  UGC CARE Listed (Group -I) Journal Volume 10, Iss 4, Dec 2021

ANALYSIS ON EFFICIENCY IMPROVEMENT OF JOINTS THROUGH THE USE OF FRICTION PLUG WELDING METHOD

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ABSTRACT

Friction plug welding (FPW) does not require the use of external heat or the joining of molten materials to join two unlike or comparable materials. Because no melting takes place throughout the process, friction welding is more of a fake than a true fusion welding technique. By interpolating heat sources or preheating the work piece surface, joins can be made more effective. The friction coefficient must also be taken into account when calculating the heat flux produced at the mean surface. By adjusting the plug's diameter and watching how the temperature distribution is impacted, one may alter the width of the land. By using mathematical and analytical model formulas, it is possible to determine the impact of pre-heating. The temperature distribution values were calculated for a variety of plug sizes and pre-heating temperatures ranging from 2500C to 5500C. The values were determined even while the work piece was in operation. It was chosen to employ the response surface analysis technique in this study to examine the impact of different factors on the tensile strength of friction plug welding (FPW) joints composed of 6082 aluminium alloy. The temperature field and the force analysis have been used to explain why the joint's root seems to be a weak zone. Why this appearance appeared was explained. The rotating speed was shown to be more important than the upsetting speed and welding duration in influencing the tensile strength of FPW joints.

Keywords*:* Friction stir welding, Friction plug welding, Heat, Friction, Temperature, Hardness, Tensile etc.

I. INTRODUCTION

One of these manufacturing methods is called fractional welding, and it includes the friction between the two materials being fused creating heat. This method is currently in use in businesses all over the world as a reliable and automated welding operation, and it is gaining popularity.

A solid-state joining method called fractional welding causes material to coalesce under the compressive force of rotating work pieces, producing heat and plastic material displacement from rubbing surfaces without the necessity of melting. This method does not need the use of flux filters or metal filters [1].

Friction To weld challenging aluminium alloys of different series, a solid-state method called stir welding is utilised. The absence of melting and resolidification of the metal causes the weld to be porous-free and to bend only slightly. The plates that are to be connected together are brought into contact using a non-consumable spinning tool. Th As heat is produced when the tool is moved in the direction of the joining surface, e joints are formed below the solidus temperature of the materials being joined. The heat generated when the shoulder makes contact with the surface of the plates causes the connecting surface to heat up further.

The shoulder's pin stirs the joining surface, allowing the material on the underside of the pin to flow into the joining surface. As the tool travels through the metal, the metal cools, resulting in the formation of a treated zone. When connecting plates, it is vital to use a tool that is made of a more durable material than the plates that are being linked. As more durable tools are developed, the FSW process is increasingly being used to mix materials that can withstand high temperatures [2].

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Friction plug welding (FPW) is a method of joining two dissimilar or similar materials that does not require the use of external heat or a molten state. Friction welding is more of a forgery than a genuine fusion welding procedure because no melting occurs during the operation. It is possible to increase the efficiency of joints by interpolating heat sources or preheating the work piece surface. In order to calculate the generation of heat flux at the mean surface, the coefficient of friction between two materials must be calculated [3-4]. The breadth of the land can be changed by varying the diameter of the plug and observing how this affects the temperature distribution. Calculating the effect of pre-heating is accomplished through the use of analytical modelling. It was possible to compute the temperature distribution in the work piece for a variety of plug sizes and pre-heating temperatures ranging from 250oC to 550oC.

It is a type of welding in which an incorrectly welded weld material is replaced with a plug, which is then friction welded into the original position. The fundamental rule is depicted in Figure 1 of this document.

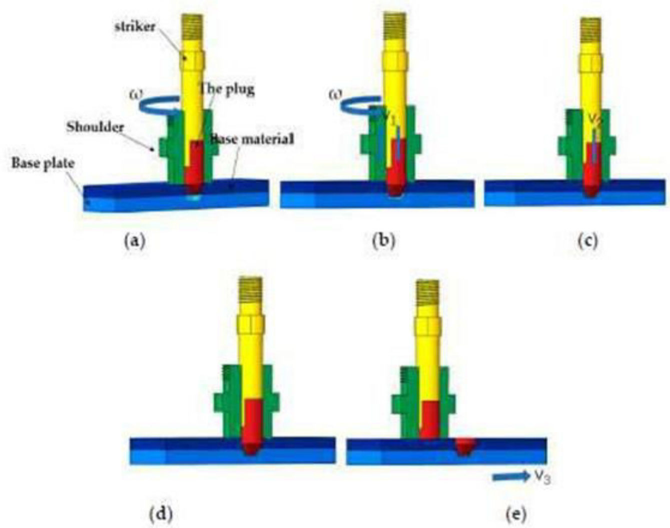


Figure 1: The schematic diagram of the FPW process displays the preheating phase, friction feed phase, upsetting phase, pressure-holding phase, and disengagement phase.

