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A Study of Process Parameters for the Friction Stir Welding of Dissimilar Aluminum Alloy by Taguchi Method

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ABSTRACT:

Welding is a technique by which two or more than two metals and alloys can be joined. There are different types of welding technique like Gas welding. Arc welding. Resistance welding and solid state welding etc, but friction stir welding having a very important application in aerospace and ship building area. Friction stir welding is a type of solid state welding and heat is generated by friction that is used to join any two or more than two metals and alloys. In present work two aluminium alloys viz. AA2011 and AA3003 having 5mm thickness of plates are joined by friction stir. welding using vertical milling machine taking different levels of parameter i.e rotational speed of tool viz. 1200, 1950 and 3080 RPM and welding speed viz. 15, 25 and 45 mm/min. to find out the maximum hardness (Rockwell hardness) of welded aluminium alloy joint.

Further Taguchi method reveals that tool rotational speed is the most significant parameter which contributes to the Rockwell hardness 75.4% subsequently followed by welding speed which contributes 24.6%.

Keywords:- welding, FSW, Taguchi method and Rockwell hardness.

1. Introduction

Welding is fabrication technique of combining two or more materials usually metals and plastics. The welding process is done by using heat and pressure. Welding can be done by using with or without filler material. Welding is the most popular technique to join the two or more pieces. In today's technology, welding is widely used. Since 1930, it has increased astronomically. This growth has outpaced the growth of the entire industrial sector. Metal, non-metal, plastic, and other materials can all be joined using the welding technique.

There are different materials like super alloys and high temperature metals used in the industries to join with the help of Gas welding, arc welding and Resistance welding. The welding technique is used in automobile industry, cars, aircrafts, ship, electronic equipment machinery industry etc [1].

There are various kind of welding procedure or Method:

Gas

Resistance

Arc

Solid state

Thermo-chemical

Radiant energy

1.2 Friction stir welding Method (FSW)

Institute received a patent for friction-stir welding. The solid state welding process includes the friction stir welding step.

The solid state is non consumable electrode process. In this process no filler metals used for welding the work-piece. The two similar or dissimilar aluminum alloys, magnesium, copper, brass, lead, tungsten, etc., can be welded using friction stir. it is an environmentally sustainable process. Friction stir takes a while to complete. Friction and heat are utilised in the friction sir welding method to fuse the two pieces together. The main factors influencing the friction stir welding are feed rate, rotational speed, tilt angle, downward force, and tool design [2].

1.4.1 Linear friction type welding (LFW)

Friction type welding includes a variety of process called linear friction welding. Linear friction welding different materials can be weld. In this welding process the joining of materials has been done when the relative motion between the materials due to frictional heat generates. The force is applied perpendiculars to welds into face.

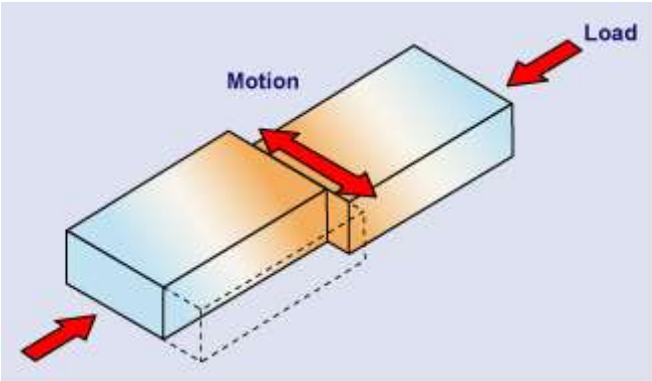


Fig 1.1 Linear friction welding

2. Literature Review

G. Cam et al [14]

Examined the mechanical characteristics of the Al – 5086 h32 aluminum plate. These 3 mm thick parts can be welded by a friction-stir butt process at various welding speeds, with a tool rotation speed of 1600RPM. About 75% of the base plate is made up of it. Additionally, it is noticeable that the high joint performance increases with a deeper penetration of stirring in the butt.

