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EFFECT OF HEAT TREATMENT ON WEAR BEHAVIOR OF AL-SI-MG ALLOY

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Abstract: *The heat treatments have high influence on microstructure, hardness, tensile properties and Tribological behaviour of Al alloy. An experimental study was carried out to check the effect of annealing, oil quenching and water quenching on wear behaviour of Al-Mg-Si alloy. The experimentation is carried out on a cylindrical sample of 8mm radius and 20mm length, the samples were heated up to 450̊C and then allowed to cool in three different conditions, few samples were cooled in the water, a few were in oil and rest were left for cooling in the furnace itself, duration for cooling samples were fixed for 5 hours. Then all the samples were tested for different loading condition and speed on Pin on Disc apparatus.*

***Key words**: Heat Treatment, Inter-metallic, Mechanical Testing, Microstructure, Tribological Properties.*

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1. INTRODUCTION:

Aluminium is one such metal which is found in the most abundant quantity in earth's crust (about 8% by weight) of the earth's solid surface [1]. Aluminium has properties like durability, light weight, extrusion ability and surface finish, which makes aluminium and its alloys to be used as an alternative for other metals (ferrous and non-ferrous), ceramics and wood[2]. Al-Si-Mg alloy shows beneficial change in mechanical properties like hardness, yield strength and elongation after heat treatment [3]. To check the tribological properties of heat treated alloy these are tested on Pin on Disc machine.

2. HEAT TREATMENT:

The major objectives of the different kinds of thermal treatments are:

a) Soften the material thus improving workability.
b) Increase the strength or hardness of the material.
c) Increase the toughness or resistance to fracture.
d) Stabilize mechanical or physical properties against changes that might occur during exposure to service environments.
e) Insure part dimensional stability.
f) Relieve undesirable residual stresses induced during fabrication.[4]

Annealing is one such processes of heat treatment, where heating is done up to a suitable temperature and is allowed to hold for certain time and then it is cooled at slow rate. If the condition of surface is not of significant importance or surface cleaning takes place after heat treatment then cooling can be done in air. If the surface finish does matters then a protective atmosphere is utilised for cooling. Typically this would be Nitrogen with a small Hydrogen addition.

Quenching process can be achieved in many ways; it is one of the most critical step in the series of heat-treating operations. The objective of quenching is to preserve the solid solution formed at the solution temperature in heat treating, by rapidly cooling to some lower temperature, usually close to room temperature. [5]

3. METHODOLOGY AND EXPERIMENTATION:

3.1 Sample preparation: An 8mm rod is taken and cut into pieces within size of 2mm for machining tolerance and then surface turning operation is applied on both circular faces of cylindrical samples. For constant and smooth surface each face is rubbed on the sand paper

(C-320) for all the samples to have almost same dimension and surface finish. Cylindrical samples are prepared of dimensions;

Diameter	=	08mm
Length	=	20mm

3.2 Heat treatment:

All the samples are heated to a temperature of 450 ^{0}C and cooled in different medium for different quenching processes resulting in different type of heat treatment process. For annealing, samples are let to cool in the furnace itself for 24 hours and when the furnace cooled to room temperature samples were taken for testing. For water quenching the samples after heating to 450 ^{0}C is immersed into normal water of 27 ^{0}C for the period of 5 hours. Similarly in case of oil quenching the oil is taken as cooling medium and the heated samples are immersed into the oil of same temperature as water again for 5 hours.

3.3 Tests on pin on disc machine:

Typical system consists of a driven spindle and chuck for holding the revolving disc, a lever-arm device to hold the pin, and attachments to allow the pin specimen to be forced against the revolving disc specimen under a controlled load condition. The wear track on the disc is a circle, involving multiple wear passes on the same track. The system has a friction force measuring system, for example, a load cell, that allows the coefficient of friction to be determined.