Figure 2a's pre-assembly demonstrates how to make sure that the base material's shoulder and top surface, as well as the plug and hole, continue to be in close contact with one another. To achieve the preheating action, the shoulder and the plug both spin at the same speed.

Friction feed stage: After a period of warming up, the shoulder and plug in Figure 2b start to press down at the same rate. As a result, there is a closer contact between the friction surface, which generates a lot of heat. The shoulder and the plug both stop rotating and moving after a certain degree of displacement.

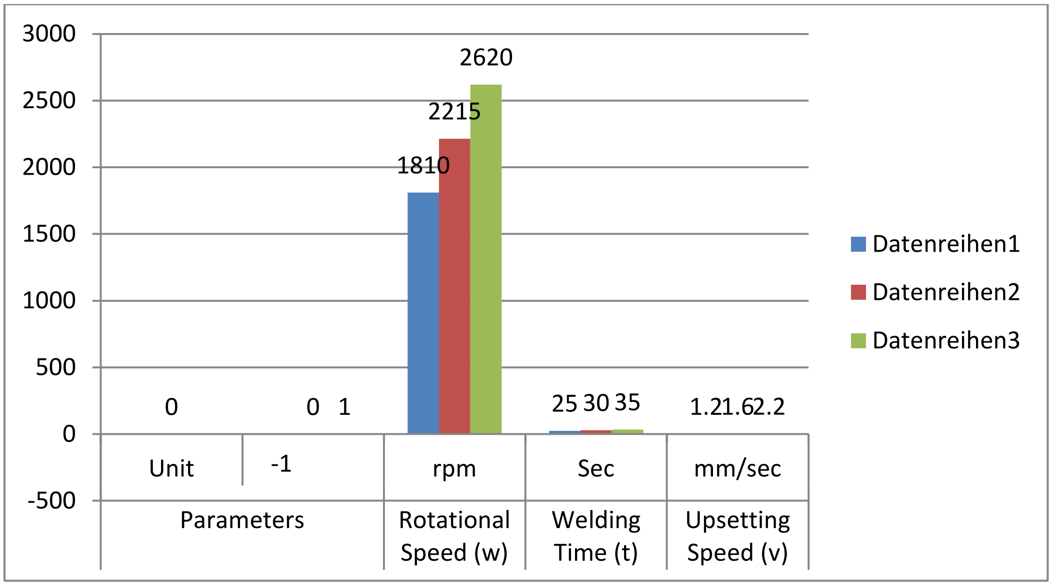
Upsetting stage: The striker instantly pulls the plug down at a predetermined pace while the electric cylinder is running, as shown in Figure 2c, after the shoulder and plug have finished revolving. The cylinder becomes unstable as a result.

Pressure-holding stage: The striker does not instantly retract after being quickly forced down, as shown in Figure 2d, but instead persists for a length of time to guarantee a tight bonding surface interaction.

Departure stage: In order to remove the unnecessary piece of the plug, as shown in Figure 2e, the worktable and plug form a horizontal relative displacement. The shoulder then expedites the removal of the extra stopper material from the workpiece.

The three parameters of the response surface experiment method (rotation speed, welding duration, and upsetting speed) were chosen in the manner shown in Table 3 with three levels for each of the three elements. We determined the optimal welding circumstances, selected two elements that had the largest impact on joint performance, and evaluated the impact of these elements on the formation of the joint.

Figure.2. Coded and actual values of FPW parameters



As previously said, the key technique for FPW is as follows: first, a hole is cut out at the point of interest with the requisite geometrical specifications. Second, under the influence of axial force, a quickly spinning plug is placed into the hole, resulting in rapid frictional heating and defacement at the interface between the hole and the plug, which is most commonly referred to as the welding stage. In order to produce an FPW weld, the plug rotation is abruptly stopped and a moulding force is given to the weld surface after the hole has been completely filled. Finally, remove the stopper and quern the surface on a flat surface to cool.

