The Effect of Melting Temperature Aluminum Metal Casting Using Mixed Degasser Based Sodium Fluoride and Sodium Nitrate

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Abstract. The effect of NaF and NaNO₃ based degasser on mechanical properties of Al-Si 12% casting has been investigated. The quality of Al-Si casting, especially in mechanical properties, is important in some applications. However, the existence of gas porosity, which is formed due to the high solubility of H₂ at melt temperature in casting process, reduces mechanical properties of Al-Si 12% casting product. In this research, we used NaF and NaNO₃ as degasser as an addition in casting process. The experiments were conducted at pouring temperature of 660°C, 680°C, 700°C and 720°C. The mechanical properties (which are determined by tensile test, hardness test and impact test) with and without degasser were measured and compared. We found that in all pouring temperature, the addition of degasser will improve all of mechanical properties measured. In addition we found that the increase of tensile strength was optimum at pouring temperature of 720°C at 25,5 % of increase, hardness was optimum at pouring temperature of 720°C at 33,3 % of increase and impact strength was optimum at pouring temperature of 720°C at 25 % of increase. The improvement of mechanical properties is due to the role of NaF and NaNO₃ by binding H₂ gases which is formed in melting process. This H₂ binding was shown in microstructure observation which shows that the porosity of casting product visually decreased.

Keywords: *Al-Si12; Degasser sodium fluoride sodium nitrate, Gravity Casting*

1. Introduction

In industries such as automotive and transportation, the use of aluminum alloys from the casting process is widely applied. However pure aluminium has relatively low mechanical properties if used for industries, so the pure aluminium has to be alloyed with other metals like silicon, copper, and magnesium to improve its mechanical properties such as hardness and strength. The use of aluminum alloys from the casting process has significant advantages, such as light weight, high castability, high specific strength, good corrosion resistance, and low shrink rate [1]-[3]. Eutectic Al-Si 12% alloys with low density, excellent castability, fit wear resistance and good hardness, are proper materials for Industries applications. The solid microstructure of Eutectic Al-Si 12% alloys be composed of Si phase primary, eutectic composition ($\alpha + \text{Si}$) and α (Al) matrix [4]-[5].

The quality of materials from casting is determined based on temperature pouring, casting pressure, and the preheating temperature of the mold. The melting temperature is a necessary factor affecting the results of casting products. Low melting temperature causes low fluidity which can cause casting defects such as

shrinkage and in the other hand, high melting temperature initiate the formation of hot cracks in the mold and forming porosity defects in the product. Moreover, high melting temperature will increase the solubility of hydrogen gas in cast products and affects the grain size of materials. Based on the effects of grain size and porosity content on the mechanical properties, the optimum melting temperature has an important role in order to decrease the grain size and porosity content from casting product [6]-[7]. Porosity is the primary defects in aluminium alloy casting and its existence is destructive for the mechanical properties of casting products [8]. Hydrogen gas is appreciably soluble in molten Al, Thus the elimination of gas hydrogen in molten Aluminium are crucial for producing good quality castings. One of the effective way for reducing hydrogen porosity is through degassing [9]-[10]. In this paper we use mixed degasser based Sodium fluoride and Sodium nitrate, we expect that this degasser decreases porosity content by binding the H₂ gas out of molten Al.

2. Experimental Methods

2.1 Making of degasser NaF and NaNO₃

Degasser is mainly composed by NaNO_3 at concentration of 18 wt% in powder form and NaF at 40 wt%. There are rest 42 wt% components are NaCl , $\text{NH}_4\text{Cl}(\text{KCl})$, Na_2SO_4 , and dye. The materials were mixed with the addition of water and were put into a mixer machine with the duration of stirring is about 30 minutes. The mixed material was then processed to change the shape of the powder into a tablet degasser using printing machine. Degasser tablet then was put into the oven at temperature of 100°C for 1 hour for evaporating water content.

