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EXPERIMENTAL INVESTIGATION OF ROTATIONAL FRICTION PARAMETERS OF AUSTENITIC STAINLESS STEEL (GRADE 316)

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Abstract - *Welding industry has been continuously facing challenges when it comes to improving productivity, efficiency, and quality of the products being manufactured. Currently, welding industry is using GMAW, TIGW, SMAW. Apart from these conventional welding techniques, industries are looking for advanced welding techniques which are more cost and time efficient along with wide range application one of those is rotary friction welding. This welding technique creates heat affected zone in between two specimens. One part goes under natural convection where another under forced convection. In this research paper, SS316 was used due to its utilization and capabilities in the industry. Microstructure test is performed on SS316. The research paper considers the analysis of Temperature, Pressure, Time for weld, hardness, microstructure, Heat affected zone in rotary friction welding technology. The research work also considers strength of the weld such as breaking, ultimate and yield strength.*

Key Words: *Friction welding, Stainless Steel SS316, Heat affected zone, Rotary Friction welding, Universal testing Machine.*

1.INTRODUCTION

Friction welding is actually a solid-state welding technology that uses heat generated during forging and friction to form welds. In current era, property and atmosphere affiliation of various materials ought to be a must. Friction attachment has the benefits of reducing production time and saving money. Friction welding, because the name implies, utilizes friction to weld seams. there's no external heat that's applied within the bonding process. As a consequence, it's so a solid-state weld rather than a fusion weld, and also the ensuing junction is sometimes as sturdy as the parent metal. This welding method is used to join components in a wide range of industries. The investigation of Heat Affected Zone, Material Hardness, Tensile Strength, and Microstructure Analysis with various cross sections necessary for welding SS316 is the subject of this research work

Types of Friction Welding

I. **Rotary Friction Welding**

It consists in rotating one of the materials on the surface of the other where welding is required; the method uses axial compression force and high speeds; This mixture plasticizes the two materials, which ultimately leads to a bond between them.

II. **Linear friction welding:**

In this other type of friction welding, one of the materials oscillates against each other at high speeds with high compressive forces in a reciprocating motion, the metal is plasticized by the heat generated on the surface and superficial oxides or impurities are burned or blown off to the side.

III. **Friction Stir Welding**

Create welds using a special instrument with a cylindrical shoulder and a contoured pin. The pin is inserted into the seam between the two workpieces until the shoulder sits on it. The tool then rotates, which softens the metal due to the friction. between shoulder and seam. The soft metal is moved by moving the profile pin linearly over the seam line.

IV. **Friction Stir Spot Welding:**

Friction stir spot attachment is one among the many types of friction stir welding. The tool is affected on the seam of the workpieces in friction stir welding. In friction stir spot welding, on the opposite hand, the tool is spun at a selected location associated not moved. It rotates and welds, then the tool is force up, deed an exit hole wherever the professor could leave. the number of the warmth needed to make the weld between the 2 metal parts determines the speed at that the relative motion happens and also the pressure equipped to the workpieces. Friction welding produces temperatures starting from 900 to 1300 degrees astronomer in steel. it absolutely was injected with an interference of infections pin.

2. METHODOLOGY

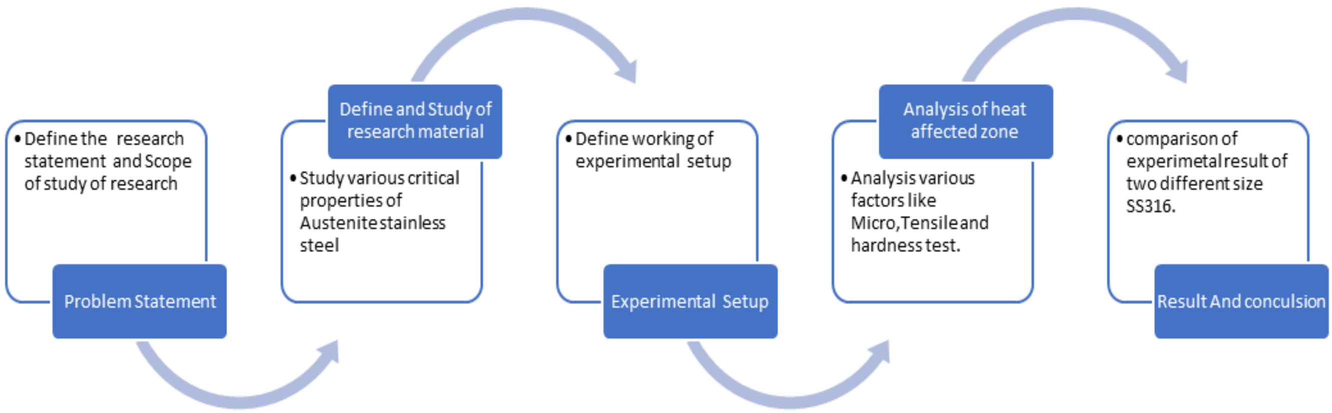


Figure No 1 -Methodology of Research Work

3.PROBLEM STATEMENT

To conduct experiment to join samples of Stainless Steel 316 of same cross sections using rotary friction welding and perform tests for strength of welded samples using hardness test of weld joints, tensile test, hardness tests at different locations in heat affected zone and microstructural examination of weld joints under Microscope.

