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Impact of Tool Shape and Rotatory Speed on Tensile Strength and Microstructure of AA6105 Friction Stir Welded Joints through Taguchi Method

Jai Singh[1] and Bikramjit Singh[2]
[1]Associate Professor, Department of Mechanical Engineering,
Guru Nanak Institutions- Mullana, Ambala (Haryana), India.
[2]Professor, Department of Mechanical Engineering,
M.M. Deemed to be University-Mullana (Haryana), India.

(Corresponding author: Jai Singh)
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ABSTRACT: Aluminum alloys 6105 is limitlessly being utilized in car connector stock, consistent and basic tubing, auxiliary individuals, stepping structures and hand rail tubing and so forth. Friction stir welding, a solid state joining practice, is for the most part being accustomed to joining aluminium combinations for marine, automotive, aerospace, railway industries, electrical and structural components and several other uses of commercial significance compared to conventional welding process, which are consistently used for joining of metals and composites. This method is an advanced metal joining procedures like friction welding being dynamically taken for welding of aluminium alloy AA6105. The tool shape profile and rotational speed showed a dynamic role in determining the quality and tensile properties of welded joint. This has been achieved by using Taguchi Technique orthogonal array for design of experiment and using Analysis of Variance for signal to noise ratio. The outcomes showed that best values of maximum tensile and fine microstructure of welded joints AA 6105 is 141.38 MPa at rotational speed 1540 rpm, with square pin profile.

Keywords: Friction stir welding, pin profiles, rotational speed, tensile strength, microstructure.

Abbreviations: ANNOVA, analysis of variance; S/N, signal to noise ratio; LB, Larger is Better; SH, shape of pin;WS, welding speed; TA, tilt angle; RS, rotatory speed; TS, tensile strength; SEM, scanning electron microscopy; O.S., operating setting; R.S., random setting; N, number of runs; D/d, diameter of shoulder to diameter of pin.

I. OVERVIEW

Friction stir welding is the metal and alloy joining procedure in which metals are joined without melting and reforming. This method is frequently used in the manufacturing of products in many industries and huge production of aluminium panels from aluminium extrusions [1]. FSW is a solid state process which yields welds of high worth in tough to weld materials such as aluminium and is fast becoming the procedure of selection for welding light weight transport assemblies such as boats, trains and aero planes. Meanwhile its innovation, the process has received world-wide attention, and these days FSW is cast-off in research and production in several sectors, comprising construction Industry, aerospace Industry, automotive, railway, shipbuilding Industry, electronic housings, coolers, heat exchangers, and nuclear waste containers. FSW has been confirmed to be an active procedure for welding aluminium, brass, copper, and other low melting temperature materials [2]. Aluminum alloy 6105 has widely used for fabrication of stressed structural members, automotive connector stock, seamless and structural tubing, Roof and ladder structures, handrail tubing, and window frames etc.

This method is generally appropriate for connexion for similar and dissimilar aluminium alloys. From the past study of researchers, it is perceived that this method appears to be more beneficial in relation to other orthodox welding techniques. The main usages of this welding practice in aluminium alloys, copper, magnesium alloys, in relation to other old welding procedures, are principally the eradication of evaporative loss and cracking of welded joints. This is attributable to the solid state welding and a welding joint with fine worked or recrystallized grain structure made by blending and producing during friction stir welding. Through this fusing process, the temperature remains lower than the melting temperature consequence in a little contraction occurrence and brilliant mechanical properties, composed with decline of residual stress within the weld zone tensile properties of the welded joints are relatively decent and fatigue properties are nearly the alike as the base metal. Commonly tensile failure arises well away from the welded region. The workings of friction stir welding method as explained in Fig. 1.

This welding method is generally consists of four distinct sections as presented in Fig. 2. Which are: (a) parent material, (b) heat affected section, (c) thermo-mechanically affected section and (d) nugget section.

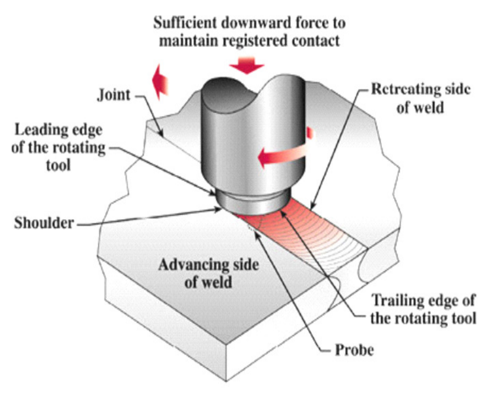


Fig. 1. Friction Stir Welding.

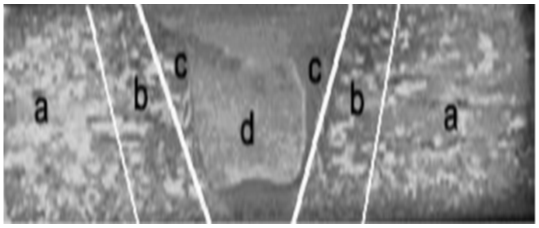


Fig. 2. Various sections of welded joint (a) Parent Material, (b) Heat affected Section (c) Thermo-Mechanically affected Section and (d) Nugget section.

