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EFFECT OF ADDITION OF NICKEL ON LM 28 PISTON ALLOY

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ABSTRACT

In this study, the influence of Nickel content on hardness and microstructural characterization of die cast Al-Si-Cu-Mg-Ni alloys have been investigated. Al-Si alloy with 0.620 to 1.12 % nickel have been utilized for this purpose. Solidification of Al-Si-Cu-Mg-Ni alloys have been prepared by melting in resistance heating furnace with a crucible and casting in a metallic die at 720°C. The solution treatment has been performed at 515 °C for 4 hours quench in air blast, followed by precipitation hardening treatment at 185 °C for 8 hours. The effects of nickel content and heat treatment on mechanical properties have been investigated.

Keywords: *Al-Si-Cu-Mg-Ni Alloys, Ni content and AlNi Phase ($AlNi_2Si$) 8C Phase*

1. Introduction

Aluminium and its alloys represent important materials due to their high technological values. [1] It is widely used in aerospace and household industries. Aluminium and its alloys offer good specific strength, excellent formability, corrosion resistance, etc. [3] Al-Si based alloys are most commonly used in automotive, aerospace and transportation industries. Nickel is precipitation strengthening agent in Aluminium. [2] Addition of Nickel increases considerably the strength of Al-Si alloy due to the precipitation of dispersed AlNi and ($AlNi_2Si$)8C phase after solidification. The X Ray analysis confirm the precipitates of nickel like AlNi and ($AlNi_2Si$)8C phase.[5] The strengthening contribution from precipitation is typically a function of precipitate size and fraction. Determining the role of nickel content on hardness and Microstructural characterization of die cast Al-Si-Cu-Mg-Ni alloy is the aim of the study. [4]

2. Experimental Methods

Six different Nickel containing Al-Si-Cu-Mg (LM 28) alloys were melted and utilized for this study. The melting operation was carried out on a resistance heating furnace in a crucible and the molten metal was cast into metallic mould of 23x23x6 cm in size at 720 °C. The experimental set up used for preparation of melt is represented in figure 1. For understanding heat treatment on microstructure, solution treatment and ageing heat treatment were applied to solidified specimen. Solution heat treatment was performed at 515 °C for 4 hours. After that specimens were quenched under air blast to obtain super saturated solid solution. The specimens were then aged at 185 °C for 8 hours. All heat treatment were carried out with platinum wounded resistance heating furnace.

The chemical composition of these alloys can be presented in table: 1.

Table 1: Chemical Composition of Alloys

	Composition (wt %)				
Alloys	Si	Cu	Mg	Ni	Al balance
LM 28 (a)	15.64	0.7	0.69	0.62	73.81
LM 28 (b)	18.10	0.3	0.38	0.82	75.01
LM 28 (c)	17.66	0.6	0.74	0.94	79.14
LM 28 (d)	16.33	0.8	0.77	1.06	77.53
LM 28 (e)	16.75	0.47	0.84	1.12	76.34

2.1 Metallographic examination

Specimens were prepared in usual manner for metallographic observations. Microstructural investigation was made by Neophot 02 optical microscope and JOEL 5610 LV type scanning electron microscope with an energy dispersive X-Ray spectroscopy (EDX) attachment.

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2.2 Mechanical testing

The Brinell hardness tests were carried out with steel ball of Ø 2.5 mm and load of 61.235 Kg. The mean of six values have been reported as the hardness value.

