JOURNAL OF MECHANICAL SCIENCE AND ENGINEERING
Vol.1 No.1 October 2013

Effect of The Pressure of the Squeeze Process on the Hardness and Micro Structure of Recycled Aluminum Materials

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Article history

Received XXXX
Received in revised form XXXX
Accepted XXXX

Abstract

A squeeze casting process produces the final accurate products with good quality. It casted microstructure results look more dense and homogeneous and have good mechanical properties when compared with those of foundry castings. The recycled materials used were 25 kg piston aluminum alloys, 25 kg and 25 kg wheel in the form of a mixture (brake, engine cover, and household furnishings) that were melted in the processing unit. The process of compacting system is undertaken with a direct squeeze casting technique. The molten metal was poured into a mold at a temperature of 750 ° C, and then pressed for 60 to 70 seconds. The pressure process of 30 MPa is applied for duration of 75 seconds. The pressure process was repeated at 50,70,90,110 MPa, 130 and 150 MPa and the casted material was removed from the body casting in the mold. The composition of the test results of recycled aluminum is 84.75% Al and 8.985% Si, with surface hardness 130 MPa at a pressure of 89.74 HBN. The squeeze casting process increases surface hardness by 22%. The hardness of squeeze surface was influenced by the pouring temperature, the time pressure and the force suppression. The microstructure of the materials tends to move up and retracts with increasing of applied pressure.

Keywords: *aluminum, recycling, squeeze casting, microstructure and hardness*

1. INTRODUCTION

The squeeze casting is a casting process of applying pressure of freezing when materials are being frozen, this is an excellent combined process of forging and casting. This squeeze casting process may improve the physical and mechanical properties of materials, especially aluminum based alloys with magnesium. It is capable of producing castings which have characteristics of those produced by a forging process.

The squeeze casting has a number of advantages such as gas reduction, reduction in shrinkage, porosity reduction: it does not require a down channel and adders. In addition, the microstructure of castings can be easily manipulated through a good process control, such as pouring temperature and the amount of pressure applied [2].

The casting squeeze process is a casting method that is easy to implement: it is economical and efficient in the use of raw materials and can produce high continuous cycle. Moreover, it can produce castings that have physical properties such as wrought results and improve mechanical properties. The grain and smooth surface can be achieved with the use of aluminum and magnesium alloys. It can also reduce the amount of porosity defects in casting products. Furthermore, it is capable of producing products with high precision shape and accuracy [1].testing 0.350 Joule/mm^2 until 1.067 Joules/mm^2.

2. METHOD AND PROCEDURE

Typical properties of materials need to be well identified because they are used for various purposes and various conditions, and the properties much desired include mechanical and technological ones. Most of these properties depend on the type and ratio of the material or the shape the elements and composition [1].

The mechanical properties of aluminium can be improved by combining with other elements such as copper, silicon, magnesium, manganese and nickel. The aluminum alloy has several advantages, for example, Al-Si, Al-Cu-Si and are commonly used for machine parts, and Al-Cu-Ni-Mg and Al-Si-Cu-Ni-Mg for heat-resistant machine parts, whereas A-Mg for corrosion-resistant parts are also obtained. Aluminum-copper alloy with 4.5% Cu has good mechanical properties and capable of being modified into a good engine. Aluminum-silicon alloys with silicon content of 2% have a nature capable of good castings [6], but have poor mechanical properties because it has a large silicon grain structure, and improvement of the mechanical properties of materials is done by adding Mg, Cu or Mn element and and is performed by the heat treatment process. When aluminum alloys is heated with Si content of 7% - 9% and Mg 0.3% - 1.7%, it will harden; it causes Mg_2Si preserved and it has very good mechanical properties. Alloys containing about 4% - 10% of Aluminum Magnesium have good properties against corrosion, because it have about 30 kg/mm^2 tensile strength and elongation above 12% [6].

Crucible furnaces and flame temperature are used to melt the aluminium alloys. In order to reduce the smelting and metal oxidation, the aluminium alloys should be cut into small pieces [6]**.** The foundry industry is generally observed using flame furnace temperture. Based on the mechanism of pouring molten metal into a mold, squeeze casting are generally grouped into two types, namely: direct squeeze casting and indirect squeeze casting [8].

