# Influence of Tool pin depth of penetration in Alluminium Alloys over joint parameters in Friction stir welding

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***Abstract*—Friction Stir Welding is very conventional but advanced itself welding method to joint non-ferrous materials also. In present study the effect of tool pins depth of penetration is understood. This paper intend to understand the effects of main parameters including tool's rotational speed, tools feed, tools axial force which are already analyzed by many researches, To understand the effect of penetration, these parameters are taken into consideration. It was found that depth of penetration has direct relation to micro structure of obtained joint. As depth of penetration can be controlled by tool itself and also by axial force also. This paper aims to co relate joint parameters with depth of penetration for obtain optimum results.**

***Keywords:*** **Friction stir welding, Alluminium Alloy, depth of penetration**

## I. Introduction

Friction Stir Welding (FSW) is a relatively new joining process which has shown much promise and potential. Extensive time and effort have been expended to understand this process and its many aspects. Researchers have explored tool geometry, tool material, equipment, resulting weld microstructure, weld performance, and many other aspects of this process. As a result of these efforts, FSW has been implemented in several applications around the world.

The immerging age of aluminium alloys having wide acceptance in industrial and research work due to its light weight and various forms available in alloys. Friction stir processing (FSP) is better way to obtain better joint in alluminium alloys or bi-metal joints. In FSW during tool pins penetration generates tool. FSW, a recently developed solid-state welding technique, is found to provide a solution to the welding issues related to differential fusion weld structures.[1] In this technique, a specially designed rotating pin with a shoulder (a non-consumable tool) is first introduced into the material and, after a small dwell time, it is made to move along the joint line between the plates being welded. Friction between the shoulder of rotating tool and the work pieces generates sufficient heat, which can soften the material and reduce the flow stress around the rotating pin and tool shoulder.[2]

There are many researches have been done by focusing parameters like speed, feed, axial force, temperature, microstructural analysis of joint, but actually there is lake of co relation between these parameters. Where the parameters like depth of penetration and friction coefficient are still not very much clearly understood. The lake of penetration causes lesser joint formability. Hence, optimum parameters combined with depth of penetration gives optimum tensile strength.[3]

## II. Depth of penetration

However depth of penetration is described as insertion of tool pin into the base material. Penetration may depend upon length of probe in FSW tool. Actually for better stirring effect optimum parameters with depth of tool pin insertion is must.

## III. Abbreviations

| **Short names** | **Meanings** |
|---|---|
| FSW | Friction Stir Welding |
| AS | Advancing side |
| RS | Retreating side |
| SZ | Scroll Zone |
| MZ | Mixed Zone |
| TMAZ | Thermo Mechanically Heat affected Zone |
| HAZ | Heat Affected Zone |

## IV. Influence of penetration

Friction stir welding mainly depends upon tool pins profile characteristics. Different combinations of parameters gives different joints with respect to material properties. Researchers have done experiments using selected parameters and material and obtained various results. Recent researches pointed toward TMAZ, HAZ and tool pin profiles. *C.N.Suresha* has shown done research on Rolled plates of AA7075-T6 aluminium alloy of 5 mm thickness using single pass method he has analyzed different tool pin profiles (Fig. 1) effect over joint. He concluded that the welded joints produced by the conical tool show better joint efficiency when compared to the square tool. And also found that it was found that the tool rotational speed has a major contribution compared to weld traverse speed and Plunge depth the case of both conical and square tools. [1].

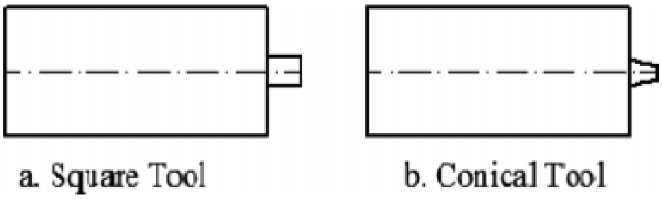


Fig. 1. Line diagram shown of tools

Generally this proves that existing study done by *C. N Suresha* is limited to tool pins rotation on square tool pins profile. Mouloud aissani has taken welding results on AA2024-T4 and AA7075-T6 sheets with two different rotation speeds, namely, 1400 and 2000 rpm and evaluated that at very slow travel rate, relatively high pressure, and high rotation speed, we can obtain a better weld appearance. During the FSW process, the temperature remains below the melting point of the material (80% of its melting point).[3] There are many other factors relate to the joint parameters likewise in bi-metal joints the AS and RS plays major role. However researchers concluded importance of AS and RS, *P. Xue* has conducted experiment 1060 aluminum and commercially pure copper (~99.9% purity) plates 5 mm in thickness, 300 mm in length, and 70 mm in width. The hard plates were fixed at the RS in some studies, sound joints were usually obtained when the hard plates were fixed at the AS. Sound defect-free joint could be obtained only when the hard Cu plate was fixed at the AS. A large volume defect was observed when the soft Al plate was fixed at the AS. This is attributed that the hard Cu bulk material was hard to transport to the AS during FSW.[4]

