WELD DEVELOPMENT FOR AXLE SHAFT AND PISTON ROD ON RFW MACHINE.

An Internship Report Submitted to
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(August 2022 to October 2022)

CERTIFICATE

This is to certify that the Internship Report entitled

WELD DEVELOPMENT FOR AXLE SHAFT AND PISTON ROD ON RFW MACHINE.

Submitted by

Harish Deshpande (1032191325)

in partial fulfilment of requirement of an Internship at Friction Welding Technologies, is a bonafide record of the work carried out by him during the period from August 2022 to October 2022. He has worked under the supervision of Mr. Satesh Bangar and Prof. Pankaj Dhatrak. He has fulfilled the requirement of the submission of the Internship report for Third/Fourth Year Engineering as per the syllabus prescribed by the MIT World Peace University, Pune. The material obtained from other sources has been duly acknowledged in the report.

Mr. Satesh Bangar	Prof. Dr. Pankaj Dhatrak	Prof. Dr. Ganesh Kakandikar
Company Supervisor	College Supervisor	Head,
		School of Mechanical
		Date:

ACKNOWLEDGEMENT

The internship opportunity I had with Friction Welding Technologies Pvt. Ltd. was a great chance at learning new skills and an overall professional development. Therefore, I consider myself lucky as I was provided with an opportunity to be a part of it. I am thankful for having a chance to meet many skilled industrialists and professionals, who guided me throughout my internship.

I take this opportunity to express my deepest gratitude and special thanks my supervisor Mr. Satesh Bangar, Production Manager of Friction Welding Technologies Pvt. Ltd., who despite being extraordinarily busy with his duties, took his valuable time out to hear, guide and keep me on the right path, allowing me to carry out my project at their esteemed organization and extending his regular attention during the training.

I'd like to thank Mr. Satesh Bangar, Production Manager, for engaging in crucial decisions, offering necessary advice and direction, and putting up all of the facilities to promote learning. I've selected this moment to express my gratitude for their efforts. I'd want to express my heartfelt appreciation to Ms. Dipvarsha Pawar, the HR administrator, for providing me with the chance to perform my industrial training.

This chance, in my opinion, marks a significant turning point in my professional life. To achieve my career goals, I will attempt to utilise my newly acquired skills and information as effectively as possible and to continually develop them. I hope to work with every individual in this organisation again in the future.

Sincerely,

Harish Deshpande

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1. INTRODUCTION

Like many other welding techniques rotary friction welding technique is one of a kind that has been adopted for welding of Ferric, Non-ferric metals. However little research has been done on what the technique is and how this process is conducted. So, the process is not known to many. Therefore, this paper is structured on theoretical and experimental study on what rotary friction welding process is and the weld quality delivered by this process. The weld goods are verified by performing various tests for clear understanding of microstructure, strength, hardness, and essential mechanical properties. With the help of this paper, you will understand what rotary friction welding is, what are the advantages of this process over other welding processes.

Friction welding, few individuals are familiar with this type of skilled welding. As the name suggests, friction is used to create the weld. The process is quite simple to understand. Friction Welding process is a solid-state welding process. It produces coalesce of material under compressive force contact of workpiece rotating or moving relative to one another to produce heat and physically displace material from the faying surfaces. Normally the faying surfaces do not melt. It does not require any filler metal, flux, shielding gas etc. Friction welding process is an automatic process essentially for circular motion. The weld produced is characterized by absence of fusion zone, narrow heat affected zone and physically displaced material around the weld(flash). The weld quality is dependent on quality of material (which includes chemical composition and grain structure), joint design, welding variables and post weld processes.

There are three different sorts of processes in this type:

1. Linear Friction welding
2. Stir Friction Welding
3. Rotary Friction Welding

1.1 Linear Friction welding- Linear Friction Welding (LFW) is a solid-state process in which one part moves in a linear motion at high speed and is pressed against another part held stationary. The resulting friction heats the parts, causing them to forge together.

1.2 Stir Friction Welding- Friction stir welding (FSW) is a solid-state joining process developed at TWI Ltd in 1991. FSW works by using a non-consumable tool, which is rotated and plunged into the interface of two workpieces. The tool is then moved through the interface and the frictional heat causes the material to heat and soften.

1.3 Rotary Friction Welding- (RFW) is a solid-state welding process in which one piece is rotating about its axis in this position, stationary. The second piece is tightly attached to a horizontal support and moves in opposition to the first piece. As force is applied, at the contact of the two components, heat is produced due to friction. This increase in temperature aids in the joining of the components.

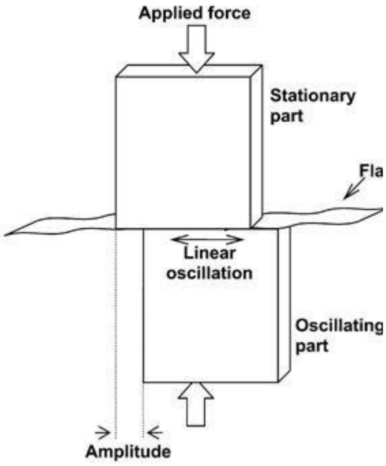


Figure No.1 Linear Friction welding

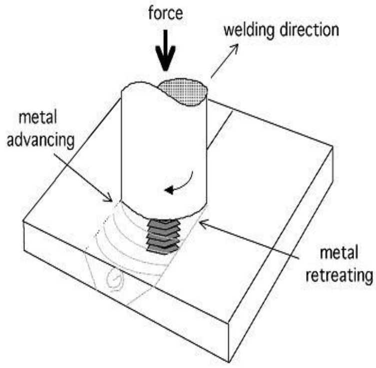


Figure No.2 Friction stir welding

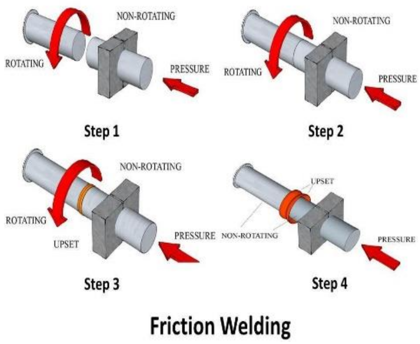
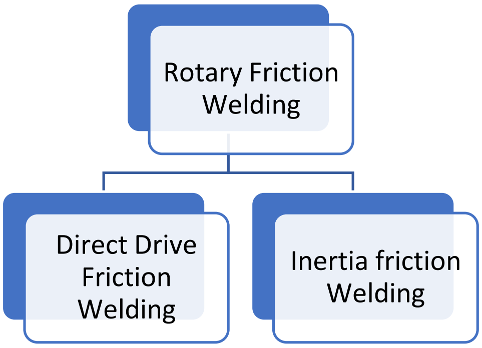


Figure No.3 Rotary Friction welding

2. CLASSIFICATION OF FRICTION WELDING PROCESS BY ENERGY SOURCE



2.1 DIRECT DRIVE:

One of the work parts is attached to a motor-driven unit in direct drive friction welding, while the other is prevented from rotating. The work item is then rotated using a motor at a predetermined consistent speed. After moving the work parts into position, a friction welding force is then applied. As the faying surfaces (weld interface) rub against one another, heat is produced. This goes on for a preset period or until a certain level of upheaval occurs. The rotating workpiece is stopped by the application of a braking force once the rotational driving force has been halted. After rotation stops, the friction welding force is kept constant or increased for a predetermined period. A direct drive welding machine uses a straightforward slide movement measurement for length control.