II. MATERIAL AND METHOD

Vertical Milling Machine: A conventional Vertical Milling Machine can be used to carry out the FSW process at Geeta Institute of Management and Technology Machine shop, Kanipla, Kurukshetra (Haryana) India. The machine must have the ability to apply significant pressure onto the work piece, should offer wide range of tool rotation and feed rate speeds, provides enough space for its working table to holding the welding assembly and rigidly during the welding operation. Fig. 3 shows Vertical Milling Machine.

Fig. 3. Machine during operation.

Fig. 4. diagram of Fixture used for Holding Work piece.

Size and Specification:

Table 1: Sizes and Specification of Vertical Milling Machine

Make	Pacmill (semi-automatic)
Spindle position	Vertical
R.P.M range	90 – 4600
Longitudinal bed range	950 mm
Cross bed range	400 mm
Diameter of tool holder	50 mm
Longitudinal feed range	14 – 900 mm/min
Motor	3 HP, 2300 rpm

Fixture: The primary joint pattern is acquired by fixing the work pieces in location using mechanical fastens to fabricate the welded joints. The work pieces to be welded have to be securely clamped to prevent the joint phases from being forced apart. Fixture provides the medium in which work pieces are rigidly clamped. Special types of fixtures can be designed as per requirements. Work pieces are clamped on to fixture which is further mounted on the Vertical Milling Machine. Fig. 4 shows fixture used for holding work pieces.

Work piece preparation: The work pieces of required size (100 × 75 × 6 mm) have been prepared from plates of 6 mm depth by power hacksaw cutting and milling machine. To make welded joints, the Rectangle butt joint shape has been prepared.

Tool: To manufacturing the welded joints, the tool made of high carbon steel have been utilized. The Tool nomenclature, design and specification and dimensions of tool are as shown in Fig. 5, 6 and 7 respectively. The sizes of work piece and test specimen are presented in Fig. 8.

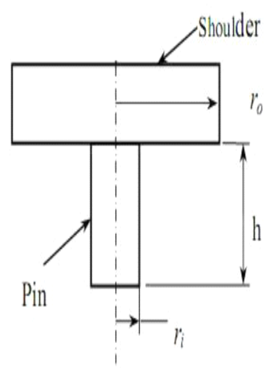


Fig. 5. Nomenclature of Tool

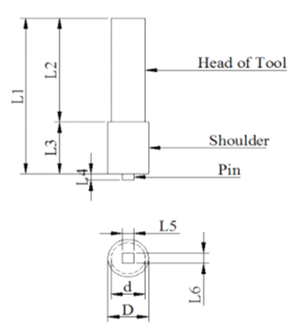


Fig. 6. Design and Specification of Tool.

Table 2: Tool Specifications.

Particular's	Tool Length	Tool Head	Length of Shoulder	Height of Pin	Diameter of Pin	Dia. of Tool Head	Diameter of Shoulder	Tool Material	Hardness of tool material
Index	L1	L2	L3	L4	L5	d	D	H13	60-62 HRC
Value	120mm	50mm	50mm	5.7	6	17	18		

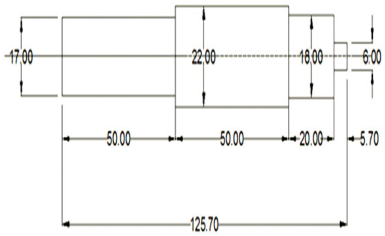


Fig. 7. Dimensions of Tool.

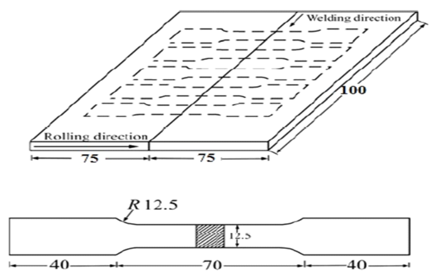


Fig. 8. Dimensions of Work pieces and Test Specimen.

Tool Pin Profiles: The four pin shapes (cylindrical threaded, cylindrical tapered, cylinder-shaped, and square shaped) which are taken for the welding are introduced beneath in Fig. 9 and are used for the experimental work.

Fig. 9. Different Tool Shapes.

Fig. 10. Photo of Welded Joints.

Taguchi's Method

Introduction: Taguchi technique is a factual strategy created by Taguchi and Konishi, (1987) [3]. At first it was created for improving the quality of products fabricated (producing process advancement), later its application was extended to numerous different fields in Engineering, for example, Biotechnology [4] and so forth. Proficient analysts have recognized Taguchi's endeavors particularly in the advancement of plans for examining variety. Accomplishment in accomplishing the ideal outcomes includes a cautious determination of process variables and bi-furcating them into control and noise factors. Determination of control factors must be made with the end goal that it nullifies the impact of noise factors. Taguchi Method includes identification of appropriate control variables to get the ideal outcomes of the process. Orthogonal Arrays (OA) are utilized to direct a lot of tests. Consequences of these tests are utilized to investigate the data and foresee the quality of products created. Here, an endeavor has been made to show the utilization of Taguchi's Method to improve the tensile strength of welded joints that were processed on a friction stir welding machine.

