Destructive And Non-Destructive Testing Of Friction Stir Welded Joints Of Al-Cu

Kishore B S[1], Pavan Kumar L[2], Prakruthi S V[3], Kiran A Suryavanshi[4], Mr. Suresh K R[5]
[1,2,3,4] Dept of Mechanical Engineering
[1,2,3,4] Nitte Meenakshi Institute of Technology, Bengaluru-64
[5]External Guide, Technical officer, Bamul.

Abstract- *In present work friction stir welding is done to produce the dissimilar weldment of AA6061 and pure copper of thickness 3mm with butt configuration. Friction stir weld joints are produced in a vertical milling machine using H13 steel hardened tool with straight cylindrical profile for very low weld speed of 7mm/min and 10mm/min. On this welded specimens both destructive and non-destructive testing are conducted. X ray image of weld joint is taken to easily identify the some of the defects and also tensile test is done for specimens using UTM."*

Keywords- FSW, Copper and Aluminium, Destructive, Non-Destructive testing.

I. INTRODUCTION

Friction stir welding is a solid-state bonding process developed and patented by The Welding Institute (TWI) which has emerged as an effective technique for welding alloys that is difficult to combine using conventional technology. This technique prevents solidification and porosity formation. In FSW, a non-consumable rotating tool with special geometry, consisting of a shoulder, sweeps the welding seam and joins the pieces to be processed as it passes through the weld. The main process parameters, such as the rotation speed, the welding speed and the tool pin length, influence the friction of the quality of the welding joint. Welded seams show superior mechanical properties thanks to fine grains and equal axes recrystallized in the ladies' area. The FSW is associated with some unique defects such as joint defects, cavities or furrows (tunnel defects below the surface) due to insufficient heat input, voids, lack of bonding, large masses of flash due to excessive heating and induced cavities from abnormal agitation."

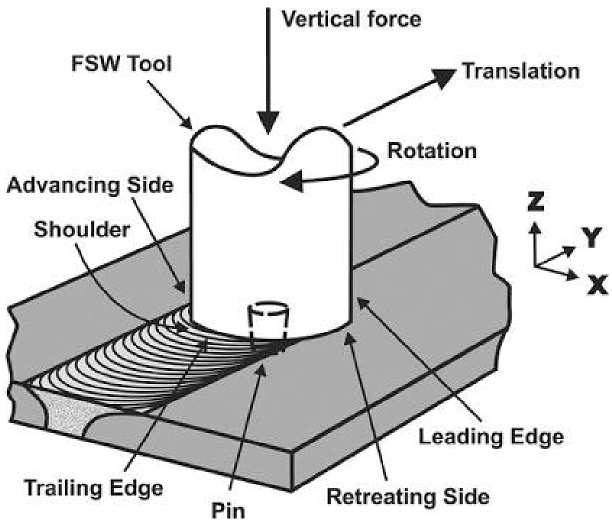

Fig.1: Friction Stir welding

Non-destructive testing (NDT) is a large group of analytical techniques used in science and industry to evaluate the characteristics of a material or component without damaging it. There are many different types of NDT; the most commonly used are ultrasonic tests, magnetic probes, liquid penetration, X-ray tests and parasitic current tests. Among these ultrasonic tests and X-ray radiography is the best technique. X-ray radiography can detect defects or discontinuities in welds, such as cold inclusions, porosity and slag. Liquid penetration is generally used to detect surface cracks and other surface defects.

II. PRINCIPLE

The Friction stir welding of butt joints of similar and dissimilar metals like Al6061-T6 and Copper were welded using vertical milling machine.

"In FSW, a cylindrical, shouldered High speed steel H13 grade tool (Non consumable tool) with a profiled probe is rotated in clockwise direction and slowly move downwards(plunged) the dissimilar metal joint line with an axial force on the tool, until shoulder contact the surface of the work piece and then tool transverse along the weld line."

