International Journal of Thermal Technologies
E-ISSN 2277 – 4114
Available at http://inpressco.com/category/ijtt/


*Research Article*

# Investigation on the Tensile Strength of the Friction Stir Welded similar joint of Al/Al alloy using high thermal diffusivity backing plate material

**Akshansh Mishra[#]*, Abhishek Kumar Sharma[^], Hardik Kapoor[^], Jaspreet Singh[^] and Krishna Kumar[^]**

[#]Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattangulathur, India
[^]Department of Mechanical Engineering, Inderprastha Engineering College, Ghaziabad, India

Received 15 April 2018, Accepted 30 May 2018, Available online 01 June 2018, **Vol.8, No.2 (June 2018)**

### Abstract

*Friction Stir Welding process is a novel green solid state joining process for soft materials such as aluminium alloys. The weld quality is governed by the proper selection of parameters such as forge force rotational speed of the tool, welding speed, backing plate material etc. Thermal boundary condition at the bottom of the work piece plays an important role for obtaining the sound joint. The backing plate material governs these thermal conditions. In this case study, high thermal diffusivity backing plate material which consisted of AA2099 was used for joining of the plates of Structural Aluminium alloy. It was observed that the tensile strength was improved.*

**Keywords:** *Friction Stir Welding; Magnesium alloy; Backing plate; Tensile Strength*

## 1. Introduction

The friction stir welding (FSW) method is widely considered to be one of the most significant developments in joining technology to emerge in the last 30 years. The technique has originally been developed for joining difficult-to-fusion-weld Al-alloys, particularly for high strength grades and now widely used in various industrial applications, such as transport industries. On the other hand, the application of FSW to high temperature materials such as steels is hindered due to the problems associated with the stirring tools although there is a wide interest for the application of this technique to these materials.

The pin tool generates heat through friction and plastic strain energy release during mechanical deformation of the workpiece, which softens the material to be welded. Once the shoulder of the tool is in contact with the material, it is generally hot enough have reached the plastic region, and the tool begins to traverse along the joint line. The material in front of the tool is then extruded around the pin where it is deposited behind the pin and forged into a solid-state joint.

The tool follows the joint line, taking the material from in front of the tool, and mechanically mixes it together to form a joint. It is important that sufficient down force is applied to maintain shoulder contact with the material, since the shoulder contact is a critical component of the forging action that happens behind the tool.

In Friction Stir Welding process there are two types of material flow i.e. "pin driven flow" and "shoulder driven flow". Tool pin profile plays an important role during Friction Stir Welding process. Tool pin is inserted into the work piece and it is a given a rotation which plasticizes the material at the given joint. The depth of tool pin is slightly shorter than the thickness of the alloy plate. The heat is generated during Friction Stir Welding due to mechanical working of the welding tool.

The majority of the material flow in these joints is longitudinal with the weld; however, vertical material flow can also take place under "hot" processing conditions (slow feed rate with high spindle rotation speed) and is aided through different pin tool geometries such as the addition of threads to the pin.

In this research AA6082 plates were used which belongs to 6XXX grade of Aluminium alloys. AA6082 is also known as a structural alloy, it has replaced AA6061 in many applications field due to its higher strength. AA 6082 is widely used in Trusses, transport applications and high stress applications. The chemical composition of AA6082 is shown in Table 1.

**Table 1**: Chemical composition (wt %) of AA6082

| Composition | Al | Si | Fe | Cu | Mn | Cr | Mg | Zn | Ti |
|---|---|---|---|---|---|---|---|---|---|
| Weight % | Bal | 0.7 | 0.5 | 0.1 | 0.4 | 0.2 | 0.06 | 0.2 | 0.5 |

*Corresponding author's ORCID ID: 0000-0003-4939-359X
DOI: https://doi.org/10.14741/ijtt/v.8.2.1

## 2. Role of backing plate material

During Friction Stir Welding process, the main reason for defect formation in stir zone is generally due to a small tool shoulder diameter which leads to formation of insufficient heat generation and flow of plasticized materials due to small contact area. For carrying out a proper Friction Stir Welding process, the material diffusivity of backing plate material is an important factor.

Materials such as mild steel, stainless steel, aluminium alloys, pure copper, medium carbon steel etc. can be used as a backing plate.

