Journal of Metallurgical and Materials Engineering, Vol.31, No.2, 2020.

The Effect of Heat Input on Microstructure and Mechanical Evolutions of A7020-T6 Alloy Joined by TIG Welding

Mohamad Alipour Behzadi[1] Khalil Ranjbar[2]
Reza Dehmolaie[3]

1. Introduction

The alloy 7020 is a medium strength aluminum alloy which is widely used in different aerospace and shipbuilding industries. It is considered weldable in 7000 series Al-alloys. In fusion welding of these alloys, weld fusion zones typically exhibit coarse columnar grains and most of the precipitates are disolved because of the prevailing thermal conditions. This often results in inferior weld mechanical properties and poor resistance to hot cracking. That's why hardness and strength of the weld metals are usually lower than the base metal in age hardened or work hardened conditions. The reduction in grain size of the weld metal and the HAZ region, can reduce the tendency to hot cracking and enhance the mechanical properties. Investigations show that using pulsed TIG welding instead of constant current welding, can prevent grain growth in weld metal and HAZ region. The earlier studies show limited information on the effect of pulsed current on welding of 7020-T6 alloy. So, an attempt was made to study the effect of heat input on fusion welding specification of the alloy by applying a pulsed current welding technique. The resultant changes in HAZ width, the microstructure and the mechanical properties of the joints were also investigated and discussed.

2. Exprimental

Commercial 7020 aluminum alloy sheets of 7 mm thickness, 100 mm width and 100 mm length in T6 condition were used. The welding processes were conducted using tungsten inert gas welding (TIG) technique with the filer metal ER5356. Three passes of welding were applied and interpass temperature of 110 °C was maintained throughout the welding. During the welding process, a multi-channel thermo detector (type K thermocouples) was used for measuring the transverse distribution of the weld temperature. The samples for metallographic observation were cut from the base metal, weld nugget, and the heat affected zones, ground, polished, and etched using Keller's reagent. Thermal analysis was conducted using a METTLER TOLEDO differential scanning calorimeter (DSC). Microstructural examinations were performed using a Mira 3-XMU type scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectroscopy (EDS). Foil specimens were prepared and observed on a JEOL JEM-2100F transmission electron microscope (TEM) at 200 KeV. The Vickers microhardness profile was measured under a load of 300 g along the centerlines of welding cross section with an interval of 0.5 mm. Tensile samples were cut along the transverse direction of the weld joints utilizing SANTAM electronic tensile machine.

3. Results and Discussion

Figure 1a represents the optical micrograph of the as-received base alloy sample and Figure 1b shows the micrograph of the weld metal with constant current. In former case, matrix grains are very large in size and elongated. In the latter case, grains are relatively coarser and equiaxed. In Figure 2, grain structure of the weld metal is further refined using pulsed current (P160A). The change in average grain size of the weld metals for different samples is shown in Figure 3. It is clear that using pulsed current reduces the average grain size in weld metals. The effect of pulsed current on refining of grain structure in fusion welding has been reported in earlier studies.

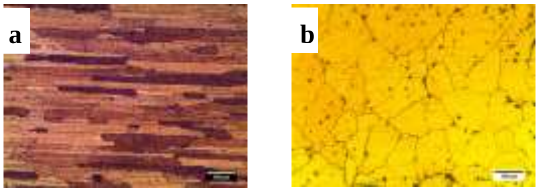

Fig. 1. Optical micrographs of the base alloy 7020-T6, (a) before FSW, and (b) after welding AC140A

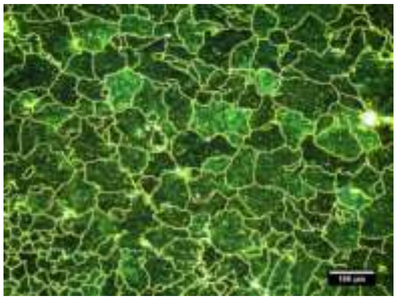

Fig. 2. Optical micrograph of the weld subjected to P160A

---

[1] Corresponding Author: M.Sc. Student Materials Science and Engineering Department, Faculty of Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
Email: Alipourmohamad@yahoo.com

[2] Professor, Materials Science and Engineering Department, Faculty of Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

[3] Assistant Professor, Materials Science and Engineering Department, Faculty of Engineering, Shahid Chamran University of Ahvaz, Ahvaz, Iran.

