



REVIEW OF FRICTION STIRS WELDING FOR AL 6063 ALLOY USING TAGUCHI METHOD

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Abstract:

Friction stir welding (FSW) is a solid-state joining process that has gained significant attention in recent years due to its numerous advantages over conventional fusion welding techniques. In this study, the optimization of FSW parameters for Al 6063 alloy using the Taguchi method was carried out to enhance the weld quality and mechanical properties. The Taguchi method is a statistical approach that enables the efficient optimization of process parameters by considering the interactions between them. Four process parameters, namely rotational speed, traverse speed, axial force, and shoulder diameter, were selected as the factors affecting the FSW process. The L9 orthogonal array was employed to conduct a series of experiments with varying levels of the selected factors. The output responses considered for optimization were tensile strength, hardness, and weld defect occurrence. Signal-to-noise (S/N) ratio analysis was performed to determine the optimal parameter settings that would maximize the desired responses. The analysis of variance (ANOVA) was employed to evaluate the significance of the process parameters and their interactions.

Key Words: Friction Stir Welding, Analysis of Variance, Efficient Optimization

Introduction:

Friction stir welding (FSW), a solid-state joining process, is a potential replacement for standard fusion welding processes for aluminum alloys. It has several advantages, including reduced distortion, no filler, a smaller heat-affected zone, and better mechanical properties. FSW creates a high-quality weld connection by generating frictional heat and plastically distorting the work piece material with a spinning non-consumable tool. Aluminum alloy 6063 is widely used in a range of industries, including automotive, aerospace, and construction, due to its remarkable combination of strength, corrosion resistance, and formability. To achieve optimal weld quality parameters and mechanical properties in FSW of Al 6063, however, careful monitoring of process parameters is required, as their variations can have a significant impact on the microstructural properties and weld performance. Genichi Taguchi developed a statistical method known as the Taguchi method, which has been successfully applied in a variety of engineering domains for process optimization. It permits effective parameter space exploration and the discovery of optimal parameter values by taking into account variable interactions. The objective of this study is to optimize the FSW process parameters for Al 6063 alloy using the Taguchi method. The selected process parameters include rotational speed, traverse speed, axial force, and shoulder diameter. These parameters have been reported to influence the weld quality and mechanical properties of FSW joints. By systematically varying the levels of these parameters using the Taguchi L9 orthogonal array, a series of experiments will be conducted. The output responses considered for optimization include tensile strength, hardness, and the occurrence of weld defects. The signal-to-noise (S/N) ratio analysis will be employed to determine the optimal parameter settings that maximize the desired responses.

Friction Stir Welding Process:

The method of welding is becoming more complex. Welding technology is continuously growing to meet society's needs, but industry is changing rapidly. Robotic welding, other semi-automatic and remote controlled are the most popular types to overcome the traditional method. Different industrial environments such as automotive industry, electrical industry, sheet metal industry, and other technological area involved in mass production directly engage in welding and materialation works. Lately, those industries recognize the need to use the most popular approach in welding process by using the efficient approaches such as oxy-acetylene gas welding, Tungsten Inert Gas (TIG) welding, Gas Metal Arc welding (GMAW), Metal Active Gas (MAG) welding, Friction Stir Welding (FSW). Advanced friction welding, also known as friction stir welding (FSW), is possible with FSW. Moving the elements to be bonded relative to one another over a typical interface and exerting compressive powers across the joint constitutes the final step in classical friction welding. In order to create a solid weld, the metal must be mollified by the frictional heat produced at the edge due to scouring, and then the relative movement must be stopped and the compressive powers expanded before the weld is allowed to cool.

Need of the Study:

Friction stir welding (FSW) for the alloy Al 6063 needs to be optimized for a variety of reasons. To begin with, aluminum alloys, including Al 6063, are widely used in industries such as construction, aerospace, and the automotive industry due to their excellent mix of strength, corrosion resistance, and lightweight. Although producing high-quality welds with great mechanical properties in aluminum alloys can be difficult, optimizing the FSW process is critical. FSW provides several advantages over traditional fusion welding processes, including less distortion, no filler material, and increased joint stability. These advantages can be enhanced even further by optimizing the FSW process for Al 6063, which results in homogenous, trustworthy welds with improved mechanical properties. The FSW process factors, including rotating speed, traverse speed, axial force, and shoulder diameter, have a direct impact on mechanical properties and weld quality. Understanding the optimal parameter values and how they interact is critical for optimizing the FSW process for Al 6063.

