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Parametric Analysis of Rotary Friction Welding Process Based On Comparative Study between Mild Steel and Stainless Steel 304

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Abstract - **Demands for improved productivity, efficiency, and quality challenges to the welding industry. As materials become ever more sophisticated in their chemical composition to provide ever-better functionally specific properties, a more complete and precise understanding of how such materials can be joined for optimal effectiveness. In this research study paper, Mild Steel and Stainless Steel 304 materials were used, due to their utilization and capabilities of these materials in the industry. The research study considers the analysis of Temperature, Time for weld, Heat affected zone in rotary friction welding joint. After rotary friction welding sample preparation, the tensile test has been carried out for examine the strength of the weld (breaking, ultimate, yield strengths).**

Keywords: *Friction welding, Rotary friction welding, Universal Testing Machine, Heat affected Zone.*

I. INTRODUCTION

Metal industries are using various types of fabrication methods to join different components and the joining methods can be either permanent or temporary depending on the type, design and application of the product. Welding is one of the most common metal joining processes in the manufacturing industry. The involvement of interdependent factors in the process which varies with the type of metals to be welded and the needs of the customers. Designers and manufacturing engineers need to have full knowledge of all available welding and joining processes so they can make the best selection of potentially efficient manufacturing methods. This research paper deals with the study of Heat Affected zone analysis with various cross sections welding for SS304 and Mild steel welding materials. A non-uniform liberation of heat on the friction surfaces, conforming to general rules, as well as accidental phenomenon (different intensity of loading of some sections of the surface compared to others) is the basic cause for temperature difference at various points of friction surface. But as the heating progresses, the temperature on the welding surfaces level off, primarily because of heat conduction and redistribution of heat liberation. Metal surface heated to a high temperature becomes plastically deform before other and under the influence of axial force are deformed and flatten out. They cease to resist axial force and the latter is now transmitted by cooler portions of the friction surface where heat liberation is then increased, the temperature being continuously evened out across the specimen. In this study same diameter but two different materials used to do rotary friction welding analysis and after sample preparation tensile test has been carried out for analysis of strength of weld.

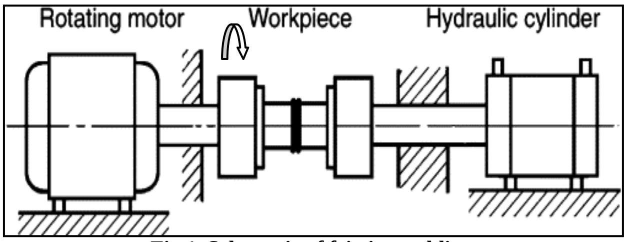

Fig.1. Schematic of friction welding

II. LITERATURE REVIEW

Abu Bakar Dawood, Shahid Ikramullah Butt, Ghulam Hussain, Mansoor Ahmed Siddiqui, Adnan Maqsood and Faping Zhang are working on research based on “Thermal Model of Rotary Friction Welding for Similar and Dissimilar Metals” Friction welding develops excellent quality weld joints between similar and dissimilar metals. The weld is developed using heat, generated from frictional force by rubbing two work-pieces. In the most

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unpretentious form of frictional welding, pressure on the rotating metal piece is escalated to reach an appropriate welding temperature. Once nominal temperature is achieved, the rotating work-piece is stopped and the stationary piece is forced with increased pressure to coalesce with the counter-piece. Continuing growth in welding equipment purchases shows that worldwide utilization of welding is still increasing and its use is expected to grow further due to its economic advantages. The future growth of welding depends on the adoption of modern welding processes and on developments in the materials used. Such materials and alloys include high-strength, low-alloy steels and new high-alloy, high-temperature steels. Thus new technological strategies are needed, in order to develop welding technology concurrently with the development of new materials.

A. Reasons to Consider Friction welding process

Similar and dissimilar metals can join together. The process is very fast comparing with conventional welding techniques. Friction welding process is versatile to join a wide range of part shapes, materials and sizes. Friction welding joint preparation isn't critical machined, saw cut, and sheared surfaces are weldable. Resulting joints are of forged quality, with a 100% butt joint weld through the contact area. The machine-controlled process eliminates human error, and weld quality is independent of operator skill. It's ecologically clean no objectionable smoke, fumes, or gases are generated that need to be exhausted.

B. Problem Statement

To conduct experiment to join samples of Mild Steel and Stainless Steel of same cross section using rotary friction welding and perform tests for strength of welded samples using tensile test and perform parametric analysis of heat affected zone.

