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Friction Stir Welding of Similar Metals by Taguchi Optimization Technique -A Review

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Abstract— *In order to meet the global competition and the survival of products in the market a new way of thinking is necessary to change and improve the existing technology and to develop products at economical price.This paper discusses use taguchi experiment design technique for maximizing tensile strength of friction stir welding AA6061 and AA6061. In friction stir welding, the joints are formed in the solid state by utilizing the heat generated by friction. The objectives of this study are obtaining friction weld element of aluminium 6061 to aluminium 6061 and optimising the friction stir welding parameters in order to establish the weld quality. Effect of tensile strength of friction stir welding process parameter (Rotational speed, travel speed, axial force and tilt angle) is evaluated and optimum welding condition for maximum tensile strength is determined.*

Keywords— Friction Stir Welding, Aluminium alloys, Similar, Tensile strength, Optimized by Taguchi methodology.

I. INTRODUCTION

Friction Stir Welding (FSW) is a new technique employed to fuse two or more metal pieces in order to improve its properties. Depending on the tool rotational speed, Transverse speed or travel speed, and axial force the properties of the jointed metals varies such as yield strength, tensile strength. Joining methods for similar and dissimilar polymer structures are used in industry. By this process thick plates can also be welded with high productivity. FSW welds have improved mechanical properties compared with fusion welds.

A method of solid state joining on a workpiece offers a tool pin of material harder than the base metal's continuous surface which causes relative cyclic movement between the pin and the base metal. The frictional heat is generated as the pin stirs the workpiece so as to create a plasticized region in the metal around the probe, stopping the relative cyclic movement, and allowing the plasticized material to solidify around the probe. In the field of welding, weld quality mainly depends on the welding type, mechanical properties of the weld metal and heat affected zone (HAZ), which in turn is influenced by metallurgical characteristics and chemical compositions of the weld.

INPUTS		**OUTPUTS**
Tool rotation speed (rpm), Tool profile Tool feed, m/sec	**FRICTION STIR WELDING PROCESS**	Tensile strength Yeild strength % of Elongation Hardness

Fig.1: A Schematic black box for Friction Stir Welding Process

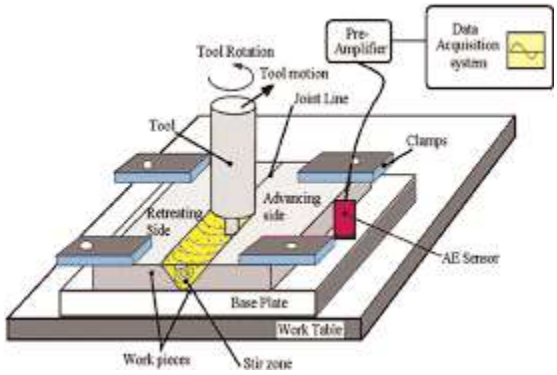

Fig.2: Friction Stir Welding setup

TAGUCHI METHOD

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering and other areas. Taguchi method is a systematic application of design of experiment technique for the purpose of designing and improving product quality. The flow chart of taguchi method is given below in fig 4. Optimisation of process parameters is the key step in the taguchi method to achieving High quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the taguchi method are insensitive to the variation of environmental conditions and other noise factors.

The main objective in the Taguchi method is to design robust systems that are reliable under uncontrollable conditions the method aims to adjust the design parameters known as the control factors to their optimal levels, such that the system response is robust. In contrast,

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taguchi approach is based on executing one large comprehensive experiment. This approach is not sequential experiment and analysed by the term signal-to-ratio. Finally, based on this calculation, taguchi shows how to choose the 'Optimum condition'.