As the depth is slightly smaller than the thickness of the work piece, an axial force is been applied on the work piece.

When the tool touches the surface of the work piece, due to friction, heat is generated between the work piece and non consumable H13 tool, this heat causes the work piece to soften without reaching the melting point i.e., at solid state.

"The subsequent plasticized material is exchanged from the front edge of the device to the back edge of the instrument test and is produced by the thin contact of the device bear and the pivot profile. After cooling, a solid phase bond remains between two pieces. After cooling, this leaves a solid phase bond between two pieces."

The tool is then retracted back from the weld leaving behind an exit hole which makes the completion of the weld and then extra material is flushed out from the tool shoulder is finely grinded to get a fine weld.

III. WELDING PARAMETERS

Parameters or factors involved in friction stir welding are:

Tool speed-"The speed is largely determined by the application and the metal being joined, but they are not mutually exclusive, a slowly rotating tool cannot move incredibly fast across the joint line, for instance."
Tool tilt-"Inclination of the instrument: the inclination of the cylindrical instrument can have important effects on the welding process. A general range for tool tilt is between 2 and 4 degrees, in such a way that the tool leans into the joint."
Welding speed-Speed at which the tool traverse along the weld line.
Plunge depth-Depth to which the shoulder of the tool sinks into the material.

IV. EXPERIMENTAL SETUP

Design of FSW tools

After extensive literature survey we decided to design tool by using H13 steel for they were non-reactive and had the best hardness properties. The machined H13 steel was 55 HRC. Among the various tool designs we chose to use straight cylindrical configuration. The tool designs along with the dimensions are given below.

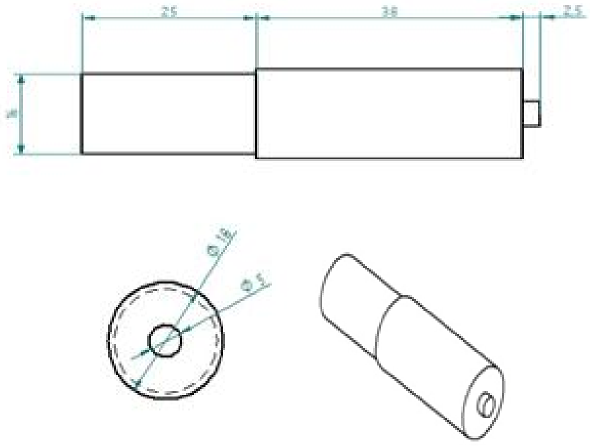

Fig.2: Draft of Straight cylindrical tool profile

V. DESIGN OF EXPERIMENTS

According to our need we have considered three major influencing parameters i.e., tool speed, feed rate, pin length at two levels each. Let us consider the following factors at two tool designs for the above consideration is as follows:

TABLE 1: Design of Experiments

Experiments	Tool speed rpm	Feed rate mm/min	Pin length mm
1	1010	7	2.0
2	1010	7	2.5
3	1010	7	2.0
4	1010	7	2.5
5	1010	10	2.0
6	1010	10	2.5
7	1010	10	2.0
8	1010	10	2.5

VI. RESULTS AND DISCUSSIONS

The tests we are performing are Destructive and Non-Destructive tests.

❖ DESTRUCTIVE TESTING

"Trial of delayed protection in the most serious working conditions, proceed until the segment, the hardware or the example of the item fizzles (it breaks or is crushed).The purpose of destructive testing is to determine service life and to detect design weaknesses that may not show up under normal working conditions
Types of Destructive testing are Bend test, Break test, Tensile test, Hardness test, Impact test, Micro and Macro examination etc."

Following tests were conducted under Destructive testing and the results are tabulated below.

1. ROCKWELL HARDNESS TEST

The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods. The test results of Rockwell Hardness test are tabulated in TABLE 2.

