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"Optimization and Microstructural Characterization of Friction Stir Welded Dissimilar Materials": A Review

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Abstract: These days, a wide variety of cutting-edge techniques for joining are accessible in order to meet the requirements of the process problems and to connect the distinct application domains of the industrial sector. Industrial applications in the sectors of autos and aircraft are anticipating the development of procedures that will connect diverse combinations of materials to achieve lightweight and increased performance from engineering designs. This will ensure that current difficult desires are met. In light of the expanding scope of the research, which now includes identifying appropriate material combinations for the purpose of achieving the goal of lower weight and also satisfying application-related characteristics, friction stir welding has emerged as the ideal platform on which to demonstrate fresh forms of material integration.

Friction stir welding (FSW) is kind of solid-state bonding operation, plays vital role in industrial sectors like aerospace, automotive and manufacturing industry. Objective of this paper is to research and analyze the influence of critical parameters through FSW. Hence review based on process-based methodology of different materials like ferrous materials, non-ferrous materials and dissimilar material has been focused. Parameters influencing the operations and their effect on mechanical behavioral in the respective categories of material inter-mixing has been highlighted. Further recommendations indicates that FSW can also be used for effective application in case of polymeric materials.

***Index Terms* – Dissimilar Materials Friction Stir Welding, Microstructure, Tensile Strength, Hardness**

I. Introduction

Materials, particularly materials, find their implementation across a wide range of sectors during the early days of civilization and the advent of small and medium-scale enterprises in order to meet the expanding industrial demands. All mechanically embedded processes, including manufacturing, fabrication, and joining procedures, rely heavily on engineering materials. The experimentally oriented procedure can be carried out by selecting appropriate components based on their structures and behavioral qualities. The hunt for composite materials with desirable qualities that are tailored to specific industries is proceeding at a breakneck pace. The majority of commercially accessible materials, such as steel, continue to encompass a diverse array of structural approaches. However, there is currently a growing focus on process operations aimed at the development of lightweight components that are both effective and cost-efficient.Rising fuel prices as well as tightened automotive regulations engulfs the automobile manufacture ring unit to develop low fuel consumption engines and lightweight parts. One technical approach to achieve weight reduction in automotive components is replacing traditional materials, such as steels, with lighter alternatives, such as light metals and polymers.

Still, there is a lack of expertise in building dependable and cost-effective structures across industries. This is especially true with hybrid structures, which often combine materials with drastically different characteristics, such as metals and thermoplastics. To improve the process parameters and the mechanical qualities, steels have been substituted by newer combinations of materials. Plastic's low weight, high specific strength and elastic modulus, design flexibility, and lower production costs have led to growing use of the material in engineering constructions.[1]

The conventional welding process involves the connecting of metal to metal, metal to dissimilar materials, and the fabrication of various weld ments. Conventional welding exhibits certain advantageous characteristics such as practical performance and robust bonding capabilities. Nevertheless, these advancements also gave rise to some significant disadvantages, such as the emission of dangerous radiations, fumes, and vapors, as well as the potential distortion of the workpiece.

The researchers were motivated to concentrate their efforts on the development of a novel and emerging technique known as Friction Stir Welding (FSW) due to the influence of these factors. The propensity for this performance inclination can be extended to a wide range of materials, encompassing both ferrous and non-ferrous materials, contingent upon the specific requirements of the experimental and application domains. This paper aims to examine recent research on the application of friction stir welding in combining similar and different materials, and to suggest areas that require further exploration.

1.1 Friction Stir Welding:

Friction stir welding is a technique employed to fuse metallic components together without reaching the point of melting. The invention can be attributed to Wayne Thomas, who developed it at TWI. The initial patent applications were filed in the United Kingdom in December 1991. The heating process is facilitated by the frictional interaction between the tool and the workpiece. The plastic deformation of workpieces results in the preservation of a cohesive connection beyond the tool interface. The production of workpieces results in the joining of materials beyond the tool interface. The use of localized heating induces a softening effect on the material surrounding the pin, facilitating the rotation and translation of the tool assembly. This movement results in the displacement of material from the front to the rear of the pin. As a result, a cohesive bond will be established in the solid state.[2]

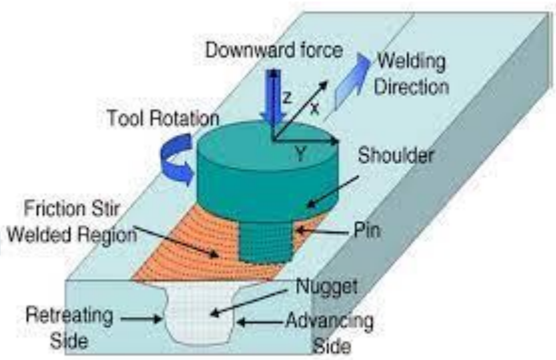


Figure 1 Illustration of friction stir welding process[3].

II. LITERATURE SURVEY

Based on FSW process, research findings of various materials and their combinations, process parameters selected for experimental investigations were highlighted in the literature survey. This section focuses on following aspects with respect to Friction stir welding of:

A. Ferrous Materials.
B. Non-Ferrous Materials.
C. Dissimilar Material Combinations.

A. Friction Stir Welding of Ferrous Materials.

Saman Karami et al[4] This research examined the effects of friction stir welding on the microstructural characteristics and welding parameters of austenitic stainless steel. The macroscopic investigation revealed the presence of flaky surfaces in the weld ments of the samples. The observed phenomenon of an increase in transverse speed leading to a decrease in heat input, and an increase in welding speeds resulting in a decrease in the time required for the pin and workpiece to associate, has been documented. The present study examines the microstructural aspects of base metals, specifically focusing on the phase transformation of austenite to ferrite and partite structures, as well as the presence of austenite phase in the heat affected zone. Tensile test for specimens signalled that lager magnitude of yield strength and slighter amount of uniformed elongation in comparison with parent material.

