Influences of Welding Speed and Speed of Pin Tool Rotation from Semi-Solid State Joining of Aluminum Alloy SSM 5083 Covered by CO_2 Gas

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Abstract

The purpose of this research was to examine the butt joint welding of aluminum alloy SSM 5083 with semi-solid metal processing. The variables in welding were the rotation speed of tool pin at 1,200 and 1,500 rpm. The welding speed was at 120 and 160 mm/min. The welding temperature of carburizing flame was at 590 to 610 °C and CO_2 was applied to cover the welding line.

After the welding experiment, there was no crack which occurred from not joining condition on both top and down welding area. The porosity was occurred less in macro structure the rotation speed of tool pin at 1,200 rpm with welding speed at 160 mm/min. The micro structure, in the rotation speed of tool pin at 1,200 rpm with welding speed at 160 mm/min, there was spheroidal structure and grain dispersed regularly. On the rotation speed of tool pin at 1,500 rpm of both welding speed, the dendrite structure was occurred. It can be concluded that the rotation speed of tool pin at 1,200 rpm is most suitable for semi-solid state joining.

Keywords : Semi-Solid State Joining, Microstructure of Aluminum Alloy SSM 5083, Welding Parameters

1. Introduction

Metal welding processing is to join and assemble the components and it takes a major role in various industries such as automobile industry which its welding processes progressing develop. It starts from arc welding with bare wire, gas welding up to shielding gas welding which is fusion welding. Afterward, the process has been developed to friction stir welding (FSW). (Muangjunburee, P., 2551) FSW is non-fusion welding or solid state welding which welding temperature used was under the melting point of metal. The heat was occurred from friction force between tool pin and the surface of work pieces. For welding process of some metal such as aluminum, fusion welding would cause some error in joint like pneumatic space or crack in welding joint. Consequently, to solve this error in welding joint, frictions stir welding has been applied for aluminum welding and when compared with fusion welding it caused good metallurgical properties and the mechanical properties of welding joint which was higher than fusion welding.

Currently, there are the competitions in semi-solid metal (SSM) casting technology in both Thailand and oversea. In Thailand, the research and technology on semi-solid metal has been started and applied to inside-country industry for 1 to 2 years ago such as in airline industry, machinery builder and electronics in order to decrease weightiness. Furthermore, the latest and effective energy technology in casting is semi-solid metal welding in Rheo-casting with Gas Induced Semi Solid (GISS) technique (Chucheep, T., 2007) which its casting method was releasing inert gas through graphite anode for metal flowing to be spheroidal grain structure (Wannasin, J., and Thanaburungkul, S., 2008). Then, it was formed by casting while some parts of them are semi-solid metal condition.

Nevertheless, in order to bring aluminum alloy piece that casts through semi-solid method to work effectively, it would relate to forming and repairing. Later, semi-solid aluminum would be worked unavoidably with similar joint or dissimilar joint welding. Semi-solid welding would be applied because the structure of this aluminum was spheroidal and to keep it as the former structure, the welding process would take an important role in joint welding. Semi-sold welding is non-fusion in welding line which it categorizes as new technology for applying with aluminum alloy SSM 5083 which is also the developing material because when it is welding, its structure is in semi-solid condition. At that point, its welding line would not change phrase into dendrite. Consequently, the whole information and reasons as mentioned above is the basis of this research project.

2. Objective

2.1 The study of welding parameters from semi-solid state joining of aluminum alloy SSM 5083 covered by CO_2 gas.

2.2 The effects compare on microstructure properties from semi-solid state joining.

3. Methods

3.1 Materials

The material in this experimental research was SSM 5083 aluminum alloy which was casted by semi-solid technology with GISS process and its chemical composition was shown in table 1. The prepared work pieces for welding was length 120 mm, width 60 mm and thick 5 mm. There were 24 work pieces and they were repeated experiment for 3 times.

Table 1. Chemical composition (wt. %).

