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Characterisation of aluminum alloys by octopus fluidity test

Alüminyum alaşımlarının ahtapot akışkanlık testi ile karakterizasyonu

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Characterisation of Aluminum Alloys by Octopus Fluidity Test

Highlights

- ❖ *Octopus design can produce different section thickness at the same time*
- ❖ *Octopus design gives better insight of fluidity characterisation of aluminum alloys*
- ❖ *A206 has better fluidity compare to A201*
- ❖ *Ag addition increases strenght but decreases fluidity*
- ❖ *A380 reveals quite good fluidity and mechanical properties close to A201*

Graphical Abstract

New proposed octopus design to test the fluidity characteristics of cast alloys

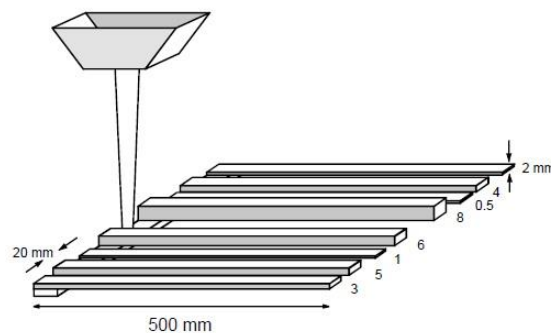


Figure. Octopus fluidity test design

Aim

Determination of fluidity and tensile property characteristics of A206, A201 and A380 alloy with new octopus design

Design & Methodology

Melting and casting of alloys into sand moulds. Measurement of fluidity length and tensile properties

Originality

New fluidity test mould design where different cross section thicknesses are used to characterise the alloy properties

Findings

A356 has the lowest fluidity. A201 has lower fluidity compare to A206 but has the highest strength. A380 has similar characteristics with A201

Conclusion

A380 can be an alternative choise for A201 alloy

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Characterisation of Aluminum Alloys by Octopus Fluidity Test

Araştırma Makalesi / Research Article

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ABSTRACT

Aluminium and its alloys are the most commonly used alloys in the transportation sector due to their high lightness and strength ratio. The higher corrosion resistance increases the reason why this alloy is preferred. In order to increase the strength values to the desired levels, aluminium alloys are subjected to grain refining with Ti, solution hardening with Mg and Cu and microstructural modifications with Sr. In this study, the relationship between Ag addition to Al-Cu alloy, mould filling ability with Sr addition to Al-Si alloys were investigated. In addition to the traditional spiral tests, newly developed 8-spoke, which is named as octopus design, was used to characterise the fluidity. Ag addition in the Al-Cu alloy (201) has no effect on fluidity particularly in spiral test but it has been observed to increase the strength by 50-80 MPa. On the other hand, high fluidity and strengths up to 350 MPa were achieved by A380 alloy.

Keywords: Al-Cu, Al-Si, fluidity, spiral, octopus.

Alüminyum Alaşımlarının Ahtapot Akışkanlık Testi ile Karakterizasyonu

ÖZ

Alüminyum ve alaşımları hafiflik ve yüksek mukavemet oranlarından dolayı taşımacılık sektöründe en yaygın şekilde kullanılan alaşımlardır. Bu alaşımın neden tercih edildiğinin sebebini yüksek korozyon direnci pekiştirmektedir. Mukavemet değerlerinin arzu edilen seviyelere yükseltmek için alüminyum ve alaşımları, Ti ile tane inceltme, Mg ve Cu ile çökelme sertleşmesi ve Sr ile içyapısal değişimlere tabi tutulurlar. Bu çalışmada Al-Cu alaşımına Ag ilavesi, Al-Si alaşımlarına Sr ilavesi ile kalıp dolmuş kabiliyeti arasındaki ilişki araştırılmıştır. Geleneksel sarmal (spiral) testlere ilave olarak yeni geliştirilen ahtapot tasarımı olarak isimlendirilen 8-kollu kalıp akışkanlığı karakterize etmek için kullanılmıştır. Al-Cu alaşımına (201) Ag ilavesi spiral akışkanlığa hiç etki etmezken, mukavemeti 50-80 MPa arttırdığı gözlemlenmiştir. Diğer taraftan A380 alaşımı ile yüksek akışkanlık ve 350 MPa'a kadarlık bir artış elde edilmiştir.

Anahtar kelimeler: Al-Cu, Al-Si, akışkanlık, spiral(sarmal), ahtapot.

1. INTRODUCTION

Aluminium has attracted considerable attention due to its properties such as lightness compared to most other metals, ability to reach desired strength when alloyed, high heat and electrical conductivity, high corrosion resistance, recyclability, high formability.