R. Ramesh and colleagues [5] The study is centered around the application of the Friction Stir Welding (FSW) process to High Strength Low Alloy Steel (HSLA).Several flaws were observed due to a decrease in heat input and inadequate stirring.The increase in welding speed leads to a reduction in the quantity of upper bainite. The microstructure of the weld nugget has been determined to include the presence of ferrite and pearlite phases. Significant enhancement in the microstructure of the base metal was observed within the weld nugget zone.The results of the tensile strength test indicated that the joint efficiency reached its highest value when the traverse speed was set at 77mm/min.

B. Frictions stir welding of non-ferrous materials.

Friction stir welded copper joints had their properties examined by **Pankaj kumar and Satpal Singh[6].** The experimentation used a full factorial design matrix, with rotational speed, tool travel speed, and tool material all serving as independent variables. Welded specimens have tensile strengths between 62 and 112 MPa. The average tensile strength increases with increasing rotational speed, reaching 95 MPa at 5000 rpm. The tensile strength falls as the traversal speed increases because less heat is created at any given point of contact.

Lenin and Dharmalingam[7] showed how friction stir welding might be used to attach the copper plates in a variety of ways. The welding speed of 19 mm/min produced weld joints with higher tensile strengths than the starting material. At a rate of 19 mm/min, the ultimate tensile strength was measured at 256.9 MPa.The toughness of the weld nugget was maximized at welding speeds on the side that was retreating.At a rotating speed of 635 rpm and a travel speed of 19 mm/min, a defect-free weld junction was produced.

The authors of this study are **Sreenivas P and Sreejith P S [8].**The metrics and microstructural examination of the AA 2219 alloy were analyzed. The welds produced by the threaded pin profile demonstrated the highest levels of tensile strength and microhardness.In instance of AA2219 alloys, Al2Cu precipitates were discovered as the second phase particles in the nugget zone.The findings from SEM and EDS examination indicate that the formation of Al2Cu particles was more pronounced in the welds produced using the threaded pin profile.

C. Friction stir welding of dissimilar material combinations.

N.F.M. Selamatet al [9] Investigated the aluminum alloys of series AA5083-AA6061 subjected to FSW. Visionary inspection appeared that weld surfaces of dissimilar joints of AA5083-AA6061 was polished because of sufficient heat input supplied .Macrostructure on the cross sections of the variant joints had contrasting colours because of various reactions to chemical reagent after etching and no defects were formed. AA6061-AA5083 showed decreased micro-hardness value ranging starting with 80HV to 35HV caused by the mechanical effects of AA6061 showed on retreating sides. Tensile strength was found at 113MPa. for AA6061-AA5083

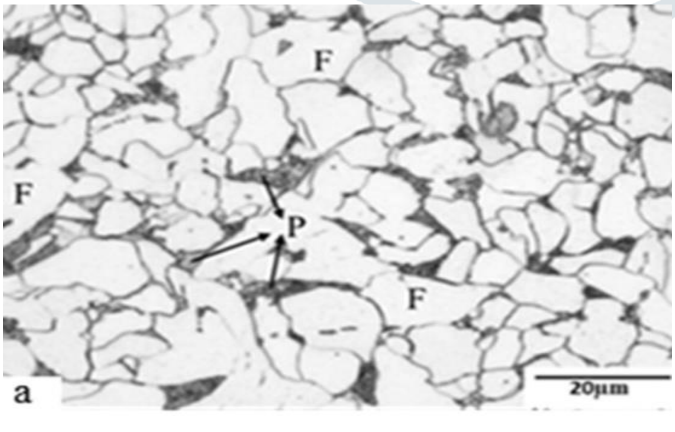
.**S. Thirumavalavanet al [10]**Studied friction stir welding of aluminum –scilicon alloy (Al-Mg-Si alloy).Taper cylindrical threaded pin of refined 3 – 4 mm of size near to weld nugget. Fine refinement of grains around the weld nugget indicating that taper cylindrical threaded pin yielded preferable welds on comparison with the rest of the profiles. In case of tensile test, pins with threaded profile have superior tensile characteristics with respect to the unthreaded pins. Taper cylindrical threaded pin profile gave better elongation characteristics of 14.867%.Micro-Vickers test justifies that welds made up of taper threaded pin of cylindrical profile has hardness value of 68.71 VHN.

Hassan Abd El-Hafez, Abla El-Megharbel [11]Aluminum alloys of series AA2024-T365 and AA5083-H111 were welded. Optical inspection of the specimens involving defects such as tunnel and voids at the region of welded zone. Tensile strength was notable at welding speed of 80 mm/min. Microstructures noticed that the stirring behaviour as well as the blending of alloys varied from one specimen to another. In the stirring zone profile shape of square pin generates better strength because of pulsed nature that produced good metal flow, as a result of effective stirring. **Yudhviret al [12].**Rotation speed, traverse speed and tool tilt angle were selected for analysis using cause and effect diagram .Results showed that tests for Tensile strength yielded from 0.141kN/mm^2 to 0.091kN/mm^2. Rockwell Hardness variation is from 62 HRC to 27 HRC. It was noticed that Tool rotational speed contributed significantly on comparison to all the parameters.

