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Design and Development of Micro Friction Welding Machine and Investigation of Welding Parameters for Similar Materials

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Abstract—Friction welding is considered as a solid state welding process that generates heat through mechanical friction between amoving workpiece and a stationary component, with the addition of lateral force called “upset” to plastically displace and fuse the materials. Technically, because no melt occurs, friction welding is not actually a welding processin the traditional sense, but a forging technique. However, due to similarities between these techniques andtraditional welding, the term has become common. Friction welding is a recent technique that utilizes a non-consumable welding tool to generate frictional heat and plastic deformation, thereby affecting the formation of weld joint. The principal advantages of friction welding being a solid state process are less defects, low distortion, no filler, and cost. The recent applications of friction welding are welding for submarine rescue, aerospace, Production of micro cutting tools like drills, taps etc. [7].

Though the basic principle of friction welding is same but the innovation lies in the fact that the entire old table lathe machine is assembled to perform further experimental investigation in friction welding on smaller and dissimilar components. This paper presents the study of micro friction welding carried out on a retrofitted table lathe machine at constant rotational speeds (2250 rpm, 2900rpm and 4980rpm) and designing of adapter to hold stationary work piece, reversible circuit for reversing the rotation of motor for sudden braking , design of new tailstock spindle with a load cell fixture for axial pressure measurement and a load cell fixture for torque measurement was carried out after which feasibility study was carried out for the samples of Aluminum, Copper and Brass having a diameter of 8mm. Based on the preliminary feasibility study[1], investigation of various welding parameters such as welding temperature, welding pressure, Torque is carried out. Tensile strength testing has been carried out to study the welding strength.

Index Terms—Micro friction welding, welding temperature, welding pressure, torque, tensile strength, coefficient of friction, break load, upset, etc

1 Introduction

Conventional welding of many similar and dissimilar material/metals combination is not feasible owing to the formation of brittle and low melting inter-metallic bond due to metallurgical incompatibility, wide difference in the melting point, thermal mismatch, etc.

On the other hand, the Friction Welding process obtains its heat from the resistance caused by moving one piece against another stationary piece under extreme pressure. No burning fuel is used to generate the heat, nor is any filler added. The resulting joint is a solid-state fusion of the two base components across the entire face of the weld zone. The solid state joint offers superior strength because it does not rely on a third material limited to the perimeter to hold two components together [2].

The image outlines the principle phases of a friction weld. This is based on Rotary Friction Welding used by American Friction Welding Association. The x-axis indicates time in seconds. The y-axis indicates the three remaining parameters that are key to friction welding: Pressure in green, RPM in violet and Length-Loss in orange.

The rotational speed, the axial pressure and the welding time are the principal variables that are controlled in order to provide necessary combination of heat and pressure to form the weld [3].

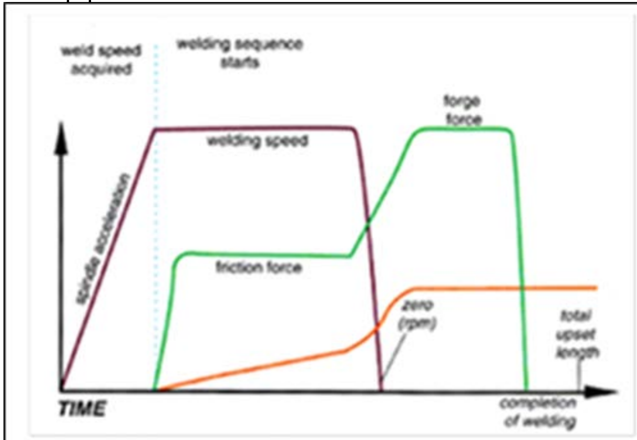

Fig. 1. Weld playback graph.

Retrofitted design is for eco-friendly concepts which can also be capable of friction-stir-welding and in-situ pre and post (finishing) operations of micro components (is a necessity) [4]. The results of study conducted by Wen-Y, Min Yu, Jinglong L, Guifeng Z, Shiyuan W in 2009 explains the solution for rotary friction welding of cylindrical bars of 4 mm diameter [5]. The machine developed is a continuous drive micro friction weld-

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ing machine capable of welding jobs having diameter of range of 4mm [6].

