A Radical Study on the Effect of Tool Pin Profiles and Mechanical Properties on AA 6061 and AA 7175 Friction Stir Welded Butt Joint

A. Satya Dinesh, R. Raghunatha Reddy

***ABSTRACT** Friction stir welding (FSW) is a novel solid state welding process for joining metallic alloys and has emerged as an alternative technology used in high strength alloys that are difficult to join with conventional techniques and which avoids bulk melting of the basic material, hot cracking and porosity. The function of FSW process are used in several industries such as aerospace, rail, automotive and marine industries for joining aluminum, magnesium and copper alloy. In aerospace industries most of the component is manufactured with aluminum material by welding process. Aluminum welding cannot be done by conventional process because temper characteristics of material will be changed. To overcome this drawback, friction stir welding process is selected. To investigate the effect of welding parameters and different tool pin profiles over Friction Stir Welding of dissimilar AA 6061 and AA 7175 and also compare single pass friction stir welding and multi pass friction stir welding. The parameters considered were tool rotation speed, welding speed, tool pin profiles, tilt angle and number of passes. Different tool pin profiles are threaded triangular, threaded cylindrical, threaded hexagonal and threaded taper pin profiles plays a vital responsibility in deciding the weld quality. This work includes tensile tests, hardness test and impact test.*

***Keywords:** (FSW) The function of FSW process are used in several industries such as aerospace, rail,*

I. INTRODUCTION

Friction Stir Welding (FSW) falls in the category of solid state welding which was invented by The Welding Institute (TWI) in 1991 for joining low melting temperature alloys like aluminum, magnesium and copper (Thomas et al. 1991). The basic principle of FSW involves plunging a spinning tool that has a specially designed pin and shoulder into the work pieces that are intended for welding. Friction Stir Welding (FSW) is considered to be the most significant development in metal joining in a decade and is a "green" technology due to its energy efficiency, environment friendliness and versatility. Chromium hot worked tool steels are classified as group H steels by the AISI classification system. Series of steels are H1 to H19. H13 chromium hot work steel is widely used in hot and cold work tooling applications. Due to its excellent combination of high toughness and fatigue resistance H13 is used more than any other tool steel in tooling applications. A feed rate of 40 mm per minutes is maintained throughout the welding process.

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II. LITERATURE REVIEW

The influences of multi pass friction stir welding on the micro structural and mechanical properties of AA6082 and AA5083 the effects of material's position and different pin profiles were studied on the parameters like material flow, tensile property, micro hardness and micro structure [1]. The study of behavior of aluminum cast alloy (Al-6063) processed by friction stir processing technique. Microstructures, strength were studied with various methods and compared with base metal Al-6063[2]. The joining of dissimilar AA2024 and AA6061 aluminum plates of 5mm thickness was carried out by friction stir welding (FSW) technique [3]. The influence of multi pass friction stir welding on the micro structural and mechanical properties of AA6082 and AA5083 [4]. The effect of welding speed and tool pin profile on FSP zone formation in AA2219 aluminum alloy. Different tool pin profiles have been used to fabricate the joints at three different welding speeds [6].

III. EXPERIMENTAL PROCEDURE

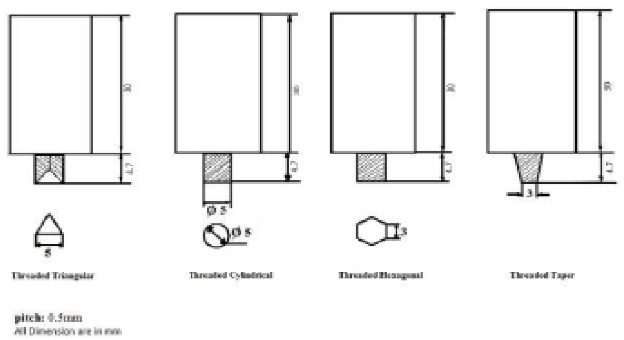

Fig. 1

In this experimental process AA6061 and AA7175 aluminum metal pieces are welded using friction stir welding. The metal pieces are welded in single pass as well as double pass using H13 tool of different cross section. Followed by izod impact testing, charpy impact test, brinell's hardness test, ultimate tensile strength test

Izod Impact Testing

Impact tests are used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. The impact value of a material can also change with temperature. Generally, at lower temperatures, the impact energy of a material is decreased.

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The size of the specimen may also affect the value of the izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impact energy. The below results are the specifications which we used and the values which we determined with threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper tool pin profiles. The specimen or the work piece has the following dimensions : length 60mm, thickness 5mm, width 5mm and depth of notch 2mm. Fig.s 2 and Fig. 3 of before and after izod impact test of single pass are as follows.