Direct Squeeze Casting (DSC) (Figure 1) is a term used in the casting process in which molten metal has cooled (frozen) and exerted pressure directly in order to eliminate the onset of gas porosity and the shrinkage. This process is known as liquid metal forming, squeeze forming, casting and extrusion pressure crystallisation.

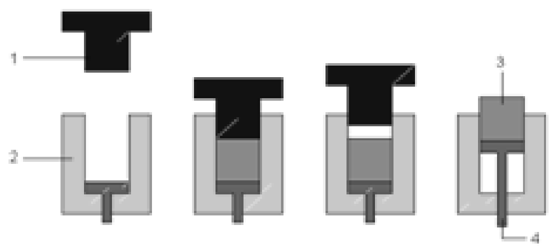


Figure 1. Direct mechanisms Squeeze Casting.[5]

Indirect squeeze casting (ISC) [4] is the process of the metal injection into a mold cavity with the help of small-diameter piston in which the mechanism of suppression is maintained until the molten metal is solidified. ISC's main advantage is the ability to produce castings with more complex shapes by providing some core expenditure system (core pull). This process is actually a hybrid of the low pressure and high pressure die casting. ISC process is not as good as the DSC, in particular there are two drawbacks when ISC is compared with DSC.

Inefficient use of raw materials due to the necessity of making the runner and gating system. The efficiency of material usage is only 28% [6]. For example, to produce a piston with a weight of 0.62 kg of casting materials, 2.2 kg of wrought aerospace alloys are required because they have high strength. It is basically difficult to process with ISC, even if the results cannot be free of defects in castings. The principe of ISC process is shown in Figure 2.

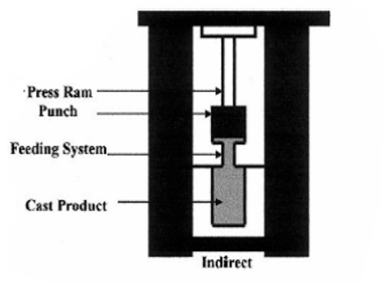


Figure 2. Mechanism of Indirect Squeeze Casting.[4]

The most important factor in the ISC is the process of filling the cavity smoothly without causing turbulent flows. This means that the liquid flow is laminar during the filling of the cavity to mold. The lower the speed of charging, the higher it causes chances of getting laminar flows. But the speed of low charging may cause larger heat loss, lead to the premature solidification and cold shuts [4]. Therefore it is necessary to determine the optimum charging speed. Thus the flow must be in laminar type. The most efficient way to get the optimum charging speed is by using numerical simulations because it can eliminate the trial and error time, save the use of materials and minimize the use of labor.

Squeeze Casting Process for casting products to meet the ideal conditions of a sound-cast, there are some parameters that need to be considered, namely: [8]

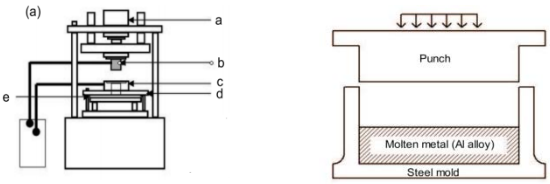
1. Melt Volume. It requires accurate control when molten metal is poured into the cavity of the mold.
2. Casting Temperature. The temperature depends on the type of alloy and shape castings or components. Usually the temperature castings taken from 6 to 55^{o}C above the temperature of liquid.
3. Cooling Temperature. The normal of cooling temperature is 190 up to 315^{o}C. To make product by casting that have relatively thick cross section, it is better that the temperature can be set up to a certain value. Regular temperature is set

on punch 15 to 30 ° C that is below the lowest temperature to allow for looseness or adequate ventilation. Excessive clearances between punch and processes cause erosion on both surfaces.