III. MICRO STRUCTURES AND MECHANICAL CHARACTERISATION

3.1 Ferrous Materials

3.1.1Mild Steel: The comparison of Figure 3.2 reveals that the fractional area of the heat-affected zone (HAZ) in sample 1 is greater than that in sample 2. This suggests that an increase in rotation speed can lead to a higher heat input, resulting in an increase in the fractional area of the HAZ. The limitation of the heat-affected zone (HAZ) region can be achieved by increasing the welding speed and decreasing the rotating speed. The microstructure of the base metal was observed to comprise of equiaxed ferrite phase with a certain grain size, as depicted in Figure 3.1. Additionally, pearlite was also present in the microstructure. The region of grain refining in the heat affected zone is located in close proximity to the stir zone. At this time, the temperature reaches the single phase austenitic range, as depicted in Figure 3.3.During the cooling process, the comparatively large austenite grains undergo a transformation into smaller ferrite and pearlite structures. Flaky surfaces were seen in the weldments through macroscopic investigation, as depicted in Figure 3.4.



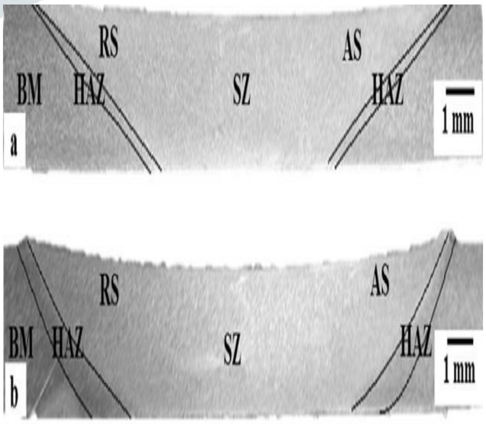
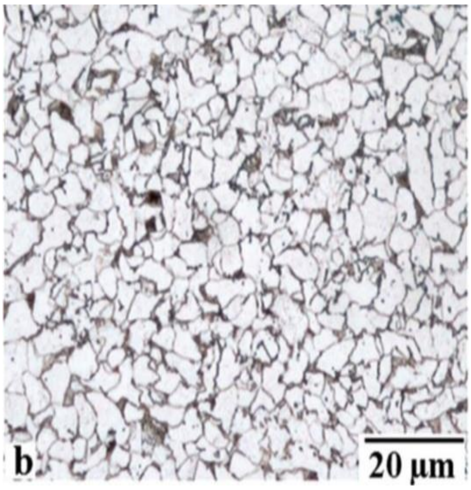


Fig3.1**:**micrograph of the base metal[4] Fig 3.2:micrograph of a transverse section



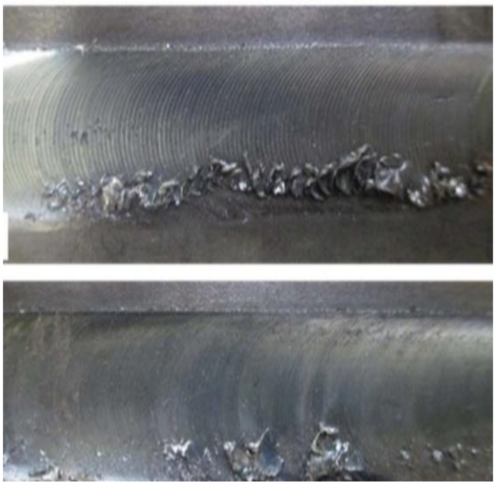
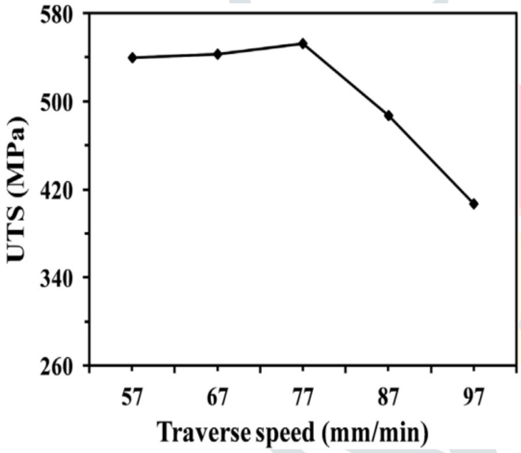


Fig 3.3:Optical micrographs of HAZ regions [4] Fig 3.4:Image of the weld bead- flaky surfaces [4]

3.1.2 High strength low alloy steel: Tensile strength test suggested that a maximum joint efficiency with respect to traverse speeds as shown in fig3.5. The average grain size reduced with an increase in traverse speed as mentioned in the fig 3.6. Microstructure of the base metal is significantly refined in the weld nugget. The microstructure of all the weld nuggets is not same which suggests that the welding conditions greatly influenced the resultant microstructure subsequent to welding. Weld nugget confirmed the presence of two major stages namely ferrite and pearlite as shown in fig 3.7. It is evident from fig 3.7 that, weld nugget microstructure is composed of upper bainite and fine ferrite.