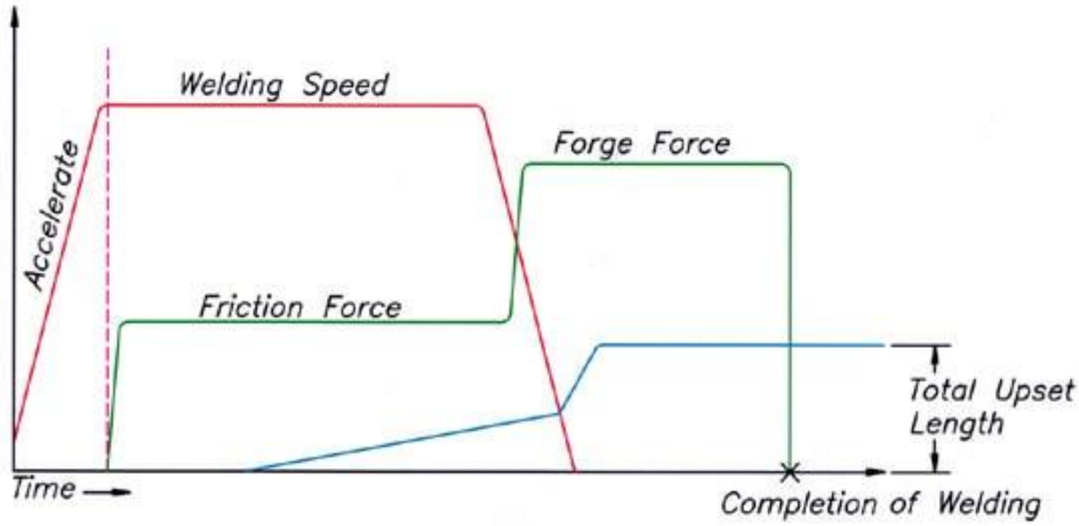


Figure No. 5 Weld process Graph

3. DIRECT DRIVE FRICTION WELDING MACHINE

Fixed head friction welding machine: Friction welding with the rotation of one of the components to be welded or one of the parts to be joined and the linear movement of the other i.e., fixed head friction welding machine.

The machine's design is determined by the predetermined needs of welding specific component. Additionally, there are prerequisites for producing precise, reproducible welds. The size of the components that need to be welded is necessary to determine the machine's maximum dimensional capabilities and reach. The process parameters are then set based on the application of the welded component. Thus, the proper motors and hydraulic power units are chosen. The cycle time, which is chosen with consideration for the quality of each process, also has an impact on this.

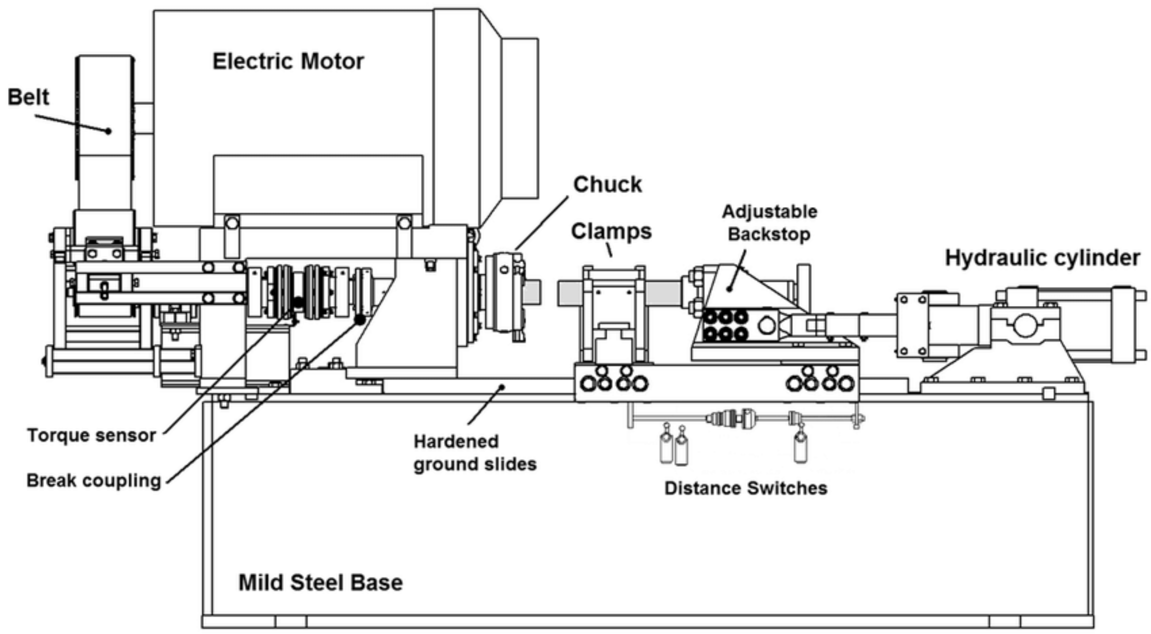


Figure No. 6 Direct drive rotary friction welding

1. Machine frame
2. Headstock with drive spindle
3. Chuck – for rotating component
4. Clamp – for fixed component
5. Machine slides
6. Force actuator
7. Flash removal unit
8. Safety guards
9. Hydraulics power packs
10. Electrical control cabinet
11. Machine control panel

Spindle: Spindles are a variety of sized, electrically, or air-powered machines. The tool is often held together by a shaft, powered by a motor, and controlled by a taper. The spindle then revolves around an axis. Commands from either a person or a computer are used to move the axis.

Chuck: A chuck is a specific kind of clamp designed to hold radially symmetrical objects, particularly cylinders.

Clamp: It is designed as a fixture or tool to hold the fixed component. While the vice moves against the spindle, pressing the fixed component against the spinning component, the clamp firmly holds the component and maintains its position. Because the spindle side component rotates when pressure is applied, the clamp helps retain the component firmly and with strong resistance to torsional force and shearing force.

Machine slide: It serves as a platform on top of which the vice is set. It moves in two directions: right to left and left to right. The vice side component is moved in the direction of the spindle side component using this slider.

Flash removal unit: Let's first define flash so that we can understand this. Flash is extra material that is forced out while it is still molten during the upsetting phase (during weld formation).

Safety guards: These are the doors that guard against probable accident damage brought on by malfunctions such rotating component slipping from spindle, flash removal tool breaking, or screw shooting under severe pressure.

Hydraulic power pack: An independent system made up of a drive motor, hydraulic pump, and hydraulic fluid tank is known as a hydraulic power pack. The hydraulic pump is driven by the drive motor, which is connected to it by a shaft. This is also what drives the slider's movement and the clamping and unclamping of the chuck.

Electric control cabinet: In its most basic form, an electrical control panel is a collection of electrical components that use electricity to regulate the numerous mechanical operations of large-scale machinery or industrial equipment. Panel structure and electrical components are the two primary categories of an electrical control panel.

Machine control panel: from here the operator can operate the machine setting up the parameters, access the previous weld data, check the acceptance and rejection of weld, conduct dry runs and check the visualize the weld graph.