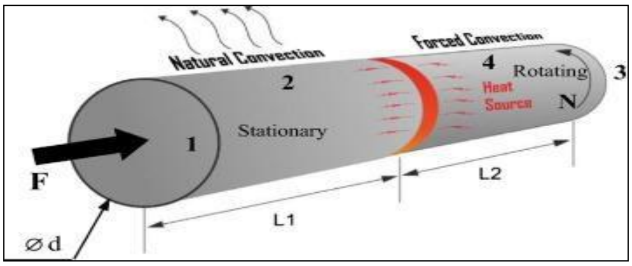


Fig. 2.Friction Welding Process (HAZ)

C. Parameters considerations during welding.

1. Force 2.Time 3.Speed 4 Temperature.

Fig.3. Heat affected Sample

D. Objective.

- To perform study and experimental work of rotary friction welding process with samples of Mild Steel and Stainless Steel of same cross section.
- To study temperature variation of Heat Affected Zone.
- Tensile Test.

Material used: Mild steel & Stainless Steel 304, Specimen 1, 2, and 3 resp.

Cross Section: For M.S. and SS304 Dia. = 10 mm, 12 mm and 14 mm.

All geared lathe machine were used to perform experiment (Max. rpm = 1500) and to obtained welded joints. All the reading were taken on the constant rotating speed 1500 rpm.

III. NUNMERICAL SIMULATION

A theoretical formula on heat produced in the friction welding method was carried out in this study. Then, various trails were taken independently. Heat variations, during welding and after welding, in welded parts were determined. The welding surface is the heat affected zone in which mechanical energy is converted into thermal energy under pressure, and it exposes to high temperature. The mathematical expression between operating characteristics on friction welding and heat energy produced on account of friction. It was assumed that friction pressure is homogeneously spread on the interface of rotated and non-rotated parts. The produced heat and its variation can be determined with respect to operating characteristics and dimensions of parts. Produced heat energy (dQ) can be expressed as: $T = (2\pi\mu PR^3)/3$

$$dQ = \omega \cdot dT \;\ldots\ldots\; (1)$$

where, ω is angular velocity, and dT is differential torque of circle at width dr, Then, torque dT can be expressed,

as : $dT = r \cdot dF \;\ldots\ldots\; (2)$

where, dF is a friction force over a circle at width dr and r is radius of circle.

Then, it can be determined that friction force dF. equals friction-coefficient multiplied by axial-force of pressure P over circle at width dr.

$$\boxed{dF = \mu \cdot P \cdot 2\pi r \cdot dr} \;\ldots\ldots\ldots\; (3)$$

It can be determined that total energy occurring at friction- surfaces is heat occurring over friction-surface with respect to distance r and thickness dr from rotation axis,We obtain heat occurring at welding surface by integrating with R of equation (4) as follows:

$$\boxed{dQ = 2\pi \cdot \mu \cdot \omega \cdot P \cdot r^2 \cdot dr} \;\ldots\ldots\ldots\; (4)$$

The obtained temperature must be very close to melting point of material under application for proper welding of parts. Forging pressure in some materials are determined depending on the lower strength material. Forging pressure in some materials are determined depending on the lower strength material. The lower rpm of rotating parts causes enormous moments and non-uniform heating results in. On the other hand, lower rpm values minimize formation of inter metallic compounds. With higher rpm of rotating parts, weld widens, and power supply is not affected. To prevent overheating in the welding region, friction pressure and friction time have to be carefully controlled. Pressure values applied in welding is very significant because it controls temperature gradient and affects rotational torque as well as power. Friction and forging pressure are directly related to geometry and material properties of parts to be welded. The application of forging pressure especially during friction process improves welding properties. Forging pressure depends on the heat yield stress of the material. It should neither be high enough to cause welding accumulation nor is it low enough to cause under welding.

Dia. (mm)	Density (kg/m^3)	Mass(kg)	Volume (m^3)
10	8000	0.2513	3.14×10^{-5}
12		0.3617	4.52×10^{-5}
14		0.4923	6.15×10^{-5}

Table 1: Calculation for SS304

Dia. (mm)	Density (kg/m^3)	Mass(Kg)	Volume (m^3)
10	7850	0.2465	3.14×10^{-5}
12		0.3548	4.52×10^{-5}
14		0.4831	6.15×10^{-5}

Table 2: Calculations for Mild Steel

E. Sample Calculation for SS 304

Density of SS=8000 kg/m^3

ρ=m/v then, 8000=m/3.14x10^{-5} , Mass = 0.2513 kg.

F. Sample Calculation for MS

Density of MS=7850 $kg/m^{3,}$

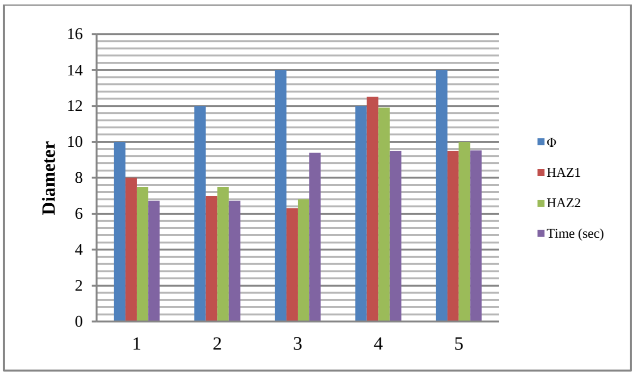
ρ=m/v then, 7850= m/3.14x10^{-5}, Mass = 0.2456 kg.