4. MATERIAL SPECIFICATION.

This is the most popular stainless-steel kind, and for good reason. It's widely utilized in a variety of industries, including medical, automotive, aerospace, and industrial applications, because to its high heat and corrosion resistance. This category is recognized for its unrivalled strength and formability, as well as the fact that it cannot be heat hardened.

Properties of Austenite stainless steel (SS316)

Table No 1– Properties of SS316

Physical Property	Value	Mechanical Property	Value
Density	8.0 g/cm^3	Proof Stress	200 Min MPa
Melting Point	1400 °C	Tensile Strength	500 to 700 MPa
Thermal Expansion	15.9 x10^-6 /K	Elongation A50 mm	40 Min %
Modulus of Elasticity	193 GPa	Hardness Brinell	215 Max HB
Thermal Conductivity	16.3 W/m.K		
Electrical Resistivity	0.74 x10^-6 Ω .m		

5. EXPERIMENTAL SETUP

Rotary Friction attachment was performed On Sparta five Machine factory-made by Friction attachment Technologies (FWT), Pune, India. Machine had capability of 5 ton with most diameter of 16mm and minimum diameter of 8mm needed for weld. 1800 revolutions per minute was unbroken constant for welding 10mm and 14mm samples respectively. Soft Friction pressure, Speed, Upset Delay, Upset force-feeds lubricating system and burn off were kept constant. once 2 materials are friction welded, heat is generated at the contact sites thanks to the relative motion between them and therefore the pressure applied to them. because the method progresses, the quantity of warmth generated increases, and the two materials begin to become viscous at the contact sites. Again, the motion between the 2 encourages mix of the two parts at their sites of contact, leading to weld.

