Finite Element Analysis and Optimization of Process Parameters of Fsw for Al-Alloys

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Abstract: Friction Stir Welding (FSW), invented by Wayne Thomas at TWI (The Welding Institute) Ltd in 1991, overcomes many of the problems associated with traditional joining techniques. FSW is a solid-state process which produces welds of high quality in difficult-to-weld materials such as aluminum, and is fast becoming the process of choice for manufacturing lightweight transport structures such as boats, trains and aero-planes. Friction stir welding different cutting tool profiles are (round, taper and square) designing in CREO parametric software and analyzing in ANSYS software. friction stir welding materials are 1) aluminum alloy and aluminum alloy 2) copper and copper 3) copper and aluminum alloy for work pieces and cutting tool material high carbon steel material, cutting tool speeds are 800, 1000 & 1200rpm & welding speeds 30, 40 &50 mm/s. Static analysis to determine the deformation stress and strain, modal analysis to determine the deformation with respect to frequencies at different materials and different speeds. In addition, a new TAGUCHI analysis on the L 9 orthogonal array with three factors is performed and results in-dicate that among the parameters considered (i.e., the materials, pin profiles, and speeds), the most significant parameter on the weld quality is the rotational speed.

Keywords* — *FSW, lightweight, deformation stress and strain, TAGUCHI analysis, pin profiles, rotational speed.

I. INTRODUCTION

In order to avoid the problems concerned in welding of Aluminum by way of conventional welding strategies a brand new method, Friction stir UK. It can weld all aluminum alloys, together with those that can't typically be joined by means of conventional fusion welding strategies together with aluminum-lithium alloys.

Friction stir welding FSW

Friction stir welding has loved international interest for the reason that its inception because of its advantages over conventional joining techniques. Essentially, FSW is a nearby thermo-mechanical metal running system with additional adiabatic heating from metallic deformation that changes the local properties without influencing homes within the remainder of the shape. As noted later, the pin and shoulder of the device may be changed in a number of approaches to influence fabric flow and micro-structural evolution. A rotating device with pin and shoulder is inserted within the fabric to be dealt with, and traversed along the road of hobby (Figure-1). The rotating device provides a continual warm working movement, plasticizing metal inside a slender region whilst transporting metal from the main face of the pin to its trailing area. The processed zone cools without solidification, as there may be no liquid and hence a disorder-free re-crystallized exceptional grain microstructure is shaped.

The Machine

The photographs below show a typical friction stir welding (FSW) machine. This one is at the Joining and Welding Research Institute (JWRI) of Osaka University, Japan.

Figure-1 Vertical axis milling machine

The Tool

An illustration of some types of tools. Each tool has a shoulder whose rotation against the substrate generates

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most of the heat required for welding. The pin on the tool is plunged into the substrate and helps stir the metal in the solid state.