3.1 BASIC CALCULATION FOR MACHINE REQUIREMENT

Machine capacity in tons:

$$\pi r^2 * \frac{\frac{15kg}{mm^2}}{1000}$$

15 kg/mm^2 is standard for steel with medium carbon composition.

where, r is the radius of faying surface.

Maximum force in kgs:

Machine capacity * 1000

Max/upset pressure kg/mm^2:

$$maximum \frac{force}{area} of\ cylinder$$

Cycle time:

Time for travel without regeneration = when the oil is supplied for cylinder from the pump.

Time for travel with regeneration = when the oil used to supply the force comes from both the oil tank and the chamber that is pushed backwards by the cylinder during the removal upsetting force.

Here, the volume available when the upsetting force is applied from behind the cylinder is twice that available when the upsetting force is released. It thus lessens the time taken for applying pressure by cylinder into half.

The machine application determines the axial force(s), rotational speed(s), and welding time. Other factors that affect machine design are carriage speed during friction, friction burn-off, brake point, forging point, torque, and moment of inertia of rotating mass.

3.2 PERMISSIBLE RANGE IN ERRORS IN PARAMETERS

Friction pressure can be calculated by multiplying the standard friction pressure for materials with carbon composition as mentioned in the table into the cross-sectional area of connecting surfaces.

Upset pressure can be calculated by multiplying the standard upset pressure mentioned for the carbon composition materials by referring table 2 to cross-sectional area of connecting surfaces. The upset time shall be set from the time upset pressure is applied to the instance where the red colour high temperature zone of friction of friction welding part goes out.

Friction time is not only affected by the speed of spindle, or friction pressure but also by shape and dimension of base material. It is recommended to set the friction time for a considerable amount of time at first test friction welding and then calculate the time taken for suitable weld development.

Table 1. Standard parameters for friction welding (JIS)

Type Of Joint	Surface Speed			Friction Pressure		Upset Pressure		Burn-off			Total Loss		
				Base Material Carbon content C (%)				Outer Diameter of connecting surface of base material D (mm)					
	Standard value	Upper limit value	Lower limit value	C<0.20	C>0.20	C<0.20	C>0.20	D<40	D<80	D<100	D<40	D<80	D<100
Type 1	3.5	7	1	40	60	100	120	3	5	7	8	12	14
Type 2	4.5	10	2	40	40	80	100						
Type 3	4.5	10	2	60	80	100	140						
Type 4	3.5	7	1	60	80	120	160						
Type 5	4.5	10	2	60	80	100	140						

Table 2. Range of permissible change of friction welding factors (JIS)

Friction Welding Condition factor	**Range of permissible change**
Speed of spindle rotation	Within 7.5% of standard speed of rotation
Friction pressure	Within 5% of standard friction pressure
Upset Pressure	Within 5% of standard pressure
Burn-off length	Within 7.5% of standard friction time
Friction time	Within 7.5% of standard friction burn-off length
Upset time	Not less than standard upset time
Total Loss	Within 10% of standard total loss

4. STAGES IN DIRECT DRIVE FRICTION WELDING

Stage 1 Soft friction: It is also called soft friction. Here, the only purpose of the contact between the surfaces is to warm them. This serves to prepare the specimen for the following stage while taking their melting points into account. As a result, any contaminants on the surfaces are cleaned. Additionally, this initial stage levels out any unevenness.

Stage 2 Friction: The actual friction stages. The sliding component is being axially pressed against the stationary rotating component. Here, friction occurs between the components as a result of the axially perpendicular force being applied to them, which produces thermal energy. Both materials become molten or semi-molten at welding interface as a result of the thermal energy generated due to friction. Then after actual forging pressure is used here.

Stage 3 Upset / Forged Pressure: Upset force is used at this point. This upset force is applied parallel to the component's axis and perpendicular to the faying surface (rod). When both components are crushed together in this instance, an upset force displaces the material, resulting in a solid connection. This upset force is responsible the strength of the weld joint, mechanical properties, and hardness at the weld section.

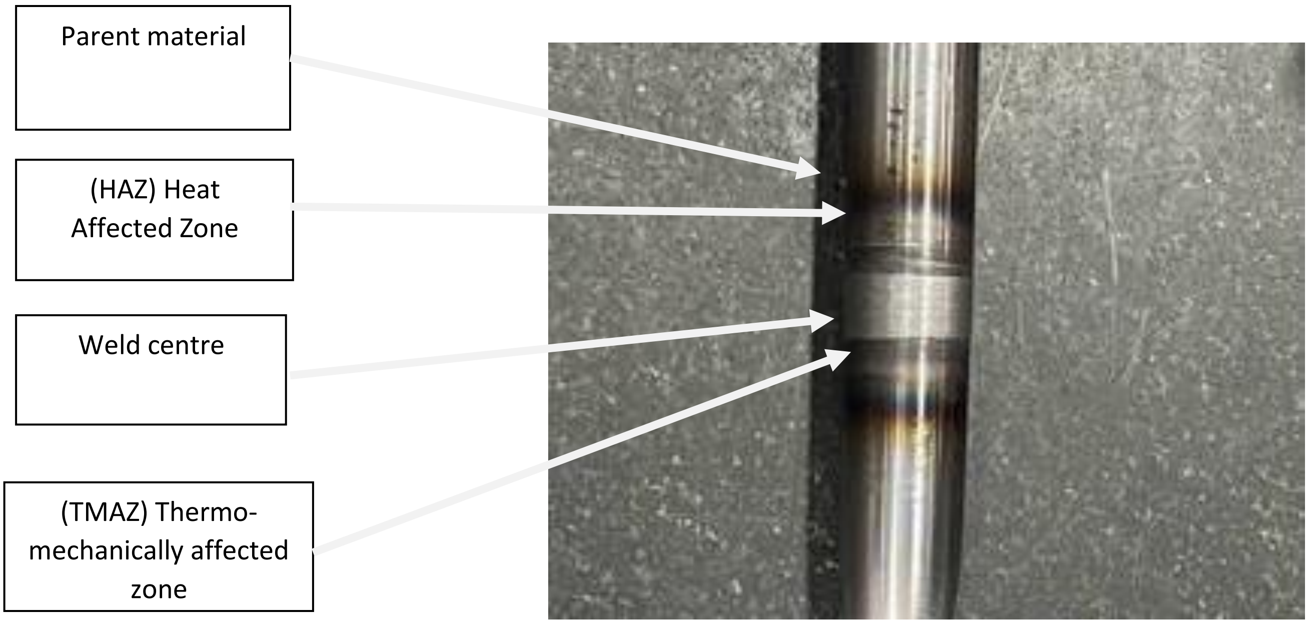


Figure No. 7 Thermally affected descriptive visual

5. QUALITY

1. These elements have an impact on the weld quality

- the amount & location shape of non-metallic inclusions in parent material/s
- the development of intermetallic phases in the weld
- the emergence of low melting point phases in the weld
- the presence of porosity in the parent material(s)
- the thermal softening of hardened materials in the weld
- the hardening of the weld metal heat affected zone

2. **For consistent weld quality following conditions should be maintained**

- chemical analysis
- structure
- strength and hardness
- dimensional and geometric tolerances
- supply conditions of the materials to be joined

3. State of connecting surfaces

- The black film, rust, plated layer, carburized layer, oil, and fat etc. on the connecting surface of base material shall be removed as a rule.
- Also, the end surfaces also shall be given finishing in case of cut made by saw cutting part, shear etc. the roughness must not be greater than 25a.

