Design and Fabrication of Friction Stir Welding Machine

Jithin Ambarayil Joy[1], Muhammad Sajjad[1], Dong-Won Jung[1,a]

[1]*Department of Mechanical Engineering, Jeju National University, 1 Ara 1-dong, Jeju-si, Jeju 690-756, Republic of Korea*

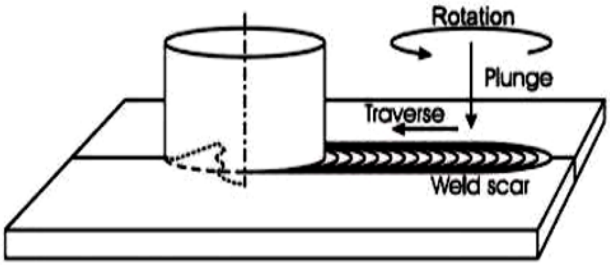
Abstract: The aim of the project is to manufacture a welding machine which simplifies the work and improve the accuracy. The working principle of this machine is different other that of other welding machine. The aluminum work piece is held in the vice. The two pieces of aluminum work piece is welded with the help high speed drilling head with friction tool. The working principle is very easy and at the same time production time is very much reduced. This machine is best suitable for mass production

Keywords: Friction, Welding, Joints, Motor, Bearings

1. INTRODUCTION

Welding is a process of joining similar metals by the application of heat. Welding can be done with or without the application of pressure. While welding, the edges of metal pieces are either melted or brought to plastic condition. Welding can be done with the addition off filler materials or without it welding is used of making permanent joints. It is used in the manufacture of automobile bodies, aircraft frames, railways wagons, machine frames, structural work, tanks, furniture, boilers, general repair work and ship building; At most in all metal working industries welding is used.

In Friction Stir Welding, the part is to weld and joined by forcing a rotating tool to penetrate into the joint and then moving across the entire joint. The solid-state joining process is been promoted by the movement of a non-consumable tool through the welding joint. It consists mainly of three phases, in which each one has been described as a period where the welding tool and workpiece to move about each other. In the first step, rotating tool is vertically displacing into the joint line (plunge period). Then period is followed by the dwell period in which the tool is held steady above workpiece rotating. The velocity between a rotating tool and the stable workpiece produce heat on mechanical interaction which results in friction work and plastic material deformation. The heat is dissipated to the neighboring material, promoting an increase in temperature and consequent material softening. After these two initial phases, welding operation can be carried out by moving either the tool or the workpiece about each other along the joint line. Figure.1 gives a schematic representation of



the FSW setup and operation.

Figure 1: Friction stir welding setup

2. COMPONENTS AND DESCRIPTION

The major components are used in this project:

- SINGLE PHASE AC MOTOR
- BEARING WITH BEARING CAP
- PULLEY
- BELT

[a] Professor Dong-Won Jung, Department of Mechanical Engineering, Jeju National University, Jeju, Republic of Korea : jdwcheju@jejunu.ac.kr

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2.1 Single Phase Ac Motor

2.1.1 Single Phase Induction Motor With Pulley

This is used to drive the wheel by using two pulleys with belt drive mechanism. Because it has but a single alternating current source, a single-phase motor can only produce an alternating field: one that pulls first in one direction, then in the opposite as the polarity of the field switches. A squirrel-cage rotor placed in this field would merely twitch, since there would be no moment upon it. If pushed in one direction, however, it would spin.
The major distinction between the different types of single-phase AC motors is how they go about starting the rotor in a particular direction such that the alternating field will produce rotary motion in the desired direction. This is usually done by some device that introduces a phase-shifted magnetic field on one side of the rotor.

