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Fabrication and Vibration Analysis on Friction Stir Welding Fixture for Mass Production

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Friction stir welding was invented for the welding of Aluminium alloys and progressively using for other different metallic alloys which was difficult to welding by other conventional welding method as fusion welding. FSW is a solid state joining welding technique in which material undergoes intense plastic deformation at elevated temperature resulting in generation of fine grain microstructure which exhibited good mechanical properties. Development of FSW is considered to be most significant for the industry of aerospace and aircraft, shipping and marine industries, railway industries etc.
There was difficulty in mass production of fabrication of soft material like aluminium. That was major challenge. And the second thing was costly FSW machine. To resolve these problems, converted vertical milling machine and flexible fixture had been designed. Fixture was designed using solid works software keeping certain things in view like groove of fixture to be such that it accommodates metal plate to be welded, then manufacturing of fixture was done using different machine tool. Apart from this a two nos. of clamps was also manufactured for holding the plates firmly and subsequently a stopper was also manufactured for the purpose of fixing and balancing of plates to be welded. Design was accommodating butt weld and lap joint both in single frame. The fixture was also investigated vibration analysis for machinery fault diagnosis. The vibration results were satisfactory for welded joints.

Keywords: FSW, fixture base plate, stopper plate, clamps, machine tool.

1. Introduction

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 by W.M. Thomas [1], is a solid state joining technique in which a non consumable tool with a specific designed pin and shoulder is rotating and inserted into the mating edges of clamped sheets or plates to be welded and traversed along the line of joint.

The tool perform two main functions: (a) heating of work piece by adiabatic shearing and (b) movement of material causes mechanical mixing, by which stirred material soften without melting to produce the joint. It was observed that the temperatures on the advancing side of the weld are bit higher than that of the retreating side of the weld [6]. As the material softened around the pin and combined effect of tool rotation and translation leads to the material to move from front to the back of the pin and by this result, joint is produced which strength also depend on tool penetration depth and the relative thicknesses of the sheets employed[5, 9]. As the tool traverse along the line of joint, force applied by plasticized material at rear of tool tip is assisted by clamping force of fixture. Pin design variation affected the welding force which opposes tool translation in which stage shoulder forging pressure generates the vertical force [10]. The welding zone macrostructure examination used to reveal joints quality which is affected by material flow behaviour which is influenced by FSW process parameter and tool profile [7, 8].

Processing parameters during FSW governed generated heat, peak temperature and cooling rate in which cooling rate is mostly affected to weld nugget microstructure in which HAZ is weakest section [12]. FSW as advanced joining technique is an integral part of manufacturing processes of light weight structures such as aluminium alloy. At present, Friction Stir Welding has found various applications in a number of areas as shipping and marine industries, aerospace industries, railway industries, land transport etc. Considering effort has been expended to develop easy operate fixture for welding process.

2. Material of fixture

Mild steel is the material used for manufacturing the fixture base plate, clamps and stopper. Since mild steel has high strength and toughness which is required to withstand unbalanced force and pressure during FSW operation. The selection of tool rotational speed and traverse speed are crucial for heat generation and the forces applied on the tool should be minimum in order to create good flow of material around the tool pin so chosen material is good for fixture development for sound friction stir welding [11]. Its properties are mention below in Tab. 1.

3. Fixture design

Fixture plays very important role in FSW as it maintains the position of the welding work piece from going apart in plunging phase and in operation. In fixture designing for FSW the considering factors are high temperature reaching during welding operation and in extreme condition, the welded work piece are likely to remain stuck to the fixture compromising both the fixture integrity and soundness of the joint[4]. Fixture should be designed and fabricated so that it should bear the forces and rising temperature during welding process without distortion. To joining

Table 1 Fixture material properties

Material	Structural ASTM A36 steel
Density	7.85 gm/cm^3
Thermal Conductivity	50.2 W/mK
Melting Point	1427 ^{0}C
Young Modulus	200 GPa
Shear Modulus	79.3 GPa
Bulk Modulus	140 GPa
Poisson$'$s ratio	0.26
Elongation	23%
Hardness	120 HB
Carbon	0.20 %
Ultimate tensile strength	400 - 550 MPa
Yield strength	250 MPa

metal piece support, the fixture is designed and fabricated using different method, for our need few idea were generated and best design that can suit the objective of creating adjustable feature is selected based on the decision matrix method [2, 3]. This method evaluated based on several criteria which will define its suitability for overall project, as summarized in Tab. 2.

Table 2 Fixture design criteria

Criteria	Description
Design complexity	Number of different component, number of symmetrical and complex shape
Functionality	The range of adjustable angle it can provide
Handling ability	Ease to be operated and used by end user, time taking for preparing the fixture before proceeding to FSW process
Strength	Maximum downward force of machine spindle it can sustain during FSW
Procurement of material	Expected price of material and its availability in market
Working ability	The capability of available machine, size, dimension tolerance and level of accuracy needed
Machinability	Vibration absorbing capability, damping capability

Component of fixture:

1. Fixture base plate.
2. Clamp – 2 No.
3. Stopper plate.

1. Fixture base plate: It maintains the position of the welding work piece from going apart in plunging phase and in operation. It sustain at high temperature reaching during welding operation and in extreme condition, the welded work piece are likely to remain stuck to the fixture compromising both the fixture integrity and soundness of the joint.

