

Conversion of a Conventional Lathe Machine into a Friction Welding Machine and Performing Some Experimental Tests for its Operational Feasibility

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ABSTRACT

In today's manufacturing environment, there is always a need to use cost effective methods and materials for production purposes. Friction welding is one of such method that offers cost effectiveness and high productivity rate as compared to other similar welding processes. Friction welding process has been used widely in the manufacturing world. It is an adjustable and tolerant process that can join most engineering materials. It is a well-established welding process that can produce good quality weldment between similar and dissimilar materials. Due to this flexibility of use of different materials, it has been used in many applications such as aerospace, automotive and other related manufacturing industries *etc.* The main objective of this research is to study possibility of doing friction-welding on a typical lathe machine instead of doing it on a friction welding machine and also to check the reliability of the welded joint. Conventional Lathe machine was converted into a friction-welding machine by adopting a systematic procedure. The fixture of the attachment was designed, manufactured and installed and different parameters such as applied pressure and spindle rpm were tested in order to achieve the welding joint by friction. The materials used for welding were Stainless Steel 070M20 and Aluminum 2011-T3.

Keywords: Friction Welding, Lathe Machine, Ultimate Tensile Strength (UTS), Brinell Hardness Test (BHT)

1. INTRODUCTION

Nowadays, welding is one of the most famous ways to join materials together. It is a good choice for joining materials permanently. According to American Welding Society, some fifty (50) different types of welding operations have been catalogued [1]. Some of the most important among them are Metal Inert Gas (MIG) welding [2], Gas Tungsten arc welding (TIG) [3], Arc Welding [4] and friction-welding [5]. Friction welding is a solid-state process in which same or different materials are

coalesced by mechanical friction between them. In this process, materials are joined together via mechanical friction that is generated through rotary and translation motion. As a result plastic deformation occurs between materials and they form a permanent joint. Friction welding has been carried among similar metals such as Al alloys [6, 7] and dis-similar metal such as dis-similar AL alloys[8], Mg alloys [9], Steels [10], Al-Mg [11], Al-Steel [12, 13], Al-Cr [14], and Zn-Al [15], and Mg-Steel [16].

From literature review, it is found out that a lot of

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research has been carried out in the field of friction welding since 1950. Strength and hardness of welded joint are the major issues in case of friction welding. Watanabe *et al.* [17], studied a butt joint formed by friction stir-welding between aluminum alloy and a mild steel plates. It was found that the tensile strength (max) of the joint was 86% as compared to aluminum alloy plate. Seli *et al.* [18], investigated the mechanical properties that changed due to thermal effect of friction-welding of two dis-similar metals *i.e.* aluminum and mild steel. It was reported that welded materials have low hardness and tensile strength as compared to parent materials. Fauzi *et al.* [19] successfully joined alumina-6061 aluminum alloy by friction welding using modified centre lathe machine. Heat affected zone was more prominent on 2500 rpm as compared to 1250 rpm. The bending strength was also greater on joint of 2500 rpm when compared with 1250 rpm joint. Kim *et al.* [20], considered three friction stir-welding conditions of aluminum die casting alloy due to different tool plunge downforces. Patel *et al.* [21] investigated the effect of speed of rotation on friction stir-spot welding of AA 5052-H32 and AA6082-T6 Al alloys. The tensile shear strength on 1500 rpm joint was larger than 1070 rpm joint which was further greater than 765 rpm. Uzun *et al.* [22] studied microstructure, fatigue and hardness properties FSW joint of Al 6013-T4 alloy and X5CrNi18-10 stainless-steel. Fatigue properties of Al 6013-T4/stainless steel joints were approximately 30% lesser than that of the Al 6013-T6 alloy base metal. Panda *et al.* [23] showed that welded AA 7020 Al alloy had maximum UTS at rotational speed of 1050 rpm with traverse speed of 95 mm/min and having force (axial) of 8 kN. Mitelea *et al.* [24] examined the carbon-enriched layer in the burr of carburized and a volume-hardened steel joint. Higher axial force and friction stroke helps in expulsion of carbon layer. Stainless steel-Al and Al-Cu materials were welded successfully by Sahin *et al.* [25]. Hardness of steel-Al materials near the weld interface was greater than that of base material. Whereas in aluminum-copper joint, hardness of Al was lower than that of copper near weld area. Ahmed *et al.* [26] welded Aluminum alloys AA7075-T6 and AA5083-H111 using friction stir-welding at constant rotation rate of 300 rpm and different traverse speeds of 50,100, 150, and 200 mm/min in similar and dis-