The high thermal diffusivity materials such as pure copper, aluminium alloy results in increased heat extraction rate. While lower thermal diffusivity materials such as asbestos, ceramic floor tile, granite etc. result lower heat transfer rate.

Many case studies have been done on composite backing plate material also. In this arrangement low diffusivity backing plate (LDBP) material is placed below stir zone and high diffusivity back plate (HDBP) material below heat affected zones. Base metal maintains sufficient high temperature in the stir zone and at the same time enhances the cooling rate at HAZs thus there is a decrease in the time at temperature for precipitation coarsening and hence improves HAZs minimum hardness.

P. Upadhyay et al. (2015), studied effect of different back plates such as ceramic, AL6XN, steel, aluminium on friction stir welded AA6056 and AA6061. Low thermal diffusivity back plate such as ceramic,Ti-6Al-4V results in homogeneous temperature distribution throughout the thickness due to which weld properties i.e., grain size and hardness were homogenized compared with high diffusivity back plates such as aluminium.

Back plate has significant effect on the forge force which is another important process parameter of friction stir welding. As heat transfer from the workpiece via the back plate increases the optimum forge force also increases. It is clear that substantial changes in process response can be brought about by changes in either forge force, backing plate diffusivity or both while keeping other process parameters constant such as welding speed, rotational speed (P. Upadhyay et al. (2012)).

P. Upadhyay et al., (2014) measured temperature difference between mid-plane and at the root side of the weld i.e., along thickness direction of 25 mm thick AA6061. Stable temperature was obtained at both the locations for ceramic back plate while for aluminium back plate root temperature was 450 degree celsius lesser than mid plane temperature. This indicates that back plate has significant effect at the root side than mid plane portion. For insulating ceramic back plate the grain size at the root and mid plane are same due to the temperature homogeneity, for aluminium back plate the grain size at the root side is half of that at the mid plane due to the high heat extraction at the root side. Therefore, in case of aluminium there is a large drop in hardness from value of 100 HV at the mid plane to 80 HV near the root.

The aluminium back plate showed better tensile strength compared to two types of composite back plates. This may be due to the greater heat dissipation from the bottom of workpiece (Zhang et al. (2013)). Nugget zones (NZs) are different under different back plates i.e., granite, steel and copper for AA2024-T3. A basin shaped defect free nugget zone was obtained under the steel back plate. The root flaw and void defect was present in the weld owing to insufficient heat input and plastic metal flow when copper back plate of high thermal diffusivity was used.

Under low diffusivity back plate like granite, the interface between stir zone and heat affected zone disappears at the retreating side which demonstrates that the full recrystallization occurs at the thermo mechanically affected zone of retreating side and thus heat input is sufficient. Joints obtained under the granite and steel back plates have fractured in heat affected zone (HAZ) adjacent to thermo mechanically affected zone (TMAZ) on the advancing side. The reason for is that a sharper NZ/TMAZ interface exist on the advancing side in contrast to retreating side. Ultimate tensile strength (UTS) firstly increases with increasing the back plate diffusivity and then decreases to low level due to the existence of void defect at the nugget zone of advancing side. Zhang et al., (2014), improved mechanical properties of friction stir welded AA2024-T3 joints by varying width of low diffusivity back plate i.e., medium carbon steel below stir zone. In case of AA2024-T3 GPB zones and fine S phase precipitates results in higher hardness for which higher cooling rate is required.

## 3. Materials and methods

In this case study, AA 6082-T6 plates of dimensions 200 mm X 80 mm X 4mm were used. Firstly, the surfaces of the plates were machined to remove the irregularities and roughness. Any presence of irregularities and non - smooth surfaces results poor qualities of joints. The material used for fabrication of weld tool was SS 304. The selection of tool material is done in such a way that it possesses more hardness value than the material to be welded. The arrangements of the plates to be welded were placed on the backing plate material as shown in the Figure 1l. The plates were mounted on the fixture in a proper orientation as show in the Figure 2. The design of fixture plays an important role while carrying out Friction Stir Welding process . Thirdly, the welding tool pin was plunged deep into the faying surface of the two respective plates until there is contact between tool shoulder and the upper surface of work piece. The angle between the tool to work piece was 2.5 degree from the vertical axis in all welds.