Especially the density (2.7 g / cm³) is the preferred material for many applications in the automotive and aerospace while it is about one-third of the density of the iron. Al-Cu has high tendency for hot tearing but lacks in

fluidity [1-4]. Addition of Ag to Al-Cu alloys typically increases strength and corrosion resistance [5].

Al-Si alloys have the highest fluidity among all aluminum alloys, but strength is moderate, particularly compare to Al-Cu alloys [6-7]. However, by applying grain refinement and/or silicon modification, strength values can be increased with a further increase in fluidity. Strontium is added to alter silicon to finer fibrous structure while Ti-B master alloys are also widely used as grain refiners. Yet, fluidity can be significantly affected by the presence of defects such as oxides [8-9]. One of the most important defects is the bifilms that impede fluidity [10-12]. Birru [13] investigated the fluidity of Al-Cu alloys by fly ash additions using spiral

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mould. It was found that low amount of fly ash additions at low pouring temperatures had increased fluidity where fly ash had grain refining effect. Similarly, Prukkanon [14] studied the effect of Sc on Si modification in A356 and showed that with addition of Zr, fluidity was significantly improved. Timelli [15] looked into the effect of superheating and oxide content over the fluidity of A356. It was concluded that as bifilm index [11] was decreased from 31 mm to 18 mm, fluidity was increased from 792 mm to 909 mm. Sanchez [16] worked with A319 and A356. The addition of Ti and Sr had decreased the formation of cold shut defects which had resulted in increased fluidity.

Caceres and Selling [17] reported that inclusion content, oxide films, and porosity had a dominant effect over the mechanical properties of Al-Si alloys. The tensile and fatigue properties were directly affected by the cross-section area of the defect with regard to the axis of force. Similarly, Eady [18] investigated the change in Mg ratio in Al-Si alloys over the porosity formation and mechanical properties. It was found that when Mg content was below 0.26 %, any existing pore would tolerate the elongation at fracture well above 1 %. Herrera and Kondic [19] looked into the ratio of pores over the tensile properties and concluded that there could not be a direct relationship. However, it was reported that as porosity was decreased, mechanical properties were increased. Caceres [17] confirmed the same findings and discussed that such uncertainties in correlation between defects and mechanical properties were related to the shape, size, and distribution of pores along the direction of forces applied. On the other hand, Dispınar [12] showed that mechanical properties were directly related to bifilm defects and there was a correlation between bifilm index and tensile properties. Weibull analysis was used to statistically show the relationship.

Table 1. Chemical analysis of aluminum alloys used in experiments

Alloy	Si	Cu	Ag	Ti	Mg	Mn	Sr	Al
A201	0.00	4.60	0.55	0.23	0.31	0.29	0.00	Rem.
A206	0.01	4.65	0.00	0.25	0.26	0.28	0.00	Rem.
A356	7.50	0.20	0.00	0.20	0.45	0.10	0.03	Rem.
A380	7.75	2.65	0.00	0.25	0.45	0.10	0.03	Rem.

2. MATERIAL AND METHOD

In this study, A201, A206, A356, and A380 aluminum casting alloys fluidity and tensile test samples were produced via spiral and octopus moulds. The chemical analysis of alloys is given in Table 1.

Before the tests, rotary degassing was applied for 15 minutes at 250 rpm by nitrogen, and castings were made to sand moulds at 750°C.

Two different fluidity tests were used in this study. The first of these tests was the spiral fluidity test method. In the spiral fluidity test method, it is desired that the liquid metal travels along the spiral mould cavity with a

constant cross-section. Another fluidity testing method was the 8-spoked “octopus design fluidity testing method”. The test pattern used in this method (Figure 1) has 8 arms of the same width/length ratio, have different thicknesses with the same solidification modulus. Chrome-based sands were used for moulding and bentonite was selected as the binder. Four tests were carried out in order to check the reliability of test results.

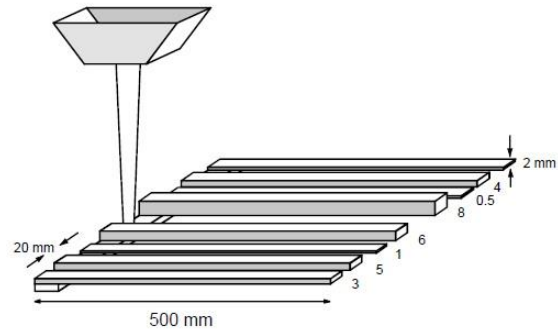


Figure 1. Spiral (top) and Octopus Design (bottom) fluidity test methods

In this study, tensile test samples were cast to compare the mechanical properties of the alloys. The results of

each of the three different tests conducted in the study were also examined comparatively.

