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Recycled Aluminium from Motorcycle Pistons with Home Industry Casting Process

[1]Syamsul Hadi, [1]Anggit. Murdani, [1]Wirawan, [1]Haris Puspito Buwono and [2]Imam Muda Nauri
[1]*Department of Mechanical Engineering, State Polytechnic of Malang, Jl. Soekarno-Hatta No. 9, Malang 65141, Indonesia*
[2]*Department of Mechanical Engineering-Automotive Engineering, State University of Malang, Jalan Semarang No. 5, Malang 65145, Indonesia*

Key words: Tensile specimen, tensile strength, recycled aluminium, motorcycle piston aluminium, shrinkage tolerance

Corresponding Author:
Syamsul Hadi
Department of Mechanical Engineering, State Polytechnic of Malang, Jl. Soekarno-Hatta No. 9, Malang 65141, Indonesia

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Abstracts: Changes in tensile strength of recycled aluminium from the piston as a problem encountered. The objective of this research is to know the tensile strength of recycled aluminium from piston for the next use. The methods used are: design and manufacture of tensile specimen mold, specimen casting, tensile testing, material composition testing and data analysis. The test results showed that the tensile strength of the motorcycle piston aluminium worth 376 MPa was decreased to 191 MPa for the 1^{st} recycled (49%) from the 1^{st} recycled to the 2^{nd} recycled value of 118 MPa (38.3%) and from 2^{nd} recycled to 3^{rd} recycled worth 117 MPa (0.8%) caused by loss of elements during recycling include Cu, Si and Fe. The shrinkage tolerance in a successful foundry into a tensile test specimen is smaller than 6%. The SEM photographs show that the porosity of the 3^{rd} recycled aluminium is less than in the 2^{nd} and 1^{st} recycled which means the solubility of the alloying element is preferable, wherein the insoluble elements (Cu, Si and Fe) are decreased.

INTRODUCTION

The casting of aluminium recycling is mostly done by the home industry for the needs of supporting components such as a handle for brake, clutch or push step of a motorcycle or other accessories. The strength of aluminium for such supporting products is often not adequately addressed, about to passenger safety, therefore research on these products is important to do with an abundance of aluminium scrap and accident prevention for passengers.

Knowledge of recycled aluminium tensile strength and the cause of the drop of tensile strength can provide information for the foundry to adjust its critical cross-sectional area, thus obtaining adequate strength for a recycled product.

As a comparison of the ranking of quality of several casting methods for the production of safety boxes between four methods including Low Pressure Die Casting (LPDC) is better than Sand Casting (SC), SC is better than Gravity Die Casting (GDC), GDC is better than High Pressure Die Casting (HPDC)[1], so, the aluminium casting process with a GDC is better than an HPDC. The solidification time of Al (20%)-Sn in the sand casting of practice and theory results is 105.88 and 83s and on-die casting is 2.5 and 1.77s while solidification time of Al (40%)-Sn on sand casting is 111.33 and 91s and on-die casting is 2.88 and 1.98s[2]. In the study used die casting with raw material from aluminium motorcycle pistons scraps and cooling with air naturally about 2 min, then casting products can be removed from the steel mould.

Counter gravity casting technique is an ingenious method in the production of aluminium alloy parts to obtain superior mechanical properties by using a simplified vacuum control system and manually positioning the moulding flask[3]. The research used gravity casting technique but without being made vacuum because in the small industry the availability of equipment and capital is limited and the product is used for needing with general mechanical properties/not superior. The number of defects is reduced for the gating system from the bottom compared to the gating system from the side and the top[4]. It has been obtained better conditions if the gating system is designed from the direction of the bottom because it can minimize the occurrence of voids in the product.

Continuous feeding of sponge iron pellets into the electric induction furnace is a convenient way of producing high quality cast iron and steel[5], unlike aluminium smelting by using a brander with LPG fuels whose quality is not as high as using an electric induction furnace.

The tensile strength in wrought material is larger than cast material[6]. The difference in tensile strength of the lower cast material than the wrought material makes an important point related to the microstructure and its mechanical properties.

The quantitative study of the effect of Al casting alloy elements with 12% Si mass for pistons depends on Ni and Cu content. As the Ni and Cu contents increase, they can increase the tensile strength of the matrix but the elongation decreases[7]. Ni content that has a melting temperature of 1455°C and Cu 1085°C can increase the tensile strength of aluminium piston for hot operating conditions.

Aluminium 6063 cast results show a significant increase in hardness (33.7 HB) with the use of naturally bonded sand mould and exhibit the highest impact strength when used in metal mould rather than sand mould and centrifugal mould[8]. The use of mold produces castings with different mechanical properties.