Literature Review:

Ade et al. (2017) examined the methods and evaluation of FSW with aluminum and lithium alloys. The study confirmed the investigation determination for analyzing the outcomes of method constraints of FSW on aluminium-lithium alloys and eliminated all of the defects concerning fusion welding. The mechanical properties of the joints were improved through the formation of recent recrystallized grains. The sizzling cracking problem which at all times occurs in Al-Li alloys may also be eliminated by using the FSW system.

Shah et al. (2017) worked within the discipline of FSW provided an perception of the FSW of aluminium alloys. The study gives vital awareness and logical assessment of the arrangement of aluminium alloys, fsw system parameters, mechanical testing, friction stir welding properties, macro-structure and evolution of microstructure, welding defects and industrial functions of a method during friction stir soldering. The lessons discussed further the variations in the soldering approach; however the soldering and temperature of dissimilar aluminum alloys are beyond the scope of this gain.

Shinde et al. (2016) examined the outcome and investigation of welding parameters on the tension shear force in the Friction Stir Welding procedure. The investigational readings have been carried out under various device Rotation speed (rpm), software visiting pace (mm/min), and power Tilt attitude (measure). The settings of welding parameters had been decided by means of using the Taguchi experimental design system. Experiments have been performed on AA6061 Aluminium alloy in a Vertical finishing computing device point. The productivity aspects are analyzed in UTM. Results exhibit a robust relation and potent assessment between the weldment force and process parameters. Therefore FSW procedure variable database is to be established for a large sort of material and compounds for determination of premiere procedure parameters for an effective weld.

Yoo et al. (2015) The experimental research offered to have an impact on microstructure, mechanical properties and exceptional joint rotation and soldering speed. The knowledge of the processing window provides invaluable know-how that makes successful friction soldering part of the alloy. Special value consistent with the system variety show tensile resistance and elongation. The maximum tensile strength is 73.4 percent of the base material. Compared to procedural parameters the macrostructure of the welding joint. The alternation of border form between the rise zone and the advancing part is therefore observed and a defect is eventually initiated when the parameters of the approach are some distance from a wide range.

Taiki Morishige et al (2008) Increased plastic flow in the nugget and in the thermo-mechanically influenced zone (TMAZ) and increased heat change in the warmth influenced zone (HAZ) of the weld are the results of optimized FSW process parameters that control the rigidity and the fatigue lifetime of AAAl 6063 combination. The normal plastic plasticity of an FSW joint and the occurrence of deformity types, unique to the FS technique, can influence the fatigue behavior of the joints; thus, a comprehensive relationship exists between microstructure and weariness execution.

T. Björk et al. et al. (2013) Tensile joint houses were evaluated and related to the development of the FSW zone. From this examination it was determined to produce solid and metallurgically imperfect soils that were in contrast to several joints by the rotary speed at 1120 rpm and welding rates at 40 mm / min. Product geometry and rotational speeds have been recognized as the basic parameters affecting Friction Stir Welding (FSW) mix area micro-structure and properties. At 900 rpm and 1400 to 1000 rpm, the joint generated was also shown to scale down homes of elasticity as in correlation with the joints produced at rotational speed of 1120 rpm. In relation to the soldering speed of 40 mm / min, three joints made from three distinctive soldering rates of 25 mm / min and 80 m appeared in a mechanical structure.

Dinesh et al. (2018) Ascertained the spatial and temporal distribution of heat in an A6061-T6 work piece during head-to-head friction welding. Using a wide variety of thermocouples, we were able to reconstruct the temperature history of FSW at various points on the work piece. The experimental measurements of the temperature along the breadth route of the work piece were found to fit well with a 2d-order polynomial curve. There were also traction and Vickers hardness evaluations performed, and the results were compared to the basic metal.

