Influence of Tool Shoulder Geometry on Friction Stir Welding: A Literature Review

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***Abstract*– FSW is solid state joining process. It is widely used for joining hard alloy like steel, titanium, aluminium alloy which is very difficult to join by fusion welding. FSW joint quality mainly influenced by shoulder & pin geometry, its diameter, tool material, tool rotation speed and linear travelling speed. In FSW, tool shoulder is main source of heat generation and also it give an axial force on weld zone for joining the two materials which may be same or different.So, its geometry and dimension have grate impertinence in FSW weld. This review present different shoulder geometries with different shoulder diameter of FSW tool.**

***Keyword* –FSW process, FSW tool, shoulder geometry, shoulder diameter**

I. INTRODUCTION

From last some years, world focus on developing efficient and environment friendly metal joining processes. So, for joining two materials focus on Friction Stir Welding (FSW) is increased now. FSW developed by W. Thomas at TWI in 1991.FSW is advance welding technology and has emerged as a solid state joining process which used to join that materials which is difficult to join by fusion welding processes.This technique is use in aerospace, shipbuilding, automobile industries.

The basic concept behind the FSW process is that, after matting the two weld edges, a non-consumable rotating tool is plunge between them and give feed to it along the weld seam. The metal is extruded from the base plate around the tool before being forged by the shoulder. In FSW 70% heat is generated by the shoulder and rest by pin probe.[1]Here the heat generated by toolis only enough to weld material at solid state and metal flow due to stirring action of a pin. FSW is also an effective mean to refining the grain size of alloys via recrystallization. That's why FSW is significant potential for joining the low melting point non-ferrous metals in simple and complex geometry. FSW process is shown in figure 1.

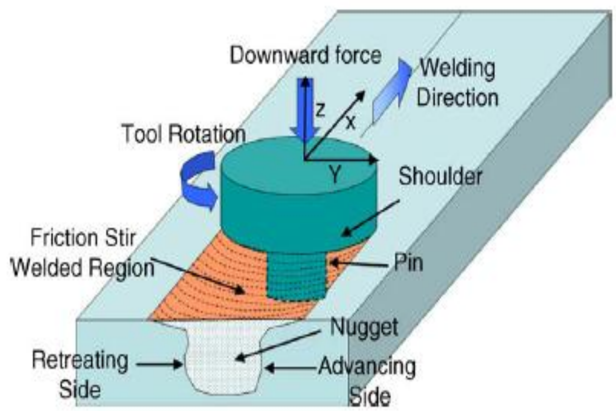


Fig. 1 FSW Process Principal [6]

FSW give the grater microstructural properties and quality then base metal compare to other welding process because of crushing, stirring and forging action of tool [2]. Due to continuous good quality of weld, FSW is used for existing products or go ahead for new complex products.

Advantages of FSW:

- Low distortion and shrinkage, even in long weld.
- One tool can typically be used for up to 1000 m of weld length in 6xxx series alloys.
- No grinding, brushing or picking required in mass production.
- Operate in all position.
- No porosity, fume and spatter.
- Excellent mechanical properties.
- No filler metal required.

II. FSW TOOL

FSW tool mainly consisttwodistinct parts namely pin and shoulder shown in figure 2.

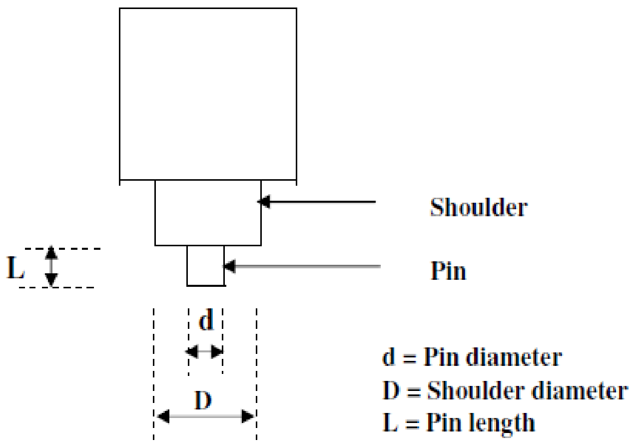


Fig. 2 FSW Tool[17]

An overview of FSW has been given by Terry Khalid [1]. FSW joints usually consist of 4 different regions as shown in Figure3 (a) Parent metal, (b) HAZ, (c) TMAZ and (d) NZ.