Methods to Product/Process Improvement

Numerous strategies have been created and executed throughout the years to enhance manufacturing processes. Some of the broadly utilized methodologies are as given underneath:

One Factor at a Time: The "one-factor-at-a-time" approach is planned for improvement the process by running an experiment at one specific condition and repeating the experiment by changing some other one factor till the impact of all variables are recorded and analyzed. Obviously, it is a very tedious and costly methodology. In this process, interactions between variables are not considered.

Build-Test-Fix: The "Build-test-fix" is the most primitive approach which is rather inaccurate as the process is carried out according to the resources available, instead of trying to optimize it. In this method the process/product is tested and reworked each time till the results are acceptable

Design of Experiments:

The Design of Experiments is considered as one of the most exhaustive methodology in item/process improvements. It is a factual methodology that endeavors to give prescient information on a complex, multi-variable procedure with scarcely any preliminaries. Following are the significant ways to deal with DOE:

Full Factorial Design: A full factorial analysis is a trial whose structure comprises of at least two factors, each with a discrete conceivable level and whose exploratory units take all possible combinations of all those levels over every single such factor. Such an investigation permits considering the impact of each factor on the reaction variable, just as on the impacts of interactions between variables on the response variable. A common experimental design is the one with all input variables set at two levels each. On the off chance that there are k factors each at 2 levels; a full factorial plan has 2k runs. Hence for 6 variables at two levels it would take 64 preliminary runs. So it is not generally practical for five or more factors because number of experiments doubles sequentially with addition of each factor.

Taguchi Method: The Full Factorial Design requires an enormous number of trials to be completed as expressed previously. It gets difficult and complex, if the number of variables increment. To defeat this issue Taguchi recommended an uncommonly planned technique called the use of orthogonal array to examine the whole parameters space with lesser number of tests to be conducted. Taguchi therefore, suggests the loss function to quantify the performance qualities that are deviating from the ideal objective worth. The value of this loss function is further converted into signal-to-noise (S/N) proportion. Generally, there are three classes of the performance characteristics to examine the S/N proportion. They are: nominal the-best, bigger the-better, and smaller-the-better

Analysis of Variance: Analysis of Variance is a numerical technique for characterizing the level of distinction or similitude between at least two bunches of information. This strategy is focused on the evaluation of the normal estimation of shared segments. The rate contribution of a few process factors to the assigned performance characteristic can be evaluated by ANOVA. A logarithmic change of mean square deviation recommended by Taguchi is called signal-to-noise proportion (S/N proportion) for investigation of the outcomes. To gauge the deviation of quality characteristic from the objective, the Signal-to-noise proportion is utilized. In this examination" so as to maximize the responses, the S/N proportion was chosen by the guideline, the "larger-the better [5].

To obtain the objectives for all the responses, the S/N proportion for the “larger-the-better” was considered as follows. The condition Larger the better is utilized for registering S/N proportion as given underneath.

$$(S / N)LB = -10 \log [1/n \sum \{1/yi2\}] \quad (1)$$

Where n is the quantity of tests (for one lot of factors n=1) and Yi is the reaction for ith test [6]. The test results were changed over into signal-to-noise (S/N) proportion utilizing programming Minitab 18. The estimations of tensile strength are controlled by ascertaining the S/N proportion estimations of all levels as introduced in Table 3. The plots for mean and S/N proportion of tensile strength, is appeared in Fig. 11. Bigger S/N proportion matches to prevalent quality highlights. Henceforth, the ideal degree of methodology variable is the degree of most extreme S/N. proportion.

Two Sample t-tests: T-test is utilized to look at tests or reactions from two separate gatherings which have a place with various populaces [7, 4]. It as certain that the derived samples could have been arisen due to sampling fluctuations from some value that has been given in advance.

T- Distribution is utilized for little example size for example at the point when test size is either 30 or less, at that point t - test is applied to it (http/www. 2SampleT.aspx) [8]. It works on following assumptions

Samples in each gathering are autonomous of tests having a place with some other gathering.

The population from which the samples are drawn must be a normally distributed population.

In this manner, t - test is a measurable theory test in which test insights follows a methodology to test a provided speculation so as to decide if two arrangements of information are altogether not quite the same as one another or not (http://en.wikipedia.org/wiki/Student's_t-test) [9].

III. RESULTS AND DISCUSSIONS

Investigational Outcomes: According to the design network, The sixteen tests were led, with their four process variables and four levels, and Testing Results of Experiments with Responses (Means and S/N proportion), as introduced in Table 3.

Table 3: Testing Outcomes of Experiments with Responses (Means and S/N ratio).