5. Post welding treatment

Post welding treatment should be carried out according to the customer requirements as well as considering the application of the welded component.

6. IMPORTANCE

The friction welding procedure is carried out by process parameter. It's a model-driven approach that's at least as perceptive, clever, and effective as any other. The guidelines for the welding process are unambiguous and easy to establish. The method results in the least amount of material waste. The needed alignment is challenging to maintain in industries where welding is done manually. Additionally, certain welding techniques take a lot longer. Therefore, it is frequently difficult to reach the aim within the allotted time. However, friction welding can be finished in much less time relative to conventional welding methods, depending on the target weld and whether the flash needs to be reduced. The technique had the benefit of being straightforward to set up thanks to the machinery developed by recognised companies like Friction Welding Technologies. Other welding techniques produce more waste and are therefore less cost-effective. Because there are no by-products of the process or catalyst additives, it is simple and amazing for efficient and clean welding.

There are countless possible weld combinations that can be produced with friction welding. Calculations can be made based on strength and hardness disparities for proper, precise welding. It is possible to substitute more expensive forgings and castings with less expensive forgings that are welded to bar stocks, tubes, and plate-like structures.

Time is saved significantly since the process is far quicker than the bulk of traditional welding methods.

7. OBJECTIVE

- To develop fixtures and tooling for friction welding axle shaft and piston rod.
- To finish the procedure efficiently and at a lower cost.
- To weld dissimilar metals
- To use friction welding to obtain the strength of the parent material.

8. SCOPE

- Understanding RFW process.
- To determine the process variables that control the creation of a weld between two components.
- Developing fixtures and tools for axle shaft and piston rod welding.
- Testing the welded parts to ensure that their mechanically machinable thermal characteristics meet the needs of their application.

9. PROBLEM STATEMENT

- To create the materials and equipment necessary for welding axle shafts and piston rods, as well as to establish the ideal welding parameters.

10.LIMITATIONS

- Only objects/components with one cylindrical part may be linked together using this technique.
- Non-metallic materials cannot be joined together using welding.

11.WELD DEVELOPMENT PROCESS

Numerous components need to be welded before being used. Industrialists would not choose to create a separate machine for each such component. As a result, we attempt to modify the current machine with enhanced equipment so that it can perform the welding operation on a high number of components. This lessens the absurd use of resources, labor, and time when creating a new machine. It really is a smart way to cut costs. Here, we demonstrate the capabilities and adaptability of the machines we build and provide confirmation of their high level of functionality through development and customization.

So, to get the idea of what we do here let us recollect how we start the designing process of a machine. Essential information required is dimension of the component to be weld, material to be weld and the additional features that the customer requires like flash turn-off, automating the loading and un-loading of raw material etc. Hence, we get the idea of possible customization possible to meet the needs.

Development process takes place in following steps:

1. We proceed to the next phase if the new component that needs to be welded fits within the dimension’s parameters of the current machine.
2. We may determine whether the clamp can hold the component by measuring its diameter on the slider side, or else we can construct a new clamp dimension fixed on self-centering bowls.
3. By measuring the component's diameter on the spindle side, we can determine whether the master collet can clamp the component or if collet walls or pads must be designed to hold it. Or else a totally new fixtured is design in accordance with the component that is to be held.
4. If additional tools are required, they are designed to hold the component on the slider side so that it remains in the axis of rotation of the stationary rotating component on the spindle side.

11.1 MARKET SURVEY

First, we conduct a survey to determine the components those are in reach and capabilities of the machines we have created so far. This helps us identify areas for improvement and the things we can best deliver. The target market has already been condensed since we produce rotary welding machines. We now conduct a market analysis to identify a suitable, weldable component or a novel component with increased demand in industry, and we develop our machine in response. Here, it is simple to aim for the components that resemble those that we have been welding.

11.2 DIMENSIONAL BOUNDARIES

The dimensions of the required component are now considered when constructing a machine, and a standard tolerance is maintained in both the radial and length directions. In doing so, we may specify the machine's maximal capabilities as well as its dimensional range.

11.3 SELECTION OF ARRANGEMENT FOR WELDING PROCESS.

There are four types of arrangements on direct drive friction welding machine. Here are those:

- friction welding with the rotation of one component to be welded or one of the parts to be joined and liner movement of the other. Also called as fixed head welding machine.
- Welding with rotation and linear movement of one component to be welded and the other one held static. Also called as sliding friction welding machine.
- Rotation and linear movement of two component against a static middle component. Also called as double ended friction welding machine.
- Rotation of central component with linear movement of 2 end components. Also called as

It is essential to understand and employ the proper welding process assembly when developing a welding machine for the welding of a certain component. This results in a better, more appropriate method that can provide a fantastic weld. It’s important to keep in mind that the type of arrangement and joint design do have a significant impact on how a weld will develop.

11.4 SELECTION OF MATERIALS FOR THE DESIGN OF TOOLS AND FIXTURES.

It is now essential to comprehend the kind of material we will be welding. Therefore, the tooling needs to be made properly. It is important to choose the correct material for the tool because if it is made of a relatively soft substance, high-pressure friction in a hot environment will eventually weather the material. In sophisticated assemblies, variable tolerances brought on by tool wear are also unacceptable. Because it goes against the principles of consistently creating welds with nearly flawless accuracy, this is rarely acceptable. Additionally, modifications are made to the tool’s design to make it more resistant to stress and shearing if the proper material cannot be found. This design change is essential since it could prevent the flash removal tool from malfunctioning.

12. RESEARCH METHODOLODY

12.1. Feasibility check: Initially, the customer enquires the finished product's specifications for us. If the dimension of the material to be welded is within the capabilities of our current machine, we move on to the next step. If not, we cannot proceed further.

12.2. Drawing Reading: The customer sends us the finished product design as well as the basic raw material design with dimensions that he wants us to weld. If a similar type of component has been welded previously, we can cross-check the raw material dimensions (via basic calculation) that our customer is providing us with and request changes if necessary.

12.3. Reverse Engineering: Here, we work from top to bottom approach. As the machining calls for a specific required strength and allowance (tolerances) in some essential cases that will be described further, understanding the needs of our customer, and assisting him with the best weld finish is necessary.

12.4. Designing of tools: If the welding can be done with the existing tools, we will begin immediately. If not, we create new tools based on the requirements and assess the setup's reach. The design of the V-bowl where the support is given to the Piece 2 and the master collet where the Piece 1 is clamped for stationery position is designed and manufactured according to the dimension of the set to be clamped. We proceed to the next step after thoroughly inspecting the setup.

12.5. Process parameters optimization: We optimize the process parameters guiding the welding process before beginning. This covers the spindle's rotational speed, soft friction force, friction force, upset force, brake delay time, and welding modes (burn off, time specific, fixed position upset).

12.6. Welding process: Now throughout the welding process, we can observe rejection for 1-2 pieces from the sample test we perform initially. This is due to some slight miscalculations or impurity of the raw material received. We adjust the parameters correctly to eliminate that, which leads to the perfection of our welding process. This perfection can be achieved within few samples testing.

