International Journal For Technological Research In Engineering
Volume 4, Issue 10, June-2017 *ISSN (Online): 2347 - 4718*

WEAR PROPERTY EVALUATION OF EUTECTIC, HYPEREUTECTIC AND SPECIAL EUTECTIC ALUMINIUM ALLOYS UNDER VARIOUS HEAT TREATED CONDITIONS BY EXPERIMENTAL APPROACH

K.A.Jayasheel Kumar[1], Dr.C.M Ramesha[2]
[1]Senior. Assistant Professor, [2]Associate Professor
[1]Dept of Automobile Engg, New Horizon College of Engg, Bengaluru-560103
[2]Dept. of Mechanical Engg., M.S.Ramaiah Institute of Technology, Bengaluru-560054

ABSTRACT: The study deals with the evaluation of wear property of eutectic, hypereutectic and super eutectic aluminium alloy under various heat treated conditions. Pistons are produced from cast or forged, high-temperature resistant aluminium silicon alloys. There are three basic types of aluminium piston alloys. The standard piston alloy is a eutectic Al-12%Si alloy containing in addition approx. 1% each of Cu, Ni and Mg. Special eutectic alloys are also evaluated for improved strength at high temperatures. Hypereutectic alloys with 18 and 24% Si provide lower thermal expansion and wear, but have lower strength. The wear analysis is carried out under the various conditions like speed, time and loading conditions and for all the conditions of eutectic, hypereutectic and special eutectic aluminium alloys. The experimentation is carried on a pin on disc type wear testing machine by varying the speed of the disc, various loads applied and various timing conditions. The properties are evaluated for various heat treated conditions like operating temperature, quenching conditions, annealing conditions. It is concluded that based on the wear properties, type of material can be selected as the piston material.

Key Words: Eutectic, Hypereutectic and Special Eutectic Al Alloy, Heat treated, Wear properties

I. INTRODUCTION

Pistons are produced from cast or forged, high-temperature resistant aluminium silicon alloys. There are three basic types of aluminium piston alloys. The standard piston alloy is a eutectic Al-12%Si alloy containing in addition approx. 1% each of Cu, Ni and Mg. Special eutectic alloys have been developed for improved strength at high temperatures. Hypereutectic alloys with 18 and 24% Si provide lower thermal expansion and wear, but have lower strength (see tabled property data on the following pages). In practice, the supplier of aluminium pistons use a wide range of further optimized alloy compositions, but generally based on these basic alloy types. The majority of pistons are produced by gravity die casting. Optimized alloy compositions and a properly controlled solidification conditions allow the production of pistons with low weight and high structural strength. Forged pistons from eutectic and hypereutectic alloys exhibit higher strength and are used in high performance engines where the pistons are subject to even high stresses. Forged pistons have a finer microstructure than cast pistons with the same alloy composition. The production process results in greater strength in the lower temperature range. A further advantage is the possibility to produce lower wall thicknesses - and hence reducing the piston weight. Also aluminium metal matrix composite materials are used in special cases.

Pistons with Al_2O_3 fibre reinforced bottoms are produced by squeeze casting and used mainly in direct injection diesel engines. The main advantage, apart from a general improvement of the mechanical properties, is an improvement of the wear behaviour [5]. Depending on the silicon concentration in the alloy and the cooling conditions, the structure of the casting will essentially comprise mixtures of aluminium grains, silicon crystals and aluminium silicon eutectic as well as various intermetallic phases formed from other alloying additions (Mg_2Si, $CuAl_2$). The aluminium grains can grow very large however, under slow cooling conditions, such as in sand castings or heavy sections, and this can lead to poor casting and mechanical properties.

The system Al-Si alloy

Among commercial aluminium casting alloys those with silicon as the major alloying element are the most important, mainly because of their excellent casting characteristics. Additions of Si to pure aluminium impart high fluidity, good feeding characteristics, low shrinkage and good hot cracking resistance [1]. The properties of aluminium-silicon alloys make them very popular in various applications including the automotive, aerospace and defence industries. The high strength to weight ratio is one of their most interesting characteristics [2].