3. RESULTS AND DISCUSSION

According to the spiral tests, the highest fluidity value was obtained in A380 alloy (Figure 2). The superiority of Al-Si alloys in mould filling ability was so clear. Traditionally, A201 alloy, which is preferred for engine block applications, has low viscosity and is highly unstable. In addition, the Ag addition (A206) does not affect fluidity properties but the scatter of the results decreases.

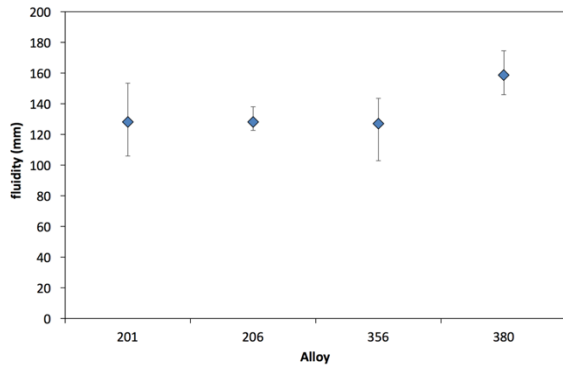


Figure 2. Spiral fluidity tests of four alloys

For the octopus mould, A201 alloy was able to completely fill the mould effectively for values above 6 mm thickness (Fig. 3). While the viscosity values of 5 mm and thinner sections were decreasing, the filling of 0.5 mm and 1 mm was never achieved by this alloy.

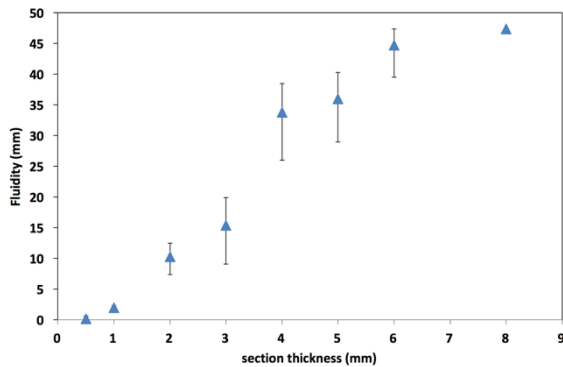


Figure 3. Fluidity test results of A201 alloy for octopus design

A206 alloy revealed an interesting filling characteristic in octopus mould. It was able to fill 0.5, 1, and 2 mm section very slightly to 5 mm length. On the other hand, For section thicknesses above 4mm, it was able to completely fill mould cavity as seen in Figure 4. Thus, it can be concluded that there is a noticeable decrease in fluidity below 4mm thickness.

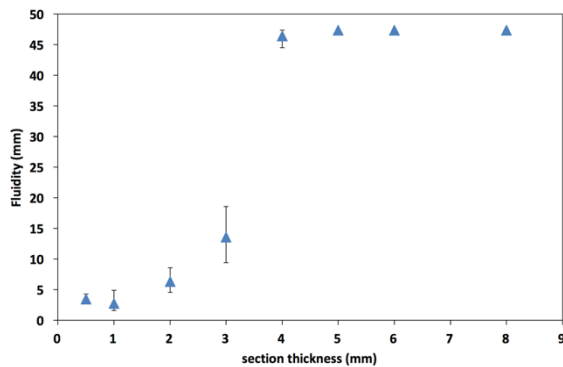


Figure 4. Fluidity test results of A206 alloy for octopus design

An increase can be seen in the fluidity test results of A356 alloy which is containing 7 wt% Si. Relative to the 2xx series, it has better fluidity (Figure 5). However, similar difficulties were encountered in filling the arms with a thickness of 5 mm and 1 mm. With regard to the four castings, there was a lot of scatter in fluidity values. The error bars are widely distributed for thicknesses between 2 mm to 6 mm. Thus, the reliability of filling characteristics of A356 was found to be quite low.