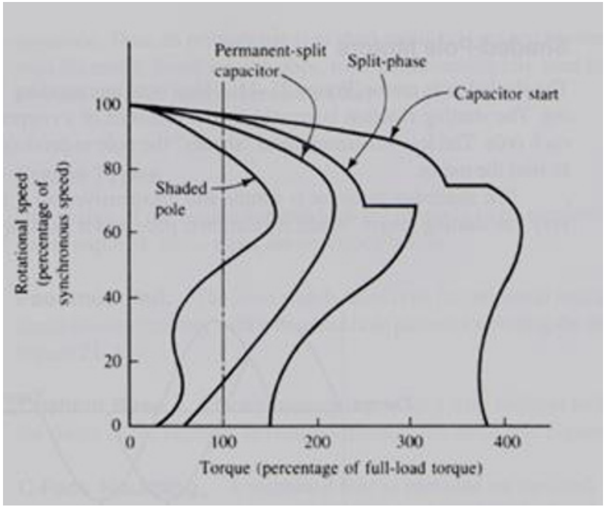

Figure 2: The performance curves of the four major types of single-phase AC motors

2.1.2 *Split-Phase Motors*

The split phase motor achieves its starting capability by having two separate windings wound in the stator. The two windings are separated from each other. One winding is used only for starting and it is wound with a smaller wire size having higher electrical resistance than the main windings. From the rotor's point of view, this time delay coupled with the physical location of the starting winding produces a field that appears to rotate.

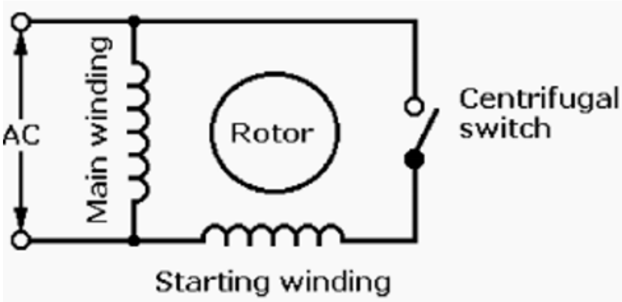

Figure 3: Circuit diagram of Split – Phase Motor

The apparent rotation causes the motor to start. A centrifugal switch is used to disconnect the starting winding when the motor reaches approximately 75% of rated speed. The motor then continues to run on the basis of normal induction motor principles.

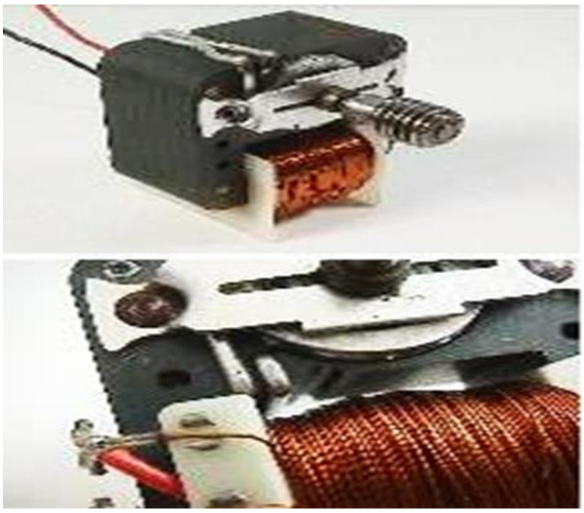

Figure 4: Split-phase motors

2.1.3 *Capacitor-Start Motors*

Capacitor start motors form the largest single grouping of general purpose single phase motors. These motors are available in a range of sizes from fractional through 3HP.
The winding and centrifugal switch arrangement is very similar to that used in a split phase motor. The main difference being that the starting winding does not have to have high resistance. The addition of this capacitor produces a slight time delay between the magnetization of starting poles and the running poles. This moderately priced motor produces relatively high starting torque, 225 to 400% of full load torque. The capacitor start motor is ideally suited for hard to start loads such as conveyors, air compressors and refrigeration compressors. Due to its general overall desirable characteristics, it also used for many applications where high starting torque may not be required.

