A Study on The Application of The Taguchi Method on Piston & Hydraulic System

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Abstract- The present study is Associate in Nursing experimental investigation to check result of vital friction stir welding (FSW) process parameters on hardness of surface changed 60/40brassplates, to optimize these parameters and to work out that of them is critical by exploitation Response surface methodology and Taguchi optimization method. Experimental work was done out to provide completely various levels of method parameters; friction stir welding joints were generated. tool rotation speed, Tool travel speed and range of passes. Tool rotation speed is varied at 3 levels (710,1000 and 1400 rpm), whereas tool travel speed is varied at 3 levels (20,28 and 40 mm/min). Tool angle and plunge depth area unit's unbroken constant. Optimum combination of method parameters setting is found: tool rotation speed of one thousand rate, tool travel speed of twenty mm/min & two No. of passes.(Tool motion speed, traverse speed, pin profile (based on taper angle), the quantitative relation between shoulder diameter (D) and pin diameter(d) (D/d ratio), tool angle, plunge depth, and base metal location.

Keywords- brass plates, Quadratic regression model, Input Parameters, Friction stir welding, Response Surface Methodology.

I. INTRODUCTION

Wayne Thomas invented friction stir welding (FSW) at TWI (The Welding Institute) in the Gregorian calendar month of 1991. "Friction stir welding (FSW)" is a newly designed solid phase joining technology that is both energy efficient and flexible. FSW has been a solid- state connection technology that generates high-quality, high-strength joints with minimum distortion since its introduction in 1991 by "The Welding Institute (TWI)",UK [1,2], and it's capable of constructing either butt or lap joints in a wide range of fabric thicknesses and lengths. Because FSW is a solid-state technology, it eliminates various fusion welding flaws such as shrinkage, hardening cracking, and body. Friction stir welding (FSW) has been utilized to weld a variety of alloys such as Al [1–6], Mg [7, 8], and Cu [1, 9–12] alloys, which are categorized as largely unwieldable material in traditional welding strategies such as fusion welding by a number of

global organizations. However, earlier studies on FSW focused on lap or butt welding of flat-surface plates, and only a small number of inquiries looked at FSW technique methodology for connection pipes.
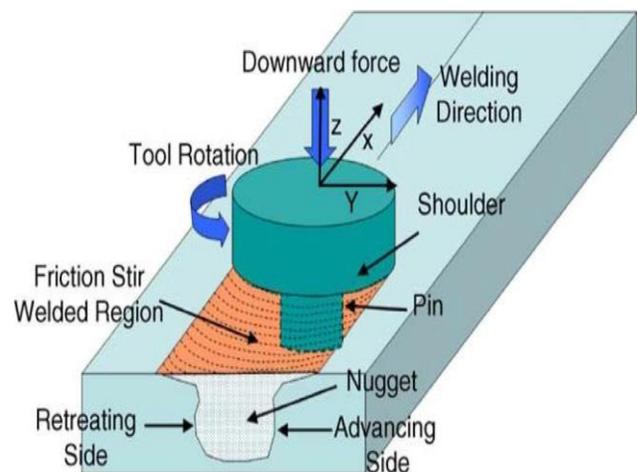

Fig.1. Illustrative representation of FSW [4]

Principle of FSW Technique

Friction Stir welding is a solid-state welding procedure that involves rotating a cylindrically shaped shouldered tool on the surface of the workpiece to be connected. The workpiece is firmly fastened in the fixture of the FSW machine, and an axial force is applied to the welding surface as the tool rotates. The workpiece is plasticized due to the development of heat and friction when anon-consumable tool is used to unite workpieces without melting them during the welding process.

FSW is based on a simple concept: a non-consumable rotating tool with a specifically designed pin and shoulder is inserted into the a butting edges of the two pieces to be connected and traversed along the joint line.

