Experimental investigation of tunnel(channel) creation in AA3102 through friction stir Tunneling-FST

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***Abstract*—Friction stirs processing (FSP) is a method of changing the properties of metal through intense, localized deformation. Where Friction Stir Welding (FSW) is Mechanical joining properties are dramatically pushed into deterioration when a tunnel defect is formed. FST is effect found due to regulated heat input and regulated material flow. Sometimes defects in the weld are generated applying certain variations in welding parameters. In this study, the tunnel formation in AA 3102 was experimentally studied by taking various parameter incorporating speed and feed. The effect of tunnel formation was evaluated by Radiography test. Here we are creating the tunnel through the length and which dimension can be control by tool geometry, spindle speed, and feed rate. This experimental investigation covers methodology to enhance the word "defect" to "tunnelling effect" which is created by changing some parameter during processing and welding.**

***Index Terms*—Tunnel, Tool, Radiography test, Friction Stir Welding, friction stir processing.**

I. INTRODUCTION

The manufacture of aluminium weldments for use in the aerospace, automotive, rail, and maritime industries usually includes the solid-state joining technique known as friction stir welding (FSW). Unlike other fusion welding methods, friction and deformation heating brought on by a revolving tool are employed to produce heat, keeping the highest temperature below the melting point of the base metal. Because coalescence happens while the material remains solid, it's indeed possible to prevent the majority of faults brought on by solidification in the weld zone [1]. The complicated stirring action induced by the welding tool can, however, result in the production of flow-related defects including cavities [2], tunnels [3],[4], and grooves [5] because the metal is heated and changed into a plasticized state. [8] created processing maps for 4 mm ADC12 butt welds and observed that when inadequate or excessive heat input was employed, cavity type flaws appeared. Their findings also shown that the axial force was more efficient at lower thermal inputs but less so at larger heat inputs in terms of reducing void size.

The significance of identifying this flaw during the inspection process is highlighted by the fact that the presence of fragment faults might be taken as evidence for the development of additional flaws (tunnelling and void defects). No study has been published on using the radiography test (RT) to identify the fragment flaws in dissimilar joints made by FSW, despite the fact that it can be one of the best ways to readily show the fragment faults [9].

Friction stir processing (FSP), a novel processing method recently created by Mishra et al. [11],[12] for microstructural alteration, is based on the fundamental ideas of FSW. In this instance, a rotating tool with a pin and shoulder is introduced in a single piece of material to modify the local microstructure for the improvement of a certain feature. For instance, using FSP, a fine-grained microstructure for high-rate super plasticity was created in the industrial alloy 7075Al. FSP offers a number of advantages. First, FSP is a one-step, short-route solid-state processing method that produces microstructural uniformity, densification, and refinement. Second, by enhancing the tool design, FSP settings, and active cooling and heating, the microstructure and mechanical characteristics of the treated zone may be precisely controlled. Third, it is challenging to accomplish an optionally adjustable processed depth using traditional metalworking processes; nevertheless, the depth of the processed zone may be optionally altered by changing the length of the tool pin, with the depth range between many hundred micrometres and tens of millimetres. [13] As mansion above tunneling come in defect that effect the strength an well as life cycle of the product, but can this defect can be create as per our need so that it don't effect the above problem and can be used for some product to increase its productivity.

II. LITERATURE REVIEW

Ghaz et al (2020) The work in this paper is focusing on effect of friction stir welding parameter on the quality of aluminium alloy joint. The operation is conducted using different parameters which include speed and feed rate. After operation tensile test were performed to know the results i.e., strength of the weld joint. Where lateral flash was observed when there is low speed and feed. And incomplete root penetration is observed on every operation [13].

Zhao et al (2019) The work in this paper is focusing on void formation using friction stir welding in aluminium alloy. Heat two plate are welded using friction stir welding to form butt joint in which void defect has been created by changing the parameter. To analyse the defect formed during FSW, 3-D computational fluid dynamics (CFD) model-based software is use. Hear macrostructure images has been use to see the defect that can be observed on the surface and that has formed a tapper geometry. In the modelling different type of formula were used to get the numeric values. Hear defect free joint were observed when low speed operation was performed [14].