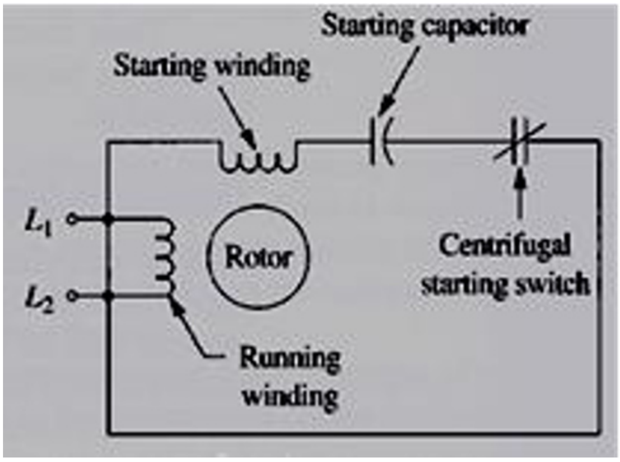

Figure 5: Circuit diagram of Capacitor-start motor

2.1.4 Permanent-Split Capacitor Motors

The starting torque is quite low, roughly 40% of full-load, so low-inertia loads such as fans and blowers make common applications. Running performance and speed regulation can be tailored by selecting an appropriate capacitor value. No centrifugal switch is required.

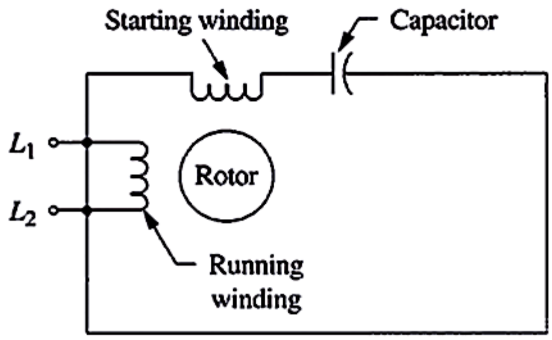

Figure 6: Circuit diagram of Permanent-Split Capacitor Motors

2.1.5 Shaded-Pole Motors

The shaded pole motor is the simplest of all single phase starting methods. In the shaded pole motor, the stator poles are notched and a copper short circuiting ring is installed around a small section of the poles. The shaded pole motor is simple and inexpensive, but has low efficiency and a very low starting torque. Speed regulation is poor, and it must be fan-cooled during normal operation. Shaded-pole motors are thus used in shaft-mounted fans and blowers, and also small pumps, toys, and intermittently used household items.

3. CONSTRUCTION AND TYPES OF BALL BEARINGS

A ball bearing usually consists of four parts: an inner ring, an outer ring, the balls and the cage or separator. To increase the contact area and permit larger loads to be carried, the balls run in curvilinear grooves in the rings. The radius of the groove is slightly larger than the radius of the ball, and a very slight amount of radial play must be provided. The bearing is thus permitted to adjust itself to small amounts of angular misalignment between the assembled shaft and mounting. The separator keeps the balls evenly spaced and prevents them from touching each other on the sides where their relative velocities are the greatest. Ball bearings are made in a wide variety of types and sizes. Single-row radial bearings are made in four series, extra light, light, medium, and heavy, for each bore, as illustrated in Fig. 1-3(a), (b), and (c)

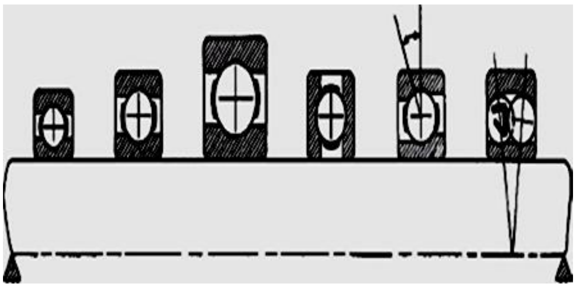

Figure 7: Types of Ball Bearings

The heavy series of bearings is designated by 400. Most, but not all, manufacturers use a numbering system so devised that if the last two digits are multiplied by 5, the result will be the bore in millimeters. The digit in the third place from the right indicates the series number. Thus, bearing 307 signifies a medium-series bearing of 35-mm bore. For additional digits, which may be present in the catalog number of a bearing, refer to manufacturer's details.

