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EFFECTS OF WETTING TIME ON PROPERTIES OF STEEL-ALUMINIUM BRAZED JOINT

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Abstract

The brazing of 1080 steel to 6063 aluminium alloy was conducted under various wetting time to investigate the properties of the joint. Generally, joining of steel to aluminium using high temperature joining method can cause formations of hard and brittle intermetallic compounds that reduce the strength of joint. Brazing wetting time were varied to observe the effect of this parameter to the shear strength and microstructure at the interface of brazed joint. Shear testing showed that the strength of joint with brazing time of 5 to 15 minutes have exceeded the strength of the 6063 aluminium alloy. Microstructure analysis revealed that brazing with 15 minutes wetting time has better joining profile at interface between the steel and aluminium alloy than the other wetting durations. Optimization of the brazing wetting time improved the strength of brazed joint by minimizing the formation of brittle layer within the join interface.

Keywords: Brazing; steel-aluminum joining; intermetallic compound

Abstrak

Pematerian keatas keluli 1080 dan aloi aluminium 6063 telah dijalankan untuk menyiasat sifat-sifat sambungan pateri dibawah pelbagai masa pembasahan. Secara umumnya, proses penyambungan logam keluli ke aluminium dengan menggunakan suhu yang tinggi boleh menyebabkan pembentukan sebatian antara logam yang keras dan rapuh yang akan mengurangkan kekuatan sambungan pateri. Masa pembasahan semasa proses pematerian telah dipelbagaikan untuk mengenalpasti kesannya keatas kekuatan ricih dan struktur mikro di kawasan antara sambungan pateri. Ujian kekuatan ricih menunjukkan sambungan pateri dengan masa pembasahan antara 5 ke 15 minit mempunyai kekuatan sambungan yang melebihi kekuatan aloi aluminium 6063. Analisis keatas struktur mikro menunjukkan sambungan dengan 15 minit masa pembasahan mempunyai profil struktur mikro yang lebih baik daripada sambungan dengan masa pembasahan yang lain. Kekuatan sambungan pateri dapat dioptimumkan dengan mengawal masa pembasahan semasa proses pematerian untuk meminimumkan pembentukan sebatian antara logam yang keras dan rapuh di antara muka sambungan pateri.

Kata kunci: Pematerian; penyambungan keluli-aluminum; sebatian antara logam

1.0 INTRODUCTION

The combination of aluminium and steel to replace the existing steel body are desired due to required mechanical properties and weight reduction of the car. The use of the aluminium alloys and steels and finding the surrogating material for some of the sensitive components is relatively influenced by the controlling forces like current regulations to encounter fuel efficiency standards by decreasing vehicle weight, and to meet recycling standards [1]. There are several joining method that have been attempted and practically used to joint steel to aluminium such as adhesive bonding, welding, riveting and brazing process [2]. Brazing aluminium to steel is one of the low cost and reliable process (compared with welding process) that have a good potential for automotive application due to lower temperature used and ability of much tighter control over tolerances and produces a clean joint without the need for secondary finishing. Lower temperatures means the process require less energy, which can result in significant cost savings [3].

In brazing dissimilar material, it is important to reduce the brittle phases to assure the structure integrity by optimizing the brazing specification. There are several investigation on the effects of wetting time on the properties of brazed join, researchers found that brazing wetting time plays an important role on the properties of brazed joint [4,5,6,7]. Sound brazing joints with acceptable strength remains to be obtained because of the formation of a thick and brittle Al-Fe intermetallic compound (IMC) layer at the welding interface and degradation of strength of the base materials because of additional adverse thermal effects [8].

Controlling the formation of IMC layer is important to obtain a reliable joint due to their significant effect to the strength of the braze joint. The strength of the joint is decreased with increasing thickness of IMC layer [9]. Therefore, by controlling the brazing wetting times, the quality and strength of the braze join can be optimized. In this paper, the effects of wetting time on the shear strength and microstructure of the brazed joint are studied and observed to optimize the wetting time for brazing steel to aluminium.

2.0 EXPERIMENT SETUP

2.1 Materials and brazing conditions

The base metals used in this study are wrought aluminium alloy 6063 and 1080 steel plates with dimension of 100mm x 25mm x 3mm. Aluminium and steel plate edges are ground and flat edges are brushed using a stainless steel wire brush. The oxide layer on the surface of base metals is removed using SiC grinding sheet. The surfaces of the base metals are roughen by using 180 grits SiC sheet to increase the contact surface area to the filler metal. Al-Zn rolled strips are used as filler metal for joining the base metals together. This filler metal strip is placed between the steel and aluminium base metal and the assembled part is held together by using steel wire.