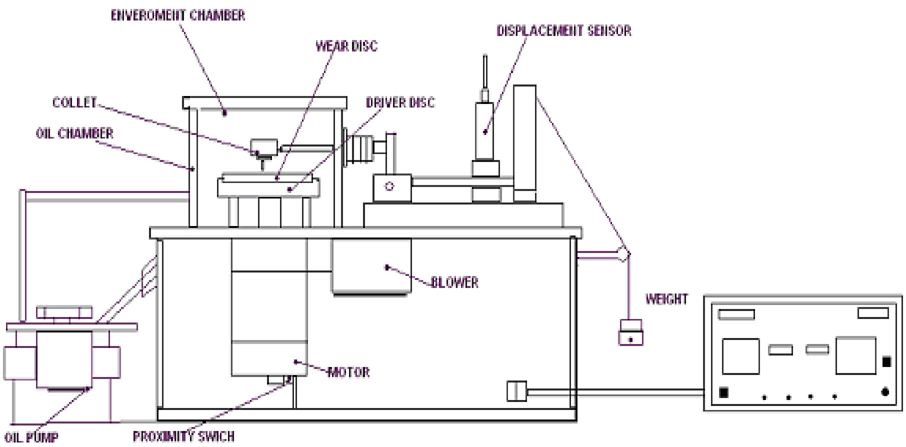

Figure 1: Block diagram of pin on disc machine

In this experiment the wear of pin is tested and disc is taken of En31 material.It is well known that En31 is much harder then Al-alloy so it will not undergo wear process as of being disc. The path of pin on the disc having radius of 82mm and each experiment is carried out for 30 minutes.

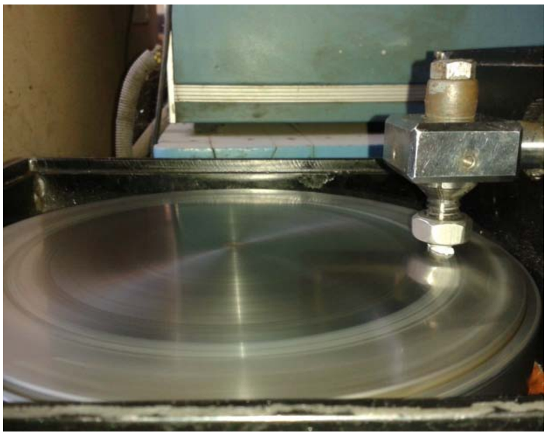

Figure 2: Experimental setup of pin on disc machine

Figure 3: Weighing machine

The samples are labelled in accordance to heat treatment and cooling method employed. These samples are weighed and their respective weights are noted before and after testing to measure the wear during experimentation thus loss of material indicates the wear of tested samples.

4. Result and Discussion:

Table 1: Annealing Treatment

S. No.	Load (gm)	Time (min)	RPM	Coefficient of friction	Weight (mg)		Weight loss (mg)	MRR (mm^3/min)
					Before (mg)	After (mg)		
1	1000	30	1500	0.171	2611.5	2424.1	187.4	2.31358
2	1000	30	1000	0.175	2684.0	2517.3	166.7	2.058025
3	1000	30	500	0.185	2683.0	2488.1	194.9	2.406173
4	750	30	1500	0.189	2459.8	2361.6	98.2	1.212346
5	750	30	1000	0.193	2520.8	2428.4	92.4	1.140741
6	750	30	500	0.195	2640.0	2613.4	26.6	0.328395
7	500	30	1500	0.204	2571.0	2541.8	29.2	0.360494
8	500	30	1000	0.203	2723.0	2667.4	55.6	0.68642
9	500	30	500	0.203	2462.0	2452.7	9.3	0.114815

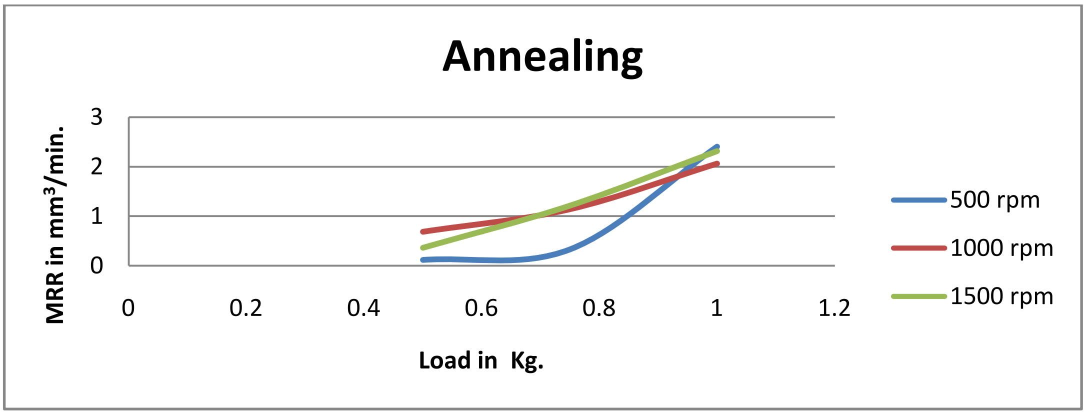

Figure 4: Graph analysis of annealing at different rpm

It is observed that material removal rate increases as increasing load is applied and after a limit it starts increasing more rapidly. On higher rpm higher material removal rate is observed, but in some cases it reduces.

