THE CHARACTERISTICS OF FRICTION WELDED JOINTS FOR AIR CONDITIONING APPLICATION

Łukasiewicz Institute of Welding
AGH University of Science and Technology

Węglowski M. St.[1], Węglowska A.[1], Pietrzak J.[1], Richert M.[2], Noga P.[2]
[1] Łukasiewicz – Institute of Welding
[2] AGH University of Science and Technology

Introduction

The European directives 2006/40/EC on the greenhouse gasses elimination demand to stop using traditional refrigerant and to change it to R744 (CO_2) medium in cars air conditioning installation. The R744 refrigerant is enviromentally friendly medium if compared with standard solution such as R12, R134a or R1234yf and safer for passengers than R1234yf. Carbon dioxide has been used as a refrigerant since the mid to late 19th century. With the introduction of fluorocarbons in the 1930s, CO_2 fell out of use by the 1950s. However, due to its low environmental impact, CO_2 is now regaining popularity from refrigeration system designers when an alternative to fluorocarbons is being sought. R744 is now regaining popularity due to a number of advantages: low toxicity, non-flammability, zero ozone depletion potential, very low global warming potential (GWP=1), excellent thermodynamic properties and low energy requirements. The main applications include static and mobile air conditioning systems, chilled warehousing, commercial refrigeration, chill cabinets and vending machines, industrial heat extraction, process chilling, low and ultra-low temperature applications. R744 is often used as secondary refrigerant, for example, alongside ammonia. A comparison of the most popular refrigerants is given in Table 1.

Commercial name	R12	R134a	R1234yf	R744
Chemical name	Dihlorodifluoro metan	Tetra Fluoro Etan	tetrafluoropropane	hydrocarbon
Ozone depleting	1,0	0.03	0	0
Global worming potential	10600	1430	4	1
Boiling point [°]	-29.6	-26.3	-29.0	-78.4

Table 1. Comparison of refrigerants

However, the systems based on CO_2 refrigerant have also some disadvantages as follows: new designs required for all systems and components, high tooling/production costs, additional components and safety system needed, increased system weight and full efficiency potential needs to be demonstrated. Moreover, system leakage is a very serious problem due to the extremely small molecule size of CO_2 and ultra-high operating pressures, leak detection method needed, and training of personnel. It should be noted, that the air conditioning system working with R744 refrigerant operates at a high temperature (up to 150°C) and high pressure (up to 130 bar). These two parameters are much higher than for other refrigerants. Thus new materials as well as joining technologies are strongly needed for these systems.

The main goal of the presented research was to apply friction welding to manufacture air conditioning components.

Experimental details

The investigation was carried out on test welded joints of the Al 6082 (nipple) and Al 5049 (pipe) aluminium alloys grades. The components of High Pressure High Temperature line (HP HAT) are shown in Figure 1.

Figure 1. a) The components for friction welding, nipple and pipe, b) Joint configuration

To produce the test friction welded joints of aluminium alloys, high speed rotation friction welding was applied. Harms&Wende high-speed friction welding machine RSM 400 (Fig. 2) was used. The microstructure of friction welded joints was observed by an Eclipse MA 200 (Nikon) light microscope (LM) as well as scanning electron microscope (SEM) Hitachi SU 70.

Figure 2. High-speed friction welding machine RSM 400

Results and discussion

The main goal of investigation was to study the influence of friction welding technologies on macro- and microstructure of welded joints. The welding parameters were as follows: welding time 0.1-0.8 s, welding force 1.0 bar, forging time 3-6 s, forging pressure 5-6 bar, rotation speed 15000 – 20000 rpm. The macrostructure of high speed friction welded joint was presented in Figure 3.

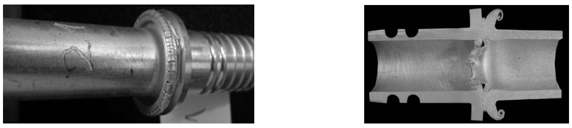

Figure 3. a) View of the components after welding, b) Macrostructure welded joints

The microstructure of friction welded joints was presented in Figure 4. Differences in micro-structure of welded alloys can be observed. The performance of this joint can be seen through the plastic range deformations and the way the material flows from the sample axis inwards in the direction of the flash, which on the 5049 alloy side is much larger compared to the material 6082. It may be caused by higher strength of alloy 6082 at higher temperature. About the microstructural transformation (mainly dynamic recrystallization and/or recovery) caused by an increase of temperature during the welding process can testify to differences in grain sizes in different parts of welded joint. In the axis a strip structure in which the grain size grows in the direction of the outflow. Observation using scanning microscopy has been shown in Figure 5, it confirmed the differences in materials used for friction welded joints. In Figgure 5A, a change in the structure of the weld axis was observed, characterized by elongated grains towards the outflow. Due to pressure and friction internal, there was a strong plasticization of 5049 aluminium over a length of 250 µm from the axis of welds and 60 µm from the axis of the 6082 aluminium weld. Moreover, in Figure 5C therewas observed the emergence of eutectic as a consequence of transition of 5049 micro-regions to the state of ticostropic. This phenomenon applies to alloys with relatively eutectic temperatures low.

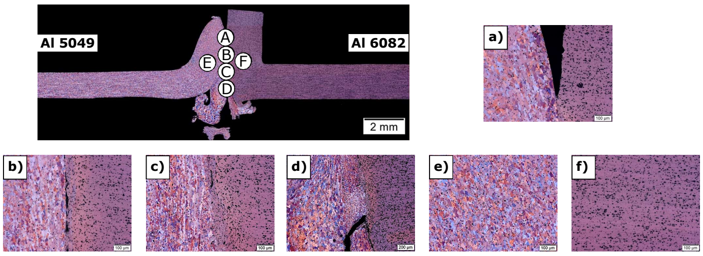

Figure 4. Microstructure of high speed friction welded joints, LM

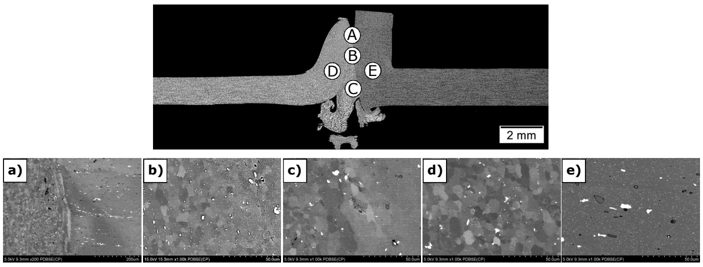

Figure 5. Microstructure of high speed friction welded joints, SEM

Summary

This paper describes the influence of high-speed friction welding process on the macrostructure and microstructure of welded joints of Al 6082 (nipple) and Al 5049 (pipe) aluminium alloys. The results of this research are summarized as follows:

- high-speed friction welding process for air conditioning systems can be adopted, the proper quality of welded joints can be achieved,
- the welding process has a dominant influence on geometry and macrostructure of welded joints,
- the high-speed friction welding guarantees proper quality of welded joint,
- due to pressure and friction internal, there was a strong plasticization of 5049 aluminium over a length of 250 µm from the axis of the welds and 60 µm from the axis of the 6082 aluminium weld.

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Contact:
Marek St. Węglowski Ph.D., Eng
Łukasiewicz – Institute of Welding
Bl. Czeslawa Str. 16-18
44-100 Gliwice
tel. +48 32 33 58 236
www.is.lukasiewicz.gov.pl
marek.weglowski@is.lukasiewicz.gov.pl