similar joints. EBSD was used to study microstructure of base material and welds. Whereas hardness and tensile testing machines were used to study the mechanical properties. Strength and failure analysis of similar and dis-similar friction stir spot welds was done by Garg and Bhattacharya [27]. Effects of different tools were studied on lap shear strength for similar and dissimilar friction stir spot welded joints. Magalhaes *et al.* [28] provided a perspective on the current development of the Friction Stir Welding (FSW) technology. The industrialization of the technology and related research were assessed by analyzing patent and scientific publications databases. Cheepu *et al.* [29] investigated to improve the mechanical properties of stainless steel to titanium with aluminum insert metal joints. It was found out that those welds with aluminum insert prohibited formation of brittle intermediate compounds in the interface of weld. Higher tensile properties were attained of such joints.

The main task of this research was to design and manufacture a fixture that could help to perform the friction welding on an ordinary lathe machine. The primary purpose was to construct a low-cost attachment that could do the required job. Friction welding of stainless steel 070M20 and aluminum 2011-T3 was done after the fixture was installed. Different diameters of steel to steel and aluminum to aluminum were welded and results are presented. In contrast to the normal practice of using hydraulic system to apply pressure, pneumatic system was employed instead.

2. MATERIALS AND METHODS

To convert a conventional lathe into the friction welding machine, the most important task is to design a fixture that can connect the pressure applying mechanism to the stationary part of the specimen that has to be welded. To achieve this goal first, an attachment was designed that could be fitted on the ordinary lathe without compromising its operation.

The primary consideration was to make it as rigid as possible as it had to hold the pneumatic cylinder (to apply equal pressure for friction welding process) with its components and the chuck. The fixture had four

parts, base, head, rectangular plates to maintain the height of it and chuck holder. The thickness of the base was 30mm with (500 x 300) mm of width and length whereas the thickness of the head was 250mm with (500 x 300) mm of width and length (Fig. 1-2).

Three rectangular plates were welded together. The thickness of the first and second plate was 200mm and for the third plate it was 5mm. All the plates shared the same width and length i.e., (300x70) mm. They were positioned under the base (Fig. 3).