The friction stir welding process (FPW) is used to correct weld faults in the context of friction stir welding (FSW). If you're looking to weld aluminium alloys, the FPW beats all other welding methods. Improved joint strength, less stress, and less deformation can all aid in the correction of the problem.

FPW is a solid phase welding procedure that includes rapidly spinning a circular plug while applying force to fill a hole in a piece of metal or plastic.

Using a friction plug welding technique to correct defects that may have appeared during the friction stir welding process is one of the recommended approaches for mending flaws that may have appeared during the friction stir welding process. Figure 2 illustrates a schematic representation of the friction plug weld procedure.

When the moving part generates frictional heat at the bottom of the hole, the joining process begins, allowing plasticization to take place at the bottom of the hole. Through the use of a three-dimensional finite element analysis, the heat transmission and thermal phenomena of aluminium FSW were explored. Two welds, one with a lengthy pin and the other with a very short pin, were subjected to close inspection. The heat flow has been estimated, and the boundary condition for FSW has been set in stone.

In this work, friction plug welding of aluminium alloy is taken into consideration for mathematical modelling purposes. When calculating heat flux generation, the frictional heat is taken into consideration. Modifying the pre-heating of materials within a specific range has the effect of altering their temperature profiles on the work piece. In order to compute the temperature distribution for different plug diameters, one-dimensional heat conduction is used.

II. LITERATURE REVIEW

An innovative welding method called friction stir welding (FSW) creates high-quality, inexpensive joints made of aluminium alloy. Evaluating the body of literature that is already accessible on the chosen topic is the first and most important stage in conducting research in any field. To ascertain its viability, Yong-Jai Kwon et al. [1] studied friction stir welding between 5052 aluminium alloy plates with a thickness of 2 mm. The tool rotation speeds varied from 500 to 3000 revolutions per minute, while the traverse speed remained constant at 100 mm per second. The tool was rotated at rates of 1000, 2000, and 3000 rpm to produce weld connections, accordingly. The onion ring structure in the friction-stir-welded zone and the ring structure in the surrounding zone (SZ) were both easily discernible at 500, 1000, and 2000 rpm. Onion rings were found to be affected by the tool's rotational speed. It should be noticed that the SZ gain size is smaller than the base metal gain size, and that it gets smaller as the tool rotation speed gets slower. The study's conclusions indicate that the junction's tensile strength is higher than that of the parent metal. The analysis's findings show that the junction is also less ductile than the parent alloy.

J. Adamowski et al. [3] studied the mechanical properties and microstructural changes in Friction Stir Welds in the AA 6082-T6 using a variety of process parameters. After the welds were tensile tested, it was possible to determine the link between the process parameters. Using an optical microscope, researchers looked at the microstructure of the weld interface and found it to be satisfactory. A measurement was also made of the micro hardness of the final joint. Weld nugget and heat affected zone of the test welds showed signs of hardness loss, however HAZ was shown to be resistant to increased welding speed. This phenomenon was caused by a kinetic and thermal imbalance that existed during the FSW process. The interface between the weld nugget and the TMAZ, which was still under development, showed a longitudinal, volumetric defect. The material's hardness was less than that of the metal utilised in fusion welding. It was discovered that the nugget zone included tunnel (worm hole) flaws.

H.J.LIU et al. [4] found a correlation between the parameters in their analysis of the friction welding characteristics of AA 2017-T351 sheet. The researchers also looked at the weld joints' microstructure. The following figures show the correlation between revolutionary pitch and strength, the relationship between revolutionary pitch and Vickers Hardness, the relationship between revolutionary pitch and fracture site at joints, and the correlation between revolutionary pitch and distance from the weld centre. The results of the hardness and tension tests show that FSW considerably weakens the material's tensile strength and softens it. The presence of the cracks in the joint at the point where the thermodynamically damaged zone meets the weld nugget is confirmed by microscopic inspection.

M.Vural and colleagues [5] evaluated the friction stir welding performance of the EN AW 2024-0 and EN AW 5754-H22 aluminium alloys. Commonly used in the manufacturing sector are these two aluminium alloys. The experiment caused EN AW 2024-0's weld area hardness value to rise by an average of 10 to 40 Hv. A closely packed grain structure in the substance may have formed as a result of recrystallization. On the other hand, recrystallization and the development of a loose grain structure in EN AW 5754-H22 have resulted in a decrease in hardness. Compared to EN AW 5754-H22, EN AW 2024-0 has a welding performance rating of 96.6 percent, whereas EN AW 5754-H22 has a 57 percent welding performance rating. The test results for the weldability of the two different aluminium alloys, EN AW 2024-0 and EN AW 5754-H22, were 66.39 percent and 66.39 percent, respectively. A scanning electron microscope was used to look at the microstructure of the welding zone, but no alterations were found. The distribution of the material's hardness did not significantly change at the weld zones. R. Nandan and colleagues [6] looked at a number of contemporary trends in the FSW process, weldment structure, and material properties at weld joints. The fundamental understanding of the process and its molecular effects was the aim of this research, which it successfully attained. Welding heat generation, heat transmission, and plastic flow, as well as the components of welding tool design, defect development analysis, and the structure and properties of welded materials, are the subjects of more research.

