

# EFFECT OF NICKEL CONTENT ON MICROSTRUCTURE OF MODIFIED ZINC- ALUMINIUM CAST ALLOYS

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**Abstract**—The objective of this paper is to study the micro structural features of ZA27 alloy containing nickel in the range from 1 to 3 wt. %. The microstructure of the alloy was examined using both optical and SEM. High percentage of nickel helps in imparting strength to the alloy and also to overcome dimensional instability as it forms various intermetallic compounds containing hard particles. Small percentage of magnesium in the alloy helps in reducing intergranular corrosion. The microstructure consists of small, flaky and rod like irregularly shaped intermetallic compound in the interdendritic and eutectic regions. Metallographic studies showed that addition of nickel resulted in microstructural modifications of the alloy involving the formation of complex intermetallic compounds  $\alpha$ .

**Keywords**— ZA alloys; Microstructure; Al-Ni master alloy; SEM; Dimensional instability.

## I. INTRODUCTION

The conventional high strength zinc-based alloys comprising 8–27% Al, 1–3% Cu and 0.05% magnesium have been observed to be potential materials to substitute a variety of ferrous and nonferrous alloys [1–2]. However, they suffer from sharp deterioration in mechanical properties at temperatures above 100°C, and dimensional instability [3]. Dimensional instability in the zinc-based alloys occurs due to the transformation of a metastable phase into stable T phase when the copper content in the alloy exceeds 1-2% [4, 5].

Interestingly, addition of copper in the said limit is essential in zinc-based alloys in order to impart high strength [6]. But as far as possible it is necessary to reduce/replace the copper content by taking appropriate measures to compensate for the loss in mechanical properties and to overcome the problem of dimensional instability.

Partial or total replacement of copper with high melting elements in the conventional zinc based alloys has been reported to reduce the problem of dimensional instability [6, 7]. Alloying with high melting point elements such as nickel and silicon improves the elevated temperature properties of the alloy system [8–9]. Recently, limited efforts have been made to develop and characterize the mechanical and microstructural properties of modified versions of the zinc-based alloys [10–12]. However, systematic studies pertaining to understanding the effect of high percentage nickel on the microstructural features in the modified zinc-based alloys seems to be lacking.

In view of this, an attempt has been made in this investigation to analyze the effect of nickel on the microstructure and related properties of modified zinc-based alloys.

## II. EXPERIMENTAL DETAILS

### A. Casting of alloys

Alloys were prepared by conventional liquid metallurgy route in a permanent cast iron mould in the form of cylindrical

castings of 22 mm in diameter and 150 mm long. An electrical resistance furnace was used at the first stage for melting the Al in a graphite crucible. After melting the Al, the melt temperature was increased to 7500C and then Al-Ni master alloy was introduced to the melt. Subsequently, Zn was added and the melt temperature was decreased to 6500C. At final stage, pure magnesium (99.99 wt. %) was added to the melt at about 600–6200C with vigorous stirring. The melts were then poured into permanent cast iron mould pre-heated to about 2000 C. The raw materials used were commercially pure Al (99.8 wt. %), Zn (99.95 wt. %), Al-Ni master alloy. The addition of Ni was done to the extent of 0, 1, 2 and 3wt%. Thus, four different Zn-Al-based alloys were prepared.

### B. Alloy Chemistry

The chemical composition of the developed alloys determined by atomic absorption spectroscopy and is presented in Table 2.1 and 2.2.

### C. Microstructural analysis

Microstructural examination of the experimental alloys was conventionally carried out on ground and polished samples using optical microscope. The etching agent used was a solution containing 5g CrO<sub>3</sub>, 0.5g Na<sub>2</sub>SO<sub>4</sub> and 100 ml H<sub>2</sub>O. A scanning electron microscope (SEM) was also used for detailed microstructural studies.

Nickel content	Al	Ni	Cu	Mg	Fe
0	26.71	0.001	0.03	0.105	0.09
1	26.53	1.09	0.03	0.102	0.09
2	27.12	1.95	0.034	0.108	0.09
3	26.10	3.10	0.035	0.120	0.092

**Table 2.1: Chemical composition of the experimental ZA27 alloy (wt %)**

Nickel content	Ti	Pb	Mn	Zn
0	0.00069	0.0031	0.007	Rem
1	0.0007	0.003	0.007	Rem
2	0.0007	0.003	0.007	Rem
3	0.0007	0.003	0.007	Rem

**Table 2.2 : Chemical composition of the experimental ZA27 alloy (wt %)**

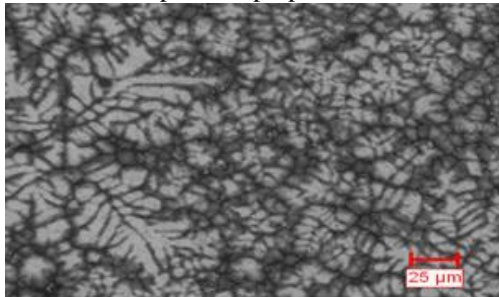
## III. RESULTS AND DISCUSSIONS

The microstructure of the binary alloy shown in figure1(a) consists of heavily cored aluminum-rich ( $\alpha$ ) phase and zinc-rich ( $\eta$ ) phase, while the grey structure surrounding it is a mixture of zinc-rich and aluminum rich phases ( $\alpha+\eta$ ). The dark regions are the zinc-rich ( $\eta$ ) phase.

