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EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF PROCESS PARAMETERS OF ULTRASONIC WELDING FOR DELRIN MATERIAL

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ABSTRACT

This paper speaks about the, joining of two delrin materials (plastic material) using ultrasonic welding. There are two types of parameters. They are machine setting initial parameters and running parameters. The running parameters have a large impact on the weld strength. The welding was carried out by varying its parameters such as weld time, weld hold time, weld delay time to evaluate the strength of the weld. After welding of the specimens, various tests were done on the welded materials to check the weld strength of the material. The tensile strength of the material gets better by optimizing the running parameters. The major application of this material is, it is used in impeller.

Keywords: Ultrasonic welding, Delrin material, Influencing Parameters, Torsion test.

I. INTRODUCTION

1.1. Ultrasonic Welding

Ultrasonic Welding is a classification among the Solid State Welding process, in which two work pieces are joined as a result of the pressure applied to the welded parts combined with application of high frequency acoustic vibration (ultrasonic).It causes friction between the parts, which results in a closer contact between the two surfaces with simultaneous local heating of the contact area. Inter atomic bonds, formed under these conditions, provide strong joint. Ultrasonic cycle takes about 1 sec. The frequency of acoustic vibrations is in the range 20 to 70 KHz.

1.2. Area of Use

Thickness of the welded parts is determined by the power of the ultrasonic generator. It is used mainly for bonding work pieces of smaller size in electronics, for manufacturing communication devices, medical tools, watches, in automotive industry. It is a quasi-solid-state process that produces a weld by introducing high frequency vibration to the weldment as it is held under high clamping forces.

1.3. Types

There are two types of USW, they are

1. US Roller welding and

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2. US spot welding.

We are using the **US spot welding.**

1.4. Basic Elements:

All ultrasonic welding systems consist of basic elements. The parts to be assembled are pressed, assembled under pressure and a nest or anvil where the parts are placed and allowing the high frequency vibration to be directed into the interfaces. An ultrasonic stack composed of an optional booster, converter or piezoelectric transducer and a sonotrode. All three elements of the stack are specifically tuned to resonate at the same exact ultrasonic frequency. There is a converter which converts the electrical signal into a mechanical vibration.

The booster modifies the amplitude of the vibration which is standard systems to clamp the stack in the press. The sonotrode is used to apply the mechanical vibration to the parts to be welded. An electronic ultrasonic generator is used to deliver high power AC signal with the frequency matching the resonance frequency of the stack. The weld is produced without melting of the base materials. In some respects, ultrasonic welding is an infant process that still awaits thorough exploration. A greater understanding is needed of the processes that occur at the bond interface. Specifically, the interaction of the process parameters, as well as their role in bond development, needs to be better understood.

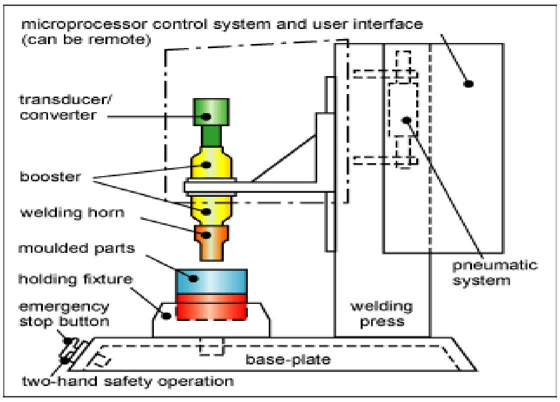

Fig.1 Schematic representation of USMW

II. LITERATURE REVIEW

J.Pradeep kumar et al [1] depicts experiments to copper wire with copper sheet using USM spot welding. The lateral drive system is used to perform experimental trials in this work. The experiment was conducted by varying weld pressure, amplitude and welding time. Here a suitable DOE based on Full Factorial design methodology was designed and executed for conducting trials. ANOVA is used to interpret the results from actual experiments. Marius Pop-Calimanu et al [2] describe the problem faced by researchers and industry with respect to ultrasonic welding process in poor strength of the weld, due to improper selection of welding parameters. Here also the welding pressure, welding time and amplitude are selected as the optimal parameters. It was observed that welding pressure and welding time has a significant effect on the response.