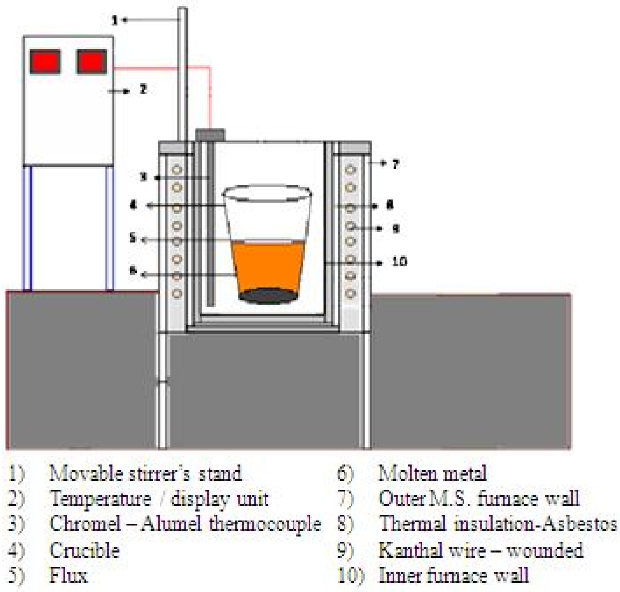


Fig. 1 Experimental Set –up

3. Result and Discussion

3.1 Microstructure

Figure 2 shows the optical micrographs of as cast different nickel containing system. Figure 2 (a) indicates the dendrites of α aluminium along with dispersed needle like eutectic silicon particles. The size of α aluminium and silicon needles are quite coarser compare to others system. As increase in nickel percentages from 0.820 to 1.12 refinements of α aluminium and silicon needles were observed. The optical micrographs do not reveal presence of precipitates of nickel enriched phase within α aluminium dendrites. To identify these precipitated intermetallics phases back scattered electrons are used in SEM which can be seen in figure no. 3. In SEM micrographs, Cu-Ni-Fe enriched intermetallics precipitates appeared in white contrast and can be easily separated. Figure no. 4 shows the EDS analysis of the Cu-Ni-Fe enriched intermetallics precipitates. The EDS analysis proved that precipitate contains highest amount of nickel. The X Ray analysis confirm the presence of nickel enriched intermetallics phases like AlNi in LM 28(a) and both AlNi and $(AlNi_2Si)8C$ phases in LM 28 (e).

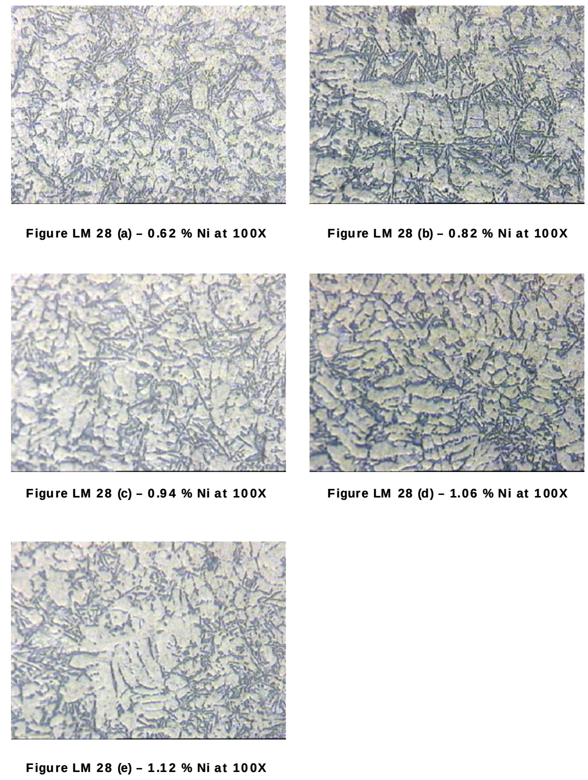


Fig. 2 Indicates Microstructure of as Cast Alloy Containing Nickel from 0.62 to 1.12 wt. %