As the density of Si is 2.3 g/cm3, it is one of the few elements which may be added to aluminium (2.7 g/cm3) without loss of weight advantage [3]. Aluminium-silicon alloys that do not contain copper additions are used when good cast ability and good corrosion resistance are needed. Magnesium can act as a substitute for copper. Magnesium and silicon can form the intermetallic hardening phase Mg2Si which precipitates in the α-aluminium matrix and increases the yield strength [4].

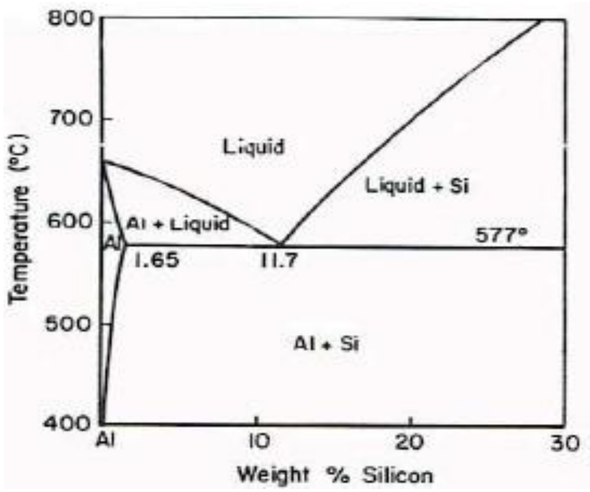

Fig.1-Equilibrium binary Al-Si phase diagram

Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface. The need for relative motion between two surfaces and initial mechanical contact between asperities is an important distinction between mechanical wear compared to other processes with similar out come [5]. Additionally, most modern pistons contain a large amount of silicon. Silicon is added to the aluminum because the resulting alloy is more resistant to wear and expansion than an alloy that doesn't contain silicon. Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics. [6][7] The specific amount of silicon added to the aluminum ranges from 9-18%. At percentages below 12%, whatever silicon that is added to the aluminum dissolves into the solution. Once you reach 12% (or thereabouts), the aluminum alloy become saturated with silicon. This specific point is called the saturation point, and any silicon added after the saturation point will not dissolve in the finally aluminum alloy [8]. Instead, this excess silicon will form a hard precipitate that remains separate from the aluminum. An aluminum alloy that is sutured with silicon is known as "eutectic." When the alloy contains silicon at a percentage that is less than saturated, it's called "hypoeutectic." When the alloy contains more silicon that then saturation limit, it's called "hypereutectic." The characteristics of pistons in each of these categories are very distinct. Hypereutectic alloys are stronger, resist scuffing and seizure, and reduce groove wear and cracking of the crown at extremely high temperatures. They're also very resistant to expansion, because the high percentage of silicon essentially "insulates" the piston from the effects of heat. Hypereutectic designs also allow for decreased distance between ring grooves, which improve the "seal" between the rings and the cylinder wall and improves efficiency. Finally, because hypereutectic pistons don't expand or contract, they're ideal for modern engines with tight clearance requirements. Generally speaking, modern engines use pistons made from a hypereutectic aluminum alloy. If there is a downsides to hypereutectic pistons, it's that they're brittle compared to forged pistons. Therefore, forged pistons are more forgiving of extreme conditions (like those found in a race car), and they give you a greater margin of error when dealing with timing problems, as detonation is less likely to destroy a forged piston than a hypereutectic cast piston.

Table 1 shows the mechanical properties of piston alloys at various temperatures and table 2 shows the physical properties of piston alloys [9].

