Effect of heat treatment on dry sliding wear behaviour on ZA-27 alloy

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Abstract - In this project, main objective is to find the volumetric wear rate, mechanical properties of a material. In this project number of tests has been carried out by employing different devices like pin on disc rotator, hardness testing machine, and other polishing machines have been employed in our project. There are mechanical properties have been incorporated in our stream. And the testes are tensile test, hardness test, wear test, and surface roughness test. In these notions, after varying the amount of %Mn and keeping all the chemicals constant will obtain new material properties and it enhances the properties of modified ZA-27 alloy by promoting the heat treatment method.

Keywords - Zinc-Aluminum, Heat treatment, Tensile, wear behavior

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I. INTRODUCTION

As long as technology grows, human can tendency to facilitate required aspects as we want. So, in the view of current engineering aspects, engineering sector plays a significant role in human's life. As far as engineering knowledge is concerned, in order to provide the desired facilitates, several mechanical and metallurgical industries had been contributing the valuable products to the society. So, there was a time, where our engineers were used to adopt different mechanical equipments to produce good kind of desired products viz… steel, cast iron, aluminum, zinc, brass, bronze etc…So, in this connection there are different natural chemical elements which are being present in our nature. Earlier many scientists were played a major role for contributing desired product. As far as material knowledge is concerned material tends to perform and exhibit different properties, which is being concerned with physical, mechanical, thermal, electrical, chemical, optical, technological properties etc...As an engineer we can expound more than these aspects by testing and scrutinizing. Now a day different materials have been found which is used in different sectors.viz… automobile, aerospace, metallurgical, mechanical, mining, production etc...Material property can be recommended by qualitatively or quantitavely. While expounding the material nature some relevant aspects have to be considered into account. Moreover there are different materials are existed in our nature. Namely metals, ceramics, composites, organics, semiconductors. As far as metal properties and service knowledge is concerned one can be seen that ferrous metal is one, it does have iron contents in its constituent. Only about 0.02% at room temperature. So in this regard steel can expose different mechanical properties like ductility (Less than non-ferrous), malleability, hardness, stiffness, formability, weldability, machinability etc…Amongst all non-ferrous metals, zinc and aluminum shows different properties under mechanical testing and other tests (by pin on disc rotator). By this various wear rate and strength can be found. So in this regard it is very essential to know about zinc and aluminum metals. As far as chemical knowledge is concerned zinc is widely used metal in earlier and now zinc had been contributing as a constituent of brass with another element (usually copper) zinc is usually melts at 419^0C. It is more ductile as compared to other elements. It is admirable resistance towards corrosion. In addition, zinc will be used as the best coating for iron and steel sheets. The main source of zinc is the zinc sulphide (ZnS). The various methods have to be adopted in order to extract pure zinc. There are various processes which can take into the casting technique has to be employed aluminum, and magnesium. Amongst all casting processes has been using over the years to produce desirable parts. Besides, die casting processes will be employed for casting gears, connecting rods, engine rods, pistons, oil pump bodies, aerospace requirements, aircraft bodies and many more. Therefore zinc can tendency to combine with another elements (Usually alloy), where metals properties can be increased so for. As far as metallurgical knowledge is concerned, several industrial persons went for producing non ferrous metals whose main constituents zinc and aluminum metals. Besides zinc and aluminum are having admirable bearing properties and good solubility properties. So both zinc and aluminum solid solution products gave well suitable mechanical properties. Several non ferrous alloys are available for bearing and other applications, but rather than bronze alloy ZA-27 alloy gives the highest bearing performance. Moreover, it is abundant in our nature. It is having high strength, good wear resistance, and high corrosion resistance. So both mechanical and metallurgists are involving research in order to find different properties and other aspects .In this session the alloy has to be speculated by employing pin-on-rotator, where rate can be found out easily. Besides, sliding wear test can be performed by varying the load and speed so for. As far the wear mechanism knowledge is concerned the internal structure of a metal is important, so for it is directly connected with the metallurgical phases, grain structures, which could be changed during wear mechanism process. Wear is the complex problem for an engineer, which reduces the life span of the mechanical components. Even though wear and friction are of the material properties, where few tribological behaviors are strongly recommended by both physical and mechanical properties. Actually the word tribology had been evolved, The principal concept tribology is to control the friction and wear of a respective metal (here ZA-27 alloy). Apart from these aspects, the wear and friction are depends upon the environmental conditions and characteristics of a material. And many more parameters which directly impact on wear and friction are gradual changes in load and metallurgical changes generally, there gradual lost attached to relative body. While sliding exists touching sense aspects in relative to the attached body could be taken place finally it gives rise to wear particles knocked out by the tips of the members.