Navdeep et al [15]

Experimental studied of the FSW weld two different aluminum alloys of AA 1100-AA 6101-t6 and platter thickness 6mm with the help of two different high speed steel tool pin. Pin have straight cylindrical (SC) and sequence thread (ST). Micro-hardness and tensile properties are better with square and thread tool pins than with (SC) Straight cylindrical tool pins, and it is observed that these properties increases with the increment in the tool's rotational speed.

Sushil kumar kamat et al [16]

Experiment has been the welding the al 6101 alloy with friction stir welding ,technique and wig welding, Tensile strength of FSW is observed to be higher than that of TIG welding (Mechanical Properties of FSW).

Jehheet Singh et al[17]

Studied the effects of tool rotation velocity on the friction welding mechanical properties of aluminium alloy AA 5083. It was found that declaring the hardness and rough grain structure is provided by increase the tool rotational speed.

Jyoti prabash et al[18]

Examined the mechanical properties of AA 6101-T6 can be effected of longitudinal welds pool oscillation. The of gas metal are welding weld to doing the alloys. Tensile strength, micro hardness and microstructure of simple joint of AA6101-t6 GMAW are compared to the oscillated GMAW joint. It has been observed that the good mechanical behaviour of the oscillated GMAW joint as compared to the simple, Stationary GMAW Joint.

Vinayak D et al[19]

Experiment perform on friction-stir to weld the butt joint of dissimilar material aluminium alloy 6101 and copper plates thickness 5mm. using the process parameter tool rotation at 600 rpm and at 10mm tool traverse-speed cylindrical h 13 tool material . They observe that the weld joint show onion ring structure has been seen at land tested at the UTM computerized.

Rahul et al [20]

Analysis the importance of DOE in designing the experiments be friction stir welling of different aluminium alloys. DOE Give series number of runs the important variable are made to critical process parameters of a system. The effect on response variable is measured. It has been noted that by examining each welding parameter separately, the impact of the parameter on the desired characteristics can be ascertained. It is extremely uncommon to use DOE for multi-factor welding of dissimilar alloys at once.

M.Ilangovan et al [21]

Investigate the micro-structure features and tensile behaviours of aluminum alloys 6061 and AA 5086 friction-stir of similar & dissimilar joint. They analysis that, dissimilar joint show a maximum hardness of HV115 and joint efficiency of 56%.

Vinayak D. et al [22]

Studied the tensile strength dissimilar aluminium alloys AA 1100 and 6101. T6 of 5mm think by the using the cylindrical tool h-13 material. It has been found that, the tensile strength of the joint different alloy less stronger to the base metal alloy (6101-16) but very close to the AA 1100).

N Sasi Karthik Sai et al[23]

Friction stir welding on alloy steel (Stainless steel 410) and aluminum (al 5086) was analyzed using MINITAB 17 statistical software. The analysis was conducted to examine the impact of process parameters on the tensile strength of the welding-joint, either according to the l9.

Heena et al [24]

Investigation into the present state of analysis for friction stir welding between two 5086 aluminum plates, by forces on the resulting welding, hardness, elongation, and tensile strength. From this approach, he derived the notion to keep the rotation speed between 450 and 1400 rpm.

Amanpreet Singh et al [25]

Examined how process parameters affected the mechanical characteristics of the AA6101/B4c composite material through friction stir processes.employing the different tool shoulder diameters (18, 20, and 22 mm) at a rate of 50 mm per minute. Following testing, it noted that, the tensile strength and microhardness of AA6101increased.

Muhsin et al [26]

Examined the use of friction-stir and the friction stir process (FSP) on AA5086-h32 plates that were 3 mm thick. Construct a traverse speed of 40 mm per minute by using a high carbon and chromium alloy steel tool with a threaded tool pin at 3 different rotational speeds (750, 1000, and 1250 rpm). It was discovered that, the friction stir welding (FSW) joint exhibited lower bending strength, tensile strength, % of elongation, and lower hardness as composed of the friction stir process (FSP) welded joint. Additionally, the microstructure grain size of the FSP welded joint was found to be slightly finer than that of the FSW joint.

Sandeep Dahiya et al. [27]

Studies and optimizes the process parameter of faction stir welling of AA 6101 T6 aluminium alloy wing H13 tool and S/N ratios were used to determine the ideal parameters for micro-hardness, joint ability, and tensile strength, according to the Taguchi method.