Table 2: Oil Quenching Treatment

S. No.	Load (gm)	Time (min)	RPM	Coefficient of friction	Weight		Weight loss (mg)	MRR (mm^3 /min)
					Before (mg)	After (mg)		
1	1000	30	1500	0.187	2624.0	2433.6	190.4	2.350617
2	1000	30	1000	0.194	2575.0	2424.9	150.1	1.853086
3	1000	30	500	0.198	2591.4	2478.7	112.7	1.391358
4	750	30	1500	0.195	2546.0	2516.1	29.9	0.369136
5	750	30	1000	0.191	2573.0	2542.1	30.9	0.381481
6	750	30	500	0.191	2680.5	2665.5	15	0.185185
7	500	30	1500	0.208	2517.4	2497.7	19.7	0.24321
8	500	30	1000	0.200	2474.0	2454.5	19.5	0.240741
9	500	30	500	0.202	2492.0	2486.3	5.7	0.07037

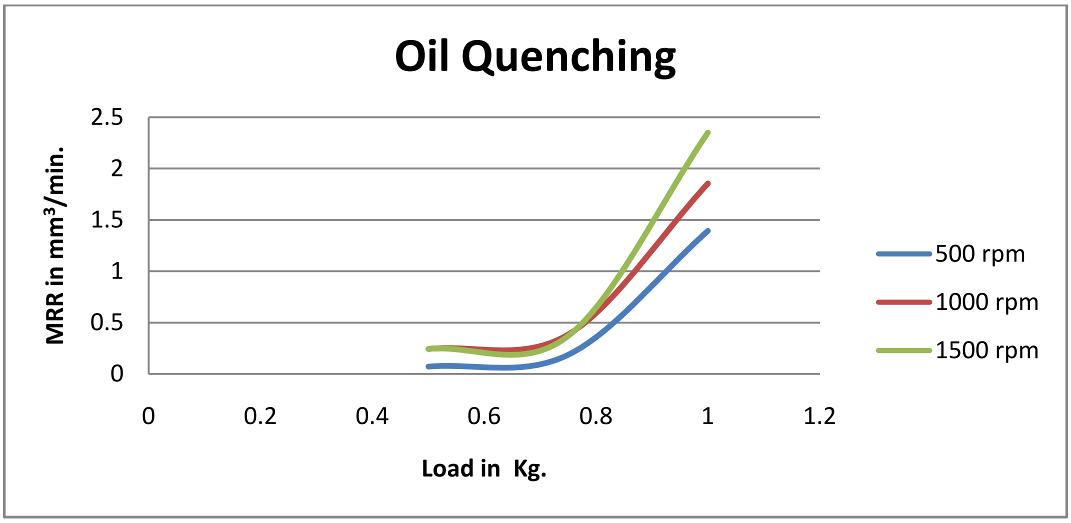

Figure 5: Graph analysis of Oil Quenching at different rpm

In oil quenching the wear rate increases at very low rate as load is applied but after certain limit the wear rate rises rapidly. The effect of rpm is similar to annealed sample. Normally wear rate increases with higher rpm but some cases wear rate is reduced.

Table 3: Water Quenching Treatment

S. No.	Load (gm)	Time (min)	RPM	Coefficient of friction	Weight		Weight loss (mg)	MRR (mm^3 /min)
					Before (mg)	After (mg)		
1	1000	30	1500	0.201	2501.4	2408.3	93.1	1.149383
2	1000	30	1000	0.198	2632.0	2514.8	117.2	1.446914
3	1000	30	500	0.197	2459.8	2447.0	12.8	0.15802
4	750	30	1500	0.200	2658.1	2609.2	48.9	0.603704
5	750	30	1000	0.197	2473.6	2458.0	15.6	0.192593
6	750	30	500	0.199	2495.5	2479.8	15.7	0.193827
7	500	30	1500	0.194	2621.7	2580.0	41.7	0.514815
8	500	30	1000	0.197	2550.4	2544.8	5.6	0.069136
9	500	30	500	0.195	2628.1	2624.1	4	0.049383