12.7. Post process inspection: We perform GD&T testing when the welding is finished. We send the finished goods to our customer after verifying the specifications.

13. SETING UP OF MACHINE BEFORE STARTING WELDING PROCESS

13.1 Fixture fitting:

We attach and fit the fixtures in accordance with the specifications before beginning the welding operation. The vice's self-centering bowls and v-bowls on the interior of the chuck have collet pads to firmly grip the part.

Currently, we are testing the machine by giving it several dry runs. This enables us to ensure that the equipment is operating properly and might assist to avoid issues that can arise when welding.

Next, we insert the spindle-side component into the chuck that is in the master collet and check the clamping and unclamping processes to see if the part is securely secured.

At this point, a problem might occur since the component might only be within or outside the collet. Therefore, we employ a stopper if the component on the spindle has a short length (a cylinder-shaped object at the base of master collet and at the end of rotating rod). Because of the heat created at the weld contact and the upsetting pressure provided to the semi-molten material during the welding process, the material is displaced. The outer end of the spindle side component must be a specified distance from the outer side of the collet; thus, we must check for this.

After installing the fixture, we examine the parallelism and the chuck and vice's center points, which enable us to precisely align both side components. Here, we may also check to determine if the component's alignment—more specifically, whether their axes are collinear—is the same on both sides of the spindle and vice.

13.2. Trial runs

We are now manually operating the machine to examine the slider's fast to feed position. This implies that the machine is aware of the location at which the slider can advance freely and the position at which the slider and spindle component will contact

14. WELDING COMPONENTS

14.1. AXLE SHAFT: Heavy-duty, load-bearing axle shafts are a common part of motorised vehicles. These parts, which are also known as CV axles or half-shafts, transmit rotational force from the vehicle's transmission system to the wheels attached to the axles.

14.1.1 Customer requirement:

1. Part Name: - Axle Shaft.
2. Application: - Transmission of rotational motion from engine to wheels.
3. Tooling Components: - rod, rod eye locator, base bowl and vertical shim.
4. Material grade: - CK/SAE 1541
5. Weld strength required: - Equivalent to parent Material.
6. Types of tests to conduct: - Micro, Macro, Tensile & Bend test.

14.1.2 Materials to be weld

1. Part 1: Axle Shaft - CK45/SAE 1541
2. Part 2: Axle-Flange forged - CK45/SAE 1541 (Axle Flange is normalized to 149-187 BHN)

Note*: normalizing is done to remove the structural irregularities or impurities and defects from the metal. It is done to improve the ductility and reduce the hardness that is caused by thermal hardening process*

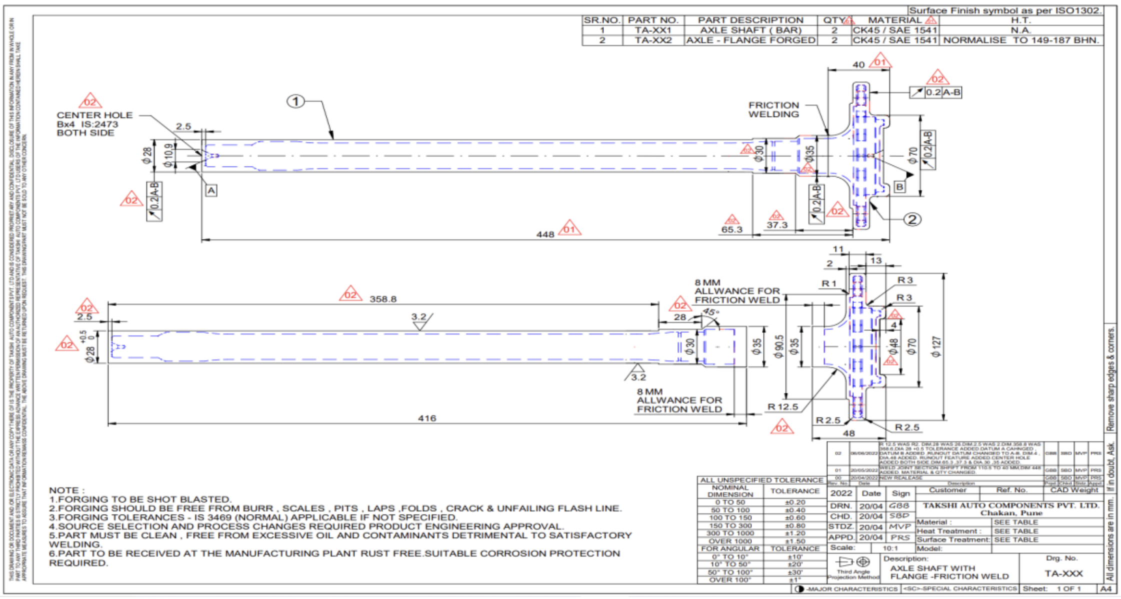


Figure No. 8 Requirement specification drawing

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14.1.3 Chemical composition of SAE 1541

C ≤	Si ≤	Mn ≤	P ≤	S ≤	Cr	Ni
–	0.09	0.75-1.05	0.04-0.09	0.26-0.35		
Mo	Al	Cu	Nb	Ti	V	Ce
–	–	–	–	–	–	–
N	Co	Pb	B	Other	–	–
-	-	-	-	-	-	-

Table 3: chemical composition of SAE1541

14.1.4 Carbon steel 1541 mechanical properties

Mechanical Properties	Metric	English	Comments
Hardness, Brinell	>= 207	>= 207	
Tensile Strength, Ultimate	>= 706.7 MPa	>= 102500 psi	
Tensile Strength, Yield	>= 600 MPa	>= 87000 psi	
Elongation at Break	>= 10 %	>= 10 %	in 2 in. (50 mm)
Reduction of Area	>= 30 %	>= 30 %	
Modulus of Elasticity	200 GPa	29000 ksi	Typical Carbon Steel
Poisson's Ratio	0.29	0.29	Typical Carbon Steel
Machinability	45.00%	45.00%	Cold Drawn AISI 1212 = 100%
Shear Modulus	78.0 GPa	11300 ksi	Typical Carbon Steel

Table 4: mechanical properties of SAE1541

14.1.5 Thermal properties of 1541

Thermal Properties	Metric	English	Comments
CTE, linear	12.0 µm/m-°C	6.67 µin/in-°F	Typical Carbon Steel
Specific Heat Capacity	0.470 J/g-°C	0.112 BTU/lb-°F	Typical Carbon Steel
Thermal Conductivity	52.0 W/m-K	361 BTU-in/hr-ft²-°F	Typical Carbon

Table 5: thermal properties of SAE1541

14.1.6 TOOL DESIGN

Figure No. 9 Tool design for welding of axle shaft

14.1.7 CALCULATION

Machine capacity in tons:

$$\pi r^2 * \frac{\frac{15kg}{mm^2}}{1000}$$

15 kg/mm^2 is standard for steel with medium carbon composition.

where, r is the radius of faying surface

$$3.14 * 17.5 * 17.5 * \frac{15}{1000} = 14.424375 tons$$

Maximum force:

Machine capacity * 1000

$$14.424375 * 1000 = 14424.375\ kgs$$

Max/upset pressure:

$$maximum \frac{force}{area} of\ cylinder$$

$$\frac{14424.375\ kgs}{961.6mm^2} = 15kg/mm^2$$

The Weld was carried out on a FWT 12 Ton direct drive Friction Welding Machine using the baseline parameters as below
Weld Speed: 1600 rpm, Weld Load: 15 kg.mm^2.