Sarathiya Mehul et al [28

Examined how various tool designs and process parameters affected the (quality of) friction stir welding of AA 6010 T6 alloy plate thickness 6mm analyses.

Sachindra Shankar et al (29)

Studied the select of friction stir of similar AA6101 plate thickness 5 mm and 3 mm using conical tool at different rotation speed (355rpm,500rpm and700rpm) and welding speeds (16mm/min, 25mm/min and 40mm/min) it found that the impact of rotational and welding speed produced the effect on the welding joint.

Girish G et al [30]

Examined the tool face tool quotation, tool transverse speed and etc they effect on the mechanical properties of aluminium allay 5086 wells with FSW. The single pass well were made by varying the tool quotation speed tool speed and farce applied on the tool constant and welding joint made at different tool quotation speeds 600,750 and 850 RPM. He measures the mechanical properties. At 600 rpm recorded the highest tensile strength 0.199KN/wa^2 and at 850 rpm recorded the lowest tensile strength 0.078 KN/mm^2

3. TAGUCHI EXPERIMENT DESIGN USING MINITAB

Both static and dynamic response types are offered by MINITAB; the quality characteristics have a fixed level. Finding the best possible parameter combination to achieve insensitivity to noise factors is the aim of the experiment. The response table, response table analysis, and mean effect plots for were produced using MINITAB.

S/N Ratio Vs. Control factors

Means Vs. Control factors

3.1 CHOOSING OF ORTHOGONAL ARRAY (OA)

Prior to deciding which specific OA will serve as a matrix for the experiments, it is important to take into account the next two points:

Number of parameters

Ranges for the parameters

In the orthogonal array actual parameter and levels are defined and has been presented in table

Table 3 Orthogonal Array Taguchi Design L9 FSW actual values

S. No	Tool rotation speed	Welding speed
1.	1950	16
2.	1950	32
3.	1950	48
4.	2300	16
5.	2300	32
6.	2300	48
7.	4600	16
8.	4600	32
9.	4600	48

3.2 EXPERIMENTAL PLAN

The objective and scope of this work have already been mentioned. The plan of experiments in this present study has been done in below manner.

- Cutting of (AA5086-AA 6101) by Shaper machine and power hacksaw to get desired dimension (150 x100 x 5) mm of the work pieces.
- Performing Friction stir welding and making butt joint at GIMT, Kanipla, Kurukshetra.
- Conditions involving various combinations of process control parameters i.e; Transverse Speed and Rotating Speed.
- Performing the Tensile strength testing at CITCO-IDFC Testing Laboratory .Chandigarh
- Performing optimization testing on Minitab 17.

3.3 EXPERIMENTAL PROCEDURE

One plate of each size, AA5086 and AA6101, measuring 150 mm by 100 mm by 5 mm, is clamped in a fixture in order to perform FSW on aluminum alloy. Tables 4.1 and 4.2, respectively, provide the composition and mechanical properties of aluminum alloys (AA5086-AA6101). A vertical universal milling machine with a high rotation speed is used as the FSW setup in the experiments to rotate the stirrer. In addition, a shaper machine and a power hacksaw were used to cut the specimen that was to be welded to the correct dimensions. The stirrer tip was thus kept from coming into contact with the surface of the metal to be welded at various points. The tool used in the FSW of aluminum alloys is made of H13 die-steel. To improve the stirring effect, the tool tip length was selected to 4.7 mm less than material thickness. Two components are needed to transform a vertical universal milling machine into an FSW setup, namely.

- FSW fixture
- FSW tool

FSW fixture is mounted on the table which two plates of size 150×100 mm can be clamped in the butt position. The fixture was prepared in such a way that two plates of size 150×100 mm can be clamped in butt position thickness is adjustable between 3 to 25 mm.

FSW tool with pin profile are prepared i.e. Square .

The parameters are chosen using quality tool cause and effect diagram. The two parameters such as rotating speed and welding speed were selected. Design data handbook is used to know the maximum and minimum range of rotating and welding speed. The tool pin profile is taken Square. The FSW is accomplished using various combinations of rotating speed and welding speed. A total of 9 sets are prepared by the following the parameter combination of given set of orthogonal array by Taguchi L9. Tensile strength testing of all specimens is performed at computerized Universal Testing Machine at CITCO Chandigarh.