Figure-2 tool pin profiles

II. LITERATURE SURVEY

Many investigators have advised various strategies to provide an explanation for the experimental and numerical investigation of friction stir welding. In this paper, skinny aluminum alloy 2024-T3 and 6082-T6 sheets, zero.8 mm thick, have been welded in the rolling path via FSW (FSW for extremely-skinny sheets). Both similar and varied joints have been successfully produced and analyzed. Dr. Muhsin Jaber Jweeg et al[1] This paper describes the first part of the development of a non-linear finite element simulation of the friction stir welding process; it is concerned with thermal analysis. A transient, three dimensional, non-linear thermal model with moving heat source was developed. Also a steady-state, three dimensional, non-linear fluid-thermal model with stationary heat source was developed. Differences of results for both models were discussed. Results of both models were compared with experimental work. Transient thermal model results appear to be more reliable as compared to the CFD approach. Mohamadreza Nourani[2] This study is intended to present a straightforward and computationally efficient methodology for optimizing the process parameters of friction stir welding (FSW) of 6061 aluminum alloy. In particular, it is shown how to minimize the heat affected zone (HAZ) distance to the weld line in the joined parts using a Taguchi optimization method and a temperature-field finite element model. The peak temperature during the process has also been minimized. Since the method is used for the first time in relation to the HAZ objective function, an auxiliary full factorial search is conducted to ensure Taguchi's orthogonal design assumption for the FSW problems. Results confirm that the method can be successfully used for minimizing both the HAZ distance to the weld line and the peak temperature, with a minimal number of simulation runs via orthogonal arrays. In addition, a new ANOVA analysis on the L9 orthogonal array with three factors is performed and results indicate that among the parameters considered (i.e., the tool rotational speed, transverse speed, and the axial force), the most significant parameter on the weld quality is the rotational speed, followed by the axial force and transverse speed. Malek Moradijoz, Hassan Basirat Tabrizi[3] One of the most efficient methods for joining of aluminum alloys is friction stir welding (FSW) process. In FSW, welding parameters and tool geometry affect the weld strength. Heat is generated by friction between the tool and the workpiece, is important to predict and identify the mechanical and micro-structural changes. In this study, first using the Taguchi approach a design of experiment technique to set the optimal process parameters is investigated. It is shown that with increasing the shoulder diameter, the tensile strength increases and with increasing the tool rotational speed the tensile strength decreases. The traverse speed has less effect. Moreover temperature distribution is investigated experimentally. Results are compared with the software based on finite element method, analytical method, and analytical-empirical method. The capabilities, weaknesses, and accuracy of each method are discussed and suggestion is given. Kirk Fraser[4] There is currently a need for an efficient numerical optimization strategy for the quality of friction stir welded (FSW) joints. However, due to the computational complexity of the multi-physics problem, process parameter optimization has been a goal that is out of reach of the current state-of-the-art simulation codes. In this work, we describe an advanced meshfree computational framework that can be used to determine numerically optimized process parameters while minimizing defects in the friction stir weld zone. The simulation code, SPHriction-3D, uses an innovative parallelization strategy on the graphics processing unit (GPU). This approach allows determination of optimal parameters faster than is possible with costly laboratory testing. The meshfree strategy is firstly outlined. Then, a novel metric is proposed that automatically evaluates the presence and severity of defects in the weld zone. Next, the code is validated against a set of experimental results for 1/2" AA6061-T6 butt joint FSW joints. Finally, the code is used to determine the optimal advancing speed and rpm while minimizing defect volume based on the proposed defect metric. V. RajKumar[5] This research paper deals with the characterization of friction stir welded dissimilar Aluminium alloys AA 5052 and AA6061. The coupons of above metals were friction - stir welded using cylindrical pin tool using at constant speed of 710 rpm and at two different feed rates of 28 and 20 mm/min. Macrographs showed proper mixing due to effective stirring of cylindrical tool pin while keeping the lower feed rate. Further, extensive micro structural examination showed variation of grain size in each zone and their influence on mechanical properties. Tensile test and hardness measurements were done as a part of mechanical characterization. Correlating mechanical and metallurgical properties it is deduced that the sample welded at lower feed rate performed better in terms of ductility.

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Muruganandam,. D[6] Friction Stir Welding (FSW) is a relatively new solid state welding technique for similar and dissimilar materials, especially on current interest with aluminum and magnesium alloys. Methods/Analysis: The Friction Stir Welding of aluminum alloys with magnesium alloys are reviewed on this paper. The basic principles of FSW are described, followed by process parameters study which affects the weld strength. Findings: The microstructure and the likelihood of defects also reviewed. Tensile strength properties attained with different process parameters are discussed. Conclusion/Application: It is demonstrated that FSW of aluminum and magnesium alloy is becoming an emerging technology with numerous commercial applications. Mohammad Amin Bozorgzadeh[7] Friction Stir Welding is a novel solid-state joining process that is both efficient, environmental friendly and versatile in its applications. Counted as one of the most significant developments in this age, Friction Stir Welding is used in the joining of high strength alloys which present difficulties with the conventional fusion techniques. As one most significant developments as far as metal joining is concerned, Friction Stir Welding is a green technology that requires less energy as compared to conventional welding methods; no flux or gas is required hence making the Friction Stir Welding process environmentally safe. Being an efficient method, Friction Stir Welding process does not involve the use of any filler metal hence any alloy can be joined without consideration of compatibility of composition as opposed to conventional welding methods where compatibility is an issue. This paper highlights the fundamentals of Friction Stir Welding and gives a literature review of studies that have been conducted to improve this technique with a focus on dissimilar materials from brass, steel to polymers.

III. PROBLEM DESCRIPTION

The objective of the present research is to develop a finite element analysis with improved capability to predict strength evolution in various materials and to determine the optimal weld parameters using FEA technique.

Table1. Materials with parameters

Materials	Tool speed (rpm)	Welding speed(mm/ min)	Tool pin profiles
➢ Pure aluminum alloy	800	30	Round
➢ Pure copper	1000	40	Square
➢ Aluminum and copper	1200	50	Taper

Methodology

• In this work frictional stir welded Pure Aluminium, copper and distinct materials (al and copper) are compared for mechanical homes. In this observe FSW specimens are organized at different welding speed of 30mm/min, 40mm/min and 50 mm/min, tool profiles are taper in 1st situation, 2nd we use round tool pin profile and finally with square tool pin profile and the varying speeds are 800 rpm, 1000 rpm and 1200 rpm.