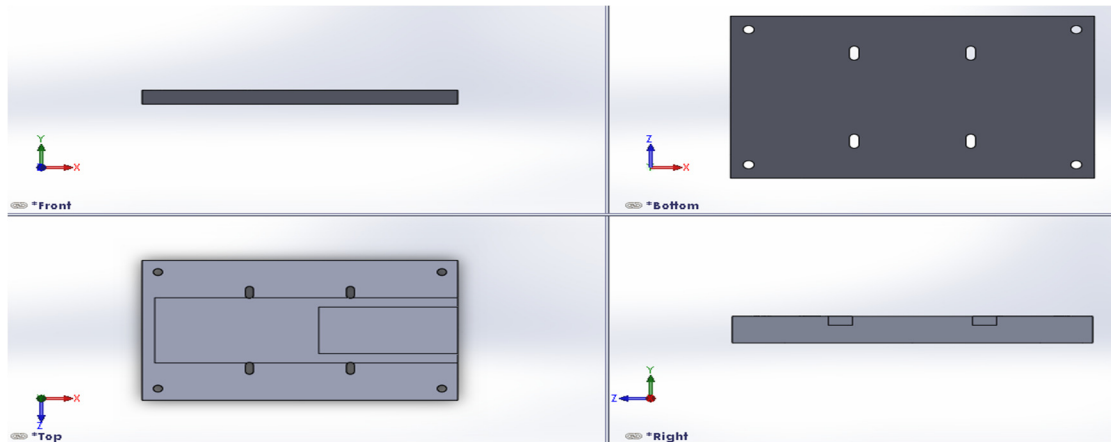


Fig. 1: Base of the fixture

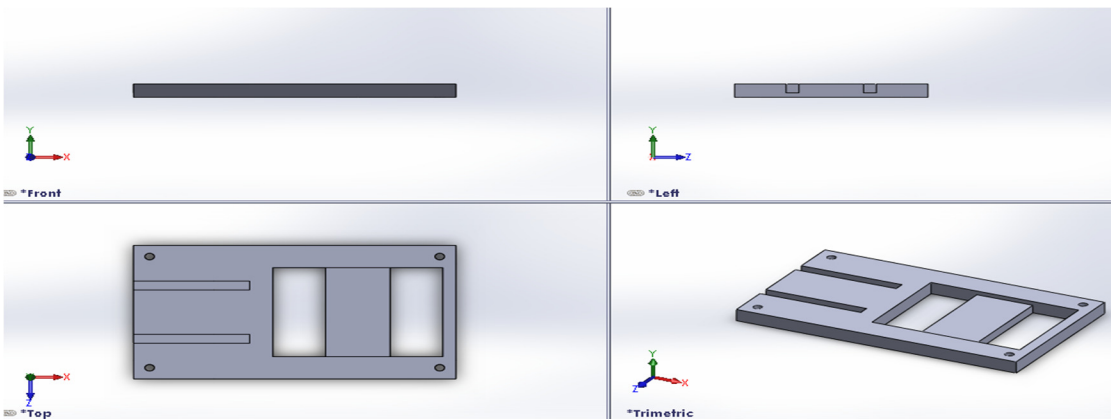


Fig. 2: Head of the fixture

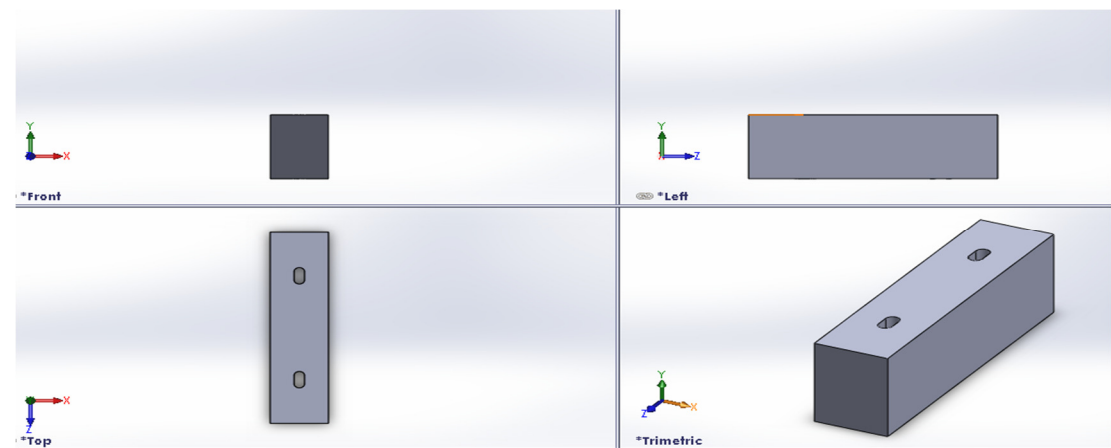


Fig. 3: Rectangular plates

Chuck holder consisted of a rectangular plate that was connected directly to the cylinder and holding the chuck by using the bolts (Fig. 4). The material used for all the parts of the fixture was SS400 carbon steel. The final fixture design after assembling all the four parts

is shown in Fig. 5. The fixture was fixed in the carriage section of the lathe machine as shown in Fig. 6. Fig. 7 shows the installed fixture on the tailstock containing the pneumatic cylinder (to apply pressure) and the chuck on the lathe.

