# Design of Special Purpose Machine for TIG Welding of Circumferential Seam of Motor Body

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*DOI : 10.22486/iwj/2018/v51/i1/166443*

## ABSTRACT

Gas Tungsten Arc Welding (GTAW) offers high quality weld deposit that becomes suitable for higher alloy contents with low rate of deposition. Hot wire GTAW is a further development of the GTAW process which is used in industries that need high quality welding with high productivity. It is essential to have an automated welding machine in pump industries to increase productivity and quality which can also make the work easier for a welder. GTAW welding with hot wire for circumferential seam welding of motor body is a major development for pump industries which is required for good quality welding and mass production of the pump motor body. So it has been planned and designed a Special Purpose Welding Machine for Circumferential Seam Welding of Motor Body which will be a major challenge for all pump industries with latest technologies at low cost with respect to the current market scenario and also the customer requirements by analyzing and implementing their needs.

**Key-words:** Pump Motor body welding machine; Circumferential Welding; Seam welding; GTAW; TIG Welding Machine, Semi-automated TIG welding Machine; SPM; special purpose machine.

## 1.0 INTRODUCTION

PSG Industrial Institute is the pioneer in manufacturing Pumps and Motors in India that has a quite good track record tracing back to the year of 1926. A typical submersible pump motor body shown in **Fig. 1** which is of different variants (i-e) 6" (V6), 8" (V8), 10" (V10) is being developed at PSG Rotary Motor Division. It has been categorized with respect to the OD of the submersible pumps motor body for different motor capacity varying from 3 hp to 32 hp. The OD of the motor body varies from Ø 140 mm min to Ø 254 mm max and the weight of the motor body varies from 30 kg min to 50 kg max for the above three variants. The Motor body consists of 3 different components (i.e.) Carbon steel body and 2 mild steel covers on either side of the body assembled and welded at the two similar joints of the body and cover.

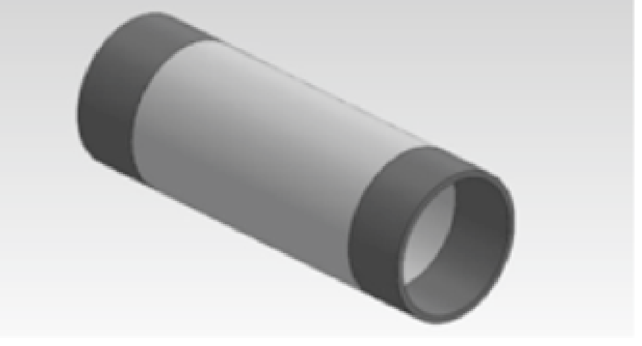

**Fig. 1 : Typical Pump motor body**

Special Purpose Machine (SPM) offers high volume production capability with low investment and production cost when compared to other machines. The SPM developed is a highly productive machine, with a specially designed fixture and tooling. It is dedicated to mass production of one component day in and day out. A well planned combination of the processes, such as loading, unloading, positioning and welding that are is done with limit switches, PLC controls and automatic job clamping, is the primary aspect of a SPM. A well planned SPM optimally utilizes the man and the machine. The proposed SPM is suitable for mass production of circumferential seam welding of motor body which is offered at low cost. Three different models of SPM design were designed with respect to the current market scenario. Out of three, one model is chosen for the development at Centre of Excellence in Welding Engineering and Technology, PSG College of Technology with respect to customer requirements and needs in a very low cost. The manually GTAW welded pump bodies are shown in **Fig. 2**.

Comparison of time duration for manual and mechanized welding is presented in **Table 1**. From this table, it is clear that mechanized welding is essential to enhance productivity.