• In this test the test plate length of aluminium and copper are equal and having 100 mm distance, 50 mm width and four mm thickness.

Here the tool is H13 material is used to manufacture the tools. Tool has pin diameter of four millimetre size. Tool dimensions: Shoulder Diameter-20 mm, Pin Diameter 6mm

• The 3D modelling of FSW with the above geometry is designed in CREO parametric software.

•Analysis we done with static evaluation, to decide the stress, strain and deformation.

These results are used and are copied in minitab software to optimise the process parameters.

IV. INTRODUCTION TO CAD

CADD output is frequently inside the form of electronic files for print or machining operations. typically makes use of vector-based (linear) environments while photograph-based totally software makes use of raster-based totally (pixilated) environments.

Introduction to Pro/Engineer

Pro/ENGINEER Wildfire is the same old in 3-D product layout, presenting enterprise-leading productiveness tools that promote high-quality practices in design whilst making sure compliance together with your enterprise and business enterprise requirements. Integrated Pro/ENGINEER CAD/CAM/CAE answers assist you to design quicker than ever, while maximizing innovation and exceptional to in the end create extraordinary products.

2D Models

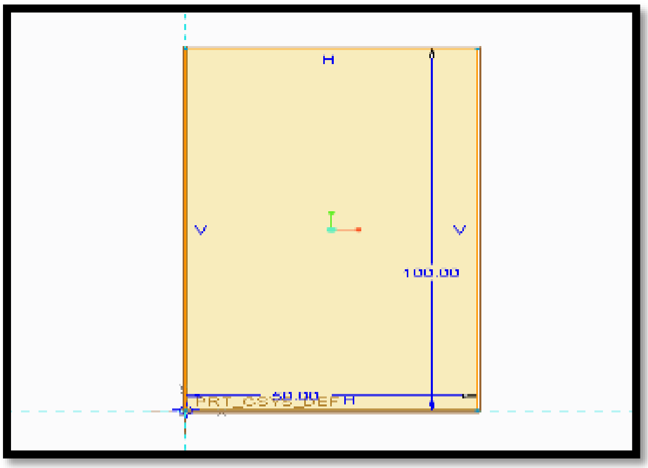

Fig 3 : 2D drawing

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3d model of plate

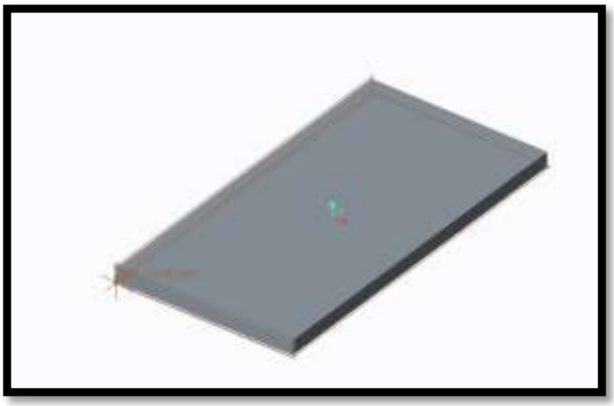

