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EVALUATION OF CAST DEFECTS IN SHIP PROPELLER OF RECYCLED ALUMINUM ALLOY

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The material used is recycled aluminum alloy. The ship's propeller is cast through a steel mold. The macroporosity, misrun, and cold shut defects formed in the cast products of the ship's propellers were observed for their location, geometric shape, and size. Defects are generally formed at the tip of the blade with various geometries and sizes, and shrinkage cavity defects are observed at the butt of the blade. No defects were found in the product when die mold was preheated.

Keywords: aluminum alloy, propeller, casting, defect, macroporosity

INTRODUCTION

Casting defects are physiological imperfections of cast products caused by the casting process, material properties and conditions, design/type of mold. Various studies on the causes of the formation of cast defects have been studied so that efforts can be made to prevent them. Defects in cast products have been observed by location, geometry, metallurgical phenomena, and processes. Cold shut defects, cold flakes, and gas pores have been observed in secondary $AlSi_{10}MnMg(Fe)$ [1]. Evaluation of hot tearing defects due to variations in casting temperature and mold design has been studied in aluminum alloys [2]. Bifilm-defect and porosity mechanisms have been discussed in aluminum, magnesium, and iron alloys [3-6]. Shrinkage cavity defects in casting components have been investigated through computational simulation [7].

The purpose of this paper is to evaluate the geometry, location, and cast defects area in ship propeller products manufactured by gravity casting.

EXPERIMENTAL PROCEDURES

Aluminum alloy is recycled using a metal melting furnace, the fuel used is liquefied petroleum gas (LPG) which was built at the Material-Casting Laboratory. During melting alloy, oxygen is added to the combustion chamber with a certain composition to maximize the combustion process. A chromel–alumel (K-type) thermocouple was placed in the molten and metal mold to observe the casting temperature and the mold temperature. The pouring temperature is set at 725 °C, while the mold temperature is conditioned at room temperature or about

