Effect of Post-weld Heat Treatment on Microstructure and Hardness Properties of Friction Stir Welded Industrial Aluminum

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Abstract: Industrial aluminum alloys generally present low weldability by fusion welding methods because of the sensitivity to weld solidification cracking, vaporization of strengthening alloys and other defects in the fusion zone. Friction stir welding (FSW) can be deployed successfully with aluminum alloys. We presented the effect of post-weld heat treatment (PWHT) on the microstructure and hardness properties of Aluminum. Semi solid plates were butt-welded by FSW at a rotation speed of 1200, 1000, 500 rpm, welding speeds of 300 mm/min.

The heat-treatable alloys Al-Fe-Zn-Mg-Cu develop their properties by solution heat treating and quenching, followed by either natural or artificial aging. The heat-treatable alloy may also be annealed to attain maximum ductility. This research was the study in post weld heat treatment (PWHT) that affected to hardness properties and microstructure. The material in testing is aluminum alloy. Post weld heat treatment temperatures were set at 400 ^{0}C and Post weld heat treatment times were controlled at 20 and 24 hours. The welded specimens were tested by hardness testing machine. This can result in increased of hardness. These results can use as data information in future for improve post weld heat treatment properties.

Key words: Friction stir welding (FSW), post-weld heat treatment (PWHT), Aluminum alloy

1. Introduction:

Friction stir welding (FSW) was developed at The Welding Institute (TWI), UK in 1991. It is a solid state joining process, in which a cylindrical shouldered tool with a profiled pin is inserted into the joint line between two pieces of material. Friction stir welding (FSW) uses a non consumable tool to produce frictional heat in the adjoining surfaces. The welding parameters like rotational speed, welding speed, tool pin length, and tool shoulder diameter play a major role in deciding the joint properties. The basic principle of the FSW process is illustrated in Fig.1a and fig. 1b. The microstructure of a friction stir weld can be classified into four different zones, as shown in Fig.2. The nugget zone exhibits a re-crystallized fine grain structure, with grain sizes increasing from the weld region to the base metal. This alloy has wide application in aircraft industry. This alloy is difficult to weld using conventional fusion techniques. This is due to the extreme sensitivity to weld solidification cracking and other weld defects. therefore, vaporization of Zn and Mg by very high vapor pressures from fusion welding reduces the effect of hardening and, therefore, the lowering of tensile strength. However, in FSW the work piece does not reach the melting point. These defects did not occur on the weld.

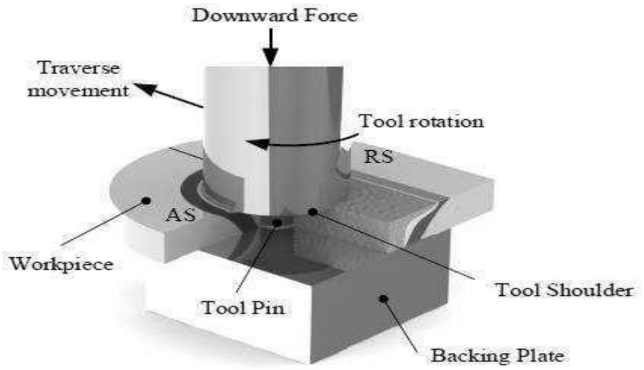


Fig.1(a)

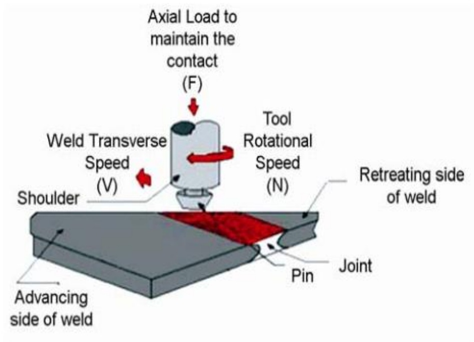


Fig.1(b)

Fig.2

After the FSW the work piece on post weld heat treatment . Heat treatment is a controlled process used to alter the microstructure of material to impart properties which benefits the working life of a component, for example increased surface hardness , temperature resistance , ductility, and strength. Annealing is basically a stress relieving process in which material is heated at a temperature above its upper critical temperature and is cooled in furnace itself. The property of the substance is the function of its grain structure and therefore refined grain structure imparts better strength and reliability after undergoing heat treatment.