FSW PROCESS

The microstructure, which is determined by the FSW process, determines the characteristics and performance of

FSW joints. Changing the welding settings can usually vary the FSW process. As a result, welding parameters must be chosen to provide the best microstructure feasible. In addition, a thorough understanding of the FSW process is required for accurate prediction of weld size, final microstructure, and mechanical properties of FSW joints. It is quite difficult to acquire insight into the joint during the actual forming process due to the complexity of the FSW process. By providing an effective technique of assessing the creation of FSW joints, numerical simulation aids in the solution of this problem [7].

A butt weld is an FSW setup in which the tool is inserted between the edges of two sheets and traverses along the joint. The key influences on the FSW process are listed below. (Ying Li, 1999) (T. Debroy and H. K. D. H. Bhadeshia, 2010) (L.V. Kamble, 2012)

− Spindle speed (rpm)
− Welding speed (mm/s)
− Axial force (N)
− Material thickness (mm)
− Spindle Speed

The material around the tool pin is mixed and fricative heat is produced by the rotating speed. To make sound joints with fine recrystallized grains, optimal mixing and sufficient heat generation are required. This has a greater wear resistance. Increased tool rotating speed leads to an increase in fricative heat obstetrics. Reduced tool rotating rates and a lack of mixing result in a lower heat input condition. As a result, material consolidation is inadequate, resulting in poor wear resistance at lower tool rotational rates. High tool rotating speeds result in more heat creation than is necessary, as well as the discharge of surplus mixed materials. Grain roughening occurs at high tool rotational rates, resulting in poor wear resistance .Furthermore, tool rotational speed affects temperature distribution, which may contribute to this trend(R.Rai,2011).

II. LITERATURE REVIEW

The impact of these parameters just on mechanical properties and microstructures of welds has been studied by several researchers [6–9]. Optimization of these factors becomes critical in order to save time and money on trials while also obtaining high-quality welds. Various approaches of improving these characteristics have been used by researchers [10,11]. The Taguchi technique is one of the most well-known, and it has seen a lot of use in optimizations. Taguchi is a method for designing and analyzing experimental results for quality criteria in a methodical way. There have been numerous studies on the Taguchi optimization technique in FSW.

S. Jambulingam [12] the chosen materials were AA7075 and AA3014, which were bonded using friction stir welding. Nine trials were carried out at various speeds, feed rates, and axial forces. Experiments were designed using the Taguchi approach. He discovered that the best settings were 1200rpm,10mm/min feed ,and a cylindrical tool profile.

Shaikh and Chouhan [20] The materials utilized were AA6061 T6 and AA2024 T0. To optimize the experiment, the Taguchi approach based on L9 orthogonal array was used. To determine hardness, as well as tensile and yield stress, a Vickers hardness tester is employed. The optimization analysis was carried out using MINITAB. Friction stir welding of dissimilar metals is problematic because to the differing heat co-efficient and chemical compositions of the base metals. Welding factors such as rotating speed, spindle speed, axial force, and tilt angle are all important in improving weld quality.

Pradeep and Muthukumaran [21] utilized a tool with a 0.4 mm clearance conical pin The Taguchi approach was used to optimize process parameters. Three process parameters, tool rotational speed, tool tilt angle, and travel speed, were used to design the experiments. As a response, tensile strength was applied. A conical shorter pin tool produced improved weld strength at a lower travel speed, and it also helps to reduce tool wear by using less tool material.

Jawdat A. and Al-Jarrah [22] Worked for optimization of FSW Parameters for Joining Aluminum Alloys Using RSM. He used aluminum alloy sheets with thicknesses of 4, 5, 6,7and 8 mm were Butt jointed. High carbon steel used as tool material with flat cylindrical shoulder diameters of 18,21,24,27 and 30mm.

Rotational speed range used were 400,700,1000, 13000 and 1600 rpm. And welding speed range used 0.5, 1.0, 1.5, 2.0 and 2.5 mm/sec.it was found that a general result for a plate thickness of 6 mm, the best combination to have maximum yield strength is 1000 rpm rotational speed with 1.5 mm/sec welding speed and a shoulder diameter of 24 mm. This experiment results defect free joints though, the superiority of welded joints depends on controlling the rotation speed with welding speed to fill up the cavity behind the pin when moving forward.