Improved mechanical properties and reduced porosity were obtained under stir cast conditions compared with conventional gravity casting materials[9]. A stirring of molten metal improves the mechanical properties and decreases the porosity of cast results.

Study the effect of casting rate and temperature on mechanical properties of the aluminium alloy at a velocity range of between 2.0 and 16.0 cm sec^{-1} while the melting temperature between 680 and 750°C produces strength in the range of 65.5 and 112 MPa with casting speeds ranging between 2.2 and 2.8 cm sec^{-1}, yields 65.4 HR_C and tensile strength of 127 MPa[10]. At aluminium casting from the recycle piston at temperatures around 800°C which is sufficient with LPG fuels with manual pouring this decreases the temperature a few degrees.

Research on the characteristics for aluminium alloys with die casting against the tendency of die soldering formation, sludge formation, the fluidity of alloy and machine-ability is influenced by Fe and Mn content. When the Fe content is high, it should be prevented to form large hard spots by keeping the Fe content at the lowest level and the Mn content must be at the highest level to prevent the occurrence of die soldering[11]. In the casting of Aluminium, alloys should be considered the presence of Fe and Mn elements that can affect the casting characteristics.

The new process has been developed for the semi-solid casting of aluminium alloy billets of diameter 75 and 150 mm, continuously cast with mechanical thread mixer and/or electromagnetic stirrer[12] resulting in solidification of mixture structure of granular particle and fine eutectic. Aluminium alloy stirring can affect casting results.

The Crimson process has better behaviour during mould filling and solidification which can reduce the metal turbulent of liquid causes the trapping of film oxide on metal liquid surfaces resulting in micro cracks and casting defects rather than conventional casting processes using gravity filling method with sand mould (SCP/sand casting process) or metal moulding (investment casting process/ICP)[13]. The Crimson process improves the conventional casting process.

Process parameters in the foundry industry require correct guidance to the quality control department of the casting defects can be given analysis and solution[13]. Research of several parameters such as blowhole, sand inclusion, sand burning, cold shut, gas porosity, mismatch, distortion, flash defect, shrinkage, crack, sink mark, metallic projection, defective surface, incomplete casting is required standardization guide.

Results of 5 samples of die-cast aluminium A380 solidified with pressure variations obtained hardness between 76 and 85 RHN. The SEM and metallographic results show that at high pressure, there is a change in the finer micro-structure with increased pressure[14]. Increased casting pressure produces a rising hardness and a finer micro-structure.

An effective recycling method in the aluminium foundry in small industries has been investigated which shows that the alloy chemistry of the piston scrap is consistently equivalent to commercial piston alloys such as AC8B and LM26[15]. The alloy chemical hypothesis generated by the small industry is consistently equivalent to the commercial alloys used from the used components that are melted.

The quality of cast products in aluminium casting plants depends on the quality of the molten metal influenced by cooling curve, reduced pressure test, Tatur test, mould k, spiral test, solubility of hydrogen in molten aluminium and melt cleanliness assessor probes[16]. The quality control of the product is strongly influenced by the completeness of the casting process equipment.

Hot tearing is a severe defect in castings as a measure of aluminium alloy cast-ability. If hot tearing occurs, then the castings must be repaired or become scrap. Test preparation of constrained rod mould, load measurements and temperatures for the measurement of contraction strength and temperatures during solidification of casting in the study of the properties of tensile coherency, crack initiation and crack propagation[17]. Hot tearing on a cast aluminium alloy is avoided as far as possible to not cause damage to products and losses.

Aluminium alloy recycling has provided economic benefits in optimizing the use of recycled metals to a more eco-friendly and neglected world because of its potential for maximizing recycling circles based on mass balance and determining the most effective composition of alloys[18]. The design of the alloy composition based on the balance of the mass must be achieved towards a more environmentally friendly world. The research of Cu-Al alloys with the addition of 8% Cu increases the yield strength and tensile strength[19].

Preheating of fine sand at 200°C slightly changes the mechanical properties and accumulation of heat can cause cracks[20].

MATERIALS AND METHODS

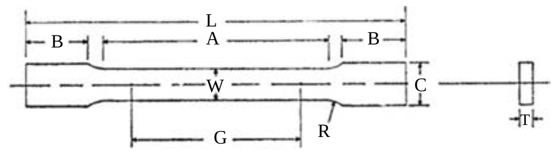
The population of the research sample is aluminium ex-piston motorcycles in the trade. The material has been preliminary tested which has a shrinkage coefficient of ≤6%. If the coefficient of shrinkage >6% occurs the specimen always breaks in its gauge length.