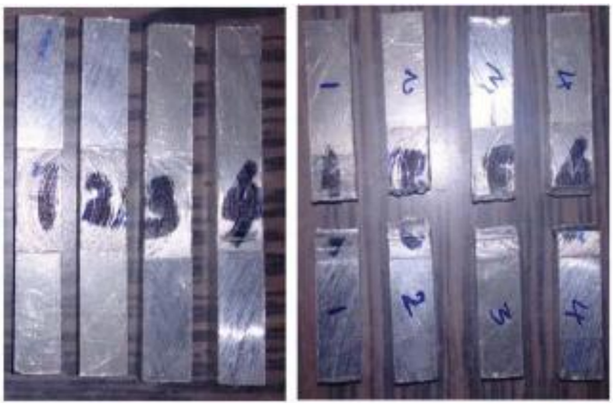

Fig. 2: Izod specimens of single pass before & after impact test

Fig. 3: Izod specimens of Multi pass before & after impact test

Fig 4 represents the values of izod impact test on in both single and multi pass welding using threaded triangular, threased cylindrical, threaded hexagonal, Threaded taper tool profiles.

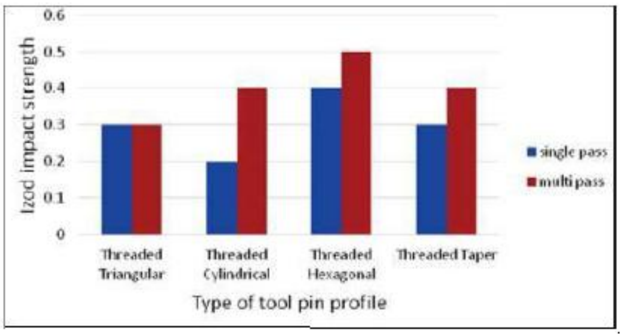

Fig. 4: Effect of izod impact test on single & multi pass welding

Charpy Impact Test

The charpy impact test, also known impact test as the charpy's V-notch test, is a standardized high strain -rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for ferritic steels that show a ductile to brittle transition with decreasing temperature. A brittle metal will absorb a small amount of energy when impact tested; a tough ductile metal absorbs a large amount of energy. The appearance of a fracture surface also gives information about the type of fracture that has occurred; a brittle fracture is bright and crystalline, a ductile fracture is dull and fibrous. The specimen or the work piece has the following dimensions: length 55mm, thickness 5mm, width 5mm and depth of notch 2mm. Fig. 5 and Fig. 6 of before and after charpy impact test of single pass are as follows.

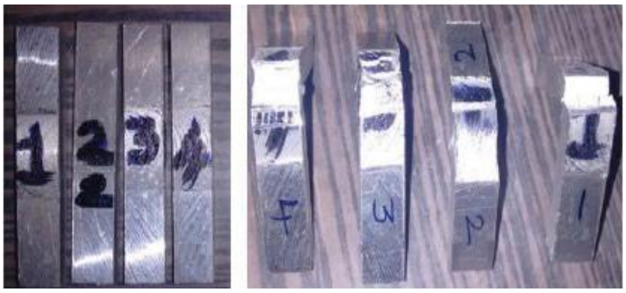

Fig. 5: Charpy's specimens of single pass before and after impact test

Fig. 6: Charpy's specimens of single pass before impact test and after impact test

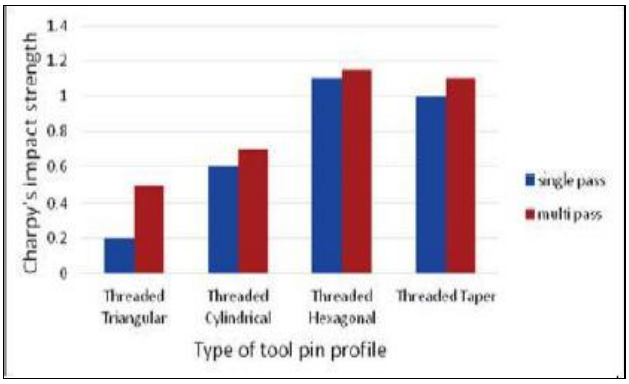

Fig. 7: Effect of charpy's impact test on single & multi pass welding

Brinell's Hardness Test

Brinell's tests are frequently done on large parts by varying the test force and ball size. The Brinell's scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. The test uses a 5 millimeters diameter of ball as an indenter with a 250kgf force.

For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball. For our investigation, we have applied a load of 250kgf and used 5mm diameter ball and the weld hardness is tested for work pieces.

Fig. 8: Comparison between the different tool pin profiles threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profiles by single pass welding for brinell's hardness test.