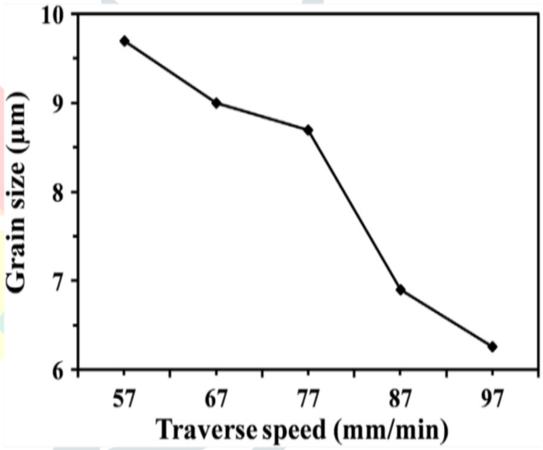


Fig 3.5: Effect of traverse speed on tensile strength[5]Fig 3.6:Effect of traverse speed on grain size [5]

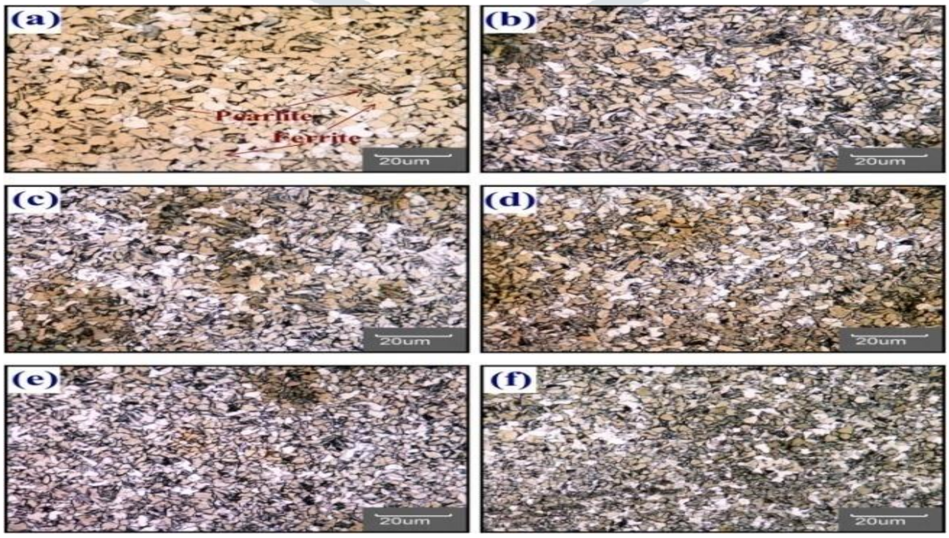


Fig3.7**:**Optical macrograph at various traverse speeds [5]

3.2 Non-Ferrous Materials:

3.2.1 Copper

Rotational speed of tool shows its influence on tensile; higher rpm gives better tensile strength as shown in fig 3.8. Increasing traverse speed, contact time decreases leading to reduced heat generation at that specific point and lower the tensile strength.

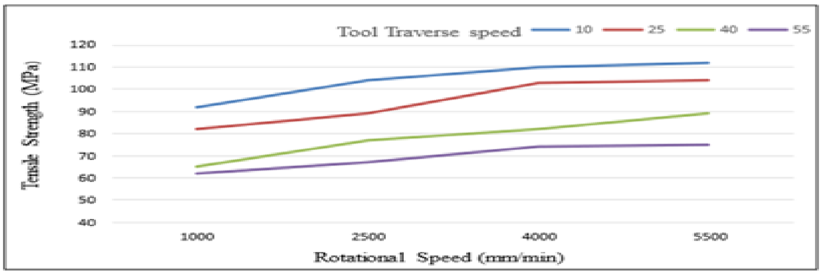


Fig 3.8: Tensile behavior of FSW joints for varying rotational speed with different travel speed [6]

3.2.2 Copper

The microstructure of the weld nugget has a significantly refined composition, characterized by a grain size measuring around 11 microns, as illustrated in Figure 3.9. The TMAZ zone is characterized by a fine-grained structure, while also being susceptible to plastic deformation and the influence of temperature. The weld structure observed in the Heat Affected Zone (HAZ) closely resembles that of the base material, as depicted in Figure 3.9, suggesting a successful and efficient welding process.It is important to acknowledge that the grain size in the heat-affected zone (HAZ) of the retreating side (RS) component is the biggest. The figure 4 demonstrates that the hardness of the weld nugget formed at lower welding speeds was observed to be higher compared to the hardness of the weld nugget formed at higher welding speeds. Defect free welds were obtained as shown in fig 4.1.

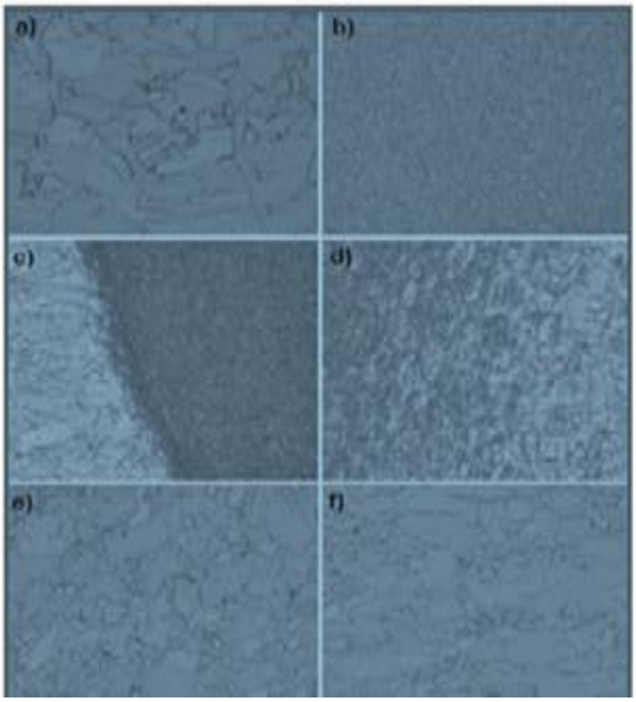


Fig 3.9:Microstructure of a) base metal, b) nugget zone, c) TMAZ of TMAZ, d) TMAZ of RS, e) HAZ of AS of f) HAZ of RS[7]