Arun et al. (2015) calculated the effect of mechanical and metallurgical homes of AA6061 Aluminium Alloy lap joint by way of making welding procedures such as GTAW, GMAW and FSW. Throughout weld metal hardening for the reason that of thermal properties, the tough columnar grains show up on the alloy of weld fusion zones. Here 6.35 mm thicknesses of rolled plates are used for this system. For making ready lap welded joints Rolled plates of were used. Aluminum alloy grade AA4043 (Al.SSi (wt%)) is utilized as the fusion steel in the plate's joining process.

Yan et al. (2012) This study analyzed the microstructure and mechanical properties of welds made from 1420 aluminum-lithium (Al-Li) alloy using a CO2 laser metal entombment gas (MIG) mixture welder. CO2 laser-MIG half and half welding was used to attach the 1420 Al-Li combination plates, each of which was 5 mm thick. Results show that the microstructures of the heat-affected zone (HAZ) and combination zone each exist as a first-rate cell dendritic constitution and a transcendently spasmodic equiaxed dendritic constitution.

Yunus et al. (2018) learned about scientific demonstrating of a rubbing mix welding framework to anticipate the joint quality of two numerous aluminum compounds utilizing test information and hereditary programming. The learn demonstrates that Genetic programming can be connected to the FSW technique to infer certain connections between the yield and enter parameters so as to get a summed-up expectation mannequin. A Genetic programming model will direct designers in evaluating the execution of FSW, and the result from this be educated would then be able to be used to gauge future requirements arranged on the notable data to give a solid goal.

Trimble et al. (2015) Time-dependent The maximum penetration of base metals is studied using an Eulerian thermal/material model of a friction soldering stream composed of pure copper and AA 1050-H16. Since coulomb frictions and the absence of shear stress in a fluid metal custom from North Newton accompany the flow of a thermal energy source, a thermal and material glide analysis was performed with the expected speed field in the stir zone. To validate the experimental result, the generated model was applied to predict the temperature gradient and material penetration in three different software offset situations. The model suggests that software is carefully compensated by the penetration of the bottom metals. In every case, the metal constant is copper on the forward side. The thermal and material glide evaluation was once carried out in an FSW procedure with a variety of copper and aluminum metals, since both a type of friction and a loss of shear stress were receive from a thermal force source. The experimental results were presented when the model results for the metal hint followed.

Wei Huang et al. (2011) We developed a three-dimensional heat model for AISI 1018 mild steel contact-blend welding to forecast the heat cycle, temperature allocation, impact of welding factors on required power, warmth age, and peak temperature. The testing results were exactly in line with the projected warm cycle, torque required, and temperatures. The top temperatures and thermal ages were chosen to be proportional to rotational speed and inversely related to welding velocity. Slower rotation rates result in reduced expenses for increases in thermal focus and height temperature, according to therapists. The cost of increasing warm fresh discharge per mm size and top temperature falls as rotational speed increases.

Selection of Process Parameters Based on Ishikawa Cause Effect:

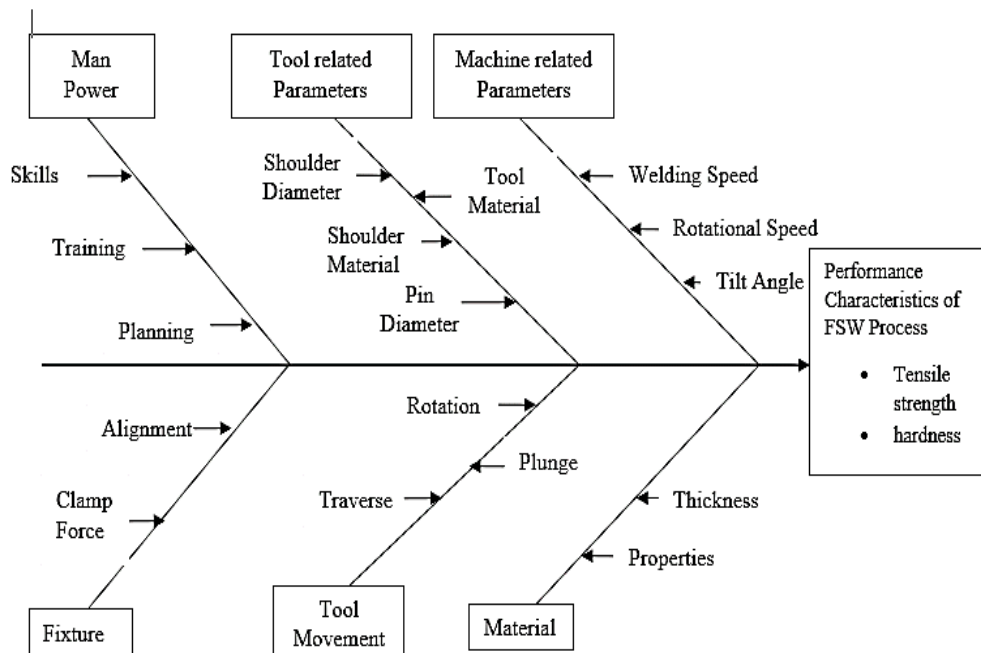


Figure 1: Cause and effect diagram

To determine the FSW process parameters that may affect FSW joint quality, an Ishikawa diagram (cause and effect diagram) is developed as shown in Figure 3.7. In this study, we focus on the welding process parameters that play a significant influence in determining weld quality, such as tool rotating speed, traverse speed, and axial force.

The cause effect diagram can uncover key the connections among the different factors and the conceivable causes give the extra understanding into procedure conduct. An Ishikawa cause-impact chart has been for deciding different information parameters that influences the ideal quality attributes of the last employment. These parameters can be recorded as pursue: Material, welding equipment's, Environment, People, Power and Procedure.

Input Control Parameters:

Control parameters are friction stir welding tool, Spindle speed, Rotational Speed and Tilt Angle. These parameters are chosen due to their simplicity of the control and because of the impediments of accessible test setup. The parameters utilized for the real analysis are given below in table.

Table 1: Input Control parameters and their values at different levels

Parameter	Unit	Level 1	Level 2	Level 3
Welding speed	mm/min	66	90	132
Rotational speed	Rpm	386	664	931
Tilt angle	Degree	0	1	1.5

Constant Parameters for Friction Stir Welding

Table 2: Constant Parameters for Friction stir welding

Type of Parent Material	Aluminum-Li 8090 T8771
Thickness of Parent Material	5 mm
Joint geometry	Simple butt joint

Levels of Various Control Parameters:

The short scope of the control components will have the minor impact on the reactions parameters that is the reason a significant scope of the control parameters had been picked in this trial think about each control factor utilized having three dimensions. The subtleties of each control factor level are as below in the Table.

Representation of Factors Levels:

For directing the last keeps running of tests all the three variables have been meant by the particular letter and the documentation utilized for the factor having their particular significance as appeared table 3

Table 3: All input control parameters and level

S.No	Factors	Level – 1	Level – 2	Level – 3
1	Welding Speed	A ₁	A ₂	A ₃
2	Rotational Speed	B ₁	B ₂	B ₃
3	Tilt angle	C ₁	C ₂	C ₃

Table 4: Values of input parameters for Friction stir welding process (set of DOE)

Factors A for welding Speed (mm / min)	Factor B for Rotational Speed (RPM)	Factor C for Tilt angle (Degree)
A ₁ = 66	B ₁ = 386	C ₁ = 0
A ₂ = 90	B ₂ = 664	C ₂ = 1
A ₃ = 132	B ₃ = 931	C ₃ = 1.5

Table 5: Process parameters and their values at different levels for Taguchi L₉ Orthogonal array

S.No	Process Parameters	Unit	Symbol	Level – 1	Level – 2	Level – 3
1	Welding Speed	mm / min	A	66	90	132
2	Rotational Speed	RPM	B	386	664	931
3	Tilt angle	Degree	C	0	1	1.5

During the welding an administrator can control the different fundamental welding parameters. It was contemplated that the principle parameters levels picked were in the operational scope of the Friction stir welding process. The distinctive trial process was finished by differing one of the welding parameters and keeping the others as consistent qualities. The determination of levels for the fundamental control parameters are given in table 5. The three unique dimensions were chosen for the investigation of three primary control parameters.