Soni et al (2017) The work in this paper is focusing on formation of the defect that are generate during friction stir welding. Hear welding operation are performed in such a manner so that it creates defect, sometime dissimilar mates are also use to create the defect. It includes defect like tunnel, flesh, kissing bond, cavity, cracks and crack line etc can be observed. Dissimilar metal like aluminium and steel, aluminium and copper etc combination were use to create the defects. Generally, defect was form due to insufficient heat input and metal flow [15].

Clucas et al (2019) The work in this paper is focusing on structural anatomy of tunnel void defect in bobbin FSW.in this paper friction stir welding is performed using bobbin tool and afterward tunnel void defect were measured using analogue modelling method. Hear 3d print plastic tool issue. Then dynamic forces like longitudinal and traverse direction weld line were measured. The main aim of the study is to predict the position of tunnel defect. In this the result show the main reason for tunnel defect is the instability of plastic deformation during entering of tool in the body [16].

Mejbel et al (2021) The work in this paper is focusing on void formation in aluminium using friction stir welding of butt joint. Here the tool is design is done for better result depend on the thick ness of the plate then bending and tensile test are performed to check the strength after the operation and also ANSYS is use to know the stress concentration factor. Because of the change in welding parameter, it has influence on microstructure of the workpiece. Because of change in parameter the heat distribution during operation intense plastic deformation around the rotating tool is observed. To avoid tunnelling and void formation, the relation beet tool circulation and travers velocities should be well taken care of [17].

Xu et al (2008) The work in this paper is focusing on study of texture pattern in friction stir welding. Here we study the texture and pattern create on the surface after the welding is done here microscopic level is check. Hear numerical simulation process is carried out to understand the texture pattern. Hear series of butt weld joint were caried out on aluminium to get the result. Both 3D and 2D plane strain simulation of selected FSW process has been performed. The result demonstrates that there is strong correlation between equivalent plastic strain and banded texture [18].

III. EXPERIMENTAL INVESTIGATION AND OBSERVATIONS

3.1 Material

Here 3102 aluminium alloy is used for experiment with 6 mm thickness. Its chemical composition is presented in Table (1).

Table 1. Chemical composition of AA 3102.- (HERTZ- Testing and training centre)

Chemical Composition	Actual wt.%
Si	0.108

Fe	0.582
Cu	0.023
Mn	0.021
Mg	0.025
Zi	0.035
Ti	0.016
Ni	0.008
Cr	0.004
Al	99.23

Grinder is use to specify the geometry of (40x30x6) mm of AA 3102. And final finishing is given by using files.

3.2 Tool geometry

The tool's design is an influential factor in the FSW process due to its heat generation function, material flow and the machine's torque. These features will govern and determine the weld's acceptance and the process application to a higher material range and over a broader range of thicknesses depending on the tool geometry. Some equations were provided by Hoyos [6] for finding the dimension with the help of thickness of the plate. In this work, the tool is designed according to the following specifications: Fig. 3.2.1 shows the FSW tool and schematic plot. The tool was made of (En31) having a pin diameter of 6 mm, a height of 5.4 mm, and 197.33 HRC hardness. The shoulder diameter is chosen four times the pin diameter with 2.5° concave angle. Table (2) shows the specification of the tool design.

Table 2. Specification of FSW tool

Dimeter of pin	6 mm
Length of pin	5.4 mm
Diameter of shoulder	24 mm
Concave angle	2.5°
Tapper	1.5°

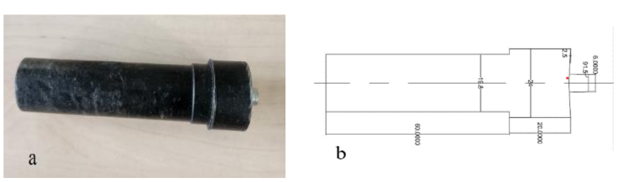

Figure 3.2.1. Friction Stir Welding Tool (a) the fabricated EN31 tool (b) CAD schematic.

3.3 Milling Machine

All the FSW experiments were carried out by on a classical milling machine (vertical type). On the bed fixture is clamped using bolt to hold the work piece and steel plate is kept to backing the work piece so it can be fixed at is position during the operation. The tool travel was within the samples' rolling direction, having a clockwise rotation concerning the milling head vertical axis. Fig. 3.3.1 illustrates the experimental setup of the FSW process at different stages. This fixture generates an opposite force because of the welding tool's plunging and moving. The clamping system consists of a flat metal plate (backing plate) made of steel, two clamp steel bars, and side screws. The clamping system was connected to the machine table by vertical bolts.