Gupta et al. (Gupta et al. 2018) [24] the chosen materials were AA7075 and AA3014, which were bonded using friction stir welding. Nine trials were carried out at various speeds, feed rate, and axial forces. Experiments were designed using the Taguchi approach. He discovered that the best settings were 1200 rpm, 10 mm/min feed, and a cylindrical tool profile.

Wakchaure et al. (Wakchaure et al. 2018) [25] to join the 6082-T6 aluminum metal, using friction stir welding parameters were combined using the Taguchi-Grey relation analysis-ANN approach. They demonstrated the viability of using ANN-GRA in conjunction with Taguchi to improve joint strength.

Pandiyarajanetal. (Pandiyarajanetal.2019) [26] FSW process parameters were optimized using the desirability technique. He was able to improve the process settings for AA6061-ZrO2-C composites to achieve optimal weld strength and nugget hardness. Optimization of milling was also carried out in a similar manner.

III. METHODOLOGY

In summary, the review of response surface methodology in Friction Stir Welding focusing on 60/40 brass plates has been successfully conducted. This will provide a comprehensive insight for the current and also provide the current state of research on response surface methodology in friction stir welding to 60/40 brass plates in order to fill the gaps with new research approaches and ideas. Furthermore, new studies on response surface methodology in Friction Stir Welding to 60/40 brass plates with respect to the selection of cost effective FSW tools and process optimization to produce sound welds still need to be developed.

SELECTION OF MATERIALS

Friction stir processing was carried out (fig.3.1) on 7 mm thick 60/40 Brass (UNS C28000 -Muntz metal) plates on BATLIBOI make BVF-5 Vertical Milling Machine. Chemical composition & mechanical properties of 60/40 brass are given in Table 3 and Table 4 respectively. An EN-8 hot worked tool steel made FSP tool was used. The design and drawing of FSP tool utilized in the present work is shown in Fig.3.1. The shoulder undersurface was diamond knurled concave surface (50), to allow the material to flow back to the stir zone. The probe was cylindrical threaded tool. The tool was shaped by machining to final geometry. The hardness of tool was 48 HRC after heat-treatment. For all 9 experimental runs a dwell time of 60 seconds & the tool tilt angle of 0° was maintained. The tool was traversed along the length of the plate with a constant plunge depth of 0.2 mm for each pass. Standard Rockwell hardness tests were carried out on friction stir processed 60/40 brass plates. For hardness testing a Casteel make NOBLEALZ-B-250 Rockwell hardness tester was used Standard Rockwell B-scale, with standard tool steel ball indenter (ϕ 1/16" ~1.6 mm) and a load of 100 kg. was used. Three readings were taken for each friction stir processed plate

&average of the same was reported for calculation of mean & further analysis.
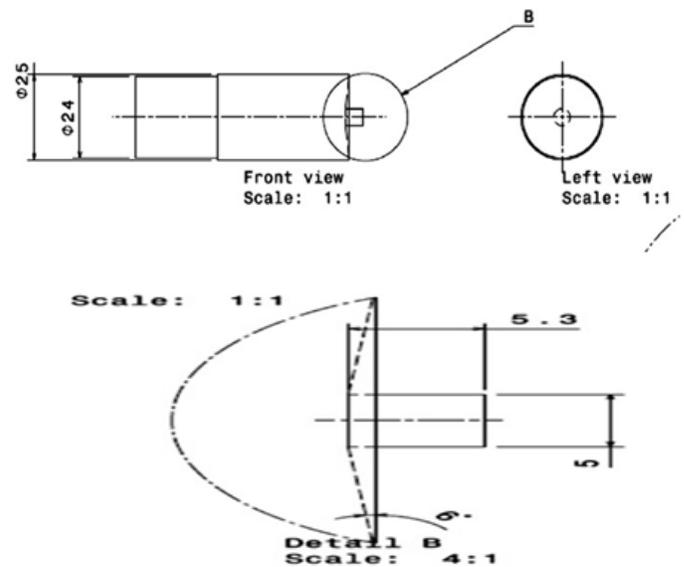

