INVESTIGATION ON INFLUENCE OF DIFFERENT TOOL PIN GEOMETRY ON MECHANICAL PROPERTIES OF WELD JOINTS

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Abstract: Friction Stir Welding is solid state joining process of similar or dissimilar metals. This technique is more energy efficient, ecofriendly. Friction Stir Welding is one of the most significant developments in metal joining process. Most of studies in literature used threaded pins since most industrial applications currently use threaded pins. However, initially threaded tools may become unthreaded because of the tool wear when used for reinforced aluminum alloys or high melting point alloys. This paper gives information about different tool pins. Based on results that square pin tool is more efficient than other tools which we used because the square pin tool covers more volume compared to other tools.

***Index Terms* - FSW, Tool Geometry, Al 6061, Tensile Strength, Micro Structure, Micro Hardness.**

I.INTRODUCTION

In the recent years the usage of aluminum AL6061 alloy has steadily increased in aircraft, automobile, ship building and metro train applications because of their excellent strength to weight ratio, corrosion resistance and good ductility and cracking resistance. But the welding of aluminum alloys still remains a challenge using conventional welding methods. Friction stir welding process becomes the most useful method in welding aluminum alloys. The welding equality using FSW depends on the welding parameters like weld speed, rotational speed, tilt angle and load applied (axial force)during the weld process. Also, the tool shape influenced the mechanical properties and microstructure of the welding area. Many researchers studied says that the effect of pin profile like (square, threaded, taper, cylindrical etc.) on the properties of the welding area and that square pin profile produced more fine grain size on the welding area rather than cylindrical, threaded profiles. However, it was founded numerically that the temperature of the welded zone increases with number of pin sides. The pin profile has related influence on metal flow that the use of threaded pin profile of tool contributes to better flow of materials between two alloys and the generation of defect free stir zone. In joining dissimilar materials, square pin profile produced a superior strength joints compared by other pin profile. However, the pin profile affects both the temperature of the welding area and the material flow during welding process.

1.1 Key benefits of friction stir welding

Metallurgical benefits:

- Solid phase process
- Low distortion of work piece
- Good dimensional stability and repeatability
- No loss of alloying elements
- Excellent metallurgical
- properties in the joint area
- Fine microstructure
- Absence of cracking

Environmental benefits:

- No shielding gas required
- No surface cleaning required
- Eliminate grinding wastes
- Eliminate solvents
- required for degreasing Consumable materials saving, such as rugs, wire or any other gases

Energy benefits:

- Solid phase process
- Low distortion of workpiece
- Good dimensional stability and repeatability
- No loss of alloying elements
- Excellent metallurgical
- properties in the joint area
- Fine microstructure
- Absence of cracking

II.TOOL PIN GEOMETRY

Tool Geometry is the most influential aspect of process development. The tool geometry place a critical role in material flow and in-turn governs the traverse rate at which FSW can be conducted. An FSW tool consists of a Shoulder and Pin. The shoulder which we are using is a featureless shoulder. The Shoulder also provides confinement for the heated volume of the material. The second function of the tool is to stir and move the material. The uniformity of micro-structure and properties as well as process loads are governed by the tool design.

III.WELD PARAMETERS

For FSW, two parameters are very important: tool rotation rate(V, rpm) in clockwise or anticlockwise direction and tool traverse speed(n, mm/min) along the line joint. The rotation of tool results in stirring and mixing of material around the rotating pin and the translation of tool moves the stirred material from the front to the back of the pin and finishes welding process. Higher tool rotation generates higher temperature because of higher friction heating and results in more intense stirring and mixing of material. In addition to the tool rotation rate and traverse speed, another important process parameter is the angle of spindle or tool tilt with respect to the work piece surface.

The Welding Parameters considered are as follows:

1. Welding Speed	-	80 mm/min
2. Spindle Speed	-	900 rpm
3. Tilt Angle	-	2 Degrees

IV.EXPERIMENTAL WORK

4.1 Preparation Of Base Material: Base material is prepared by stir casting process by reinforcing of the silicon carbide and fly ash with Aluminium

Base Metal Used: Al 6061-T6 (Al-SiC-Fly Ash).

Base Metal Plate Dimensions: 100X50X6mm.

Table 4.1 Chemical Composition of Al 6061-T6.