Measurement of Performance Characteristics:

Estimation of the execution attributes (reactions) like extreme elasticity (UTS) and hardness were executed as examined underneath. In the present examination the checking electron magnifying instrument (SEM) and scattering spectroscopy or the vitality dispersive x-beam spectroscopy (EDS) are additionally talk about. The details of these reaction factors are given below in table 6.

Table 6: Responses or output and type for friction stir welding

S.No	Responses	Unit	Symbol	Response Type
1	Tensile strength	Mpa	A	Continuous
2	Hardness	HRB	B	Continuous
3	Scanning electron microscope (SEM) and electron dispersion spectroscopy or the energy dispersive x- ray spectroscopy (EDS)			

Standard L₉ Orthogonal Array:

The standard configuration of L₉ symmetrical exhibit utilized for this trial contemplate is appeared in Table 7, taken from MINITAB 18 programming tool.

Table 7: Taguchi's standard L₉ Orthogonal array for Friction stir welding procedure

Experiment No.	Welding Speed (A)	Rotational Speed (B)	Tilt angle (C)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Conducting the Experiment:

When the variables are assigned out to a specific section of the chose orthogonal array the experiment technique has been set and the physical arrangement segment of the chose symmetrical cluster the test system has been set and the physical planning for playing out the test in performed. A few choices require to be made concerning the request of test. The randomizing the request of playing out the trial of different trails ought to incorporate a few types of randomization. The randomized trail request shields the investigation from any obscure and uncontrolled elements that may shift amid the test and may impact the outcome.

Welded Samples:

The trials were run, and the conditions were tested, on a semiautomatic milling machine by the brand name BMacT. In the present experimental work single butt joint was made as shown in figure 6 and 7.

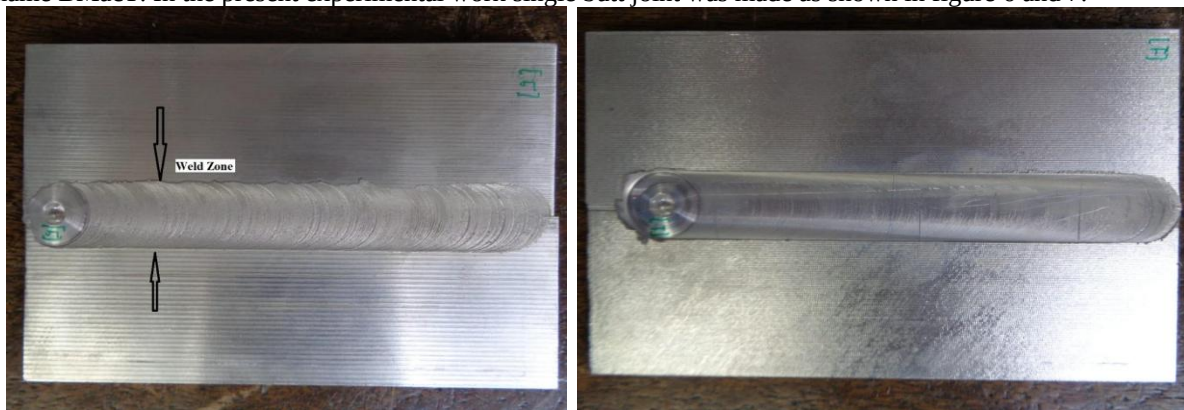


Figure 2: Welded joints by Friction stir welding

Conclusion:

In conclusion, the application of the Taguchi method in the optimization of friction stir welding (FSW) for Al 6063 alloy has provided valuable insights and recommendations for process improvement. Through the Taguchi method, the key process parameters affecting FSW performance, such as rotational speed, welding speed, and axial force, have been identified. By systematically varying these parameters based on the Taguchi design of experiments, it was possible to evaluate their individual and combined effects on weld quality. The analysis of signal-to-noise ratios and analysis of variance (ANOVA) helped determine the optimal parameter levels for achieving desirable weld characteristics. This approach allowed for the identification of the most influential parameters and their optimal settings to minimize defects and maximize weld strength. The Taguchi method also facilitated the determination of the optimal combination of process parameters that resulted in the highest weld quality. This not only improved the efficiency of the optimization process but also provided a clear roadmap for achieving consistent and reliable welds.

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