**Fig. 2 : Manually Welded pump motor body**

**Table 1. Comparison of time duration for manually and mechanized welding**

| Sl. No. | Process | Manual | Mechanized |
|---|---|---|---|
| 1. | Welding Time for Two seam of a motor body on after the other (Excluding Loading, Unloading, Fitting, etc.) | 13 mins | 7 mins |
| 2. | Welding Time for Two seam simultaneously (Excluding Loading, Unloading, Fitting, etc.) | --- | 3.2 mins |
| 3. | Total Setting Time. | 12 mins | 6 mins |
| 4. | Total Welding Time of two circumferential seams for one motor body. | 25 mins | 13 mins |

## 2.0 SPECIAL PURPOSE MACHINE (SPM) DEVELOPED

For GTA Welding of motor body a SPM is designed taking in to consideration the welding sequence, relative motion required for welding, welding tact time which is in the above table 1 and also the total weight of the motor body. The designed SPM consists of following sub-assemblies.

a) Head Stock
b) Tail Stock
c) Torch Manipulator
d) Conveyor
e) Lifter

### 2.1 Working of SPM

In submersible pump motor body welding, the motor body is positioned along the centre axis of the head stock and tail stock arrangements and clamped with a tapered collet fixture. The head stock of the machine is fixed and tail stock of the machine is moveable. The spindle mounted in the head stock has only rotary motion whereas the spindle in the tail stock has both rotary and linear motion. The motor body is made to rotate with the head stock and tail stock at $360^0$ rotation whereas the torch is mounted on the perpendicular axis of the motor body which is positioned accurately at the motor body seam where welding is to be done. The welding quality can be enhanced by Pulsed GTAW Process with hot wire attachment and increase in productivity is achieved by reducing the overall process time which is by automating the loading and unloading process by a conveyor. This can also eliminate human error. The block diagram of the proposed Special Purpose Machine is shown in **Fig. 3**.

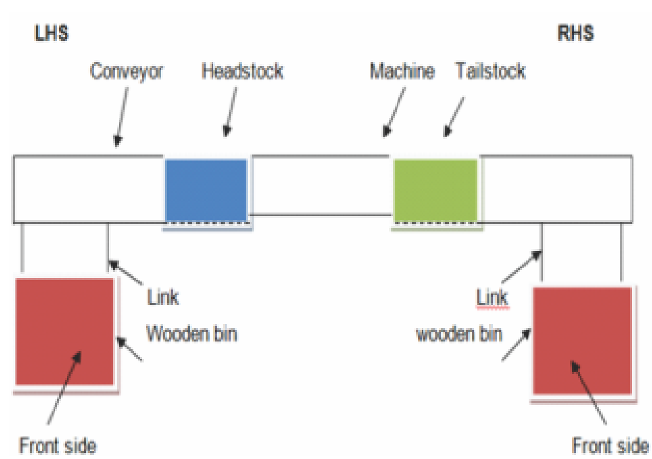


**Fig. 3 : Block diagram of the SPM developed**

## 2.2 Design of Sub assemblies

The design and selection of various components in sub assemblies of the SPM was performed according to the design requirements which are detailed below.

### 2.2.1 Head Stock Assembly

The Head stock is fixed and has only rotary motion. The Major sub-assemblies of head stock consist of three different parts which is shown in the **Fig. 4**. The features and the selection of the main parts in the headstock assembly are as explained below. Some of the parts are designed as per standard which is readily available in the market.

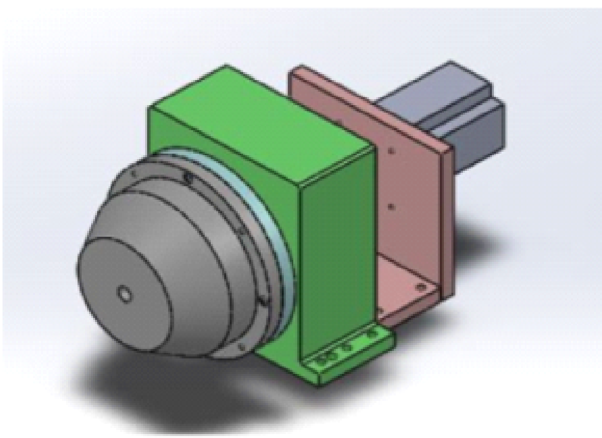

**Fig. 4 : Head stock assembly**

**Spindle** - A spindle is referred to the rotating axis of the machine, which often has a shaft at its heart. This is designed considering the available drawing and dimensions of the motor body such that which suits the 6" (V6), 8" (V8), 10" (V10) motor body dimensions and also the load applied. The maximum torque applied is 3 Nmm. The fixture which is assembled with the spindle is so called as the tapered collet fixture. The tapper is designed in such a way that it suits 6" (V6), 8" (V8), and 10" (V10) dimensions on motor body. The shaft itself is called a spindle, but also, in shop-floor practice, the word often is used to refer the entire rotary unit, including not only the shaft itself, but also its bearings and anything attached to it. The shaft or spindle is selected is with respect to the load applied and also considering the torque which is applied by the whole of the Head stock system. The Shaft or spindle Max Ø254 mm which is tapered up to Ø 120 mm for a length 100 mm with respect to the design considerations.