Elangovan Sooriyamoorthy et al (2011) [3] proposed using Taguchi's design of experiments methodology, the weld strength is maximized for Al-Al welding by optimizing the process parameters like weld pressure, weld time and amplitude of vibration. A finite element analysis model is developed that is capable of predicting the interface temperature and stress distribution during welding process. Results of experimental work and FEM

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studies are compared and found to be in good agreement. It is found from this study that as the weld time increases, the stress levels also increase indicating that the joint obtained at increased weld time show better strength. S. Elangovan et al (2009) [4] described the joining of two materials together using high frequency vibrations in ultrasonic welding without producing significant amount of heat. During the ultrasonic welding of the sheet metal, the normal and shear forces act on the parts to be welded and the weld interface. These forces are the result of ultrasonic vibrations of the tool, pressed onto the parts to be welded. They carried out a study on model for the temperature distribution during welding and stress distribution in the horn and welded joints are presented. It is capable of predicting the interface temperature and stress distribution during welding and their influences in the work piece, sonotrode and anvil. An FEM based model for ultrasonic welding has been developed, which can predict the temperature developed during welding process with parameters like material thickness, clamping force, weld time and coefficient of friction. It also described that clamping force plays a major role in deformation area resulting in increasing the force in weld area.

III. MATERIAL PROPERTIES:

The material properties of the selected material is

- Material :Delrin
- Chemical name :Polyoxymethylene
- Water absorption : 0.070

Physical properties:

- Density :0.0513 lbs/in3
- Specific gravity :1.42 g/cc

Mechanical properties:

- Tensile strength :9000 psi
- Tensile modulus :350000 psi
- Rockwell hardness :M 94(120)

Thermal properties:

- Specific heat-0.35

3.1. Parameters:

The most important parameters which will affect the weld strength are

1. Frequency rate
2. Amplitude level
3. Pressure
4. Weld time
5. Weld delay time
6. Weld hold time

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IV. UTM SPECIFICATIONS

Fig.2 Ultrasonic Welding Setup

1. Model: EGA 1526
2. Maximum capacity : 10 KN
3. Least count displacement : 0.1mm
4. Accuracy of load : 1% of indicated load from 4% to 100 of load cell capacity
5. Grip separation : 25 – 750mm
6. Straining rate : 1mm / min to 100 mm/min
7. Power : single phase 220V 50Hz AC
8. Motor : 0.5Hp

V. EXPERIMENTAL PROCEDURE

The pieces which are joined using the ultrasonic welding are circular in shape. The welded pieces can be used for various purposes such as impeller. The Design of Experiments was calculated and the Taguchi method was also used for the further improvement of the process.

5.1. TAGUCHI METHOD

Taguchi technique is one of the powerful tools designed for high quality systems. It provides a simple, approach to optimize design for performance, quality and cost. The reduced variance for the experiment with optimum setting of control parameters are provided by Orthogonal Array (OA) experiments, a method developed by taguchi. The Taguchi technique uses two factors that is, control and noise factors to identify the optimal process settings that are minimally sensitive to noise.

Control factors are those that can be controlled during the manufacturing process. Noise factors are often uncontrolled variables in a process. The log functions of the desired output are called Signal-to-Noise ratios (S/N) It serves as objective functions for optimization, help in data analysis and prediction of optimum results.

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The objective of determining signal-to-noise ratio is to develop processes that are insensitive to noise. The optimum quality with minimum variance is yielded by setting the process parameter with highest signal to noise ratio.To obtain optimal welding parameter, the larger-is-better quality

Characteristic is considered. The signal-to-noise ratio can be expressed as:

$S/N = -10 \log 10 (1/n (\sum yi-2))$.

5.2. DESIGN OF EXPERIMENTS

An important aspect of TAGUCHI method is the design of experiments (Box and Draper, 1987), usually abbreviated as DoE. The strategies were mainly developed for the model fitting for the physical experiments, but it can also be applied to numerical experiments. The Response should be evaluated from the selected points by DoE. The criteria for optimal design of experiments are mainly associated with the mathematical model of the process. The experiments are designed for particular problem for mathematical model polynomial unknown structure.