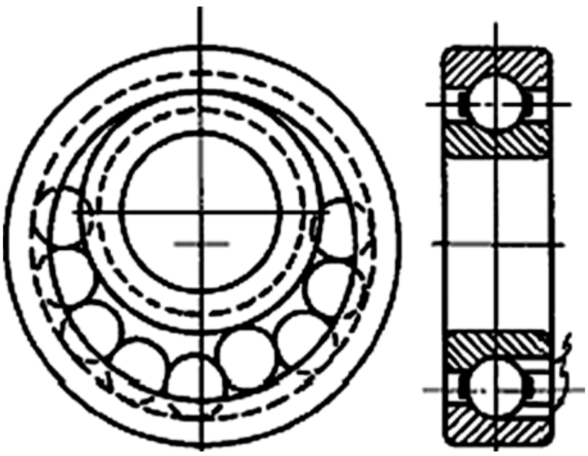

Figure 8: Conrad bearing

Some makers list deep groove bearings and bearings with two rows of balls. For bearing designations of Quality Bearings & Components (QBC), see special pages devoted to this purpose. The radial bearing is able to carry a considerable amount of axial thrust.
However, when the load is directed entirely along the axis, the thrust type of bearing should be used. The angular contact bearing will take care of both radial and axial loads. The self-aligning ball bearing will take care of large amounts of angular misalignment. An increase in radial capacity may be secured by using rings with deep grooves, or by employing a double-row radial bearing. Radial bearings are divided into two general classes, depending on the method of assembly. These are the Conrad, or non-filling notch type, and the maximum or filling-notch type.

3.1 Bearing With Bearing Cap

The bearings are pressed smoothly to fit into the shafts because if hammered the bearing may develop cracks. In our project, the 6202 bearing with bearing cap is used. The bearings are pressed smoothly to fit into the shafts because if hammered the bearing may develop cracks. Bearing is made up of steel material and bearing cap is mild steel.
Ball and roller bearings are used widely in instruments and machines in order to minimize friction and power loss. While the concept of the ball bearing dates back at least to Leonardo da Vinci, their design and manufacture has become remarkably sophisticated. This technology was brought to its present state of p erfection only after a long period of research and development. The benefits of such specialized research can be obtained when it is possible to use a standardized bearing of the proper size and type.

3.1 Pulley

There are two pulleys are used in our project. One is coupled with motor shaft and another one is coupled with spur gear shaft. These two pulleys are connected by belt drive.

3.3 Belt

This is used to transmit the power from one place to another place. In our project this is transmit power from motor to the spur gear. The belt drive mechanism is used for this project. This is used to transmit the power from the motor shaft to the brush shaft. The greater the shaft center distance, the more practical the use of chain and belt, rather than gears.

Table 1: Comparison of Roller chain, Tooth belt, V belt, Spur gear

Type	**Roller Chain**	**Tooth Belt**	**V Belt**	**Spur Gear**
Synchronization	◎	◎	×	◎
Transmission Efficiency	◎	◎	×	◎
Anti-Shock	△	○	◎	×
Noise/Vibration	△	○	◎	×
Surrounding Condition	Avoid Water, Dust	Avoid Heat, Oil, Water, Dust	Avoid Heat, Oil, Water, Dust	Avoid Water, Dust
Space Saving (High Speed/ Low Load)	×	◎	○	○
Space Saving (Low Speed/ High Load)	◎ Compact	△ Heavy Pulley	× Wider Pulley	○ Less Durability Due to Less Engagement
Lubrication	× Required	◎ No Lube	◎ No Lube	× Required
Layout Flexibility	◎	○	△	×
Excess Load onto Bearing	◎	△	×	◎
	◎ Excellent	○ Good	△ Fair	× Poor

Conveyor systems use chains, belts, or rollers, depending on the application. The general guidelines for suitability are shown in below Table.
Belt conveyors are most suitable for large-volume movement of bulk materials. Except for this situation, chains, belts, and rollers are generally difficult to compare in terms of capacity, speed, or distance of conveyance of unit materials.