Mat.	C	Mn	Cr	V	W	Other
MS	0.12 - 0.23	0.3 - 0.75	-	-	-	S-0.04, P-0.04
SS 304	0.08	2.00	18-20	1.00	8.0-10.5	S 0.03, P 0.045

Table 3: Material Properties

Sample	L1 (mm)	L2 (mm)	Φ (mm)	HAZ 1 (mm)	HAZ2 (mm)	Time (sec)
SS304	70	100	10	8	7.5	6.72
SS304	70	100	12	7	7.5	6.73
SS304	70	100	14	6.3	6.8	9.4
MS	70	100	12	12.5	11.9	9.5
MS-SS304	70	100	14	9.5	10	9.52

Table 4: Same Diameter Samples



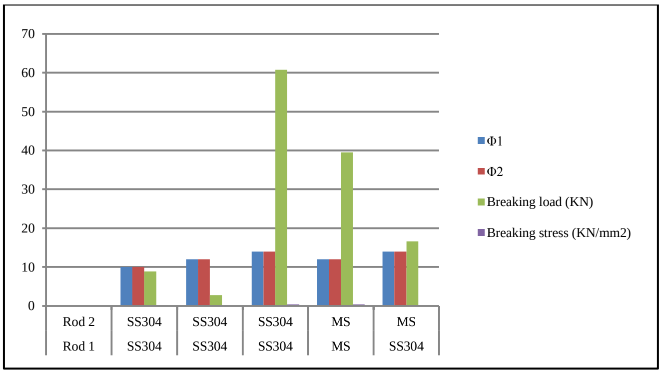
Graph 1: S304 Sample Vs Dia. HAZ & Time

IV. TENSILE TEST OBSERVATIONS

The tensile testing has been done on the welded samples SS 304 and MS on the 40 tones loading capacity machine and the following results were observed. Table no. 5 shows the Breaking load Vs Stress.

Rod 1	Rod 2	Φ1 mm	Φ2 mm	Breaking load KN	Breaking Stress KN
SS304	SS304	10	10	8.84	0.113
SS304	SS304	12	12	2.80	0.025
SS304	SS304	14	14	60.76	0.395
MS	MS	12	12	39.50	0.361
SS304	MS	14	14	16.58	0.094

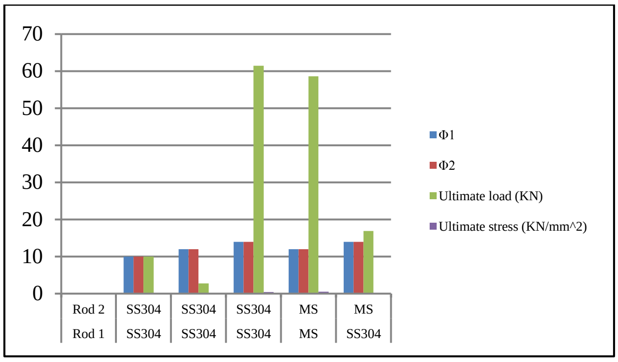
Table 5: Breaking Load Vs Stress



Graph 2: Breaking Load Vs Stress

Rod 1	Rod 2	Φ1 mm	Φ2 mm	Ultimate load (KN)	Ultimate stress KN/mm^2
SS304	SS304	10	10	9.98	0.127
SS304	SS304	12	12	2.80	0.025
SS304	SS304	14	14	61.44	0.399
MS	MS	12	12	58.6	0.538
SS304	MS	14	14	16.86	0.095

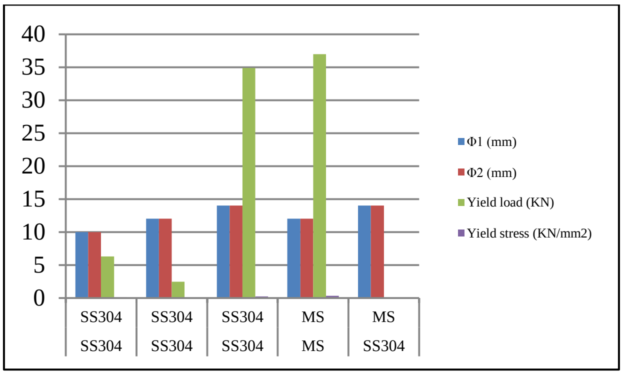
Table 6: Ultimate load and Ultimate Stress



