at 500 rpm

In Figure 5, it is clearly indicated that, at 500 rpm wear rate of water quenched Al sample is almost constant however with the increase in load wear rate is very less. Water quenched samples represents one of the best resistance to wear as compared to the other heat treatments. The oil quenched material also denotes better wear resistance but it starts deforming at higher load. In case of annealed samples, they show very less resistance to wear at higher load but remain almost same at lower load levels.

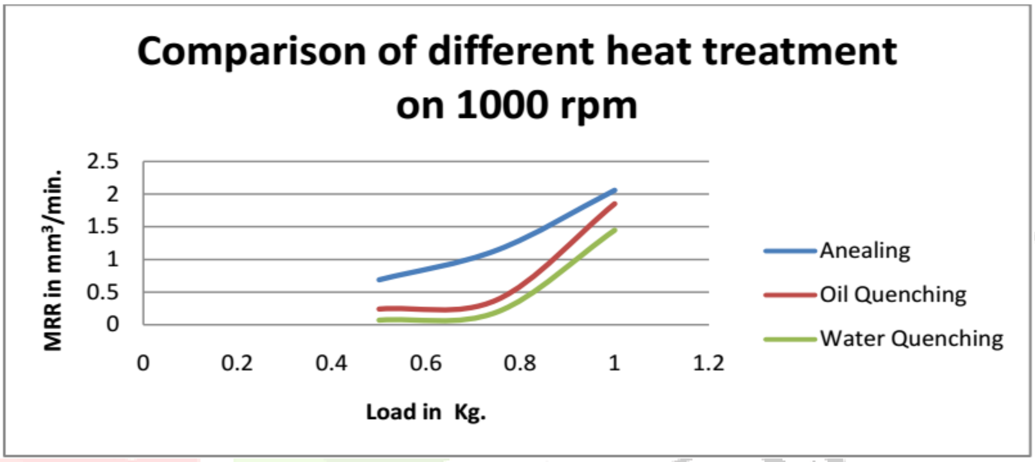

Figure 6: Comparison of wear of different heat treatment at 1000 rpm

At higher loading level, the wear graph represents that the increase in material removal rate possess identical pattern in both quenching processes. It is clearly denoted that the wear resistance in both oil and water quenching is either more or less or identical pattern with minor difference but in case of oil quenched material the wear resistance and material removal rate is high. Annealed specimen has more wear rate at lesser load and further increase in load is normally less.

At 1500 rpm, oil quenched sample having low load denotes better wear resistance compared to other materials, however as the load increases the wear rate rapidly increases. The water quenched sample signifies higher wear rate, but as the load increases a minor increment is observed. Since higher load is connected, the annealed specimen represents constant increase in material removal rate.

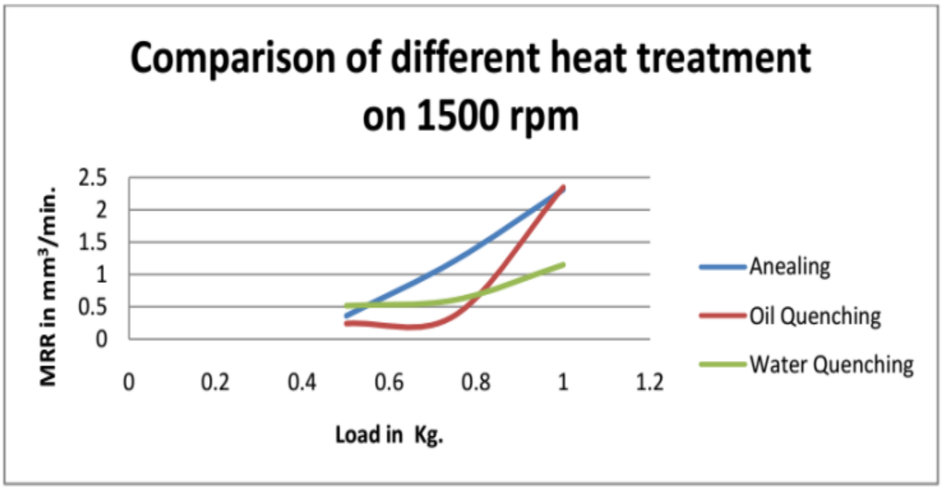

Figure 7: Comparison of wear of different heat treatment at 1500 rpm

Specimens come under heat treatment are desired to a certain temperature which force silicon particles to undergo separation that results decrease in average particle size with retaining the original particles. The heating phenomena results dissolution of the Mg_2Si phases on the entire surface of the material. The aluminum matrix is formed by the quenching of heat absorption and produce Mg-Si clusters which leads the sample become harder and the properties like strength, hardness, and elongation also enhanced that produces better resistance against wear. Due to these changes in properties quenched material creates less wear.

In the process of annealing, the material is allowed to cool for a larger time in order to remove each residual stress from the material, which makes the material softer and also less resistance against wear.

VI. CONCLUSION

The samples of different heat treatment process are experimented at various velocity and load. From this research, following observations are concluded:

I. With the increase in load wear rate increases, when load is connected on each of the heat-treated sample, it is concluded that, at lower load the increment in wear is less but, after a certain point, the wear rate increases rapidly. At load having weight 1kg, it represents very rapid wear at the initial of the experiment then decreases gradually and after a specific time it becomes constant.

II. Comparing various quenching or cooling procedures in each heat treatments, the water quenching represents superior wear resistance than oil quenched samples and annealed materials which are soften and denotes low wear resistance with load.

III. In almost all cases, the wear rate increases with respect to rpm however in some cases the wear rate shows a decreasing behavior due to high velocity.

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