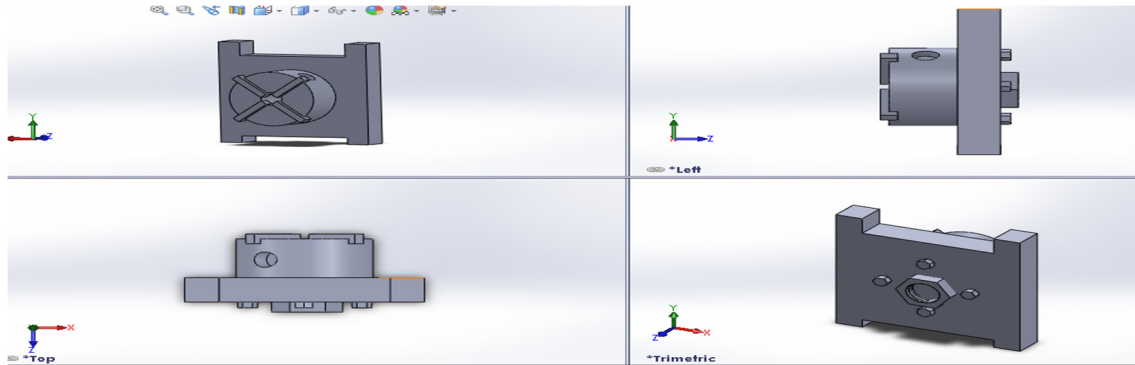


Fig. 4: Chuck holder

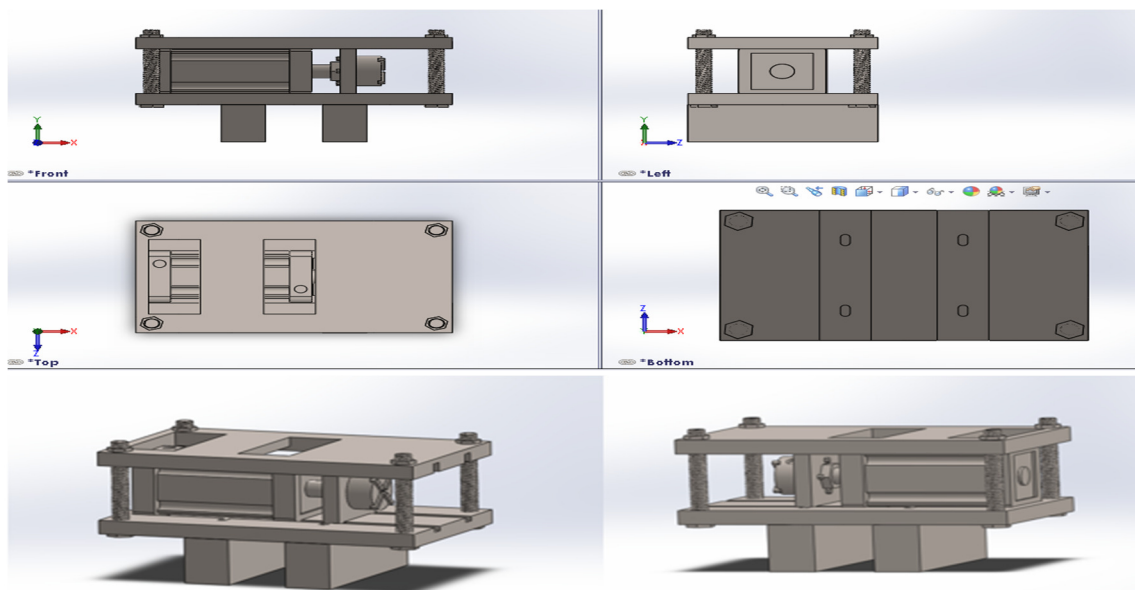


Fig. 5: Fixture assembly

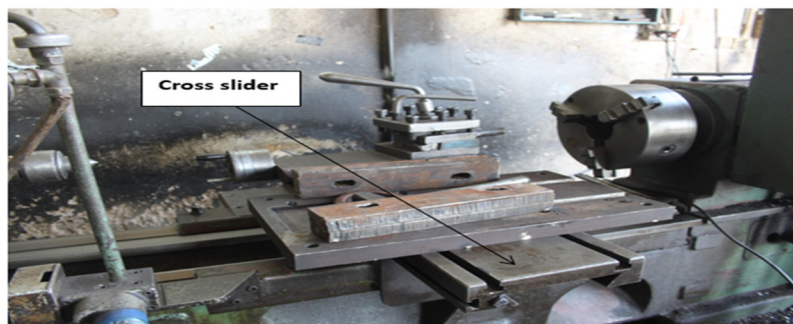


Fig. 6: Cross slider in the lathe machine



Fig. 7: Final setup of the fixture on the lathe machine

To apply the required pressure, it was decided to choose between hydraulic or pneumatic system. Hydraulic system was disregarded due to its cost and the authors opted for a pneumatic system for this purpose. Easily available pneumatic cylinder in the market worked in the pressure range from 0.5 – 10 bar (Fig. 8). There were different designs of the cylinders according to bore and stroke sizes.

At that point, it was hard to judge the capability of the pneumatic system whether it could do the job or not as mostly in the literature, researchers have used hydraulic system for pressure application. A simple experiment was carried out to check this, on the lathe machine. Aluminum was used to make a simple weld and pressure was applied with the hand. It was observed that welding was done successfully. To measure the applied pressure on the specimen, same force was applied by hand on the mass balance to know how much mass was used in the experiment. The mass was about 50 kg. Within the pressure range of the pneumatic cylinder that was between 0.5 and 10 bar, the calculation was done to find out the force that can be provided by the piston. The force was then converted to mass to compare it with experimental mass. For the chosen cylinder specifications (Table 1), the calculation is shown in Table 2.

Table1: Cylinder specifications			
Bore	125 mm	0.125	m
Area of the piston		0.012272	m ²
Stroke	100 mm	10	cm

