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Research Article

Effect of Tool Pin Profile on Mechanical Properties of Single Pass and Double Pass Friction Stir Welded Aluminium Alloys AA6061 & AA8011

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Abstract

In present work, an investigation has been carried out on single and double pass friction stir welding (FSW) of two dissimilar aluminium alloys AA6061 and AA8011 using high carbon high chromium alloy steel tool. Study of the different mechanical properties such as tensile strength and micro hardness of the joints was carried out with the use of different tool pin profiles i.e. straight cylindrical, threaded and tapered cylindrical for single pass and double pass welding at constant tool rotational speed of 1400 rpm and traverse speed of 45 mm/min. Shape of the tool pin profile and number of passes are process variables. Results show that maximum tensile strength occurs across the double pass as compared to the single pass. It has observed that hardness value of single sided welded joints is slightly greater than double sided welded joints. From this investigation it is found that threaded tool pin profile produces mechanically sound weld and superior tensile properties as compared to other joints.

Keywords: *Friction Stir Welding; Aluminium Alloys AA6061 & AA8011; Tool Pin Profile; Mechanical Properties.*

Introduction

Friction stir welding (FSW) is a relatively new solid state welding process which is used for butt and lap joints. FSW was invented by The Welding Institute, Cambridge, UK in 1991 [W.M Thomas, E.D .Nicholas, J.C. Needham, M.G. Murth *et al,* 1991] and has emerged as a candidate process for welding of aluminum alloys. This process has made possible to weld a number of aluminum alloys that were previously not recommended (2000 series & copper containing 7000 series aluminium alloys) for welding. Because the material subjected to FSW does not melt and re-solidify, the resultant weld metal is free of porosity with lower distortion. An added advantage is that it is an environment friendly process. FSW is a solid state, localized thermo-mechanical, joining process. The process and the terminology are schematically explained in Fig. 1. In FSW a non-consumable rotating shouldered-pin-tool is plunged into the interface between two plates being welded, until the shoulder touches the surface of the base material, and is then traversed along the weld line. In FSW, frictional heat is generated by rubbing of tool shoulder and base material surface, and by deformation. During traversing, softened material from the leading edge moves to the trailing edge due to the tool rotation and the traverse movement of the tool and this transferred material is consolidated in the trailing edge of the tool by the application of an axial force [Kumar K., Kailas Satish V. *et al*, 2008].

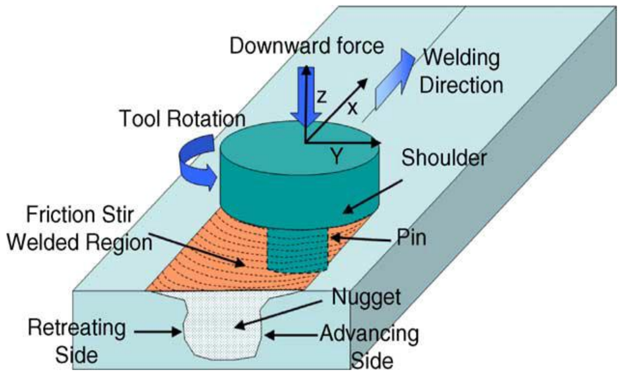

Figure 1 Schematic diagram of Friction Stir Welding [R.S. Mishra *et al*, 2005]

Experimental Work

6 mm thick rolled plates of AA6061 & AA8011 aluminium alloy were cut into the required size (180 mm × 100 mm) by power hacksaw cutting and milling. A square butt joint configuration (180 mm × 200 mm) was prepared to fabricate FSW joints. The initial joint

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configuration was obtained by securing the plates in position using mechanical clamps. The direction of welding was normal to the rolling direction. Single pass welding procedure was followed to fabricate the joints. Non-consumable tools made of high carbon high chromium steel were used to fabricate the joints. The mechanical properties of base metal are presented in Table 1.

CNC vertical milling machine was used to fabricate the joints as shown in Fig. 3. Three different tool pin profiles i.e. straight cylindrical, threaded and tapered cylindrical were prepared and used to fabricate the joints.