Material	Aluminum	Silicon Carbide	Fly ash
Percentage	89.5	7.5	3

Figure 1:casted workpiece

4.2 Different Type Of Tools That Are Used

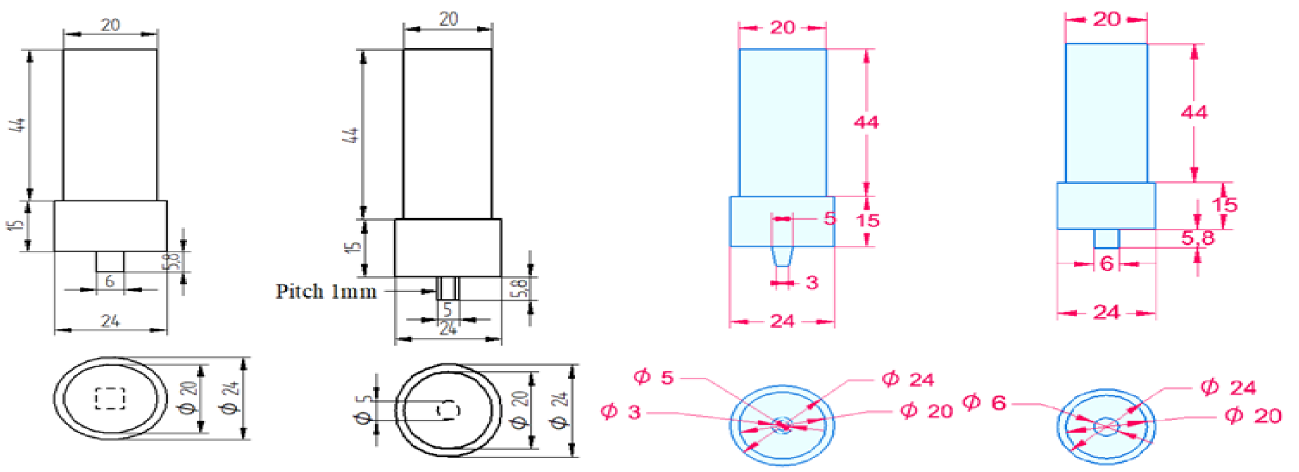
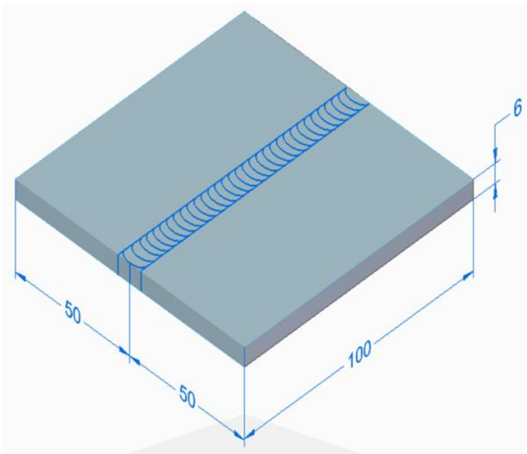


Figure2:Different types of tools used in the fsw process

4.3 Welded joint design

The most convenient joint configurations for FSW are butt and lap joints. A simple square butt joint is shown in Fig. 7a. Two plates or sheets with same thickness are placed on a backing plate and clamped firmly to prevent the abutting joint faces from being forced apart. During the initial plunge of the tool, the forces are fairly large and extra care is required to ensure that plates in butt configuration do not separate. A rotating tool is plunged into the joint line and traversed along this line when the shoulder of the tool is in intimate contact with the surface of the plates, producing a weld along abutting line. On the other hand, for a simple lap joint, two lapped plates or sheets are clamped on a backing plate. A rotating tool is vertically plunged through the upper plate and into the lower plate and traversed along desired direction, joining the two plates (Fig. 7d). Many other configurations can be produced by combination of butt and lap joints. Apart from butt and lap joint configurations, other types of joint designs, such as fillet joints (Fig. 7g), are also possible as needed for some engineering applications.

It is important to note that no special preparation is needed for FSW of butt and lap joints. Two clean metal plates can be easily joined together in the form of butt or lap joints without any major concern about the surface conditions of the plates.



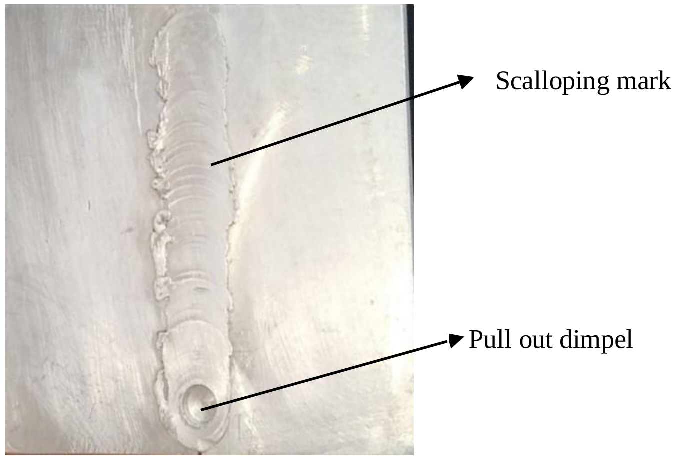


Figure3:fsw sample

Figure4:Friction Stir Welded Sample

4.4 Cutting work pieces for testing

From each fsw sample 2 dog bone shaped tensile samples of ASTM E8, 1 sample for hardness and one sample for microstructure is cutted using laser cutting machine. Since it is very difficult to go with wire drawing its better to go with laser cutting.