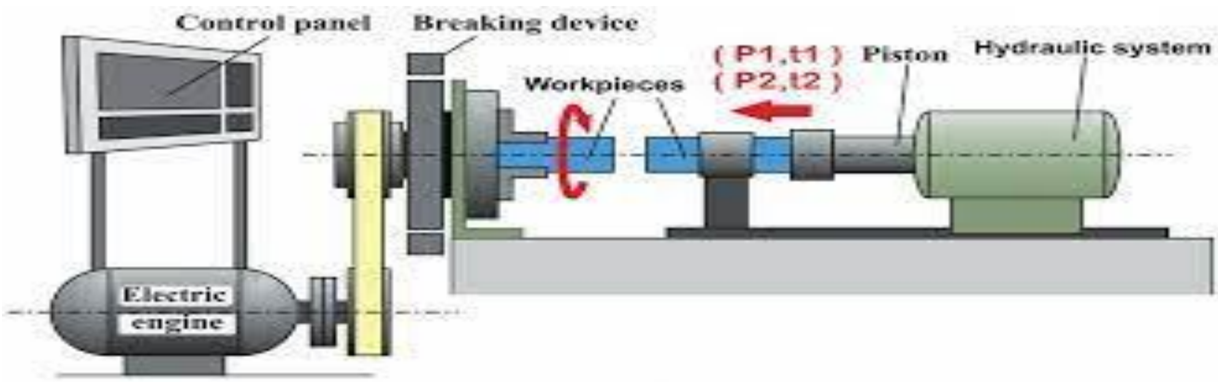


Figure No 2-. Experimental Setup of friction welding

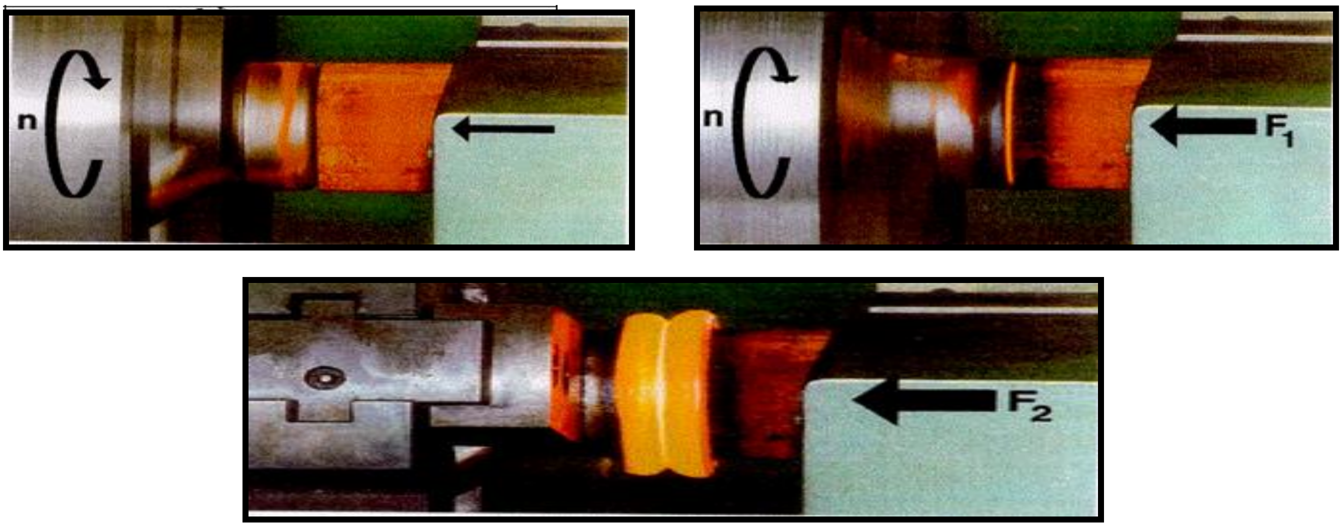


Figure No 3- Photograph of actual Friction welding

Advantages of Friction welding

1. ***Enables joining dissimilar metals:*** It permits connection dissimilar metals one in all the most important edges of friction attachment is that it will be wont to be part of dissimilar metals. Friction welding can be done on nearly any forgeable metal. Engineers have additional freedom as a result of friction welding allows them to construct bimetallic structures. It' customary to consider copper-to-aluminium connections as tough to figure with, nevertheless friction welding makes it possible.
2. **There's no external application of warmth or flux**: Friction fastening needs no external heat or flux, creating it a straightforward and clean procedure.
3. ***Minimal or no defects:*** When compared to fusion fastening, one in every of the benefits of solid-state welding is that it contains few or no defects. Friction welding has identical effects as optical device welding.
4. ***Very fast process:*** Friction attachment is one in all the quickest welding methods, with races to a hundred times quicker than ancient fusion welds.

5. ***Doesn't need much surface preparation:*** Friction attachment are often accustomed connect surfaces that are machined, saw cut, or sheared. Lubricants or oils, on the opposite hand, don't seem to be permissible for ideal weld conditions. Friction welding may be a broad phrase that refers to a spread of welding techniques. Friction welding is employed during a sort of sectors to get difficult-to-weld connections.

6. ANALYSIS OF HEAT AFFECTED ZONE

1. Analysis of Friction Welding.

Specimen Selected for Study

Material = SS316
Diameter (D1) = 14 mm
Diameter (D2) = 10 mm
Length of Final Weld (Lw)
Length of Sample = L1 and L2 (mm)

Table No 2-Process Parameters

Diameter	Density(kg/m^3)	Mass(kg)	Volume(m^3)
10mm	7861.09	0.0617	7.850*10^-6
14mm	7861.09	0.1210	15.386*10^-6

Following parameters were set in the machine for friction welding

SAMPLE 1

Material 1 = Stainless Steel 316
Material 2 = Stainless Steel 316
Diameter 1 = 10mm
Diameter 2 = 10mm
Friction Pressure = 86 kg/mm^2
Feed = 1.2 – 2 mm/min
Rpm = 1800

Table No 3

MATERIAL 1 : SS316	MATERIAL 2 : SS316
WELDING DIAMETER : 10 mm	**WELD AREA** : 78.5 mm²
BREAK OFF MODE : YES	

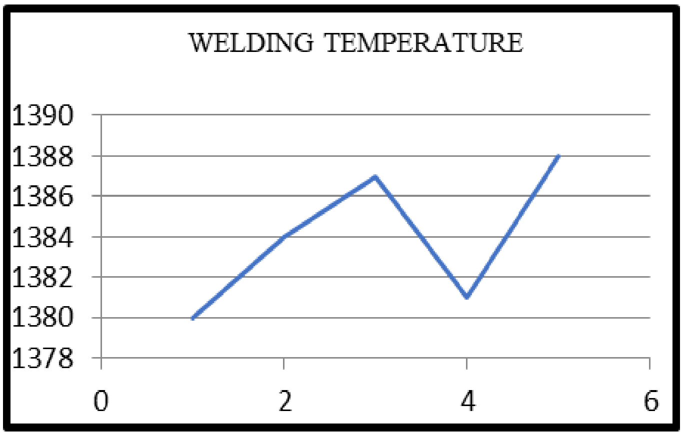
Figure No 4. SS316 10mm Diameter Samples

Table No 4 -SS316 welded Parameters

PARAMETERS	1	2	3	4	5
SPINDLE SIDE LENGTH 1	103.5	104	104	104	103
SLIDER SIDE LENGTH 2	105.5	109.2	106	104.5	104
TOTAL (L1 + L2)	209	213.2	210	208.5	207
FINAL LENGTH (AFTER WELDING)	204.2	209	205.5	204	203

