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Analysis of Bonding Strength of Ultrasonic Welding Process

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Abstract: - In ultrasonic welding, high frequency vibrations are combined with pressure to join two materials together quickly and securely. Ultrasonic welding can join dissimilar metals in a split second, ultrasonic welding eases problematic assembly and this cost effective technique may be key to mass producing fuel efficient. In this work effect of various parameters on weld strength have been studied. Welding of .5 mm aluminium plates were successfully welded by 20 kHz ultrasonic welding system. One dimensional vibration system for ultrasonic lap spot welding of metal plate of aluminium have studied .The relationships between weld strength and the variables of weld energy, duration of weld cycle, have studied Experiment was carried out to determine the mechanism of aluminium- aluminium plate bonding. These experiment, including effect of amplitude and pat tern of bond formation. Experiment was carried to find out the optimum parameter for maximum strength.

I. INTRODUCTION

Ultrasonic welding is an industrial technique whereby two pieces of plastic or metal are joined together seamlessly through high-frequency acoustic vibrations. One component to be welded is placed upon a fixed anvil, with the second component being placed on top. An extension ("horn") connected to a transducer is lowered down onto the top component, and a very rapid (~20,000 Hz), low-amplitude acoustic vibration is applied to a small welding zone. The acoustic energy is converted into heat energy by friction, and the parts are welded together in less than a second.

II. ULTRASONIC METALS WELDING

The system that is used to scrub the pieces together consists of four major components. The first of these is the anvil. This is simply a piece of the machine, usually with a replaceable head, that holds one of the components still while the other is rubbed against it. The "business end" of the ultrasonic system consists of three major parts. The first of these is the ultrasonic transducer. This component takes an electrical signal from a power supply that is providing a 20 khz AC signal and converts it to a mechanical motion at the same frequency as shown in fig 1. The vibration that results is at a frequency that is appreciably above the range of human hearing, hence the name ultrasonic. There is a power supply which elevates the frequency of the electrical current from the grid, then the transducer that transforms electrical into mechanical energy, then a booster that modifies the shape and magnitude of vibrations an finally the horn that vibrates the material to be welded, while it is clamped unto the stationary anvil.

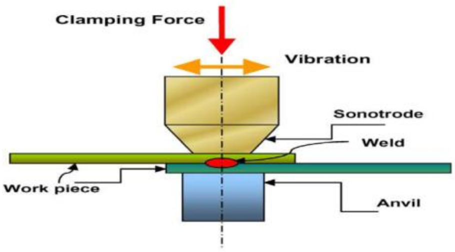

Fig 1 Ultrasonic metal welding

III. PARAMETER CONTROL

1. Welding pressure or clamping pressure
2. Welding voltage
3. Welding current
4. Ultrasonic frequency
5. Welding time
6. Welding energy
7. Constant amplitude
8. Weld location

IV. WELDING IN THE ENERGY MODE

Welding in energy mode, i.e. with a constant energy setting, is known from ultrasonic plastics welding and can also be used for ultrasonic metal welding. To achieve a constant quality the welding time is automatically adjusted. Although this type of quality control is good with ultrasonic plastics welding, the approach has to be more carefully applied when it comes to ultrasonic metal welding.

V. WELDING IN ENERGY MODE

Energy: 2000 ws
Weld location: at middle of lap
Amplitude: 70%
Pmax =300 w

Sr. NO.	WELD TIME IN SECONDS(T2)	%Pmax	T2*% Pmax	strength(WEIGHT) IN KG
1	2.8	55	154.55	8.5
2	3.386	53	179.46	8.5
3	4.86	40	194.4	9
4	3.2	62	198.4	9.5
5	3.93	55	216.3	10
6	3.64	62	225.8	11.5

Table 1 - weld time and strength in energy mode

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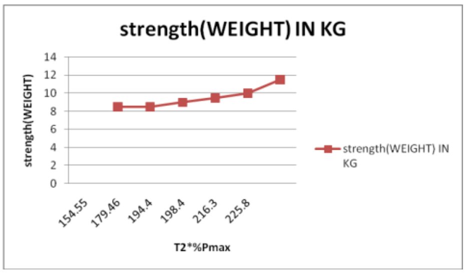


Fig 2. Relation between weld time and strength in energy mode

VI. WELDING IN THE TIME MODE

This is the most suitable mode for ultrasonic metals welding. Welding energy and rate of compression are variable, but we only consider the variation in energy because rate of compression does minor effect on weld strength subject to the deviations of the work piece. They should, however, stay within acceptable limits. The welding process ends automatically as soon as the nominal time value is achieved. The welding time is defined as the duration of ultrasonic and can be both a constant parameter and a variable parameter adjusted with the help of quality control devices for an optimum weld. Depending on the application the welding time can be between 0.1 and approximately 4 seconds.