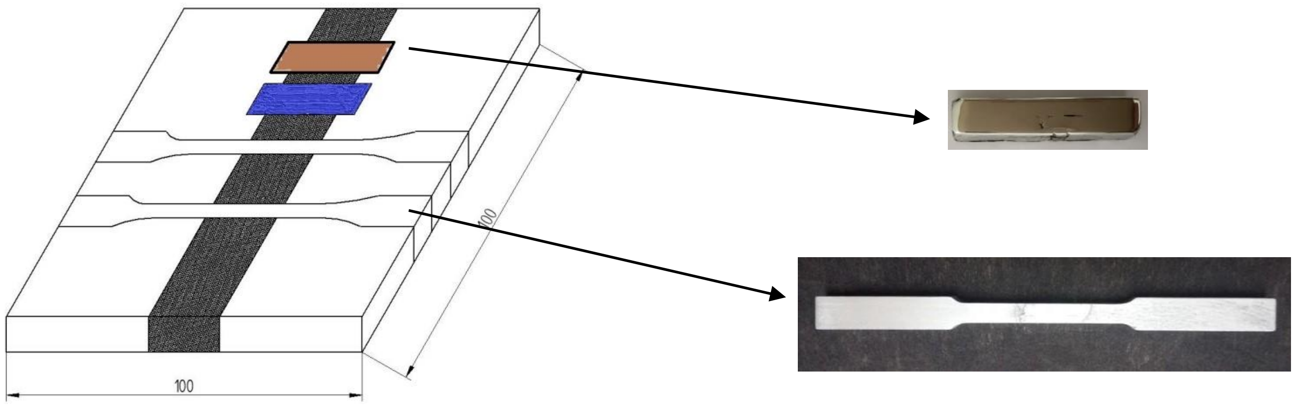


Figure5:cutting of friction stir welded joint for tensile and micro structure

V.RESULTS AND DISCUSSIONS

5.1 Case – 1: Testing for FSW welded joint using square tool

5.1.1 Tensile test results

This tensile testing says that the weld joint made with square pin tool has highest Ultimate Strength of 131.619 N/Sq-mm, it has Peak Load of 4266.00 N with Peak Displacement of 4.616 mm and Break Load of 1618.15 N Break Displacement of 4.701 mm

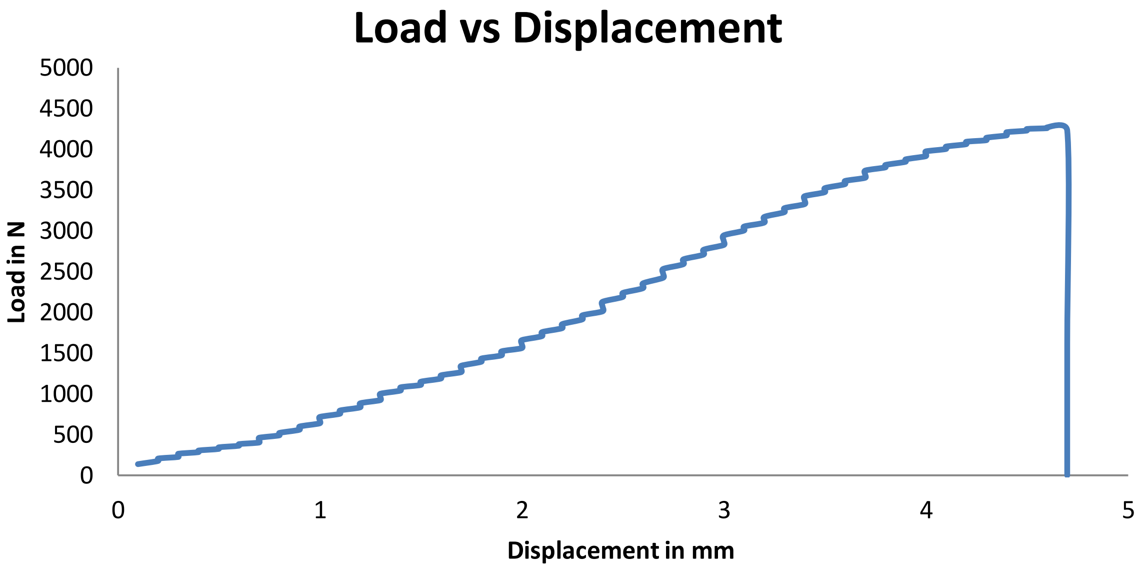
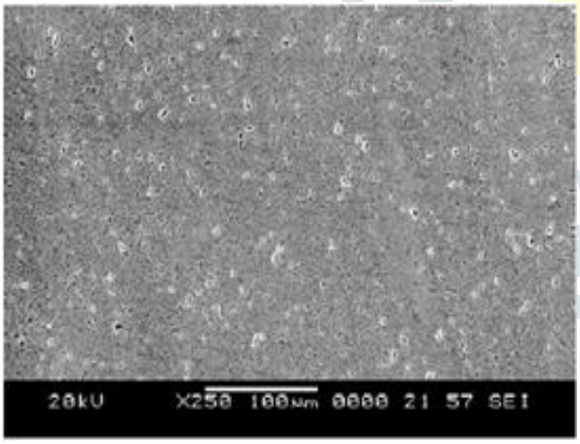