4. Results

4.1 TAGUCHI DESIGN RESULT

4.1.1 Means analysis and signal-to-noise ratio calculation The primary feature taken into account in this study characterizing the quality of FSW joints is tensile strength. The means and signal-to-noise ratio (S/N) for each control factor are computed in order to access the influence of factors on the response.

In both welding speed is having high delta value so rank 1 is given to welding speed and 2 is rotation speed.

Table 4.1 Tensile strength S/N ratio Response table

Level	**Rotational speed**	**Welding speed**
1	44.87	44.82
2	45.15	44.89
3	44.06	44.36
Delta	1.09	0.54
Rank	1	2

Table 4.2 Responses for Tensile strength means

Level	**Rotational speed**	**Welding speed**
1	175.3	174.3
2	181.0	176.7
3	159.7	165.3
Delta	21.3	11.0
Rank	1	2

4.2.2 Analysis of Variance

The goal of the ANOVA test is to determine how important the process variables are that impact the FSW joints' tensile strength. Tables 5.4 and 5.5, respectively, provide the ANOVA results for the tensile strength of means and S/N ratio. Furthermore, when F is large, the process that significantly affects tensile strength is identified using the F-test. Generally, process parameter changes have a significant impact on quality characteristics. According to the ANOVA result, the process parameters under consideration have a significant impact on the tensile strength of FSW joints.

For every significant item, the contribution percentage is determined by calculating the sum of squares.

Table 4.3 Analysis of variance table for Tensile strength Means

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**% of Contribution**
Rotational Speed	2	732.7	732.7	366.33	7.14	0.048	64.1
Welding Speed	2	206.0	206.0	103.00	2.01	0.249	35.9
Residual Error	4	205.3	205.3	51.33			
Total	8	1144.0					100%

Table 4.4 Analysis of variance table for Tensile strength S/N ratio

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**% of Contribution**
Rotational Speed	2	1.9247	1.9247	0.9623	7.25	0.047	64.2
Welding Speed	2	0.5094	0.5094	0.2547	1.92	.260	35.8
Residual Error	4	0.5310	0.5310	0.1327			
Total	8	2.9651					100%

