مجلة جامعة بني وليد للعلوم الإنسانية والتطبيقية

تصدر عن جامعة بني وليد – ليبيا

Website: https://jhas-bwu.com/index.php/bwjhas/index

العدد التاسع والعشرون، 2023

Recyclability of aluminium piston alloy

Mohammed A. Abuqunaydah[1], Zayad M. Sheggaf[2*], Muheieddin Meftah Elghanudi[3], Salem A. Salem[4]
[1]High Vocational Libyan Center of Casting, Libya
[2]Libyan Centre for Engineering Research and Information Technology, Bani Walid, Libya
[3]Mechanical Engineering Department/Surman College of Science and Technology, Surman, Libya
[4]Mechanical Engineering Department/College of Technical Sciences, Bani Waild, Libya
*Crosspnding author: zayad1976@gmail.com

تاريخ الاستلام: 18-06-2023 تاريخ القبول: 3-07-2023 تاريخ النشر : 07-09-2023

Abstract: One of the most recycled and recyclable materials now in use is aluminium. Frequently, aluminium cans, automobile components, and window frames are recycled back into itself. A vital component of the contemporary aluminium industry is recycling. Recycled aluminium production uses only around 5% of the energy required to produce new aluminium, resulting in lower carbon emissions and cost savings for both corporations and end users. As a result, today's use of roughly 75% of all aluminum created throughout history. Recycling rates for aluminium exceed 90% in the majority of industrial sectors, including the construction and automobile industries. Every year, the United States saves more than 90 million barrels of oil equivalent through industry recycling. Capability to re-melting aluminium alloys scrap without losing its alloying elements and finding optimum pouring temperature are the purpose of this paper, and the results will determine the possibility of reusing piston alloy to make components similar to those they were recycled from. Automotive cast aluminium scrap obtained from pistons were used as experimental specimens, which were melted via an electrical furnace then poured at four different temperatures, namely 680, 720, 760, and 800 °C into a strip fluidity steel mould. The chemical composition of the four specimens were examined using spark emission spectrometer and the length of melted metal that flowed through the mould strips was measured as well to determine fluidity. Also, an optical microscope was used to detect microstructure defects. The chemical composition ratios of alloying elements before and after recycling showed that the resulting alloys could be closely equivalent to the commercial alloy that was originally used to make the components. In addition, the higher the pouring temperature the greater the casting fluidity. Generally, the consumed aluminium piston alloy can be re-melted and used to produce many parts.

Keywords: (casting, recycling, aluminium alloys)

Introduction

Due to their unique properties, such as low density, high thermal conductivity, simple net-shape fabrication techniques (casting and forging), ease of machinability, high reliability, and excellent recycling characteristics, aluminum alloys are the preferred material for pistons in both gasoline and diesel engines. Al-Si casting alloys are chosen often to produce engine parts due to their great castability, where silicon plays an important role, particularly, having high thermal properties, which increases fluidity [1, 2]. Castability is the ability of an alloy to be cast without formation of defects such as cracks, segregations, pores and porosity. In addition, loss-alloying element during re-melting could occur. Therefore, casting characteristics of AI-Si alloys require careful melting, degasifying, and pouring. Failure to exercise adequate control during the melting and casting processes is one of the most prominent problems [3]. The pouring of molten metal into the mold and subsequent filling are crucial processes in the casting process. It has been noticed in foundry practice that some alloys fill the mould cavity completely and reproduce its intricacies in the finished casting better than others do when filling moulds of sophisticated design, particularly those that involve thin portions. Therefore, testing for mould filling capacity is crucial since it not only aids in choosing the right alloy composition for a certain application, but also helps with quality control and lowers the likelihood of casting rejections. A lack of fluidity could contribute to the development of mistune castings or the absence of surface characteristics [4, 5].