Fig 4: 3D model

3d model of tool

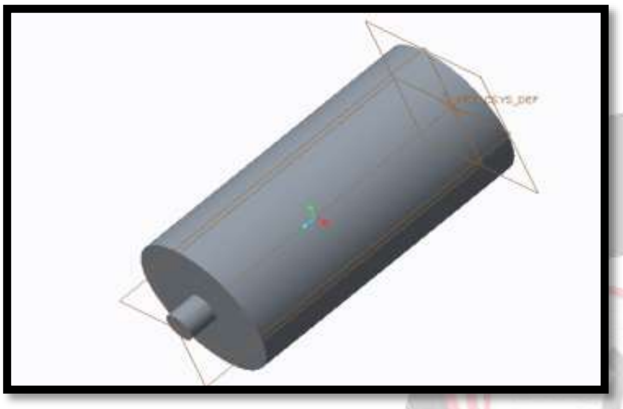

Fig 5 : 3D model of tool

Assembly

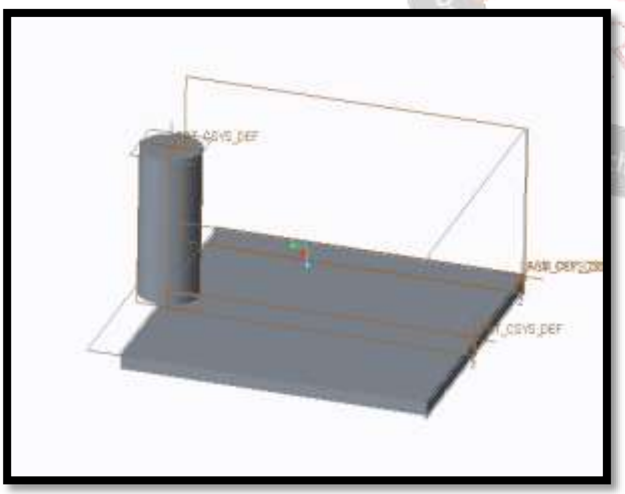

Fig 6 :3D model of assembly

V. INTRODUCTION TO FEA

By the early 70's, FEA become limited to high priced mainframe computers commonly owned by using the aeronautics, car, defense, and nuclear industries. Since the speedy decline in the value of computer systems and the outstanding boom in computing strength, FEA has been developed to an exceptional precision. Present day supercomputers at the moment are capable of produce accurate outcomes for all varieties of parameters.

Static Analysis of Friction Stir Welding

ANSYS workbench is a new generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results

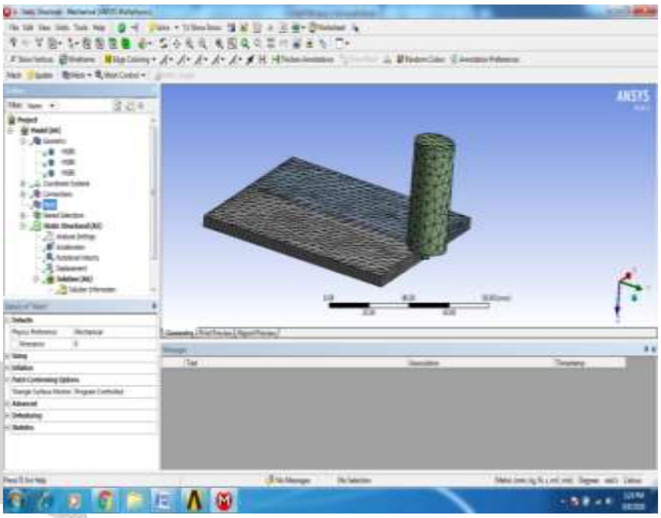

Fig 7: Meshed model

Applying for boundary conditions loading and fixing (analysis settings …right click ….go to insert Fixed support and forces select the surfaces, edges, volumes ,etc

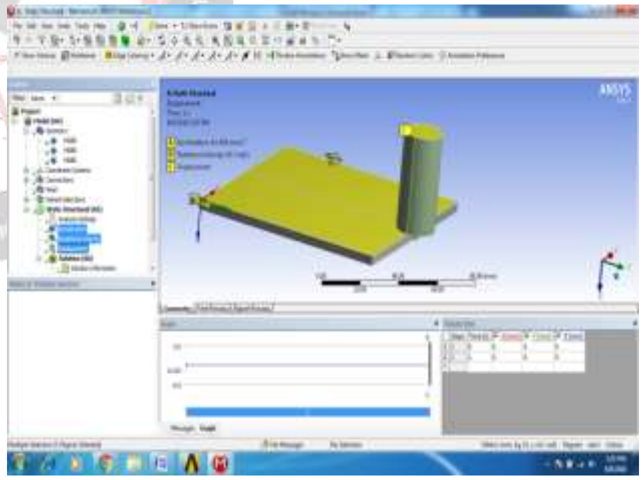

Fig 8: Boundary conditions

After the above settings go to solution ….in right window insert the stresss, deformation etc

Then solver, after solver the results can capture in Microsoft office word .go to print review select and send the Microsoft world.

VI. RESULTS AND DISCUSSION

Material: Pure Aluminum Alloy

Tool Pin Profile: Round

Figure shows the stress, strain and total deformation

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Condition 1: At Tool Speed -800 Rpm