Fig.3.1Friction Stir Processing (FSP)

Fig.3.2Tool Design [42]

Taguchi Method:

Also called the robust design method; pioneered by Dr. Genichi Taguchi in 1940s, greatly improves engineering productivity. This method is one of the most powerful methods available to reduce product cost, improve quality, and to reduce development interval. A large number of experimental works has been done when the process parameters are increased along with their levels. To solve this, Taguchi method is used with a design of orthogonal arrays to study all parameters. He proposed optimization in three steps: system design, parametric design and tolerance design.

Solve this problem; the Taguchi technique uses a special style of orthogonal arrays to review the whole parameter space with only small range of experiments. The best advantage of this technique is to avoid wasting the trouble in acting experiments: to avoid wasting the experimental time,

to cut back the price, and to find out significance factors quick.[17]

Taguchi strong style technique may be a most powerful tool for the look of a high-quality system. He considers 3 steps during a process's and product's development: system style, parameter style, and tolerance style. In system style, the engineer uses scientific and engineering principles to work out the basic configuration. Within the parameter style step, the precise values for system parameters square measure determined. Tolerance style is employed to work out the simplest tolerances for the parameters.

Analysis of variance (ANOVA)

Analysis of variance (ANOVA)is a statistical method for determining the existence of differences among statistical method for determining the existence of differences among several population means? While the aim of ANOVA is the detect differences among several populations means,the technique requires the analysis of different forms of variance associated with the random samples under study-hence the name analysis of variance.

Analysis of variance was developed by the English Statistician Sir Ronald A. Fisher during the first part of this century. Much of the early work in this area dealt with agricultural experiments where crops were given different treatments, such as being grown using different kinds of fertilizers. The researchers wanted to determine whether all treatments under study were equally effective or whether some treatments were better than others[16].

ANOVA is used to determine the influence of any given process parameters from a series of experimental results by design of experiments, and it can be used to interpret experimental data.

S/N Ratio Analysis

Signal-to-noise compares the level of a desired signal to the extent of background signal. It's the magnitude relation of signal power to the noise power, typically expressed in decibels. The Taguchi methodology uses a loss perform to workout the standard characteristics. Loss function values also regenerate to a {signal-to-noise(S/N) signal-to-noise magnitude relation signal/noise ratio signal/noise(S/N ratio) (S/N) ratio (η). In general, there are 3 totally different quality characteristics in S/N magnitude relation analysis, particularly "Nominal is that the best", "Larger is that the better" and "Smaller is that the better", for every level of process

parameters, S/N is calculated supported S/N analysis. The best level of the method parameters are that the level having highest S/N magnitude relation.

Loss operate is to work out the standard characteristics utilized by Taguchi technique. Loss operate values also are regenerate toa signal-to-noise (S/N) ratio η. The term "signal "represents the fascinating price (mean) for output characteristic and also the term "noise "represents the undesirable price for the output characteristic. There square measure 3 classes of the performance characteristics within the analysis of the S/N magnitude relation, i.e., lower-the-better, nominal-the-better and higher-the-better. The S/N magnitude relation for every level of method parameters relies on the S/N analysis performed on MINITAB seventeen. The optimum levels of the method parameters are that the level having highest S/N magnitude relation.