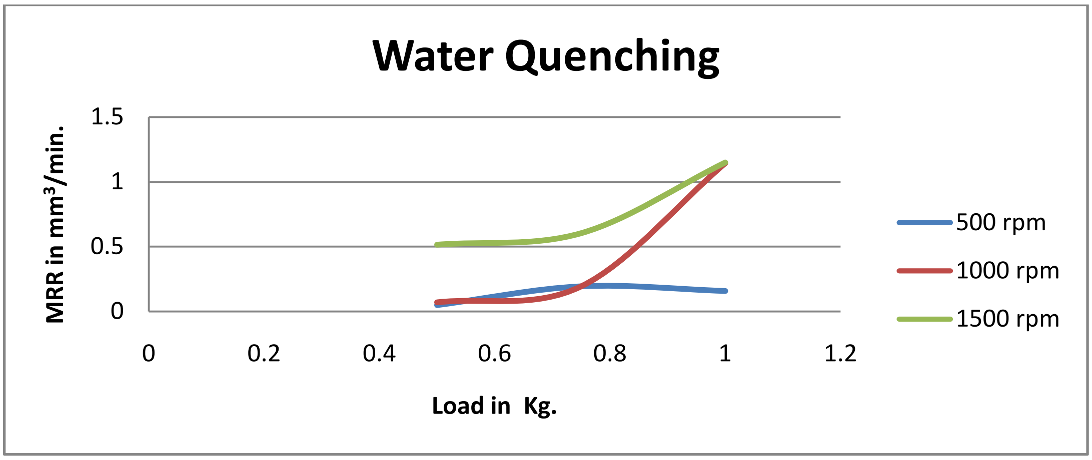

Figure 6: Graph analysis of Water Quenching at different rpm

The behaviour of water quenched samples constantly shows variation for different wear rate at different rpm. At 500 rpm the wear rates increases very slowly and remain almost constant while in case of 1000 rpm it increases with load and increases very rapidly after a limit.At 1500 rpm wear rate is high at low load also and increases as the load increases.

4.1 Comparison of heat treatments:

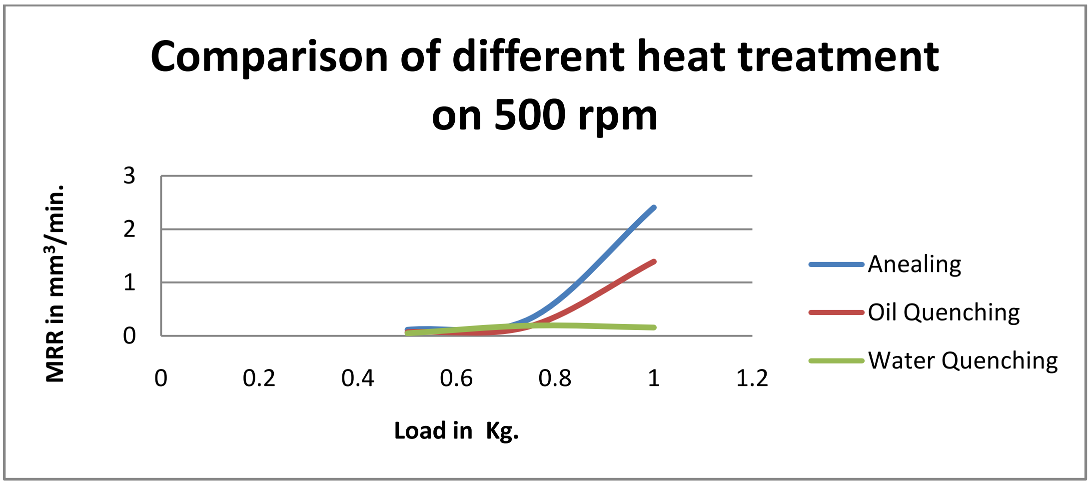

Figure 7: Graph Comparison of wear of different heat treatment on 500 rpm

At 500 rpm wear rate of water quenched aluminium is almost constant wear rate is very less with the rise in load. Water quenched samples shows the best resistance to wear as compared to the other heat treatments. The oil quenched material also shows good wear resistance but at higher load it starts deforming. Annealed samples show very less resistance to wear on higher load but remain almost same at lower load levels.