The selection of shaft materials selected is case hardened steel, this is processed to achieve desirable properties to maximize bearing performance and life which is done with respect to the application. It has also been proved theoretically using the following equation.

$\tau/r = T/J = G\theta/L$

where.

T = Torque (Nmm)

J = Polar 2n moment of inertia (mm4)

[3.14*$d^4$ /32 for solid shaft]

G = Modulus of Rigidity (Mpa)

$\theta$ = Angle of Twist (rad)

L = Length (mm)

r = Radius (mm)

$\tau$ = Shear Stress (Mpa)

**Angular contact bearing** - Angular contact ball bearing have inner and outer ring raceways that are displaced relative to each other in the direction of bearing axis. This means that these bearings are designed to accommodate combined loads, i.e. simultaneously radial and axial loads. The bearing is used to reduce the friction between rotating elements. Since, shaft is the rotating element, it is provided with angular contact ball bearing. The angular contact bearing is selected based on the universal standards which have three or more dimensional series as given below to accommodate higher speeds or higher loads than "standard". There are different materials for the production of the various bearing components selected with respect to the applications. The bearing materials are processed to achieve desirable properties to maximize bearing performance and life.

- ISO 18 Series - highest speed, lowest load bearings
- ISO 19 Series - second highest speed, with the second lowest load bearings
- ISO 10 Series - highest load, second lowest speed bearings
- ISO 02 Series - highest load, lowest speed bearings

**Motor -** The motor selected is Servo motor with gear for constant speed control. This is used for the rotary motion of spindle which is coupled to the spindle with a flexible coupling. The motor is selected based on the torque required to rotate the entire weight of the motor body. The calculated toque is 3 Nmm. The motor is mounted on a mounting plate and all these components are assembled and mounted in such a way that it has minimum deviation with reference to the centre axis. In other words it is mounted to the mounting plate taking the centre axis as the reference and in which minimum deviation with respect to the Centre axis with as per standard is accepted. The assembled view of these components are shown in **Fig. 5**.

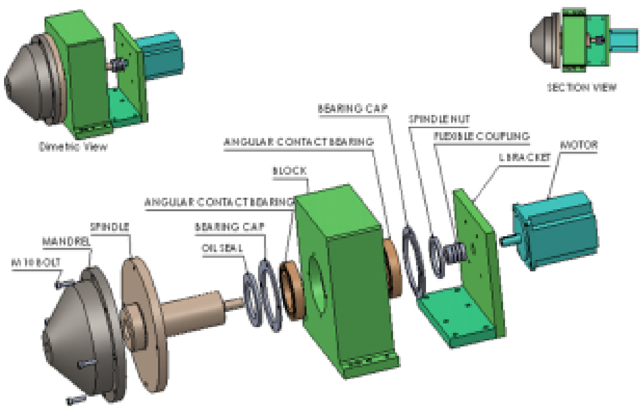


**Fig. 5 Exploded view of Head Stock Assembly**

### 2.2.2 Tailstock Assembly

In this assembly, the tailstock spindle has both linear and rotary motion. The linear motion is carried out with help of pneumatic cylinder and the rotary motion is carried out by the clamping force exerted at the revolving Centre of the tail stock for rotating work piece without any slippage. For this purpose, the spindle is provided with the revolving centre as shown in **Fig. 6**.