Brazing method that used for this study is furnace brazing. The effect of brazing parameter on the properties of the brazed joint was observed. The measured temperature between the steel and aluminium interface was 460˚C. The brazing heating cycle was shown in Figure 1. The temperature was held in the range of 5 to 20 minutes to allow the molten filler metal to wet the surface of the base material. The final step is the cooling stage, whereby the heat source was cut off to allow the molten metal to freeze and forming a braze joint.

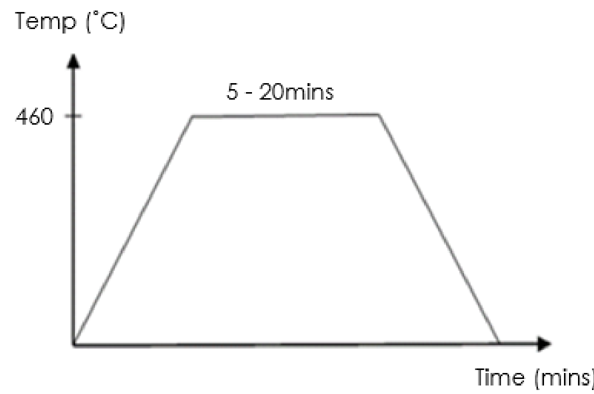

Figure 1 The brazing heating cycle

2.2 Temperature measurement

The temperature generated during brazing was measured using K-type thermocouples. The tip of the thermocouple was placed at the steel-aluminium interface where the filler metal melted and forming a braze joint.

2.3 Shear Test

The plates were machined into the shear test specimen through EDM Wire Cutter. All test specimens have rectangle contact area 25mm x 30mm. It consists of three layers of material; steel base plates, aluminium base plates, and filler metal. The shear testing and joint strength evaluation was conducted by using Zwick Roell universal tensile test machine according to section 4.5.1 of AWSC3.2M/C3.2:2008, Standard Method for Evaluating the Strength of Brazed Joints [10].

2.4 Microstructural Analysis

For the microstructural analysis, the brazed sample was cut into dimension of 10mm x 100mm x 5mm. The samples were ground and polished using manual rotating polishing and grinding machine. They were then etched using electrolytic etching method to reveal the microstructure of the brazed region. The cross section of the brazed joint was observed using ZEISS optical microscope. The focused of the microstructural analysis was the interface zone area between the base metal and the filler material.

2.5 Hardness Test

The hardness values of filler metal were compared to identify the influence of wetting times. The hardness of filler metal region after brazing process were measured using Zwick Roell Indentec Vickers hardness testing machine by according to ASTM E92 - 82(2003), Standard Test Method for Vickers Hardness of Metallic Materials [11].

3.0 RESULTS AND DISCUSSION

3.1 Shear Strength of Brazed Joints

The shear load increased with increasing the wetting times from 5 minutes to 15 minutes, and it decreased at the wetting time of 20 minutes. Figure 2 shows the shear loads of different wetting times used after shear test. There are different locations of failure were observed depending on the wetting time used (figure 3-6). For the brazed joints with 15 minutes wetting time and less, the failure occur at the aluminium base metal with maximum load of 2560N. This indicates that the strength of these joints are stronger than the strength of the aluminium base metal. The shear load of the joint with 20 minutes wetting time is 938N and the location of failure is at the interface between the aluminium and steel base metals. The failure occur at this location indicates that the strength of the brazed joint with 20 minutes wetting time is lower than the strength of both base metals.

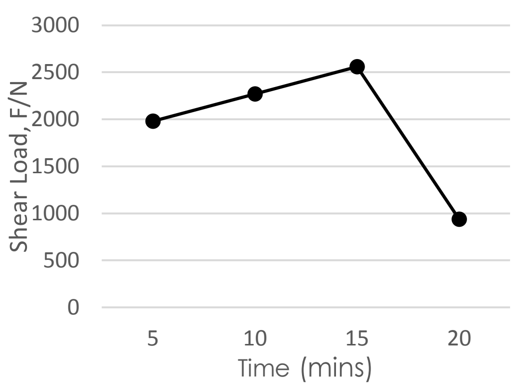

Figure 2 Relationship between wetting times and shear load

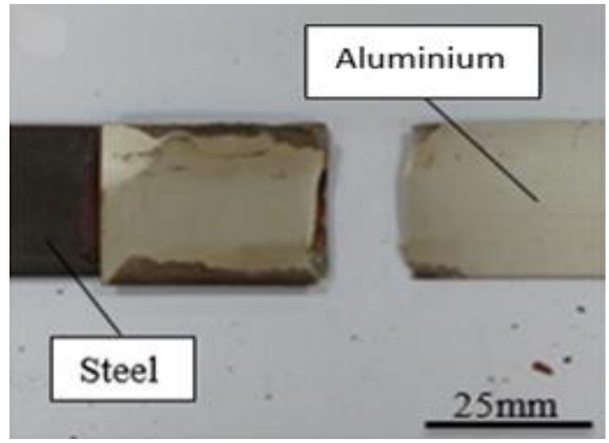

Figure 3 Failure location of brazed joint with 5 minutes wetting time after shear test.