Table 1 Mechanical properties of AA6061 & AA8011

Specimen	Ultimate tensile Strength (N/mm^{2})	Micro-hardness
AA6061	310	107
AA8011	110	25

Non-consumable tools made of high-carbon high chromium steel have been used to fabricate the joints. The dimensions of the tool are presented in Table-2. Single pass and double pass welding procedure was followed to fabricate the joints.

Table 2 Tool Material and Dimensions

Specifications	Values
Tool Material	HCHCR Steel
Length of tool	90 mm
Tool shoulder diameter	18 mm
Pin diameter	6 mm
Pin length	5.6 mm

The welded joints are sliced using power hacksaw and then machined to the required dimensions to prepare tensile specimens as shown in Fig. 2. American Society for Testing of Materials (ASTM E8M-0.4) guidelines were followed for preparing the test specimens. UTM machine was used for tensile testing. The specimen finally failed after necking and the load versus displacement has been recorded. The ultimate tensile strength has been evaluated. Vickers's micro hardness testing machine has been employed for measuring the hardness across the joint with 0.2 kgf load for a period of 15 seconds.

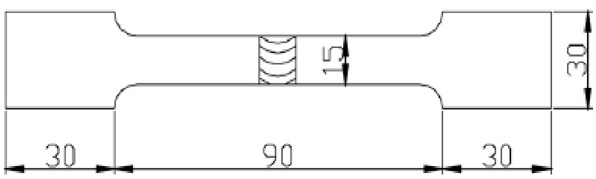


Figure 2 Dimensions of Tensile Specimen

Figure 3 Welding Process

Results and Discussion

The results of tensile testing and micro-hardness have been described in two subsections below.

Tensile Testing

The welded specimens were taken under tensile testing and the values of ultimate tensile strength were noted. The results of tensile loading of welded specimens in single and double pass are shown in Table 3 and Table 4 respectively. The variation of ultimate tensile strength is shown in Graphs 1. The tensile testing results show that tensile properties of double pass welded specimens were improved as compared to single pass welded joints and this trend is common for all specimens.

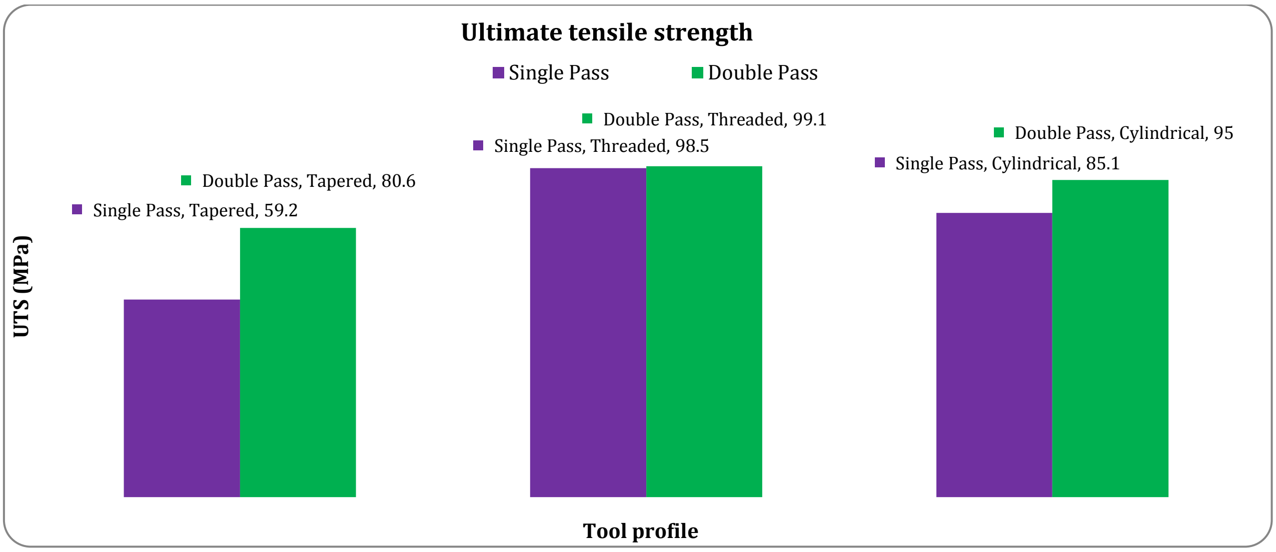
Table 3 Tensile Test Results of Welded Specimens In Single Pass Welding