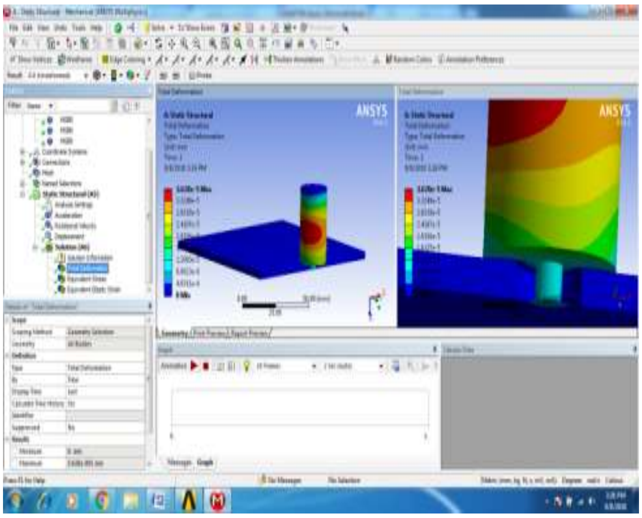

Fig 9: Total deformation

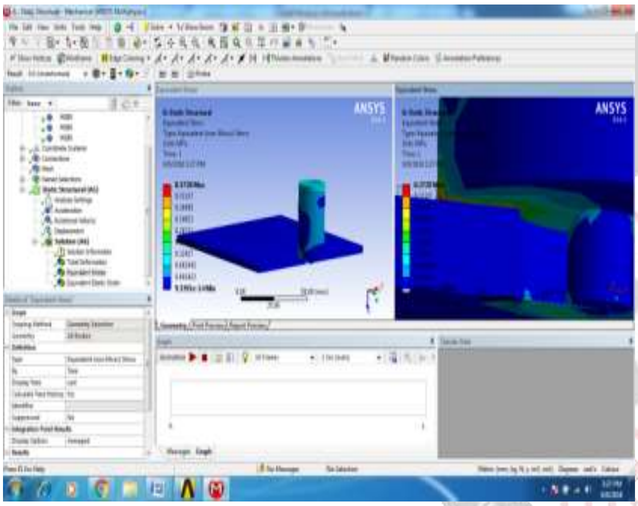

Fig 10: Stress

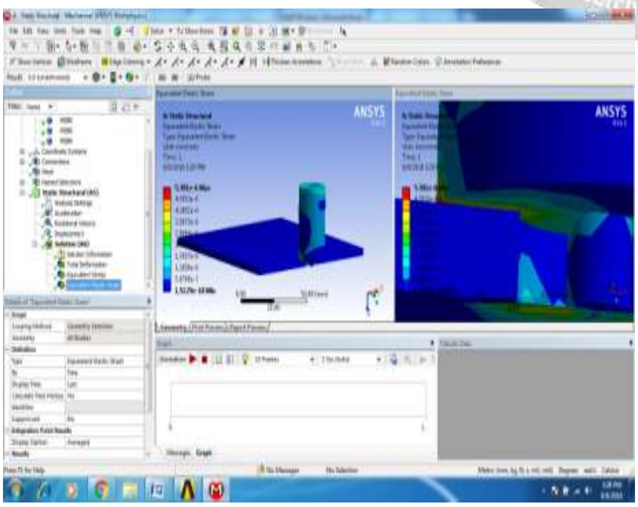

Fig 11: Strain

RESULT TABELS

Material- Aluminum Alloy

Tabel 1-Material Aluminum Aloy

Tool PI Profile	Tool Speed (RPM)	Deformation (mm)	Stress (N/mm2)	Strain
Round	**800**	3.26e-5	0.3728	5.381e-6
	1000	5.378e-5	0.58344	8.421e-6
	1200	8.177e-5	0.84026	1.212e-5
Square	**800**	3.643e-5	0.38742	6.2753e-6
	1000	5.528e-5	0.58792	9.523e-6
	1200	7.962-5	0.84671	1.3715e-6
Taper	**800**	3.632e-5	0.41625	6.1856e-6
	1000	5.675e-5	0.65036	9.664e-6
	1200	8.173e-5	0.93664	1.3919e-5

This result table shows the deformations, stresses and strains of different tool pin profiles at rpm of 800, 1000 and 1200 respectively for Al-Al combination of plates.

Material- Copper

Tabel 2 -Material: Copper

Tool PI Profile	Tool Speed (RPM)	Deformation (mm)	Stress (N/mm2)	Strain
Round	**800**	7.051e-5	1.1198	1.0436e-5
	1000	0.00011018	1.7495	1.6306e-5
	1200	0.0015868	2.5197	2.3483e-5
Square	**800**	6.8119e-5	1.1154	1.1641e-5
	1000	0.00010727	1.7565	1.833e-5
	1200	0.00015449	2.5296	2.602e-5
Taper	**800**	7.047e-5	1.2443	1.1925e-5
	1000	0.00011024	1.9464	1.8653e-5
	1200	0.0015859	2.7999	2.6833e-5

This result table shows the deformations, stresses and strains of different tool pin profiles at rpm of 800, 1000 and 1200 respectively for Copper-Copper material plates.