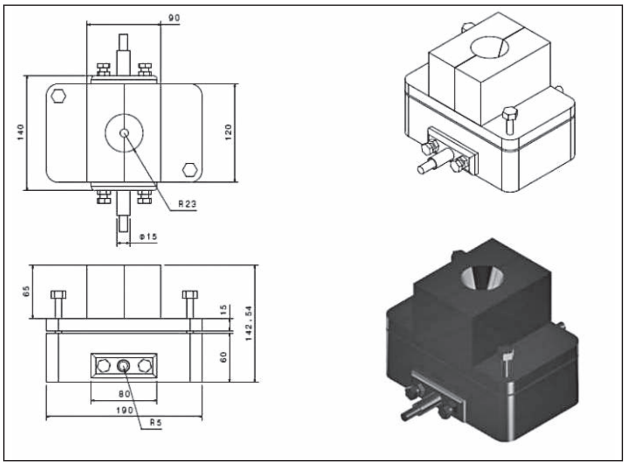

Figure 1 Dimensions and 3D view of the steel mold

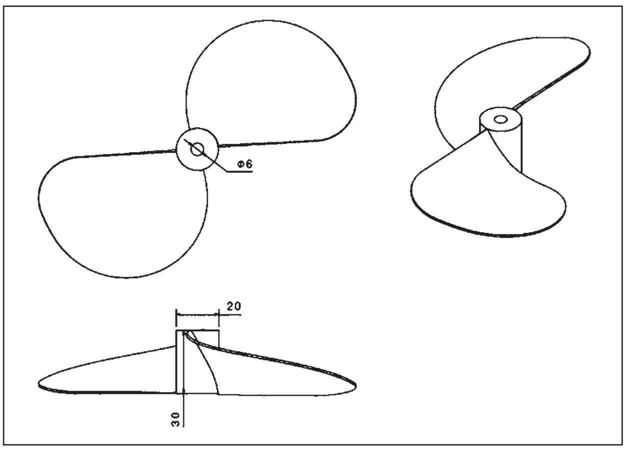

Figure 2 Dimensions of the ship's propeller

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26 °C and 250 °C (±3 °C). Recycled aluminum is cut into small pieces so that it can be placed in a ladle for further placement in the combustion chamber during the melting process. The chemical composition of aluminum alloys was analyzed using standard metal spectroscopy. The molten metal is poured into a permanent mold made of carbon steel EMS/17330 and allowed to freeze at room temperature, the mold cavity is in the shape of a ship's propeller. The dimensions of the steel mold are as shown in Figure 1 and the dimensions of the ship's propeller are as shown in Figure 2. Casting product defects are observed through a digital camera. The area and geometry of defects in cast ship propeller products were measured using the ImageJ application.

RESULTS AND DISCUSSION

The chemical composition of the propeller products produced by metal casting was analyzed by standard metal spectroscopy, as shown in Table 1. The material used was recycled aluminum alloy.

Figure 3 shows an enlarged Al-Si phase diagram with Si composition up to 12 wt.pct, with a temperature range from 300 to 700 °C. Referring to the chemical composition of the recycled aluminum metal alloy, the composition of the Silicon (Si) alloy is 10,92 wt.pct. So the melting point of this aluminum alloy is about 588 °C.

Table 1 **Chemical composition/wt.%**

Si	10,92
Fe	0,476
Cu	2,696
Mn	0,029
MG	0,573
Cr	0,022
Ni	1,746
Zn	0,120
Ti	0,057
Sn	0.012
V	0,026
Zr	0,060
Co	0,015
Li	<0,300
Al	Bal.

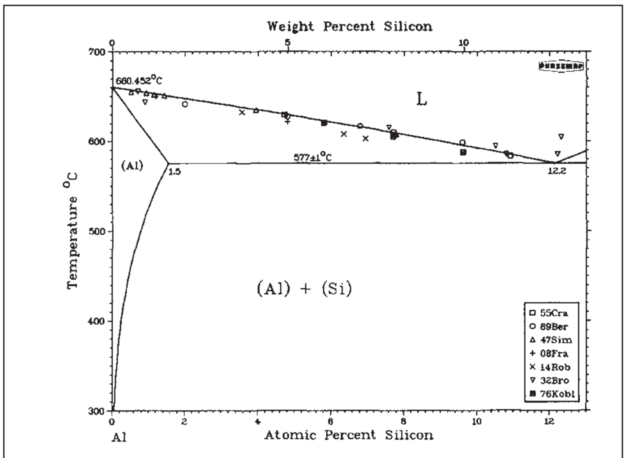

Figure 3 Enlargement of the (Al) liquidus with selected data [8]

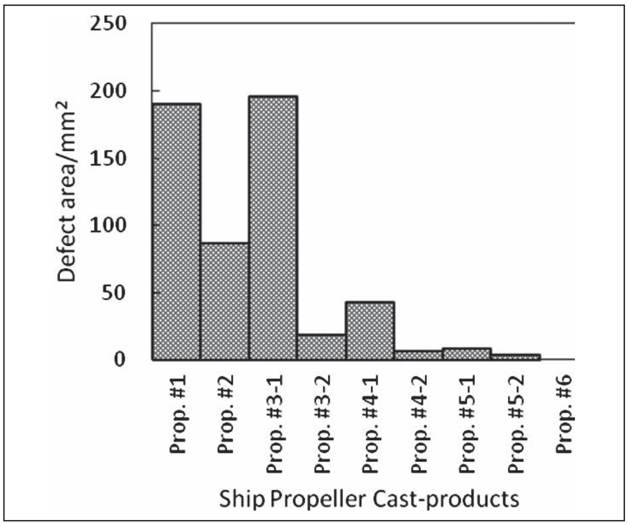

Figure 4 Defect area in cast propeller products

In this experiment, the metal casting temperature was set at 750 °C (the superheat of the molten metal was 137 °C). Meanwhile, two mold temperatures were given in this experiment: 26 and 250 °C.

