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Experimental Investigation of Rotary Friction Welding Parameters of Aluminum (H-30) and Mild Steel (Aisi-1040)

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ABSTRACT: In this experimental work tensile and hardness tests of weldments have been carried out on an aluminium (H-30) and mild steel (AISI-1040) by Rotary Friction welding process on medium duty lathe machine at different spindle speeds. The temperatures, time taken for welding, tensile test and hardness test of weldments were evaluated and compared at different spindle speeds of two different diameter materials (10mm, 12mm of aluminium(H-30) and 10mm, 12mm of mild steel(AISI-1040)). The experimental results pertaining to different welding parameters for the above materials using Rotary Friction welding are discussed and compared. . Investigations are carried on mild steel (AISI 1040) and aluminium (H-30), both as similar and dissimilar combinations. The results indicate that aluminum and AISI 1040 steel can be joined by friction welding.

KEYWORDS: Rotary friction welding, Dissimilar materials, Tensile, Hardness.

I. INTRODUCTION

Friction welding is one of the most important types of solid-state welding process and it involves moving one component relative to the other component to generate required amount of heat and then applying lateral force (called upsetting force) to plastically displace and fuse materials. Technically, because no melt occurs, friction welding is not actually a welding process in the traditional sense, but a forging technique. However, due to the similarities between these techniques and traditional welding, the term has become common.

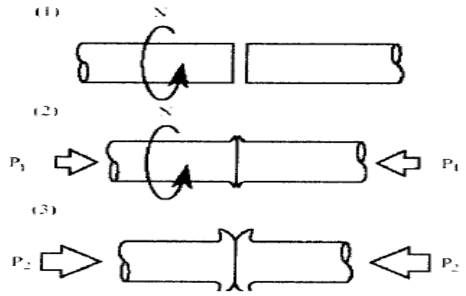
Friction welding requires no filler materials. Hence, the properties won't be altered to a great extent and the weld doesn't suffer from any inclusions and gas porosity as compared to any other type of welding. Also, it is a very fast process because of which heat affected zone in the base metal is much less when compared to other welding processes. The weld obtained will also have greater strength than that of the other welding process. 100% metal to metal contact can be achieved using friction welding.

G. KiranKumar, K. Kishore, and P.V.GopalKrishna [1] reviewed that because of the existence of intermetallic phase, the welding of non-ferrous metals is very hard. But, continuous drive friction welding method can suitably be adopted for welding of different ferrous and non-ferrous materials. . Fuji, A., Kimura M., North, T.H., Ameyama, K. and Aki, M [2] investigated that the friction welding process was very efficient in the welding of dissimilar materials such as aluminium and stainless steel. It is showed by the results of tension mechanical tests that presented mechanical properties which are not possible to achieve by means of fusion welding processes. Jessop, T.J. and Dinsdale, W.O. 1976[3] reviewed that as compare to other welding technique, the continuous drive friction welding is of highly materials saving, low producing time, high quality, high efficiency and high reliability characteristics.

Experiments are conducted on similar and dissimilar materials and the results are obtained several trials have been made to perform different types of welding on lathe. However, with proper attachments friction welding can be performed on lathe without any hassle. We are trying to perform rotary friction welding on a medium duty lathe by attaching necessary equipment to it.

II. EXPERIMENTAL PROCEDURE

The work pieces were made of H-30 aluminium and Mild Steel AISI-1040 of various diameters i.e. 10mm and 12mm. The test specimens were machined in the size of 150 mm length welded with Rotary Friction welding process.



: ***Basic steps in friction welding process***

Fig.1: Basic steps in friction welding process

Rotary friction welding experimentation is carried out on 3 combination sets of specimen materials i.e. MS-MS, MS-Al, Al-Al Of diameters: 10mm and12mm. At 4 variable speeds: 558rpm 896rpm 1372rpm 2095rpm (*Note: speed of lathe spindle is measured with the help of tachometer) Temperature measurement with the help of Laser/Infrared pyrometer in^{0}**C.** For time readings: Stop watch is used. First, measure the diameters of the two jobs using vernier calipers and fix them in the two chucks firmly using key. Move the housing using the hydraulic pump closer to the main chuck till the two work pieces just touch each other. Make sure that the shaft in the stationary housing is locked using the locking lever so that the 2nd work piece is not allowed to rotate. Now, turn on the lathe so as to rotate the 1st work piece at the required speed. Speed can be checked using a tachometer. Start the stop watch and apply the pressure using hydraulic pump. Slowly increase the pressure till the required amount of heat is generated and burr is formed. Using the infrared pyrometer note the temperature developed at the interface. Now, release the lock lever so that the two jobs rotate together and stop the watch and wrote down the time. Turn off the lathe and carefully take out the welded job out of the chucks. And take the specimen for further testing.

III. TEMPERATURE AND TIME MEASUREMENT

These tables include temperature and time taken for welding at different rotational speeds of similar and dissimilar metals of 10mm and 12mm diameters. The most heat is generated for mild steel than aluminium combination.