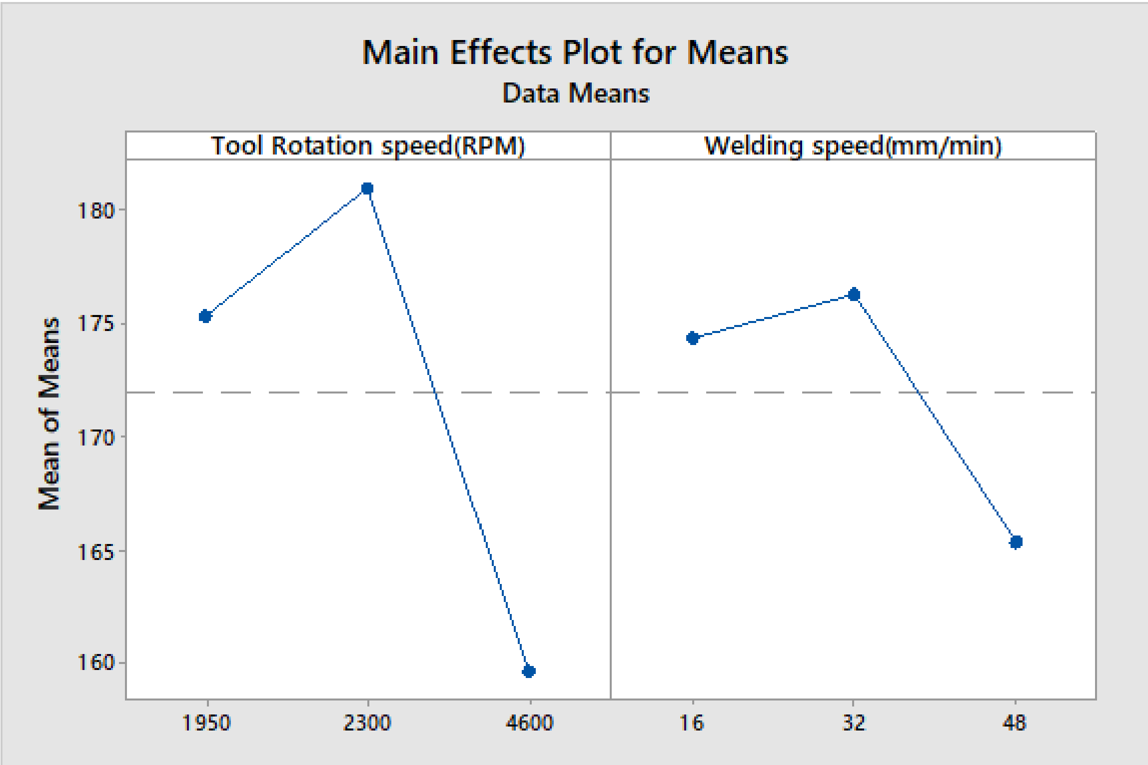


Fig 4.1 Result analysis of Tensile strength Data means Vs Rotational Speed and Welding Speed

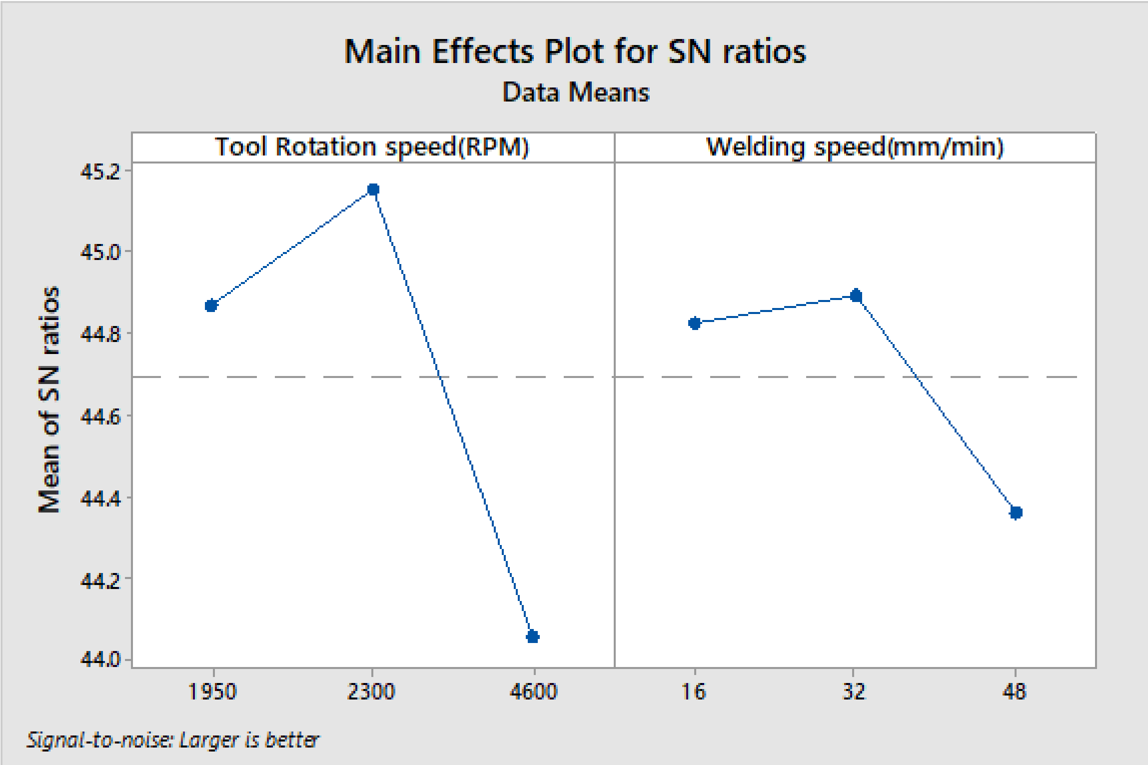


Fig.4.2 Result analysis of Tensile strength S/N ratio Vs Rotational and Welding Speed

The Fig.4.1 and 4.2 are the graph between response (Tensile Strength) Vs parameters means and S/N ratio respectively. For the significant factors Fig.4.1 and 4.2 indicates that parameters A and B the overall optimum condition thus obtained are A1and B2 .