III. FRICTION WELDING PROCESS

The first effective use of this technology was in metal welding, which was originally documented in 1956 by the Russian Federation. This method was previously used to successfully combine thermoplastic polymers. When the parts are resting under a greater axial load, the increased friction between the two sections helps to produce heat and facilitate the joining of the two pieces. Comparable in appearance to the joint created by electrical resistance butt welding is the junction created by this friction welding technique. This friction welding technique [8] does not call for the use of filler metal, shielding gas, or flux. This procedure can be used to weld symmetrical, quickly rotating components like gears in addition to welding cylindrical parts like tube or rod.

Energy based classification

Continuous drive technique is a variation in which power or energy is maintained for a predetermined amount of time from an indefinite duration source [9].

Stored energy

The process variant where the energy for welding is supplied by the kinetic energy stored in a rotating system or fluid storage system [3].

Relative motion based classification

It is a method in which one component is rotated relative to and in contact with the mating face of another component.

Linear oscillation

One component is moved in a linear oscillating motion relative to and in touch with the mating face of another component in this approach.

Angular oscillation

One component is moved in angular oscillating motion along a shared component axis relative to and in contact with the mating face of another component in this approach.

Orbital

This approach includes rotating one component about its own central axis while another component rotates at the same speeds but with its axes displaced [10, 24].

A uses for the friction welding process

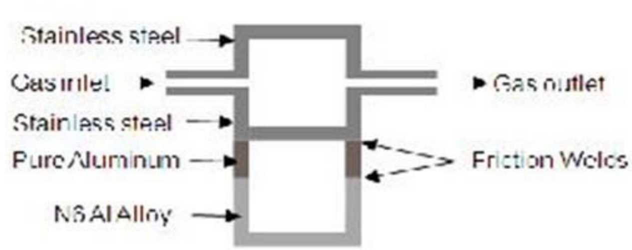


Figure 3: Nuclear Power Plant

Figure 4: Aluminium to SS304 Bi-Metallic Joint

Lack of bonding

As seen in Figure 5, there is insufficient bonding between the faying surfaces in this type of defect.
Low rotating speed, incorrect surface preparation, insufficient heating time, or prolonged friction time are the causes of this. By improving surface preparation and optimising the welding factors, this flaw can be avoided.

a. Within the vicinity of the heat-affected zone or its periphery.
b. At the weld flash transitional area's sharp edges
c. flash weld inside, axial direction
d. On the faying interface inside

As a result of the formation of coarse carbides in these zones, the heat-affected zone or its periphery region cracks. Corrective action is taken to improve carbide quality by preheating the work piece to minimise cooling rates after welding.

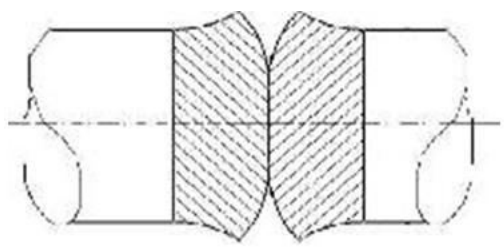


Figure 5: An friction-welded connection that is not bonded As seen in Figure 6, the application of high forging pressure causes fractures along the sharp edge transitional area to weld flash. Consequently, reducing forge pressure and altering weld variables are additional steps in the prevention of this kind of defect.

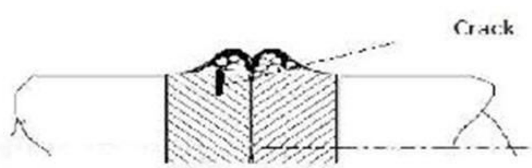


Figure 6: Crack at the point where the sharp edge and weld flash transition

High forge pressure and insufficient high heat output throughout the procedure can both result in cracks inside the weld flash, as seen in Figure 7. By speeding up the rotation and managing the length of the weld cycle,

IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
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enough heat may be produced before the final forge pressure is applied.