Material	Mg	Mn	Fe	Si	Cr	Cu	Zn	Ti	Al
SSM 5083	4-4.9	0.4-1	0.4	0.4	0.25	0.1	0.25	0.15	Bal.

3.2 Tool pin preparing

1) Tool pin in welding process was made from SKH 57 metal as in JIS standard with cylindrical shape (Elangovan, K. et al., 2007). The diameter of pin shoulder was 8 mm and its radius between shoulder and head was 1.8 mm. The diameter of tool pin was 3.6 mm and the length of tool pin was 3.4 mm.

2) The flame of welding was carburizing (Oxygen – Acetylene gas).

3) Data Logger Thermocouple was used to take the temperature of work pieces and gather data while welding.

3.3 Welding parameter

1) The speed of pin tool rotation was at 1,200 and 1,500 rpm with the welding speed was at 120 mm/min and 160 mm/min.

2) The CO_2 gas was applied to cover the flow rate was 0.6 Nm^3/h

3) The welding temperature was around 590 to 610 ˚C

4) The welding tilt angle of pin tool was at 2 degree.

5) The direction of pin tool rotation was followed the clockwise.

6) The working pieces were specified moving to the pin tool in this experimental research.

3.4 Semi-solid welding process

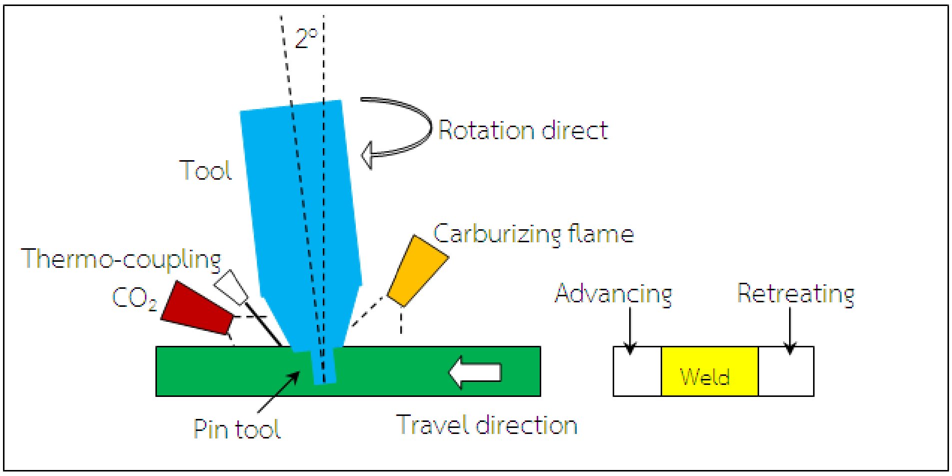

Figure 1. The welding continued according to specified variables until finished.

This research was experiment under various variables from fundamental welding of welding speed, the speed of pin tool rotation and the adjustment of welding flame. The semi-solid welding was occurred when some part of the metal was fusion. This process was butt weld which would not erode the working pieces and attached them with bracket of vertical milling machine. Before welding, the working pieces were warmed by carburizing flame around 2 minute then blow the flame on the surface of working pieces that connected with tool pin around 12 minute. The temperature occurred on the welding line was 590 to 610°C. The temperature at welding surface was taken and controlled by thermocouple. CO_2 gas was applied to cover the welding line with flow rate at 0.6 Nm^3/h. After that, putting the pin tool with rotation speed and clockwise to working piece until the shoulder of pin was touched the surface of the working piece for around 12 seconds. Then, welding as variable set until all the process was finished (Figure 1) and after welding, the welding line was set as advancing side, which the rotation of pin tool and the direction of welding were in the same direction, and retreating side, which the rotation of pin tool and the direction of welding were in the opposite direction.

4. Results

4.1 The welding surface appearance was convex wave and rough from pin tool stirring. There was no crack which occurred from not joining condition on both top and down welding area. It can be concluded that the rotation speed of tool pin at 1,200 rpm is most suitable for semi-solid state joining.