The range of mass after calculation was (62.54 – 1250.9) Kg that is higher than experimental mass of 50 kg. It was concluded from this simple calculation that the pneumatic system would do its job correctly by applying any required pressure needed to execute the weld.

Pressure			Force	M
Bar	Mpa	Pa	N	kg
0.5	0.05	50000	613.5923	62.54764
1	0.1	100000	1227.185	125.0953
2	0.2	200000	2454.369	250.1905
3	0.3	300000	3681.554	375.2858
4	0.4	400000	4908.739	500.3811
5	0.5	500000	6135.923	625.4764
6	0.6	600000	7363.108	750.5716
7	0.7	700000	8590.292	875.6669
8	0.8	800000	9817.477	1000.762
9	0.9	900000	11044.66	1125.857
10	1	1000000	12271.85	1250.953

After selecting the required pneumatic cylinder, the next task was to how to produce, control and measure the pressure. The pressure was generated from air compressor connected to the double acting pneumatic cylinder (Fig. 8). It is worth mentioning that using pneumatic system for friction welding is limited. The pneumatic cylinder had a diameter of 125mm with 100 mm stroke and could provide pressure up to 1000 kPa.



Fig. 8: Double acting pneumatic system.

The cylinder movement was controlled by manual control valve as shown in the Fig. 9.



Fig. 9: Manual Control Valve

A pressure gauge (Fig. 10) was installed to take the pressure measurement.

The whole process set-up is shown in Figs. 11 – 12. It can be seen, how the pneumatic cylinder and the control valve are attached to the fixture and how the generated pressure from the air compressor is supplied to the cylinder with the help of pneumatic pipes. This pneumatic system will push one piece of the rod towards the rotating rod connecting to a chuck of the lathe machine that would result in the formation of friction joint between rods.



