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Investigating the Capabilities of Medium Duty Lathe for Friction Welding

G. Kiran Kumar, K. Kishore, and P.V.GopalKrishna

Department of Mechanical Engineering,
Vasavi College of Engineering., Hyderabad, India
Corresesponding Author: P.V.GopalKrishna

Abstract:
Friction welding is a widely used solid state welding method for joining of similar or dissimilar metals. Friction welding requires rapid rotation of one component at high rpm and the other component is brought into contact at high forging pressure to get upset. Traditionally friction welding is carried out on a dedicated machine because of its adaptability to mass production. In the present work, modifications are made to a medium duty lathe by retrofitting it with a powerful motor for high spindle speeds and the tail stock is modified to apply forging pressure. The mechanical properties obtained at different spindle speeds are recorded and hardness at the heat affected zone is measured. The findings proved that a simple engine lathe can perform friction welding up to 12mm diameter. Investigations are carried on mild steel (AISI 1040) and aluminum alloy (AA6351), both as similar and dissimilar combinations.

Keywords: *friction welding, retrofitting, breaking strength, dissimilar metals, hardness*

INTRODUCTION

Many ferrous and nonferrous alloys can be friction welded. Friction welding also can be used to join metal of widely differing thermal and mechanical properties. Often combinations that can be friction welded cannot be joined by other welding processes because of the formation of brittle phase. Further the sub melting temperatures and short weld times of Friction welding allow many combinations of work metals to be joined. Metal matrix compositions, ceramics, plastics are some combinations of materials that have been joined successfully according to the literatures and equipment manufacturing data.

Preparation of work pieces, other than that necessary to ensure reasonably good axial alignment and to produce the required length tolerance for a specific set of welding conditions, is not critical. Frictional wear removes irregularities from the joint surfaces and leaves clean, smooth surfaces heated to welding temperature. In some applications where weld integrity is important, a small projection at the center of one of the weld members is used to ensure proper heating and forging action and to eliminate center defects. This projection is especially helpful in welding large diameter bar.

Many similar and dissimilar metal combinations can be friction welded, and in most combinations, a sound metallurgical bond is formed. In some combinations, the bond is not as strong as the base metal. And post weld heat treatment may be needed to develop full weld zone strength in alloy steels and hardenable stainless steels. High-speed tool steel can be welded to carbon and alloy steel shanks for making drills, reamers, and other cutting tools. Heat treated steels can be friction welded with only localized changes in hardness because the heating is confined to a very narrow zone. Also, the rapid self quenching restores hardness to the weld zone, the weld upset can be removed by grinding or machining immediately.

Friction welding is recognized as the most successful among solid state welding methods due to several interesting features such as no filler metal requirement, flux and shielding gas are not required. The process is environmentally clean, surface cleanliness is not as significant, compared with other welding processes, very narrow heat-affected zones, in most cases, the weld strength is as strong as or stronger than the weaker of the two materials being joined, operators are not required to have manual welding skills, the process can be automated for mass production, welds are made rapidly compared to other welding process, plant requirements (space, power, special foundations, etc.) are minimal. These reasons have drawn the attention of modern welding Investigations towards friction welding.

Mechanical testing of friction welded dissimilar metals are reported by Jessop and Dinsdale (1976). Friction welding of composite materials and their performance was studied by Sassani, and Neelam, (1988) Mechanical properties such as tensile strength, ductility are thoroughly investigated by Fuji et,.al (1997) on titanium, stain less steel and aluminum alloys. Stress and strain characteristics of low carbon steel are carried out by Yokoyama and Ogawa (2001). This Japanese investigator also extend the work for aluminum alloys and stainless steel as well. However the literature survey reveals that all the investigations used a dedicated friction welding machine with considerable rigidity. The current investigation is carried out on a retrofitted medium duty lathe to identify the possibility of this machine for friction welding purpose. The findings are encouraging and this study we hope will be useful for small and medium industries, which cannot afford expensive friction welding machine.

RETROFITTING LATHE FOR FRICTION WELDS:

This paper deals with the design manufacture and performance evaluation of friction welding fixture for use on lathe. Friction welding is welding of two dissimilar metals by the heat generated due to friction. This involves rotation of a work piece at greater speed and lineal motion is given to other piece to weld it to first piece. The maximum speed that can be obtained from lathe is 1200rpm. A special attachment is designed to get required rpm. This involves a motor of 1440rpm connected to spindle of lathe through shaft and pulley arrangement. Pulleys of required diameters are taken so as to get required rpm. The maximum speed that can be obtained is 2880rpm. The pieces to be welded are placed in headstock and tailstock respectively. Chuck produces rotational movement while the linear movement to pieces to be welded is given by tailstock. Force is applied through tailstock screw mechanism.