II. EXPERIMENTAL SET UP

1. Material Preparation

The nominal chemical compositions of respective material are to be based on the ZA-27 alloy. The material is to be obtained by gravity die casting. The ZA-27 alloy is to be heated at elevated temperature at about of 740^0C during casting process alloy constituent elements are to be added at different temperature. The molten metal has to be poured into the sand moulds, by using different Material equipments. And which is to be preheated at require temperature.

Table 1 Chemical composition of experimental material

SL.NO	Al	Cu	Mg	Si	Mn	Zn
M1	27	2	0.04	3.5	0.2	Bal
M2	27	2	0.04	3.5	0.5	Bal
M3	27	2	0.04	3.5	1.0	Bal

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2. Heat Treatment Processes

Heat treatment process is a combination of de-solidification and solidification of a metal or an alloy is called heat treatment process. While performing and conducting experiment on ZA-27 alloy it is need to go for heat treatment process. Usually a muffle type of furnace is to be used for heating a metal or an alloy. So while operating one can satisfy the requirements of muffle furnace that is it is need to maintain the temperature uniformly thought the furnace. And temperature should be controlled for different stages of heat treatment process. In order to analyze the mechanical behavior and microstructure of modified ZA-27 alloys, wear test samples of size Φ10 mm, 30 mm length were heat treated using muffle furnace. One group of samples were subject to heat treatment of solution at 370^0C, soaked for 5 h, then quenched in water and then artificially aged at 160^0C for 3h (T6).

3. Material Characterization

The mechanical properties were studied to know the quality of modified ZA-27 alloy for the application by conducting various tests and the results tabulated in table 13.

Hardness was measured in Vickers (Hv) hardness tester, sample was cut using hacksaw of 10 mm diameter, thereafter smoothened to attain flat and smooth surface. A major load of 10 kgf was applied; the average hardness values were taken and recorded from three readings.

Tensile test was conducted as per ASTM A370 standards at ambient temperature with a strain rate of $1.3x10^{-3}$/s using universal testing machine. Tensile strength and percentage of elongation of the alloys were determined on specimens 12 mm in diameter, 60 mm gauge length.

4. Experimental Design

Design of experiment is a prevailing investigation tool for modelling and analyzing the impact of control factors on performance output. The most vital stage in the outline of analysis lies in the determination of the control factors. In this way, various elements are incorporated with the goal that non-huge factors can be recognized at most earliest opportunity. The wear tests are carried out under working conditions given in Table 2. The tests are conducted at room temperature as per experimental design given in Table 3. Three parameters viz., % of Mn content, load and sliding speed each at three levels, are considered in this study in accordance with L9 (3^3) orthogonal array design. In Table 3, each column represents a test parameter and a row gives a test condition which is nothing but a combination of parameter levels.

The trial perceptions are changed into signal-to-noise (S/N) ratios. There are few S/N ratios accessible relying upon the type of characteristics. The S/N ratio for least wear rate coming under smaller is better characteristic, which can be ascertained as logarithmic transformation of the loss function as shown below.

Table 2. Levels for various control factors

Control Factors	Codes	Units	Level I	Level II	Level III
% of Mn content	A	Wt%	0.2	0.5	1.0
Load	B	N	10	20	30
Sliding speed	C	m/s	0.5	1.0	1.5

The plan of experiment is as follows: the first column is assigned to percentage of Mn content (A), the second column is assigned to Load (B) and the third column is assigned to sliding speed (C).