Fig. 10: Pressure Gauge

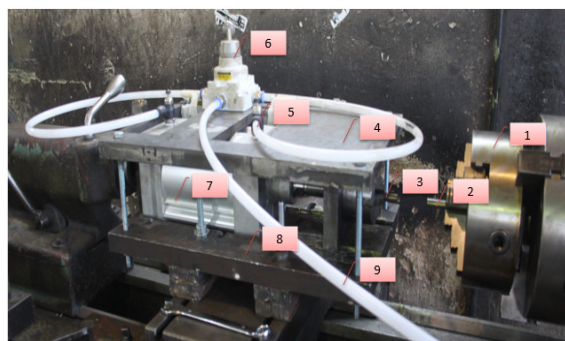


Fig. 11: Process setup (1)

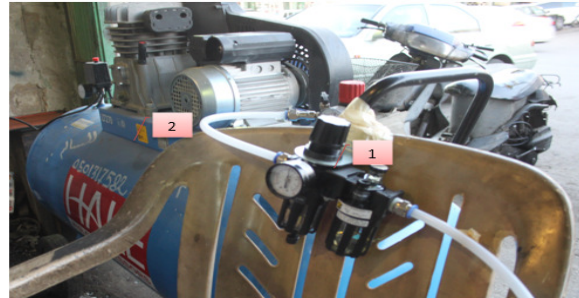


Fig. 12: Process setup (2).

The rotating speed is very critical in the friction welding process. The rotating speed plays a very strong role in increasing the friction and the temperature to cause the material to melt. It is necessary to know the speed of the specimen. The rotating speed was directly noted from the lathe machine that had a range of 1000 rpm to 2000 rpm.

3. RESULTS AND DISCUSSION

During the welding process, several parameters were tried for both steel and Aluminum having diameters of 10 mm and 12 mm. Tests were done at three different pressure values (400, 600 and 800 kPa) and at three different rotational speeds (1000, 1400 and 2000 rpm). Table 3 and 4 show the parametric values that have been used to perform the friction weld.

Successful welds indicate that the whole exercise of converting an ordinary lathe machine to friction welding machine is fruitful. The cost, being a very primary factor in the design and manufacturing of the system, was also around 160,000 Pak Rupees, which is not much if we compare it with a proper friction-welding machine. It can be seen at rotational speed of 1000 rpm, weld of steel-to-steel was unsuccessful at all the three applied pressures. Aluminum showed entirely opposite behaviour as the machine was not able to weld at 2000 rpm instead of 1000 rpm as that of steel. This observation is interesting, and it shows that both materials show different welding characteristics.

Successful welds were subjected to some mechanical tests. The ultimate tensile strength, fracture point and hardness of the successful welds are shown in Table 5 for both steel and Aluminum joints.

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Table 3: Experimented parameters for Steel rods

Test No.	Diameter (mm)	Pressure (KPa)	Rotational Speed (RPM)	Weld time(Sec)	Reduction in length(cm)	Condition
1	10	400	1000	*	*	Unsuccessful
2	10	600	1000	*	*	Unsuccessful
3	10	800	1000	*	*	Unsuccessful
4	10	400	1400	2.235	0.7	Successful
5	10	600	1400	2.615	0.7	Successful
6	10	800	1400	2.73	0.9	Successful
7	10	400	2000	2.625	1.3	Successful
8	10	600	2000	2.705	1.4	Successful
9	10	800	2000	3.445	1.5	Successful
10	12	400	1000	*	*	Unsuccessful
11	12	600	1000	*	*	Unsuccessful
12	12	800	1000	*	*	Unsuccessful
13	12	400	1400	2.445	0.6	Successful
14	12	600	1400	2.25	0.5	Successful
15	12	800	1400	2.55	0.4	Successful
16	12	400	2000	2.915	0.9	Successful
17	12	600	2000	2.93	0.7	Successful
18	12	800	2000	3.545	0.8	Successful

Table 4: Experimented parameters for Aluminum rods.

Test No.	Diameter (mm)	Pressure (KPa)	Rotational Speed (RPM)	Weld time(Sec)	Reduction in length(cm)	Condition
1	10	200	1000	11.78	0.2	Successful
2	10	400	1000	2.87	0.3	Successful
3	10	600	1000	3.785	0.4	Successful
4	10	200	1400	3.955	0.7	Successful
5	10	400	1400	2.735	1.5	Successful
6	10	600	1400	2.945	1.2	Successful
7	10	200	2000	*	*	Unsuccessful
8	10	400	2000	*	*	Unsuccessful
9	10	600	2000	*	*	Unsuccessful
10	12	200	1000	12.13	0.2	Successful
11	12	400	1000	8.55	0.9	Successful
12	12	600	1000	4.115	0.3	Successful
13	12	200	1400	4.645	0.2	Successful
14	12	400	1400	4.02	1.7	Successful
15	12	600	1400	5.57	2.9	Successful
16	12	200	2000	*	*	Unsuccessful
17	12	400	2000	*	*	Unsuccessful
18	12	600	2000	*	*	Unsuccessful