4. Waiting time. It is the length of time measured from the start of pouring molten metal into the mold cavity until the punch touches surfaces and begins tapping the surface of molten metal. A complex cross-sectional shape requires sufficient time for the molten metal to fill the entire cavity of the mold. There is the need for a considerable time before the punch touches and presses the molten metal. This will avoid the occurrence of porosity due to shrinkage.
5. Pressure Limit. The normal pressure range is 20 to 211 MPa or depending on geometry of component and mechanical properties required. The minimum pressure is about 20 Mpa **[5]** .
6. Requirement. The required time is calculated from the current emphasis punch at its lowest point until the punch is removed. Casting of 9 kg varies between 30 to 120 seconds. But usually this duration also depends on the geometry of the desired castings. For composite materials, the pressure time after freezing, will not improve the properties but only adds to the cycle time alone.
7. Lubricant. Oiling the squeeze casting requires lubrication on the surface, in order that it is easy for a product to remove the product from the mold. However, the lubrication system is sought not to cover the ventilation holes on dies. For aluminium alloys, magnesium, and copper, the surface of the dies are usually sprayed with colloidal graphite lubricants. While ferrous casting, dies usually coated with a surface similar ceramic materials to prevent the effects of welding between the surface casting products.
8. Filling Rate. The lower the charging speed, it would lead to the higher possibility to get laminar flow. But imposing low speed can lead to large heat loss, result in the occurrence of premature solidification and cold shuts. It is therefore necessary to determine the optimum charging speed, so that the filling into laminar flow and does not cause the occurrence of turbulence [7].

EXPERIMENTAL PROCEDURES

The material used for the manufacture of test specimens was taken from recycled aluminium in the form of 25 kg piston alloys, wheel alloys 25 kg, 25 kg of shoe brakes and engine housing. The materials were then cut into pieces. It was made up component of raw materials for the manufacture of test specimens with the DSC. The process of making the test spaciments were done. The input material recycled aluminium that were cut, were heated by preheating in the furnace at a temperature of 100 °C to 750 °C. The mold was preheated at a temperature of 300 ^{o}C. The molten metal was poured into a mold at a temperature of 750°C, and then pressed for 60 to 70 seconds. The process of providing pressure, starting at 30 MPa with a duration of 75 seconds. The process was repeated at pressure 50, 70, 90, 110 130 and 150 MPa respectively. Then the spacimen was removed from the mold. The mold was cleaned to make the next test.



(a) (b)

Figure 3. (a) Hydraulic System Pressures (b) Mold squeeze system [8]

RESULTS AND DISCUSSION

Composition Testing

Material composition affects the mechanical properties and the physical properties of a material. The mechanical properties of aluminum alloys was determined by the transition metal elements which can lead to the solid solution hardening elements such as copper, zinc, iron, and magnesium. The mechanical properties of aluminum alloys can also be identified by combining material castings and by adding certain amounts of other elements of Cu, Zn, Pb, Sn, Mo, and so on. However, such strategy sometimes cannot be implemented because of the high price of these elements.

The process of adding the element was conducted at the time when the metal melts and freezing occurs during the process atom substitution. The freezing of casted parts causes a contact with the mold, then the core-crystallized grows. The size of grains in this region was relatively smaller and is called the chill zone. The casting inside the cools more slowly than the outside, so that the crystals are grown from the core origin and crystal grains are elongated like a column (Columnar Zone). This structure appears clearly when a large temperature gradient occurs on the surface of castings. The central zone has a small temperature gradient that contains relatively larger grain sized than the chill zone and this area is the arrangement of the crystal grains of polygons with arbitrary orientation.

The process of combining or solute atoms enter the lattice as a solid solution solvent always produce alloys that are stronger than pure metals. There are two types of solid solutions. If the solute and solvent atoms have the same size, solute atoms will occupy lattice (lattice point) solvent atoms in the crystal lattice. This process is called solid solution substitution. If the size of the solute atoms is much smaller than the solvent atoms. Solute atoms occupy positions in the lattice solvent insertion process is called solid solution insertions (Interstitial Solid Solution). The carbon, nitrogen, oxygen and boron atoms are often used in marin applicattion.

Ductility aluminium alloys at the room temperature can be improved by adding alloy elements with more resilient properties. The elements can be either copper, zinc, iron, magnesium and Si. The material composition affects the mechanical properties and the physical properties of a material. The process of testing the composition of the test material in this study conducted on aluminium alloy casting products.