Table 3. Orthogonal Array for L9 (33) Taguchi approach design

L9 (3^3)	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3

6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

5. Wear rate

Wear rate modified ZA-27 alloy specimen dry sliding wear test has to be conducted so for. Here in dry sliding wear test a simplified is to be used. That is pin-on disc rotator used for performing wear test on modified ZA-27 alloy specimen. The researchers were performed a test on rotating disc where they have found tribological wear properties. There are different machines are available to measure out the wear rate of a material, apart from these pin on disc rotator plays an important role for measuring tribological wear rate of a material. Figure shows the Pin-on disc rotator machine, pendulum, steel disc.

III. RESULTS AND DISCUSSIONS

1. Tensile Strength and Elongation

From the Fig 1, at the room temperature, there is an increase in the tensile strength as the Mn content increases. While, there is first increase in Mn content there is increase in elongation up to 0.5% Mn content, then decreased with increase in the Mn content. This reveals that due to increase in size and volume fraction of the hard phases' increases with increase in the Mn content.

Table 4 Mechanical Properties of ZA-27 as Cast and T6 Type alloy

Type of heat treatment	Mn %	Hardness (Vpn)	Tensile strength (MPa)	Elongation (%)
As-cast	0.2	134	157	3
	0.5	136.3	149	4
	1	138	158	3
T6 type	0.2	154.3	206	4
	0.5	158.6	198	5
	1	160.3	224	4

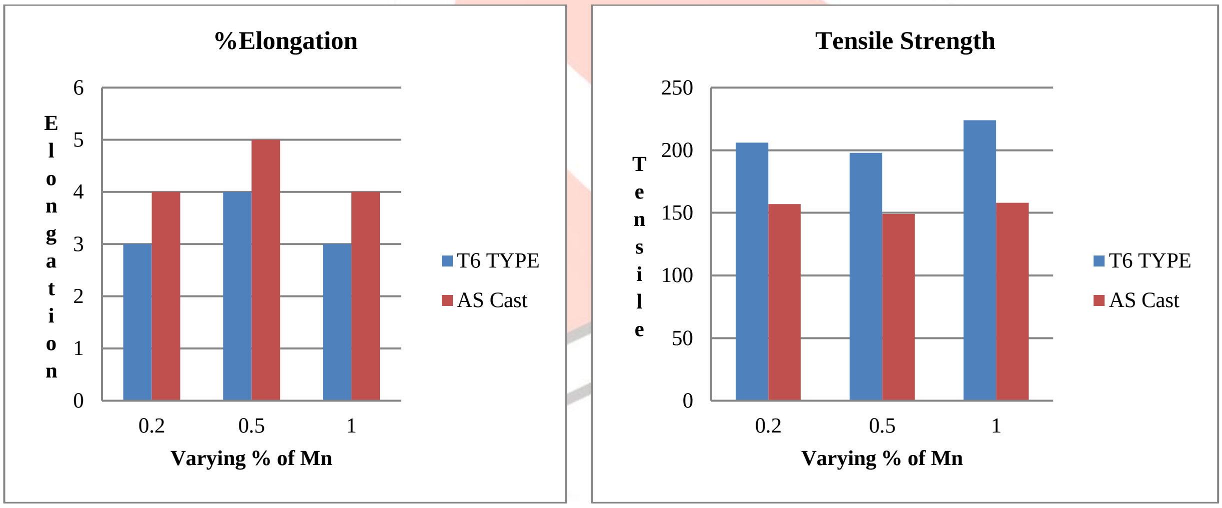


Fig 1 Effect of Mn content on elongation and Tensile strength of ZA-27 alloy

2. Hardness

From Fig 2, it reveals that with increase in the presence of Mn content Vickers hardness increases. When comparing with as cast, T6 type heat treatment specimens shows increase in the hardness values. This increase in hardness due to the presence of hard Al-Mn precipitates but also their shape and distribution. And also formation of fine lamellar, as long as the presence of manganese is detected, could contribute to the measured increase in hardness.