The characteristics of mould and metal jointly are involved in determining fluidity, and pouring temperature is one of the factors related to metal. G. Timelli et. al [6] investigated the fluidity of four different high pressure die cast Al–Si and Al–Si–Cu alloys at a pouring temperature range of 580–760 °C. They found that fluidity linearly increases at increasing temperatures. In the other study, Chennakesava Reddy et. al [4] found out that influence of pouring temperature on fluidity of Al-Si-Mg cast alloys is positive, whereas the higher the pouring and mould pre-heat temperature the greater the casting fluidity, as pouring temperature range is between 650 and 850 °C, and the mould was preheated before pouring to 400 °C. An effective recycling temperature in the aluminium foundry has been investigated in this study, which shows that the alloy chemical composition of the melted piston scrap is consistently equivalent to original piston alloy, also the strip fluidity of Al-Si piston alloy with different pouring temperature has been studied, that is used for gravity die casting, the strip fluidity test measures the ability of alloy to fill a mould of different cross sections and thus provides a wider specification of actual casting conditions.

Experimental

A consumed car engine's pistons were used in the present investigations. The chemical composition of the samples was determined using FUNDARY-MASTER Pro emission spark spectrometer before and after recycling. The pistons were cut into small pieces then melted in an electrical furnace, and the tests were carried out in the pouring temperature range of 680 – 800 °C with a step of 40 °C. Because fluidity is an empirical measure of a processing characteristic, this property measures in one of the several types of fluidity tests. Two common types are the mould fluidity spiral and the strip fluidity test. According to previous studies [4, 8], a strip fluidity testing mould (a tool steel strip type mould) was chosen for this investigation, the design of which is shown in Fig. 1, which includes four strips, a pouring basin, and a running system. Each strip was of 10 mm width and 200 mm length. The thicknesses of the strips were 1, 3, 5, and 7 mm.

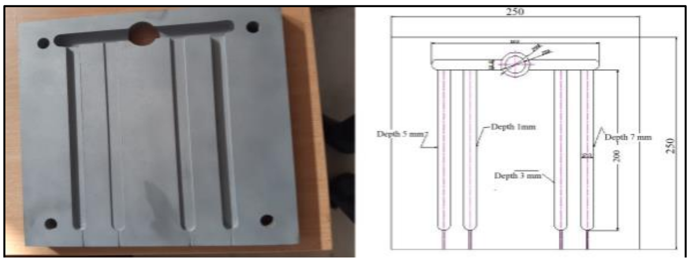

Fig. 1: Fluidity test mould

Results and Discussion

Figure 2 shows the ingot after solidified, the molten metal flow can be seen through the strips with 5 and 7mm depth only, as the mould is not heated (casting with mould at room temperature). The same results were found by A. Heidarzadeh et. al [7] as the molten metal did not pass through the strip with 1 mm thickness and solidified at running system which was cast without preheating the mould. However, the length of the metal flow in strips mould of 5 and 7 mm depth are taken as a measure of casting fluidity.

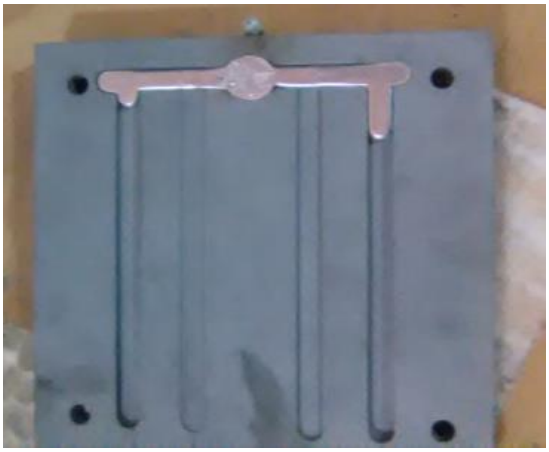

Fig. 2: Photographic view of strip fluidity test casting

The effect of pouring temperature on the fluidity alloy is shown in Figure 3. It can be seen that the fluidity increases with raising pouring temperature. The degree of super heat of the alloy grows with increasing pouring temperature, this leads to keeping the alloy as a molten form for a longer period, also the super heating of alloy decrements the fluid viscosity, so the liquid melt is able to flow over a longer distance due to increase in fluid life [4, 7]. In addition, increasing the pouring temperature delays the nucleation and growth of fine grains at the tip of the flowing metal into the mould channel, which leads to increment of the fluidity. [8]. On the other hand, an increase in the fluidity of the alloy as a result of an increase in the pouring temperature may lead to one of the most important defects of the microstructure, which is porosity. Porosity in castings mainly occurs due to gas entrapment in the melt at a highly turbulent flow of liquid metal into the die cavity [9].