Table-1 Mechanical properties of piston alloys

	Eutectic Alloy AlSi12 CUMgNi		Hypereutectic Alloy AlSi18CuMgNi		Special Eutectic Alloy AlSi12Cu4Ni2Mg
	cast	forged	cast	forged	cast
Yield Strength $R_{P0,2}$ (MPa) at Temperature					
20°	190 – 230	280 – 310	170 – 200	220 – 280	200 – 280
150°	170 – 220	230 – 280	150 – 190	200 – 250	–
200°	120 – 170	–	100 –150	–	150 – 200
250°	80 – 110	90 – 120	80 – 120	100 – 140	100 – 150
300°	50 – 80	–	60 – 80	–	85 – 100
Ultimate Tensile Strength R_m (MPa) at Temperature					
20°	200 – 250	300 – 370	180 – 230	230 – 300	210 – 290
150°	180 – 230	250 – 300	170 – 210	210 – 260	–
200°	160 – 200	–	160 – 190	–	170 – 210
250°	100 – 150	110 – 170	110 – 140	100 – 160	130 – 180
300°	80 – 100	–	90 – 130	–	100 – 120
Elongation to Fracture A_5(%)					
20°C	0,3 – 1,5	1 – 3	0,2 – 1,0	0,5 – 1,5	0,1 – 0,5
Hot Hardness after 200 hours at temperature: Hardness ($HB_{5/50/30}$)					
20°C	90 – 125	90 – 125	90 – 125	90 – 125	100 – 150
150°C	80 – 90	80 – 90	80 – 90	80 – 90	80 – 115
200°C	60 – 70	60 – 70	60 – 70	60 – 70	60 – 75
250°C	35 – 45	35 – 45	35 – 45	35 – 45	45 – 50
300°C	20 – 30	20 – 30	20 – 30	20 – 30	30 – 40
Fatigue Strength σ_w (N/mm^2)					
20°C	80 – 120	110 – 140	80 – 110	90 – 120	90 – 120
150°	70 – 110	90 – 120	60 – 90	70 – 100	90 – 120
250°	50 – 70	60 – 70	40 – 60	50 – 70	60 – 80
300°	–	–	–	–	45 – 60

Table-2 Mechanical properties of piston alloys

	Eutectic Alloy AlSi12 Cu MgNi		Hypereutectic Alloy AlSi18CuMgNi		Special Eutectic Alloy AlSi12Cu4Ni2Mg
	cast	**forged**	**cast**	**forged**	**cast**
Density (kg/dm^3)					
at 20°C	2.70	2.70	2.68	2.68	2.80
Linear thermal expansion coefficient (1/K)					
between 20° and 200°C	20.5 - 21.5	20.5 - 21.5	18.5 - 19.5	18.5 - 19.5	20.5 - 21.5
Thermal conductivity (W/cm · K)					
at 20°C	1.43 - 1.55	1.47 – 1.60	1.34 - 1.47	1.43 - 1.55	1.30 – 1.40
Specific heat (J/g · K)					
at 100°C	0.96	0.96	0.96	0.96	0.96
Youngs modulus (MPa)					
at 20°C	80.000 - 81.000	81.000	83.000 - 84.000	84.000	82.000
at 200°C	73.000 - 74.000	-	75.000 - 76.000	-	78.000
at 250°C	68.000 - 72.000	74.000	-	76.000	72.000
at 300°C	-	-	-	-	70.000

II. EXPERIMENTAL DETAILS

Wear test (Dry sliding wear):

The wear analysis was carried out using the pin on disk type wear machine. The system is driven by electric motor. It consists of a spindle and disc material which is made of hardened steel is held by chuck. A lever-arm device is used to hold the pin and attachment to allow the specimen to be forced against the revolving disc with controlled load. Figure 2 shows the Pin-On-Disc wear testing machine. The detailed procedure for wear tests conducted is given below. Figure 3 shows the wear specimen.