IV. RESULT AND DISCUSSION-

RESPONSE SURFACE METHODOLOGY OF EXPERIMENT

It's commonly used in the industry because it's the most effective technique for meeting welding requirements. This research looked at how to prepare low-cost goods and how to improve welding defects so that they work properly. This type of technique is commonly used to minimize costs and increase product quality, and it logs as functions of desired performance. Via rigorous design of experiments, the approach and variance in a process are minimized to aid in data interpretation and prediction of optimal outcomes. The following are the key RSM objective sand measures for the parameter design phase:

i.   First, to set the objective for the overall experiment with the proper displacement.
ii. Output response will be identified with the proper measurements.
iii. Factors should be considered that affect the output response with the given level sand the interactions.
iv. The array should be set with the tests of experiments conducted on O.A.
v.   To reduce the noise variance and the significance of process parameters full analysis for the sets off actors be formed with the defined array.
vi. Final set of optimal design parameters will be used to conduct confirmatory experiments.

The new optimization for welding speeds and currents with their proper gas shielding effect is discovered after a thorough analysis. In pulsed Stir welding, response

surface methodology is used to adjust the weld for base metal dilution. With the same procedure the advantages for the results & their optimization for the reduced hot cracking sensitivity, reduced width of heat-affected zone (HAZ) and reduced residual stress with the proposed reports are observed in the previous study. To make certain changes to previous systems, it is really to know the exact picture behind the new scenario. So, gap analysis formed and the review of papers taken for the existing systems and their gap, which are as in next chapter.

Numerical optimization

The purpose of this research is to find the best parametric settings to achieve maximum impact strength of welded specimens at the same time, which is ideal for good welded joint efficiency. The desirability analysis is used to determine the best parametric setting to obtain the absolute Hardness of the welded specimens. The Stir welding process is optimized using the Minitab18 program. The common steps and procedures that are followed in the Minitab software are described in detail here. The results of multi-objective optimization for Hardness are shown in fig. 7. Optimal Hardness: and 85.3333 (J) has been obtained at(a) Tool Rotation Speed (rpm) A2 1000 rpm (b) Tool Travel Speed (mm/min), B1 20 mm/min (c) No. of passes B2 The mixed desirability factor D has a value of 1.000.
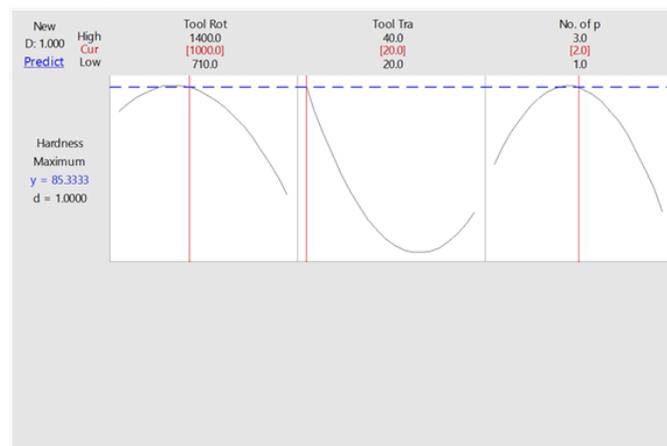

Fig.4.1 Optimization results of Hardness by RSM

Confirmation test

The optimization results obtained have been validated by performing confirmatory experiments. Table 4.1 represents the results of confirmatory tests that are conducted in optimal conditions. It is seen from the table that the error in terms of percentage between the estimated and experimental results is very small and is less than 1%. This indicates that the optimized Stir welding process parameters higher NTS and

UTS of Brass can be obtained. Three fresh experiments are conducted for confirmation of models Eqs. (3) And (4), with achieved optimal values of cutting parameters. The average of measured values for Tool Rotation Speed(rpm) A 21000rpm (b) Tool Travel Speed (mm/min), B 120mm/min (c)No. of passes. The accuracy of the models is analyzed on the basis percentage error. These errors are found is less than 1% during machining which affects the measurement techniques. Since the error is less than 10%, it is evidently proved that there is a good agreement between experimental and predicted values [38].