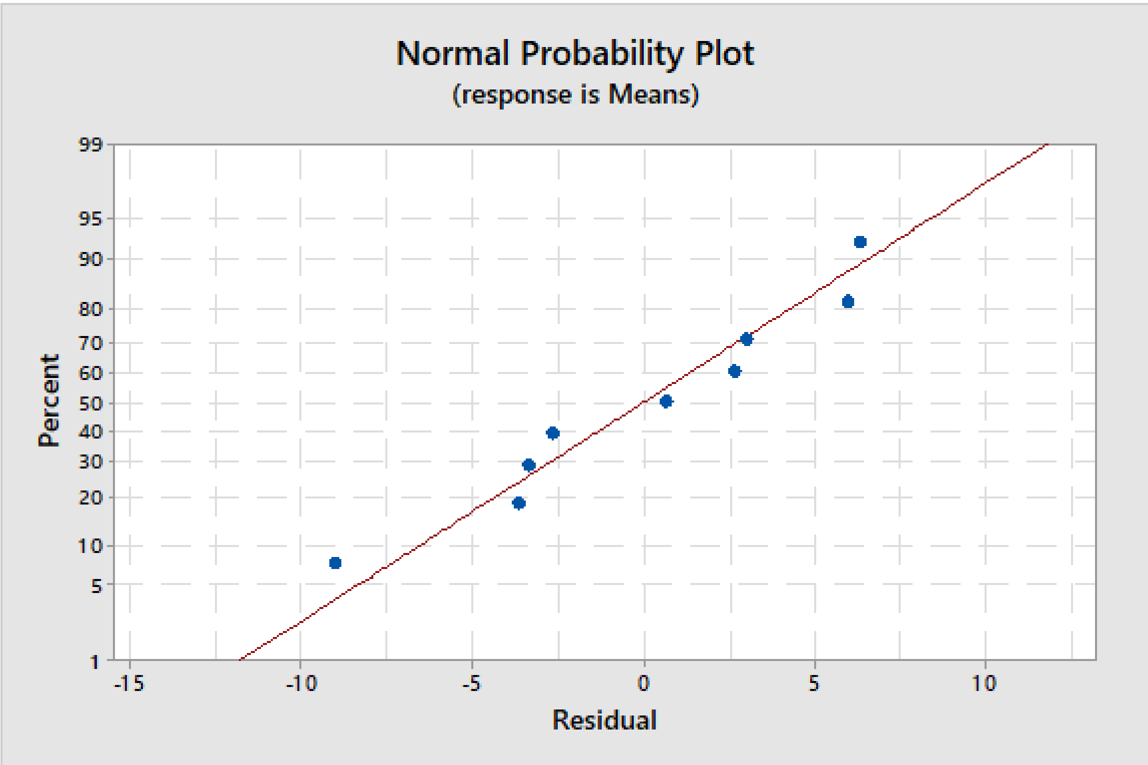
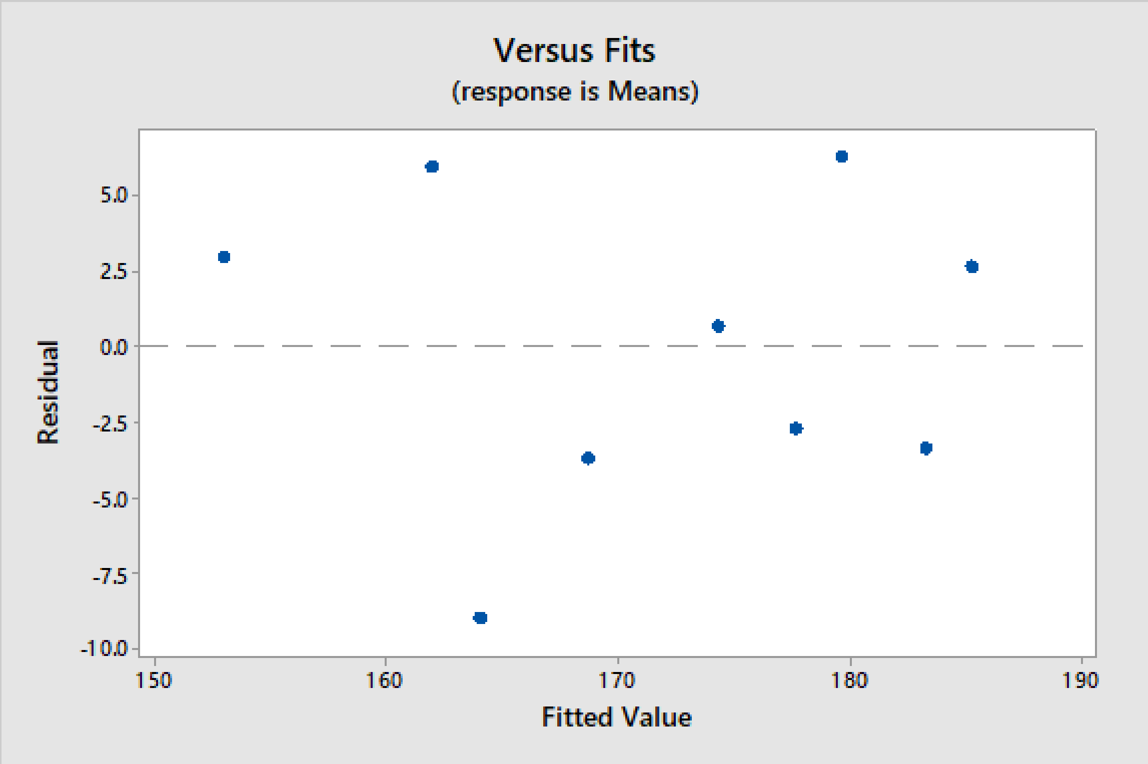