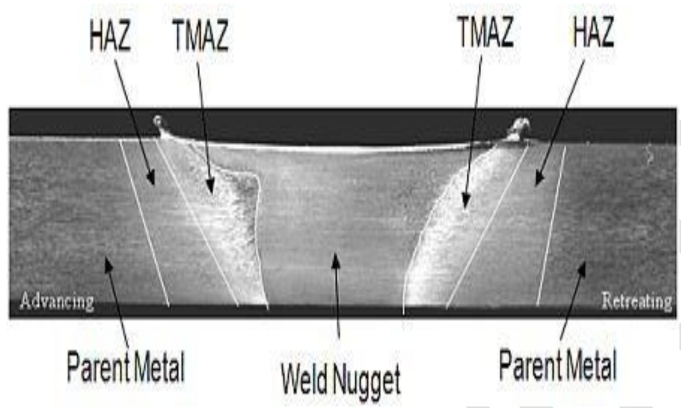


Fig. 3Micro Structural Evolution[6]

Tool geometry is the main factor for controlling the flow of material, heat generation and quality of weld.Shoulder geometry has significant influence on the peak temperature, power requirement and torque. [3]Tool shoulder diameter is main parameter for plastic deformation of work piece and it optimum value mainly depended upon rotation speed, supplied torque and D/d ratio. Results shows that as shoulder diameter increase, the state of deforming material change from high flow-stress and low temperature to low flow-stress and high temperature. [3]

III. RELATED STUDIES ON DIFFERENT SHOULDER GEOMETRY OF FSW

D. Li et al. (2015) [4] and S.D. Ji et al. (2014)[5] use stationary shoulder friction stir weld, figure (5) on 7075-T651 and 6005A-T6 aluminium alloy. They found that this unique tool give the defect free weld with narrow TMAZ area compared to conventional one.

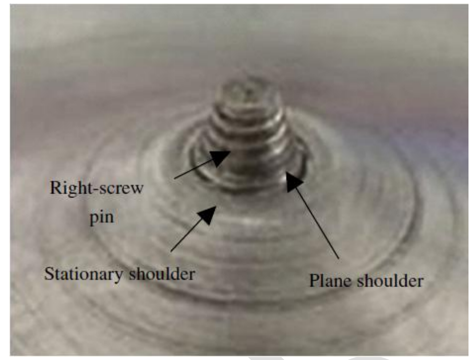


Fig. 4 Stationary Shoulder Tool [5]

G.Casalino et al. (2014)[3]undertake the study on 3 mm thick plate of 5754H11 Aluminium alloy with 4 different shoulder diameter with or without carbide coatingFSW tool. They conclude that diameter of the shoulder influenced the size of the microstructural zones and the hardness profile. Also they shows that large shoulder with coated tool give defect free weld on 5754H11 Aluminium. [3]

L.Trueba et al. (2014)[7]develop 6 unique tool shoulder, figure (4) to improve the metal flow and constraint on 6061-T6 Aluminium alloy. Raised spiral shoulder geometry give the best weld with good surface quality and mechanical properties even under non-ideal condition.

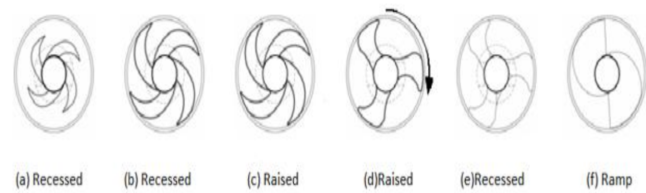


Fig: 5Sixunique tool shoulder geometries [7]

P. K.Sahu and Sukhomay Pal (2014)[8]identify the effect of the shoulder diameter and plunging depth of tool which made from H-13 tool steel, on mechanical properties ofFSWonAM20 alloy. They undertake the study of (16, 20, 24) mm diameter tools with different plunging depth (0.03, 0.12, 0.21) mm. As shoulder diameter increase with other parameter constant, the mechanical properties of weld increase. Also as plunging depth increase up to certain limit, it give better mechanical properties.

M.Paidar et al. (2014) [9] done the FSSW on 1.6 mm thick 2024-T3 aluminium alloy and measure the effect of different tool rotation speeds (630, 1000 and 1600 rpm) and shoulder penetration depth (0.3, 0.5 and 0.7 mm) on mechanical properties and failure modes of weld. Result is that, the failure modes increase with increase in tool rotation speed and shoulder penetration depth.

K.Ramanjaneyulu et al. (2014)[10] conduct the FSW experiments on AA 2014 aluminium alloy to define the role of shoulder diameters (12 to 24 mm) and rotation speed on high temperature plastic deformation. As shoulder diameter increase the shoulder driven metal flow decrease.

I. Galvao et al. (2013) [11]study the effect of 3 different shoulder geometry, figure 6on the 1-mm thick copper-DHP plates. They varying the rotation speed between 400-1000 rev/min and traverse speed 160-250 mm/min of the tools. The scrolled geometry gives the suitable metal flow and good grain structure in the nugget zone of the weld.