TABLE 2: Rockwell Hardness Test

Experiment no.	Rockwell Hardness number
1	76
2	82
3	85
4	77
5	71
6	72
7	67
8	72

In Rockwell hardness we used the indenter of 1/16″ and a load of about 100 kg is applied. The results so obtained are tabulated in the table above and the relationship between rpm and hardness number. From the above results we have observed that the hardness of the material increases when the tool rpm decreases, so we can say that the hardness of the material is inversely proportional to tool speed.

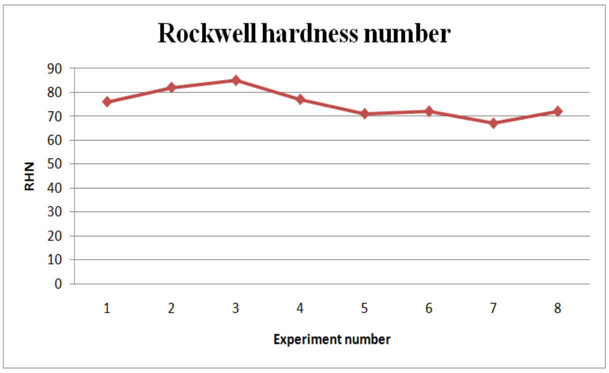

Fig 5.1: Graph of Experiment no. vs RHN

Fig.3: Graph of Experiment no. vs. RHN

2. TENSILE TEST

Tensile test was performed in order to evaluate the static properties of welded joints at room temperature using UTM. The test results of tensile test are tabulated in TABLE 3.

TABLE 3: Tensile Test

Experiments	Feed rate mm/min	Pin length mm	Ultimate tensile strength [Mpa]
1	7	2.0	39.5
2	7	2.5	80.3
3	7	2.0	32.8
4	7	2.5	42.9
5	10	2.0	34.8
6	10	2.5	46.0
7	10	2.0	39.6
8	10	2.5	70.3

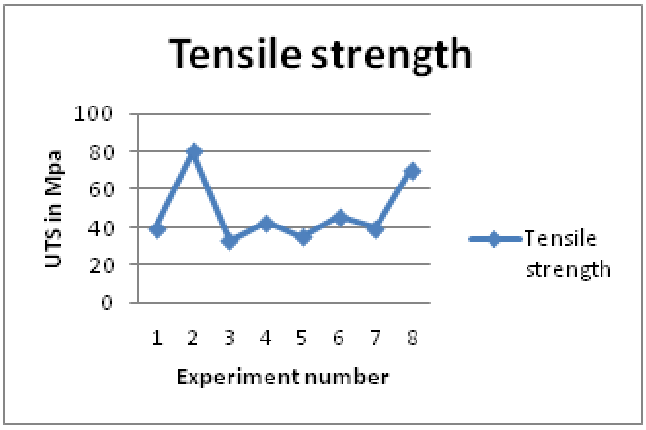

Fig.4: Graph of Experiment no. vs. UTS

The following graph shows the variation of engineering stress vs. engineering strain for the highest tensile strength specimen.

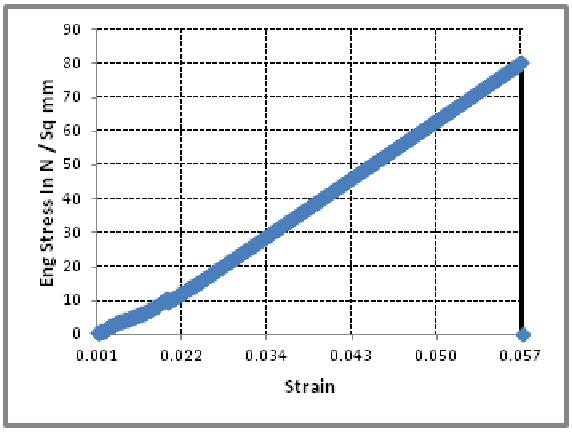

Fig.5: Graph of Eng Stress vs. Strain for highest tensile strength

❖ **NON-DESTRUCTIVE TESTING**

"Quality control method that does not damage or destroy the tested material or product. Performed on a finished item instead of on a material sample, it uses infrared radiation, radiography, ultrasound, x-rays, and other techniques to detect fatigue effects, structural flaws, and other such defects."