2.2 Characterization of Al-Si 12

The aluminium casting product were characterized by mechanical testing such as tensile test, hardness test, and impact test to find out the mechanical properties and metallography examination to obtain microstructure of aluminium casting product. The tensile testing was conducted by using GOTECH AI-7000 LA 10 machine with JIS Z2241 standard. The hardness testing was conducted by using LCB3100 LECO brinell machine with 10 mm diameter of steel ball indenter and 500 kgf force. To obtain the impact value, Frank impact testing machine was used with the charpy method. Preparation for metallography observation were carried out by standard metallographic procedures, started by grinding with sand paper, polishing with kovac (TiO_2) and etching with keller reagent. The composition of keller reagent is 2 ml HF, 5 ml HNO_3 , 3 ml HCl and 190 ml aquadest. Optical microscope was used to observed the samples. For analyze more deeply, Planimetri method was used to obtain fraction of phase porosity [11].

Table 1. Chemical composition of Al-Si12 (%)

Al	Si	Fe	Cu	Mn	Mg	Zn	Cr
87. 3	12. 4	0.09 38	0.00 15	0.00 45	0.00 03	0.002 40	0.00 48

Fig. 1 shows the schematic design of metal mold. The specimen of this experiment was determined on a design used metal mold casting. The experiment was conducted in foundry laboratory metallurgical and material engineering departments. Casting products was obtained from metal mold are shown in t1, t2, t3 and i1, i2, i3 which will serve as sample specimen in testing the mechanical properties cast products. Down sprue which shown at number 1 was located in the left side of casting with a diameter 20 mm. down sprue is a place of pouring molten metal into a metal mold. Runner which shown at number 2, as where the molten metal flows fills the sample's tensile and impact casting. Gas tunnel which shown at number 3 was located in the right side of casting, as a place for removing gas from within the metal mold. After casting was finished, the sample of the specimen was observed to probe the properties of the casting material.

3. Results and Discussion

3.1 Mechanical properties of casting Al-Si 12 with degasser

Fig. 1 Schematic of casting design. (a) Top View ; (b) Front View (1) ; Down-sprue (2) ; Runner (3) ; Gas Tunnel ; (t1, t2, t3) Tensile Specimen ; (i1, i2, i3) Impact Specimen.

Fig. 2 Effect of degasser NaF and NaNO₃ addition on tensile strength of Al-Si 12%

Fig. 3 Effect of degasser NaF and NaNO_3 addition on hardness of Al-Si 12%

The results of tensile tests are shown in Fig. 2. From the figure shows that effect of degasser NaF and NaNO_3 addition has important effects for tensile properties. Porosity in castings represent a significant role in increasing the mechanical properties [12]-[13]. The existence of hydrogen gas in casting product decreases the mechanical properties like tensile strength of the materials [14]. From figure 1, it was shown that the degasser addition yields higher tensile strength. The tensile strength increased 17,2%, 15,5%, 17,7%, 25,5% at temperatures of 660°C, 680°C, 700°C and 720°C respectively. The effect of degasser, in this case was found to be effective at pouring temperature of 720°C. NaF and NaNO_3 in degasser binds H_2 gas from the molten metal forming other compounds so the porosity is reduced and the tensile strength increases.

Fig. 3 shows the results of hardness tests. The results show with the addition of degasser it will increase the hardness of the aluminium alloy casting product. The most major factor that affect the hardness is porosity, as the porosity amount increase it would decrease the hardness of casting product. [15]-[17]. The hardness increased 8,4%, 9,8%, 23,5%, 33,3% at temperatures of 660°C, 680°C, 700°C and 720°C respectively. The effect of degasser, in this case was found to be effective at pouring temperature of 720°C. Effect addition of degasser is reduced porosity and make the SDAS (secondary dendritic arm spacing) become smaller and it is increasing the hardness [18].

Fig.4 shows the impact strength values for both alloys with degasser and without addition of degasser. The impact strength plays a significant role in particular applications. It can estimate the ductility of an aluminium alloy casting product under the conditions of rapid loading [19]. One of the advantages that was obtained from modification alloy is improved ductility [20]. The addition of degasser increases strength and may improve ductility. The impact strength increased 20,5%, 11,1%, 15,4%, 25% at temperatures of 660°C, 680°C, 700°C and 720°C respectively. The effect of degasser, in this case was found to be effective at pouring temperature of 720°C.