Exp. No.	SH	WS	TA	RS	TS	SNRA1	MEAN1
1.	SQ	30	0.5	1200	125.9	42.00	125.9
2.	SQ	50	0.0	1540	135.6	42.64	135.6
3.	SQ	40	1.5	1950	131.3	42.36	131.3
4.	SQ	60	2.0	2300	127.0	42.07	127.0
5.	TC	60	0.0	1200	119.6	41.55	119.6
6.	TC	40	0.5	1540	138.5	42.82	138.5
7.	TC	50	2.0	1950	132.0	42.41	132.0
8.	TC	30	1.5	2300	124.5	41.90	124.5
9.	SC	50	1.5	1200	127.2	42.08	127.2
10.	SC	30	2.0	1540	133.0	42.47	133.0
11.	SC	60	0.5	1950	129.1	42.21	129.1
12.	SC	40	0.0	2300	120.1	41.59	120.1
13.	THC	40	2.0	1200	124	41.86	124.0
14.	THC	60	1.5	1540	136.1	42.67	136.1
15.	THC	30	0.0	1950	123.9	41.86	123.9
16.	THC	50	0.5	2300	128.5	42.17	128.5

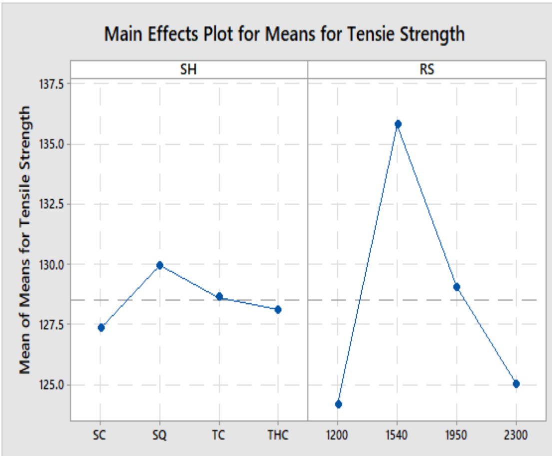


Fig. 11. Main Effects Plots (Means) for Tensile Strength.

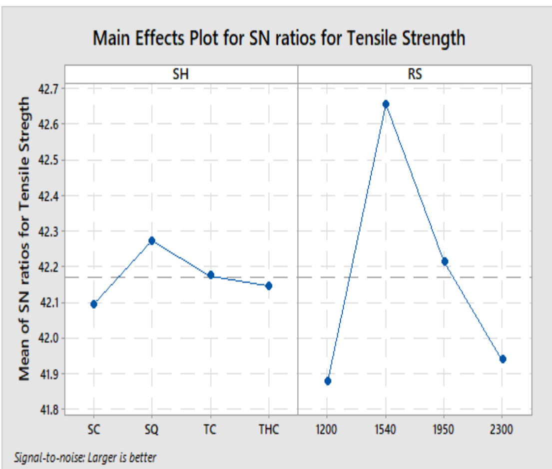


Fig. 12. Plots for (S/N Ratio) versus Tensile Strength.

Table 4: Responses for Signal to Noise Ratios of Tensile Strength.

Level	RS	WS	TA	SH
1	41.88	42.06	41.91	42.09
2	42.66	42.16	42.31	42.27
3	42.21	42.33	42.26	42.17
4	41.94	42.13	42.21	42.15
Delta	0.78	0.27	0.39	0.18
Rank	1	3	2	4

Table 5: Responses for Means of Tensile Strength.

Level	RS	WS	TA	SH
1	124.2	126.8	124.8	127.3
2	135.8	128.5	130.5	129.9
3	129.1	130.8	129.8	128.7
4	125.0	127.9	129.0	128.1
Delta	11.6	4.0	5.7	2.6
Rank	1	3	2	4

Impact of Tool Rotatory Speed on Tensile Strength: Rotatory pace gives off an impact of being the most extreme significant input parameter as it will in general impact the translational speed. Greater tool rotatory paces are caused in a more prominent heat and lesser quenching rate in the welding processing area afterward welding. An upper rotatory pace reasons over the top appearance of mixed materials to the top territory, which resultantly produced pores produced in nugget section [10]. Lesser heat produced because of lesser rotatory pace caused in absence of mixing. The territory of the nugget zone decreases with and lessening the tool rotatory pace and impact the temperature dispersion in the nugget section. As the rotatory pace builds, the stressed area broadens, and the area of the greatest strain at long last travels to the propelling sideways from the first withdrawing adjacent of the joint. It demonstrates the break area of the joint is additionally influenced by the rotatory pace [11]. The Tensile strength of the nugget zone masterminded with different process variables combinations brought about most minimal tensile strength at rotator pace for a given transverse pace.

As the rotatory pace expanded from 1200 to 1540rpm, the tensile strength improved, arriving at a greatest value of tensile strength at 1540rpm a fore dropping over at great rotatory paces of 1950 rpm and 2300rpm. At tool rotary pace of 1200 rpm, the tensile strength was obtained as 124.2 MPa followed by 135.5 MPa as the tool rotatory pace was expended up to 1540 rpm. Be that as it may, there were, nonetheless, clashing results acquired as the tool rotatory pace was additionally expanded, the tensile strength of the weld joint diminished and arrived at 125 MPa at the tool rotatory pace of 2300 rpm.