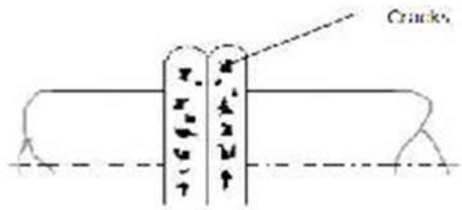

Figure 7: C Internal weld crack flash By regulating the behavior of inter-metallic compounds at the faying surfaces, an internal fracture that developed during the welding of different component materials, as illustrated in Figure 8, may be repaired.

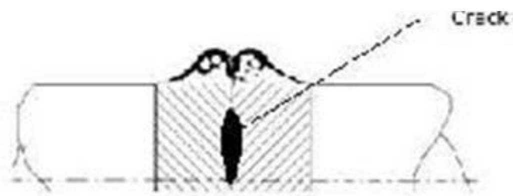

Figure 8: Cracks on the faying interface from the inside

c) Non-metallic inclusion

Figure 9 illustrates a non-metallic inclusion, which is a fault in friction welding caused by solid inclusions of non-metallic forging material in the contact area.

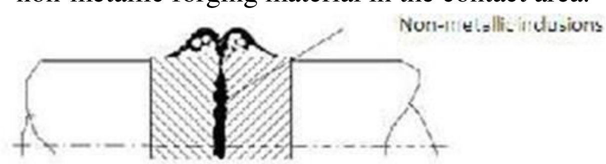

Figure 9: Entrapped nonmetallic impurities between the faying surfaces

Throughout the process of forging, inclusions are trapped. These impurities on the faying surfaces include scale, rust, cutting fluid, drawing grease, and others. These defects may have their origins in the work piece's soiled central bores. Cleaning the forging surfaces and the centre bore will stop this fault [21].

Inter-metallic phase accumulation

Figure 10 illustrates the production and depletion of intermetallic phases with contact area. The main causes of its occurrence are incorrect welding variables and different component materials. Optimisation of welding parameters including rotating speed, cycle time, and forge pressure as well as careful material selection for component selection are examples of preventive methods.

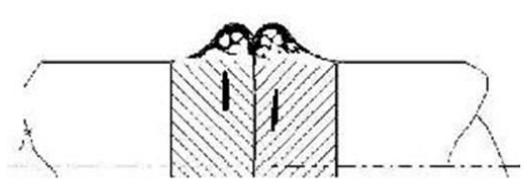

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Figure 10: Inter-metallic phases inside contact

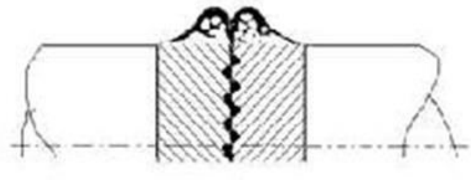

Figure 11: Inter-metallic phases along contact area

The bonding zone along the contact region may also accumulate carbides, oxides, and nitrides, as shown in Figure 11. This is a result of inadequate material preparation. The component material being welded must be more homogeneous, and welding variables must be properly chosen and adjusted to produce the desired weld connection.

CONCLUSION

The influence of welding characteristics on the mechanical properties of the FPW joint was investigated using the response surface analysis technique, and the optimal welding parameters were selected. The researchers used the change in axial force to better understand the development and fault of 6082 aluminium alloy plug welded joints. In this study, the response surface optimisation technique was utilised, and it was determined that the welding parameters had a greater impact on the joint's tensile strength than the other variables ($w > v > t$). The best welding settings were a rotating speed of 2277 rpm, a welding time of 35 seconds, and an upsetting speed of 3 mm/s. The highest tensile strength of the FPW joint was 265 MPa.