NOTE: In this discussion, bulk materials refer to items like grain or cement that may shift during conveyance. Unit materials, such as automobiles or cardboard, are stable when conveyed.

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Table 2: Conveyor Type

Conveyor Type	**Chain**	**Belt**	**Roller**
Bulk Handling	◎	◎	×
Unit Handling	◎	○ Only for light conveyor	◎
Dust in Conveying Bulky Goods	◎	× / ○ (○for closed conveyor)	
Space Required	Small	Large	Large
	◎Excellent	○Good	×Poor

4. DESIGN CONCEPT

4.1 CAD/CAE

Computer aided design or CAD has very broad meaning and can be defined as the use of computers in creation, modification, analysis and optimization of a design. CAD/CAE is employed in numerous industries like manufacturing, automotive, aerospace, casting, mold making, plastic, electronics and other general-purpose industries. It is used for the complete modelling, analysis and manufacturing of products. The design and development of products, which took years in the past to complete, is now made in days with the help of high-end CAD/CAE systems. The main advantage of using Cad is we create the model before the manufacturing of the product, which is the easy and economical way to get the perfect product.

4.2 Modeling

Model is a Representation of an object, a system, or an idea in some form other than that of the entity itself. Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. On the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally this model which is intended for a simulation study, is a mathematical model developed with the help of solid works.

Figure 9: Model view of friction stir welding machine

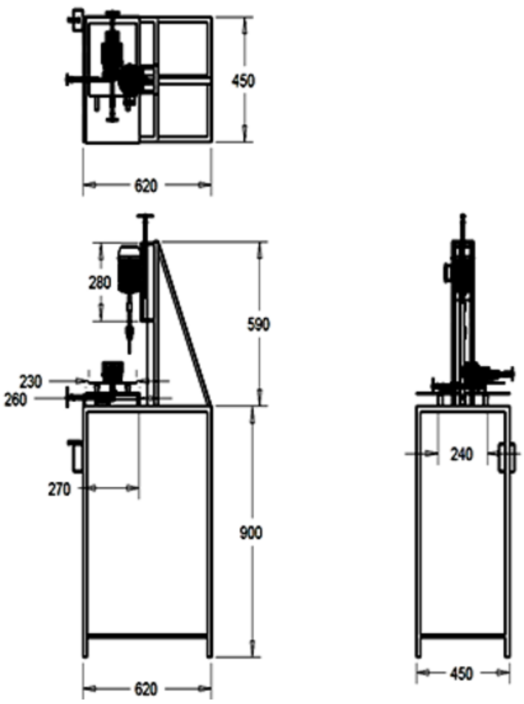

Figure 10: sketch of friction stir welding machine

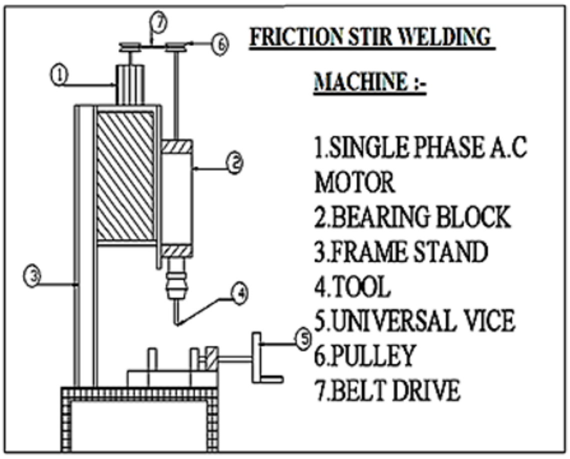

Figure 11: Components of friction stir welding machine

5. FABRICATION OF THE UNIT

The fabrication of unit consist of almost all the standard welding processes such as welding, fitting, assembling etc..
The unit necessitates the manufacturing of following parts.