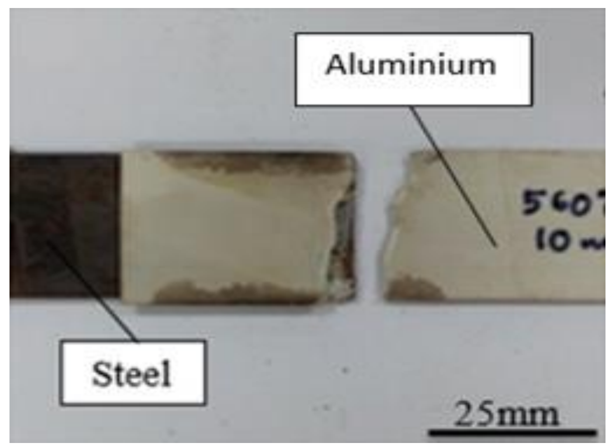

Figure 4 Failure location of brazed joint with 10 minutes wetting time after shear test.

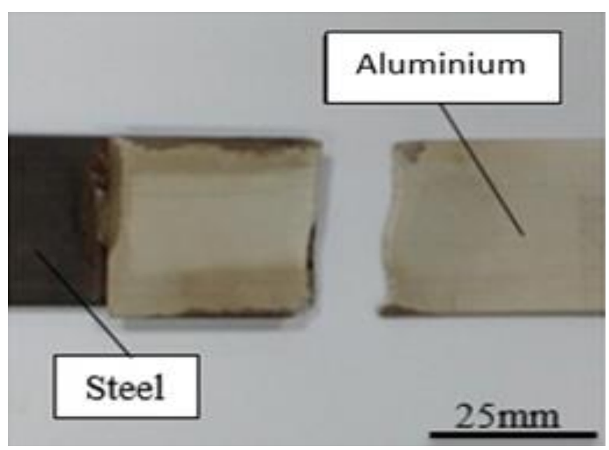

Figure 5 Failure location of brazed joint with 15 minutes wetting time after shear test.

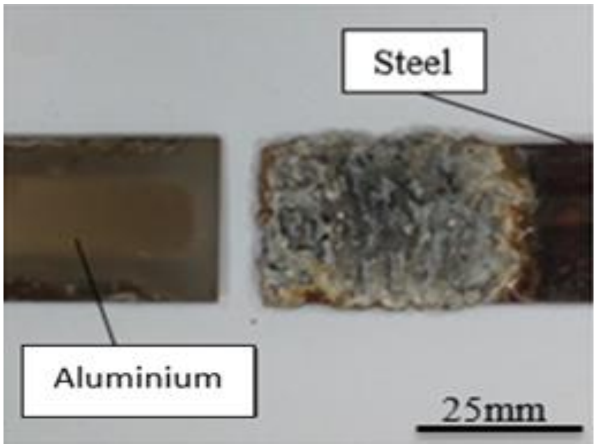

Figure 6 Failure location of brazed joint with 20 minutes wetting time after shear test.

3.2 Microstructural Analysis

Microstructural analysis revealed that there exists a continuous dark sublayer between the steel and filler metal interface. Optical microscope image at steel-filler metal interface was shown in Figure 7-10. These dark sublayers are thickest at 5 minutes wetting time and thinnest at 15 minutes wetting time. The existence of thick dark sublayer between the steel and aluminium interface (5 and 10 minutes wetting times) is due to the lack of time required by the molten filler metal to "wet" the surface of the steel base. This shows that brazing at 15 minutes wetting time has a better joining profile at interface between steel and aluminium than the other wetting durations.