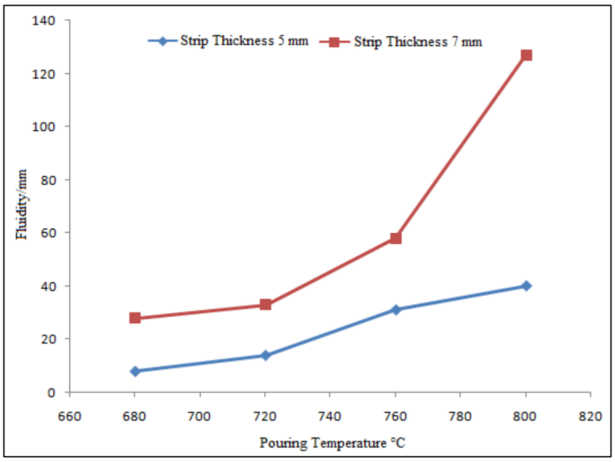

Fig. 3: Effect of pouring temperature on fluidity

Table 1 gives the chemical composition of alloys, original alloy and alloys pouring at different temperatures, which were obtained from recycled aluminium piston.

Table 1: Chemical composition of alloys

Temp. °C	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ni	Ti	Al
Origl.	10.1	0.286	3.13	0.634	0.742	0.0379	0.0168	0.26	0.0363	Bal.
680	10.6	0.467	1.88	0.336	0.725	0.107	0.0191	0.392	0.0391	Bal.
720	11.3	0.508	1.91	0.411	0.787	0.0405	0.0163	0.489	0.0314	Bal.
760	13.4	0.356	1.08	0.0621	1.13	0.0732	0.0636	0.971	0.0166	Bal.
800	11.9	0.446	1.29	0.123	0.719	0.221	0.0447	0.476	0.0418	Bal.

It can be observed that the alloy chemistries of the alloys obtained from recycled pistons are well within the normal specifications for pistons. It is noteworthy that the alloy chemistries are fairly consistent, the Cu content is slightly low, whereas its content varies from a low of 1.08 wt.% for alloy poured at 760 °C to a high of 3.13 wt.% for original alloy. Furthermore, it is anticipated that alloys made from piston scrap will include between 10.1 and 13.4 wt of Si. Typically, near eutectic Al-Si cast alloys with significant amounts of Cu, Mg, and Ni are used to cast pistons. Because of their outstanding fluidity and feedability and close to zero solidification range, eutectic alloys are chosen. High dimensional stability, scuff resistance, wear resistance, and lower thermal expansion are further benefits of the high Si content to the alloy. These are essential functional specifications that pistons must meet in order to work properly across a large operating temperature range. In some cases, pure alloying element could be added during melting to prevent the loss of that element, which is caused by oxidation [12, 13]. Finally, it is seems that the consumed piston alloys can be reused to cast components similar to those they were recycled from without significant loss of performance. Furthermore, it has been reported that rapid cooling during casting may cause segregation defect at surface of re-melted alloys, as shown in Figure 4, this defect can be fixed by removing a few millimeters from specimen surface using milling process ref. A study on the recycling 7075. Segregation process may occur at the end of solidification [14].