Table No5 -Sample vs. Temperature

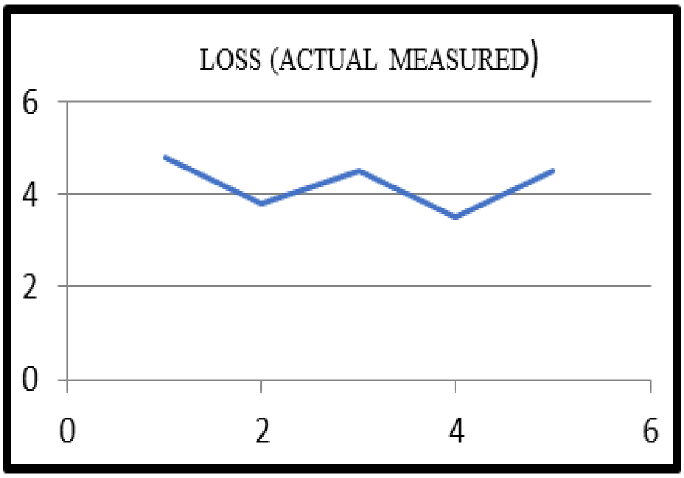
SAMPLE NO.	1	2	3	4	5
WELDING TEMPERATURE	1380	1384	1387	1381	1388



Graph No1 -Sample vs. Temperature

Table No 6 - Sample vs. loss

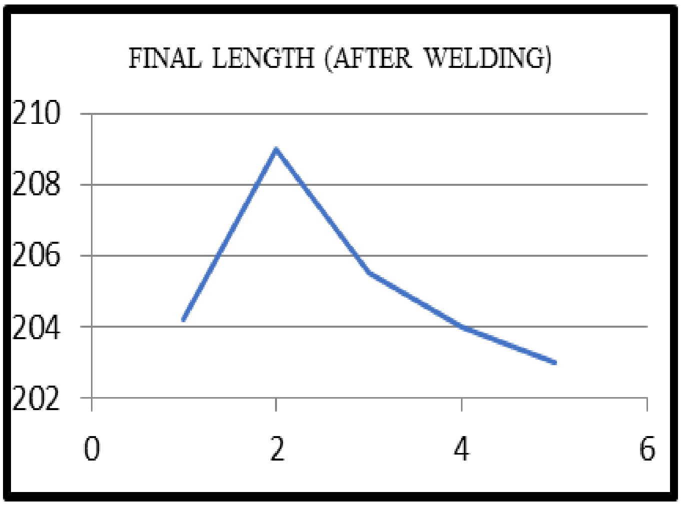
SAMPLE NO.	1	2	3	4	5
LOSS (ACTUAL MEASURED)	4.8	3.8	4.5	3.5	4.5



Graph No 2-Sample vs. loss

Table No 7-Sample vs. Final Length

SAMPLE NO.	1	2	3	4	5
FINAL LENGTH (LW)	204.2	209	205.5	204	203



Graph No 3 - Sample vs. Final length

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SAMPLE 2

Material 1 = Stainless Steel 316
Material 2 = Stainless Steel 316
Diameter 1 = 14mm
Diameter 2 = 14mm
Friction Pressure = 86 kg/mm^2
Feed = 1.2 – 2 mm/min
Rpm = 1800

Table No 8

MATERIAL 1 : SS316	MATERIAL 2 : SS316
WELDING DIAMETER : 14 mm	WELD AREA : 153.86
BREAK OFF MODE : YES	

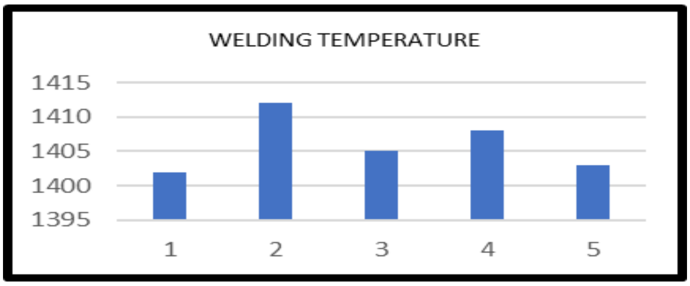
Figure No 5 -SS316 14mm samples

Table No 9 -SS316 14mm Diameter Parameters

PARAMETERS	1	2	3	4	5
SPINDLE SIDE LENGTH 1	104.3	112.3	106	108	106
SLIDER SIDE LENGTH 2	109	109	110	109	105
TOTAL (L1 + L2)	213.3	221.3	216	217	210
FINAL LENGTH (AFTER WELDING)	210.3	216	211.8	212.5	204.5