2.Experimental Procedure: The industrial aluminum used in this investigation was a 6 mm thick plate. It was prepared into the required dimensions of 300 mm× 150 mm by bend saw and filling files. Butt joint configuration was prepared to fabricate FSW joints. Its chemical composition is presented in Table 1. The cylindrical pin was used for friction stir welding. The welding tool was rotated in the clockwise direction, and the specimens, which were tightly attached to the backing plate, were traveled. In this work, the constant welding speeds 300 mm/min. The tool rotation speed was 1200, 1000, 500 r/min and the tilt angle was 3˚.

Material	**% of Material**
Fe	0.2%
Si	0.3%
Mg	0.5%
Mn	0.5%
Cu	0.4%
Al	98.1%

Table-1

These specimens were clamped tightly to a thick backing plate of low carbon steel on NC FSW machine shown in fig 3.


FSW-3T-NC Machine at IIT (BHU)

Fig.3

An experiment was conducted to illustrate the effect of heat treatment on work piece. The work piece was carried to fitting shop where it was figured to proper dimension and then cut into four equal parts of same dimension.

For Heat Treatment Apparatus used:

Muffle furnace (sometimes, retort furnace) in historical usage is a furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash. After the development of high-temperature electric heating elements and widespread electrification in developed countries, new muffle furnaces quickly moved to electric designs. Today, a muffle furnace is (usually) a frontloading box-type oven or kiln for high-temperature applications such as fusing glass, creating enamel coatings, ceramics and soldering and brazing articles. . They are also used in many research facilities, for example by chemists in order to determine what proportion of a sample is non-combustible and non-volatile (i.e., ash). The muffle furnace used had following specifications: Maximum temperature – 1200 degree Celsius• Maximum voltage-220 volts• Maximum Load- 3.5 kilo watt

In the muffle furnace Post weld heat treatment temperatures were set at 400 ^{0}C and Post weld heat treatment times were controlled at 20 and 24 hours10. The muffle furnace which was set at a temperature of 400 Celsius and the test pieces were left for 1 hour at the elevated temperature for carrying out annealing

Hardness Test

The hardness of samples was measured by Brinell hardness tester under a static load of 100 kgf with a ball indenter of 16mm diameter maintained for 10 to 15 seconds. The diameter of the resulting impression was then measured with the aid of a calibrated microscope according to BS240 and ASTME 10-84 standard.

Microstructure Examination; The microstructure of the PWHT and non heat treated samples were observed under optical microscope. The specimens were mounted in hot phenolic powder and were ground on a water lubricated hand grinding set-up of abrasive papers, from the coarsest to the finest grit sizes. Polishing was carried out on a rotating disc of a synthetic velvet polishing cloth impregnated with micron alumna paste. Final polishing was carried out with diamond paste. The specimens were then etched and etching time 10-60second with a solution shown in table 2.

Sr. No	Chemical	Ml(200)
1	Hydrofluoric Acid	2ml
2	Hydrochloric Acid	3ml
3	Nitric Acid	5ml
4	Distilled Water	190ml

Table-2

3.Observation and Results:

The specimen for the minute inspection was set up by metallographic methodology scratched in Keller's specialist, analyzed under optical magnifying instrument. The micrographs plan show the confirmation of negligible porosity in both without Heat Treatment and with Heat treatment. The variation in microstructures in the SZ associated with all welding conditions. It can be seen that grain size decreases as the rotational speed decreases. The size of re-crystallized grains in the SZ depends on two factors such as degree of deformation and the peak temperature obtained during FSW. A decrease in degree of plastic deformation causes the re-crystallized grain size to increase, and the decrease in peak temperature decreases the grain size of the SZ. In the post weld heat treatment microstructure Fig.1(1000rpm),2(1200rpm),3(500rpm) in grain size decrease compare then without Heat Treatment work piece shown in Fig.5(1000rpm),6(1200rpm), 7(500rpm).Fig.4 is base metal.