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at middle of lap
Amplitude: 70%
Pmax =300 w

Piece no	Weld energy. In WS	%Pmax	%Pmax*weld Energy.	Strength(weight) In Kg
1	912	33	30096	3
2	1043	39	40677	4
3	1281	64	81984	10
4	1450	57	82661	10
5	1451	60	87060	10
6	1345.8	71	95556	10.5
7	1655	60	99300	11
8	1845	55	101475	11
9	1708	68	116144	12.5

Table 2 weld energy and strength at 70% amplitude

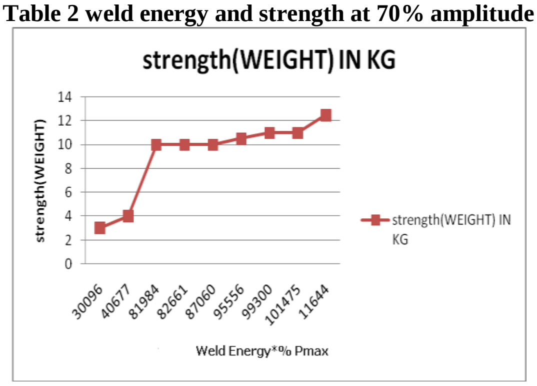


Fig. 3. Relation between weld energy and strength at 70% amplitude

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at end edge of lap
Amplitude: 70%
Pmax =300w

Piece no	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	670	45	30150	6.5
2	680	47	31960	6.5
3	720	46	33120	6.5
4	754.5	52	39308	9
5	881	45	39645	9
6	816	50	40800	9
7	850	50	42500	9.5
8	964	51	49164	10

Table 3- weld energy and strength at 70% amplitude at end

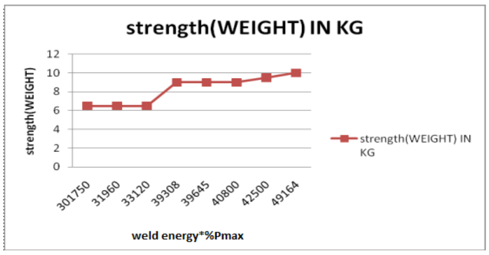
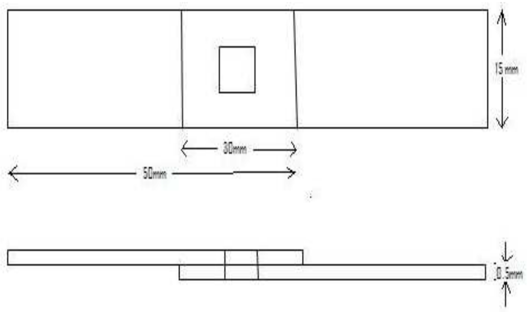


Fig 4. Relation between weld energy and strength at 70% amplitude at end

VII. COMPARISON BETWEEN WELDING AT THE MIDDLE OF THE LAP AND AT THE EDGE OF THE LAP

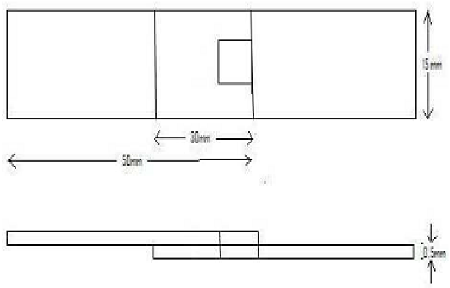
Front view



Top view

Fig 5 Welding at middle of lap

Front view



Top view

Fig 6. Welding at end edge of lap

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TIME: 2.5 s
Amplitude: 70%
Pmax =300w

Sr. no	At the middle of the lap		At the edge of the lap	
	Energy (ws)	Strength (Kg)	Energy (ws)	Strength (Kg)
1	912	3	670	6.5
2	1043	4	680	6.5
3	1281	10	720	6.5
4	1450	10	754.5	9
5	1451	10	881	9
6	1345.8	10.5	816	9
7	1655	11	850	9.5
8	1845	11	964	10

Table 4. Comparison between welding at the middle of the lap and at the edge of the lap

Table 4 shows that in case of welding at the edge of the lap the bonding strength is much more compare to welding at the middle of the lap. It also consumes less energy and gives better strength. Because in case of welding at the edge of the lap the surrounding is mainly air Which have low thermal conductivity compare to aluminum in case of welding at the middle of the lap. Because of high thermal conductivity of aluminum, the heat losses is more in case of welding at the middle of the lap compare to in case of welding at the edge of the lap. So the welding at the edge is prefer than welding at the middle.