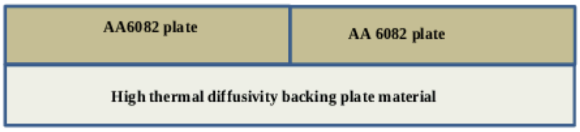


**Figure 1:** Arrangement of plates to be welded using FSW process

**Figure 2:** Plates butt welded on the fixture

In order to obtain the sound weld joint, the tool profile should be designed in such a manner that it results less formation of flashes and less chips formation as shown in the Figure 2.

## 3. Tensile Testing

The tensile test was carried out on Universal Testing Machine based on ASTM-B557 to determine the tensile strength of 4 specimens which were welded using different pin profiles. The tensile test specimen of width 19.05 mm and cross sectional area of 158.57 $mm^2$ was prepared.

For Hexagonal tool pin profile as shown in the Table 2 it was observed that it has maximum tensile strength of 82.1 MPa at tool rotational speed of 1200 rpm and traverse speed of 42 mm/min.The backing plate used in this was stainless steel. In the second test the backing plate material was changed to AA2099 of 4mm thickness. Under the same parameters, two similar plates were Friction Stir Welded. After carrying out the tensile strength, it was observed that the it has maximum tensile strength of 100.76 Mpa as shown in the Table 3.

**Table 2**: Tensile test of the specimen obtained by Hexagonal tool pin profile using steel as backing plate

| Tool pin profile | Hexagonal |
|---|---|
| Tool Rotational speed (rpm) | 1200 |
| Traverse speed (mm/min) | 42 |
| Ultimate Tensile Strength (MPa) | 82.1 |

**Table 3**: Tensile test of the specimen obtained by Hexagonal tool pin profile using AA2099l as backing plate

| Tool pin profile | Hexagonal |
|---|---|
| Tool Rotational speed (rpm) | 1200 |
| Traverse speed (mm/min) | 42 |
| Ultimate Tensile Strength (MPa) | 100.76 |

So it is observed that there is 22.74% increase in strength is attained by the use of high diffusivity aluminium back plate as compared to steel back plate with moderate thermal diffusivity. The elongation of welded joints also significantly increased with the use of aluminium back plate.

The future scope of this research is to study the corrosion properties of the welded joints. . Many times welded joints are used in the marine structures, ship building industry etc. Welded joints must withstand with corrosive environment for several years. If welded joint has poor corrosion resistance than corrosion will make changes in microstructure which finally deteriorates the mechanical properties of joint and causes joint failure. It is necessary to study experimentally the effect of back plate on corrosion resistance of joints as well so as to determine which back plate results in excellent corrosion resistance of joints which is not systematically studied yet.

## Conclusions

From this case study, it is seen that the high diffusivity back plate such as aluminium results in improved ultimate tensile strength and % elongation as compared to low and moderate diffusivity back plate as well as composite back plate. Low diffusivity back plate is suitable to reduce power requirement and to make friction stir welding process more energy efficient. Extremely high thermal diffusivity materials such as copper is not suitable as a back plate because it results in excessive heat extraction rate at bottom of workpiece to be joined and ultimately in the formation of void defect.

## References

P. Upadhyay, A.P.Reynolds (2015), Thermal management in friction stir welding of precipitation-hardened aluminium alloys, Journal of Manufacturing, 67,1022-1031.

P. Upadhyay, A.P.Reynolds (2012), Effects of forge axis force and backing plate boundary condition on FSW of AA6056, Material Science and Engineering, A 558, 394-402.

P. Upadhyay, A.P.Reynolds (2014), Effect of backing plate thermal property on friction stir welding of 25 mm thick AA6061, Metallurgical And Materials Transactions, 45A, 2091-2100.

Z. H. Zhang, W.Y.Li, J.Shen, Y.J.Chao, J.L.Li, Y.E.Ma (2013), Effect of backplate diffusivity on microstructure and mechanical properties of friction stir welded joints, Materials and Design, 50, 551-557

Z. H. Zhang, W.Y.Li, Y.Feng, J.L.Li, Y.J.Chao(2014), Improving mechanical properties of friction stir welded AA2024-T3 joints by using a composite back plate, Material Science and Engineering, A 598, 312-318