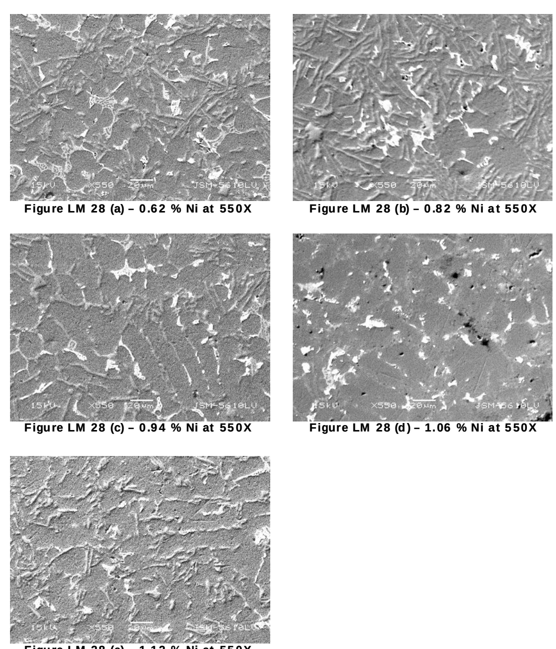
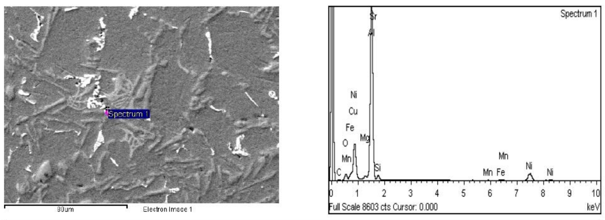


Fig. 3 Indicates SEM microstructure of as cast alloy containing nickel from 0.62 to 1.12 weight %



Element	C K	O K	Mg K	Al K	Si K	Mn K	Fe K	Ni K	Cu L	Sr L	Totals
Weight %	5.3	5.55	0.86	54.63	2.23	0.58	2.38	24.5	3.77	0.2	100

Fig. 4 Indicates EDS Analysis of Nickel Enriched Phase

3.2 Differential Thermal Analysis (DTA)

Figure no. 5 shows the DTA curve for system LM 28 (e). The DTA curve indicates the melting behavior of an alloy with a sharp endothermic at 571 °C temperature.

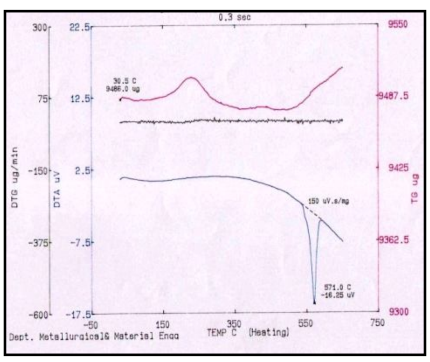
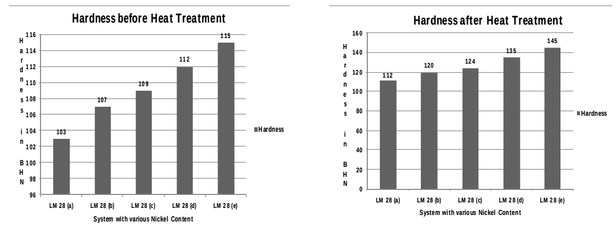


Fig. 5 Indicates DTA curve for LM 28 (e) System

3.3 Hardness

To understand the effect of nickel content and heat treatment hardness value of nickel containing alloys were measured both in as cast and heat treated condition. The dimension of hardness specimens were 2 x 2 x 2 cm and all the specimens were prepared in the usual metallographic manner. Figure no. 6 (a) and (b) shows the graphical representation of hardness value of the alloy before and after heat treatment condition respectively. All the given values of were average of 6 measurements. It is obvious that increasing the nickel content in the alloys increases the hardness. After heat treatment, the hardness value increases. The increase of the hardness after heat treatment is more effective when nickel content is high in LM 28 alloy.



(a) (b)

Fig. 6 (a) Indicates the Hardness value of as Cast Structure and (b) after Heat Treatment

3.4 Tensile test

Following Figure no. 7 indicate the size and shape of tensile test sample.

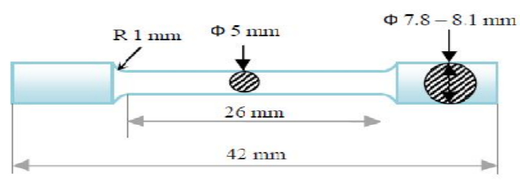


Fig. 7 Line Diagram of Tensile Test Specimen

The tensile properties of various piston alloys have been measured to examine the effect of nickel variation and heat treatment. With increase in nickel concentration, generation of intermetallics phases also increases which strengthens the LM 28 alloy. As the nickel content increases tensile strength value also increases from 117 N/mm^2 to 180 N/mm^2 in case of cast condition. The following table 2 and 3 indicate the properties like tensile strength and % of elongation of as cast and heat treated condition samples.