At the lower tool rotatory pace of 1200 rpm, heat input was low. Because of this there was poor plastic progression of the metal bringing about arrangement of sharp interface between the SZ and TMAZ (Expt. No. 1-4). This more honed interface causes a bungle among WN and the TMAZ of advancing side which was the failure location of tensile specimens. Also, because of the lower tool rotatory pace coarse grains and imperfections in the SZ are seen in the micrographs. (Expt. No. 1-4). In this way, these might be the reasons of lower tensile strength at lower tool rotatory pace.

Hirata *et al.,* (2007) [12] reported the influences of welding variables on the grain size of friction stir welded aluminium alloy 5083. At the point when the tool rotatory pace expended from 1200 rpm to 1540 rpm, there was increment in the warmth input. Besides, there was sufficient plastic deformation of which restrains the arrangement of sharp interface among SZ and TMAZ. Moreover, development of fine grains of normal grain happens in the stir zone because of adequate warmth input and these outcomes in upgrade of the tensile strength of the joint. So these were the causes behind higher tensile strength of the joints welded at tool rotating pace of 1540 rpm. Further increment in the tool rotating pace, from 1540 rpm to 2300 rpm, prompted higher warmth input bringing about moderate cooling rate.

Tang *et al.*, (1998) [13] investigated the effect of weld pressure and tool rotation rate on the temperature field of the weld zone. Also, the moderate cooling rate gives abundant opportunity to the grains to develop in the stir zone and HAZ).This was supported by the SEM micrographs showing welding imperfections (Table Epxt. No. 13-16). It might be the explanation of low tensile strength of the joint welded at upper tool rotary pace (2300 rpm).

Siva Rama Krishna *et al.,* (2013) [14] also reported the Optimization of Process Variables of Friction Stirs Welding of Aluminum Alloys (6061) Using Taguchi Method. When the tool rotary pace is 1000rpm, the tensile strength is found 108 Mpa, at 1200 rpm the tensile strength is found 151 Mpa and at 1400rpm the tensile strength is found 116 Mpa. This is obvious that, in friction stir welding, as the rotatory pace rises, the warmth produced likewise increments. This marvel can be portrayed by the accompanying two causes: first, the coefficient of friction diminishes when a neighbourhood soften happens, and consequently drops when a heat increases; furthermore, the idle warmth retains some warmth input. It has spoken that at high rotatory paces, second stage particles would persevere through more cracks and prompts disconnection of particles in various zone of the TMAZ [14]. As the rotatory pace is diminishes, and the hotness inside the piece gets lesser and the volume division of rough grain particles increments. "The weld joint produced at a tool rotatory pace of 900 rpm have been found to possess lower tensile strength compared to the joints fabricated at a tool rotatory pace of 1400 rpm. The weld joint fabricated at a rotatory pace of 1800 rpm have been found to possess lower tensile strength properties compared to the joints fabricated at a rotatory pace of 1400 rpm. [16]". The weld joint fabricated at a tool rotatory pace of 1000 rpm have been found to possess lower tensile strength of 118 Mpa compared to the joints fabricated at a tool rotatory pace of 1200 rpm having tensile strength 151 Mpa The weld joint fabricated at a rotatory pace of 1400 rpm have been found to possess lower tensile strength of 114 Mpa [17].

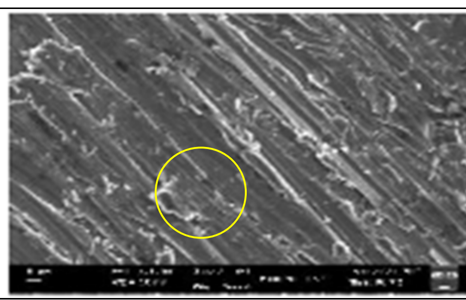
Henceforth, the rotatory pace need be streamlined to acquire nugget area with acceptable grain size consistently conveyed all through the welding. Among out of four various rotatory paces, the welding made-up at a rotatory pace of 1540 rpm, with square pin profile revealed good tensile strength, independent of other pin shapes. The solidified effect of higher number of throbbing blending activity during metal stream and a perfect tool rotatory pace may be the reason for better tensile properties and better microstructure at the welding zone of the joint made at a rotatory speed of 1540 rpm utilizing square probe tool as showed up in Fig. 11 and 12.