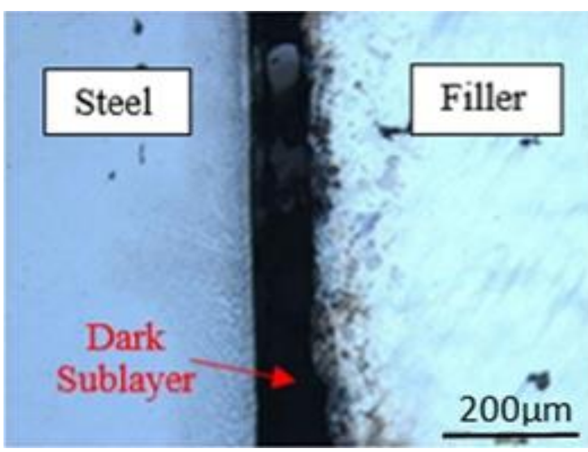

Figure 7 Optical microscope image at steel-filler metal interface at 5 minutes wetting time.

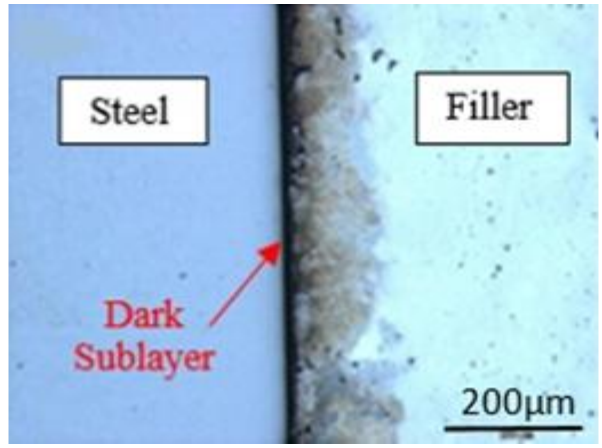

Figure 8 Optical microscope image at steel-filler metal interface at 10 minutes wetting time.

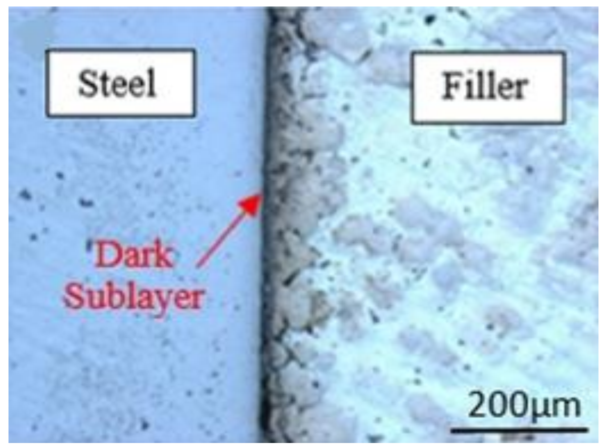

Figure 9 Optical microscope image at steel-filler metal interface at 15 minutes wetting time.

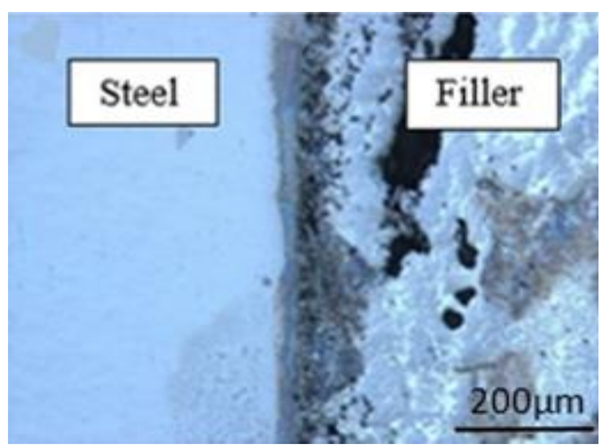

Figure 10 Optical microscope image at steel-filler metal interface at 20 minutes wetting time.

3.3 Hardness of Filler Metal

The hardness values of filler metal after brazing with different wetting times are shown at Figure 11. The hardness values of the filler metal are reduced with increasing brazing wetting times from 5 minutes to 15 minutes wetting time. The hardness value of the filler metal with 15 minutes wetting times is 80HV, the lowest hardness value among other wetting durations due to the sufficient time for grain size enlargement. The highest recorded value is 125HV, the hardness value after brazing with 20 minutes wetting time. At this stage, the hardness value was increased due to the excessive diffusion of brittle dark sublayer into the microstructure of filler metal [12]. This will cause the filler metal in this condition becomes brittle and the failure occur at the joint interface.