The test result of Aluminium alloy are undertaken means of X-Ray Spectrograph Poertaspec Model 2501 (Non Destructive Test) and the data obtained from the testing of aluminum composition can be seen in Table 1.

Table 1.Aluminum alloy Material Composition

Spacimen	Al	Si	Ni	Fe	Cu	Mn	Zn	Mg	Pb	Ti	Bi	others
1.	84.6	9.11	0.257	0.907	2.42	0.157	1.97	0.22	0.0774	0.066	0.046	0.1696
2.	84.9	8.86	0.254	0.852	2.43	0.164	1.95	0.23	0.0791	0.0644	0.051	0.1655
Average	84.75	8.985	0.2555	0.8795	2.425	0.1605	1.96	0.225	0.07825	0.0652	0.0485	0.16755

We can see that there is a difference in composition elements that make up the dominant alloy testing which was conducted on the dominant elements of aluminum and silica, if it is compared to the standard product tables, recycled material composition reaches the composition of 4xxx series aluminum alloys (4343/ANSI) as in the following table (Table 2).

Table 2. The composition of aluminum alloy Standard Series 4

Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	others	-
88.05	8.2	0.8	0.25	0.1	0.15	0.15	1.7	0.2	0.2	0.2	4343(AA/ANSI)

The Fe element in the product affects the characteristics of corrosion resistance. This is due to the high content of element of Fe in recycled materials. As we konw that the materials used as spacimens were the results of the turning process. The comparison of the elements Cu and Zn were balanced but there was an element of Zn which was more dominant of existance. The tribological behavior of aluminum alloys states that the ideal type of aluminium alloy having poor wear resistance is silicon type of aluminium alloy. The dominant composition of Si used 5% to 20%. Properties of wear-resistant alloys is possible because of the nature of the elements Si are very hard.

Hardness Testing

Surface hardness is a result of the penetration resistance of materials and it is found by the rate of hardness quotient P load (kgf) on a surface area of press steel ball. The hardness test results on aluminum alloy were conducted by squeeze casting technique that may increase the surface hardness. Increasing levels of pressure on the aluminum alloy on surface has given a significant pressure on the process, and this was due to the density of the alloying elements during solidification process. The greater the pressure, the hardness will increase. However, the amount of pressure has its limits due to the metal solidification process and the nature of incompressible liquid metal. Despite the great pressure of the nature of the liquid metal solidification, the compressible liquid metal needs to be hindered.

The process of casting porosity often leads to defects on the surface of casting product, so that the low rate of hardness can cause the surface to improve with a bit of pressure on the li.quid metal combination. Casting techniques and materials used, casting system use the force of gravity or the hold of a very large influence on the mechanical properties of materials, especially surface hardness.

From the results of surface hardness testing of aluminum alloys (Figure 4) which were not under pressure 70.38 BHN, hardness increases. The hardness occurrs at a pressure of 130 MPa as much as 86.67 BHN. The process of the pressures imposed also increases the surface hardness when compared to aluminum alloys that were not imposed pressure. It is caused due to an increase in density of each alloy elements in the alloys.