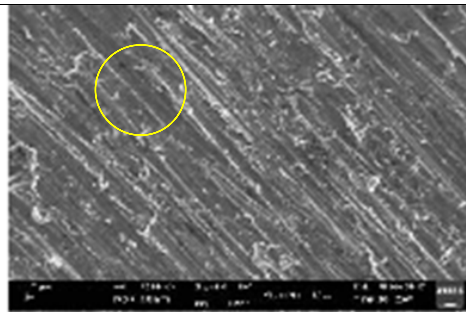
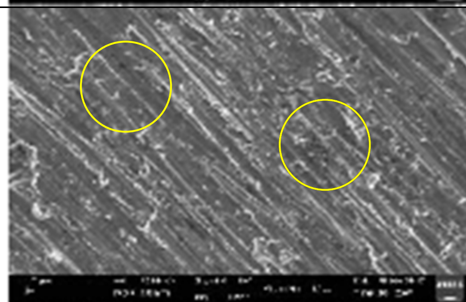
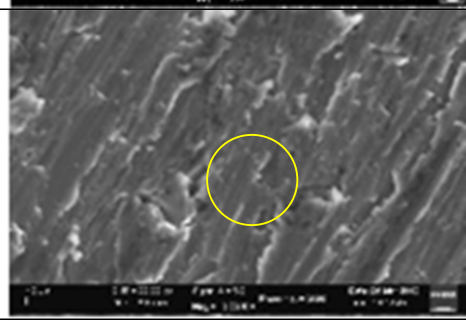
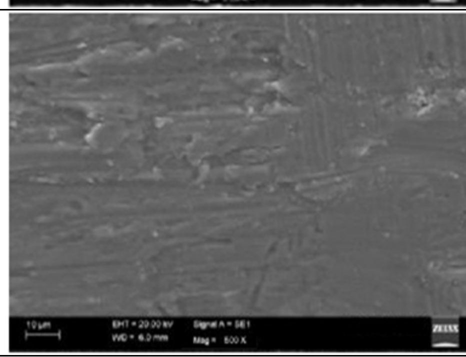
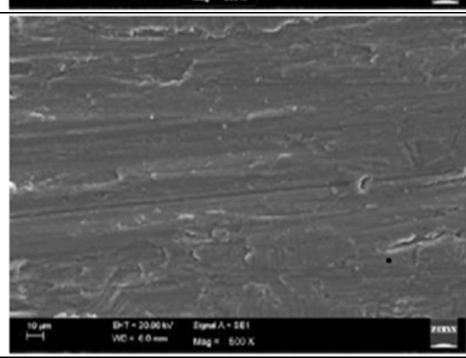
Impact of Tool Pin Shape on Tensile Strength: The principle capacity of the non-consumable tool pin is to blend the plasticized material and travel a similar material behindhand it to have great weld. Probe shape assumes a fundamental job in metal stream and thusly manages the transverse velocity of the welding procedure. The joints are portrayed by all around characterized joint piece and stream structures, nearly sphere-shaped in contour; these shapes are subject to the probe profile, process variables and procedure settings utilized [18]. It is recognized that the job of probe pin in the welding, the probe pin is to shear the material to its back during translation of the mechanical assembly and the installed probe pin brings the material at the different sides of the joint line to the plastic state, helped by frictional warmth contribution of the shoulder [19]. As the rotatory speed expanded from 1200rpm to 1540rpm, the tensile strength improved, getting a supreme value of tensile strength at 1540 rpm before falling again at high rotatory speeds of1950rpm and 2300rpm.The same patterns were trailed by three other probe profiled tool.

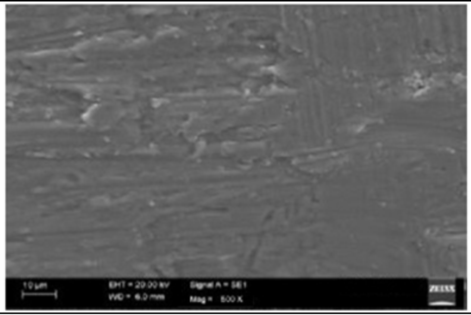
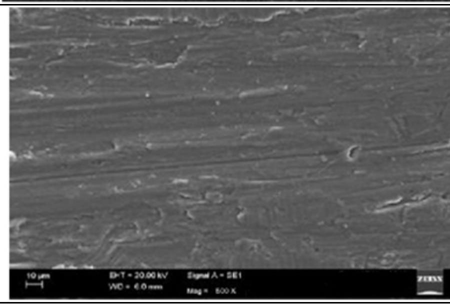
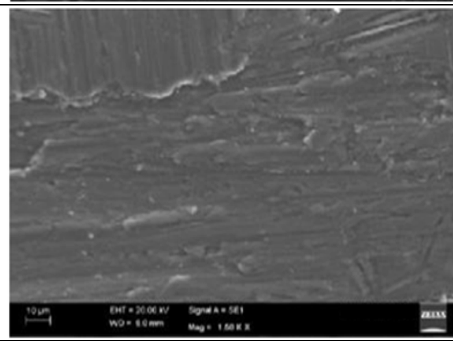
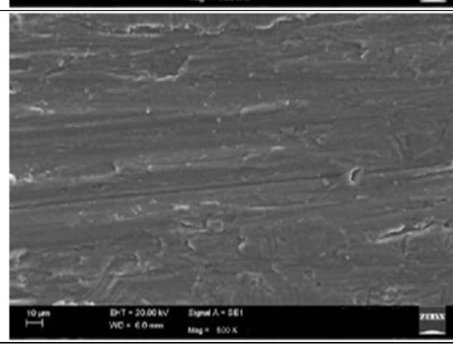
Fig. 11 and 12 displays the influence of probe shape on tensile strength of welding joints. Amongst the four probes, the joints created by square probe tool showing most noteworthy tensile strength regardless of process variables. Following to square probe profile, tapered cylindrical probe tool displaying some less tensile properties to that of square probe trailed by remaining two probe profiled tool. 'Tensile property of the joints have been estimated and associated with the nugget zone formation. From this study it is shown that the square pin profiled tools created mechanically rigorous and metallurgical imperfect welds compared to the other tool pin profiles [20]'.