Table No 10 - Sample vs. Temperature

SAMPLE NO.	1	2	3	4	5
WELDING TEMPERATURE	1402	1412	1405	1408	1403



Graph No 4 - Sample vs. Temperature

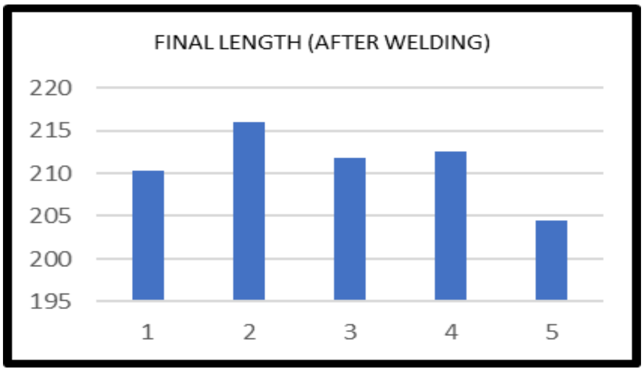
Table No 11 - Sample v. loss

SAMPLE NO.	1	2	3	4	5
LOSS (ACTUAL MEASURED)	3.0	5.3	4.2	4.5	5.5

Graph No 5 - sample vs. loss

Table No 13 -sample vs. final length

SAMPLE NO.	1	2	3	4	5
FINAL LENGTH (AFTER WELDING)	210.3	216	211.8	212.5	204.5



Graph No 6 - Sample vs. Final length

2. Analysis of Hardness Test

Rockwell hardness take a look at had in deep trouble SS304 exploitation one hundred twenty-degree diamond cone indenter. take a look at is finished on each Fine polished surface at weld centre. The hardness variety differs from purpose to point due to its Heat affected zone properties. Location1 (weld centre) is at the centre of the weld (for welded pieces). 5mm faraway from the tip from the weld centre is point 2A and 2B respectively. 2mm away is point 1A and 1B. Hardness test is carried. out for this zone

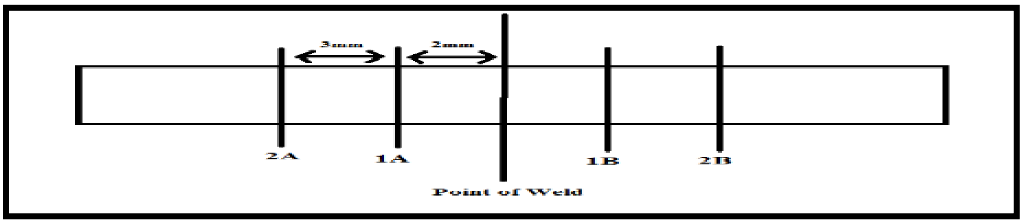
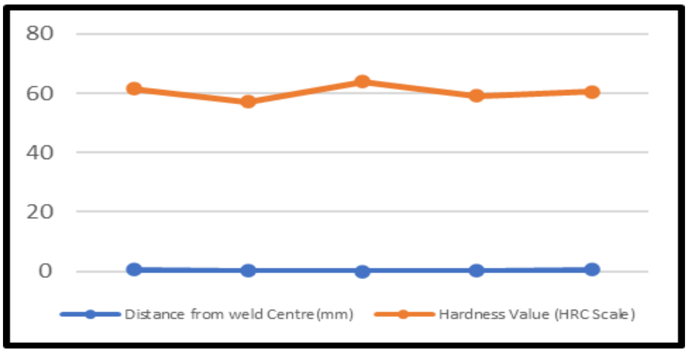


Figure No 6-Point of indentation Contact

Table No 14- SS316 10mm Diameter Readings

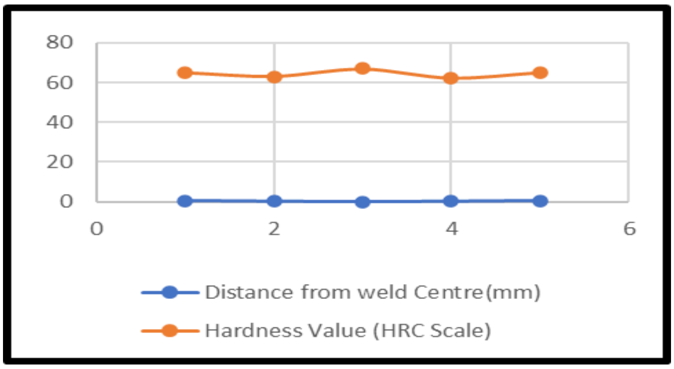
Point Number	Distance from weld Centre(mm)	Hardness Value (HRC Scale)
2A	0.5	65
1A	0.2	63
Point of Contact (weld centre)	0	67
1B	0.2	62
2B	0.5	65



Graph No 7 -SS316 10mm HRC Scale Readings

Table No 15 - 14mm SS316 Hardness readings

Point Number	Distance from weld Centre(mm)	Hardness Value (HRC Scale)
2A	0.5	61
1A	0.2	57
Point of Contact (weld centre)	0	64
1B	0.2	59
2B	0.5	60