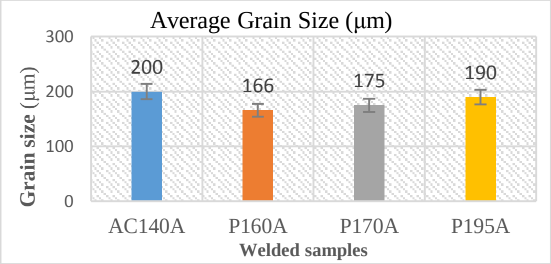

Fig. 3. Average grain size of the weld metals for different samples

Based on the results of DSC, (Figure 4) a minimum temperature (142 °C) at which precipitate evolution may appear and complete, is considered as the HAZ limit temperature. And accordingly, the far most location from the welding interface towards the base metal which may be exposed to this temperature is considered as the end of HAZ region. But, the width of HAZ could not be estimated accurately since it was larger than the width of the samples (10 mm). Indeed, this is attributed to the high heat input induced by the TIG welding extending the HAZ region. According to the results obtained from the EDS analysis and the metallographic observations, there is a large number of intermetallic compounds in the base metal and weld metals. These compounds are mainly composed of Fe, Mn, and Si which are partly dissolved, fragmented and re-distributed because of pulse current which produces excessive pool agitation. The results showed that hardness decreases in the weld metals due to the dissolution and coarsening of precipitates, but it gradually recovers towards the HAZ region.

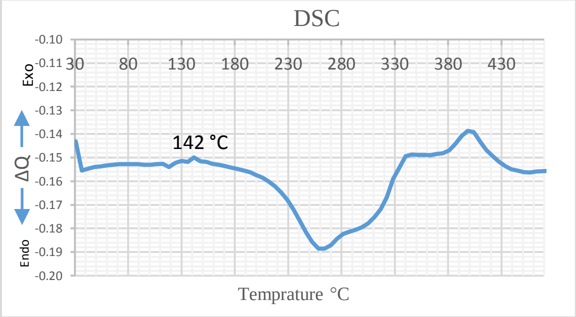

Fig. 4. DSC analyses of the AA7020 in T6 condition

The results of the tensile test (Figure 5) conducted on the TIG welded samples revealed that maximum and minimum of tensile strength, belong to the P195A and AC140A samples, respectiveley. The tensile strength of weld metals with pulsed curent (P170A and P195A) was reatively higher than the base metal. The improvement in tensile sterngth in these samples (pulsed current welded samples) is attributed to the aout-aging where precipitates are reformed while cooling down from the welding temperature. Infact, higher heat input reduced the cooling rate and as a result, the exposure time and duration at or above 142 ºC increased. Therefore, welding zone was aged on cooling from the welding temperature and the strengthening/ hardening phase reprecipitated.

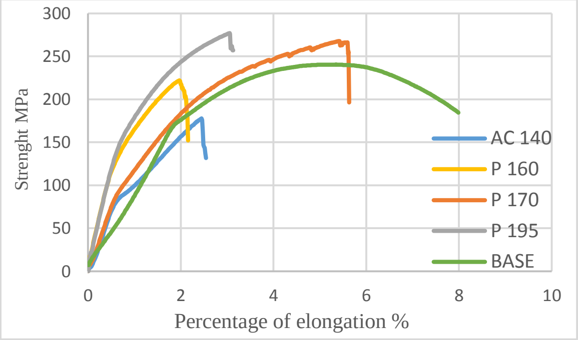

Fig. 5. Typical stress-strain curve of the tensile tested specimens

4. Conclusion

In this study butt joining of 7020-T6 alloy was performed using tungsten inert gas (TIG) welding with continuous (constant) and pulsed current. The effect of heat input on microstructure and mechanical properties of the joints were investigated. The main results are:

1. The initial large and elongated grain structure of the base alloy was transformed into finer and equiaxed grains with pulsed current welding due to the nature of pulse current which produces excessive pool agitation. The grain size in weld metal reduced significantly with pulse TIG welding, when compared to the constant current welding.
2. The tensile strength increased in weld metals with increasing pulse intensity, and a maximum strength of 275 MPa was obtained in P195 sample.
   Tensile strength was higher in pulsed TIG welded samples, compared to the constant current welded samples as well as the base metal. The hardness also changed in the same manner. The recovery of mechanical properties in the weld and HAZ was attributed to the re-precipitation of strengthening/hardening phase on cooling from the weld temperature (auto-aging).
3. In both the pulsed and constant current welding, high heat input resulted in a wide HAZ; so the HAZ width was not in the range to be estimated.