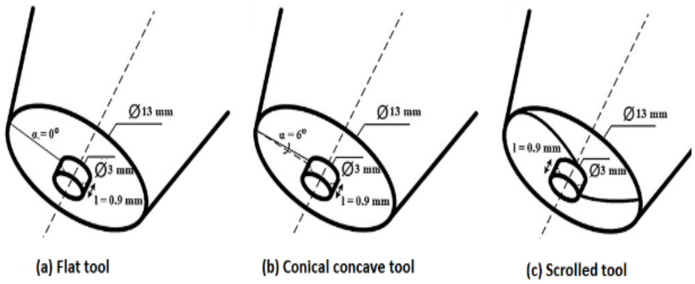


Fig: 6[11]

P. J.Ramula et al. (2013) [12] studied the influence of shoulder diameter and plunging depth on the formability of FSW of 2.1 mm thick AA6061-T6 sheets. The formability of FSW welded sheets is batter then the unwelded region.

H.K. Mohanty et al. (2012)[13]used mainly 3 different geometry tool with different shape of shoulder and pin probe profiles (total 27 tools).FSW tool geometry significantly effect on weldment reinforcement, micro hardness and weld strength.

R.M. Leal et al. (2011)[14]observed that the weld mainly affected by tool rotation speed. Showed that the conical cavity shoulder require higher spindle torque then other shoulder.

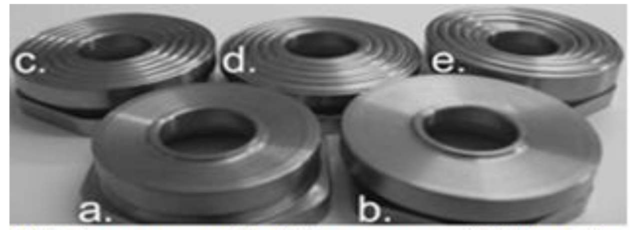
Dr. A. M. Takhakhet al. (2011)[15]investigated the FSW spot welding with different diameters on 1200 aluminium alloy. The hardness decrease gradually through the base material to the HAZ to TMAZ then slightly increase at NZ because friction heat and amount of plastic deformation.

I. Galvao et al. (2011) [16]observed the FSW of aluminium and copper with the use of two different shoulder geometry (conical & scrolled). Every geometry gave different morphology and intermetallic content.

G. Padmanaban and V. Balasubramanian (2009)[17]take the 5 tool pin profiles and tool materials (MS, SS, AS, HCS, HSS), 3 shoulder diameter and do the FSW welding on AZ31B magnesium alloy. The high carbon steel tool with threaded pin profile and 3 D/d ratio exhibit the better tensile properties of weld zone.

M. De Giorgi et al. (2009)[18] use 3 shoulder geometry, same as fig (8) on 1.5 mm thick AA6082-T6 aluminium alloy and give the relation between residual stress and fatigue behaviour. This relation not give the clear result about tool geometry because of low transversal residual stress level.

L. Cederqvist et al. (2009) [19]welded the 5 cm thick copper canisters through FSW. They develop 5 unique shoulder geometry as figure 7.



(a) Ø 60 mm concave (b) Ø 70 mm concave (c) Ø 70 mm flat scroll (d) Ø 70 mm convex scroll (e) Ø 70 mm concave-convex scroll

Fig: 7[19]

A. Scialpi et al. (2007) [20]use three different shoulder geometry as shown in fig. (8) on 1.5 mm thick 6082 Aluminium alloy sheet. The (Cavity + fillet) tool give higher longitudinal and traverse strength of joint and also a best crown on thin sheets.

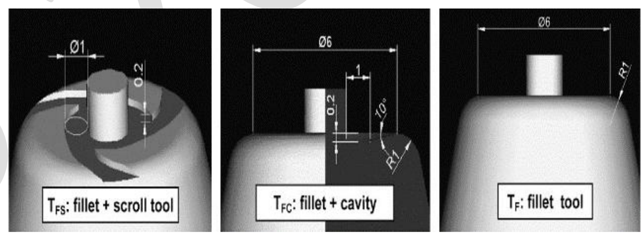


Fig: 8[20]

R. Mishra and Z.Y. Ma (2005) [6] showed 5 different types of tool shoulder geometry as figure 9.

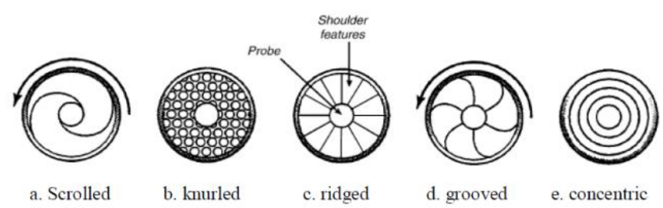


Fig: 9Tool shoulder geometries,
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IV. CONCLUSION

From last some year, there is some significant improvement in FSW process. Various types of tool shoulder and pin geometry with different diameters have been designed. Today, the main requirement of FSW is good material flow and less flash formation during welding process. For that effective shoulder geometry with optimum shoulder diameter are required. So, further work should focus on designing effective shoulder geometry with optimum shoulder diameter.

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