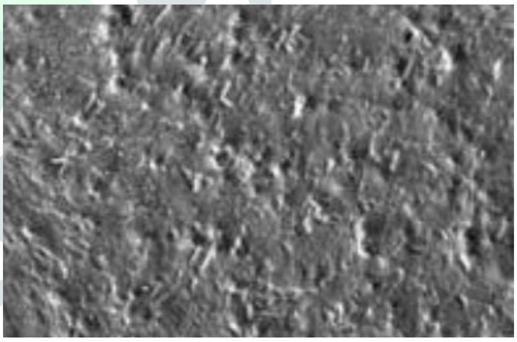
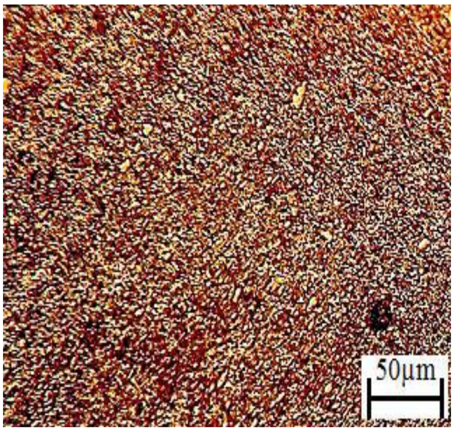


Fig 4.: Defect free weld at 19 mm/min welding speed [7]

3.2.3 Aluminum alloy 2219 (AA 2219)

In comparison to the taper pin profile, the interface region of the thermo mechanically affected zone (TMAZ) and the nugget zone (NZ) in the welds produced by the threaded and straight cylindrical profiles exhibited disoriented grains. This was observed even though the grains looked to be finer due to fragmentation, as depicted in Optical micrographs figures 4.2 and 4.3.The Nugget Zone of the threaded pin profile exhibited distinctive features, including boundary misorientation of grains and a higher proportion of finer grains in comparison to the other pin profiles. This observation is supported by the optical micrograph presented in Figure 4.4. The weld that was created utilizing the threaded pin profile demonstrated the highest level of hardness. The welds produced by the threaded pin profile exhibited the highest level of tensile strength, as illustrated in Figure 4.5.



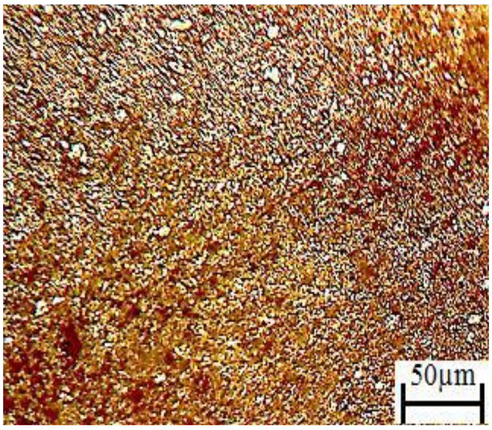
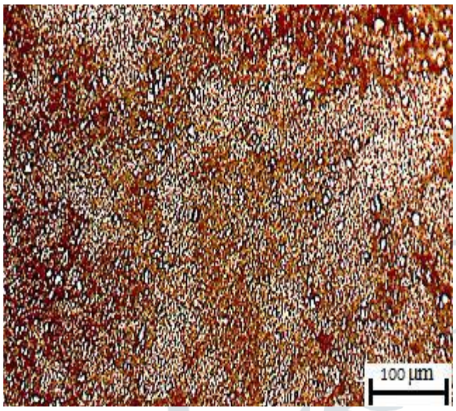


Fig 4.2: Interface zone, Threaded pin profile [8] Fig 4.3: Interface zone, cylindrical pin profile [8]



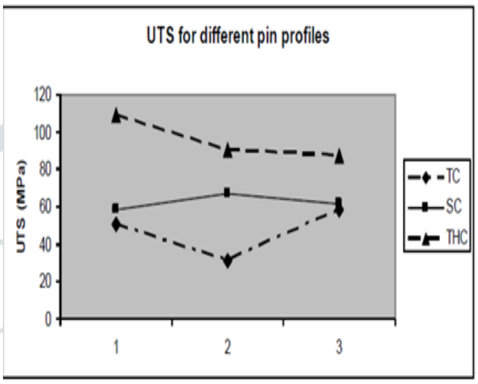


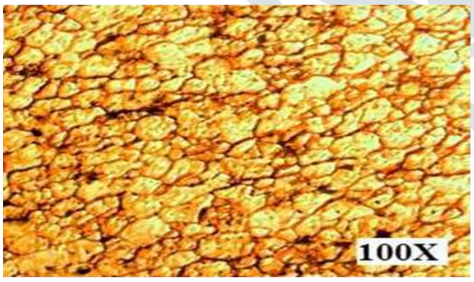
Fig 4.4:Optical micrograph of Nugget zone–Threaded pin [8]

Fig 4.5: Tensile Strength for different pin profiles [8]

3.3 Dissimilar Materials:

3.3.1 Aluminum Alloys (AA5083 - AA6061)

The grain size of the base material is reduced to a great extent due to elevated temperatures and extensive plastic deformation caused by the stirring action of the tool probe. The joint created with a square pin profiled tool achieved an optimal tensile strength of 173.84MPa. As the rotational speed increases, there is a corresponding decrease in the hardness of the weld ments. The microstructure exhibits a higher degree of grain refinement under optimal welding circumstances, as depicted in Figure 4.6.The properties of specimens that have been exposed to certain parameters are depicted in Figure 4.7.