14.1.8 PROCESS PARAMETER

Job Description	Required	1	2	3	4	5
Welding length Tube	48.0	48.1	48.0	48.1	48.0	48.0
Welding length Piston Post	406	406.9	409.1	407.0	406.9	406.9
Total Length	454	455	457.1	455.1	454.9	454.9
Final Length	448 ±1	447.8	448.6	446.9	447.0	447.2
Loss Actual Measured	8 - 9	7.2	8.5	8.2	7.9	7.7
Shrinkage Range	8 – 14	7.7	8.7	9.1	9.0	8.0
Soft Friction time T1A	2.0	0	0	0	0	0
Friction time T1B	12	12	12	12	12	12
Burn Off	X	5.7	7.5	7.5	5.4	5.8
Brake Delay	0.1	0.1	0.1	0.1	0.1	0.1
Upset Delay	0.6	0.6	0.6	0.6	0.6	0.6
Upset Delay	3	3	3	3	3	3
Soft Friction Pr.4.6 kg/mm^2 (P1)	45	45	45	45	45	45
Friction Pr. 11.1 kg/mm^2 kg.mm^2 (P2)	110	110	110	110	110	110
Upset Pr. 15 kg/mm^2 (P3)	150	150	150	150	150	150
Feed (mm/min)	85%	85%	85%	85%	85%	85%
RPM	1600	1600	1600	1600	1600	1600
Run out	0.5	0.5	0.5	0.5	0.5	0.5

Table 6: Weld process 0utput sheet

This case demonstrates that the manufactured tools and fixtures are flawlessly constructed and correctly incorporated into the machine assembly through their minute existence, or more precisely their accurate presence within allowable run-out. The data in the above table can be used to assess how consistently the weld was created by the process parameters. As a result, the parameters for the welding process are accurate, and the weld was successful.

Figure No. 10 Axle shaft after welding

14.2 SOCKET AND PISTON ROD: a piston rod joins a piston to the crosshead and thus to the connecting rod that drives the crankshaft or (for steam locomotives) the driving wheels.

14.2.1 Customer requirements

1. Part Name: - Piston Rod.
2. Application: - Steering wheel.
3. Tooling Components: - rod, rod eye locator, base bowl, and vertical shim.
4. Material grade: - EN8 & EN 8 Forged
5. Weld strength required: - Equivalent to parent Material.
6. Types of tests to conduct: - Micro, Macro, Tensile & Bend test.

14.2.2 Materials to be weld:

1. Part 1: Socket – EN8
2. Part 2: Piston rod – EN8 forged.

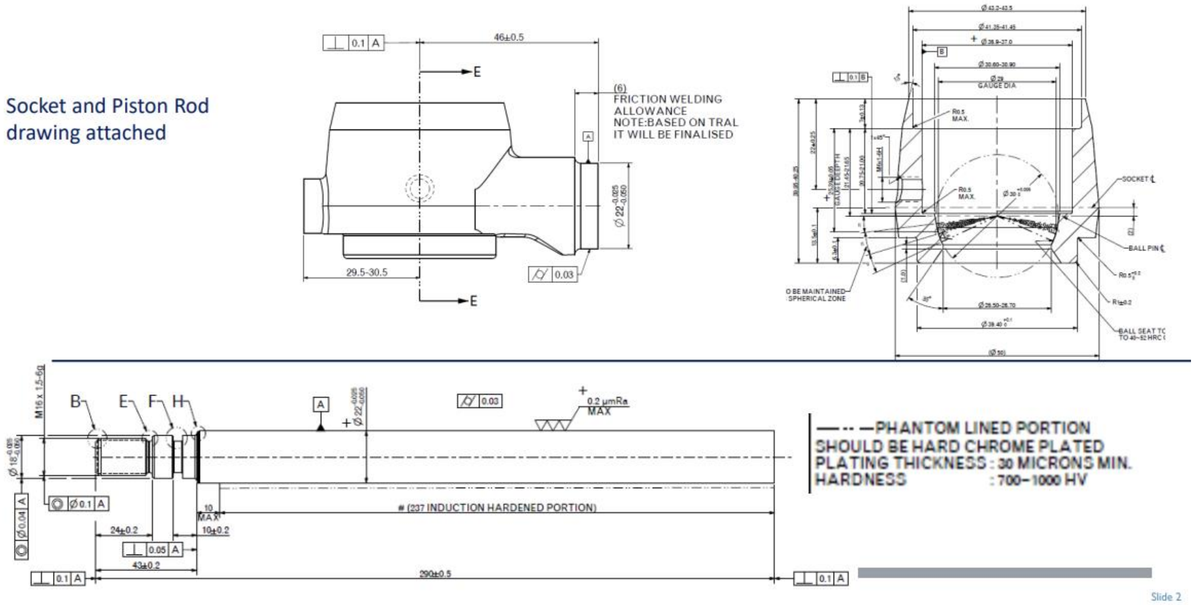


Figure No. 11 Requirement specification drawing for piston rod

14.2.3 Chemical composition EN8 and EN8 forged

080M40 (EN8) Specification chemical composition.	
Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050 Max
Phosphorus	0.050 Max
Chromium	-
Molybdenum	-
Nickel	-

Table 6 Chemical properties of EN8and EN8 forged

14.2.4 Mechanical properties EN8 and EN8 forged:

080M40 (EN8) - mechanical properties in "R" condition		
Max Stress	700-850 n/mm^2	
Yield Stress	465 n/mm^2 Min	(up to 19mm LRS)
0.2% Proof Stress	450 n/mm^2 Min	(up to 19mm LRS)
Elongation	16% Min	(12% if cold drawn)
Impact KCV	28 Joules Min	(up to 19mm LRS
Hardness	201-255 Brinell	

Table 6 Mechanical properties of EN8

14.2.5 Thermal Properties of EN8 forged:

Heat Treatment

- EN8 or 080m40 can be tempered at a heat of between 550°C to 660°C (1022°F-1220°F), heating for about 1 hour for every inch of thickness, then cool in oil or water.
- Normalizing of EN8 bright mild steel takes place at 830-860°C (1526°F-1580°F) then it is cooled in air.
- Quenching in oil or water after heating to this temperature will harden the stee

Welding

- Modern EN8 bright mild steel contains a lot less carbon than it uses to, this mean that it is possible to weld pieces up to 18mm thick without preheating using MIG wire (SG2) or a 7018 electrode.
- Over 18mm would require a pre-heat of 100°C (212°F) in order to prevent cracking.
- Anneal afterward is recommended to prevent breaking.