VIII. EXPERIMENTATION AND DATA COLLECTION

Symbols	Process parameter	Levels		
		Low	Medium	High
V	Voltage (Volt)	230	340	450
I	Current (amp)	1.5	3.5	6.4
P	Pressure (MPa)	.34	.43	**.52**

Table 5:-parameters and their levels of experiment

A. *Experimental results*

Experiment no.	Voltage (v)	Current (amp)	Pressure (MPa)	Strength (Kg)
1	230	1.5	.34	3.5
2	230	3.5	.43	8.5
3	230	6.4	.52	9
4	340	1.5	.52	10.5
5	340	3.5	.34	6.5
6	340	6.4	.43	8
7	450	1.5	.43	8.7
8	450	3.5	.52	12.5
9	450	6.4	.34	7.5

Table 6:- consolidated design of experiment table

In this work, the controllable factors taken are Voltage (V), Current (I) and pressure (P). Since they affect strength and welding operation and these factors are controllable in the ultrasonic welding process, they are considered as a controllable factor.

B. *Analysis of means and response graph for strength*

Analysis of means

The analysis of each controllable factor is studied and the main effect of the same is obtained in table. Main effect of each factor at individual level i.e. at low, medium and high level is equal to the mean of strength of all experiments with the factor at individual level.

(a) The main effect of voltage on strength at various level calculated as follows

L = (3.5+8.5+9)/3 =7.0 Kg
M = (10.5+6.5+8)/3 =8.33 Kg
H = (8.7+12.5+7.5)/3 =**9.57 Kg**

(b)The main effect of current on strength at various level calculated as follows

L = (3.5+10.5+8.7)/3 =7.57 Kg
M = (8.5+6.5+12.5)/3 =**9.17 Kg**
H = (9+8+7.5)/3 = 8.17 Kg

(c) The main effect of pressure on strength at various level calculated as follows

L = (3.5+6.5+7.5)/3 = 5.83 Kg
M = (8.5+8+8.7)/3 = 8.4 Kg
H = (9+10.5+12.5)/3 =**10.67 Kg**

Symbols	Controllable factors	Strength (Kg)		
		Low	Medium	High
V	Voltage	7	8.33	**9.57**
I	Current	7.57	**9.17**	8.17
P	Pressure	5.83	8.4	**10.67**

Table 7 mean responses for strength

C. *Response graph for means*

The value obtained from the response table are plotted to visualize the effect of three parameters. From the means response graph observation finding are illustrated as follows-

(a) Level III for voltage (V_3) =9.57 Kg indicated as the optimum situation in terms of strength.
(b) Level II for current (I_2) =9.17 Kg indicated as the optimum situation in terms of strength.
(c) Level III for voltage (P_3) =10.67 Kg indicated as the optimum situation in terms of strength.

Main effect plot for Strength Data means

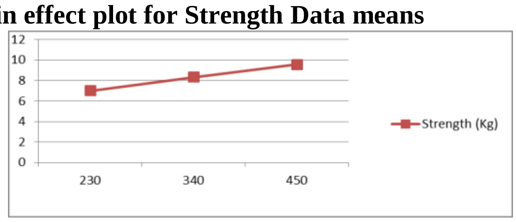

Fig 7.(a) Strength v/s Voltage

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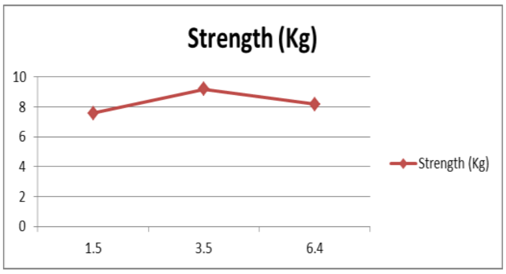

Fig 7.(b) Strength v/s Current

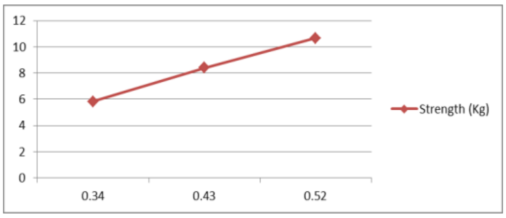

Fig 7.(c) Strength v/s pressure

Fig 7. Mean response graph for strength

D. *Confirmation of experiment*

For maximum strength the combination of optimum parameters (V3,I2,P3).It means high voltage, medium current and high pressure. For this combination **V3=450 v , I2=3.5** amp and **P3= .52 MPa** ,the strength is **12.5** Kg.