Graph No 8- 14mm SS316 Hardness Readings

3. Analysis of Tensile Test

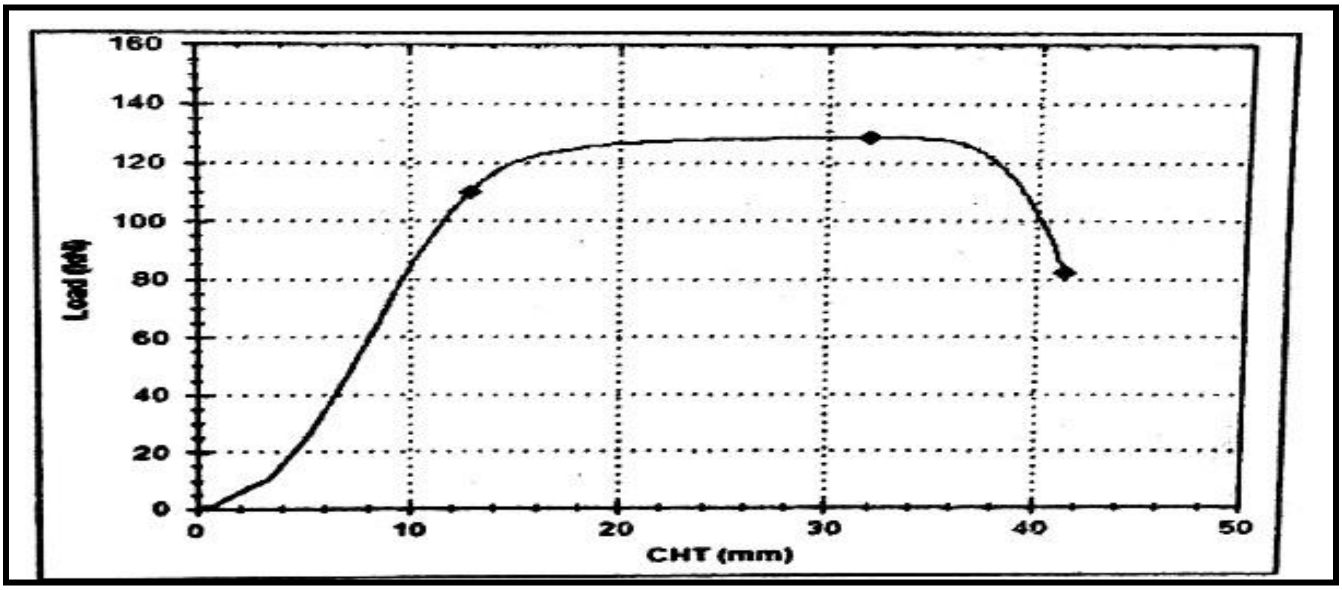
To know the breaking load and breaking stress tensile check has done on the rotary welded specimens. For SS316 Diameter one4mm provides higher results than SS316 Diameter 10mm. Breaking load test is simply conducted for the specimen combination set that is utterly welded throughout friction fastening experimentation. Since all the samples are perfectly welded lastingness of the samples is additional at purpose of weld than the parent material. Load Resolution = Machine capability / 20000 elective On board Extensometer facility with 1 metric linear unit resolution & up to twenty millimetre travel. 20 knowledge set storage (00 to 19) seventy five Results Storage (Related to at least one knowledge set) knowledge Entry & Parameter choice through Keyboard Non-Volatile memory for Result & check data storage.

Figure No 7- Universal testing machine

Sample 1
Material: SS316
Diameter: 14 mm

Table No 16 - SS316 14mm diameter UTM Results

SPECIMAN SIZE	Solid Round	ELONGATION AT YIELD	10.00 mm
SPECIMAN MATERIAL	SS316	YIELD STRESS	548.663 N/mm²
SPECIMAN DIAMETER	14 mm	LOAD AT PEAK	104.250 kN
INITIAL G.L. FOR % ELONGATION	215 mm	ELONGATION AT PEAK	40.320 mm
PRELOAD VALUE	0 kN	TENSILE STRENGTH	677.221 N/mm²
MAXIMUM LOAD	1000 kN	LOAD AT BREAK	69.980 kN
MAXIMUM ELONGATION	250 mm	ELONGATION AT BREAK	47.480 mm
CROSS SECTION AREA	153.928 mm²	BREAKING STRENGTH	454.599 N/mm²
FINAL DIAMETER	7.7 mm	% REDUCTION IN AREA	69.75 %
FINAL GUAGE LENGTH	250 mm	% ELONGATION	16.28 %
FINAL AREA	46.57 mm²	YS/UTS	0.81
LOAD AT YIELD	84.46 kN	UTS/YS	1.234