The variables studied were tensile strength through tensile force and elongation recording. The Ultimate Tensile Strength (UTS) calculation was obtained from:

$$\sigma y = F/A \quad (1)$$

Where:
F = Tensile force
A = The cross-sectional area of the gauge length

Strain:



Width of specimen (W): 12.5 mm
Gage length (G): 50.0±0.1
Specimem Thickness (T): selected 10 mm
Fillet Radius (R): 12.5 mm
Overall Length (L):200 mm
Length of clamping by grips (B): 50 mm
Width of the section clamped grips (C): 20 mm

Fig. 1: Standard specimens E8/E8-08[21]

$$\varepsilon = \Delta L/Lo \quad (2)$$

Where:
ΔL = Elongation
Lo = Gauge length

The recycled material composition was obtained from Energy Disperse Spectroscopy (EDS) are shown in Table 1. The cross-section of the tensile test specimen is a rectangle referring to the ASTM E8/E8M-08 standard[21] as Fig. 1.

Data collection techniques are carried out by noting the Force (F) and elongation (ΔL), since, the initial periodic withdrawal of the specimens until the material reaches yield and breaks. It should be noted the average gauge length of 3 measurements to obtain the thickness and width of the specimen in the middle and both ends as well as mechanical marking and gauge length and specimen codes before the tensile test.

Materials of research: aluminium recycled from motorcycle piston 20 pieces of sample on 1st recycled and 15 pieces on 2nd recycled and 10 pieces on 3rd recycled (decrease of specimen number due to oxide in the form of slag on liquid surface permanent marker as a marker of the specimen and paper-120 mesh, band saw, files and paper and pens.

RESULTS AND DISCUSSION

Casting: The mould of the tensile test specimen is made of steel and castings as shown in Fig. 2. The mould comprises a bottom mould (bottom plate) of which there are a mold cavity and a topped sheet in the form of a mould cover (top plate) in which there is a sprue and a raiser as a guarantor for the mould cavity is filled with metal which means non-porous castings (Table 1).

To fuse aluminium scrap is required a brander fuse along with hoses and LPG gas cylinders. Home industries use appropriate technology and supply of equipment and materials available on the market. The condition of the aluminium scrap smelting is accoMPanied by heating the mould around the fire and when pouring the aluminium scrap liquid into the casting chamber on the mould as

Table 1: Chemical analysis of the materials used in the research (wt.%)

Elements	C	O	Na	Mg	Al	Si	K	Ca	Fe	Cu	Zn
1st cycle	9.93	13.08	0.96	0.89	59.3	12.84	0.51	0.82	1.67	-	-
2nd cycle	4.27	1.83	-	0.76	77.36	11.87	-	-	0.83	1.83	1.25
3rd cycle	15.14	5.58	-	0.47	66.53	9.26	-	-	0.82	1.17	1.02

Fig. 2: A pair of molds (top) and specimen (bottom)

(a)

(b)

Fig. 3: Smelting aluminium scrap (a) and pouring it into the mold (b)

shown in Fig. 3. The furnace shape is simply a refractory brick arrangement that surrounds the fuse plate directed to it by the operator.

Example of aluminium scrap castings that fail when using pure aluminium as Fig. 4. After removal of aluminium scrap castings along with sprue (a) and (riser, b), the gauge length of the specimen is broken because the shrinkage of the material is too large.

Fig. 4: Aluminium casting results that fail after removal from the mold

(a) (b)

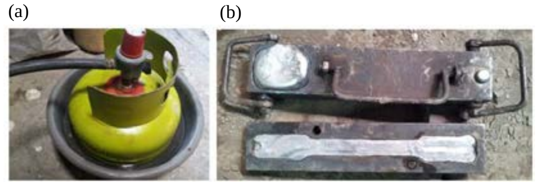


Fig. 5(a, b): Warming of LPG tubes (a) and successful aluminium castings (b)

Fig. 6: Aluminuim scrp castings are easily removed after the bottom mold is sprayed with graphite powder

The heating technique of LPG tube with boiling water can push one-third of the remaining gas contents out into a fire, if not heated, then the flame decrease immediately and the aluminium scrap castings are successfully shown as shown in Fig. 5.

Pure aluminium has considerable shrinkage, so, even if some casting is done, the product can always be broken in the gauge length area because the shrinkage after solidifying exceeds the tolerance of the elastic length. The smelting and casting of aluminium scrap experiments resulted in successful results after cooling was given sufficient time, resulting in reduced casting volume and cast results easily removed. Graphite powder is used as a bulkhead between the casting product and the cavity surface, so as not to stick and easily removed as Fig. 6.