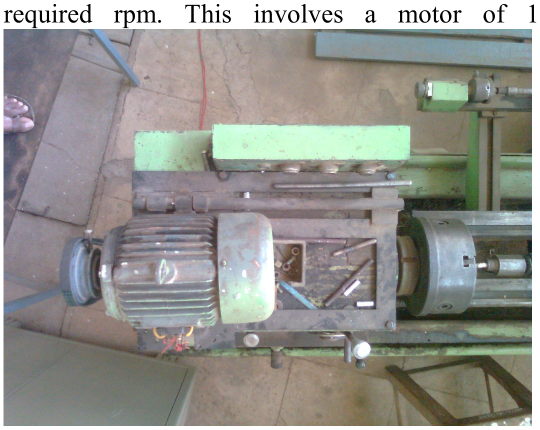

Figure 1: Attachment to lathe- top view.

A special drive is designed and attached to tail stock for holding the other end of the work, due care is taken so that the alignment is not disturbed. A hallow mandrel is attached to the tail stock spindle for this purpose, how ever this attachment is capable of holding bar of 10mm diameter, the mandrel is to be changed for other diameters. A special belt drive is attached to the main spindle and the spindle is operated in neutral position to avoid the gear drive of
the head stock, the speeds are changed by changing the diameter of the driven pulley on the spindle extension, above tumbler gear arrangement. The setup is shown in figure 1.

EXPERIMENTATION METHODOLOGY

The process parameters considered are the speed of the work piece. Investigations are carried out for different work materials. The breaking strength, hardness are evaluated for different speeds. The experimental results and the analysis performed are shown below:

- All the experiments are carried out on 10mm diameter work pieces
- The up set is removed by turning, as shown in figure 2.

Figure 2: Typical welded work pieces.

Table 1: Breaking strength vs. RPM

S. No	Speed in rpm	Breaking Stress of Materials welded in N/mm^2		
		MS & MS	Al & Al	MS & Al
1	1000	60	50	60
2	1200	90	61	71
3	1400	100	72	80
4	1850	110	80	94
5	2800	130	98	109

The materials considered for the present investigation are AISI 1040 steel, with composition C -0.15 max; Mn

0.3 - 0.60; P 0.40(max); S 0.50 (max).and AA6351, with composition C 0.37-0.44, Mn 0.60-0.90, P 0.40 (max), S 0.50 (max).

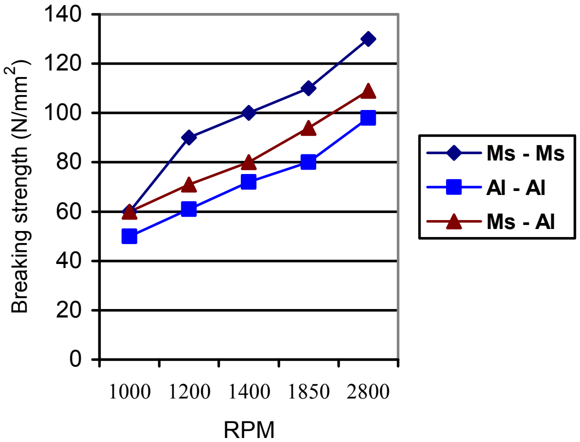

Figure3: RPM Vs Breaking strength

Table 2: Hardness from weld zone

S. No	Distance from weld (mm)	Materials welded MS & MS (HRC*)	Al & Al (HRC*)	MS & Al (HRC*) MS	MS & Al (HRC*) Al
1	At weld	27	12	15	15
2	0.5	33	15	30	18
3	1.0	36	18	34	20
4	1.5	38	23	38	22
5	2.0	41	24	40	24
6	2.5	41	25	41	25
7	3.0	41	26	41	26
8	3.5	41	26	41	26
9	4.0	41	26	41	26