Figure 4 shows the area of defects formed on one or both blades of the ship's propeller. The mold temperature for propeller 1 (Prop.#1) to propeller 5 (Prop.#5) is the mold condition at room temperature (no preheated). Thus, the product is observed to have defects in one or both blades. However, propeller 6 (Prop.#6) was preheated to the mold at 250 °C. As a result, there is no visible defect in the blade. Similarly, for the next propeller products produced, there is no indication of defects when heated in a metal mold (250 °C).

Macroporosity defects were seen in propeller 1 (Prop.#1), propeller 2 (Prop.#2), and propeller 3 (Prop.#3-1 and (Prop.#3-2), respectively, as shown in Figure 5. At propeller 1, a macroporosity defect is seen on one side of the blade with a geometry that is almost like an irregular rectangle. The defect area measured through image processing application is 160,62 mm^2. Propeller 2, the geometry of the porosity macro defect looks like an irregular oval with one sharp edge. The size is half smaller than the propeller defect 1, the measured area is 86.5631 mm^2. Propeller 3, macroporosity defects formed on both sides of the blade (Prop.#3-1 and (Prop.#3-2) with an area of 196,118 and 19,144 mm^2, respectively.

Figure 6 shows the shape and geometry of the misrun defects seen on one of the blades of the propeller 4 product (Prop.#4-1), so the dimensions of the blade are not perfect. On the other hand, cold shut defects were also seen on blade 2 (Prop.#4-2) of the same product (propeller number 4). The area of each defect is 43,293 mm^2 for misrun defects and 6,341 mm^2 for cold shut.

Cold shut causes discontinuity in the propeller blade product. The cause of the cold shut defect in the formation of two flows of molten alloy that do not join properly is when the liquid fills the cast cavity.

Figure 7 shows the shape and geometry of the shrinkage cavity defects formed in the two-blade base areas (near the sprue). The measurement of the defect area is