Fig. 9 shows comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profile for brinell's hardness test.

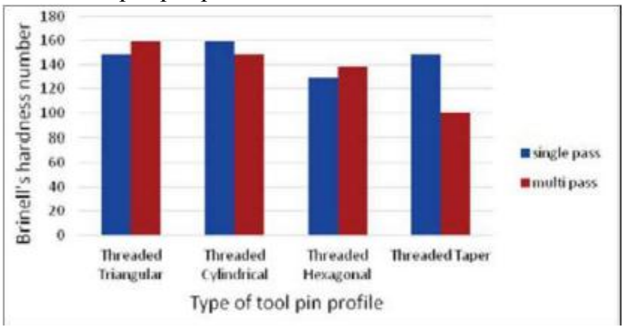

Fig. 9: Effect of brinells hardness test on single & multi pass welding

Ultimate Tensile Strength Test

Ultimate tensile strength (UTS) often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is distinct from compressive strength. Some materials break sharply, without plastic deformation, in what is called a brittle failure others, which are more ductile, including most metals, experience some plastic deformation and possibly necking before fracture.

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures.

Considering our experiment ultimate load, ultimate yield strength, elongation, ultimate tensile strength are found out and are compared for both the welds which are performed by using cylindrical threaded and triangular threaded pin profiles on an UTM machine.

Fig. 10: Ultimate Testing Machine

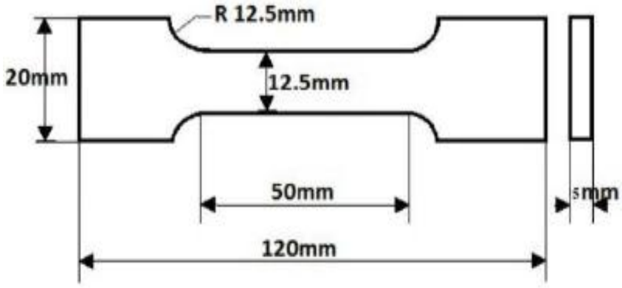

Fig. 11: Geometrical drawings of I cross section ASTM- E8

The welded pieces are cut in the above shown dimensions and are tested for ultimate strength.

Fig. 12 shows the single pass welded pieces before ultimate tensile test for different tool pin profiles. Fig. 13 shows the single pass welded pieces after ultimate tensile test for different tool pin profiles.

strength with different tool pin profiles are threaded triangular, threaded cylindrical, threded hexagonal and threaded taper.

Fig. 12: I cross section of the single pass welding before tensile test

threaded taper pin profile for load (KN) vs. displacement (mm).

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Fig. 13: I cross section of the single pass welding after tensile test

Similarly as experiment performed on the single pass weld, experiment is also conducted for multi pass weld. Fig. 14 shows the multi pass welded pieces before ultimate tensile test for different tool pin profiles. Fig. 15 shows the multi pass welded pieces after ultimate tensile test for different tool pin profiles.

After completion of the experiment on the I sections the results are compared in the Fig. 16 for ultimate tensile

Fig. 14: I cross section of the Multi pass welding before tensile test

Fig. 15: I cross section of the multi pass welding after tensile test

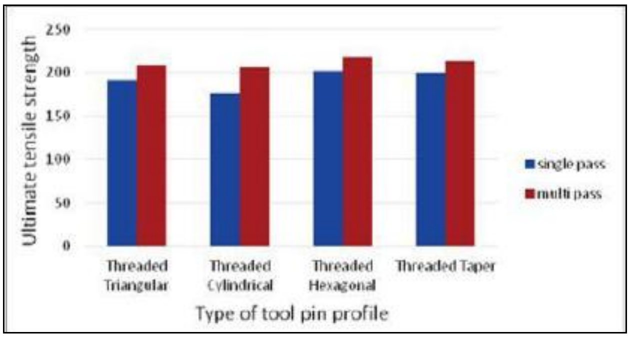

Fig. 16: Effect of ultimate tensile strength on single & multi pass welding

Fig. 16 shows the comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profile for ultimate tensile strength.

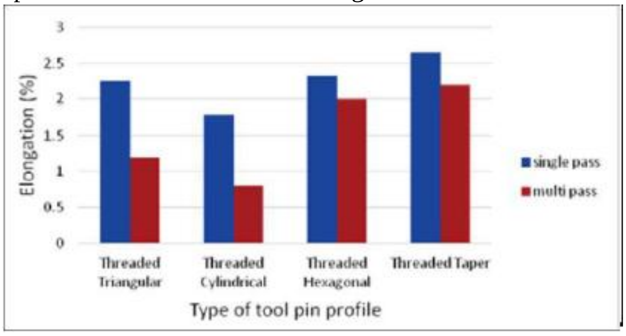

Fig. 17: Effect of elongation on single & multi pass welding

Fig. 17 shows the comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profile for elongation.