3.1 Effect of applied pressure on Material Strength

The mechanical properties of a weld joints changes with changing the parameters during welding. It is concluded that some specimens have excellent mechanical properties due to proper selection of parameters. The stress strain diagram gave valuable

information about the strength. One of the factors that must be considered in friction welding is the applied pressure. An accurate selection of the pressure can make excellent mechanical properties. Fig. 13 shows pressure effect on UTS of the steel. Both the diameter and the rotational speed during friction welding were fixed. The diameter and rotational speed was 10 mm

Table 5: Welded joints properties

Weld type	UTS (MPa)	Fracture Strength (MPa)	BHN	Weld type	UTS (MPa)	Fracture Strength (MPa)
SD10P400N1400	954.38	506.27	246.8	AD10P200N1000	291.45	163.74
SD10P600N1400	1063.08	590.270	225.3	AD10P400N1000	309.57	170.26
SD10P800N1400	1000.74	548.98	204.7	AD10P600N1000	247.20	128.31
SD10P400N2000	815.41	481.58	99.3	AD10P200N1400	324.89	179.35
SD10P600N2000	921.90	514.79	94.6	AD10P400N1400	275.73	150.95
SD10P800N2000	951.08	543.02	166.1	AD10P600N1400	298.07	154.68
SD12P400N1400	827.49	470.66	254.8	AD12P200N1000	251.14	143.38
SD12P600N1400	802.96	468.88	239.6	AD12P400N1000	260.04	134.14
SD12P800N1400	711.71	411.61	237.4	AD12P600N1000	301.75	153.04
SD12P400N2000	615.43	354.67	234.1	AD12P200N1400	129.12	78.39
SD10P600N2000	760.53	438.98	259.5	AD10P400N1400	270.53	144.54
SD10P800N2000	552.69	300.99	231	AD10P600N1400	140.96	71.60

*SD10P400N1400 stands for steel-to-steel weld with 10 as thickness of the material used with applied pressure of 400 kPa and rotational speed of 1400 rpm. AD stands for Aluminum-to-Aluminum weld. Same convention as mentioned here can be used to identify the weld type.

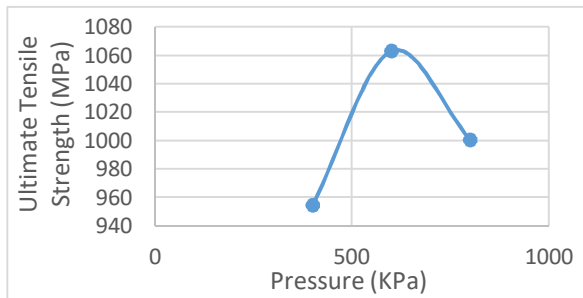


Fig 13: Effect of pressure on the UTS for steel

and 1400 rpm respectively. The only variable was the applied pressure. As shown, the maximum ultimate tensile strength was achieved at a pressure of 600KPa. For Aluminum, with a diameter of 10mm and spindle speed of 1400 rpm, the maximum UTS was for the weld at a pressure of 200kpa as shown in Fig. 14.

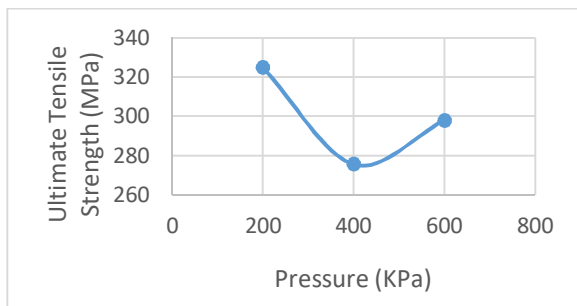


Fig 14: Effect of pressure on the UTS for Aluminum

3.2 Effect of applied pressure on Material Hardness

Hardness is an important property that can tell more about the mechanical properties of the joint. Hardness test is done to the welded joint to assess hardness of the joint. Type of hardness test was Brinell Hardness Number (BHN).