Figure6:tensile graph case 1

5.1.2 Microstructure

Better grain structure is seen in the weld joint which is welded with square tool because it has 4 CORNERS so it covers more volume than the other tools. that is why it got the better grain size.



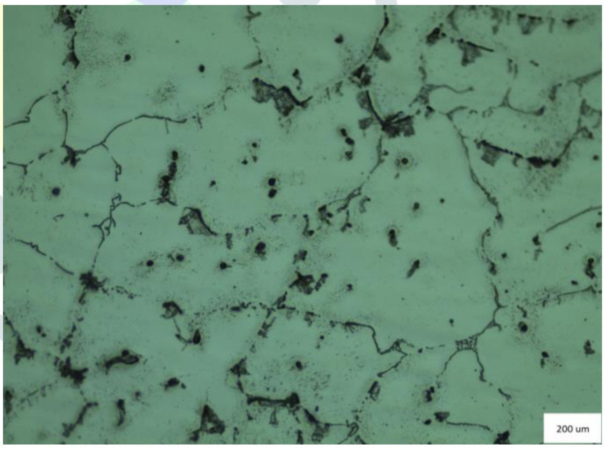


Figure7:SEM Image for case-1

figure8: Micro structure at welded joint fore case-1

5.1.3 Hardness

Hardness value is tested from different positions from the weld joint to find the strength of the weld, the highest value is found on the weld joint and the value is 103.

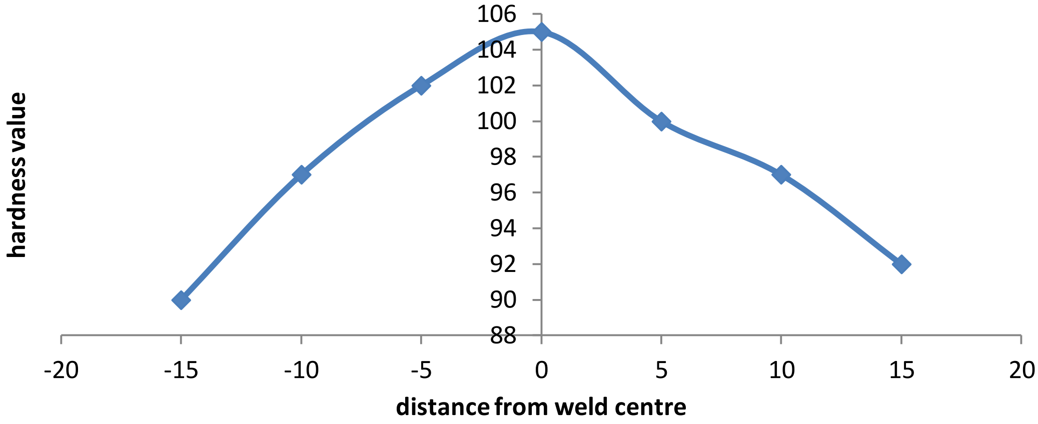


Figure9: Hardness value graph for case 1

5.2 Case – 2: Testing for FSW welded joint using threaded tool

5.2.1 Tensile test results

This tensile testing says that the weld joint made with square pin tool has highest Ultimate Strength of 112.372 N/Sq-mm, it has Peak Load of 4099.30 N with Peak Displacement of 4.735mm and Break Load of 2030.049 N Break Displacement of 4.820 mm

