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Morphology of aluminium with nickel addition on sand casting process

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ABSTRACT

Purpose: his research aimed to examine the morphology, elemental changes, and phase in the aluminium cast alloys with variations in nickel addition of 1%, 2% and 3%.

Design/methodology/approach: Aluminium 98% was melted in sand casting process. The sand casting process was operated at 7000C and atmospheric pressure. The addition of nickel contain of 92.19% of its element. Specimens consist of 4 pieces Al-Ni with the size of 1 x 1 x 0.5 cm for morphological testing, while for phase identification testing consist of 4 pieces Al-Ni with the size of 1 x 1 x 2 cm. The morphological testing was performed using FEI Inspect S50 Scanning Electron Microscope (SEM) and the phase characterisation was conducted using Nikon ME5 Optical Microscope.

Findings: The results showed that the addition of 1% nickel in the aluminium cast product could affect the morphology in granular shape with as similar size, at 2% nickel addition also has granular shape, while at 3% of nickel addition, the morphology of Al-Ni was in elongated shape. Phase identification of Al-Ni cast alloy shows that there were Al matrix with nickel that spread in grain boundary of Al. By increasing the percentage of nickel, it shows that the nickel dominated the grain boundary of Al. These results shows that Al-Ni alloy can be produced at simple route on sand casting process.

Research limitations/implications: Sand casting process with 80% silica sand, 10% bentonite, 5% water. Raw material of aluminium contains of 92-99% of purity. Nickel as addition element contain of 90-92% purity.

Practical implications: The addition of nickel should be prepared wisely in term of the calculation of alloying treatment because it will effect the mechanical properties of Al alloy itself. This research can be improved by varying the temperature of casting process, variation of nickel percentage, and observation of mechanical properties of Al-Ni alloy.

Originality/value: Simple route of making Al-Ni alloy using sand casting method in laboratory and also the observation of nickel addition in aluminium matrix as the result of casting product.

Keywords: Morphology, Phase, Alloy, Aluminium, Nickel, Casting

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MATERIALS

1. Introduction

Today's technology is advancing very rapidly. Demand for better-quality production goods is also escalating in the industrial world. Correspondingly, engineers have undertaken various studies to improve the production quality by modifying the material properties.

One way to modify the properties of the material in the industrial world is through metal processing, namely metal casting. This method is widely used in ready-made components for production. This industrial sector handles the utilisation of metals starting from metal processing to finished products. The advantages of metal casting are its ability to produce simple to complex products with varying weights from grams to tons and also minor finishing processes hence time-efficient and cost-effective [1].

With the demands of industries of high strength aluminium, various effort were taken to increase the properties of aluminium. Modification of Al alloy has been done by adding Zn, Mg, Cu, and Ni [2]. More attention gain on alloying aluminium with nickel since nickel is one of transition metal that is cheap and abundant. Nickel also plays important role in solid solution strengthening and improve the mechanical properties of Al-7Si Alloys [3].

Alloying nickel for aluminium will easily done by casting method. The percentage amount of nickel will described in this paper.

2. Methodology

This was experimental research, namely a one-shot case study. Experimental research is a study that investigates the influence of certain variables on other variables under tightly controlled conditions. [3] This study was conducted to gain insight into the effect of nickel content variations on Al-Ni alloys in the sand casting process. Descriptive analysis was used to analyse the morphology, elemental composition, and phase characteristics of the Al-Ni casting products.

The variables used in this research were independent, dependent, and control variables. The independent variable was Nickel (Ni) content (1%, 2%, and 3%). The dependent variables included the analysis of morphology, element, and phase. The control variables were (a) the metal melting temperatures of 760-900°C, (b) the mixing of metal at the start of the melting process, (c) the periodic stirring at the beginning of the melting point of alloying metal, and (d) the composition of sand mould composed of silica sand and bentonite binder.

The objects under study were Al-Ni cast alloys made using sand moulds. Prior to the casting, the raw metal of aluminium and nickel was tested for its composition to identify the constituent elements of metal.

The data in this study were collected through two stages, preparation and data collection. At the first stage, the instruments and materials used in the research were prepared. At the data collection stage, three activities were conducted. First, the making of specimens: (a) 4 pieces of Al-Ni with a size of 1 x 1 x 0.5 cm were prepared for morphological and elemental tests, (b) 4 pieces of Al-Ni, 1 x 1 x 2 cm in size, were made for phase testing, and (c) all the specimens for testing were 8 pieces in total. Second, the implementation of the morphological and elemental tests: (a) the specimens were prepared and then inserted into the SEM and EDX devices, (b) the specimens were placed properly to be well photographed, and (c) the specimens' morphology and elemental composition with and without variations in nickel content were observed with SEM and EDX.