TABLE 1 WELDING OF SPECIMENS AT 558RPM SPEED

S.NO	Material combination	Dia(mm)	Temperature (^{0}C)	Time (secs)
1	MS-MS	10	390	29
2	Al-Al	10	157	22
3	MS-MS	12	765	32
4	MS-Al	12	241	24
5	Al-Al	12	184	25

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TABLE 2 WELDING OF SPECIMENS AT 896RPM SPEED

S.NO	Material combination	Dia(mm)	Temperature (^{0}C)	Time (secs)
6	MS-MS	10	410	25
7	MS-Al	10	165	16
8	Al-Al	10	165	19
9	MS-MS	12	759	30
10	Al-Al	12	190	20

TABLE 3 WELDING OF SPECIMENS AT 1372RPM SPEED

S.NO.	Material combination	Dia(mm)	Temperature (^{0}C)	Time (secs)
11	MS-MS	10	460	20
12	Al-Al	10	173	14
13	MS-MS	12	753	22
14	MS-Al	12	239	14
15	Al-Al	12	196	16

TABLE 4 WELDING OF SPECIMENS AT 2095RPM SPEED

S.NO	Material combination	Dia(mm)	Temperature (^{0}C)	Time (secs)
16	MS-MS	10	470	16
17	MS-Al	10	144	9
18	Al-Al	10	177	10
19	MS-MS	12	767	18
20	Al-Al	12	203.6	12

IV. TENSILE TEST RESULTS

To know the breaking load and breaking stress tensile test has done on the rotary welded specimens at different rotational speeds. For aluminium combination it gave better results than mild steel combination. Breaking load test is only conducted for the specimen combination set which is perfectly welded during friction welding experimentation.

TABLE 5 BREAKING LOAD OF VARIOUS SPECIMENS' FRICTION WELDED AT 4 DIFFERENT SPEEDS

S.NO	Specimen	Specimen dia (mm)	Speed at which the specimen is welded (rpm)	Breaking load-P (kg)	Breaking stress (MPa)$S=(P*g)\div(\pi D^2 \div 4)$
SPECIMENS FRICTION WELDED AT 558RPM SPEED					
1	MS-MS	10	558	970	121.15
2	Al-Al	10	558	1250	156.13
3	MS-MS	12	558	3050	264.55
4	Al-Al	12	558	1930	167.40
SPECIMENS FRICTION WELDED AT 896RPM SPEED					
5	MS-MS	10	896	2060	257.30
6	Al-Al	10	896	1450	181.11
7	MS-MS	12	896	3450	299.25

8	Al-Al	12	896	2230	193.42
SPECIMENS FRICTION WELDED AT 1372RPM SPEED					
9	MS-MS	10	1372	3260	407.18
10	Al-Al	10	1372	1420	177.36
11	MS-MS	12	1372	3620	313.99
12	Al-Al	12	1372	2270	196.89
SPECIMENS FRICTION WELDED AT 2095RPM SPEED					
13	MS-MS	10	2095	3860	482.13
14	Al-Al	10	2095	1420	177.36
15	MS-MS	12	2095	3970	344.35
16	Al-Al	12	2095	2380	206.43
DISSIMILAR SPECIMENS FRICTION WELDED AT DIFFERENT SPEEDS					
17	MS-AL	10	2095	550	68.07
18	MS-AL	10	896	930	116.16
19	MS-AL	12	1372	720	62.45
20	MS-AL	12	558	980	85.01

V. HARDNESS TEST RESULTS

Rockwell hardness test had done for aluminium and mild steel combinations by using different types of indenters. Test is done on both similar and dissimilar metals. The hardness number differs from aluminium to mild steel because of its properties. Location1 (Loc1) is at the centre of the weld (for welded pieces) or 2mm away from the end which is tried to be welded (for pieces which couldn't be welded) Loc2 is 5mm away from the Loc1 and Loc3 is 10mm away from the Loc1.

Table 6 Friction welded specimens tested for Rockwell hardness at 558rpm

Specimen no.	Scale used	Indenter used	Minor load (kg)	Major load (kg)	RHN		
					Loc1	Loc2	Loc3
FRICTION WELDED Ø10mm SPECIMENS AT 558RPM SPEED							
1.MS-MS	C	Diamond cone, 120◦	10	140	37	32	24
2a.MS	C	Diamond cone, 120◦	10	140	38	32	28
2b.Al	B	1/16" ball indenter	10	90	22	19	17
3.Al-Al	B	1/16" ball indenter	10	90	13	12	11
FRICTION WELDED Ø12mm SPECIMENS AT 558RPM SPEED							
4.MS-MS	C	Diamond cone, 120°	10	140	33	29	21
5a.MS	C	Diamond cone, 120°	10	140	29	28	26
5b.Al	B	1/16" ball indenter	10	90	23	18	16
6.Al-Al	B	1/16" ball indenter	10	90	17	16	12