Specimen No.	Ultimate tensile Strength (N/mm^{2})
S-1	59.2
S-2	98.5
S-3	85.1

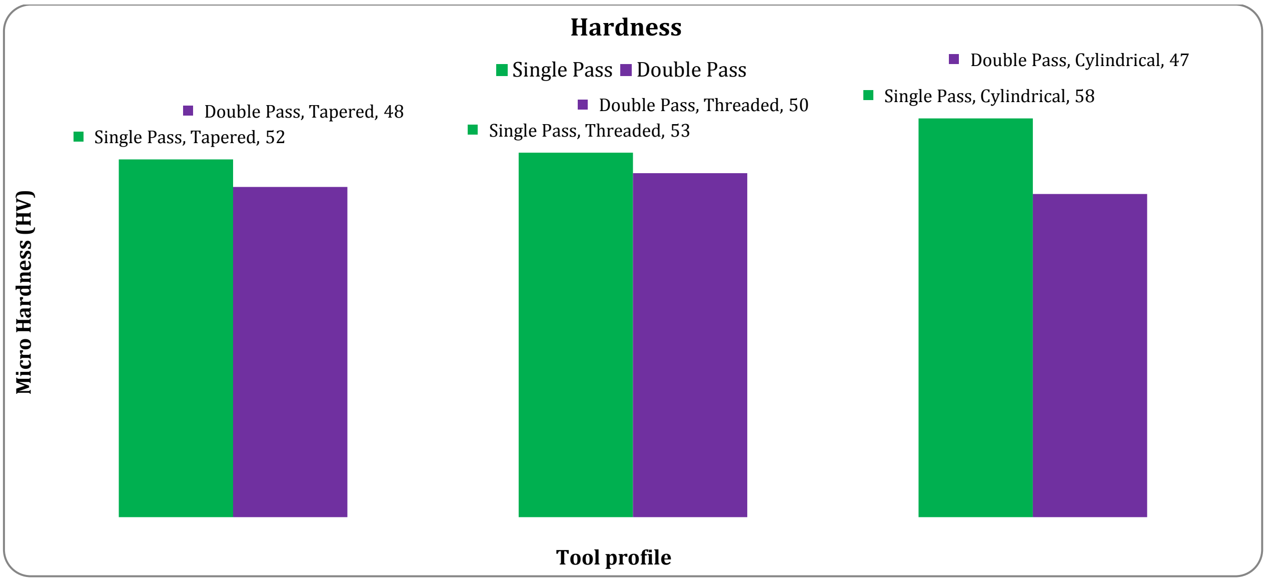
Table 4 Tensile Test Results of Welded Specimens In Double Pass Welding

Specimen No.	Ultimate tensile Strength (N/mm^{2})
S-4	80.6
S-5	99.1
S-6	95

Threaded tool pin profile tool exhibited superior tensile properties compared to other joints, irrespective of tool rotational speed in double pass. The maximum and minimum ultimate tensile strength using single pass welding was 98.5 N/mm^2 and 59.2 N/mm^2 respectively while maximum and minimum ultimate tensile strength in double pass welding was 99.1 N/mm^2 and 80.6 N/mm^2 respectively.



Graph 1 Variation of Ultimate Tensile Strength



Graph 2 Variation of Micro-hardness

Micro-Hardness Testing

The welded samples were tested for micro-hardness on Vickers Hardness Tester. The micro hardness result of welded specimens in single pass and double pass welding is shown in Table 5 and 6 respectively. A plot of micro hardness data as a function of position from the weld centre-line in single pass and double pass welding with respect to various tool profiles is shown in Graph 2.