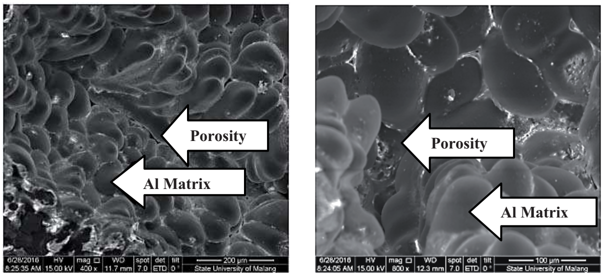
Third, the phase identification testing. The phase type of each specimen could be identified from the photomicrograph. The metallography investigation was obtain through the following steps: (a) each specimen was polished with 200, 500, and 1000 grits until its surface was smooth and non-wavy, (b) the surface of the specimen was immersed in etching solution, (c) the surface of the specimen was dried, d) the specimen was was observed by optical microscope.

3. Results and discussion

3.1. Results of morphology testing

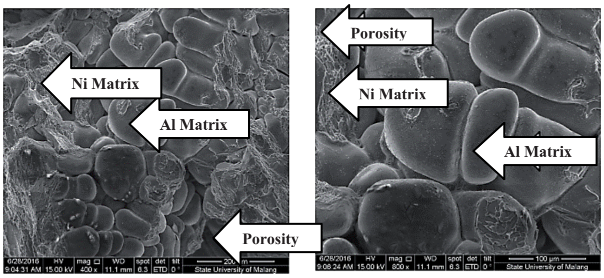
The results of the Scanning Electron Microscope (SEM) analysis on pure cast aluminium (Al) and cast aluminium specimens containing various amounts of nickel, i.e. 1%, 2%, and 3%.

According to Maznoy [4] the addition of nickel (Ni) makes the alloy structure more homogeneous. Previously, Rammelyadi [5] explained that the addition of nickel (Ni) to Al-Ni alloys results in a relatively similar microstructure (granular) but with different grain sizes. The homogeneous alloy structure can increase the hardness of the alloy without reducing the ductility of the alloys. Figure 1 (a) and (b) are the SEM images of pure aluminium specimen at 400x and 800x magnification at one point. The pure aluminium was granular with relatively the same grain size. It appeared to be a longer elongated form of granular shape and tended to solidify.



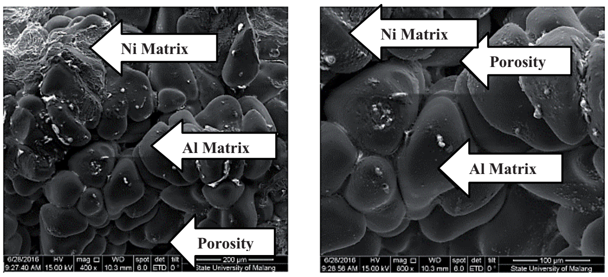
(a) (b)

Fig. 1. Result of SEM on raw material (a) at 400x magnification, (b) at 800x magnification



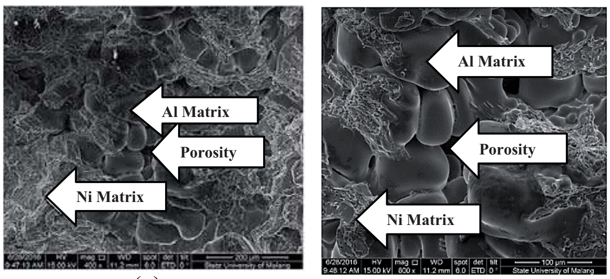
(a) (b)

Fig. 2. (a) Result of SEM on aluminium with nickel addition 1% (a) at 400x magnification, (b) at 800x magnification



(a) (b)

Fig. 3. Result of SEM on aluminium with nickel addition 2% (a) at 400x magnification, (b) at 800x magnification



(a) (b)

Fig. 4. Result of SEM on aluminium with nickel addition 3% (a) at 400x magnification, (b) at 800x magnification

Figures 1, 2, and 3 are the micrograph of Al-Ni alloy with different percentage of Nickel addition. Figure 1 shows micrograph of raw aluminium without nickel addition. It shows that only aluminium matrix and porosity appear. The grains in homogen form and granular shape. Figure 2 shows that aluminium matrix in coated with nickel matrix. It shows the porosity between Al matrix and also how nickel matrix covers Al grains. Figure 3 shows the aluminium matrix with nickel matrix covers the grain and also in grain boundary of Al matrix. Figure 4 shows the largest amount of nickel matrix that covered Al matrix. The homogeneus distribution of nickel in aluminium matrix, identified as Al_3Ni. It was found that the intermetallic Al_3Ni increase as the percentage of nickel content in the alloy also increase [6].

3.2. Result of phase identification

The results of phase identification obtained at 1300x magnification. The microstructure results determined the phase of raw cast aluminium (Al) and cast aluminium specimens containing various amounts of nickel (Ni), i.e. 1%, 2%, and 3%.