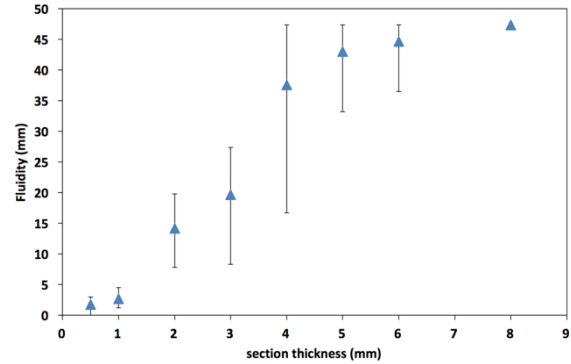


Figure 5. Fluidity test results of A356 alloy for octopus design

Within the alloys studied, A380 alloy appears to be the only alloy which is capable of full filling the moulds after a thickness of 2 mm (Fig. 6). For all the alloys tested in this work, 0.5 and 1 mm section thickness was the most difficult cross-section to fill. It can be concluded that all the alloys were unable to overcome the surface tension to smoothly flow in such thickness values.

It is important to note that it is not just the section thickness that determines the fluidity, but the surface tension and the wettability of the cross section is another critical parameter. From Figures 4 and 5, it can be seen that the fluidity increased significantly when the cross section is increased from 3 to 4 mm. This may be indication that the effect of surface tension is dominant when the cross section is thinner than 3 mm. Additionally, mould temperature is also an vital parameter when it comes to the characterisation of fluidity. However, in this work, since the castings were made into sand mould, this parameter becomes irrelevant.

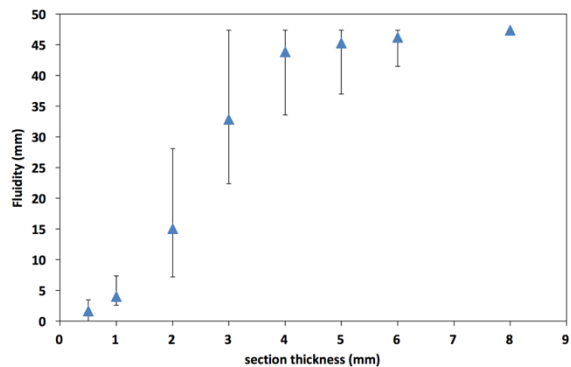


Figure 6. Fluidity test results of A380 alloy for octopus design

When the tensile test results were examined (Figure 7 and Figure 8), an average tensile strength of 400 MPa was obtained by Ag-containing A201 alloy, and also maximum of 310 MPa tensile strength can be obtained by A380 alloy. On the other hand, the difference between yield and ultimate tensile strength was around 100 MPa for A201, while this value was 25 MPa for A380 alloy.

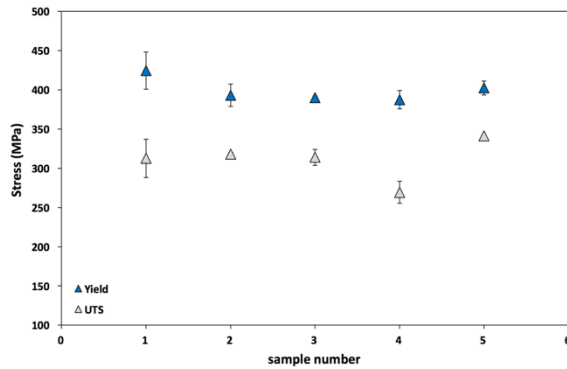


Figure 7. Tensile test results of A201 alloy

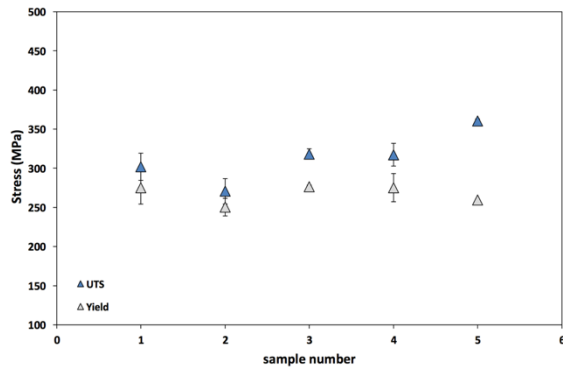


Figure 8. Tensile test results of A380 alloy

4. CONCLUSION

The fluidity of A380 alloy is quite good and has demonstrated high mould filling ability in both spiral and octopus fluidity tests. However, A201 alloy is slightly below the desired values in both fluidity tests. A201 and A206 have the highest strength values up to 400 MPa, but lacks in fluidity tests. Ag addition increases strength but significantly decreased fluidity, particularly in new octopus design.

The yield and tensile strength values of A380 alloy are lower than those of A201 but the desired minimum strength value lies above 300 MPa.

None of the alloys studied in this work (A201, A206, A356, A380) was unable to fill and mould cavity below 1 mm section thickness which indicated that these alloys suffered to overcome the surface tension to be able to smoothly fill the mould cavity.