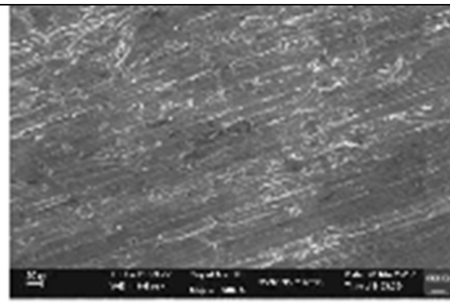
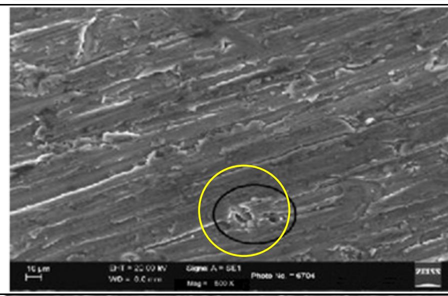
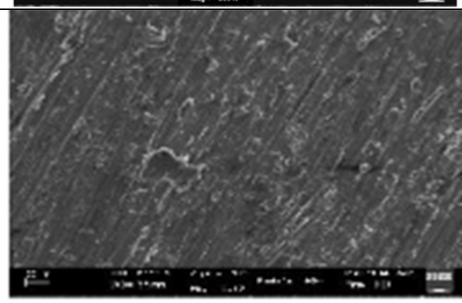
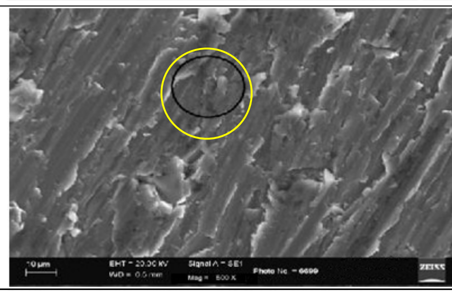
Metallography Investigation: The Investigation of weld statement at weld nugget region of welding joints of AA6105 has been carried out by employing a Scanning Electronic Microscope. The SEM photos of the joints at various runs of test at amplification of 500X are appeared in the accompanying Fig. 14.

Table 6: SEM Observations and Probable Reasons.

Expt. No.	Parameters	Micrographs	Observations and Probable Reasons
1	RS=1200 WS=40 TA=2^o SH=THC		Tunnel defect. Insufficient heat generation and improper stirring.

2	RS=1200 WS=60 TA=0^0 SH=TC		Small tunnel defect. Inadequate heat input and poor recrystallization.
3	RS=1200 WS=50 TA=1.5^o SH=SC		Rough surface and small tunnel flaws. Extra heat input and inadequate metallictransference.
4	RS=1200 WS=30 TA=0.5^o SH=SQ		Rough Surface. Improper Mixing of recrystallized material
5	RS=1540 WS=40 TA=0.5^o SH=TC		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains
6	RS=1540 WS=60 TA=1.5^o SH=THC		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains

7	RS=1540 WS=50 TA=0.0^{o} SH=SQ		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains
8	RS=1540 WS=30 TA=2.0^{o} SH=SC		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains
9	RS=1950 WS=40 TA=1.5^{o} SH=SQ		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains
10	RS=1950 WS=50 TA=0.5^{o} SH=SC		No defect. Sufficient heat generation and proper recrystallization of coarse grain into fine grains
11	RS=1950 WS=60 TA=2.0^{o} SH=TC		Small Tunnel defect Inadequate heat generation due to high welding speed and tilt angle

12	RS=1950 WS=30 TA=0.0^{o} SH=THC		No defect. Sufficient heat generation
13	RS=2300 WS=40 TA=0.0^{o} SH=SC		Worm hole. Extreme heat input and thinning of weld zone
14	RS=2300 WS=60 TA=2.0^{o} SH=SQ		No defect. Sufficient heat generation
15	RS=2300 WS=50 TA=0.5^{o} SH=THC		Pin hole defect and rough surface. Extreme heat produced due to tempering and work toughening.
16	RS=2300 WS=30 TA=1.5^{o} SH=TC		Worm hole and excessive flash of material. Excessive heat generation and thinning of weld zone due greater rotatory speed and lesser transverse feed.