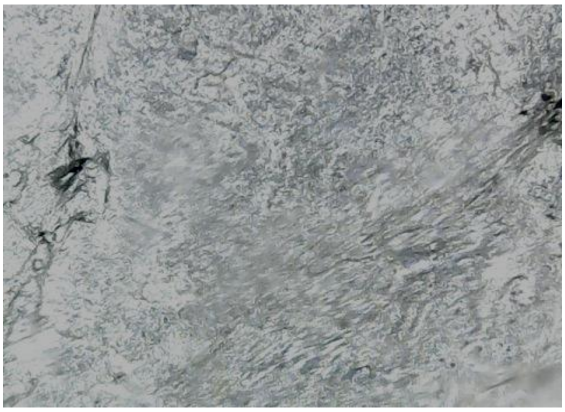

Fig. 4: Segregation process at surface of alloy poured at 800 °C, x50

When the aluminum alloys are melted at high temperatures, gases like hydrogen are easily formed in the molten metal and cause defects such as gas porosity and shrinkage porosity [10]. The increased porosity can cause a reduction in the mechanical properties [11]. As shown in the above results, melting the alloy at a high temperature caused an increase in fluidity; on the other hand, it led to form common casting defects, which can no longer be treated.

Conclusion

1. Casting fluidity of alloys increases with increasing pouring temperature of melt.
2. The mould with strips less than 5 mm of thickness needs pre-heating where the molten metal did not reach the strips.
3. Alloy addition is not required in the melting process
4. No significant change in the chemical composition after re-melting can be observed.
5. Segregation process can be reduced to a minimum with slow cooling during casting process.
6. The consumed aluminium piston alloy can be re-melted and used to produce many parts, as recycling is one of the most effective ways to produce alloys in our country.

Acknowledgment

The authors would like to express their deepest gratitude to the foundry and metallurgical lab technicians at High Vocational Libyan Center of Casting.

References

1. Davis, J.R., Aluminum and aluminum alloys. 1993: ASM international.
2. Stefanescu, D., J. Davis, and J. Destefani, Metals Handbook, Vol. 15--Casting. ASM International, 1988, 1988: p. 937.
3. Sigworth, G., The modification of Al-Si casting alloys: important practical and theoretical aspects. International Journal of Metalcasting, 2008. 2(2): p. 19-40.
4. Sumanth, M., A.C. Reddy, and V. Murti, FLUIDITY TESTING ON Al-Si-Mg CAST ALLOYS. life. 1: p. 2.
5. Radwan, B., Treatment of a Liquid Al-Si Alloy: Quality Control and Comparison of Two Melt Degassing Processes. 2020.
6. Timelli, G. and F. Bonollo, Fluidity of aluminium die castings alloy. International Journal of Cast Metals Research, 2007. 20(6): p. 304-311.
7. Heidarzadeh, A., et al., The effect of copper addition on the fluidity and viscosity of an Al-Mg-Si alloy. Journal of materials engineering and performance, 2014. 23(2): p. 469-476.
8. Srinivasa, R. and R. Patil, Characterization of Casting and Deformation Process of a Metal Alloy. International Research Journal of Engineering and Technology, 2017. 4(2).
9. Wilczek, A., P. Długosz, and M. Hebda, Porosity characterization of aluminium castings by using particular non-destructive techniques. Journal of Nondestructive Evaluation, 2015. 34(3): p. 1-7.
10. Ahmad, R., N. Talib, and M. Asmael. Effect of pouring temperature on microstructure properties of Al-Si LM6 Alloy sand casting. in Applied Mechanics and Materials. 2013. Trans Tech Publ.
11. Irfan, M., et al., Porosity reduction and mechanical properties improvement in die cast engine blocks. Materials Science and Engineering: A, 2012. 535: p. 108-114.
12. Barnes, S. J., & Lades, K. (2002). The evolution of aluminium based piston alloys for direct injection diesel engines (No. 2002-01-0493). SAE Technical Paper.
13. Özer, G., Burgucu, S., & Marsoğlu, M. (2012). A study on the recycling of aluminium alloy 7075 scrap. Materials Testing, 54(3), 175-178.
14. Otani, L. B., Matsuo, M. M., Freitas, B. J. M., Zepon, G., Kiminami, C. S., Botta, W. J., & Bolfarini, C. (2019). Tailoring the microstructure of recycled 319 aluminum alloy aiming at high ductility. Journal of Materials Research and Technology, 8(4), 3539-3549.