Table 3. FSP parameters for AA3102.

Case no.	Rotation speed (RPM)	Travel speed (mm/min)
1	500	250
2	500	200
3	250	100
4	250	125
5	250	160

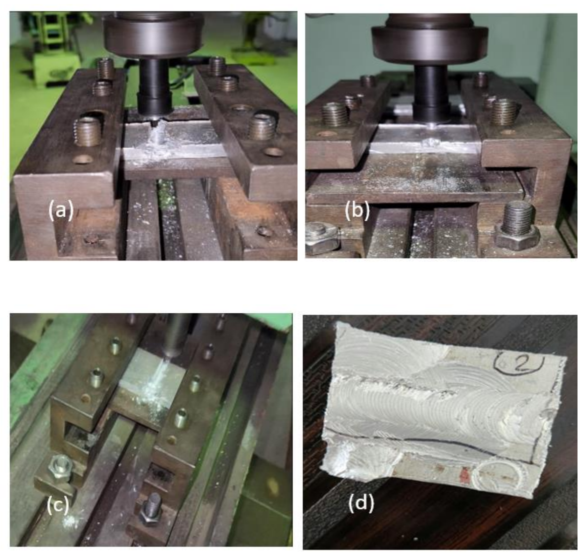

Figure 3.3.1. Experimental setup with various stages of the FSW process from (a) to (d)

3.4 Observations:

- First of all, we have set the fixture on the bed of the conventional milling machine.
- In it we have kept a steel base plate for the support of the workpiece.

- The workpiece is then hold in the fixture with the Allen key bolt so that it doesn't move during operation.
- Then speed and feed is set as per required.
- Then the tool is brought near the workpiece and tool tip is stir in from one side of the work piece
- Because of the friction the heat is generated in the workpiece surface and then flow if the direction.
- Because of the rotation speed the heated metal which has start deforming some near the tool bottom and space is created.
- Then because of feed the tool start traveling on a linear direction while creating the space till the stir is out of the workpiece.

3.5 Assumptions

- Machine is mounted rigidly.
- Less tolerances of operating parameters.
- Operator-researcher is skilled enough to perform the FSP.
- The machine operating parameters are same as mentioned on machine.
- Tool geometry should be design as per workpiece thickness.

IV. RESULT AND DISCUSSIONS

4.1 Tool hardness test:

To increase the life of the tool we have done oil quench on the tool to increase its hardness so more no of trial can be perform without damaging the tool tip. This helps us to reduce the tool cost which also effect the overall cost for the experiment.

Table 4: hardness test result En31- (HERTZ- Testing and training centre)

Sr No	Sample No	1	2	3	Avg. Value
1	Oil quench	297	285	298	293.33
2	With out quench	193	198	201	197.33

4.2 Radiography test:

It is a non-destructive test performed for metal testing to know if there are any crack or space inside the metal using X-ray. It helps us to know the defect without damaging the metal. Here we have performed the test on A 3102 metal after the operation to see the result. Conventional radiography produces a single image of an object by measuring the attenuation of an x-ray beam passing through it. When imaging weakly absorbing tissues, x-ray attenuation may be a suboptimal signature of disease related information [7].

The figure 4.2.1 is the radiographic result perform on the case 4(250 RPM,125 mm/min) here we can see that the space is create throughout its length which mean it is a good parameter that can be used to create the tunnel.

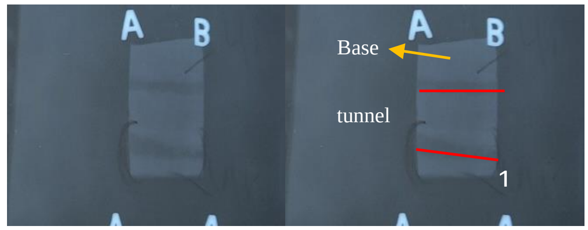

Figure 4.2.1. Radiography test result (250 RPM, 125 mm/min)

The figure 4.2.2 is the radiographic result perform on the case 5 (250 RPM,160 mm/min) here we see the tunnel is forming but because of high feed the tunnel is not create on the middle part, it can also because of some play on the feed screw that led to this result.