The formation of the eutectic phase in aluminium with variations in nickel content in this study is in line with Kartaman revealing that the κ phase reaction started to form in the composition of 0.04-42% by weight of Ni at temperatures below 640°C [7]. The κ phase was the result of a transformation of the Al and Ni alloy following the eutectic phase reaction, i.e. $L \rightarrow \alpha + \kappa$; if the Ni content in the alloy exceeds the solid-solubility limit above 0.04%, the formation of phase κ ($NiAl_3$) will occur. Offoiach explained that the intermetallic phase (κ) is represented by a dark-grey matrix, while the Al matrix is characterised by a light-grey matrix [8].

Figure 5 is the microstructure of raw aluminium specimen. The image shows that Al (α) matrices in the form of large grains spread evenly on the surface of the specimen. The Al matrices (α) were in light grey colour, while the grain line was flat and black. Porosity was found on the surface of the specimen due to the excessive cooling rate and the trapping of air resulting in the transformation into the grain form not occurring. This porosity is considered a casting defect.

Figure 6 is the microstructure of Al-Ni specimen containing 1% nickel. The image shows that Al (α) matrices in the form of elongated grains spread evenly on the surface of the specimen. Porosity was found on the surface of the specimen but the level was less than that found in the pure aluminium specimen. The alloy formed an intermetallic (κ) phase following the $NiAl_3$ eutectic reaction at some points.

Figure 7 is the microstructure of Al-Ni specimen containing 2% nickel. The image shows that grains of Al (α) matrices are smaller than those in the specimen with 1% nickel. The matrix sspread evenly on the surface of the specimen. The phase formation was higher than that in the specimen containing 1% nickel.

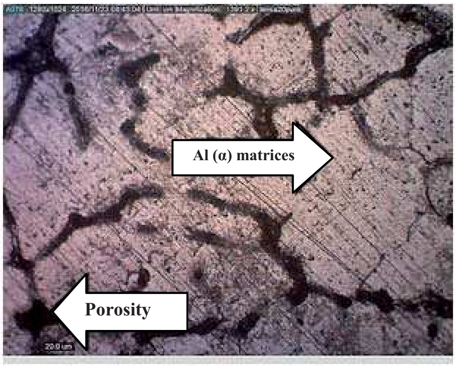


Fig. 5. Microstructure of pure aluminium

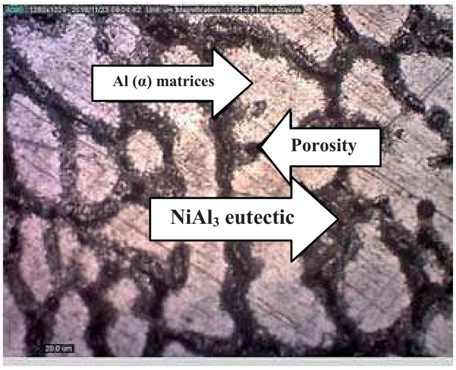


Fig. 6. Microstructure of specimen with 1% nickel

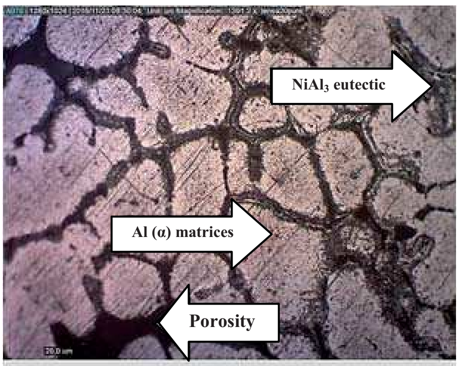


Fig. 7. Microstructure of specimen with 2% nickel

Figure 8 is the microstructure of Al-Ni specimen containing 3% nickel. The image shows that Al (α) matrices in the form the smallest grains compared to the other specimens. Porosity was found on the surface of the specimen but the level was less than that found in the former variation.

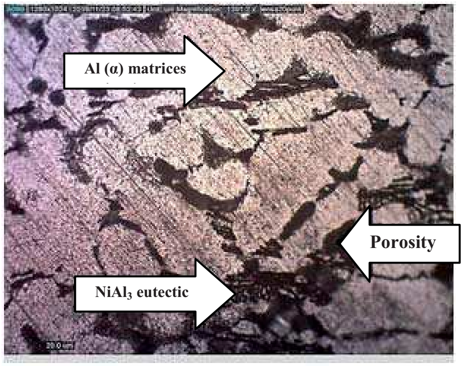


Fig. 8. Microstructure of specimen with 3% nickel

4. Conclusions

In terms of its morphology, the Al-Ni alloy specimen with a variation of 1% in nickel content had a granular shape with unequal grain size (large and small) and narrow pores were found in particular parts of the specimen. The Al-Ni alloy specimen with a variation of 2% in nickel content had a granular shape with relatively equal grain size (homogenous) and pores were found in particular parts of the specimen. The Al-Ni alloy specimen with a variation of 3% in nickel content had a granular shape with relatively equal grain size (homogenous) and pores were found in most parts of the specimen. The alloy formed an intermetallic (κ) phase following the $NiAl_3$ eutectic reaction at some points.

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