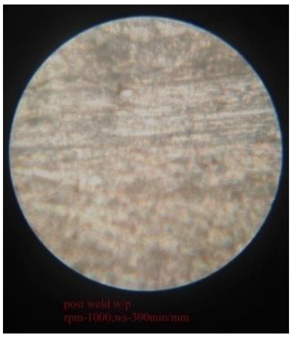


Fig.1

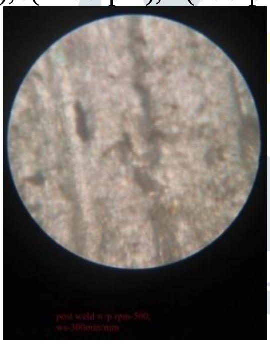


Fig.2

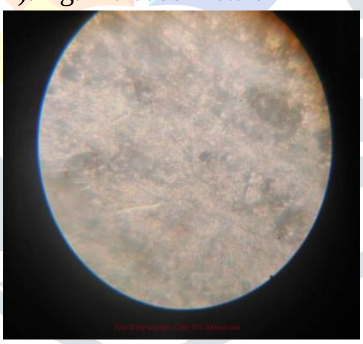


Fig.3

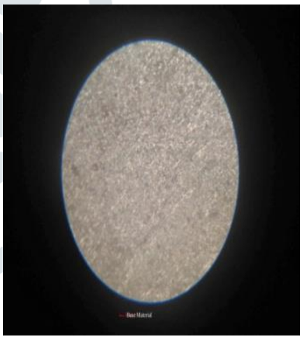


Fig.4


Fig.5 (500)


Fig.6(1000)

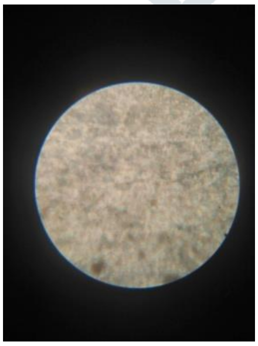
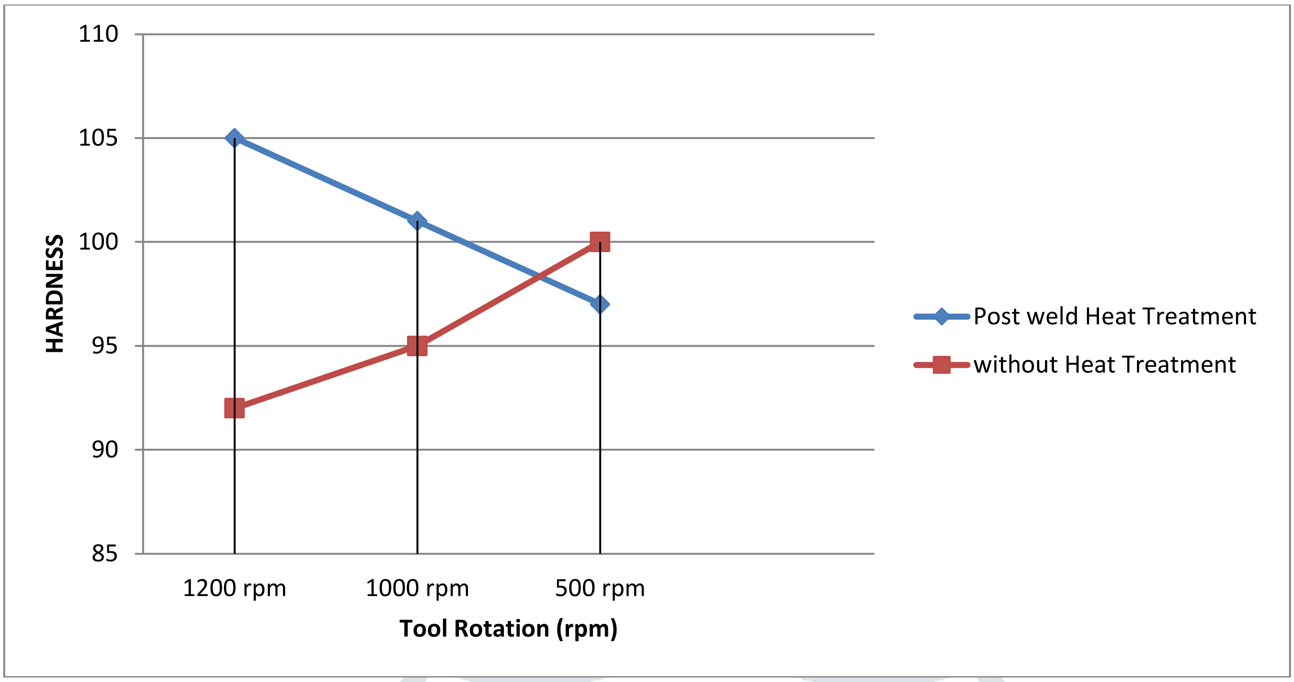


Fig.7(1200)



In the Hardness test without Heat treatment work piece the effect of tool rotation decease with high rpm tool rotation but after post weld heat treatment hardness increase with high rpm tool rotation.

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