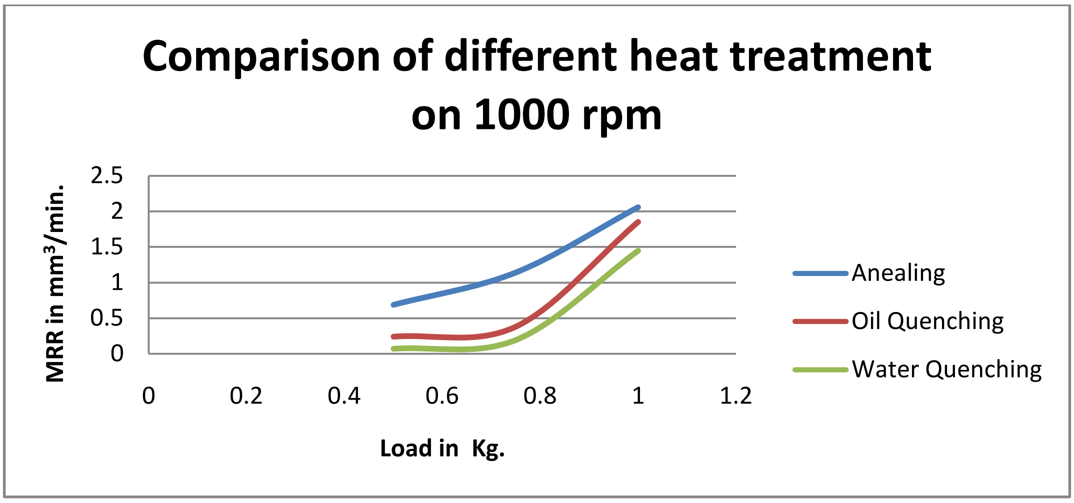

Figure 8: Graph Comparison of wear of different heat treatment on 1000 rpm

The wear graph depicts that the increase in material removal rate at higher loading level shows similar pattern in both quenching processes. Graph shows clearly that the wear resistance in both water and oil quenching is more or less or similar pattern with very little difference but it is high in case of oil quenched material, it has higher material removal rate. Annealed sample has higher wear rate at lower load and further increase with load is significantly less.

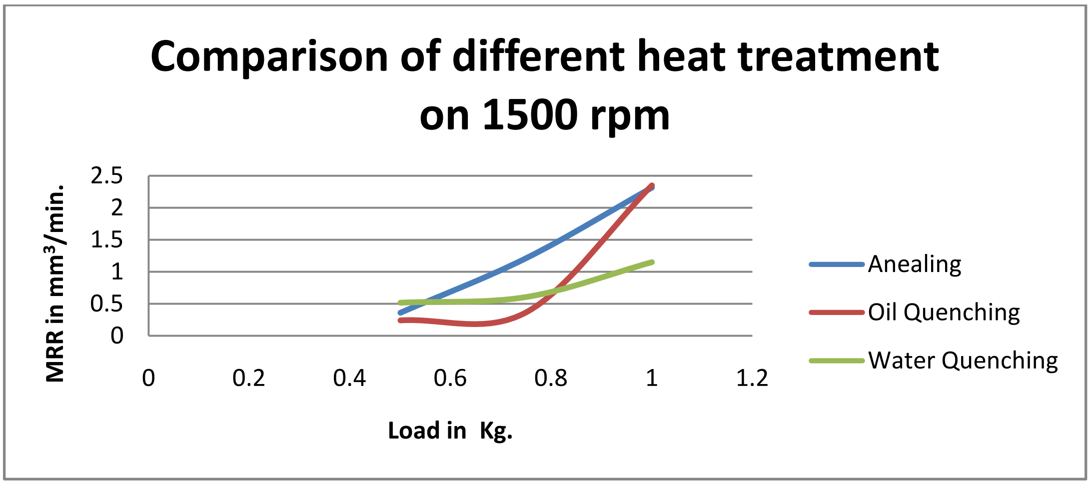

Figure 9: Graph Comparison of wear of different heat treatment on 1500 rpm

At 1500 rpm on low load oil quenched material shows good wear resistance compared to other but as the load increases the wear rate increases very rapidly. The water quenched sample shows higher wear rate but only a small increment is observed later as the load increases. The annealed sample shows constant increase in material removal rate as higher load is applied.

Samples undergoing heat treatment are maintained to a temperature which forces silicon particles to go under separation so that average particle size decreases with retaining the original morphology. The heating cause dissolution of the Mg_2Si phases which are distributed throughout the material. Due to sudden heat absorption by quenching the aluminium matrix are formed and quenching produce Mg-Si clusters which hardened the material and the mechanical properties like strength, hardness, and elongation also improved which creates better resistance against wear. Due to these changes in mechanical and micro structural properties quenched material give less wear.

In case of annealing the material is cooled for a very long time so that all the residual stresses are removed from the material, making it softer, which shows less resistance against wear.

5. CONCLUSION:

The samples of various heat treatment process are tested at different load and velocity and following observations are made:

a) Wear rate increases with the increment in load, when load is applied on all the heat treated samples, at lower load the increment in wear is less but, after a certain limit the wear rate increases at much faster rate. At 1000gmload, it shows very rapid wear at the start of the experiment then slowly decreases and become constant after some time.

b) Comparing different quenching or cooling methods in all the heat treatments, the water quenching show best wear resistance followed by oil quenched samples and then comes annealed materials that are soften and show least wear resistance with load.

c) With respect to rpm the wear rate increases in maximum cases but in some cases due high velocity dynamic action the wear rate shows a decrease too.

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