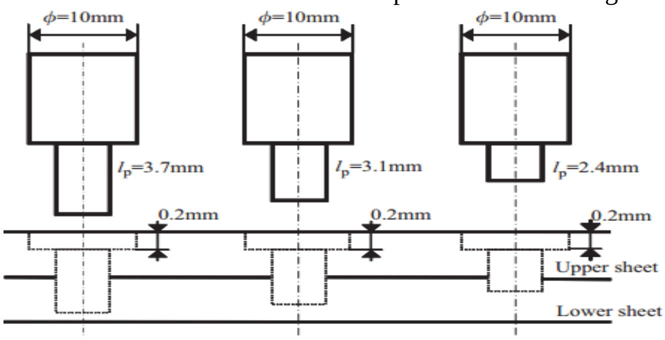


Fig. 2. Tools of different probe length

Tool holding time also effects along with tool pin's depth of penetration. *Billic* has done research on the effect of tool geometry on microstructure and static strength in friction stir spot welds of 6061 aluminium alloy sheets by choosing tools with three different probe lengths shown in Fig. 2. to join the aluminium sheet with different tool rotational speeds and tool holding times. As The tensile shear strength increased with increasing probe length, while the cross-tension strength was not affected significantly by probe length.[5]

Tool pins depth of penetration acts as incremental parameter for string effect. Of course there are other parameters like tool shoulder diameter and pin diameter also takes active part in frictional heat generation and stirring effect. As before *Billic* has kept diameter of shoulder at 10 mm fixed but another researcher *M. Mehta* said in his published paper that shoulder plays major role in tool geometry the shoulder generates most of the heat, induces flow of plasticized materials, and prevents its escape from the workpiece during welding.in experimental procedure he used Aluminum alloy AA7075-T6 plates 172-mm long, 97-mm wide, and 3.5-mm thick are welded in a square butt joint configuration. All the welds are made at 2 degree tilt angle. Upon his research its concluded that increase in pin taper angle resulted in higher peak temperature.[6]. However tool shoulder comes into contact with base material surface to generate heat but actually depth of penetration of tool decides how much material to be stirred and bond strength also depends on depth of penetration. Local rise in temperature causes the material immediately below the shoulder surface to become softened. The softened material at the leading edge of the pin is gradually transferred to the trailing edge due to the conjoint influence of rotation of the tool and its traverse motion.[7] *K.kumar* has investigated that ratio of diameter of pin to diameter of shoulder should be 2.5 for obtain optimum results. *K. Elangovan* observed that Lack of penetration in the weld root usually occurs mostly if the pin length is too short for the plate thickness being welded. Generally, these defects result from incorrect tool design and process parameter selection. In sufficient heat input or incorrect tool orientation also resulted in lack of penetration.[2]. Hence this shows the relation between tool inclinations to pin's depth of penetration. Tools depth of penetration is not likely depend to the pin probe length but also on the axial forces applied over it.

*M.St. Weglowski* has established relation between torque temperature and penetration of tool. The range of travelling speeds applied in experiments was between 112 and 900 mm/min, whereas the rotational speed varied from 112 to 1800 rpm. he obtained one of the conclusion that increase of the rotational speed decreases the penetration depth and the increase of the travelling speed has a negligible effect on the penetration depth compared to the influence of the rotational speed.[8] Where increase in travelling speed of the tool increases the torque and decreases the temperature. This means if increment in the travelling speed, it causes decrement in penetration depth. This parameter depends on microstructural properties of material also. If penetration is poor then it causes defect in microstructural body. *C. Mandache* and *D. Levesque* done NDT test to prove lake of penetration defects in stir weld.