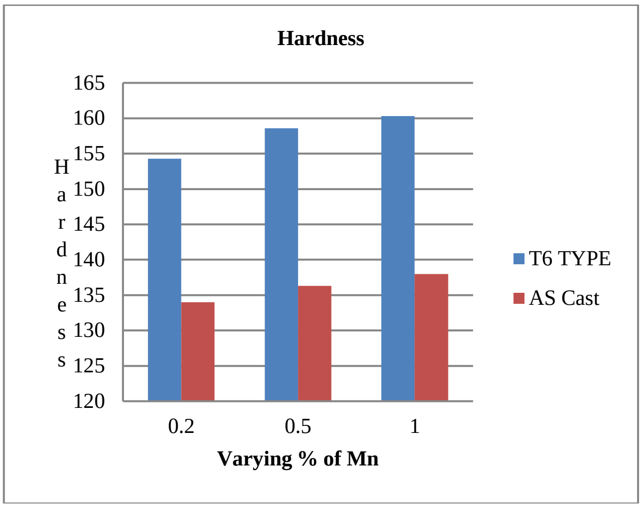


Fig 2 Effect of Mn content on hardness test of ZA-27 alloy

3. S/N Ratio Analysis

Parameter is to be set then optimum required quality would be very high. The control parameter with the strongest recommendations was determined by the difference between the higher and lower value of the mean of S/N ratios. Greater the difference between the averages of S/N ratios, the more influential would be the control parameter. Average value of S/N ratio and rank based on delta value for required level of the control parameters is to be presented in the tables 5 to 8 for as cast and T6 type heat treatment of modified the various tests have been carried out the orthogonal arrays The tested merit had been converted into S/N ratios to estimating quality employing MINITAB 16. Recommendations while controlling by containing amount of Mn are to be analyzed on volumetric wear by using S/N ratio responsive analysis. And it is need to analyze that, the process ZA-27 alloys. It is obvious from the response tables 5 to 8 that rank 1 is given to the factor with highest delta value and rank 2 is given to the factor with second highest delta value and so on.

Table 5 Response Table for Signal to Noise Ratios –smaller the better (As cast-volumetric wear rate)

Level	A	B	C
1	60.25	66.47	63.18
2	64.88	61.30	64.09
3	63.31	60.67	61.17
Delta	4.63	5.79	2.92
Rank	2	1	3

Table 6 Response Table for Signal to Noise Ratios –smaller the better (As cast-frictional force)

Level	A	B	C
1	-19.06	-13.77	-19.64
2	-18.08	-19.49	-18.88
3	-19.88	-23.76	-18.50
Delta	1.80	9.99	1.15
Rank	2	1	3

Table 7 Response Table for Signal to Noise Ratios –smaller the better (T6 heat treatment-volumetric wear rate)

Level	A	B	C
1	63.78	66.27	62.82
2	67.07	66.80	69.12
3	66.14	63.91	65.04
Delta	3.29	2.89	6.30
Rank	2	3	1

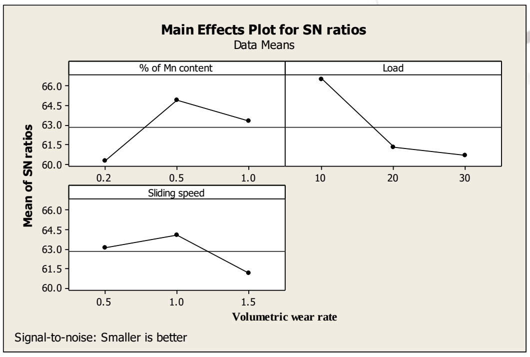
Table 8 Response Table for Signal to Noise Ratios –smaller the better (T6 heat treatment-frictional force)