Table 2: Percentage shrinkage of aluminium cast material for tensile test specimens

Materials	Shrinkage (mm)	Percentage	Specimen result
Pure aluminium	1.75	7.99	Fail in gauge length
Aluminium scrap	1.15	5.32	Success
50% Pure aluminium and 50% aluminium scrap	1.25	5.71	Success

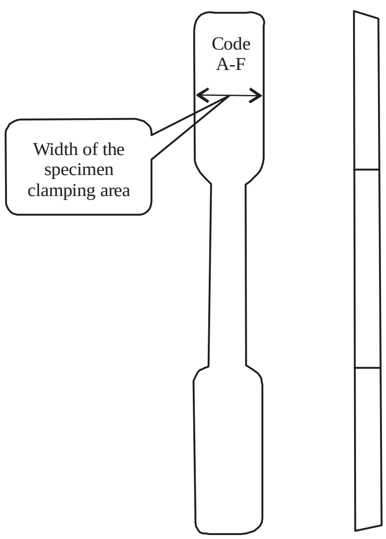


Fig. 7: Location of shrikage measurements of aluminium srap specimens

Evaluation on an Aluminium scrap with a small expansion coefficient and sufficient cooling time allowing sufficient casting results. The duration of cooling is influenced by the temperature of the mould heating before the aluminium casting. After calculation, the expansion value of the width of the specimen clamping area by the tensile machine grips as Fig. 7 is 20.15 mm and the size of the mould is 21.9 mm which means the shrinkage is 1.75 mm or 1.75/21.9 = 7.99%. Shrinkage results with aluminium scrap and pure aluminium are shown as in Table 2.

Evaluation of the cast aluminium expansion coefficient should be small enough (<6%), so that, the specimen does not break in the gauge length area, the cleaning of the oxide formed during the melting should be sufficiently clean and the aluminium pouring should be carried out immediately when the heating fire is reduced. aluminium scrap specimen castings and Tarno Grocky tensile test machines are shown as Fig. 8.

Specimen tensile testing: The stress-strain plot of the aluminium scrap tensile test data after averaging is shown as Fig. 9. The comparison of UTS of aluminium 5005 = 118 MPa and the 1st, 2nd and 3rd recycled aluminium scrap were 191; 118 and 117 MPa which

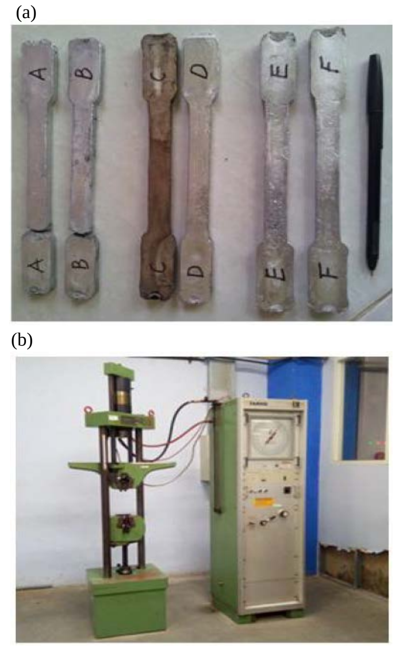


Fig. 8: The results of a pure aluminium tensile test specimen (a and b) and aluminium scrp (C-F) (a) and Tarno Grocky tensile test machine (b)

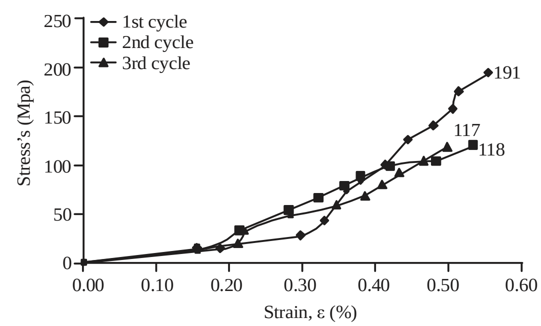


Fig. 9: Results of the stress-strain plot of all data averages of recycled aluminium tesile test results

means the recycling of the 2nd and 3rd aluminium scrap alloys disappears during the melting process, proved after the 2nd and 3rd tensile tests, its UTS is relatively similar to pure aluminium UTS. Elements whose liquid temperature is >800°C, certainly can not be liquid because its melting temperature is only enough to reach aluminium alone, considering that heating only uses LPG and brander. No melting of other alloying elements after stirring the possibility of joining together the aluminium oxide present on the surface of the liquid before being cast aside, so as not to clog the sprue on the mould.