- Vertical Movable bed
- Horizontal Moving Bed
- Vice
- Friction Tool
- Motor
- Frame stand

The components manufactured in process involved in manufacturing in detail in the report else. The manufacturing and assembly of this arrangement is made as rigid as possible.

5.1 Vertical Movable Bed (Upper Arm)

Upper arm is also called as movable Bed. As the arm can move up and down, it is called as movable arm. The upper arm is connected to the frame stand. The motor is fixed on this moving bed with suitable bolt and nut arrangement.

5.2 Horizontal Moving Bed (Lower Arm)

Horizontal moving bed also called as Lower arm. As the arm can move linear it is called as movable arm. The lower arm is connected to the frame stand. The vice is fixed on this moving bed with suitable bolt and nut arrangement.

5.3 Vice

The vice is found over the base of the machine and from the bottom of the moving bed. This type of vice is used to hold the work piece in a straight manner as well as in a tilted manner. Such a way the jaws are found in the vice. The various part of the vice is supporting jaw, screw rod with self-tilting jaw.

5.5 Supporting Jaw

It is found on the either end of the vice which is fixed on the base plate by the help of bolt and nut. Its supports the work piece can be moved of max angle fixing the jaw the work piece to be cut is placed to an angle whose edge. Handle is rotated the self-tilting jaw, when approaches the other side of the work piece automatically moves to angle and grips the work piece.

5.1 Friction Tool

Friction tool is made up of mild steel. It is fixed to the three phase induction motor which is held on the vertical moving bed.

6. MOTOR

6.1 Three-phase AC induction motors

Disassembled 250W motor from a washing machine, the 12 stator windings are in the housing on the left. Next to it is the "squirrel cage" rotor on its shaft.
Where a poly-phase electrical supply is available, the three-phase (or poly-phase) AC induction motor is commonly used, especially for higher-powered motors. The phase differences between the three phases of the poly-phase electrical supply create a rotating electromagnetic field in the motor.
Through electromagnetic induction, the rotating magnetic field induces a current in the conductors in the rotor, which in turn sets up a counterbalancing magnetic field that causes the rotor to turn in the direction the field is rotating. The rotor must always rotate slower than the rotating magnetic field produced by the poly-phase electrical supply; otherwise, no counterbalancing field will be produced in the rotor.
Induction motors are the workhorses of industry and motors up to about 500 kW (670 horsepower) in output are produced in highly standardized frame sizes, making them nearly completely interchangeable between manufacturers (although European and North American standard dimensions are different).
Very large synchronous motors are capable of tens of thousands of kW in output, for pipeline compressors, wind-tunnel drives and overland convertor systems.
There are two types of rotors used in induction motors.

6.2 Squirrel Cage rotors

Most common AC motors use the squirrel cage rotor, which will be found in virtually all domestic and light industrial alternating current motors. The squirrel cage takes its name from its shape - a ring at either end of the rotor, with bars connecting the rings running the length of the rotor. It is typically cast aluminum or copper poured between the iron laminates of the rotor, and usually only the end rings will be visible. The vast majority of the rotor currents will flow through the bars rather than the higher-resistance and usually varnished laminates. Very low voltages at very high currents are typical in the bars and end rings; high efficiency motors will often use cast copper in order to reduce the resistance in the rotor.

In operation, the squirrel cage motor may be viewed as a transformer with a rotating secondary - when the rotor is not rotating in sync with the magnetic field, large rotor currents are induced; the large rotor currents magnetize the rotor and interact with the stator's magnetic fields to bring the rotor into synchronization with the stator's field.