REFERENCES

1. Yong-Jai Kwon, Seong-Beom Shim, Dong-Hwan Park, Friction stir welding of 5052 aluminum alloy plates, Trans. Nonferrous Met. Soc.China 19(2009) s23−s27.
2. G.Cao, S.Kou, friction stir welding of 2219 aluminum: behavior of theta (Al2Cu) particles, The Welding Journal, January 2005.
3. P. C. Lin, S. H. Lin, J. Pan, T. Pan, J. M. Nicholson and M. A. Garman, Microstructures and failure mechanisms of spot friction welds in lap-shear specimens of aluminum 6111-T4 sheets, Proc. of SAE World Congress, Detroit, USA (2004).
4. H. J. LIU, H. FUJII, K. NOGI, Friction stir welding characteristics of 2017-T351 aluminum alloy sheet, JOURNAL OF MATERIALS SCIENCE 40 (2005) 3297 – 3299.
5. M. Vural, A. Ogur, G. Cam, C. Ozarpa, On the friction stir welding of Aluminium alloys EN AW 2024-0 and EN AW 5754-H22, Archives of Materials Science and Engineering, Volume 28,Issue 1,January 2007.
6. R. Nandan,T. DebRoy,H.K.D.H.Bhadeshia;Recent Advances in Friction Stir Welding – Process, Weldment Structure and Properties, Progress in Materials Science 53 (2008) 980-1023.
7. P. Thornton, A. Krause and R. Davies, Aluminum spot weld, Weld. J., 75 (1996) 101-108.
8. Li, K.; Liu, X.-M.; Zhao, Y. Research Status and Prospect of Friction Stir Processing Technology. Coatings 2019, 9, 129.
9. Magalhães, V.M.; Leitão, C.; Rodrigues, D. Friction stir welding industrialisation and research status. Sci. Technol. Weld. Join. 2017, 23, 400–409.
10. A. Gean, S. A. Westgate, J. C. Kucza and J. C. Ehrstrom, Static and Fatigue Behavior of Spot-Welded 5182-0 Aluminum Alloy Sheet, Weld. J., 78 (1999) 80-86.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Iss 4, Dec 2021

11. Li,W.; Jiang, D.; Yang, L.; Pan, J.; Qu, R.; Sun, T. Numerical simulation of temperature field and prediction of microstructure in friction hydro pillar processing. J. Mater. Process. Technol. 2018, 252, 370–380.
12. Sun, Y.; Fujii, H.; Sato, Y.; Morisada, Y. Friction stir spot welding of SPCC low carbon steel plates at extremely low welding temperature. J. Mater. Sci. Technol. 2019, 35, 733–741.
13. Hartley Paula, J. Friction plug weld repair of space shuttle external tank. Weld. Metal. Fabric. 2000, 68, 6–8.
14. Metz, D.; Barkey, M.E. Fatigue behavior of friction plug welds in 2195 Al–Li alloy. Int. J. Fatigue 2012, 43, 178–187.
15. Du, B.; Cui, L.; Yang, X.; Wang, D.; Sun, Z. Weakening mechanism and tensile fracture behavior of AA 2219-T87 friction plug welds. Mater. Sci. Eng. A 2017, 693, 129–135.
16. Hynes, N.R.J.; Velu, P.S.; Nithin, A.M. Friction push plug welding in airframe structures using Ti-6Al-4V plug. J. Braz. Soc. Mech. Sci. Eng. 2018, 40, 158.
17. Cui, L.; Yang, X.; Wang, D.; Hou, X.; Cao, J.; Xu, W. Friction taper plug welding for S355 steel in underwater wet conditions: Welding performance, microstructures and mechanical properties. Mater. Sci. Eng. A 2014, 611, 15–28.
18. Du, B.; Yang, X.; Liu, K.; Sun, Z.; Wang, D. Effects of supporting plate hole and welding force on weld formation and mechanical property of friction plug joints for AA2219-T87 friction stir welds. Weld. World 2019, 63, 989–1000.
19. Metz, D.F.;Weishaupt, E.R.; Barkey, M.E.; Fairbee, B.S. A Microstructure and Microhardness Characterization of a Friction PlugWeld in Friction StirWelded 2195 Al-Li. J. Eng. Mater. Technol. 2012, 134, 021005. Metals 2020, 10, 1454 14 of 14.
20. Landell, R.; Kanan, L.F.; Buzzatti, D.; Vicharapu, B.; De, A.; Clarke, T. Material flow during friction hydro-pillar processing. Sci. Technol. Weld. Join. 2019, 25, 228–234.
21. Cui, L.; Yang, X.;Wang, D.; Cao, J.; Xu,W. Experimental study of friction taper plug welding for low alloy structure steel: Welding process, defects, microstructures and mechanical properties. Mater. Des. 2014, 62, 271–281.
22. T. Iwashita, Method and apparatus for joining, US Patent 6,601,751, published 5 August (2003).
23. T. Iwashita, Method and apparatus for joining, EP Patent 1,149,656, published 19 October (2005).
24. H. Badarinarayan, F. Hunt and K. Okamoto, Friction stir welding and processing, in Friction Stir Welding and processing (ed. R.S. Mishra etal, .), ASM International (2007) 235-27