Friction welding is a versatile process, meaning it is suitable for producing a wide variety of components such as those used in industries such as light and heavy automotive, electrical, chemical and civil engineering.

2 Conceptual Design

Apart from traditional welding methods, several welding parameters can be controlled in friction welding. These parameters include diameter of experimental rod, rpm of the part, friction contact time, forging delay time, forging time, time of friction pressure, friction pressure. Moreover, other parameters such as geometry of parts and material properties are also significant.

The rpm of rotating parts, friction time, friction pressure, forging pressure and time are the parameters needed to be taken into account while optimizing the welding process. A successful welding process can occur if parameters are optimized.

The lower rpm of rotating parts causes enormous moments and non-uniform heating results in. On the other hand, lower rpm values minimize formation of inter metallic compounds. To prevent overheating in the welding region, friction pressure and friction time have to be carefully controlled.Pressure values applied in welding is very significant because it controls temperature gradient and affects rotational torque as well as power.

Friction and forging pressure are directly related to geometry and material properties of parts to be welded and have a wide range.Over applied pressure values increase power needs accordingly. The variable of pressure can be controlled by the temperature in welding region and decrease in axial length.

Optimum pressure must be applied to materials in order to get uniform deformations throughout.Friction pressure has to be high enough to allow the removal of oxides, to get uniform heating throughout and to interrupt the affinity between surfaces and the air. The application of

forging pressure especially during friction process improves welding properties.

2.1 Morphology of Design

In order to identify our problems and find their solutions, a study was carried out during which the following problems were identified.

a) Identification of machine for holding jobs of 4mm to 8mm diameter.
b) Requirement of high rpm.
c) Accuracy and Precision of setup.
d) Arrangement for application and measurement of axial pressure.
e) Clamping arrangement for stationary work piece.
f) Arrangement for variable speeds of motor.
g) Arrangement for measurement of torque and tem perature during welding.
h) Sudden braking to avoid weld offset.
i) Weld integrity and repeatability.
j) Weld ability of different materials.

The result of this study was the designing and development of a table mounted mini lathe machine which can perform rotational friction welding for applications of 4mm to 8mm diameter with an arrangement for variable speeds, sudden braking and measurement of various parameters required for the experiment.

3 Design And Development Of Machine

The designing and fixing of parts was done on the machine. This machine uses a single phase motor of 1420 rpm and 370 W Induction motor as the prime mover with a belt and pulley arrangement for transmission. Various combinations of belt arrangements are used to achieve variable higher speeds.

3.1 Tail Stock

A new tail stock was made with an arrangement to hold a load cell to measure the axial pressure. The new tail stock was of a shorter length than the original thereby reducing vibrations and the spindle attached to the lever arrangement was made hollow for balancing.

Further drilling operation was carried out on the head of the tailstock and an adapter arrangement was made to hold the stationary work piece in place.

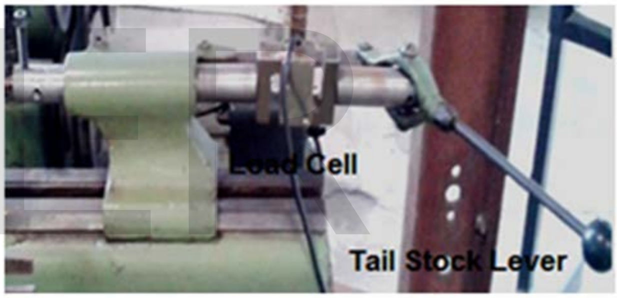


Fig. 2. Arrangement for measuring axial pressure

3.2 Torque Sensor Arrangement

The torque acting on the spindle directly corresponds to torque acting on the work piece. For torque measurement, firstly a platform was created on which a load cell was mounted. Then a C- clamp was designed and attached to the load cell. A hole was tapped on the tail stock into which a torque lever was designed and fitted. The free end of the torque lever was fits into the C- clamp.