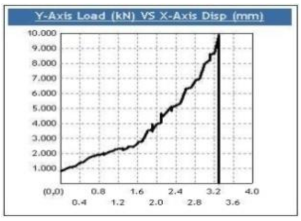
Graph 3: Ultimate Load Vs Ultimate Stress

Rod 1	Rod 2	Φ1 mm	Φ2 mm	Yield load KN	Yield stress KN/mm^2
SS304	SS304	10	10	6.300	0.080
SS304	SS304	12	12	2.48	0.022
SS304	SS304	14	14	34.90	0.227
MS	MS	12	12	36.98	0.338
SS304	MS	14	14	0.0	0.0

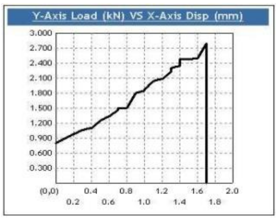
Table 7: Yield Load and Yield Stress



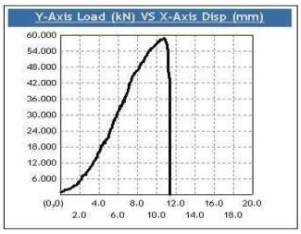
Graph 4: Yield Load and Yield Stress



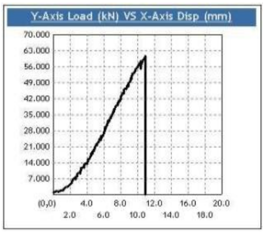
Dia. 10 mm SS 304



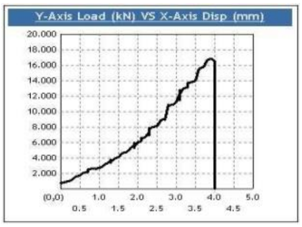
Dia. 12 mm SS 304



Dia. 12 mm MS



Dia. 14 mm SS 304



Dia. 14 mm MS - SS 304

Graph 5:Tensile test results

G. Temperature Distributihon from line of contact

In the following table no.8 to 11. shows the HAZ and the temperature variation from the centre of weld to the i.e distance from line of contact of sample 1 and sample 2.

Distance from Line of Contact on Sample 1	Distance from Line of Contact on Sample 2	Temp. on Sample 1	Temp. on Sample 2
0	0	1380	1380
4	4	1220	1200
6	6	1000	1100
10	10	820	810

Table 8: HAZ SS304 Sample-1

Distance from Line of Contact on Sample 1	Distance from Line of Contact on Sample 2	Temp. on Sample 1	Temp. on Sample 2
0	0	1395	1380
2	2	1300	1290
4	4	1200	1250
10	10	990	990

Table 9: SS304 Sample-2

Distance from Line of Contact on Sample 1	Distance from Line of Contact on Sample 2	Temp. on Sample 1	Temp. on Sample 2
0	0	1440	1440
4	4	1400	1400
8	8	1320	1320
12	12	820	860

Table 10: Mild Steel Sample 1

Distance from Line of Contact on Sample 1	Distance from Line of contact on Sample 2	Temp. on Sample 1	Temp. on Sample 2
0	0	1440	1440
4	4	1400	1390
8	8	1320	1280
12	12	800	840

Table 11: Mild Steel Sample 2

V. FUTURE SCOPE

In this research study it has been observed that rotary friction welding process has lot of future scope and can be widely used in the joining of similar and dissimilar type of materials and study can be perform with different combinations of materials and various parameters setting and with different solid bar sizes can be used. Also study can be carried out for joining of two similar cross sectional tubes. Rotary friction welding with optimization of parameters, changing of various geometrical shapes, pre and post processing with any suitable software can be carried out. And also mechanical bending test, impact test and tensile test, microstructure analysis of welding joint with similar and dissimilar materials can be perform.

VI. CONCLUSION

The conclusions obtained on same diameters of rods and time for welding, HAZ on both rods is almost same with variations of +/- 1 to 2 mm. When sample has rough surface, then time required for welding at same rpm is more. When same sample has fine surface finish, then time required for welding at same rpm is less. So, we conclude for SS304 samples is that with increasing diameter temperature increases. With increasing diameter HAZ decreases. With increase in temperature HAZ decreases. Difference in HAZ for both rods is quite considerate HAZ1 = 10 mm. Conclusions obtained from results on weld strength by using Universal testing Machine. Test was conducted on MS and SS304 samples and combinations of MS and SS304 samples. For Diameter 14 mm, for SS304 sample tensile load for weld breakage is 61.4 KN. For Diameter 12 mm, MS sample tensile load for weld breakage is 58.8KN. For Diameter 10 mm, for SS304 sample tensile load for weld breakage is 9.98 KN. And for Diameter 14 MS and SS304 is 16.86 KN. So, It is conclude that diameter increases strength of the weld increases.

VII.ACKNOWLEDGEMENT

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