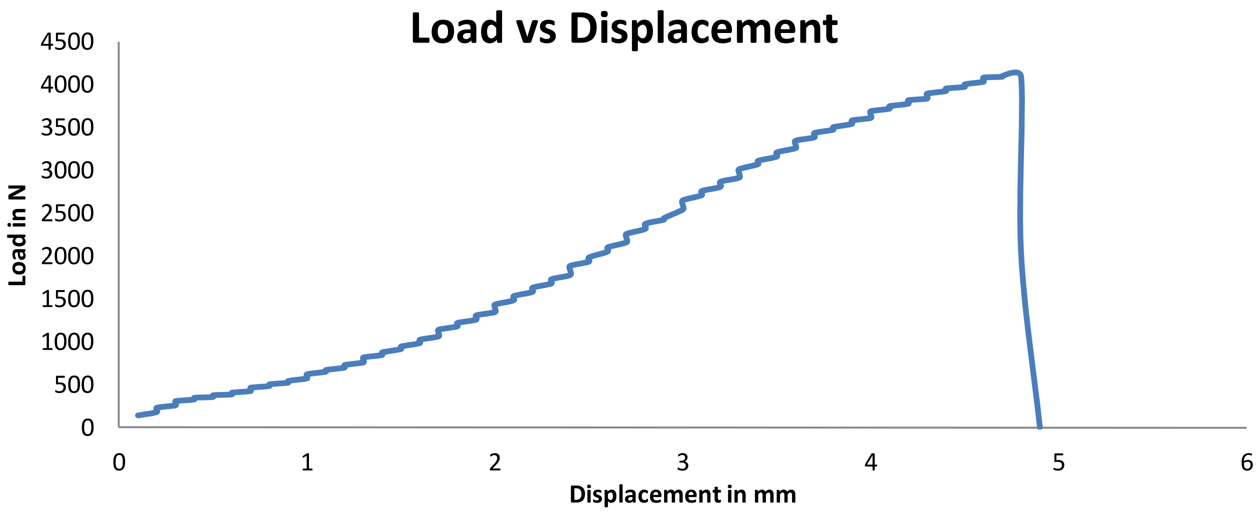
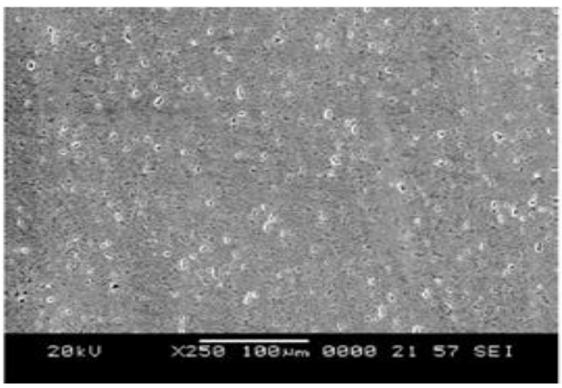


Figure10:tensile graph case 2

5.2.2 Micro structure

Better grain structure is seen in the weld joint which is welded with square tool because it has threaded pattern so it has more surface contact than other tools. that is why it got the better grain size.



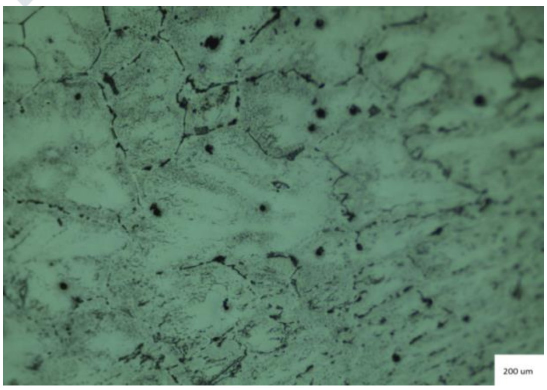


Figure11:SEM Image for case-2 Figure12: Micro structure at welded joint for case-2

5.2.3 Hardness

Hardness value is tested from different positions from the weld joint to find the strength of the weld, the highest value is found on the weld joint and the value is 105.