An unloaded squirrel cage motor at synchronous speed will consume electrical power only to maintain rotor speed against friction and resistance losses; as the mechanical load increases, so will the electrical load - the electrical load is inherently related to the mechanical load. Furthermore, a stalled squirrel cage motor (overloaded or with a jammed shaft) will consume current limited only by circuit resistance as it attempts to start. Unless something else limits the current (or cuts it off completely) overheating and destruction of the winding insulation is the likely outcome. Virtually every washing machine, dishwasher, standalone fan, record player, etc. uses some variant of a squirrel cage motor.

6.3 Wound Rotor

An alternate design, called the wound rotor, is used when variable speed is required. In this case, the rotor has the same number of poles as the stator and the windings are made of wire, connected to slip rings on the shaft.

Compared to squirrel cage rotors, wound rotor motors are expensive and require maintenance of the slip rings and brushes, but they were the standard form for variable speed control before the advent of compact power electronic devices. Transistorized inverters with variable-frequency drive can now be used for speed control, and wound rotor motors are becoming less common. (Transistorized inverter drives also allow the more-efficient three-phase motors to be used when only single-phase mains current is available, but this is never used in household appliances, because it can cause electrical interference and because of high power requirements.)

Several methods of starting a poly-phase motor are used. Where the large inrush current and high starting torque can be permitted, the motor can be started across the line, by applying full line voltage to the terminals (Direct-on-line, DOL). Where it is necessary to limit the starting inrush current (where the motor is large compared with the short-circuit capacity of the supply), reduced voltage starting using series inductors, an autotransformer, thermistor, or other devices are used.

The speed of the AC motor is determined primarily by the frequency of the AC supply and the number of poles in the stator winding, according to the relation

$$N_s = 120F / p$$

Where,
N_s = Synchronous speed, in revolutions per minute
F = AC power frequency
p = Number of poles per phase winding

Actual RPM for an induction motor will be less than this calculated synchronous speed by an amount known as *slip*, that increases with the torque produced. With no load, the speed will be very close to synchronous.

When loaded, standard motors have between 2-3% slip, special motors may have up to 7% slip, and a class of motors known as *torque motors* are rated to operate at 100% slip (0 RPM/full stall).

The slip of the AC motor is calculated by
$S = (N_s - Nr) / N_s$
$Percentages\ lip = (N_s - Nr) / N_s * 100$
Where
N_r = Rotational speed, in revolutions per minute.
S = Normalized Slip, 0 to 1.

As an example, a typical four-pole motor running on 60 Hz might have a nameplate rating of 1725 RPM at full load, while its calculated speed is 1800.

The speed in this type of motor has traditionally been altered by having additional sets of coils or poles in the motor that can be switched on and off to change the speed of magnetic field rotation. However, developments in power electronics mean that the frequency of the power supply can also now be varied to provide a smoother control of the motor speed.

6.4 Three-phase AC synchronous motors

If connections to the rotor coils of a three-phase motor are taken out on Slip-rings and fed a separate field current to create a continuous magnetic field (or if the rotor consists of a permanent magnet), the result is called a synchronous motor because the rotor will rotate in synchronism with the rotating magnetic field produced by the poly-phase electrical supply. The synchronous motor can also be used as an alternator.

Nowadays, synchronous motors are frequently driven by transistorized variable-frequency drives. This greatly eases the problem of starting the massive rotor of a large synchronous motor. Once the motor reaches synchronous speed, no current is induced in the squirrel-cage winding so it has little effect on the synchronous operation of the motor, aside from stabilizing the motor speed on load changes.

Synchronous motors are occasionally used as traction motors; the TGV may be the best-known example of such use. One apparently unusual use for this type of motor was its use in a power factor correction scheme. This exploited a feature of the machine where it consumed power at a leading power factor when its rotor was over excited.