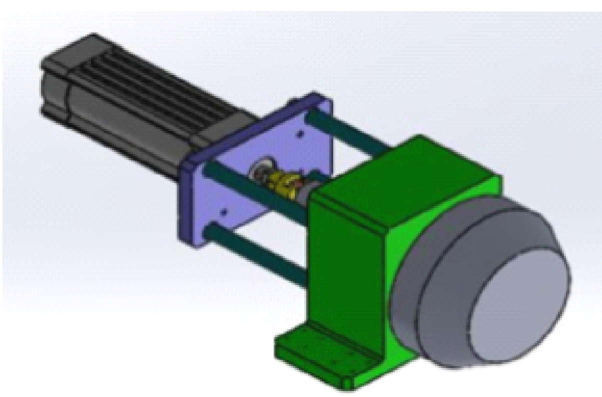

**Fig. 6 : Tail Stock Assembly**

**Revolving center** - This is similar to the spindle which is in head stock assembly but it rotates freely along with the work piece. It has 3600 rotation in both directions but it is allowed to rotate in one direction only.

**Spindle -** The spindle is capable of linear motion, the rotary motion of the spindle is arrested by means of a keyway (i.e.) the rotary motion of the whole shaft is arrested by mean of a pin mounted perpendicularly to the shaft and the spindle. The spindle is directly coupled to pneumatic cylinder by means of a flexible coupling and a bush to reduce its friction for the linear motion.

**Pneumatic cylinder** - In this proposed SPM, the pneumatic cylinder is selected considering the force applied and the max stoke length required. It is a mechanical device which uses the power of compressed gas to produce the required force for providing reciprocating linear motion. The piston is made to be in contact with the spindle and it is mounted on the cylinder mounting plate. The Max force applied is 100kg.

The detailed assembly of tailstock of the machine is shown in **Fig. 7**

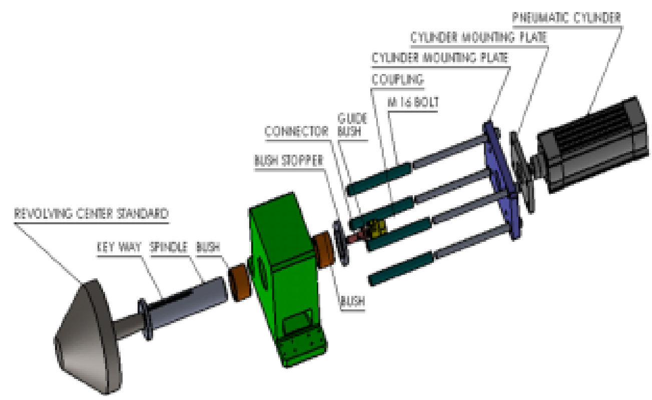


**Fig. 7 : Exploded view of Tail Stock Assembly**

### 2.2.3 Conveyor

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. In this proposed system, the Conveyors are especially useful in applications involving the powered transportation of heavy or bulky materials.

The selected conveyor is roller conveyor. These conveyors are suitable for light applications up to 70 kg motor bodies which is also called as powered conveyors. The Centre spacing and the capacity of the selected roller conveyor are calculated as given below.

**Roller Centre spacing**

The design is made in such a way that a minimum of three roller must support the required load.

Roller Centre Spacing = motor body length / 3

Example:

If length of the motor body is 18", there will be 18" / 3 = 6" Roller centers.

**Roller Capacity**

To determine the roller capacity the maximum weight of the motor body is divided by minimum number of rollers that will carry the load at any single moment.

Minimum Capacity required per roller = Max Weight of the motor body / No of rollers under load.

If maximum weight of the motor body is 30 kg, the capacity required per roller is Kg / 3 = 10 kg.

### 2.2.4 Torch

This is designed in such a way that it has X, Y & Z axis of movement. Two ball screw rod of Ø 40 mm is used for the X axis and Y axis moment of the torch and one ball screw rod of size Ø 30 mm is used for Z axis moment of the torch. The ball screw rod has been selected for precised moment of the torch.

## 3.0 DESIGN VALIDATION FOR HEAD STOCK & TAIL STOCK ASSEMBLY

Stress analysis is done as a primary task for validating the design of Head Stock and Tail Stock assembly to withstand the load of the motor body as shown in **Fig. 8**. The two ends of the spindle is fixed and the motor body is clamped with the head stock and tail stock spindle the load applied on the motor body is uniformly distributed load which is 600 N. This FEM analysis is done using a module called solid works simulation in solid works software package.