4.2 The porosity was occurred mostly in macro structure of the top area of welding lines in every variable especially in the rotation speed of tool pin at 1,500 rpm with welding speed at 120 mm/min. The porosity was occurred less in the rotation speed of tool pin at 1,200 rpm with welding speed at 160 mm/min.

4.3 On micro structure, in the rotation speed of tool pin at 1,200 rpm with welding speed at 160 mm/min, there was spheroidal structure and grain dispersed regularly. On the rotation speed of tool pin at 1,500 rpm of both welding speed, the dendrite structure was occurred.

5. Conclusion and Discussion

5.1 Examination on the welding surface

The examination on the welding surface in semi-solid state joining (Figure 2) with digital camera, it was found that the welding surface was convex and rough from the stirring of pin tool. The crack from unjoining weld of the top and down area was not found (Yao Liu., et al. 2012). From observation, the black trail occurred at the edge of the welding area which this area was influenced from the flame. Moreover, the rotation speed of pin tool at 1,200 rpm of both welding speed, the welding surface were more complete and fine than the rotation speed of pin tool at 1,500 rpm. It can be concluded that the rotation speed of tool pin at 1,200 rpm is most suitable for semi-solid state joining.

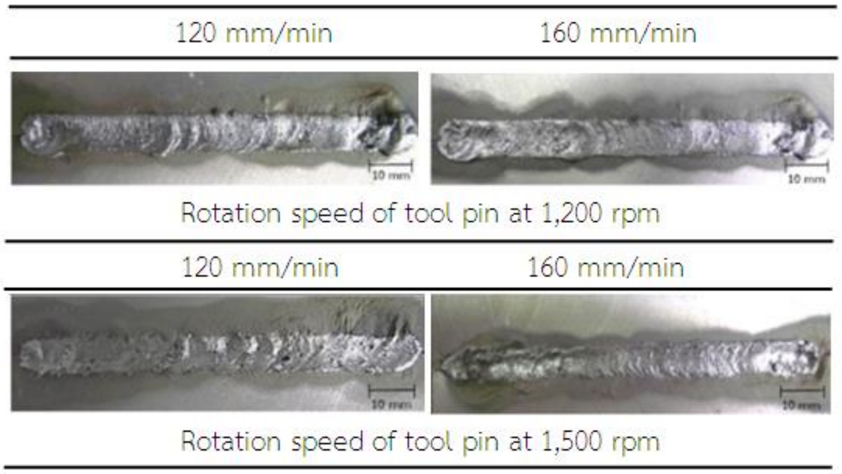

Figure 2. The welding surface in semi-solid state joining.