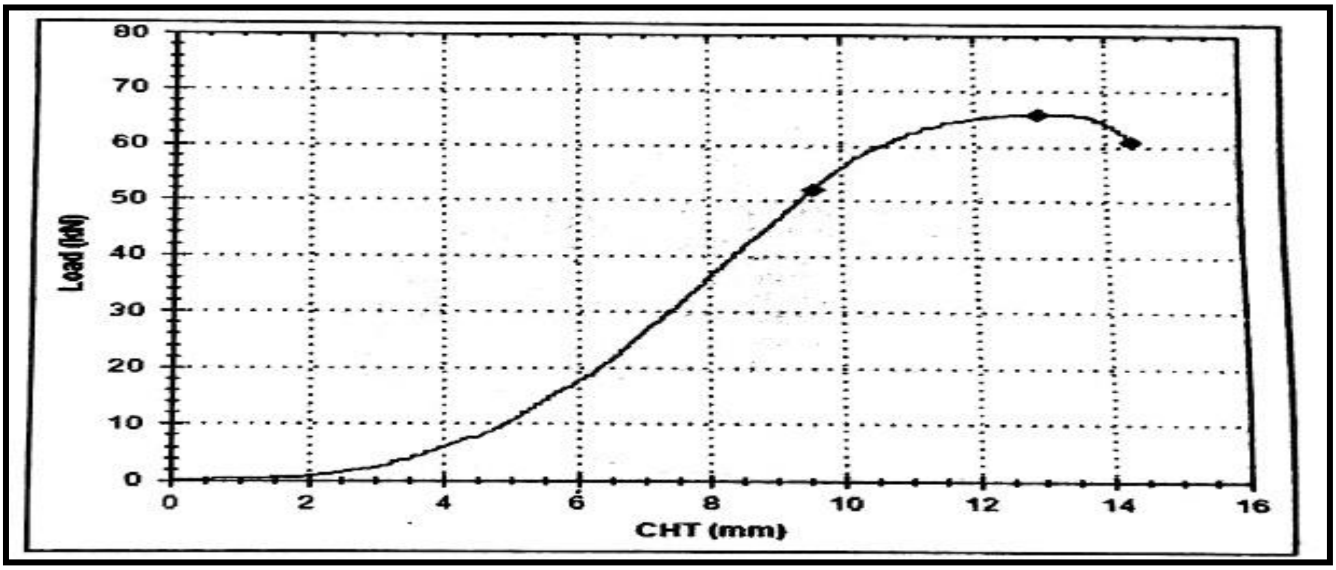


Graph No 9 -load vs. cross trave

Sample 2
Material: SS316
Diameter: 10 mm

Table No 17 - SS316 10mm diameter readings

SPECIMAN SIZE	Solid Round	ELONGATION AT YIELD	9.600 mm
SPECIMAN MATERIAL	SS316	YIELD STRESS	1033.513 N/mm²
SPECIMAN DIAMETER	10 mm	LOAD AT PEAK	65.700 kN
INITIAL G.L. FOR % ELONGATION	51.05 mm	ELONGATION AT PEAK	13.430 mm
PRELOAD VALUE	0 kN	TENSILE STRENGTH	1307.061 N/mm²
MAXIMUM LOAD	1000 kN	LOAD AT BREAK	60.820 kN
MAXIMUM ELONGATION	250 mm	ELONGATION AT BREAK	14.400 mm
CROSS SECTION AREA	50.265 mm²	BREAKING STRENGTH	1209.976 N/mm²
FINAL DIAMETER	7.9 mm	% REDUCTION IN AREA	2.48 %
FINAL GUAGE LENGTH	208.41 mm	% ELONGATION	308.25 %
FINAL AREA	49.02 mm²	YS/UTS	0.791
LOAD AT YIELD	51.95 kN	UTS/YS	1.265



Graph No 10 - load vs. cross travel 10mm diameter

4.Analysis of Microstructural Examination for Grainsize Evaluation

Welded Cross section are first cleaned and polished for examination. After polishing lapping is completed with silicon carbide paper with fineness of 300, 600, 800, 1200, and 1500. After lapping solution is kept in etching reagent for few minutes. Villella's reagent (picric acid 1gm, HCL 5gm, Ethanol 100ml). Now to material is observed under microscope then before testing the material after rotary friction is normalised at room temperature under air cooling.