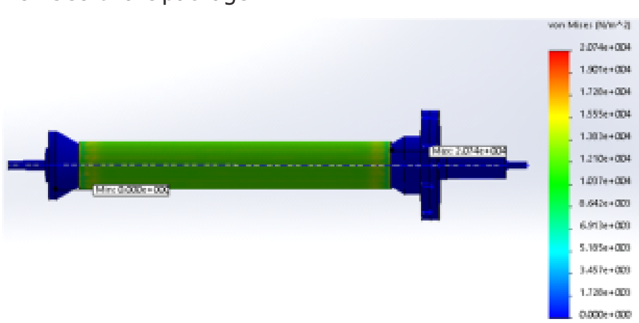

**Fig. 8 : Stresses induced in head stock & tail stock assembly**

In this proposed SPM, stress analysis is performed through experimental testing as explained above.

The maximum stress induced due to the force exerted by the work piece is 2.107e+004 $N/m^2$ which do not exceed the limit 3.175e+008. So the design is acceptable.

Here the maximum displacement is 8.779e-006 mm.

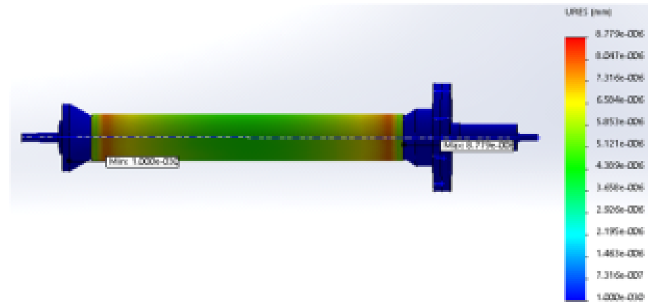

**Fig. 9 : Displacement analyzed in head stock & tail stock assembly**

## 4.0 SPM MACHINE

**Fig. 10** shows a solid works model which is designed and analyzed with respect to the customer needs and requirements. The overall layout of the machine including the conveyor setup is 4.5m x 2.5m. The Layout of the machine without conveyor is shown in **Fig. 10**. The Centre axis of the machine is 1.1m from ground level.

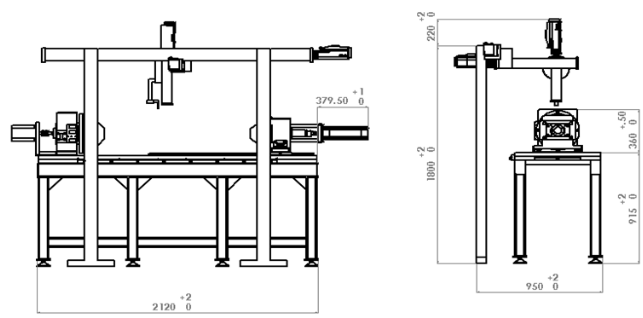

**Fig. 10 : The SPM machine layout**

The head stock and tail stock sub-assemblies are designed and assembled in such a way that both the spindle are assembled to same centre axis whereas the tail stock spindle is concentric with reference to head stock spindle, this is assembled in such a way that the run out in the assembly is minimized to a level as per standard. This kind of design will lead to a major defect in the process. The Conveyor acts as the heart of the machine where it helps in auto loading, unloading of the motor body which comes from below the machine bed. The work piece is supplied to the machine by a lifter which is a pneumatic driven lifter lifts the motor body to the centre axis of the machine in the provided gap at machine bed as shown in Fig. 11. There is a Vibro mount provided to machine for mounting the machine on irregular surface.

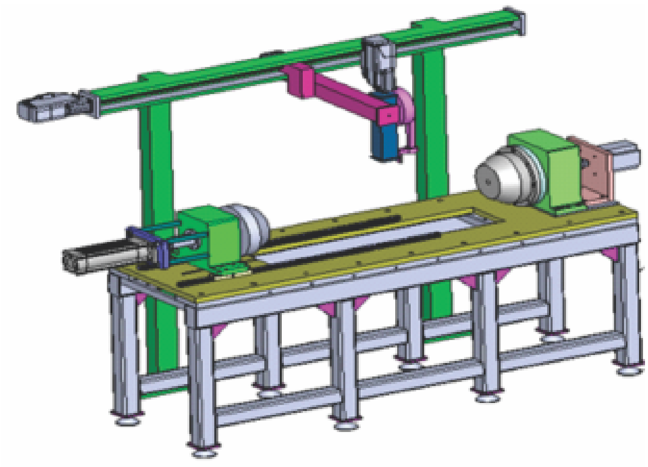

**Fig. 11 : The SPM model**

The proposed SPM has four different steps of automation.