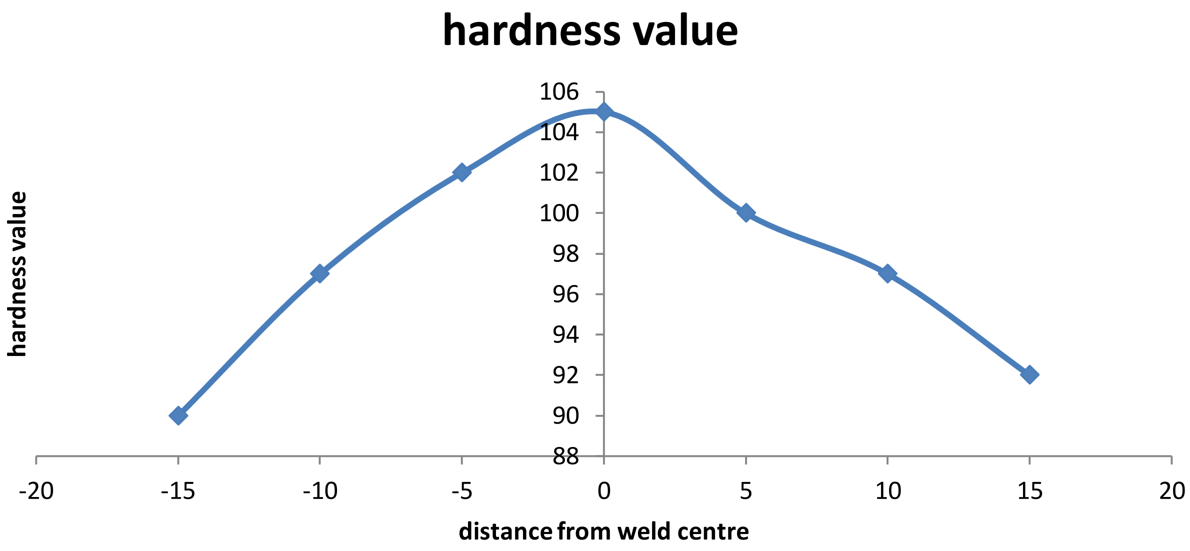


Figure13: Hardness results for case-2

5.3 Case – 3: Testing for FSW welded joint using taper tool

5.3.1 Tensile test results

This tensile testing says that the weld joint made with square pin tool has highest Ultimate Strength of 98.335 N/Sq-mm, it has Peak Load of 3422.60 N with Peak Displacement of 4.684 mm and Break Load of 254.982 N Break Displacement of 4.947 mm

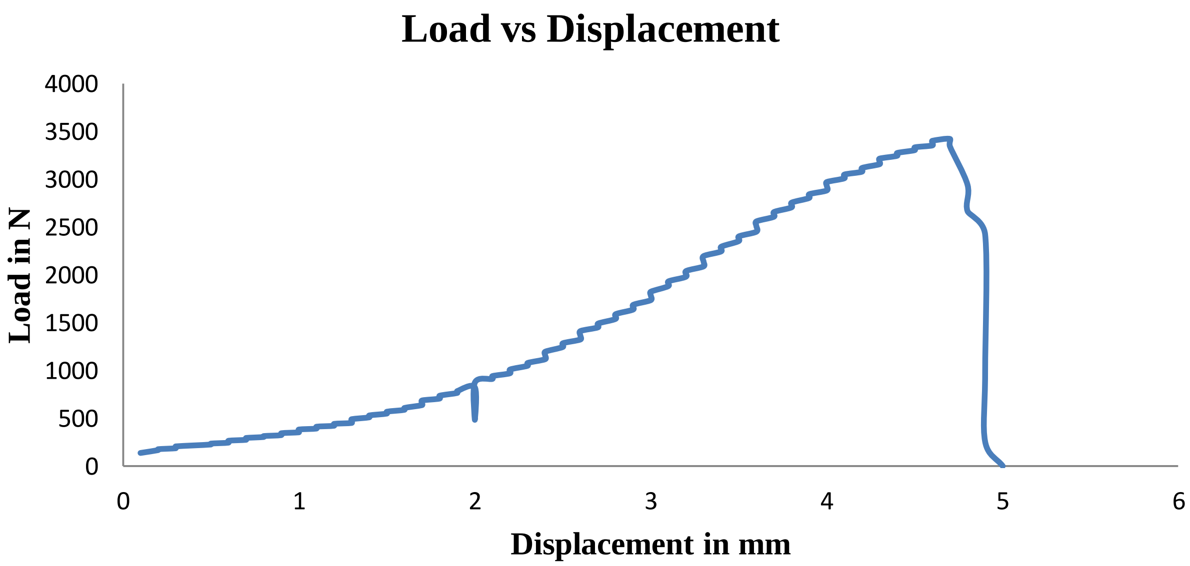


Figure14:tensile graph case 3

5.3.2 Micro structure

The grain structure is seen in the weld joint has little uneven because the taper tool has two different diameters .

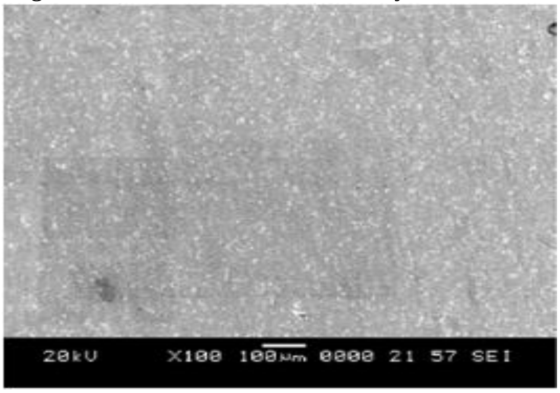


Figure15:SEM Image for case-3

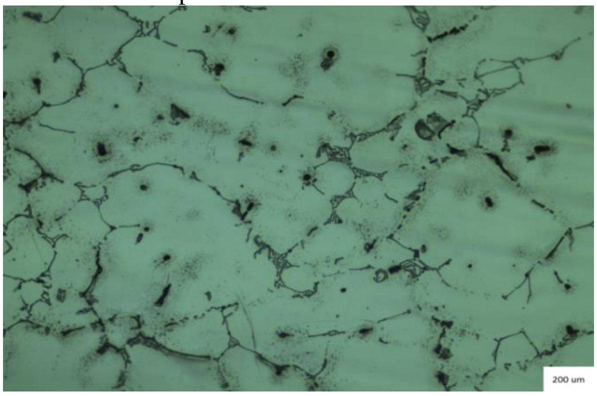


figure16:Micro structure at welded joint for case-3

5.3.1 Hardness

Hardness value is tested from different positions from the weld joint to find the strength of the weld, the highest value is found on the weld joint and the value is 103.