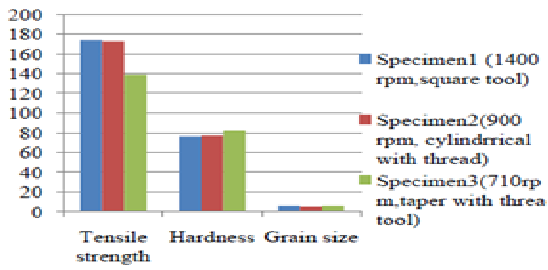


Fig4.6: Micro structure of circular with threaded Probe tool [9]

Fig4.7:EvaluationProperties[9]

3.3.2 Aluminum –Silicon Alloy

Taper cylindrical threaded pin has given better weld and improved tensile characteristics of 0.182kN/mm2as shown in fig 4.8 and 4.9 accordingly. The weld composed of a simple cylindrical threaded pin exhibits a higher hardness value. The taper cylindrical threaded pin leads to a more precise refinement of the weld nugget, resulting in a finer grain size of 3-4 m.

Fig 4.8: Welds Obtained using various Pin Profiles [10]

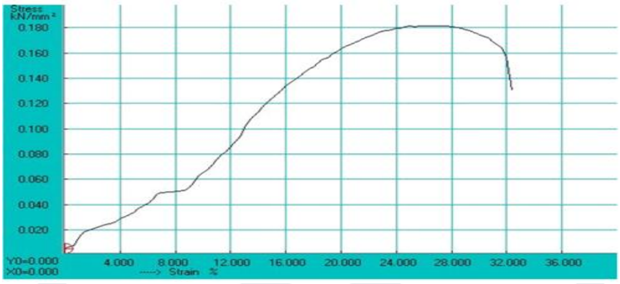


Fig 4.9: Stress vs. Strain curve for Taper Cylindrical Threaded Pin Weld [10]

3.3.3 Aluminum Alloys (AA2024-T365 and AA5083-H111)

Observation with the naked eyerevealed that there were problems in the weld region, such as tunnels and voids, as can be shown in figure 5.As can be seen in figure 5, the behavior of stirring as well as the mixing of dissimilar alloys differs from one specimen to the next. This is something that may be observed.1. The best strength was achieved at 1120 revolutions per minute of rotating speed in addition to 1400 revolutions per minute and 80 millimeters per minute, as illustrated in figure 5.2. A square pin profile provides leading strength because of its pulsed action, which results in good metal flow and, as a consequence, good stirring.

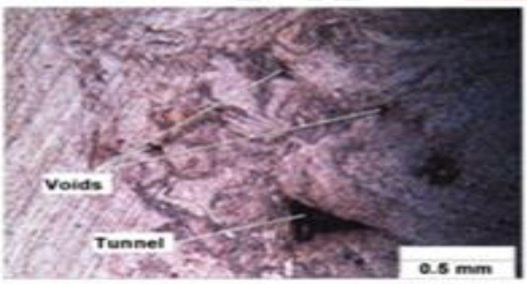


Fig 5: Micrographs forSome Welding Defects [11]

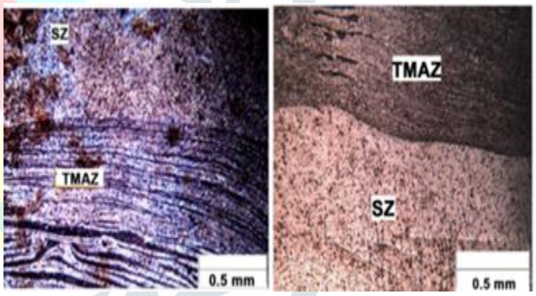


Fig 5.1:Microstructure oftheSZ/TMAZ at Various Speeds [11]

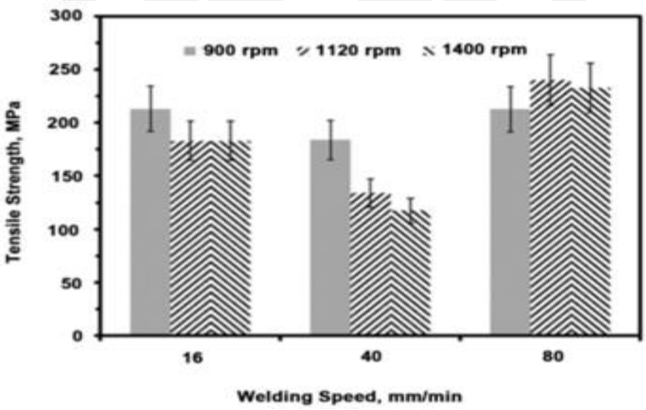


Fig 5.2: Effect of Rotational and Welding Speeds [11]

3.3.4 Aluminum Alloys (AA8011 and AA3003)

The two properties under consideration are tensile strength and hardness. The values were acquired within an optimal range of 0.141 kilo newtons per square milli meter to 0.091 kilonewtons per square millimeter and 62 Rockwell C hardness to 27 Rockwell C hardness, correspondingly. The response variable is subject to various influences from control factors. Figure 5.3 illustrates the signal-to-noise ratio (S/N ratio) and mean values pertaining to the tensile strength. Based on the optimization of findings, it can be inferred that a welding speed of 60mm/min yields a more favorable value for tensile strength. Figure 5.4 illustrates the signal-to-noise ratio (S/N ratio) and the means for hardness.