SAMPLE 1 SS316 Diameter 14mm

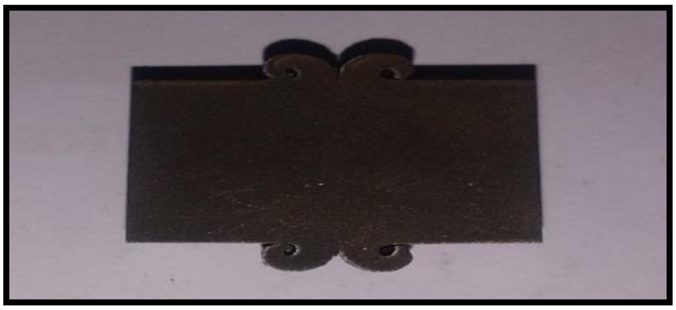


Figure No 8 Friction Welded 14mm Bar

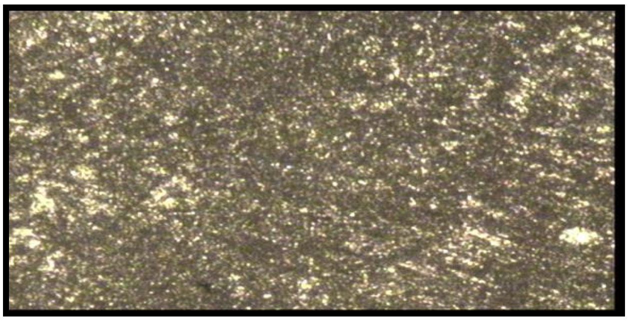


Figure No 9 Microstrure of Parent metal

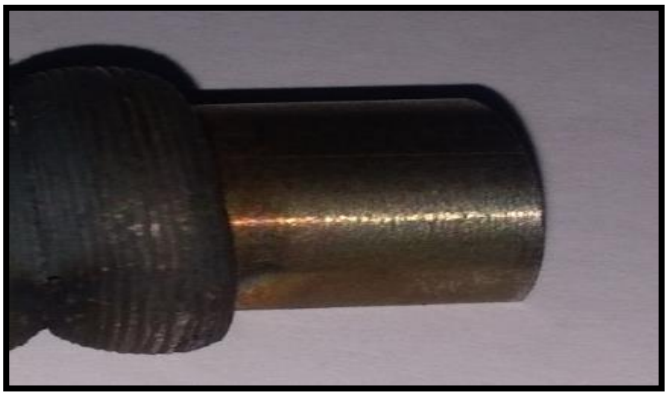


Figure No 10- Actual Heat Affected Zone 14 mm bar

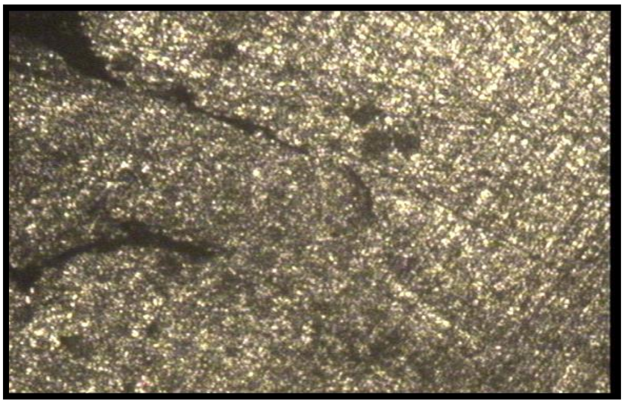


Figure No 11 -Micro. Of Heat Affected Zone

SAMPLE 2 SS316 Diameter 10mm

Figure No12- Friction Welded 10mm Bar

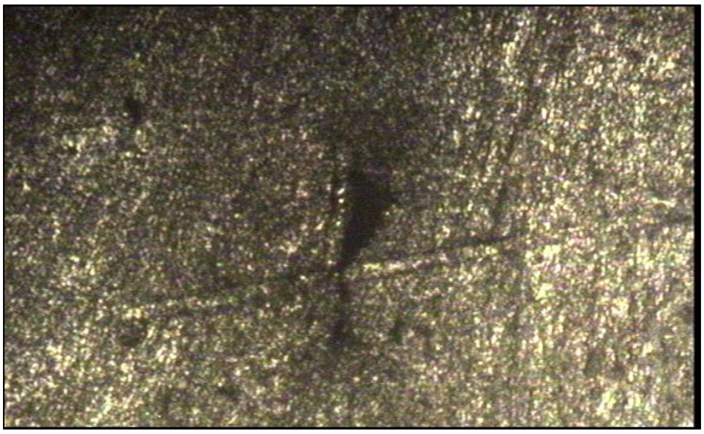


Figure no 13 -Microstrure of Parent metal

Figure No 14 -Actual Heat Affected Zone 10 mm bar

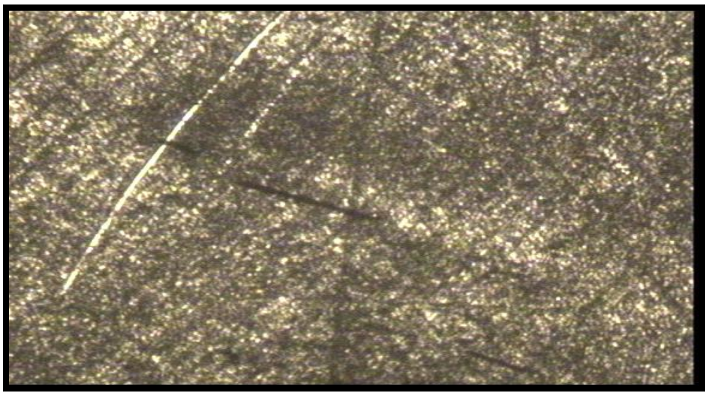


Figure No 15- Micro. Of Heat Affected Zone

Figure No 16-SS316 14mm Tensile Test Sample

7. RESULT AND CONCLUSION

I. For SS316 14mm Diameter loss is 3.032 and for Diameter 10mm loss is 5.778 so thus we conclude that as the diameter of the sample increase, losses decrease. Yield elongation for 14 mm diameter is 10mm while breaking load is69.980 KN and yield stress is 548.663 N/mm^2. However, for 10mm diameter respective values are 9.6mm, 60.820Kn and 1033.513 N/mm^2. From the above values we conclude that Elongation at yield changes with change in the diameter.

Greater the diameter, greater is the yield elongation. Yield stress is inversely proportional to diameter. Breaking load is directly proportional to diameter.

II. According to hardness test maximum hardness is observed at the weld centre while hardness recedes as we approach the parent material hardness. At points 2A and 2B. On Rockwell hardness scale at 150kgf on HRC scale.

III. From Microstructural examination we observe that minimum grain size is obtained at weld centre while maximum grain size is obtained at paerent material.

IV. According to the above results obtained we could conclude that As the grain size increases Strength of the material decreases. Fineness of the material i.e. smaller is the grain size higher is the tensile strength, hardness and larger breaking load is required to break the material. As observed from the tensile test, weld was stronger than SS316 parent material and material broke at parent martial rather than weld centre. From all the above conclusions we conclude that Rotary Friction welding decreases the grain size of the material at the weld joint eventually increasing its tensile strength, hardness of the material and breaking load.

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