Material- Dissimilar Material (Aluminum and Copper)

Tabel 3 -Material: Dissimilar Material (Aluminum and Copper)

Tool PI Profile	Tool Speed (RPM)	Deformation (mm)	Stress (N/mm2)	Strain
Round	800	3.6303e-5	1.0661	6.286e-6
	1000	5.672e-5	1.6657	9.888e-6
	1200	8.1688e-5	2.3989	1.424e-5
Square	800	3.5886e-5	0.84334	7.3303e-6
	1000	5.6038e-5	1.3177	1.1453e-5
	1200	8.0707e-5	1.8977	1.6494e-5
Taper	**800**	3.6525e-5	1.2168	6.2976e-6
	1000	5.7067e-5	1.9012	9.8395e-6
	1200	8.2187e-5	2.7381	1.4171e-5

This result table shows the deformations, stresses and strains of different tool pin profiles at rpm of 800, 1000 and 1200 respectively for Al-Copper Material plates.

Introduction to Taguchi Technique

•Taguchi defines Quality Level of a product as the Total Loss incurred via society because of failure of a product to perform as preferred whilst it deviates from the delivered target overall performance levels.

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•This includes charges associated with bad overall performance, working costs (which modifications as a product a long time) and any brought charges because of harmful facet results of the product in use.

Taguchi Methods

•Help businesses to carry out the Quality Fix!

•Quality problems are due to Noises in the product or method machine

•Noise is any undesirable effect that will increase variability

•Conduct full-size Problem Analyses

•Employ Inter-disciplinary Teams

•Perform Designed Experimental Analyses

•Evaluate Experiments using ANOVA and Signal-to noise techniques

The Taguchi Process

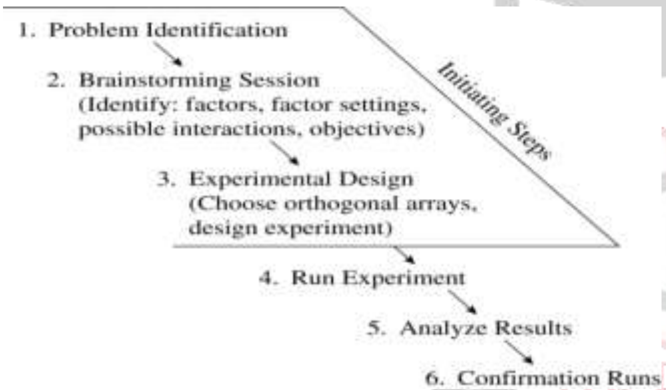

Fig 12: Taguchi Process

Optimization of Stress Using Minitab Software

Material-Aluminum Alloy

Levels

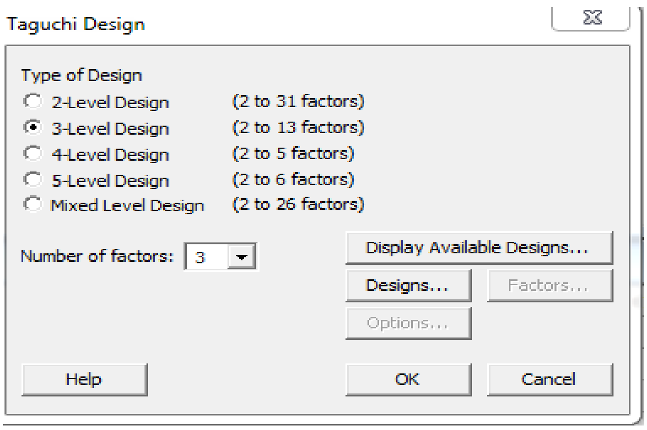

Fig 13: Design steps

Factors

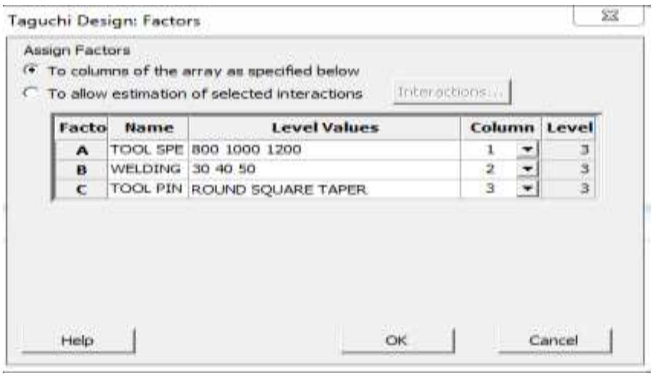

Fig 14: Work Sheet

↓	C1	C2	C3-T
	TOOL SPEED	WELDING SPEED	TOOL PIN PROFILES
1	800	30	ROUND
2	800	40	SQUARE
3	800	50	TAPER
4	1000	30	SQUARE
5	1000	40	TAPER
6	1000	50	ROUND
7	1200	30	TAPER
8	1200	40	ROUND
9	1200	50	SQUARE