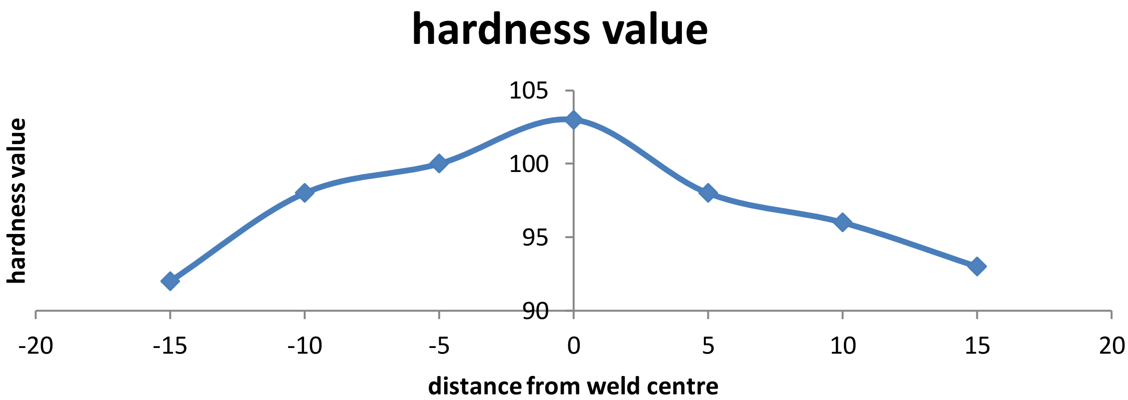


Figure17:Hardness results for case-3

5.4 Case – 4: Testing for FSW welded joint using circular tool

5.4.1 Tensile test results

This tensile testing says that the weld joint made with square pin tool has highest Ultimate Strength of 55.488 N/Sq-mm, it has Peak Load of 2167.30 N with Peak Displacement of 3.148 mm and Break Load of 353.052N Break Displacement of 3.640 mm

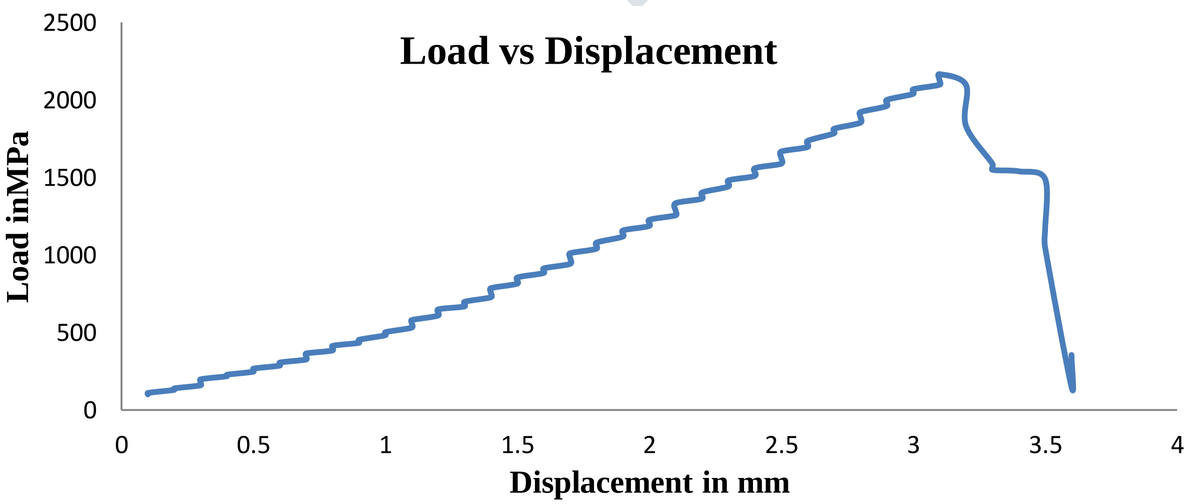


Figure18:tensile graph case

5.4.2 Micro structure

Better grain structure is seen in the weld joint which is welded with square tool because it has 4 CORNERS so it covers more volume than the other tools. that is why it got the better grain size.