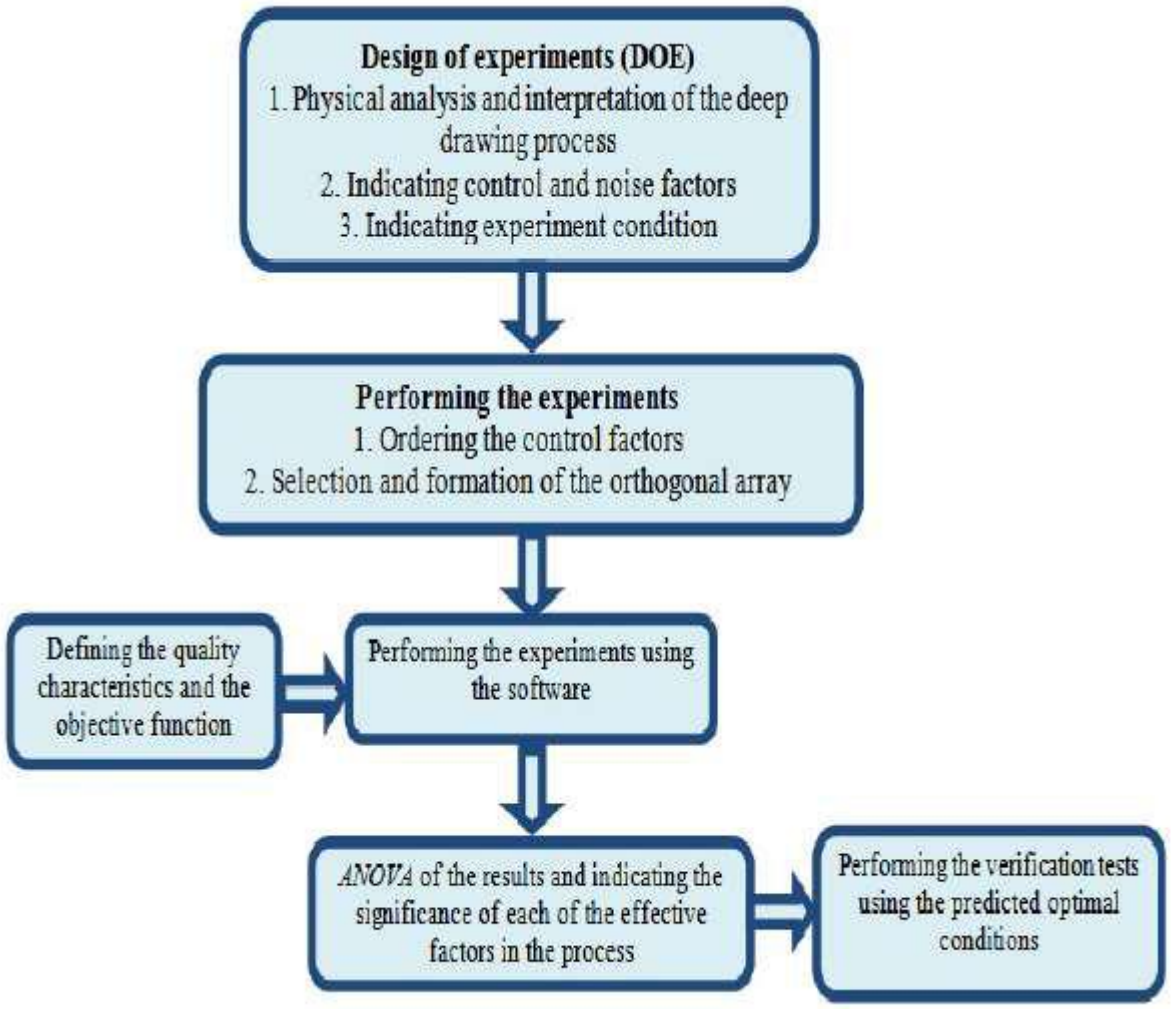

Fig.4: Flow chart of the Taguchi method

Taguchi proposed that engineering optimization of a process or product should be carried out in a three-step approach:

1. System design
2. Parameter design
3. Tolerance design

System design:

This design is conceptualization and synthesis of a product or process to be used that is this stage consists of new ideas, concepts and knowledge in the areas of science and technology.