Following tests were conducted under Non-Destructive testing and the results are shown below.

1. DYE PENETRANT TEST

This is a non destructive testing in which the welded materials are used to check the non uniformity of weld. It detects flaws that are open to the surface example cracks, seams, laps, lack of bond, porosity, cold shuts etc.

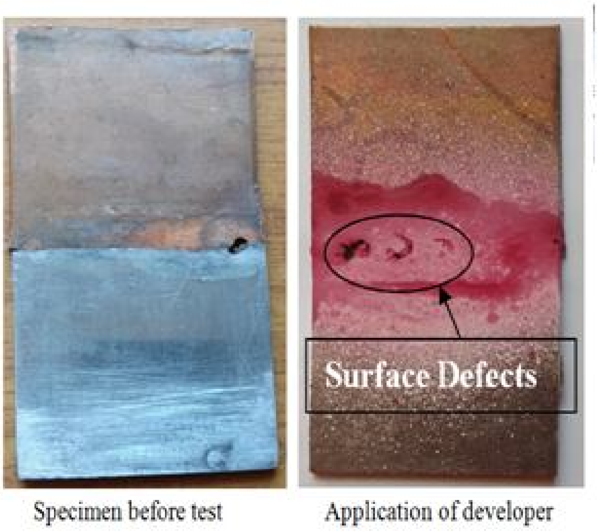

Fig.6: Dye penetration samples

2. X-RAY TEST

X-rays are part of the electromagnetic spectrum and have a short wavelength, which allows them to easily pass through matter. X-rays can penetrate many types of materials, as well as detect surface and internal flaws.

The test results of X-Ray test of both the samples are Good penetration of tool, Good fusion welding for Sample1, and for Sample 2 are Lack of penetration of tool (Crack formation shown in figure using arrows) and Slight low fusion welding.

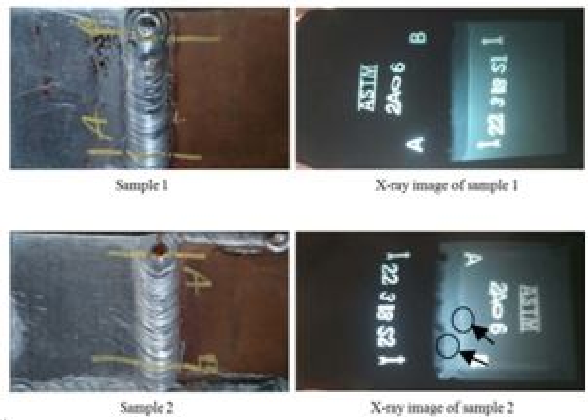

Fig.7: X-Ray images of weld samples

VI. CONCLUSION

The FSW of Aluminium AA6061-T6 and pure copper were carried out using vertical milling machine. The following conclusions are drawn from the work.

- The defect-free weld between the base metals was obtained at speed of 1010 rpm and plunge depth of 2.5 mm and at a feed rate of 7mm/min.
- Under tensile test the friction stir welded copper and aluminium material revealed lower yield and ultimate stresses due to low plunge depth of tool and vibration in the milling machine, and the dissimilar joints displayed intermediate properties.
- "Non-Destructive testing techniques viz: visual inspection and x-ray radiography were successfully conducted on welds, produced at various parameter combinations. It can be concluded that visual inspection of the welds is not the best technique since it was found that despite all the welds they have passed this test and appeared as defect-free welds, but some small cracks can be visualized by using dye penetrant whereas the x-ray radiographic testing technique successfully detected the internal cracks present in the welds and can be said to be appropriate in this regard."

VII. ACKNOWLEDGMENT

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