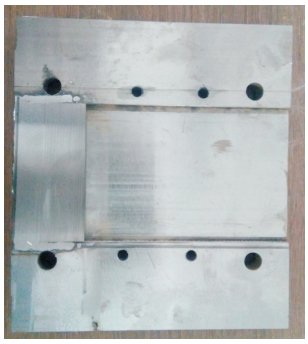

Figure 1 A fixture base plate

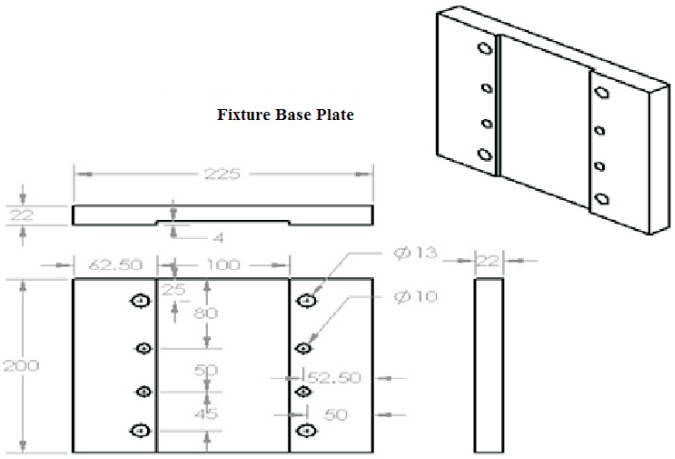

Figure 2 Dimensions of fixture base plate

2. Clamp: Clamp is required for the tool axial force and deflection, tool rotational force and separation. Clamp is using for easier to join or separate the workpiece and workpiece buckling due to thermal expansion. With this clamp help in preventing the longitudinal and cross sliding of workpieces during welding.

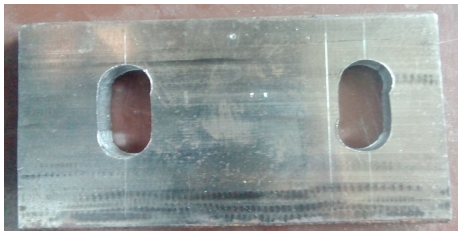

Figure 3 Actual view of clamp

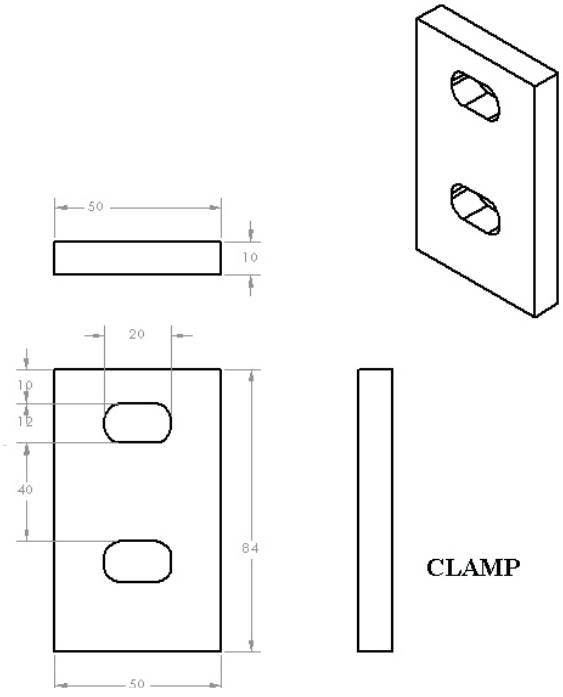

Figure 4 Dimensions of clamp

3. Stopper: Stopper is required for preventing the longitudinal sliding of workpieces. It also help the fixture for sustain in the tool axial force and deflection, tool rotational force and separation with this help in preventing the workpiece buckling due to thermal expansion.

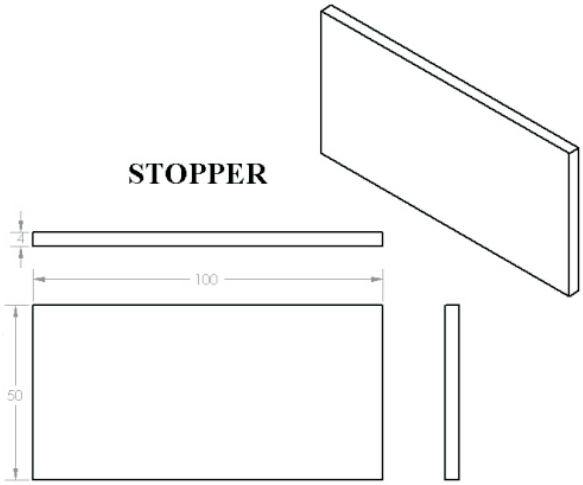

Figure 5 Dimensions of stopper plate

Table 3 Fixture manufacturing process

Sr. No.	Process
1	Edge preparation
2	Facing
3	Slotting
4	Drilling, grooving and taping
5	Welding
6	Surface grinding
7	Assembly