Fig. 4.3 Normal Probability distribution plot for means



4.3 CONFIRMATION TEST

Verifying that the experiment's tensile strength has improved while maintaining Taguchi's ideal welding speed of 32 mm/min and tool rotational speed of 2300 RPM is the last stage. Tensile strength is expected to be 188 N/mm2 after the ideal conditions were entered into Minitab 17.The outcome of running the FSW with the optimized value is displayed in Table 4.4.

Table 4.4 Optimized Result of FSW

S. No	Parameters	Taguchi
1	Tool speed	2300 RPM
2	Welding-speed	32 mm/min
3	Tool-pin profile	Square
4	Tilt Angle	1 Degree
5	Tensile strength	188 N/mm2

From the table 4.4, it shows that predicted value and experimental value of Tensile strength Some more than the base metal. we can say that result obtained is very satisfactory.

5. Conclusions and Future scope

5.1 CONCLUSION

This study offers a useful method for figuring out the ideal friction stir process parameters in a variety of scenarios. This investigation was able to be carried out with a sample of nine work pieces thanks to the utilization of Taguchi in MINITAB 17 software, with two Control parameters and two constant parameters. The research discovered that the response variable is affected by the control factors in different ways. The tool's welding speed has the biggest impact. Through the use of DOE techniques, the many combinations of design parameter settings can be easily controlled. The following actions can be taken to wrap up the current study:

- The FSW joints manufactured with the ideal square tool pin profile, 2300 RPM tool speed, 32 mm/min welding speed, and one degree tilt angle demonstrated the maximum tensile strength.
- Welding speed is the most significant which contributes to the tensile strength 60.5% subsequently followed by rotational speed which contributes 39.5%
- For optimal tensile strength, a tool rotation speed of 2300 RPM and a welding speed of 32 mm/min are required.

5.2 SCOPE FOR FUTURE WORK

The future scope about this project given as below:

- Experimental work can be done by using factors regarding material properties i.e melting point, thickness, composition etc.
- Design of tool can be considered for optimization; this requires models that capture the influence of the tool (e.g flow model) and application of the shape or topology optimization techniques.
- Percentage contribution of various process parameters can be done with the help of software tools like as MCDM, GRA.
- Research work can be done by considering various factors such as clamp geometry, clamp force, shoulder pin diameter ratio, heat deception factor etc.

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