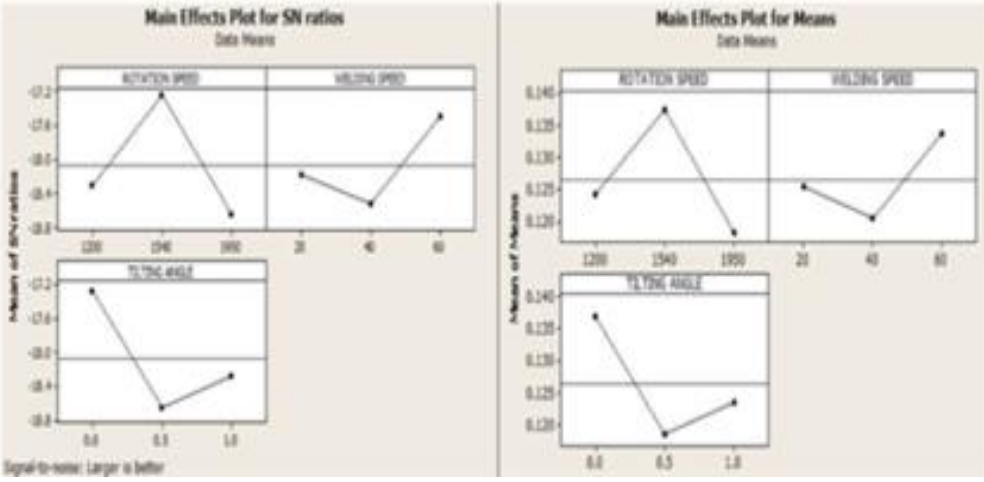


Fig 5.3: Analysis of S/N ratio and Means for Tensile Strength [12]

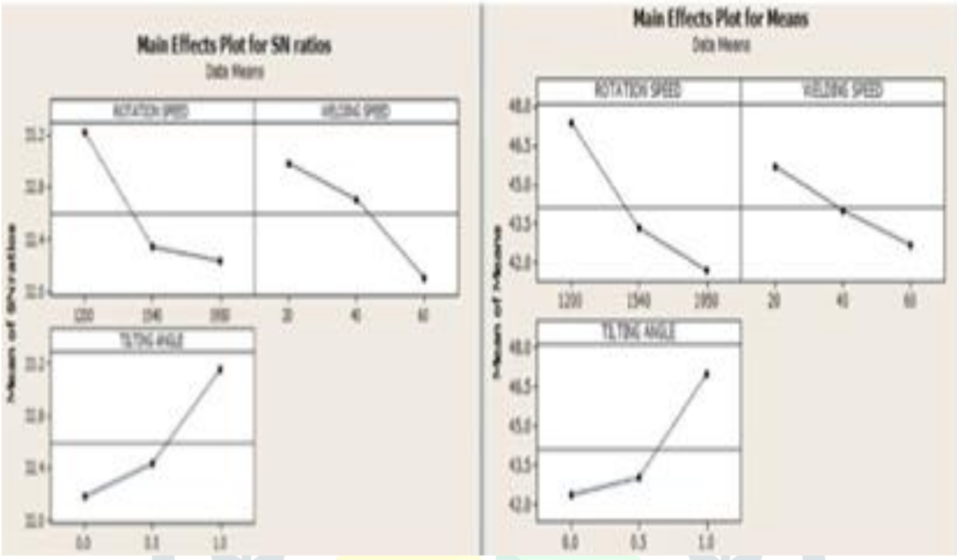


Fig 5.4: S/N ratio and Means for Hardness [12]

IV. WELDING PARAMETERS ON FRICTION STIR WELDING.

The efficacy of friction stir welding is predominantly contingent upon the selection and optimization of its parameters, which play a crucial role in determining the mechanical and other associated features. Therefore, the selection of materials for experimental investigations is significantly influenced by the welding settings. The subsequent tables present the diverse parameters employed in friction stir welding for the purpose of joining ferrous, non-ferrous, and dissimilar materials in distinct combinations.

Ferrous Materials	Sl No	Parameters Assessed									
		Tool Rotational Speed (Rpm)	Welding Speed (Mm/Min)	Tool Material	Tool Force kN	Tool Tilt Angle ^{0}	Tool Pin Profile				
							Square	Cylindrical	Stepped	Tapered	Equilateral Triangle
	01	✓	✓	Tungsten Alloy	-	✓	-	-	-	✓	-
	02	✓	✓	Tungsten rhenium Alloy	✓	-	-	✓	-	✓	-

Table 4.1: Parameters used in ferrous materials

Non Ferrous Materials	Sl No	Parameters Assessed										
		Tool Rotational Speed (Rpm)	Welding Speed (Mm/Min)	Tool Material	Tool Force kN	Tool Tilt Angle ^{0}	Tool Pin Profile					
							Square	Cylindrical	Stepped	Tapered	Triangle	Threaded
	01	✓	✓	AISI 4140	-	-	-	✓	-	-	-	-
	02	✓	✓	Die steel	-	✓	-	-	-	-	-	✓