The Fig. 15 shows the change in hardness number with applied pressure during welding. The diameter and the rotational speed were fixed i.e.10mm and 1400rpm respectively. The hardness of the material was decreasing with increasing pressure. To have harder material, the pressure should be less.

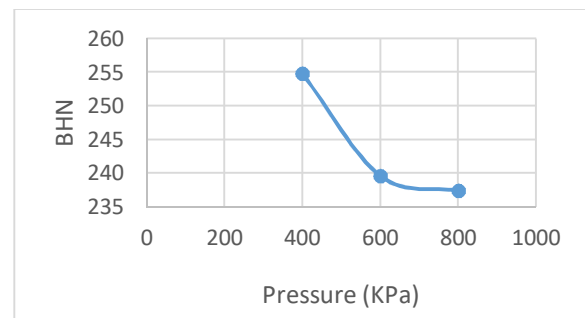


Fig 15: Effect of Pressure on hardness for steel

3.3 Effect of spindle speed on Material Strength

Rotational speed is the main parameter that must be considered during friction welding. Fig. 16 displays the rotational speed effect on ultimate tensile strength of steel. The maximum tensile strength of the welded joint was recorded at a rotational speed of 1400 rpm.

3.4 Effect of spindle speed on Material Hardness

The material hardness property also changes with change in spindle speed. Fig.17 indicates the influence of rotational speed to the material hardness of steel. The maximum BHN was for the weld at 1400 rpm.

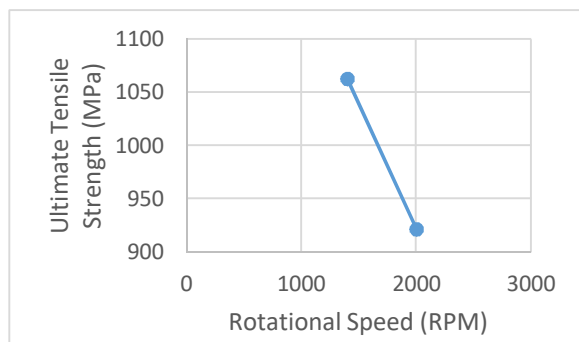


Fig. 16: Effect of speed on the UTS for steel

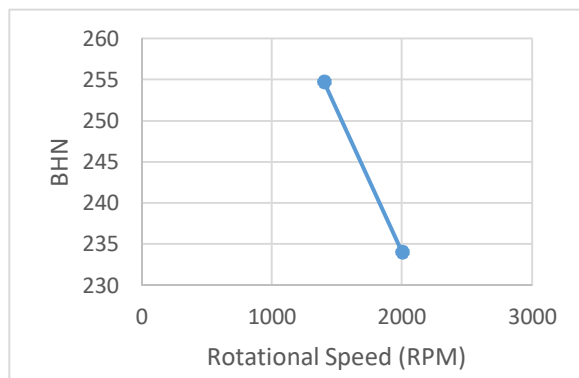


Fig. 17: Effect of speed on hardness for steel

4. CONCLUSIONS

Friction welding of Stainless Steel 070M20 and Aluminum 2011-T3 rods is done in this work. The main purpose of the study was to convert a conventional lathe machine into friction welding machine by keeping the cost to minimum. The task was achieved and the whole process is discussed in detail. In addition, pneumatic system was used in

contrast to the hydraulic system in this work, which also contributed to the low cost of the machine. After the conversion, different tests were performed to check the operation of the machine. Diameters of 10mm and 12mm rods were welded in this research. One rod was placed in the chuck of lathe machine whereas the other was connected to pneumatic cylinder that was fixed to the tailstock of a lathe machine with the help of the designed attachment. It was demonstrated that the machine was able to perform successful welding to the similar material rods. In future, the same set-up will be used to perform welding on the dissimilar materials.

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