Table 5 Micro Hardness Results of Welded Specimens in single pass

Specimen No.	Micro Hardness (HV)
S-1	52
S-2	53
S-3	58

Table 6 Micro Hardness Results of Welded Specimens in double pass

Specimen No.	Micro Hardness (HV)
S-4	48
S-5	50
S-6	47

It can be observed from the graph that the hardness values of the weld zone or the nugget is lower than the base materials. This indicates the improved ductility of the weld. The graphs of hardness in double pass exhibit a minimum in hardness associated with weld nugget of the weld as compared to single pass. Because weld nugget has been subjected to an over tempering heat treatment in double pass. The hardness minimum for the double pass weld is lower in value due to additive heating effects of the two welding passes.

Conclusion

In this investigation an attempt has been made to study the effect of tool pin profile (straight cylindrical, threaded and tapered cylindrical) on tensile strength in single and double sided friction stir welding of AA6061 & AA8011. The joints fabricated by double pass FSW have shown higher ultimate tensile strength as compared to the joints fabricated by single pass and this trend is common for all the tool profiles. Micro-hardness of double pass FSW specimens are lower as compared to the joints fabricated by single pass FSW. Of the three pin profiles used in this investigation to fabricate the joints, threaded pin profiled tool give better mechanical properties.

References

W.M Thomas, E.D .Nicholas, J.C. Needham, M.G. Murth (1991), Friction stir butt welding *International Patent Application No.* PCT/GB92/02203

R.S. Mishra and M.W. Mahoney (2007), Friction stir welding and processing *DOI*: 10.136/fswp

P. Vivekanandan, V. P. Arunachalam, T. Prakash, L. Savadamuthu (2012), The Experimental Analysis of Friction Stir Welding on Aluminium Composites, *International Journal of Metallurgical Engineering,* 1(4): 60-65 DOI: 10.5923/j.ijmee.20120104.0

Prado, RA Murr, LE Shindo, DJ Soto (2001), Tool wear in the friction stir welding of aluminium alloy 6061+20% Al_2O_3:Apreliminary study, *Scripta Materialia*, Pg-75-80.doi: 10.1016/S1359-6462(01) 00994-

R. Nandan, G.G. Roy, T.J. Lienert, and T. DebRoy (2006), Numerical modelling of 3d plastic flow and heat transfer during friction stir welding of stainless steel, *Science and Technology of Welding and Joining,* Pg-526–53

A.P. Reynolds and W.D. Lockwood (1999), Digital Image Correlation for Determination of Weld and Base Metal Constitutive Behaviour, *Proceedings of the First International Conference on Friction Stir Weldi*

T.W. Nelson, H. Zhang, and T. Haynes (2000), Friction Stir Welding of Aluminium MMC 6061-Boron Carbide, *Proceedings of the Second International Conference on Friction Stir Weld*

Kumar K., Kailas Satish V. (2008), On the role of axial load and the effect of interface position on the tensile strength of a friction stir welded aluminium alloy, *Materials and Design, Pg*-791–797

G. Raghu Babu, K.G.K. Murti, G. Ranga Janardhana (2006), An Approach to the Design of a Tapered Tool for Friction Stir Welding of Aluminium using CAD, *Proceedings of National Conference on Emerging Technologies in Mechanical Engineering for Sustainable Development 1 (A), pp. 1-4*

S. R. Sharma and R.S. Mishra (2008), Fatigue crack growth behavior of friction stir processed aluminum alloy, Scripta Materialia 59 pp 395–39

Rao P.N. (2006), *Manufacturing Technology*, Second Edition, Tata McGraw Hill Edition

Kalpakjian S. (2002), *Manufacturing Engineering and Technology*, Pearson Education Edition

Khanna O.P. (1998), *A Text Book on Welding Technology*, Revised Edition, Dhanpat Rai Publications