ACKNOWLEDGMENT

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DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission

AUTHORS' CONTRIBUTIONS

Eray ERZİ: Data collection, analysis and interpretation.

Çağlar YÜKSEL: Data collection, analysis and interpretation.

Özen GÜRSOY: Data collection, analysis and interpretation

Murat ÇOLAK: Study conception and design analysis and interpretation.

Derya DIŞPINAR: Study conception, draft manuscript preparation.

All authors reviewed the results and approved the final version of the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

- [1] Din, T., Campbell, J., "High strength aerospace aluminium casting alloys: a comparative study", *Materials Science and Technology*, 12, 644-650, (1996).
- [2] Mondolfo, L. F. "Aluminum alloys: structure and properties", *Elsevier*, (1976).
- [3] Tiryakioglu, M., Campbell, J., "Ductility, structural quality, and fracture toughness of Al-Cu-Mg-Ag (A201) alloy castings", *Materials Science and Technology*, 25(6), 784-789, (2009).
- [4] Din, T., Rashid A. K. M. B., Campbell, J., "High strength aerospace casting alloys: quality factor assessment", *Materials Science and Technology*, 12, 269-273, (1996).
- [5] Pehlke, R. D., "Thermal Aspects of Mold Filling", *In Measurement and Control in Liquid Metal Processing*, Springer Netherlands, 99-106, (1987).
- [6] Çolak M., Kayikci R., Dişpinar D., "Influence of Different Cross Sections on Fluidity Characteristics of A356", *Transactions of the Indian Institute of Metals*, 68: 275-281, (2015).
- [7] Lumley, R., "Fundamentals of Aluminium Metallurgy", *Woodhead Publishing, Cornwall, BK*, (2011).
- [8] Akkaya, B., Ertürk, E., & Dişpinar, D., "Correlation between Melt Quality and Fluidity of A356", *In Shape Casting: 5th International Symposium 2014*, Springer International Publishing: 99-104, (2014).
- [9] Di Sabatino, M., Arnberg, L., Rørvik, S., & Prestmo, A., "The influence of oxide inclusions on the fluidity of Al-7wt.% Si alloy". *Materials Science and Engineering: A*, 413: 272-276, (2005).

- [10] Ludwig T., Dişpinar D., Di Sabatino M., Arnberg L., "Influence of Oxide Additions on the Porosity Development and Mechanical Properties of A356 Aluminum Alloy Castings", *International Journal of Metal Casting*, 41-50, (2012).
- [11] Dişpinar D., Campbell J., "Porosity, Hydrogen and Bifilm Content in Al Alloy Castings", *Materials Science And Engineering A*, 528: 3860-3865, (2011).
- [12] Dişpinar D., Akhtar S., Nordmark A., Di Sabatino M., Arnberg L., "Degassing, Hydrogen and Porosity Phenomena in A356", *Materials Science And Engineering A*, 527: 3719-3725, (2010).
- [13] Birru, A. K., & Kumar, B. P., "Influence of Fluidity of Al-Cu Alloy with Fly Ash Reinforcement by Single Spiral Fluidity Test", *Materials Today: Proceedings*, 2(4-5): 2776-2783, (2015).
- [14] Prukkanon, W., Srisukhumbowornchai, N., & Limmaneevichitr, C., "Influence of Sc modification on the fluidity of an A356 aluminum alloy", *Journal of Alloys and Compounds*, 487(1): 453-457, (2009).
- [15] Timelli, G., & Caliarì, D., "Effect of Superheat and Oxide Inclusions on the Fluidity of A356 Alloy". *In Materials Science Forum*, 884: 71-80, (2017).
- [16] Sánchez, S., Velasco, E., del C Zambrano, P., & Cavazos, J. L., "Effect of titanium and strontium addition on the fluidity of A319 and A356 aluminum alloys". *In Materials science forum*, 509: 159-164, (2006).
- [17] Cáceres, C. H., & Selling, B. I., "Casting defects and the tensile properties of an Al-Si-Mg alloy". *Materials Science and Engineering: A*, 220(1-2): 109-116, (1996).
- [18] Eady, J. A., & Smith, D. M., "The effect of porosity on the tensile properties of aluminium castings". *In Materials Forum* Institute of Metals and Materials Australasia, 9(4): 217-223, (1986).
- [19] Di Sabatino, M., Arnberg, L., Brusethaug, S., & Apelian, D., "Fluidity evaluation methods for Al-Mg-Si alloys". *International Journal of Cast Metals Research*, 19(2): 94-97, (2006)