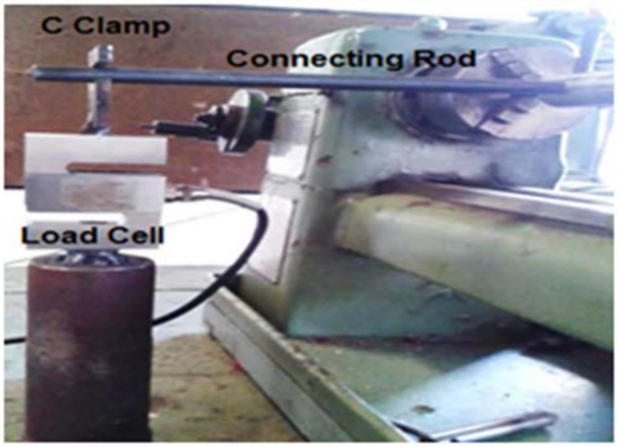


Fig. 3. Torque sensor arrangement.

3.3 Sudden Braking Arrangemrnt

A sudden braking arrangement was necessary to get desirable welds, so an arrangement of a reversible circuit was added to the induction motor and by using a single phase reversing switch and including the capacitor in the reversible circuit desired speed was obtained.

3.4 Arrangement for Temperature Measurement

An Infra Red thermal gun (IRX-68, HTC, range upto1850°C) is used to measure the temperature at the weld joint. For keeping a continuous record of temperature during whole process software of same company was installed in laptop and thermal gun was connected to it.

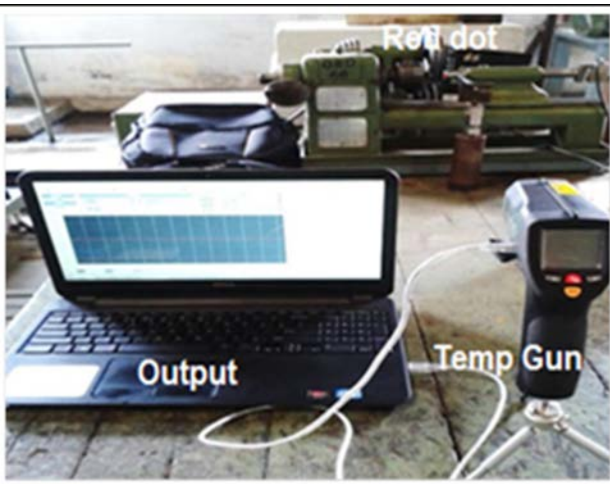


Fig. 4. Arrangement for measuring welding temperature

4 Working

Friction Welding is achieved by rotating the specimen in the chuck while applying axial pressure at the tail stock. The second work piece is held in the adapter arrangement provided with a screw with align key.

When switched on, the induction motor provides the drive for the chuck to rotate. Axial pressure is provided manually from the tailstock side with a lever provided at the end. The rotary work piece is brought to rest by the sudden braking arrangement when the upset is formed. The axial pressure applied is measured by the load cell attached in tailstock spindle whereas the torque is measured by the other load cell arrangement. Temperature is measured using the temperature gun. The output is recorded on a digital interface.

5 Feasibilty Study

After the machine was ready, feasibility study was carried on work pieces of aluminum, brass and copper of diameter 4mm to 8mm on variable speeds to check whether friction welding is possible or not on that particular machine. The results of the study are shown in the table given below: [1].

The weld categories abtained[8] are as explained below:

- Acceptable: bonded area is approximately 100%.
- Conditional: bonded area is less than100% but greater than5 %.
- Unacceptable: bonded area is less than 5 %.

TABLE 1
Feasibility study of different metals

S.NO.	RPM	TYPE OF WORK-PIECE	WELD CATEGORIES OBTAINED
1.	2250	Al – Al	ACCEPTABLE
2.	2250	Br – Br	NOT ACCEPTABLE
3.	2250	Cu – Cu	NOT ACCEPTABLE
4.	2900	Al – Al	ACCEPTABLE
5.	2900	Br – Br	CONDITIONAL
6.	2900	Cu – Cu	NOT ACCEPTABLE
7.	4980	Al – Al	ACCEPTABLE
8.	4980	Br – Br	ACCEPTABLE
9.	4980	Cu – Cu	CONDITIONAL

Fig. 5. Weld specimens.