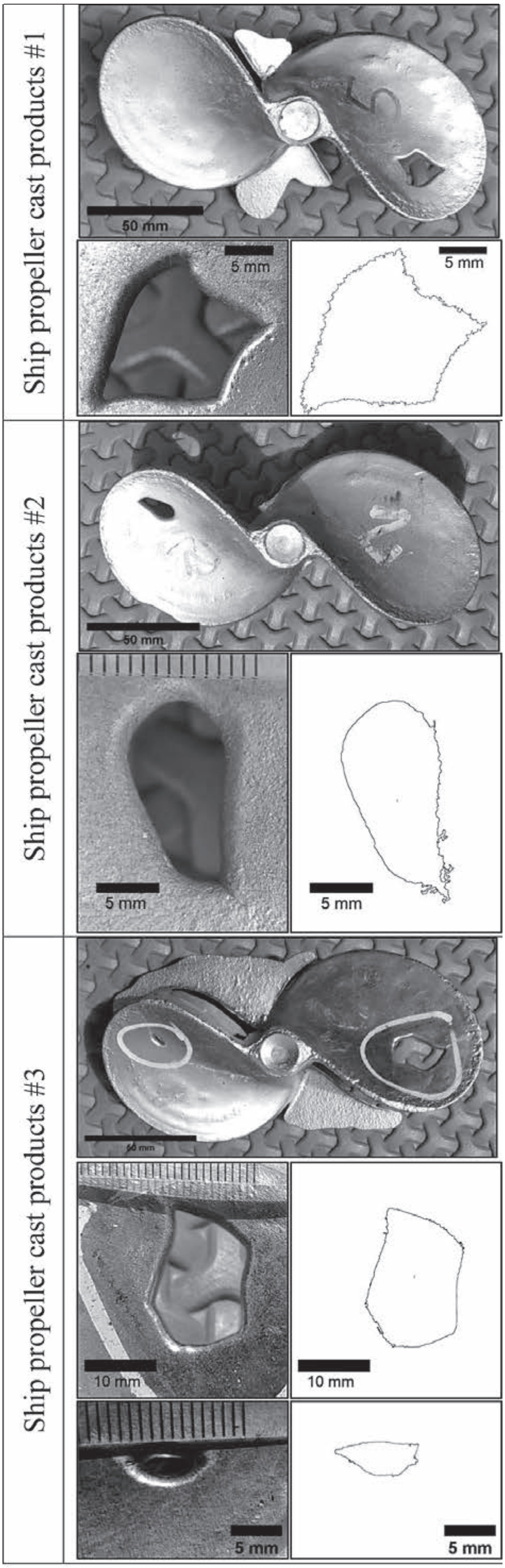

Figure 5 Macroporosity defects formed in the cast products numbers 1-3

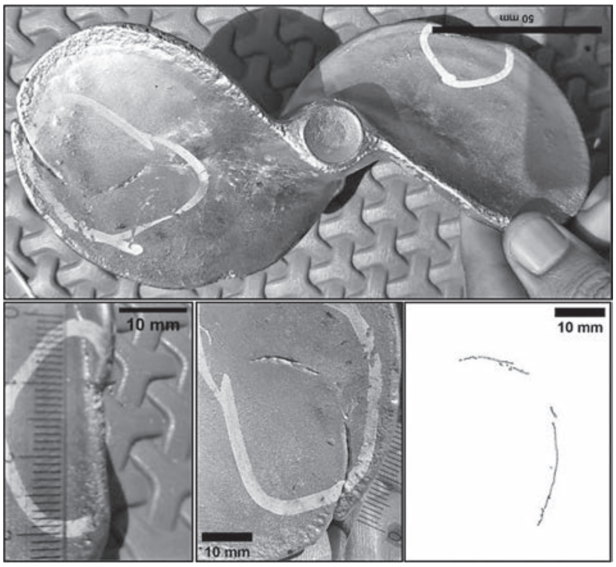

Figure 6 Misrun and cold shut defects on ship propeller cast products #4

8,67 and 3,921 mm^2, respectively (Prop.#5-1 and Prop.#5-2). Meanwhile, propeller product number 6 (Prop.#6) and so on did not find any defects on the surface or holes in the propeller blade area or tip (Figure 8). This shrinkage cavity defect is caused by a lack of liquid metal when solidifying the metal. The decrease in temperature of the metal during solidification causes shrinkage. Some parts lack liquid metal in the mold cavity, which will cause a shrinkage cavity. Holes are formed on the upper surface while the lower surface of the blade appears to be filled with solidified molten metal, this is due to gravity.

Several defects were seen in propeller products number 1 to 6, caused by no-preheating to the mold (at room temperature/ 26 ^{o}C). Meanwhile, after preheating the molds it succeeded in reducing defects such as macroporosity defects, misrun defects, cold shuts, and shrinkage cavities. The extreme drop in temperature occurs in the condition of the mold without preheating. When the molten metal touches the metal mold, thermal shock occurs and makes the liquid metal that is directly in contact with the mold cavities freeze quickly. Such rapid freezing produces defects in the tip area of the ship's propeller, as shown in products 1 to 4. The formation of defects is influenced by the cooling curve which is dramatically dropping due to heat transfer conduction from the molten metal to the metal mold and then transferred to the ambient air. A drastic drop of temperature from 760 (pour temperature) to 300 ^{o}C is recorded in the first 10 seconds when the molten metal touches the metal mold. Quick solidification is not only causing defects but also affects the properties of metal alloys [9].

In product numbers 1-3, macroporosity defects are seen with various shapes but are generally in square or irregular circles. Porosity defects are caused by extreme temperature differences between the molten and the die. Other causes are low pouring temperature, metal liquid contaminated with the dirt during the melting and casting process, lack of air ventilation, too much lubricant in the cast cavity [10].