Table 2: Tensile Properties of Various Cast Piston Alloys

Types of alloy system	Tensile strength N/mm^2 *	% Elongation *
LM 28 (a)	117	2
LM 28 (b)	130	2
LM 28 (c)	141	3
LM 28 (d)	174	2
LM 28 (e)	180	3
	* Average of three samples	* Average of three samples

Table 3: Tensile Properties of Various Heat Treated Piston Alloys

Types of alloy system	Tensile strength N/mm² *	% Elongation *
LM 28 (a)	146	5
LM 28 (b)	160	6
LM 28 (c)	184	5
LM 28 (d)	205	6
LM 28 (e)	237	6
	* Average of three samples	* Average of three samples

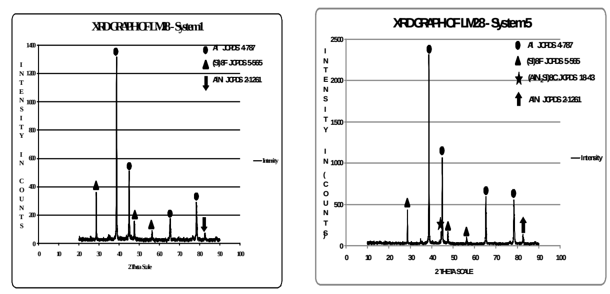
After heat treatment due to the change in morphology of silicon needles the tensile strength properties improves and varies from 146 to 237 N/mm^2. The increase in tensile strength and % elongation occurs due to the change in shape of silicon needles from sharp pointed to rounded rod type. Sharp needle shape, silicon presence act as a stress concentration sites and reduce the tensile properties of aluminium-silicon alloys. However the formation of new phase generated after heat treatment has been not evaluated and reported in this work.

The effect of modification after heat treatment had been checked by electrical conductivity method. If 10% changes in electrical conductivity after heat treatments observed than it represent the full modification. [6] The entire sample gets fully modified after heat treatment. The following table 4 indicates the % increase in the electrical conductivity from non heat treated to heat treated sample.

Table 4: Electrical Conductivity Data of as Cast and Heat Treated Samples

Types of Alloy	As Cast Electrical Conductivity	After Heat Treatment Conductivity	%Difference (IACS) International Annealed Copper Standard)
M 28 (a)	21.2	36.5	71
M 28 (b)	26.4	38.3	46
M 28 (c)	27.2	40.6	48
M 28 (d)	24.8	36.8	50
M 28 (e)	24.5	33.3	38

3.4 X-Ray Analysis



(i) (ii)

Fig. 7 (i) Indicate the X-Ray Analysis of as Cast LM 28 (a) and (ii) LM 28 (b)

The X-Ray analysis of as cast LM 28 (a) indicates the presences of α aluminium and silicon as a major phase along with intermetallics precipitates of AlNi. It is due to the presence of minor nickel content in LM 28 (a). As the percentage of nickel increase and appeared to be highest in case of LM 28 (e) indicates the presence of two nickel enriched phase like AlNi and $(AlNi_2Si)8C$.

4. Conclusion

Large precipitates of nickel enriched phases were found in the solidified alloys.

Hardness properties of LM 28 alloys largely depend on the nickel content and the heat treatment. By increasing nickel content hardness increases due to precipitation hardening. It is found that after heat treatment hardness value increases more compare to solidified alloys.

Tensile properties improve after heat treatment

Modification after heat treatment confirmed by electrical conductivity measurement

Optical and SEM micrographs represent the effect of variation on nickel content and heat treatment both

DTA peak indicates the sharp melting behavior of alloy at 571°C.

X Ray analysis of as cast samples confirm the presence of nickel enriched intermetallics phase like AlNi and $(AlNi_2Si)$ 8C phase.

5. References

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