Design of experiments can have a large influence on the accuracy of the approximation. It also can have a large influence on the cost of constructing the taguchi method. Screening experiments are performed in the early stages of the process in a traditional DoE, when it is likely that many of the design variables initially considered having a little or no effect on the taguchi.

VI. TABULATION

Based on the material chosen, the various level values are chosen so that it with stands the during the testing.

Table.1. Experimental factors and their levels

S.NO	FACTORS	DESIGNATION	LEVEL 1	LEVEL 2	LEVEL 3
1	Frequency (KHz)	A	14.864	14.866	14.868
2	Pressure (kg/cm^2)	B	5.1	5.5	5.3
3	Amplitude (µm)	C	1.8	2.0	2.2
4	Weld time (sec)	D	1.30	1.50	1.25
5	Weld delay time (sec)	E	0.80	0.82	0.84
6	Weld hold time (sec)	F	1.00	1.10	1.05

Fig.3 Welded Delrin Material

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Table.2. Results of Delrin material using Experimentation

S.NO	A (KHz)	B (Kg/cm^2)	C (μm)	D (sec)	E (sec)	F (sec)	TORSION (N-m)
1	14.864	5.1	2.0	0.80	1.30	1.00	21.92833
2	14.864	5.1	2.0	0.80	1.33	1.10	24.93348
3	14.864	5.1	2.0	0.80	1.36	1.05	21.61639
4	14.864	5.5	2.1	0.82	1.30	1.00	22.37892
5	14.864	5.5	2.1	0.82	1.33	1.10	24.79484
6	14.864	5.5	2.1	0.82	1.36	1.05	22.24028
7	14.864	5.8	2.2	0.84	1.30	1.00	25.10679
8	14.864	5.8	2.2	0.84	1.33	1.10	25.52271
9	14.864	5.8	2.2	0.84	1.36	1.05	23.72552
10	14.866	5.1	2.1	0.84	1.30	1.10	22.06697
11	14.866	5.1	2.1	0.84	1.33	1.05	23.62154
12	14.866	5.1	2.1	0.84	1.36	1.00	21.75503
13	14.866	5.5	2.2	0.80	1.30	1.10	25.92786
14	14.866	5.5	2.2	0.80	1.33	1.05	25.10679
15	14.866	5.5	2.2	0.80	1.36	1.00	22.37892
16	14.866	5.8	2.0	0.82	1.30	1.10	25.34941
17	14.866	5.8	2.0	0.82	1.33	1.05	25.97335
18	14.866	5.8	2.0	0.82	1.36	1.00	25.28009
19	14.868	5.1	2.2	0.82	1.30	1.05	24.89882
20	14.868	5.1	2.2	0.82	1.33	1.00	25.45339
21	14.868	5.1	2.2	0.82	1.36	1.10	24.76018
22	14.868	5.5	2.0	0.84	1.30	1.05	25.48805
23	14.868	5.5	2.0	0.84	1.33	1.00	25.38407
24	14.868	5.5	2.0	0.84	1.36	1.10	23.48292
25	14.868	5.8	2.1	0.80	1.30	1.05	24.62669
26	14.868	5.8	2.1	0.80	1.33	1.00	24.82958
27	14.868	5.8	2.1	0.80	1.36	1.10	24.52271

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Table.3. S/N Ratio for Welded specimen