Fig 15: Worksheet

Worksheet 1 ***

↓	C1	C2	C3-T	C4	C5
	TOOL SPEED	WELDING SPEED	TOOL PIN PROFILES	STRESS	STRESS1
1	800	30	ROUND	0.37280	0.37285
2	800	40	SQUARE	0.38742	0.38745
3	800	50	TAPER	0.41625	0.41626
4	1000	30	SQUARE	0.58792	0.58798
5	1000	40	TAPER	0.65036	0.65037
6	1000	50	ROUND	0.58344	0.58355
7	1200	30	TAPER	0.93664	0.93665
8	1200	40	ROUND	0.84026	0.85010
9	1200	50	SQUARE	0.84671	0.84910

Fig16: Insertion of parameters in worksheet

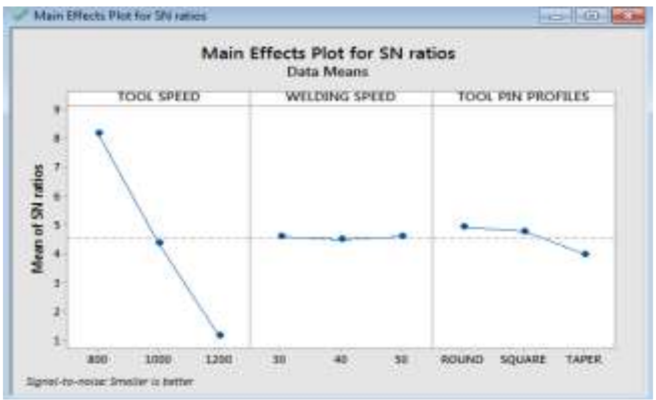

Fig 17: Result S/N RATIO

This figure shows the signal to noise ration in this figure it clearly explains that at tool speed 1200 rpm and welding

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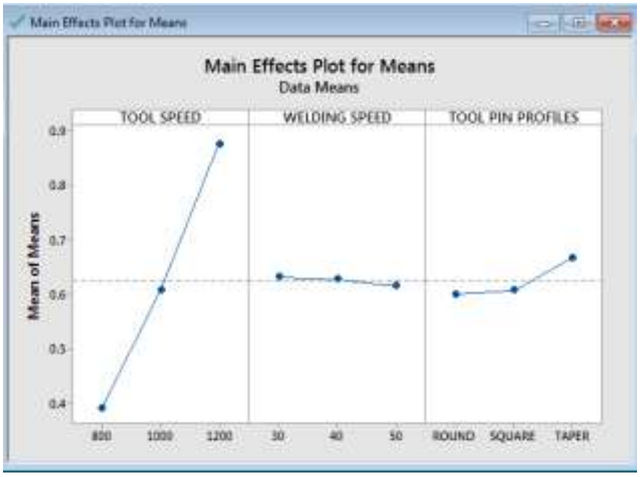
speed 40 mm/min and the Taper profile is better suitable work conditions.

MEANS VALUE



This figure shows the signal to noise ration in this figure at tool speed 800 rpm and welding speed 50 mm/min and the round profile is best

Fig 18: MEANS VALUE

Worksheet 1 ***

↓	C1	C2	C3-T	C4	C5	C6	C7
	TOOL SPEED	WELDING SPEED	TOOL PIN PROFILES	STRESS	STRESS1	SNRA1	MEAN1
1	800	30	ROUND	0.37280	0.37285	8.56990	0.372825
2	800	40	SQUARE	0.38742	0.38745	8.23602	0.387435
3	800	50	TAPER	0.41625	0.41626	7.61281	0.416255
4	1000	30	SQUARE	0.58792	0.58798	4.61319	0.587950
5	1000	40	TAPER	0.65036	0.65037	3.73686	0.650365
6	1000	50	ROUND	0.58344	0.58355	4.67926	0.583495
7	1200	30	TAPER	0.93664	0.93665	0.56850	0.936645
8	1200	40	ROUND	0.84026	0.85010	1.46087	0.845180
9	1200	50	SQUARE	0.84671	0.84910	1.43305	0.847905

Fig 19: Work sheet

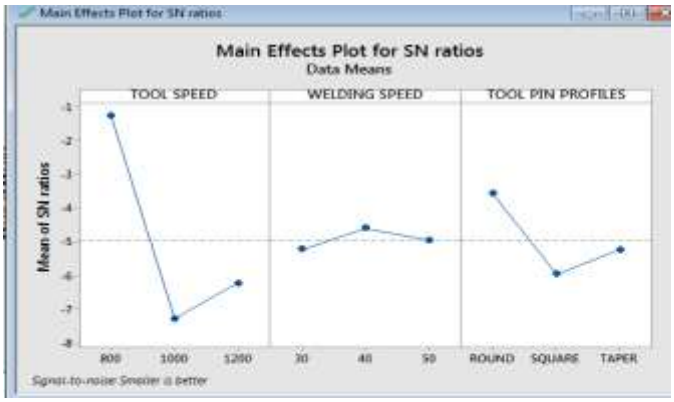


Fig 20 : For MATERIAL-COPPER

In This figure shows the signal to noise ration in this figure at tool speed 1000 rpm and welding speed 30 mm/min and the square type profile is best