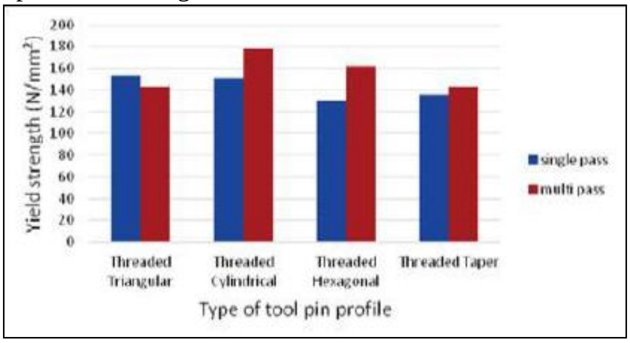

Fig. 18: Effect of yield strength on single & multi pass FSW

Fig. 18 shows the comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profile for yield strength.

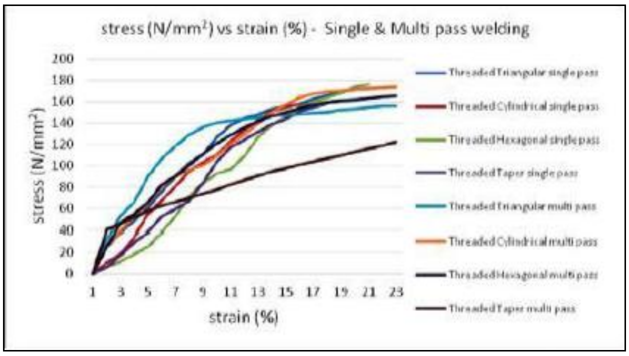

Fig. 19: Comparision between stress & strain on single & multi pass FSW

Fig. 19 comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and threaded taper pin profile for stress (N/mm^2) vs. Strain (%).

Fig. 20 Comparison between single and multi pass welding with the different tool pin profile threaded triangular, threaded cylindrical, threaded hexagonal, and

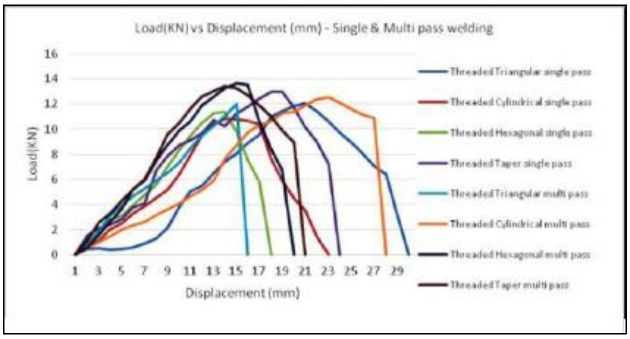

Fig. 20: Comparision between load & displacement on single & multi pass FSW

IV. RESULT & DISCUSSION

1. It is evident from Fig. 3 that single & multi pass welding; the threaded hexagonal tool pin profile has more impact strength when compared to the other types of tool pin profiles.
2. It can be inferred from Fig. 6 that single & multi pass welding, the threaded hexagonal tool pin profile has more impact strength when compared to the other types of tool pin profiles.
3. It is observed that the brinell’s hardness number for single pass welding; the threaded cylindrical tool pin profile has more hardness when compared to the other types of tool pin profiles.
4. The hardness is found to be increasing in multi pass FSW when compared to single pass FSW at HAZ.
5. It is observed that the ultimate tensile strength for single & multi pass welding; the threaded hexagonal tool pin profile has more tensile strength when compared to the other types of tool pin profiles.
6. It is observed that the elongation for single & multi pass welding; the threaded taper tool pin profile has more elongation when compared to the other types of tool pin profiles.
7. It is observed that the yield strength for single & multi pass welding; the threaded cylindrical tool pin profile has more yield strength when compared to the other types of tool pin profiles.
8. It is observed that the ultimate tensile strength for single & multi pass welding; the threaded hexagonal tool pin profile has more tensile strength when compared to the other types of tool pin profiles.
9. It is observed that the ultimate tensile strength for single & multi pass welding; the threaded hexagonal tool pin profile has more load and displacement when compared to the other types of tool pin profiles.
10. When compared with all the results it can be noted that the tensile strength for single & multi pass welding; the threaded hexagonal tool pin profile has more tensile strength when compared to the other types of tool pin profiles.
11. The friction stir welding process parameters were optimized with respect to mechanical and metallurgical properties of the weldments. In addition, tool pin profile has also influenced the weld quality.

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