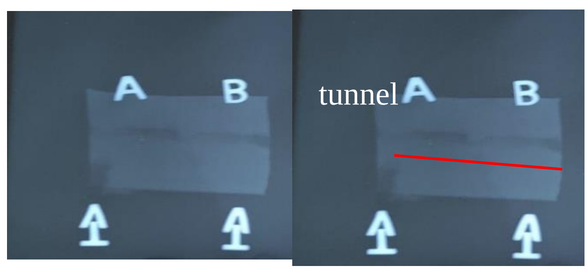

Figure 4.2.2. Radiographic test result (250 RPM, 160 mm/min)

The figure 4.2.3 is the radio graphic result perform on case 1 (500 RPM,250 mm/min) here because of the high rpm the heat generates more rapidly and cause to be weld and tunnel is not been created, in the start tunnel was forming but later due to rapid heat it starts welding and got welded reaching the end.

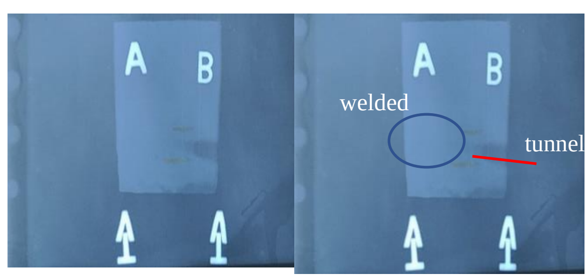

Figure 4.2.3. Radiographic test result (500 RPM,250 mm/min)

4.3 Macroscopic images:

Here, are some macroscopic images that show the dimension, inner surface, outer surface and the throughout channel which are created by following the experimental process. Here the images are capture at 40x zoom to see the detail pattern form on the surfaces due to the experiment. Here we have us digital microscope on 40x zoom.

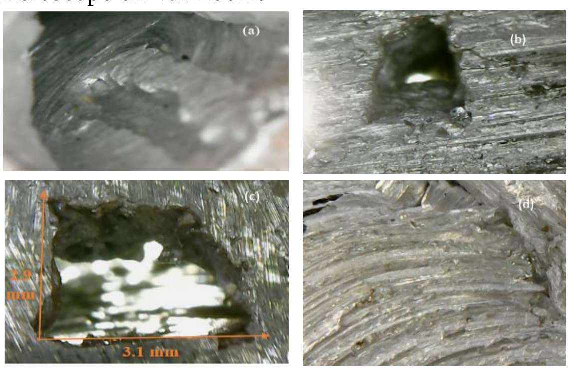

Figure 4.3.1. Macroscopic images of the workpiece

Here in figure 4.3.1(a) show the inner surface of the tunnel. We can see the circular pattern form in the inner surface, hear circular pattern in FSW are best, this pattern show that the heat distribution is very good and have good strength compare to another pattern **[10].**

In figure 4.3.1(b) show the throughout channel form, it is check with the help of; light flow test conducted on it.

In the figure 4.3.1(c) we the dimension are been measured with the help of vernier calliper. We see that the dimension we get and the dimension of the tool have as difference of 50% in the size.

In the figure 4.3.1(d) show the top surface of the work piece. Due to the proper heat distribution, we get the circular pattern which generally form when there is good plastic deformation and have good strength **[10].**

V. CONCLUSION

Tunnel form on the AA 3102. The effect of tunnel formation was evaluated by radiography test. The joints made-up using the different speeds of (250,500) rpm, travel speeds of (100,125,160,200) mm/min. The following important conclusions were made for the present study.

1. Tunnel was created from the stir point (point of plunge) to exit point (point of tool removal) of the tool but at high rpm at certain point more heat is generated at contact region which can change the stir quality.
2. The change in stir quality effect the dimension in the tunnel profile.
3. Most of the good observation have come on the range of 250 rpm with present investigation.
4. The change of the Traveling speed and Rotation leads to a change in the heat input to the workpiece; which allow the tunnel to be formed from stir in point (point of plunge) to stir out point (point of tool removal).

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