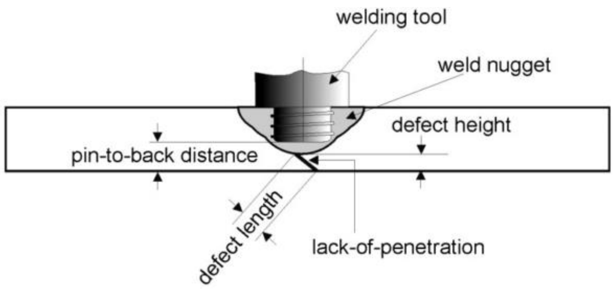


Fig. 3. Schematic of Butt joint

Above Fig. 3. Showing schematic representation of butt joint with lack of penetration. *Mandache* and *D. Levesque* has done Liquid penetration test and obtained that lake of penetration occurs till some length of specimen then it disappears.[9] Penetration defect observed till base metal not mixes up in nugget zone. Where some research papers also focused on diameter of pin. As much pin diameter that much stirring effect better but up to certain level pin diameter increment or decrement is good for joint. However tool pin's length leaves that side of exit hole during withdraw of tool. To overcome that problem researcher has used scroll tool in which pin detachable. *Y. Tozaki* has investigated on newly developed tool and its effect on FSW. A newly developed tool for friction stir spot welding (FSSW) has been proposed, which has no probe, but a scroll groove on its shoulder surface (scroll tool). By use of this tool, FSSW was performed on aluminium alloy 6061-T4 sheets.

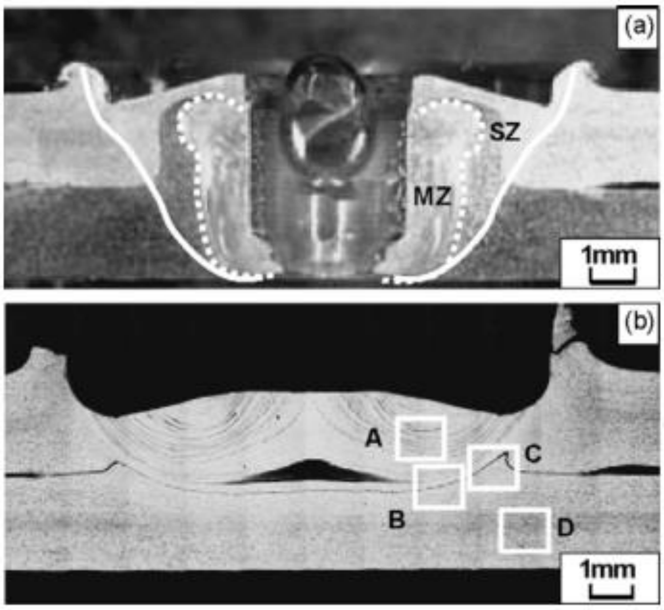


Fig. 4. Images of Scroll tool and Probe tool

The experimental observations showed that the scroll tool had comparable or superior performance to a conventional probe tool. Above fig 4(a). Showed that probe tool forming SZ and MZ where in fig 4(b) shows scroll tool view. It was confirmed that sound welding could be achieved without a probe hole, in which the scroll groove played significant roles in the stirring of the material and the shoulder plunge depth was the important processing variable.[10] Friction stir welding tool having different pin's length gives different results. *A.K Patel* showed that Axial force is directly responsible for the plunge depth of the tool pin into the work piece and load characteristics associated with linear friction stir weld during his research on AA8011 sheet using threaded tapper tool pin made of high carbon steel H-13.[11]

## V. Conclusion

To improve efficiency of obtained joint it must to optimize all parameters affecting joint. Above all researchers given results and conclusion on the bases of their research methodology and proved that optimum joint efficiency can be obtained by controlling parameters effecting tool pin's depth of penetration. Following conclusions can be derived.

Depth of penetration decides that how much material will get stirred.

Tool shoulder of friction welding tool helps to increase the heat produced during stirring effect. The ratio of tool pin diameter to pin shoulder diameter generally set to 2.5.

Gradually increment in axial force increases depth of penetration. This rule applies where thickness of the sheets to be welded are not much.

Increase of the rotational speed decreases the penetration depth; the increase of the travelling speed has a negligible effect on the penetration depth compared to the influence of the rotational speed.

Effect of feed speed directly impacts on depth of penetration, if feed speed is higher than penetration causes tunneling defects (in case of square tool pin profile), similarly lower feed speed causes increased TMAZ (Thermo Mechanically Heat Affected Zone), hence optimum feed speed and spindle rotation gives better joint.

From microstructure point of view during penetration of tool into base material decides characteristics of joint.

Increase in shoulder penetration increases in tensile strength up to certain level.

Depth of penetration plays different roles in lap joint and butt joint, it depends upon thickness of material. More penetration leads to decreased tensile strength of FSW joint.

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