Fig.2 Pin-On-Disc wear testing machine

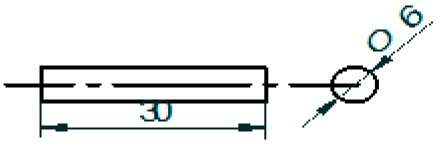

Fig.3 Wear specimen

- The surface of disc was cleaned with acetone to remove dust, dirt present on the surface.
- The specimen was initially weighed and it will be fixed in the holder provided and locked by tightening the screw about 3mm of pin projected out from the holder.
- Mains were switched on- the initial adjustments were made. (like zero setting revolution indicator, time setting will be made)
- Motor was switched on and the speed will be adjusted to the required value.
- The lever arm was loaded by applying weights on the hanger.
- The test was conducted for 20 minutes duration of time. Specimen removed from the holder was cleaned, dried thoroughly and weighed precisely in electronic balance.
- Number of revolutions made by the disc was noted down.
- Weight loss was considered for the wear analysis (i.e. the difference the between the initial and final weight)

Formulae used for finding weight loss and wear rate is as shown below

Weight loss (W_L) = Initial weight – Final weight = $W_1 - W_2$ grams

Rubbing Velocity (V) = $(2\pi rN)/60{,}000$

r = Track radius in mm

N = RPM of disc

Wear rate = Weight loss/Distance traveled = $W_L / 2\pi rN$ gm/m

Test parameters:

- Disc diameter: 380mm
- Diameter of specimen (d) : 6mm
- Length of the specimen : 30mm
- Speeds studied: 200 rpm, 250 rpm, 300 rpm and 350 rpm
- Track radius : 50mm
- Load applied: 10N, 20N, 30N and 40N
- Duration of tests: 5min, 10min, 15min, 20 minutes

III. RESULTS AND DISCUSSION

The figure shows the graph of wear rate vs load. Wear properties under as cast, eutectic, hypereutectic and special eutectic for the various heat treated temperatures. In the figure for special eutectic condition the wear rate is less for H2 and more for J2 without heat treated condition.

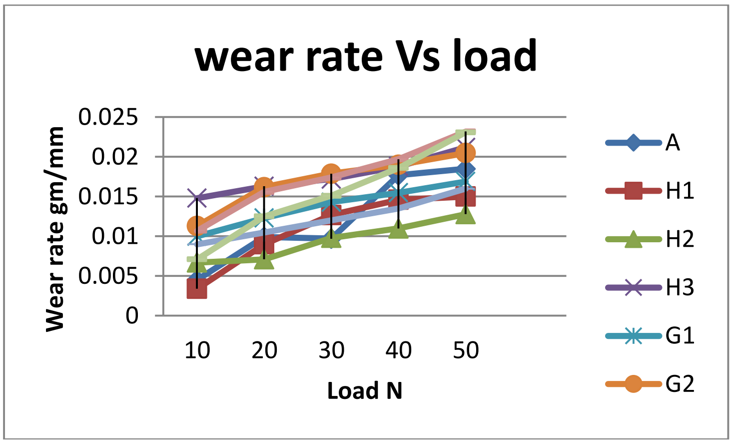

Fig.4 Wear rate of piston alloys

REFERENCES

[1] “Properties and Selection: Non ferrous Alloys and Special-Purpose Materials”, 1990, ASM Hand Book, Vol.2, Tenth Edition, pp 39-40.

[2] “Properties and Selection: Non ferrous Alloys and Special-Purpose Materials”, 1990, ASM Hand Book, Vol.2, Tenth Edition, pp 511-514.

[3] L.F.Mondolfo, “Aluminium alloys structure and properties,” First publication 1979

[4] K. Srinivasulu Reddy, G. Ranga Janardhana, “Developing a neuro fuzzy model to predict the properties of Al-Si12 alloy,” vol. 4, no. 10, december 2009

[5] Shivanath R, Sengupta PK, Eyre TS, “Wear of aluminium–silicon alloy”, Br Foundrymen 1977; 79:349–56.

[6] ASM heat treating hand book, Vol.4- Heat treatment of non- ferrous alloys, ASM international, 1991, pp 842-879.

[7] Metals hand book, Vol.8- Mechanical testing: ASM international 10th edition. 1990, pp 20, 74-75.

[8] J. Gilbert Kaufman, FASM, Properties of aluminium alloys, ASM international 3rd edition, 2002, pp 206-217.

[9] http://european-aluminium.eu/media/1570/aam-applications-power-train-1-pistons.pdf