Fig 21: S/N Ratios

Worksheet 1 ***

↓	C1	C2	C3-T	C4	C5	C6	C7
	TOOL SPEED	WELDING SPEED	TOOL PIN PROFILES	STRESS	STRESS1	SNRA2	MEAN2
2	800	40	SQUARE	1.1154	1.1120	-0.93537	1.11370
3	800	50	TAPER	1.2443	1.2510	-1.92189	1.24765
4	1000	30	SQUARE	2.7999	2.7888	-8.92563	2.79435
5	1000	40	TAPER	2.5197	2.5210	-8.02922	2.52035
6	1000	50	ROUND	1.7565	1.7610	-4.90409	1.75875
7	1200	30	TAPER	1.9464	1.9560	-5.80606	1.95120
8	1200	40	ROUND	1.7495	1.7480	-4.85456	1.74875
9	1200	50	SQUARE	2.5299	2.5230	-8.05022	2.52645

Fig 22 Material-Dissimilar Material (Aluminum and Copper)

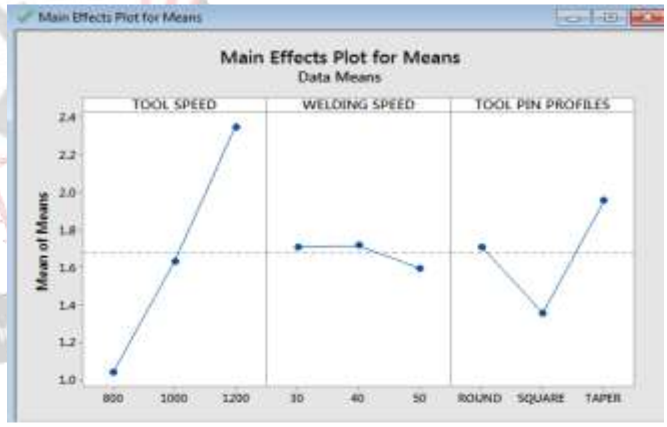


Fig 23 S/N Ratios

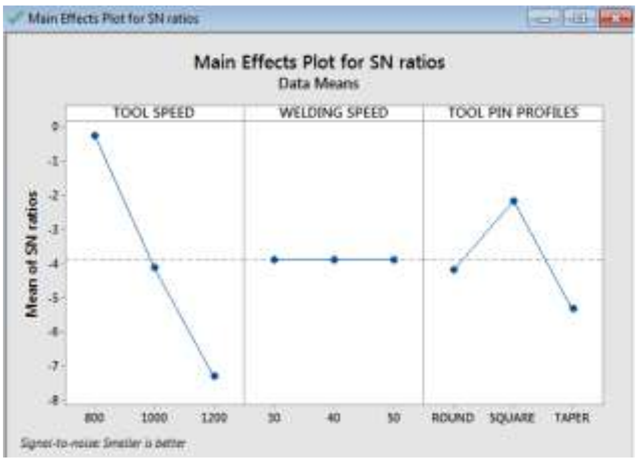


Fig 24: S/N Ratio

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VII. CONCLUSION

Friction stir welding different cutting tool profiles are (round, taper and square) designing in CREO parametric software and analyzing in ANSYS software. friction stir welding materials are 1) aluminum alloy and aluminum alloy 2) copper and copper 3) copper and aluminum alloy for work pieces and cutting tool material high carbon steel material , cutting tool speeds are 800, 1000 & 1200rpm. Static analysis are performed in ansys to determine the deformation stress and strain at different pin profiles, different materials and different speeds and the same results were shown above, these results are used for optimizing the best suitable working conditions and was performed by using the

TAGUCHI analysis on the L 9 orthogonal array by using the minitab software with three factors is performed and results indicates that among the parameters considered (i.e., the weld speeds 30, 40 &50 mm/s , pin profiles , and speeds), the most significant parameter on the weld quality is the rotational speed.By observing the static analysis results the stress values are less for square type pin profile and at work piece material aluminum alloy- aluminum alloy, cutting tool material high carbon steel the stress value is 0.87Mpa, the stress values are increase by increasing the speed by observing the analytical results and by taguchi S/N ratios the following conclusions can be made : to minimize the cutting tool speed, the optimal parameters are spindle speed – 800rpm, pin profile -square and weld speed 30 mm/s.

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