Comparison of the UTS of the aluminium piston motorcycle worth 376 MPa was decreased to 191 MPa for the 1st recycled (49%) from the 1st recycled to the 2nd

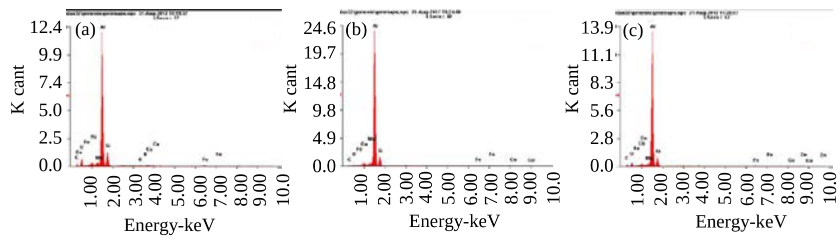


Fig. 10(a-c): The results of EDS of aluminium piston (a) Ist recycled (b) 2nd recycled and (c) 3rd recycled

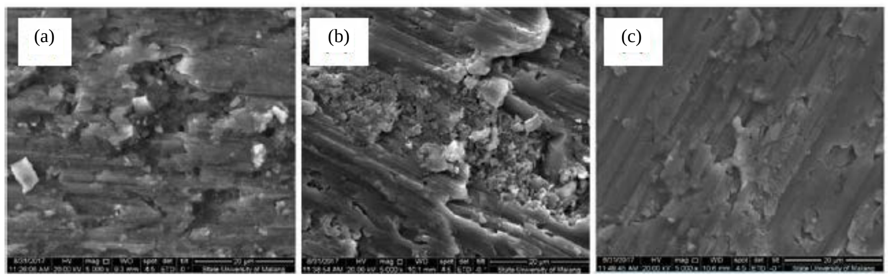


Fig. 11: SEM photographs of aluminium (a) Ist recycled (b) and (c) 3rd recycled

Table 3: Elements of pistons and melting temperature

		Recycle (wt.%)			
Elements	Tm (°C)	Piston	1st	2nd	3rd
Mg	650	1.25	0.89	0.76	0.47
Al	660	84.53	59.30	77.36	66.53
Si	1414	11.65	12.84	11.87	9.26
Fe	1538	0.96	1.67	0.83	0.82
Cu	1085	0.60	-	1.83	1.17
Zn	420	0.35	-	1.25	1.02
Ni	1455	2.16	-	-	-
Cr	1907	0.04	-	-	-
Sn	232	0.014	-	-	-
Ti	1668	0.55	-	-	-

recycled value of 118 MPa (38.3%) and from 2nd recycled to 3rd recycled worth 117 MPa (0.8%) caused by loss of elements during recycling Cu, Si and Fe, Cu at 1085°C, Si at 1414°C and Fe at 1538°C were merged into oxide slag on the aluminium liquid surface. The shrinkage tolerance in a successful foundry into a tensile test specimen is <6%. Aluminium scrap specimen with shrinkage >6% will fail after solidification. The SEM photographs show that the porosity of the 3rd recycled aluminium is less than in the 2nd and 1st recycled which means the solubility of the alloying element is preferable wherein the insoluble elements for Cu, Si and Fe are decreased.

Composition analysis: The results of Energy Disperse Spectroscopy (EDS) of an aluminium piston from recycling as Fig. 10.

The result of a Scanning Electron Microscopy (SEM) photo as Fig. 11 shows that the porosity of the 3rd recycled aluminium product is less than that of the 2nd and 1st recycles which can be interpreted as the solubility of the alloy element is preferable wherein the elements which are insoluble for Si, Fe, Cu are reduced as Table 3.

CONCLUSION

The Ultimate Tensile Strength (UTS) of 1st, 2nd and 3rd recycled aluminium scrap was 191; 118 and 117 MPa which is the 3rd recycled relatively similar to the pure aluminium UTS.

The UTS of the aluminium piston motorcycle worth 376 MPa was decreased to 191 MPa for the 1st recycled (49%) from the 1st recycled to the 2nd recycled value of 118 MPa (38.3%) and from 2nd recycled to 3rd recycled worth 117 MPa (0.8%) caused by loss of elements during recycling of Cu, Si and Fe where melting temperature of Cu at 1085°C, Si at 1414°C and Fe at 1538°C was merged into oxide slag on the aluminium liquid surface.

The shrinkage tolerance in a successful foundry into a tensile test specimen is <6%. Aluminium scrap specimen with shrinkage >6% will fail after solidification.

The SEM photographs show that the porosity of the 3rd recycled aluminium is less than in the 2nd and 1st recycles which means the solubility of the alloying element is preferable wherein the insoluble elements for Cu, Si and Fe are decreased.

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