Level	A	B	C

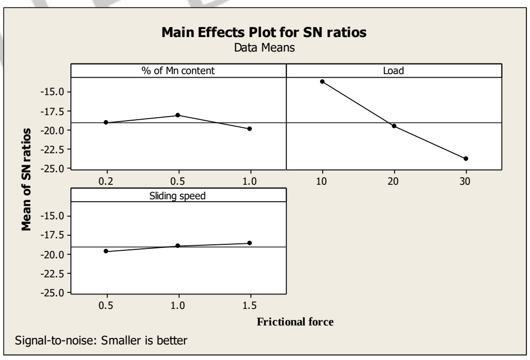
1	-20.08	-14.90	-20.43
2	-19.56	-20.69	-19.76
3	-20.67	-24.73	-20.12
Delta	1.10	9.83	0.68
Rank	2	1	3

Table 9 Test conditions with output results using L_9 orthogonal array for as cast modified ZA-27 alloy

L_9	% of Mn content	Load (N)	Sliding speed (m/s)	As Cast				T6 type heat treatment			
				Volumetric wear rate (mm3/m)	S/N ratio (dB)	Frictional force (N)	S/N ratio (db)	Volumetric wear rate (mm3/m)	S/N ratio (db)	Frictional force (N)	S/N ratio (db)
01	02	03	04	05	06	07	08	11	12	13	14
1	0.2	10	0.5	0.0006973	63.1316	4.5	-13.0643	0.000898	60.9345	5.7	-15.1175
2	0.2	20	1.0	0.0010326	59.7214	10.1	-20.0864	0.000442	67.0916	10.3	-20.2567
3	0.2	30	1.5	0.0012740	57.8966	15.9	-24.0279	0.000683	63.3116	17.5	-24.8608
4	0.5	10	1.0	0.0002740	71.2450	4.7	-13.4420	0.000223	73.0339	5.1	-14.1514
5	0.5	20	1.5	0.0009350	60.5838	6.8	-16.6502	0.000448	66.9744	10.1	-20.0864
6	0.5	30	0.5	0.0007230	62.8172	16.1	-24.1365	0.000872	61.1897	16.7	-24.4543
7	1.0	10	1.5	0.0005610	65.0207	5.5	-14.8073	0.000573	64.8369	5.9	-15.4170
8	1.0	20	0.5	0.0006608	63.5986	12.2	-21.7272	0.000482	66.3391	12.2	-21.7272
9	1.0	30	1.0	0.0008604	61.3060	14.3	-23.1067	0.000435	67.2302	17.5	-24.8608

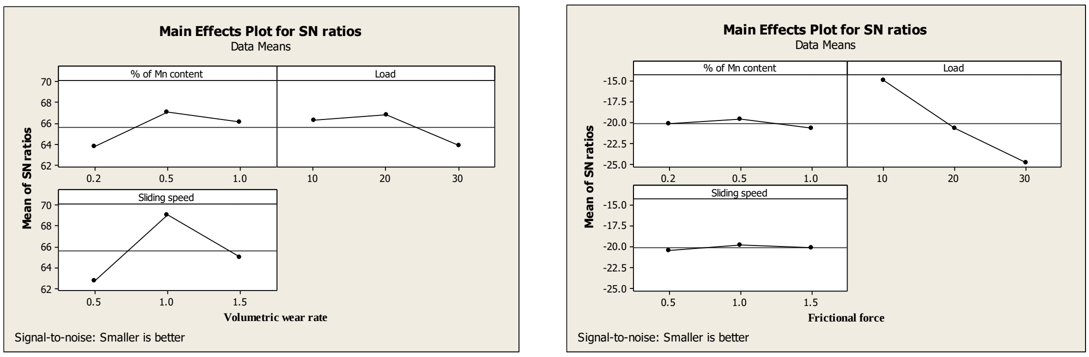


(a)



(b)

Fig 3 Main effects plot for SN ratios-as cast specimens (a) volumetric wear rate (b) frictional force



(a) (b)