6 Experimental Investigations

6.1 Investigation of Welding Parameters

After completion of primary feasibility study, few experiments were carried with 2250.2900 rpm. The Al, Brass and copper shows acceptable weld ability at 4980 rpm and the results are shown below:

TABLE 2

Material	Weding time (Sec)	Welding pressure (N)	Torque (N-m)	Welding Temp(0 C)	Coeffn of Friction (μ)
Al-Al	59	632	2.4	118.0	0.94
Br-Br	115	710	1.9	197.2	0.67
Cu-Cu	235	235	3.5	169.8	0.89

6.2 Mechanical Testing

Tensile test was dome on a UTM STS -248. The test specimen was prepared after machining and grinding.Mechanical properties of the weld material were also considered and a special collet was designed to hold the welded specimens.

The table 3 below shows that the tensile strength of weld obtained in case of aluminium is near to tensile strength of metal itsef whereas in case of brass, the value is high but not that near to original. In case of copper the value is low because of the weld category obtained (Conditional).

The collets used for holding the welds for mechanical testing were manufactured in machine lab and are shown in figure below.

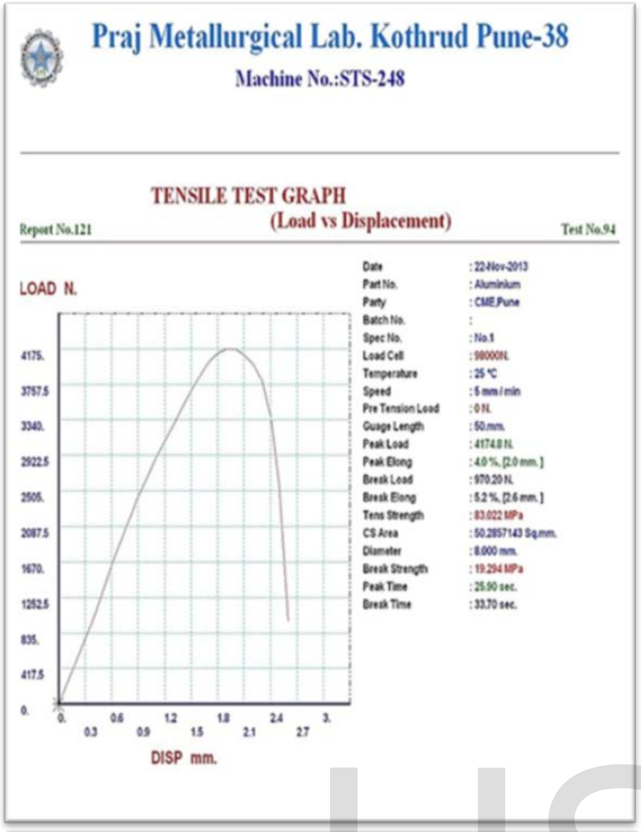
Fig. 6. Collet used for mechanical testing.

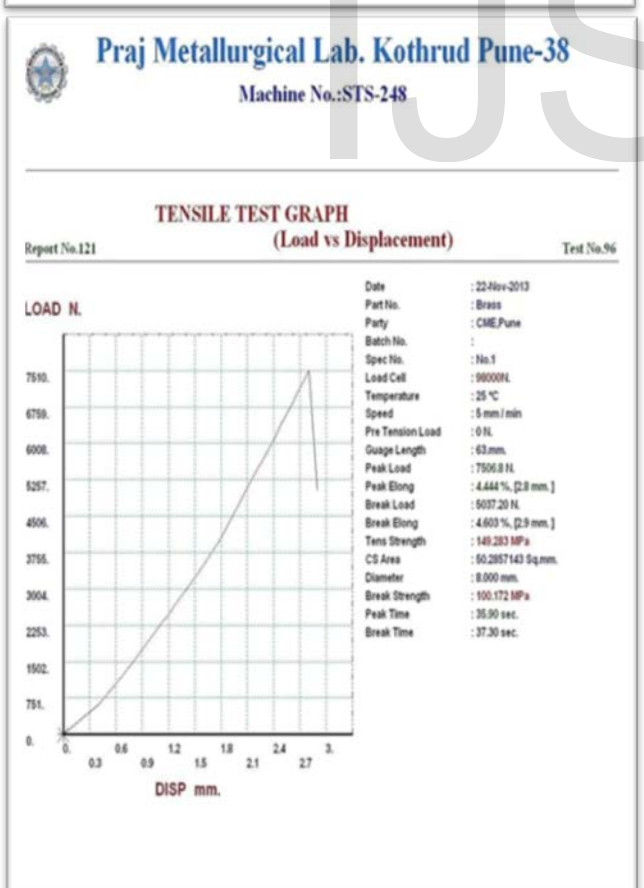
Tensile strength of metal and weld obtained at 4980 rpm is given in table 3:

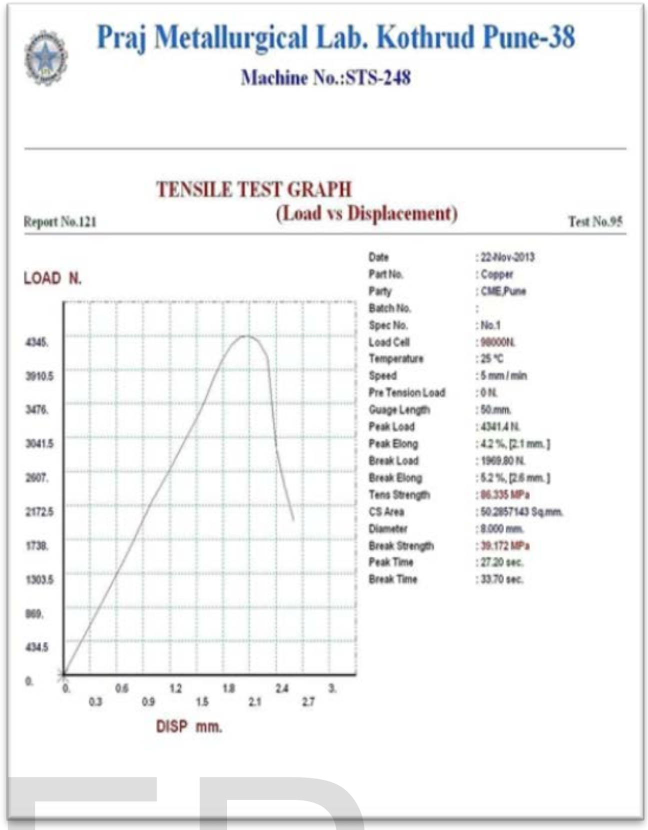
TABLE 3

Metal used	Tensile strength of metal piece (mpa)[9]	Tensile strength of weld obtained (mpa)
Aluminium	90 - 135	83.022
Copper	150 – 220	86.335
Brass	220 and above	149.283

The tensile test done on the weld pieces was carried out in Praj metallurgical Laboratory, Pune. The tensile test reports are in the next page.







7 CONCLUSION

• Friction welding process on table mounted lathe machine can be suitably adopted for specimens between 4mm to 8mm diameters.
• The welding can be done without application of conventional brake; instead reversal of motor is successfully used.
• Increased rpm reduces the friction time of the same metal done earlier at lower rpm.
• Better results are obtained at optimum parameter values.
• The welding of aluminum was possible at 2250 rpm with axial pressure of 610N and torque obtained was 2Nm, whereas Cu and Br were not acceptable.
• With the increase in rpm, the torque and coefficient of friction increases.
• At 4980 rpm, the tensile strength of weld obtained in case of aluminum is near to tensile strength of metal itself whereas in case of brass, the value is high but not that near to original. In case of copper the value is low because of the weld category obtained (Conditional).

This basic feasibility study and tensile testing of micro friction welding leads us to a variety of scopes in future like microscopic study of weld, testing of weld, welding of dissimilar metals.

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