X. MODELLING OF PARAMETERS

To generalize the result, the modeling of input parameters (Voltage, Current and Pressure) and output parameters (Strength) is done using REGRESSION MODELING and Matlab software R2011b. Now the Formula of strength in terms of voltage, Current, and Pressure

Strength (Kg) = $(\text{Voltage})^{0.5514} * (\text{Current})^{01431} * (\text{Pressure})^{1.5115}$

XI. COMPARISON OF RESULT

Strength (Kg)	
Experimental result	Result from mathematical modeling
3.5	4.16
8.5	6.7
9	9.73
10.5	9.8
6.5	5.8
8	9
8.7	10.57
12.5	12.92
7.5	7.42

Table 8 - comparison of results

A. *Comparison of result for maximum strength*

Result	Experimental result	Result from mathematical modeling
Level	V3-I2-P3	V3-I2-P3
Strength(Kg)	12.5	12.92

Table 9 - comparison of results

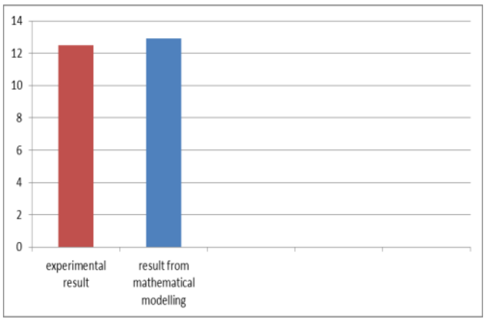

Fig 8 comparison of results

XII. CONCLUSION

- The time mode is more favorable mode for ultrasonic metal welding.
- Weld location should be considered in ultrasonic lap joint welding, due to effect of thermal conductivity of metals weld location also affect the welded quality. Welding at end edge of lap give comparative good welded quality and the more effectiveness of ultrasonic welding system.

REFERENCES

[1] "Ultrasonic welding equipment". Johs n. antonevich. IRE transaction on ultrasonic engineering Reprinted from the 1959 IRE NATIONAL CONVENRTEIOCNO RD,pt. 6, pp. 204-312 Battle Memorial Institute, Columbus, Ohio.

[2] "New Methods of Ultrasonic Metal Welding". Jiromaru TSUJINO, Tetsugi UEOKA, Ichiro WATANABE, Yusuke KIMURA Faculty of Engineering, Kanagawa University Yokohama 221, Japan. 1051-0117/93/0000-0405 $4.00 0 1995 IEEE. 1995 ULTRASONICS SYMPOSIUM – 405.

[3] "Process Innovations in Ultrasonic Metal Welding" by Jay Sheehan, Elizabeth Hetrick, and Janet Devine, Karl Graff, Joe Walsh, Larry Rutherford, David Scholl, and Zachary Berg 1997.

[4] "The ultrasonic welding mechanism as applied to aluminum" .George G. Harman senior member IEEE. Loten und Schweissen in der Elecktronik," Munich, Germany, November 25-26, 1997.

[5] "Transverse and torsion complex vibration system". J.Tsujino, T.Ueoka, T.Kashino. Faculty of Engineering, Kanagawa University, Yokohama 22 1-8686, Japan 2000.

[6] "Welding Characteristics of Various metal plate's ultrasonic seam and spot welding system using a complex vibration welding tip". Jiromaru TSUJINO and Tetsugi UEOKA Faculty of Engineering, Kanagawa University, Yokohama 22 1-8686, Japan. 0-7803-7177- 1/01/$10.00 ©

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ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 5, November 2014

2001 IEEE. 2001 IEEE ULTRASONICS SYMPOSIUM-670.

[7] "Welding characteristics of40khz ultrasonic plastic welding system". Jiromaru TSUJINO, Faculty of Engineering, Kanagawa University Yokohama 221, Japan 2002.

[8] Ultrasonic welding—an established technique for assembling metal parts by Austin Weber Assembly Magazine Aug.1, 2003.

[9] "Predicting the Failure of Ultrasonic Spot Welds by Pull-out from Sheet Metal". Bin Zhou,1 M. D. Thouless,1,2 and S. M. Ward3, 1Department of Mechanical Engineering, 2 Department of Material Science and Engineering University of Michigan Ann Arbor, MI, 48109, 3Scientific Research Laboratory Ford Motor Company Dearborn, MI, 48124 March 2006.

[10] "Temperature and stress distribution in ultrasonic metal welding"—An FEA-based study S.Elangovan, S. Semeer, K. Prakasan∗ Department of Production Engineering, PSG College of Technology, Coimbatore 641004, India. Journal of materials processing technology (2008) PROTEC-12027; No. of Pages 8.

[11] Comparison of Control Algorithms for Ultrasonic Welding of Aluminium by M. BABOI AND D. GREWELL 2011.

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