Table 4.2: Parameters used in Non -ferrous materials

Dissimilar Materials	Sl No	Parameters Assessed										
		Tool Rotational Speed (Rpm)	Welding Speed (Mm/Min)	Tool Material	Tool Force kN	Tool Tilt Angle 0	Tool Pin Profile					
							Square	Cylindrical	Stepped	Tapered	Triangle	Threaded
	01	✓	✓	H13 steel	-	✓	-	-	-	-	-	✓
	02	✓	✓	HSS	-	-	-	✓	-	✓		✓

Table 4.3: Parameters used in dissimilar materials

V. CONCLUSION AND SCOPE OF FUTURE WORK

Friction Stir Welding, as explored in the conceptual definitions, presents a diverse array of process advantages that cater to certain application domains. The aforementioned process provided a range of adaptable criteria for the selection of materials utilized in welding applications. Friction Stir Welding (FSW) has proven to effectively overcome the challenges encountered in traditional welding methods, as supported by several scholarly sources. Therefore, this can be regarded as a widely acknowledged procedural endeavor that is appropriate for investigating unexplored substances and their advantageous attributes. The friction stir welding (FSW) technology has demonstrated its effectiveness in connecting several types of materials, including ferrous and non-ferrous metals, with good outcomes. In light of this matter, it is imperative for research focused on friction stir welding (FSW) to enhance its efforts in discovering novel material combinations.

- Numerous study papers have been conducted to showcase the substantial efforts in the field of combining materials with comparable and dissimilar properties. However, there is a scarcity of studies that have delved into the realm of polymeric materials, specifically focusing on combinations of metals and polymers.
- The feasibility of utilizing welding as a means of combining metal and plastic components can result in the attainment of highly tailored properties.
- The utilization of hybrid metal-polymer coupling enhances the adoption of attributes and productivity, particularly in terms of design and manufacturing flexibility, while also contributing to a reduction in overall component weight. Efficiently optimize the welding parameters in order to achieve a suitable equilibrium in mechanical performance.

REFERENCES

1.Anjal R. Patel, Chirag G. Dalwadi , Harikrishna G. Rana “A Review: Dissimilar Material Joining of Metal to Polymer using Friction Stir Welding (FSW)” International Journal of Science Technology & Engineering , Volume 2 , Issue 10, April 2016.

2.C.M. Dinesh, B. Gajendra Kumar, S. Ganapathi, M. Gandhi, M. Janarthanan “Prediction of Al-Mg Metals using Friction Stir Welding”International Journal of Engineering Science and Computing, Volume 7 Issue No.4 April 2017.

3.D.Aravindkumar, A.Balamurugan “A Review On Friction Stir Welding Of Dissimilar Materials Between Aluminium Alloys To Copper” International Journal of Latest Research in Engineering and Technology (IJLRET) , Volume 2 Issue 2, February 2016 , PP 09-15.

4. Saman Karami, Hamidreza Jafarian, Ali Reza Eivani, Shahram Kheirandish“ Engineering Properties By Controlling Welding Parameters And Microstructure In A Mildsteel Processed By Friction Stir Welding” Materials Science And Engineering A ,670, 2016, 68-74.

5. R. Ramesha,, I. Dinaharanb, Ravi Kumarc, E.T. Akinlabib “Microstructure and mechanical characterization of friction stir welded high strength low alloy steel”Materials Science & Engineering A 687 (2017) 39–46.

6. Pankaj kumar, Satpal Singh, Gurmeet Singh, Ankit Dua “Effect Of Process Parameters On Tensile Strength Of Friction Stir Welded Joint Of Pure Copper”IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).

7. Dr. K. Lenin and S. Dharmalingam “Effect of Friction Stir Welding on Microstructural and Mechanical Properties of Copper Alloy”Advances in Natural and Applied Sciences. 11(4) April 2017, Pages: 484-493.

8. Sreenivas P and Sreejith P S “Effect of Process Parameters on Microstructural and Mechanical Properties of Friction Stir Welded 2219 Aluminium Alloys” International Journal of Theoretical and Applied Mechanics, ISSN 0973-6085 Volume 12, Number 1 (2017) pp. 135-146.

9. N.F.M. Selamat, A.H. Baghdadi , Z. Sajuri1, and A.H. Kokabi “Friction stir welding of similar and dissimilar aluminium alloys for automotive applications” , International Journal of Automotive and Mechanical Engineering (IJAME), Volume 13, Issue 2 pp. 3401 - 3412, September 2016, ISSN: 2229-8649 (Print); ISSN: 2180-1606 (Online).

10 S Thirumavalavan, R. Sabarish, U. Ganesan "Experimental Investigation On Friction Stir Welded Aluminium –Scilicon Alloy", International Journal of Mechanical Engineering and Technology (IJMET), Volume 8, Issue 8, August 2017, pp. 1629–1641, Article ID: IJMET_08_08_177.

11. Hassan Abd El-Hafez, Abla El-Megharbel "Friction Stir Welding of Dissimilar Aluminum Alloys", World Journal of Engineering and Technology", 2018, 6, 408-419.

12. Yudhvir, Gurpinder Singh, Ashwani Kumar "Optimization Of Friction Stir Welding Parameters For Dissimilar Aluminum Alloy" International Journal Of Management, Technology and Engineering, Volume IX, Issue I, JANUARY/2019, ISSN NO : 2249-7455.

13. Mahendra K C, Sreenivasa C. G., Veerabhadrappa Algur, Virupaksha Gouda H "Process Optimization and Influence of Micro Structural Characterization by Friction Stir Welding of Various Materials",International Journal of Engineering and Advanced Technology (IJEAT), Volume-9 Issue-2, December, 2019, DOI: 10.35940/ijeat.B3487.129219