Table 7 Friction welded specimens tested for Rockwell hardness at 896rpm

Specimen no.	Scale used	Indenter used	Minor load (kg)	Major load (kg)	RHN		
					Loc1	Loc2	Loc3
FRICTION WELDED Ø10mm SPECIMENS AT 896RPM SPEED							
7.MS-MS	C	Diamond cone, 120◦	10	140	43	36	28
8a.MS	C	Diamond cone, 120◦	10	140	39	35	32
8b.Al	B	1/16" ball indenter	10	90	20	17	16
9.Al-Al	B	1/16" ball indenter	10	90	19	17	16
FRICTION WELDED Ø12mm SPECIMENS AT 896RPM SPEED							
10.MS-MS	C	Diamond cone, 120°	10	140	34	30	22

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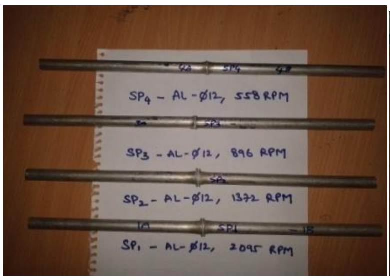
11a.MS	C	Diamond cone, 120°	10	140	32	28	25
11b.Al	B	1/16" ball indenter	10	90	22	17	15
12.Al-Al	B	1/16" ball indenter	10	90	19	18	15

Table 8 Friction welded specimens tested for Rockwell hardness at 1372rpm

Specimen no.	Scale used	Indenter used	Minor load (kg)	Major load (kg)	RHN		
					Loc1	Loc2	Loc3
FRICTION WELDED Ø10mm SPECIMENS AT 1372RPM SPEED							
13.MS-MS	C	Diamondcone,120°	10	140	49	41	32
14a.MS	C	Diamondcone,120°	10	140	40	37	35
14b.Al	B	1/16" ball indenter	10	90	17	16	15
15.Al-Al	B	1/16" ball indenter	10	90	19	17	16
FRICTION WELDED Ø12mm SPECIMENS AT 1372RPM SPEED							
16.MS-MS	C	Diamondcone,120°	10	140	35	31	23
17a.MS	C	Diamondcone,120°	10	140	35	27	25
17b.Al	B	1/16" ball indenter	10	90	21	17	15
18.Al-Al	B	1/16" ball indenter	10	90	19	18	15

Table 9 Friction welded specimens tested for Rockwell hardness at 2095rpm

Specimen no.	Scale used	Indenter used	Minor load (kg)	Major load (kg)	RHN		
					Loc1	Loc2	Loc3
FRICTION WELDED Ø10mm SPECIMENS AT 2095RPM SPEED							
19.MS-MS	C	Diamondcone,120°	10	140	56	48	36
20a.MS	C	Diamondcone,120°	10	140	42	40	38
20b.Al	B	1/16" ball indenter	10	90	15	14	14
21.Al-Al	B	1/16" ball indenter	10	90	21	19	18
FRICTION WELDED Ø12mm SPECIMENS AT 2095RPM SPEED							
22.MS-MS	C	Diamondcone,120°	10	140	36	32	24
23a.MS	C	Diamondcone,120°	10	140	37	26	25
23b.Al	B	1/16" ball indenter	10	90	20	16	14
24.Al-Al	B	1/16" ball indenter	10	90	20	19	17



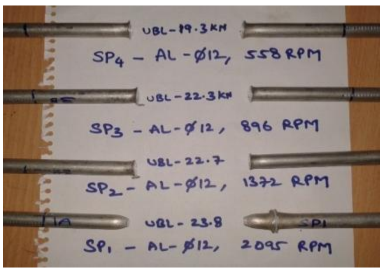


Fig.1 Rotary welded similar metals Fig 2 Rotary welded dissimilar metals Fig 3 Specimens after tensile test

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Fig 4 Retrofitted Lathe Machine

Fig 5 Infrared Pyrometer

Fig 1 shows that the Rotary welded similar metals at different rotational speeds and Fig 2 shows Rotary welded dissimilar metals. In Fig 3 the specimens after tensile test is shown the successive welds are achieved in aluminium combination at the rotational speeds 2095 and 1372rpm. Fig 4 shows the retrofitted medium duty lathe machine with slight modifications. Fig 5 is the infrared pyrometer which measures the temperature after immediately bonding is formed. If we observe the (tables 6-9) it is clear that hardness decreases as we move away from the weld.

VI CONCLUSION

Friction welding enables the joining of materials giving a weld of high strength with many advantages over the other welding processes. For friction welding of (AISI 1040) MS-MS Ø12mm and 10mm, 2095rpm was found to be the optimum speed for welding. For friction welding of (H30) Al-Al Ø12mm and 10mm 1372 and 2095rpm was found to give the best results. Among the material sets considered, MS-MS Ø12mmwelding has generated a highest temperature of 767^0 C (Table 4). The highest and lowest time taken to weld MS-MS specimens are 32(558rpm), 18sec (2095rpm). The highest and lowest time taken to weld AL-AL specimens are 25(558rpm), 12sec (2095rpm). The maximum breaking load for aluminum is found 206.43N at 2095rpm and for mild steel maximum breaking load is 482.13N at 2095rpm (Table 5). For dissimilar metals maximum breaking load is found 116.16N at 896rpm (Table 5). The maximum hardness number for aluminum and mild steel is found at 2095rpm and 1372rpm (Table 8, 9).

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