5.2 Macro structure examine

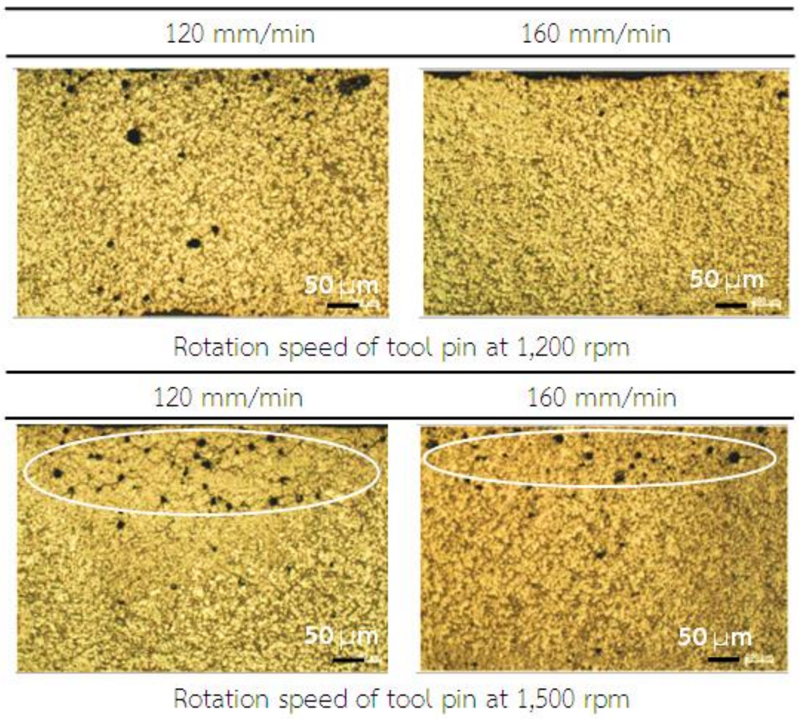

Figure 3. Macro structure examine from semi-solid state joining.

The test of macro structure of semi-solid welding (Figure 3) with digital camera in macro level, spongy trail was found that the top area of welding in every variables because the air was combined in welding and CO_2 covering gas cannot protect the air at the carburizing flame side. The spongy trails were occurred mostly at the rotation speed of pin tool at 1,500 rpm and the welding speed at 120 mm/min (Alvani SMJ., et al. 2010). This is because the accumulated heat in welding line made metal into plastic condition and in this circumstance, CO_2 gas are not much got accessed into the welding line as well as the speed of pin tool stirring was circumfluence and firmly joint (Maamar HAKEM., et al. 2012). However, at the rotation speed of tool pin at 1,200 rpm, the welding speed was 160 mm / min. There was no porosity in the weld. This is the best variant in this connection.

5.3 Micro structure examine

Micro structure SSM 5083 in the base metal (Figure 4) which scale from 50 micron picture, it was the structure from semi-solid casting with GISS technique. It consisted of spheroidal grain (white round) as aluminum phase (α) and eutectic phase consisted of aluminum phase combined with aluminum phase and magnesium phase (back and white).

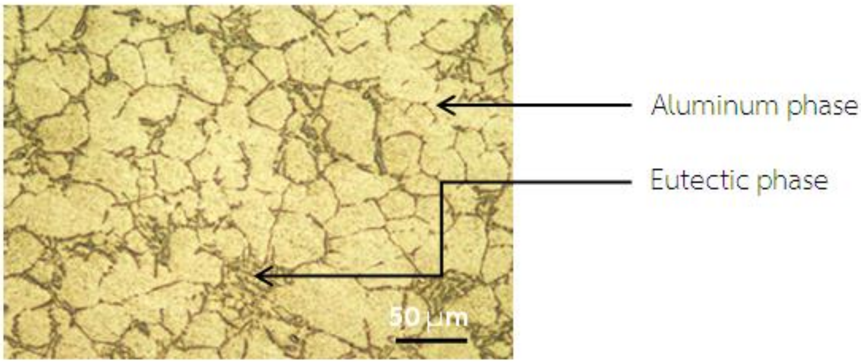

Figure 4. Micro structure SSM 5083 in the base metal.

The micro structure was examined with light microscope (Figure 5). From the examine, it was found that in the rotation speed of tool pin at 1,200 rpm of both welding speed had the spheroidal structure that similar to its former metal. Moreover, at the welding speed of 160 mm/min, spheroidal structure and the dispersing of grain was steadier that at the welding speed at 120 mm/min, as it got the appropriated flame with the welding line in the semi-solid condition and this made the plastic structure was definitely dispersion (Huibin, Xu. et al., 2012). Nonetheless, in the rotation speed of tool pin at 1,500 rpm, it was found that in both welding speed have got the dendrite structure which occurred from the changing of spheroidal structure from heat in welding line of high rotation speed (Alvani SMJ., et al. 2010).