Table 4.1Multi-objective optimization results

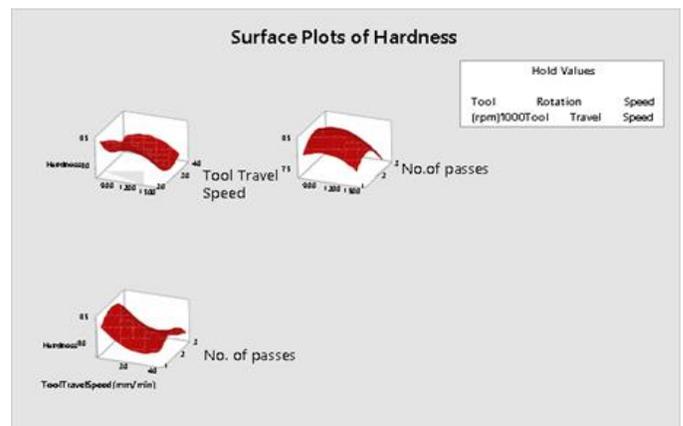| Optimal Control Parameters	Level	Optimal Level	Experimental	Predicted (RSM)	Error (%)
Tool Rotation Speed(rpm)	A	$^A2^B1^B2$	85.3333	85.3333	0
Tool Travel Speed (mm/min)	B				
No. of passes	C				

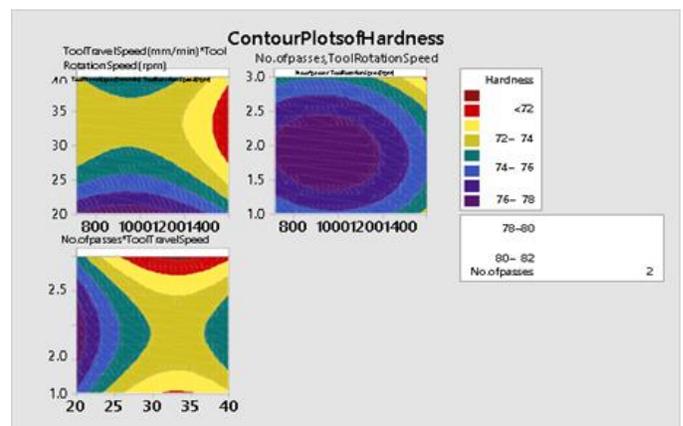**Fig.4.2The effect of the process parameters on the Hardness**

Fig. 4.3 Contour plot for **Hardness** Rotation Speed(rpm) A2 1000 rpm (b) Tool Travel Speed(mm/min), B 120mm/min (c) No. of passes

V. CONCLUSION

Experiments were conducted for various combinations of tool rotational speed and welding speed at three levels in Taguchi's orthogonal array. The strength of the joints was analyzed by hardness test.

The following observations were made from the studies:

1. Taguchi's orthogonal array has been successfully used to find the optimum level setting of process parameters
2. The optimum process parameters levels which are found to achieve greater hardness are such, The average of measured values for Tool Rotation Speed (rpm) A2 1000 rpm (b) Tool Travel Speed (mm/min), B1 20 mm/min (c) No. of passes result a maximum hardness values.
3. ANOVA result for hardness. It is observed that the Tool Travel Speed (mm/min), (P=0.015) (66.94%) is most influences the hardness followed by No. of passes (P= 0.015) (64.02%) and least significant of Tool Rotation Speed (rpm) (A)(P=0.023 (42.13%).In the present study parameters are significantly factor for the hardness..
4. Contour plots are drawn to study the interaction effect of the welding speed and the rotational speed on the Hardness of the friction stir welded joints.
5. Response surface methodology (RSM) is found to be very helpful in the process of optimization carried out in the present study. Here the predicted value obtained from the models is very near to the experimental value.

VI. FUTURE SCOPE

The piston and piston rod is crucial components used in hydraulic systems. The material used in these parts significantly affects the strength and deformation of hydraulic systems. Therefore, the feasibility of new composite materials on hydraulic systems needs to be investigated.

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