It thus appeared to the supply to be a capacitor, and could thus be used to correct the lagging power factor that was usually presented to the electric supply. The excitation was adjusted until a near unity power factor was obtained (often automatically). Machines used for this purpose were easily identified as they had no shaft extensions. They were referred to as *synchronous capacitors*.

6.5 Two-phase AC servo motors

A typical two-phase AC servo motor has a squirrel-cage rotor and a field consisting of two windings:1) a constant-voltage (AC) main winding, and 2) a control-voltage (AC) winding in quadrature with the main winding so as to produce a rotating magnetic field. The electrical resistance of the rotor is made high intentionally so that the speed-torque curve is fairly linear. Two-phase servo motors are inherently high-speed, low-torque devices, heavily geared down to drive the load.

7. CONSTRUCTION AND WORKING PRINCIPLE

Two pieces are welded together due to the pressure exerted by the two materials, which are connected to the lower and upper arms, where the upper arm is movable and the lower arm is also movable.

7.1 Working

Traditionally, friction welding is carried out by moving one component relative to the other along a common interface, while applying a compressive force across the joint. The friction heating generated at the interface softens both components, and when they become plasticized the interface material is extruded out of the edges of the joint so that clean material from each component is left along the original interface. The relative motion is then stopped, and a higher final compressive force may be applied before the joint is allowed to cool. The key to friction welding is that no molten material is generated, the weld being formed in the solid state.

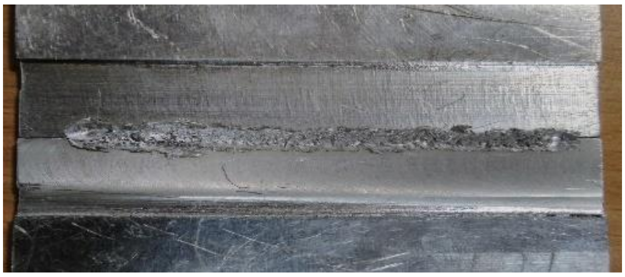

Figure 12: Welded plates sample

8. ADVANTAGES

Friction welding has been used by the automotive industry for decades in the manufacture of a range of components. The process is attractive for several reasons.

- The friction heating is generated locally, so there is no widespread softening of the assembly
- The weld is formed across the entire cross-sectional area of the interface in a single shot process
- The technique is capable of joining dissimilar materials
- The process is completed in a few seconds with very high reproducibility - an essential requirement for a mass production industry.

Now, a new variant from the same stable of friction processes, known as ‘friction stir welding’, is finding increasing use in the fabrication of automotive components, even though its processing speed is not yet as rapid.

9. DISADVANTAGES

- High speed motor is required
- Applicable for particular Products only

10. APPLICATIONS

The original application for friction welding was the welding of long lengths of material in the aerospace, shipbuilding and railway industries. Examples include large fuel tanks and other containers for space launch vehicles, cargo decks for high-speed ferries, and roofs for railway carriages. In the automotive sector the drive to build more fuel efficient vehicles has led to the increased use of aluminum in an effort save weight, which also improves recyclability when the vehicles a scrapped. Such has been the interest in friction welding, which was patented no so long ago, that considerable effort is being made in transferring the technological benefits from aluminum and magnesium to higher temperature materials such as copper, titanium and steels.

11. CONCLUSION

We feel very happy and proud in fabricating this project “FRICTION WELDING MACHINE”. Fixture is adjustable and easy to operate which leads to no shifting of welding workpiece during FSW. It’s have good vibration absorbing capacity with good axial load carrying capacity which leads to significant defect free friction stir welding. On variable condition sound FSW found without any distortion of weld material due to no excess heat effect. A performance feasibility test should be carried out to ensure that the proposed FSW joints have strength greater than or equal to that of the corresponding MIG welded joints. Functional feasibility tests and performance feasibility tests should be completed to determine the extent to which FSW may be used in automobile chassis fabrication.

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