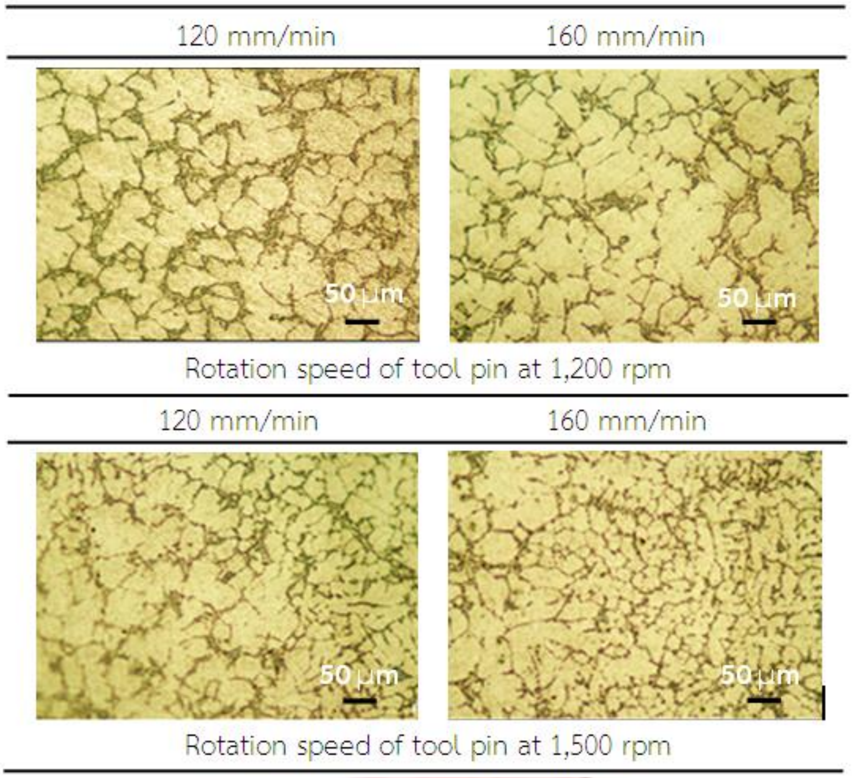

Figure 5. Micro structure from semi-solid state joining.

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7. References

Alvani SMJ., et al. (2010). Semisolid Joining of Aluminum A356 Alloy. **Partial Remelting and Mechanical Stirring**, pp. 1792-1798. (In Iran)

Chucheep, T. (2007). Semi-solid gravity sand casting using gas induced semi-solid process. **Department of Mining and Materials Engineering, Prince of Songkla University**, (In Thai)

Elangovan, K. et al., (2007). Influences of Tool Pin Profile and Welding Speed on the Formation of Friction Stir Processing Zone in 2219 Aluminium Alloy. **J Mater Process Tech** :163-175. (In India)

Huibin, Xu. et al., (2012). The Effect of Stirring Rate on Semi-solid Stirring Brazing of SiCp/A356. **Composites in Air**, 452 - 458. (In China)

Maamar HAKEM., et al. (2012). **Welding and characterization of 5083 aluminum alloy**. Centre National Recherche Scientifique et Technique en Soudage et Contrôle CSC. BP 64, Route de Delly-Ibrahim, Cheraga Alger. (In Algerie)

Muangjunburee, P. (2008). Welding and Joining Metallurgical for Aluminum. **Department of Mining and Materials Engineering, Prince of Songkla University**, 599-602. (In Thai)

Narimannezhad, et al., (2008). Microstructural Evolution and Mechanical Properties of Semi-solid Stir Welded Zinc AG40A **Die Cast Alloy**, 4112 - 4121. (In Iran)

Wannasin J, and Thanaburungkul S. (2008). Development of a semi-solid metal processing technique for aluminium casting applications. Songklanakarin, **Journal Science Technology**. 30(2): 215-220. (In Thai)

Yao Liu., et al. (2012). Microstructure and mechanical properties of aluminum 5083 weldments by gas tungsten arc and gas metal arc welding. **Materials Science and Engineering,** 7–13.