4. Fixture manufacturing

After designing the fixture, its manufacturing was done that involved following processes shown in Tab. 3 and describe below:

a) Operation on lathe machine: Edge preparation and facing operation was done to produce clean surface of the workpiece to be manufactured for the fixture plate. Once flat surface produced after machining it is placed on the bed of shaping machine. The tool used was carbide tip tool.

b) Slotting operation on shaping machine: After facing in the slotting operation, shaper machine was used for creating the slot on fixture material. The tool used was high speed steel tool.

c) Drilling, taping and grooving operation on drilling machine: After slotting, drilling and tapping operation done on the drilling machine on fixture material and drilling and grooving operation done on clamp with drilling and tapping tool.

d) Welding on electric arc welding machine: Welding of fixture base metal to stopper is performed on electric arc welding machine and then, after operation transfer for grinding.
e) Surface finishing on horizontal surface grinding machine: After all this Surface finish performed, surface grinding machine was used for removing the roughness and providing the desired tolerance.
Fixture specification regarding its purpose of use, component size, material used in fixture, colour of fixture material, fasteners dimensions and the workpiece dimensions up to which it can be welded are important factors and these are shown below in Tab. 4.

Table 4 Fixture specification

Name	FSW fixture
Application	Friction stir butt welding joint
Base plate	225 mm×200 mm×22 mm
Side plate	84 mm×50 mm×10 mm
Stopper	100 mm×50 mm×4 mm
Material	Structural ASTM A36 steel
Colour	Dark grey
Workpiece dimension	150 mm×100 mm×5 mm
Fasteners dimension	4 bolt (12.5 mm diameter) and 4 bolt (10 mm diameter)

After performing all these operations finally fixture is produced as shown in Fig. 6 which have base plate, clamp and stopper fitted on machine table and it is usable for friction stir welding on this retrofitted vertical milling machine:

Figure 6 Complete Fixture Base plate, with clamp and stopper fitted on machine table

Dimension:
This fixture has utterly firm aspect for humongous setup in this range of friction stir welding.
Capacities:
It has very good and sustainable capacity for friction stir welding of copper and aluminium alloy plates. It is capable to reduce the distortion by high temperature

and suitability. It can wear 1631 KN transverse load, 122 KN axial load and 200 KN crushing load that is quiet sufficient for aluminium and copper plate for FSW. Capabilities are shown in Tab. 5.

Table 5 Welding capability

Maximum transverse load	1631KN
Maximum axial load	122KN
Maximum crushing load	200 KN
Maximum dimension of specimen that can be weld	150 mm×100 mm×10 mm

5. Result and discussion

On above flexible condition fixture is adjustable and easy to operate which leads to good vibration absorbing capacity with good axial load carrying capacity so that at high revolution of tool rotation it firmly sustain and work. In FSW on this fixture no distortion occurs on weld material and no excess heat affected problem generated and its clamp is designed such that it is easy to disassemble and also easy to manufacture. It has been also observed that there is no shifting of welding work piece during FSW and firm welding found. It can weld up to 10 mm thick plates. It has very good axial load carrying capacity. Tensile strength of welded part is found to be 80 to 110 percent of base metal. It can be used for force and temperature measurement. It is capable to design to make automatic clamping during FSW welding in future. Parameters are shown in Tab. 6.

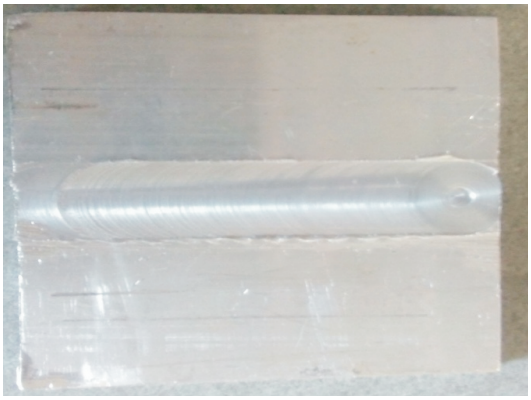

Figure 7 Welded sample

The welded part also gone through different destructive tests and gave satisfactory performance as shown in Fig. 7. The Fixture base plate and clamp were also investigated under Vibration analysis, shows good results.

Table 6 Vibration analysis on fixture

Sr. No.	Tool shoulder diameter (mm)	Experiment setup	Vibration level on clamp (m/sec^2)	Vibration level on base plate (m/sec^2)
1	22	Rotation 2000 rpm and feed 82 and 62 mm/min	21	18
2	22	Rotation 1600 rpm and feed 82 and 62 mm/min	18	16
3	22	Rotation1250 rpm and feed 82 and 62 mm/min	13	11

6. Conclusion

Fixture is adjustable and easy to operate which leads to no shifting of welding workpiece during FSW. It's have good vibration absorbing capacity with good axial load carrying capacity which leads to significant defect free friction stir welding. On variable condition sound FSW found without any distortion of weld material due to no excess heat effect. It's have scope for automation for clamping and welding.

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