Fig 4 Main effects plot for SN ratios-T6 type heat treated specimens (a) volumetric wear rate (b) frictional force

Analysis Of Variance (ANOVAs)

To know concrete visualization of effect of various factors effect on the output performance, it is to be desirable to promote analysis of variance (ANOVA) table to find out the order of significant factors. Table 10 and table 11 reveals the results of the ANOVA with the volumetric wear rate and frictional force of as cast modified ZA-27 alloys respectively. Table 12 and table 13 shows the results of the ANOVA with the volumetric wear rate, and frictional force of as T6 type heat treatment modified ZA-27 alloys respectively. This analysis is undertaken for a level of confidence of significance of 95 % i.e. for significance level of $\alpha = 0.05$. The last column of the table is to be indicated that the order of significance among factors and interactions. From Table 10, one can have ability to observe that the applied load (p = 42.85%) had the most significant parameters having the maximum statistical recommendation on dry sliding wear behavior of as cast modified ZA-27 alloy followed by % of Mn content (p= 28.57%) and sliding speed (p= 14.28). From Table 12, one can have ability to observe that the sliding speed (p = 50%) was the most significant parameters having the highest statistical influence on dry sliding wear behavior of as T6 type heat treatment on modified ZA-27 alloy followed by % of Mn content (p= 25%) and sliding speed (p= 25).

Table 10 Analysis of Variance for volumetric wear rate for as cast specimens

Source	DF	Seq SS	Adj SS	Seq MS	F	P	% of contribution
% of Mn content	2	0. Source 0000002	0.0000002	0.0000001	16.40	0.057	28.57%
Load	2	0.0000003	0.0000003	0.0000002	24.42	0.039	42.85%
Sliding speed	2	0.0000001	0.0000001	0.0000000	6.86	0.127	14.28%
Error	2	0.0000001	0.0000000	0.0000000			14.3%
Total	8	0.0000007					100%

Table 11 Analysis of Variance for frictional force for as cast specimens

Source	DF	Seq SS	Adj SS	Seq MS	F	P	% of contribution
% of Mn content	2	3.336	3.336	1.668	0.33	0.750	1.81%
Load	2	166.862	166.862	83.431	16.64	0.057	90.59%
Sliding speed	2	3.962	3.962	1.981	0.40	0.717	2.15%
Error	2	10.029	10.029	5.014			5.45%
Total	8	184.189					100%

Table 12 Analysis of Variance for volumetric wear rate for T6 type heat treated specimens

Source	DF	Seq SS	Adj SS	Seq MS	F	P	%of contribution
% of Mn content	2	0.0000001	0.0000001	0.0000000	1.25	0.445	25%
Load	2	0.0000001	0.0000001	0.0000000	1.38	0.420	25%
Sliding speed	2	0.0000002	0.0000002	0.0000001	4.80	0.172	50%
Error	2	0.0000000	0.0000000	0.0000000			0%
Total	8	0.0000004					100%

Table 13 Analysis of Variance for frictional force for T6 type heat treated specimens

Source	DF	Seq SS	Adj SS	Seq MS	F	P	%of contribution
% of Mn content	2	2.296	2.296	1.148	3.43	0.226	1.1%
Load	2	204.736	204.736	102.368	306.08	0.003	98.33
Sliding speed	2	0.496	0.496	0.248	0.74	0.574	0.23%
Error	2	0.669	0.669	0.334			0.34%
Total	8	208.196					100%

CONCLUSIONS

Based on the investigations', the following conclusions were drawn

1. T6 type heat treatment ZA-27-0.5% Mn alloy has observed minimum volumetric wear rate when compared with as-cast alloy.
2. The optimal parameters of wear tests are sliding speed of 1.0 m/s and applied load of 10 N for both as cast and T6 type heat treatment alloys.
3. With increase in the normal pressure volumetric wear rate is increased.
4. With increase in the sliding speed volumetric wear rate is decreased.
5. Frictional force is high for as cast specimens whereas it is low for T6 type heat treatment specimens.

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