14.2.6 TOOL DESIGN

Figure No. 12 Tool design for piston rod

14.2.7 PROCESS PARAMETERS

Calculation:

Machine capacity in tons:[2]

$$\pi r^2 * \frac{\frac{15kg}{mm^2}}{1000}$$

15 kg/mm^2 is standard for steel with medium carbon composition.

where, r is the radius of faying surface

$$3.14 * 11 * 11 * \frac{15}{1000} = 5.699\ tons$$

Maximum force:

Machine capacity * 1000

$$5.699 * 1000 = 5699.1\ kgs$$

Max/upset pressure:

$$maximum \frac{force}{area} of\ cylinder$$

$$\frac{5699.1}{379.94} = 14.921$$

The Weld was carried out on a FWT 12 Ton direct drive Friction Welding Machine using the baseline parameters as below
Weld Speed: 1400 rpm, Weld Load: 15 kg.mm^2.

14.2.8 PROCESS PARAMETER

Job Description	Required	1	2	3	4	5
Welding length Tube	280	280.4	280.4	280.4	280.4	280.3
Welding length Piston Post	50	50.2	49.9	49.8	49.6	50
Total Length	330	330.6	330.3	330.2	330	330.3
Final Length	323	323.9	323.1	323.2	323.5	324
Loss Actual Measured	7-8	6.7	7.2	7	6.5	6.3
Shrinkage Range	4-9	7.7	8.2	7.9	7.6	7.5
Soft Friction time T1A	0	0	0	0	0	0
Friction time T1B	7.2	7.2	7.2	7.2	7.2	7.2
Burn Off	5	5.3	5.9	5.7	5.2	5.2
Brake Delay	0.1	0.1	0.1	0.1	0.1	0.1
Upset Delay	0.6	0.6	0.6	0.6	0.6	0.6
Upset Delay	3	3	3	3	3	3
Soft Friction Pr. 0kg/mm^2 (P1)	0	0	0	0	0	0
Friction Pr. 7.5 kg/mm^2 kg.mm^2 (P2)	40	40	40	40	40	40
Upset Pr. 15 kg/mm^2 (P3)	80	80	80	80	80	80
Feed (mm/min)	85%	85%	85%	85%	85%	85%
RPM	1400	1400	1400	1400	1400	1400
Bore upset	0.1	0.11	0.09	0.03	0.07	0.09
Face 1	13.5	13.27	13.42	13.79	13.34	13.31
Face 2	25.3 ±0.5	26.67	26.71	26.81	26.35	26.63

Table 6: Weld process 0utput sheet

It's critical to realize that the amount of upsetting force required to build a bond between two materials determines how hard the resulting weld will be.

This case demonstrates that the manufactured tools and fixtures are flawlessly constructed and correctly incorporated into the machine assembly through their minute existence, or more precisely their accurate presence within allowable run-out. The data in the above table can be used to assess how consistently the weld was created by the process parameters. As a result, the parameters for the welding process are accurate, and the weld was successful.

15. TESTING

After the weld is created, the component is put through a variety of tests to demonstrate its strength, integrity, and dependability, including tensile, hardness, bend, and torsional testing.

1. UTM machine

Universal testing machine is used for testing the tensile strength and compressive strength of materials.

15.1 Tensile test

Procedure:

-First, a clamp that can hold the component at both its upper and lower ends is set up.

- After the material has been gripped by the jaw at both ends, we gradually apply pressure to the substance.
- Gradually, as the pressure rises, the material's strain rises as well.
- A load, often referred to as the displacement of the material, is plotted against the pulling force.
- The load is converted into a stress value, while the displacement is converted

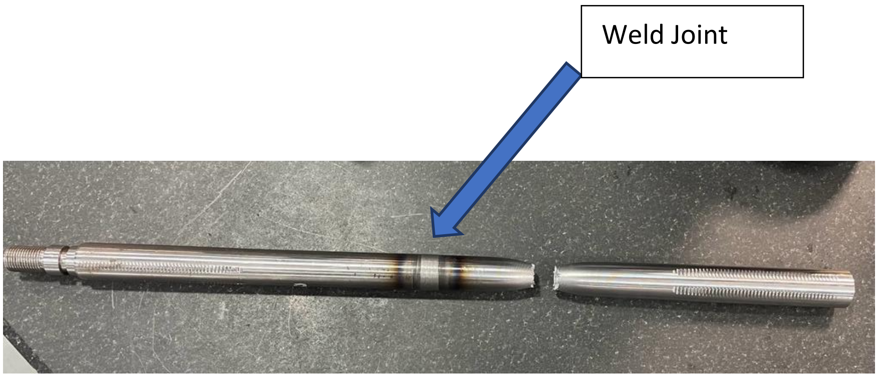


Figure No. 13 After tensile tested visuals

into a strain value.

15.2 Transverse / bend test

The anvils are first positioned on the reference plane.

- after which the specimen is placed on the anvils with a roller perched over it.
- The specimen and support anvils are set up so that the roller applying pressure is in the middle of the specimen and equidistant from both of its ends.

The test conducted on the welded material mentioned above is shown in annexure A and B weld development report.

Fig 10.: Before Bend Test

Fig 11.: After Bend Test

Sample number	Span Length (mm)	Diameter (mm)	Angle of deviation	Observation
1	108	22	50º	No Cracks Observed

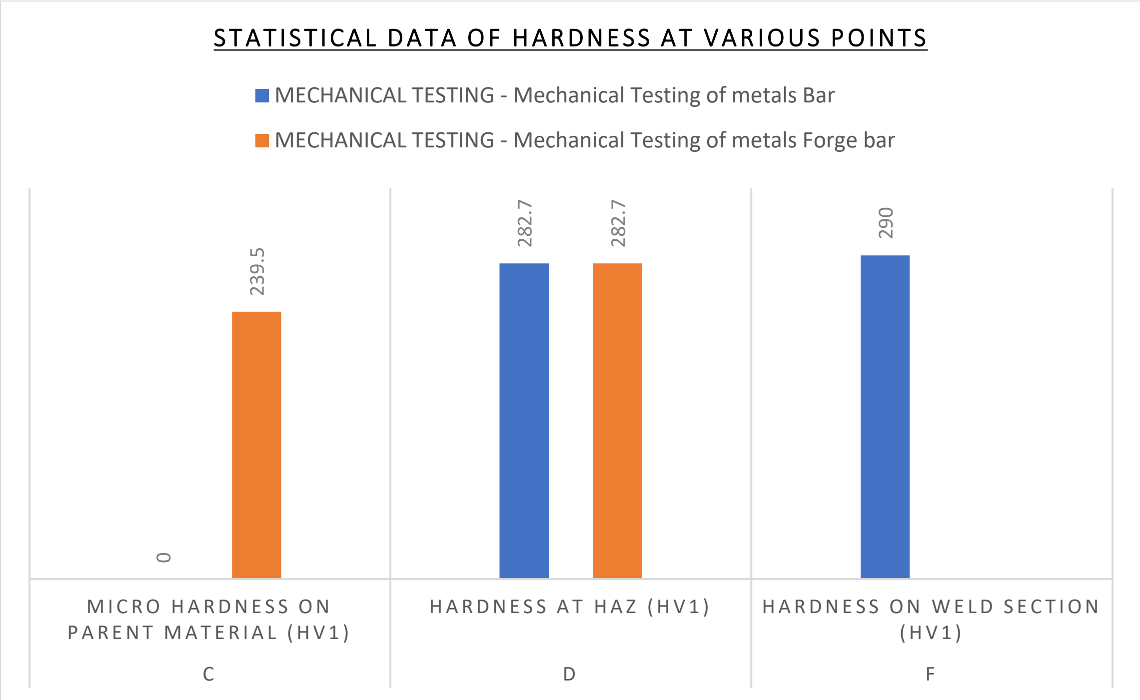
Table6: bend test output data

Remark:

While the necessary bend angle at the weld section was 45°, the transverse test on the UTM machine showed a bend angle of 50°. So, we can conclude that the bend test was successful.