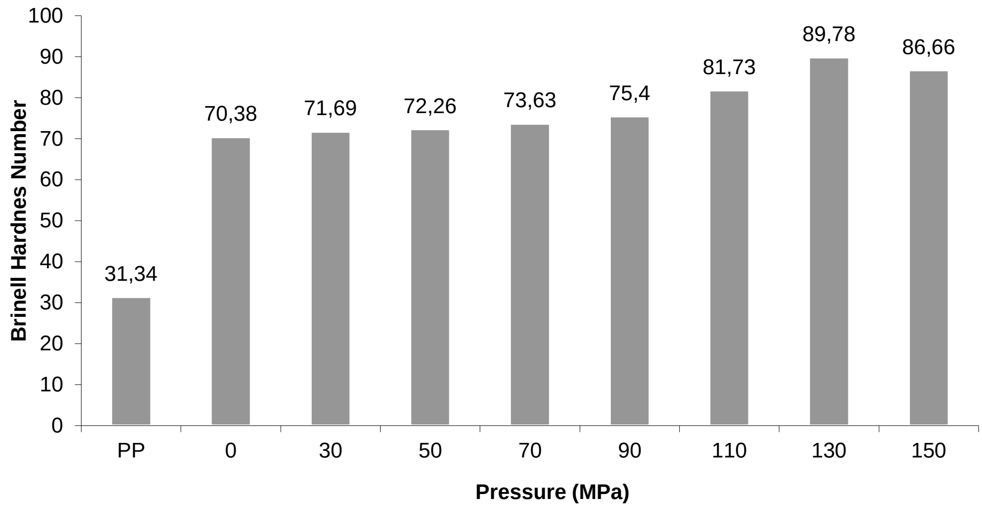
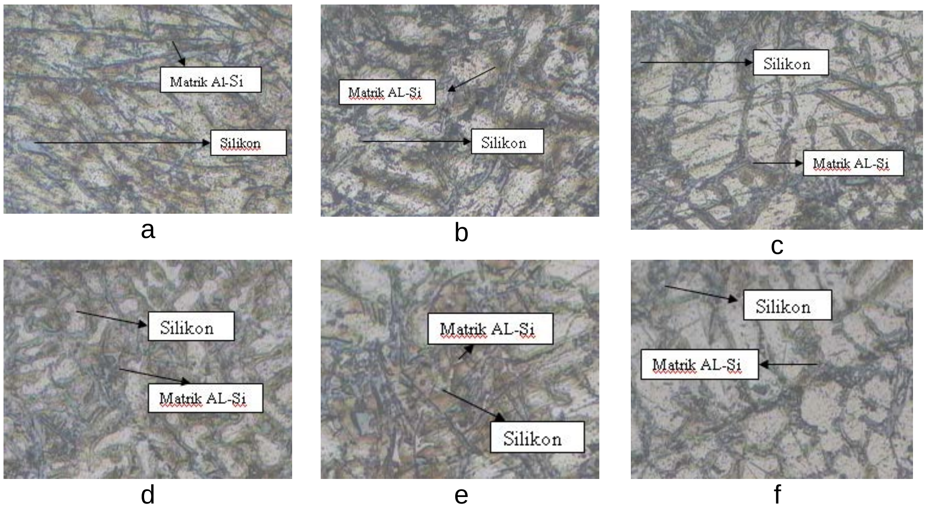
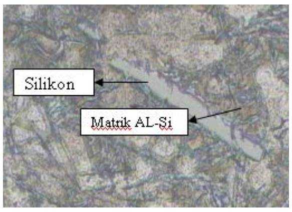


Figure 4. Surface Hardness Chart

Micro Structure Testing Materials.

For these purposes, the tests were conducted on metallografi aluminium alloys to find the image of the microstructure that was taken with the aid of an optical microscope with 5 ml HCl etching materials, 3 ml HF, 3 ml HNO_3 mixed with 190 ml of distilled water. The test material was recycled made up of alloys coming from pistons engine, engine blocks, shoe brake, wheel and household appliances. The casting process did not use smoothing material items. The normal freezing conditions resulted from casting aluminum alloy that did not use smoothing columnar grain structure. It can be seen in Figure 5a where the alloy structure has distant and rough surfaces.





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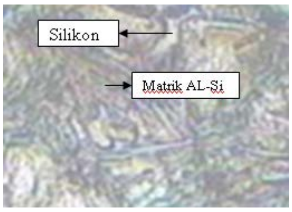

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Figure 5. Structure of Al-Si Alloy Micro a. Without pressure, b. 30 Mpa c. 50 MPa, d. 70 MPa, e. 90 MPa, f. 110 MPa, g. 130 MPa, d. 130MPa

CONCLUSION

Three conclusions are drawn from this study:

1. Squeeze casting process increases surface hardness by 22%, this process can also have high stress, capable to redce the porosity defects and can be used to produce castings which strengthened with fiber (composite).
2. Surface hardness is influenced by squeeze casting temperature, time, pressure and force.
3. Composition of recycled aluminum 84.75% Al and 8.985% Si, with a surface hardness at 130 MPa pressure at 89.74 HBN.
4.

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