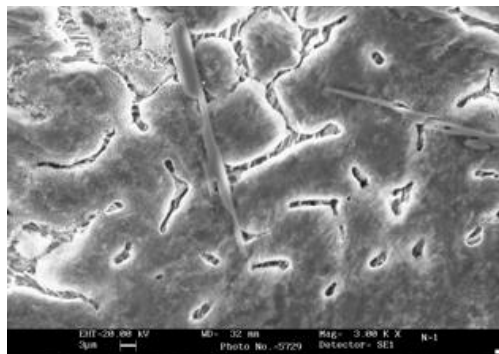
The results obtained from this investigation indicate that the micro structure of ZA-27 (fig1.a) can be modified by the addition of nickel in the range 1–3 wt. % (Figs. 1(b), 1(c) &1(d)). The addition of Ni to the alloy had a nucleating effect of the dendrites phase and also formed small, flaky and rod like irregular shaped intermetallic compound in the interdendritic and eutectic regions.

Increase in nickel content led to increase in the solid solution hardening due formation of hard and brittle nickel containing intermetallic phases along the grain boundaries of the alloys. Similar explanations have been offered by other researchers in the literature. The various intermetallic compounds noticed are AlNi<sub>3</sub>, AlNi<sub>3</sub>, and Al<sub>0.403</sub>Zn<sub>0.597</sub>

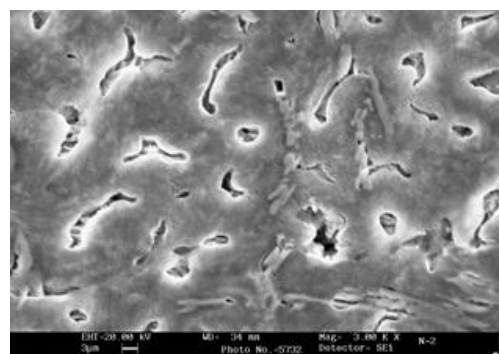
An appraisal of the observations made in this study suggests reinforcement (Ni addition) of the alloy system with hard phase particles enables it to attain dimensional stability, improved elevated temperature properties and wear behaviour.



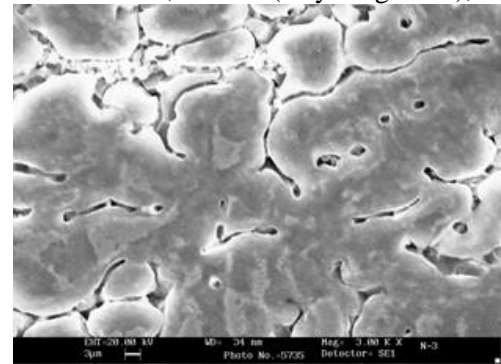
(a)



(b)



(c)



(d)

**Figure 3.1: Optical and SEM microstructures of as cast ZA27 alloy containing: (a) 0% Ni, (b) 1% Ni, (c) 2% Ni and (d) 3% Ni. Single arrow: Zinc rich  $\eta$  phase; Double arrow:  $\alpha + \eta$  eutectic phase; Triple arrow: Al rich  $\alpha$  phase; Meta stable phase**

#### IV. CONCLUSIONS

- Using Scanning electron microscope, the microstructural examination of the developed alloys was conventionally carried out on ground and polished samples. The etching agent used was CrO<sub>3</sub> and Na<sub>2</sub>SO<sub>4</sub>.
- The increase in nickel content results in increasing the solid solution hardening and formation of hard and brittle nickel-rich intermetallic phases along the grain boundaries of the alloys.
- The microstructure represents typical cored structure, consists of small, flaky and rod like irregularly shaped intermetallic compound in the dendrites and eutectic regions.
- In the range of nickel additions tried, the alloy containing 2 % is seems to be exhibit homogeneous fine microstructure.
- The addition of nickel on Zn–Al alloys reported the formation of AlNi<sub>3</sub>, Zn, AlNi<sub>3</sub> and Al<sub>0.403</sub>Zn<sub>0.597</sub> intermetallics.
- High percentage nickel is effective in improving the strength of the alloy and to overcome dimensional instability as it forms various intermetallic compounds contains hard particles.
- Addition of small amount of magnesium benefits in reducing intergranular corrosion.

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