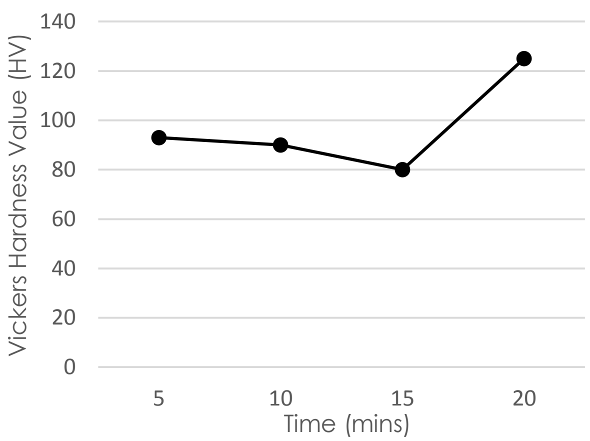

Figure 11 Hardness value of filler metal after brazing with different wetting times.

4.0 CONCLUSION

The furnace brazing of 1080 steel and 6063 aluminium alloy with Al-Zn filler has been performed in this paper. The effects of wetting time on properties of the steel-aluminium joint have been discussed. The following conclusions can be drawn from the present study are:

(a) Different locations of failure were observed depending on the wetting time used. For the brazed joints with 15 minutes wetting time and less, the failure occur at the aluminium base metal with maximum load of 2560N. The shear load of the joint with 20 minutes wetting time is 938N and the location of failure is at the interface between the aluminium and steel base metals.

(b) There exists a continuous dark sublayer between the steel and filler metal interface. These dark sublayers are thickest at 5 minutes wetting time and thinnest at 15 minutes wetting time.

(c) The hardness values of the filler metal are reduced with reducing brazing wetting times. The hardness value of the filler metal with 15 minutes wetting times is 80HV, the lowest value among other wetting durations used. The highest recorded value is 125HV, the hardness value of the filler material after brazing with 20 minutes wetting time.

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References

[1] P. F. Mendez, T. W. Eagar. 2002. New trends in welding in the aeronautic industry, *2nd Conference of New Manufacturing Trends, 2002 Bilboa, Spain*, 19-20 November 2002. 1 – 10.

[2] T. Sakiyama, G. Murayama, Y. Naito, K. Saita, Y. Miyazaki, H. Oikawa, T. Nose. 2013. Dissimilar Metal Joining Technologies for Steel Sheet and Aluminium Alloy Sheet in Auto Body, *Nippon Steel Technical Report*. 103: 91-98.

[3] Steve Marek. 2013, *Brazing vs Welding*, [Online]. From: http://www.torchbrazing.com. [Accessed on 24 August 2015].

[4] W. Jiang, J.M. Gong, S.T. Tu. 2010. Effect Of Holding Time On Vacuum Brazing For A Stainless Steel Plate–fin Structure. *Materials and Design*. 3: 2157–2162.

[5] J. Y. Kim, K. Scott Weil. 2012. Effects of Brazing Time and Temperature on the Microstructure and Mechanical Properties of Aluminium Air Brazed Joints, *Journal of the American Ceramic Society*. 90: 3830 – 3837.

[6] R. Johari Miab, A.M. Hadian. 2014. Effect Of Brazing Time On Microstructure And Mechanical Properties Of Cubic Boron Nitride/Steel Joints. *Ceramics International*. 40: 8519–8524.

[7] H. Sung, J. K. Kim, B. Y. Jeong, C. Y. Kang. 2007. Effect of Brazing Conditions on the Microstructure and Mechanical Properties of Duplex Stainless Steels to Cr-Cu Alloy with Cu-Base Insert Metal. *Metals and Materials International*. 13: 511-515.

[8] M. Watanabe, K. Feng, Y. Nakamura, S. Kumai, 2011. Growth Manner of Intermetallic Compound Layer Produced at Welding Interface of Friction Stir Spot Welded Aluminium/Steel Lap Joint. *Materials Transactions*. 52: 953–959.

[9] Peter K. Bernasko, Sabuj Mallik, G. Takyi. 2015. Effect Of Intermetallic Compound Layer Thickness On The Shear Strength Of 1206 Chip Resistor Solder Joint. *Soldering & Surface Mount Technology*. 27: 52-58.

[10] AWSC3.2M/C3.2:2008. Standard Method for Evaluating the Strength of Brazed Joints, *American Welding Society*, 2008.

[11] ASTM E92-82(2003), Standard Test Method for Vickers Hardness of Metallic Materials, *ASTM International*, 2003

[12] I. Kenji, Y. Naotsugu, T. Makoto, A. Masatoshi, 2005, Effect of Interfacial Reaction Layer on Bond Strength of Friction-Bonded Joint of Al Alloys to Steel. *Transactions of JWRI*. 3: 1-10.