From the SEM Photographs of Experiments no. 1, 2, 3 and 4, rough surface and tunnel defects has been watched.
From the SEM Photographs of Experiments no. 5-9, clearly no voids, cracks are seen in the structure and no imperfections have been found. The structure is fine and same all through on account of better weld quality and the uniform metal stream has been seen along the Joint Line for Experiments no. 5-9.
The SEM Photographs Experiments no. 10 has indicated irregular surface and small tunnel flaws.
The SEM Photographs of Experiments no. 11 has indicated that small tunnels are observed in the structure.
The SEM Photographs Experiments no. 12 has been indicating no deformities.
The SEM Photographs Experiments no. 13 has been demonstrating worm defects.
The SEM Photographs Experiments no. 14 has been showing no flaws.
From the SEM Photographs of Experiments no.15, pin opening and unpleasant surface imperfections have been watched.

From the SEM Photographs of Experiments no. 16, worm hole and rough surface flaws have been observed.

Verification of Optimization for Tensile Strength

Table 7: Results of Pilot Runs and Experimental at Optimized Settings and Random Settings for T.S.

Experiments Runs	T S at Optimized settings	T S at random settings
1	139	124
2	140	119.6
3	142	127.2
4	141	125.9
5	148	138.5
6	146	136.1
7	145	135.6
8	144	133
9	142	131.3
10	138	129.1
11	142	132
12	136	123.9
13	138	120.1
14	142	127
15	140	128.5
16	139	124.5

Two-Sample t-Test and CI: T.S. at O.S., T.S. at R.S. Method

μ_1: average of T.S. at O.S.

μ_2: average of T.S. at R.S.

Variance: μ_1 - μ_2

Equivalent Variances are not accepted for this examination.

Table 8: Descriptive Statistics of TS.

Sample	N	Mean	Std.Dev	SE Mean
T.S. at O.S.	16	141.38	3.20	0.80
T.S. at R.S.	16	128.52	5.58	1.4

Table 9: Estimation of Difference for TS

Difference	95% CI for Difference
12.86	(9.53, 16.18)

Hypothesistest

Null hypothesis

H_n: μ_1 - μ_2 = 0

Alternate hypothesis Ha: μ_1 - $\mu_2 \neq 0$

t-value	degree of freedom	p-value
8.00	23	0.000

In the first place, consider the distinction in the sample means and afterward look at the confidence interval.

The assessment for change is an assessment of the distinction in the populace means. Since this value depends on test data and not in whole populace, it is improbable that the test data difference equals the populace difference. To improved assessment the populace fluctuation, utilize the confidence interval for the difference.

The confidence interval gives a choice of expected values for the difference between two populace means. For a case, a 95% certainty level determines that in the event that you take 100 self-assertive examples from the populace, you could assume right around 95 of the examples to deliver interims that contain the populace contrast.

In these outcomes, the assessment of the difference in populace means for the samples is 12.86. So, we can be 95% confidence level that the variance in populace means is between 9.53 and 16.18

p-value ≤ α: The variance among the methods is factually significant (Discard H_n).

The p-value is lower than the importance value (p=.000), which is less than the importance level of 0.05; the judgement is to discard the null postulate and result that the outcomes of OS and RS are different. We can reason that the distinction between the populace implies is factually noteworthy. So accept the alternative hypothesis.

IV. CONCLUSIONS

The current work concentrates around the results of test examinations on welding joints of AA 6105. The tensile properties and variations in the microstructure of AA 6105 alloy of friction stir weld joints were considered with several factors. An effort is made to relate the mechanical properties attained experimentally with the Taguchi Technique to forecast the properties. The important tends from current experimental study, which might be shortened, are as per the following.

From four unique tools pin profiles, the square tool pin profile have capable moving of the material and successful putting the metal in the depression made in the welding technique.

At tool rotatory speed of 1540rpm, no macrostructure flaws have been seen in the welds.

Tensile strength of the welds increment with increment in rotatory pace and arrives at maximum at 1540rpm, however again decrements with additional increment in rotatory pace.

The tensile strength attained at rotatory pace of 1200rpm, was 124MPa, extended 139MPa as the tool rotatory speed was expanded up to 1540rpm, and afterward diminished to 125MPa at the tool rotatory speed of 2300rpm.

Microstructure of the nugget area appearances the fine grains anyway in the base metal grains was stretched.

Rotatory pace was seen to be the utmost dominant factorin fluencing mechanical and metallurgical properties of AA 6105welds.

The influence of rotatory pace and tool probe profile on the creation of the deformity free nugget section has been investigated in detail with the assistance of microstructure, tensile properties and SEM analysis. The welding parameter combinations for producing flawless welds have been set up for AA 6105.

V. FUTURE SCOPE

Impact of other process parameters like axial force, tool material, tool geometry etc. may be studied. Different design of the tool could be used to investigate the effect of the tool design like D/d Ratio, Pin Height, Plunge depth and other Pin profiles etc. The study could be extended to lap joints and investigated in the same way

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