S.NO	A (KHz)	B (Kg/cm^2)	C (μm)	D (sec)	E (sec)	F (sec)	TORSION (N-m)	S/N RATIO	RANK
1	14.864	5.1	2.0	0.80	1.30	1.00	21.92833	22.23	3.0
2	14.864	5.1	2.0	0.80	1.33	1.10	24.93348	22.88	15
3	14.864	5.1	2.0	0.80	1.36	1.05	21.61639	22.01	1.0
4	14.864	5.5	2.1	0.82	1.30	1.00	22.37892	22.52	6.5
5	14.864	5.5	2.1	0.82	1.33	1.10	24.79484	22.79	12.
6	14.864	5.5	2.1	0.82	1.36	1.05	22.24028	22.43	5.0
7	14.864	5.8	2.2	0.84	1.30	1.00	25.10679	22.98	16.5
8	14.864	5.8	2.2	0.84	1.33	1.10	25.52271	23.24	23.5
9	14.864	5.8	2.2	0.84	1.36	1.05	23.72552	22.75	10.0
10	14.866	5.1	2.1	0.84	1.30	1.10	22.06697	22.32	4.0
11	14.866	5.1	2.1	0.84	1.33	1.05	23.62154	22.68	9.0
12	14.866	5.1	2.1	0.84	1.36	1.00	21.75503	22.11	2.0
13	14.866	5.5	2.2	0.80	1.30	1.10	25.92786	23.82	27.0
14	14.866	5.5	2.2	0.80	1.33	1.05	25.10679	22.98	16.5
15	14.866	5.5	2.2	0.80	1.36	1.00	22.37892	22.52	6.5
16	14.866	5.8	2.0	0.82	1.30	1.10	25.34941	23.13	19.0
17	14.866	5.8	2.0	0.82	1.33	1.05	25.97335	23.50	26.0
18	14.866	5.8	2.0	0.82	1.36	1.00	25.28009	23.09	18.0
19	14.868	5.1	2.2	0.82	1.30	1.05	24.89882	22.85	14.0
20	14.868	5.1	2.2	0.82	1.33	1.00	25.45339	23.19	21.0
21	14.868	5.1	2.2	0.82	1.36	1.10	24.76018	22.77	11.0
22	14.868	5.5	2.0	0.84	1.30	1.05	25.48805	23.22	22.0
23	14.868	5.5	2.0	0.84	1.33	1.00	25.38407	23.15	20.0
24	14.868	5.5	2.0	0.84	1.36	1.10	23.48292	22.59	8.0
25	14.868	5.8	2.1	0.80	1.30	1.05	24.62669	23.30	25.0
26	14.868	5.8	2.1	0.80	1.33	1.00	24.82958	22.81	13.0
27	14.868	5.8	2.1	0.80	1.36	1.10	24.52271	23.24	23.5

VII. PLOT OF MAIN EFFECTS FOR MEANS AT VARIOUS LEVELS OF FACTORS FOR WELDED SPECIMEN

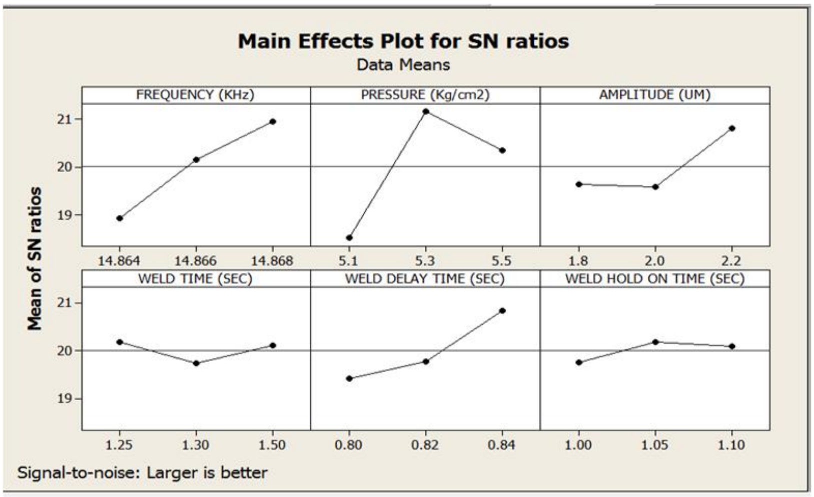

Fig.4 Graph Showing S/N Ratio

VIII. CONCLUSION

The experiments were done on the similar plastic materials using ultrasonic welding. The influencing parameters while joining the materials were identified. These parameters were optimized using taguchi method to obtain the maximum weld strength. Parameters like weld frequency, weld pressure, Amplitude, Weld time, Weld delay time and Weld hold time has significant effect on weld strength.

Experiment results proved that these parameter influence the weld strength and these parameters where optimized using taguchi method. From the experimentation, the weld strength is poor with low amplitude and high weld time and strength is good with low pressure and high weld time.

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