*** The hardness values are measured in Rockwell 'C' Scale**

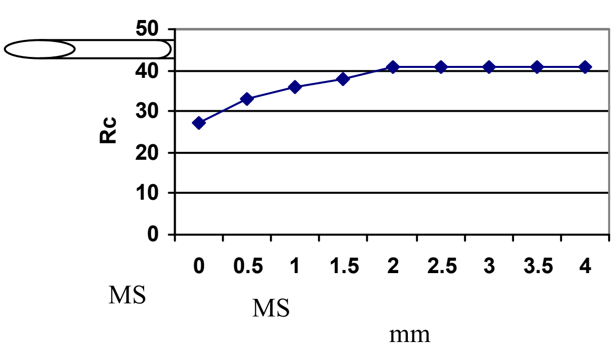

Figure 4: Rc Vs Distance from weld for MS-MS

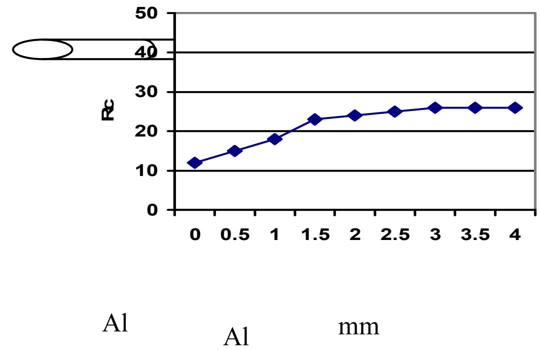

Figure 5: Rc Vs Distance from weld for A1-Al

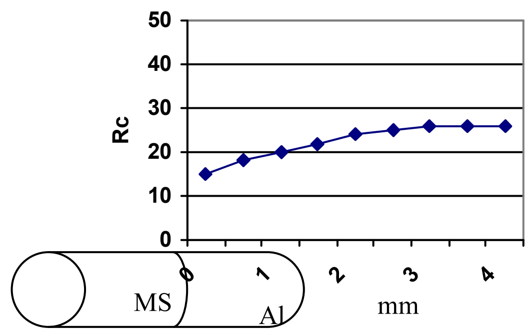

Figure 6: Rc Vs Distance from weld for MS-Al

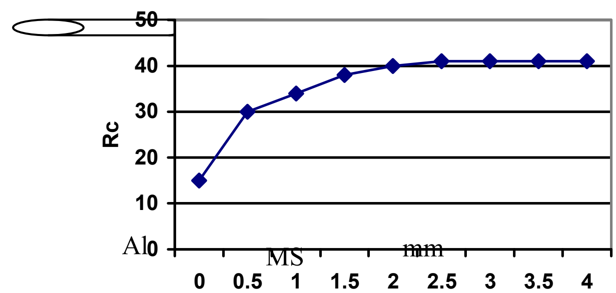

Figure7: Rc Vs Distance from weld for Al- MS

RESULTS AND OBSERVATION

Observing figures from 4 to 7 it can analyze that hardness increased due to heat effected zone up to a distance of about 2mm for M.S and then the hardness remained constant thereafter the same effect is observed up to 3mm for Al welding this may be due to higher thermal conductivity of Al when compared with steel, during dissimilar welding heat effected zone is observed up to 1.5 mm for M.S and 2mm for Al this may be due to different thermal proportion of base metals, also this stretch of heat effected zone is less in dissimilar welding generation more heat during dissimilar welding. This observation proves that the friction welding is advantageous for dissimilar welding.

The Hardness uniformly increased from weld interface during welding of Al and MS independently. Formation of inter-metallic compounds $FeAl_3$ andFe_2Al_3 contributed hardness. The hardness recorded is less near the vicinity of weld interface, due to thermal softening. The results proved the Indispensability of friction welding for dissimilar metals. As rpm increases the strength of joint increases for mild steel and Aluminum welding. Dissimilar metals such as mild steel and Aluminum can be welded by friction welding technique. It is also observed that strength of the joint is proportional to friction heat and rpm. Strength of both similar and dissimilar joints increases continuously up to 2800rpm. All experiments are conducted after machining the butt weld produced by forging pressure. Forces required for friction welding are not recorded due to manual attachment. Constant forging time of 30 seconds is maintained in all experiments. Axial alignment of centers of lathe plays a key role in the friction welding. The properties are found to vary when the upset removed by turning and Grinding. All experiments are conducted considering the limitations of a medium duty lathe.

CONCLUSIONS

- It is safe on a medium duty Lathe to perform friction welding up to Bar diameter of 10mm with good mechanical properties
- Friction welding is Indispensable tool for welding dissimilar metals
- Thermal softening led to Reduction of Hardness for both similar and dissimilar metals near the weld zone.
- Manual force from tailstock screw nut mechanism is sufficient up to 10mm diameter for friction welding.
- Vibration, difficulty in axial alignment, tail stock sliding is observed for diameters grater than 12mm.

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