Parameter design:

It is related to finding the appropriate design factor levels to make the system less sensitive to various in uncontrollable noise factors. In this way the product performs better, reducing the loss to the customer.

Tolerance design:

Tolerance design occurs when products or process are established to minimize the sum of the manufacturing and lifetime costs of the product or process. In this stage, tolerances of factors that have the largest influence on variation are adjusted only if after the parameter design stage, the target values of quality have not yet been achieved.

II. EXPERIMENTAL DESIGN

Selection of Friction Stir Welding and their levels

Welding process where metallic bonding is produced at temperatures lower than the melting point of the base metals. Rotational speed, travel speed, axial force, tilt angle are the most interesting parameters in the friction stir welding.Process Parameter of FSW While the general principles of the effect of process variables on the friction stir welding process have much in common with other welding processes, there are many factors which can

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affect output response. The main process variables in friction stir welding are listed as follows:

- Tool rotational speed
- Welding speed
- Shoulder diameter
- Pin diameter and profile
- Axial force
- Tilt angle
- Work piece material
- Shoulder and pin material

Chemical and Mehanical properties composition of aluminium alloys 6061 and 7075 which was used in the experiments are shown in the tables.

Table.1: Friction Stir Welding Parameter and their level

Parameters	**Unit**	**A**	**B**	**C**	**D**
Rotation Speed	Rpm	710	900	1000	1120
Transverse speed	mm/min	28	35	40	60
Offset	mm	2	2	2	2
Plunge depth	mm	3	3	3	3

The process parameters workable range for the experiments was chosen in order to control the weld seams quality including defects in the root, the type of defect more difficult to eliminate in sound welds.

Table.2: Friction Stir Welding Parameter and their level

R S	**T S**	**Offset**	**P Depth**	**UTS**	**YS**	**Per.**	**HV**
710	28	1	3	140.46	115.32	1.04	370
710	35	2	2	180.92	120.45	1.90	360
710	40	3	3	190.24	140.60	1.98	355
710	60	1	4	200.02	150.67	2.10	340
900	28	2	3	162.35	120.45	1.20	355
900	35	1	4	185.64	125.60	1.92	350
900	40	2	4	198.78	142.90	2.00	345
900	60	3	2	201.60	152.68	2.35	340
1000	28	3	4	184.56	180.62	1.60	295
1000	35	2	3	190.90	130.78	1.95	292
1000	40	1	2	200.01	145.68	2.00	290
1000	60	2	3	220.58	155.90	2.40	285
1120	28	1	2	240.78	215.54	1.80	245
1120	35	3	3	245.89	220.45	1.85	243
1120	40	2	4	250.78	230.98	1.90	240
1120	60	1	3	256.24	235.60	2.00	230

Selection of Orthogonal array

To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. The degree of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is.

ADVANTAGE AND LIMITATION

Taguchi's design has wide-ranging applications, generally speaking, experimental design with OA's (Orthogonal Array) can be applied where there are a large number of design factors. OA's for the design of experiments, SN ratio analysis, and cost guidance based on loss function has made his approach increasingly popular among practicing engineers. The salient features of the Taguchi methodology can be summarized as providing up front improvement of quality by design and process development, measurement of quality in terms of deviation from the target problem solving technique by involving the whole team and etc.

The most severe limitation of the Taguchi method is the need for timing with respect to product/process development. The main disadvantage of the Taguchi method is that the results obtained are only relative and do not exactly indicate what parameter has the highest effect on the performance characteristic.

III. CONCLUSION

This paper clearly reveals the efficient utilization of technologies to measure, control and optimization of Friction Stir Weld process parameters to obtain a good quality of weld. The accurate measurement of the FSW

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process is by conducting experiments using taguchi of experiments. Taguchi's robust orthogonal array design method is suitable to analyse this problem as described in this review paper. It is found that the parameter design of Taguchi method provides a simple, systematic, and efficient methodology for the optimization of the Friction Stir Welding parameters.

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