Fig. 4 Effect of Degasser NaF and NaNO_3 addition on Impact strength of Al-Si 12%

3.2 Microstructural observation and phase identification of Al-Si12

Fig. 5 shows the porosity level structure of Al-Si 12 % eutectic alloy at its various melting temperature. Aluminum molten metal was poured into the cup then was put on the porosity meter. The pressure was lowered for 315 seconds in accordance with the standard. The vacuum was applied for 5 minutes and 15 seconds is needed to reach the applied pressure. The pressure of the porosity meter is -100 mmHg, which is an optimum vacuum pressure for measurements. From the visual observation based on figure 5, it can be easily observed that the addition of degasser reduces the pores.

Fig. 7. Fraction of phase porosity Al-Si12 with degasser and non degasser at variation temperature

The microstructure of Al-Si 12 % eutectic alloy at temperatures 660 °C was shown in Fig.6. The small amount of the elongated primary Si and large number of dendritic α -Al phase in aluminium alloys was found in Fig.6. [20]. On the microstructure of Al-Si 12 % eutectic alloy with the addition of degasser NaF and NaNO_3 , at modified temperature 660°C The fraction zone of primary Si and α -Al reached the maximum, and the content porosity that occurs is very low or almost nonexistent due to the hydrogen gas in the melting aluminum binding with the compounds present in the degasser. Fig. 7 shows the fraction of phase

porosity of Al-Si 12 % eutectic alloy. Calculation fraction of phase porosity using planimetry method. Al-Si 12 % with the addition of degasser NaF and NaNO₃, fraction of phase porosity is very low from the whole phase. Low porosity at Al-Si12% eutectic alloy cause the effect of addition degasser NaF and NaNO₃. With the addition of degasser, hydrogen gas in the

molten metal decrease cause compound degasser bind the H₂ gas. Al-Si12% without the addition of degasser, fraction of phase porosity is high than with the addition of degasser from the whole phase. This is due to the solubility of H₂ gas in molten aluminum is still high so susceptible to porosity.

Fig 5. Macrostructure of porosity level of casting Al-Si12 with degasser at variation temperature: (a) 660°C; (b) 680°C; (c) 700°C; (d) 720°C and non degasser at variation temperature: (e) 660°C; (f) 680°C; (g) 700°C; (h) 720°C

Fig 6. Microstructure of casting Al-Si12 with degasser at variation temperature: (a) 660°C; (b) 680°C; (c) 700°C; (d) 720°C and non degasser at variation temperature: (e) 660°C; (f) 680°C; (g) 700°C; (h) 720°C.

3.3 Effect of Sodium fluoride and Sodium nitrate addition

The effect of addition degasser NaF and NaNO₃ can be inferred from chemical reactions in equation (1) and (2). The function of the compound contained in the degasser is to produce nitrogen gas when immersed into an molten aluminum. The presence of N₂ gas and bubbles formed will bind H₂ gas by diffusing H₂ gas into the bubbles and carrying H₂ gas to the molten aluminum surface. From the equation (1) and (2) we can conclude that the compound on the degasser can also bind impurities in the molten aluminum to oxide which will rise to the molten aluminum surface and disposed as a dross. The content porosity in metal is decreased and the mechanical properties of aluminum casting metal aluminum surface. From the equation (1) and (2) we can conclude that the compound on the degasser can also bind impurities in the molten aluminum to oxide which will rise to the molten aluminum surface and disposed as a dross. The content porosity in metal is decreased and the mechanical properties of aluminum casting metal product increased with the addition of degasser sodium fluoride and sodium nitrate.

4. Conclusion

Addition of degasser NaF and NaNO₃ improves mechanical properties of Al-Si 12% eutectic alloy such as tensile strength, impact strength, and hardness. This is due to the role of degasser in reduce gas porosity based on microstructure observation. The mechanism reducing of gas porosity, is that these degasser compounds bind H₂ gas from molten aluminum as shown in equation (1) and (2).

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