15.3 Micro Vickers hardness:

The Vickers hardness test involves pressing a Vickers indenter (below) on a surface with a specific amount of force. The force is typically held in place for 10 seconds. The finished indentation is visually examined to determine the size of the impression and to estimate the diagonal lengths.

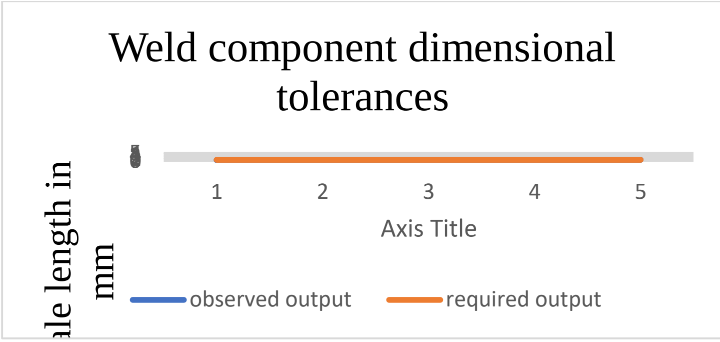


From the weld portion to the HAZ (heat affected zone), and finally to the parent material, we can see the hardness at various positions in this image. These data demonstrate that the hardness at the weld created is equal to the parent material, indicating that the entire component will behave nearly identically when subjected to high pressure and load applications.

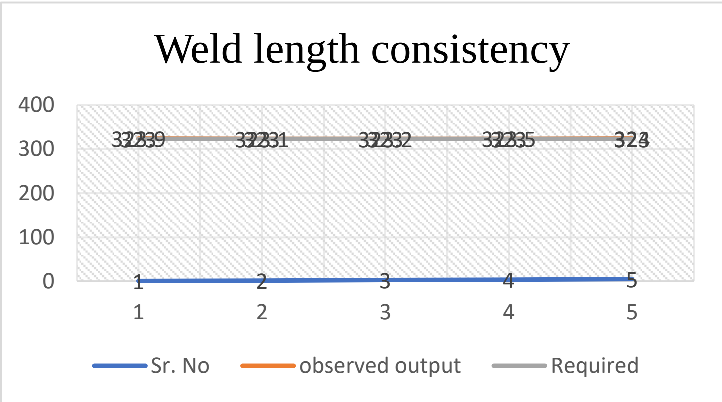
When metal is alloyed with carbon, the metal hardens. You must also be aware of the connection between one thing's hardness and another. As grain size lowers, the number of grain boundaries increases. The hall-petch effect is the name given to it. Now that this has been established, it is evident why large grain size wear out is decreased during friction at the welding interface, where grains are rubbing against one another at incredibly high pressure and temperature.

Hardness report can be seen in annex A.

16. REMARKS



As it can be observed in both



parts, several material properties, such as thermal mechanical hardness, have an impact on the formation of the weld.

As a result, the process variables that affect the weld being produced are crucial and may vary from those that have been computed theoretically. Several factors could be to blame for this fluctuation in the values of the process parameters.

Let's start with chemical contaminants and examine each one separately. Chemical contaminants and the presence of oxides on the flaying surfaces may alter the structure of the grains after the formation of ionic bonds as a result of welding. Pressure and time must be calibrated because the material has dimensional constraints that must also be considered.

Additionally, by using the data obtained after welding sufficient quantities of metallic material, the process parameter can be set by using the std welded material as a reference and only modifying the cross-sectional area and applied forces.

Despite a few small flaws in the material composition, this technique is distinct from others due to the uniformity of the weld length and tolerance.

17. RESULT

The tooling used in this weld development process was specifically created to weld axle shafts and piston rods, and it was carefully described in the restrictions to exactly suit the assembly. Dimensional tolerances like run outs and face offset variation serve as proof of this. Additionally, as the tooling was being assembled on the machine, we looked for parallelism and coplanarity to ensure that the parts would be perfectly aligned inside the fixture. After carrying out many tests, such as tensile, transverse, torsional, microstructure, and hardness, we may assess the results based on the demand as well as the application of that component.

Calculations were done to use the best process parameter that would determine how the desired weld would grow. In order to satisfy the requirements, whether they be dimensions restrictions or hardness requirements, calculations were conducted to adjust specific variables. The welded components also underwent a series of tests to demonstrate their strength and integrity in accordance with the demands of the customer. Let's examine each one separately. A 45° bend angle was required at the weld junction. The weld angle was observed to be 50° after performing a transverse test on the UTMS machine and setting up the fixtures. In addition, the tensile strength was adequate given the application area. The weld section's required hardness was equal to that of the parent material. Micro Vickers' hardness test was used to determine the hardness. The outcomes were satisfactory.

We declare that the weld development was successful after welding the components using the specified process parameters and performing many tests with successful results as recorded in test reports.

18. DISSCUSSION

Welding, particularly laser welding and wig welding, is a commercial component that is frequently associated with health risks for employees and operators. Because of the low-fume tungsten electrode used, which produces clean welds, little metal is displaced during welding. However, these benefits come with risky gas emissions, such as ozone and nitrous gases, which are classified as carcinogenic gases. Despite the fact that these methods may be technically advantageous, there is a risk involved. Consequently, an alternative to welding for welding cylindrical cross-sectional components, the RFW technique is employed. Laying the groundwork for welding is quite straightforward and simple. It has an advantage over conventional welding processes because it produces a strong, homogenous bond over the weld interface without using any additives, chemicals, or fuses to fuse the material. To satisfy geometric and dimensional boundaries, all that needs to be done is set up process parameters by computing them based on cross-sectional area and material (for consumption purpose).

Additionally, the straightforward setup and reliable weld supplied give it an advantage. However, one issue that worries them the most is the price. Instead of signing a contract for servicing, the customer may buy the machine outright and educate the operator for roughly 1-2 months to enable him to resolve some minor problems. This would also aid in the long run's cost effectiveness.

19. CONCLUSION

From this process of creation, we conclude that opting rotary direct drive friction welding for welding axle shaft and piston rod was beneficial as it provides a perfect weld. Also, the weld specific requirements that include the hardness, resistance to wear and tear and uniform reaction under circumstances along the whole component both parent material and weld section is perfectly addressed and delivered by adopting friction welding. One of the points that concerns the most is time in which the weld is delivered / completed. It takes merely about a minute for completing the weld with a consistency that couldn’t be achieved by any other method without any consequences and constraints.

20. TAKEAWAYS

- Attention to detail: the significance of paying close attention to details and adopting a meticulous approach to quality control, ensuring that even minor mistakes can have significant repercussions.
- Effective time management: includes prioritising tasks, remaining organised, and managing your workload efficiently.
- Worked as part of a team and effectively communicated with team members, vendors, and clients.
- Professional networking: the chance to meet professionals in the production industry, build relationships, and establish professional connections that could be advantageous to your future career.