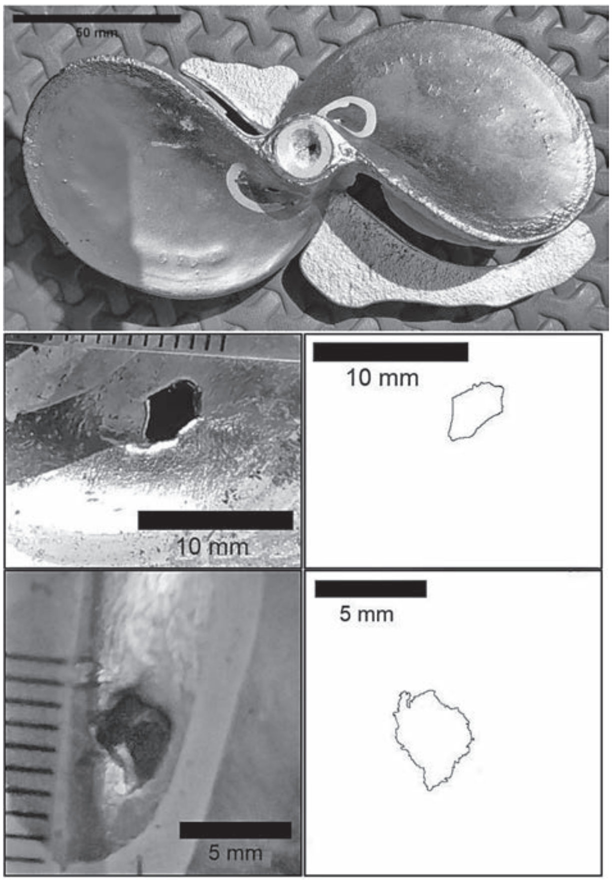

Figure 7 Defect of shrinkage cavity on ship propeller cast products #5

The effect of mold temperature on casting defects is due to high or low solidification rate. High mold temperature will cause a low cooling rate. The low cooling rate will reduce the thermal gradient which affects the ability of the metal liquid to flow in the mold cavity unevenly. The low cooling rate will also extend the time available for the liquid to move freely in the mold cavity. In addition to the casting temperature that is too low or the mold is not preheated, other causes of defects are idle casting, insufficient metallic fluid, insufficient ventilation, too little pressure due to insufficient sprue height, oxidized liquid metal, a lot of impurities during the melting process, cast cavity (angles, sharp, thin and wide).

CONCLUSIONS

Casting defects in recycled aluminum alloys have been evaluated in this experiment. Two mold temperature conditions have been treated during the production of the propellers: without preheating and preheat 250 ^{o}C in the die mold. The defects observed in cast products are macroporosity, misrun, cold shut, and shrinkage cavity defects. The location of the defect is generally formed in the tip region of the propeller blade. Geometry and area have been measured using an image analysis application. The maximum area of defects formed is 196,118 mm^2. However, defects were not found in the ship's propeller product when the die mold was preheated at 250 ^{o}C. The heat of the mold reduces the freezing interval, thus giving the liquid more time to fill all sides of the mold cavity.

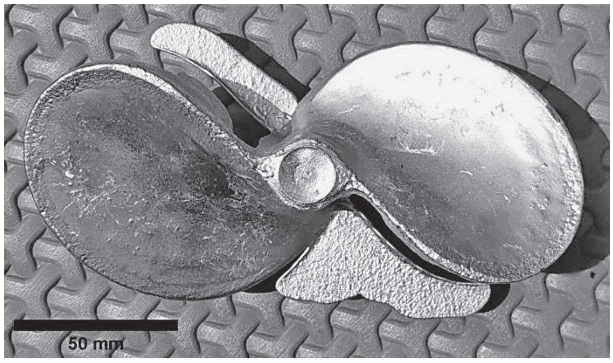

Figure 8 Products without defects in ship propeller cast products #6

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Note: The responsible English translator is Faisal - the Language Center, Syiah Kuala University, Indonesia.