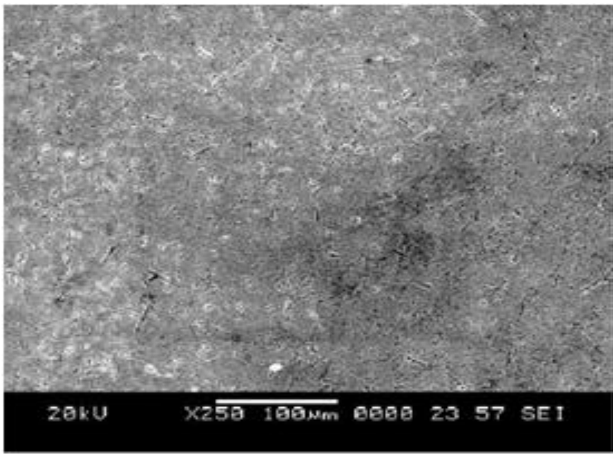


Figure19:SEM Image for case-4

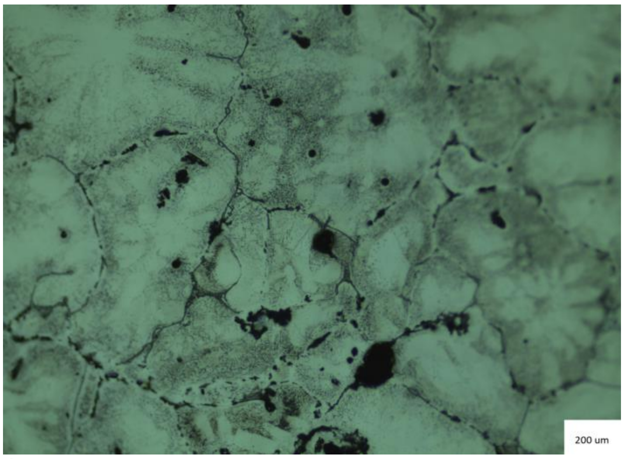


figure20:Micro structure at welded joint for case-4

5.4.3 Hardness

Hardness value is tested from different positions from the weld joint to find the strength of the weld, the highest value is found on the weld joint and the value is 103.

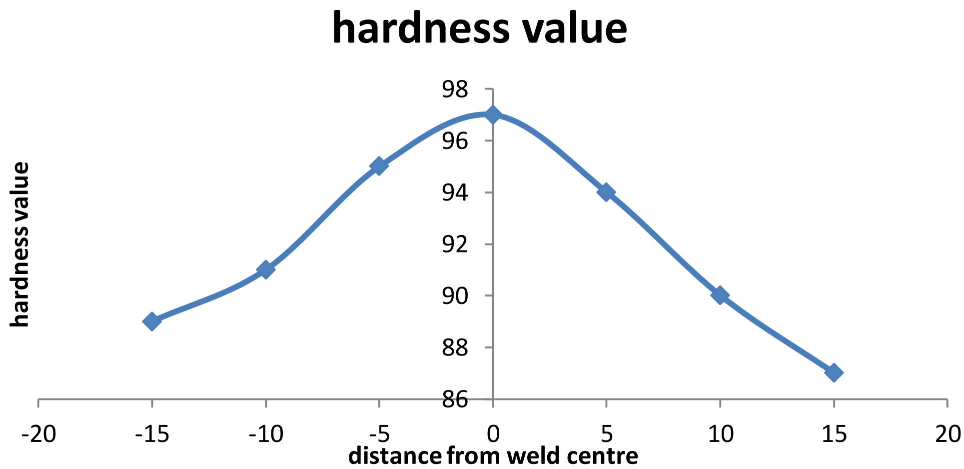


Figure21:Hardness results for case-3

Test results for all 4 cases
Table 5.1 Tensile test

	Ultimate Tensile Strength (N/sq-mm)	Peak Load (N)	Peak Displacement (mm)	Break Load (N)	Break Displacement (mm)
Square Pin	131.619	4266.00	4.616	1618.155	4.701
Threaded Pin	112.372	4099.30	4.735	2030.049	4.820
Taper Pin	98.335	3422.60	4.684	254.982	4.947
Circular Pin	55.488	2167.30	3.148	353.052	3.640

Table 5.2 Hardness test

	-15	-10	-5	0	5	10	15
Square pin	90	97	102	105	100	97	92
Threaded pin	92	98	100	103	98	96	93
Taper pin	91	94	97	100	98	95	92
Circular pin	89	91	95	97	94	90	87

VI.CONCLUSION

From the above results we can infer that

- Results prove that the square pin tool have more ultimate strength
- The tensile work piece is broken outside the weld joint in the case of square pin tool, that means weld joint is super strong
- The second highest ultimate tensile strength is given by the threaded pin tool ,but the threads on the tool is lost after few welds
- Comparing the micro structure of all the cases the square tool got better weld regions
- Hardness values are high for case1 and case 3 compared to case 2 and case 4.

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