- Loading & Un-loading: The loading of the work piece was done from the left hand side of the machine with the help of a conveyor. Here the requirement of operator is 1 for loading and Un-loading of the work piece, unloading will be done automatically in the bin at the RHS which will be later un-loaded(i-e) after welding, the welded motor body is held lowered and taken away from the right hand side conveyor. The un-loading will be done in the BIN provided on the RHS, a capacity of 10 will be un-loaded at a time one after the other and then moved to the stock area for further process of the motor body.
- Positioning: Once the loading is completed the conveyor helps the body to move and stop exactly at the place where it is required for positioning with the help of a PLC Controller. The Pneumatic lifter helps the V-block to lift up to the center axis of the machine for exact positioning as shown in Fig. below. The tapered collet pushes the tail stock spindle with the help of the pneumatic force towards the inner diameter of the motor body for clamping of the work piece.
- Welding: Once the positioning is done accurately the welding torch is moved along the X, Y & Z axis using the sequence the process with the controller and a precise moment of torch can be achieved using a joystick setup for accurate seam welding along the circumferential seam of the motor body. The length of wire stuck out from the contact tip of the guide tube to weld pool, wire diameter and wire material affect resistance, R for I2R heating of the wire. The longer the stick out and the smaller the diameter of the wire, the higher will be the resistance. Since the current across wire extension is squared, the current has a larger effect on heating than voltage. Settings are adjusted so that the wire is heated to just below melting temperature as it enters the weld pool as shown below in **Fig. 12**. The motor body is fitted with its cover on either side for about 13mm in a type of press fit. The welding is done on the seam where the joint of the body with cover has a groove about 2 mm depth at an angle 450 (2 x 450).

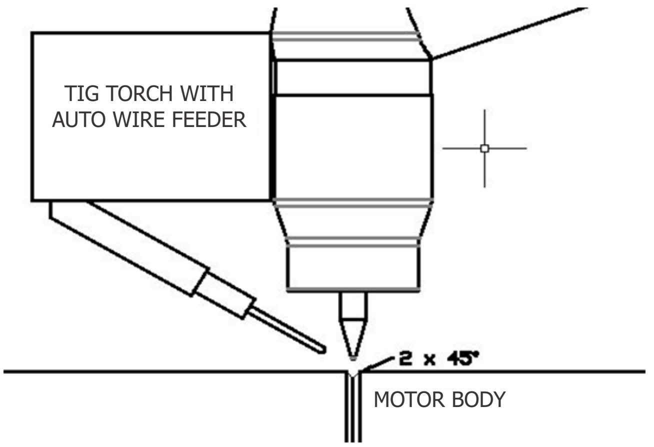


**Fig. 12. : The sketch of the welding torch**

Wire diameters are typically from 0.8 to 1.2 mm. An increase in wire heating may affect arc deflection. In general, the larger the wire diameter, the lower the cost will be. The wire must be very clean to avoid problems with contamination and residue buildup in the contact tip.

Deposition rates for applications average 2 to 3.5 kg/hr. but deposition rates > 5 kg/hr can be achieved without difficulty. For example, hot wire GTAW would be suitable for welding high-quality stainless steel tanks and vessels that are rotated during welding. Attempting to increase deposition rates by increasing hot wire current beyond certain levels or by maximizing out the wire feed speed can result in oxides on the weld bead, increased porosity and generally poor results. If deposition rates are increased, travel speed must increase and torch oscillation is required.

## 5.0 SUMMARY

- It is designed in such a way that the resource used has been optimized to maximum (i.e.) Man power used is optimized from three to one and the welding time has been reduced.

- The productivity can be increased to 65% and also there is no necessity for skilled labor for this process.
- The time has been optimized such that the total welding time is reduced by 50% compared to the existing practice.
- The quality of the weld has been enhanced by PTIG process that results in excellent bead profile and appearance without defects due to low heat input.
- The operator fatigue is reduced by 66% by eliminating the handling of the motor body through mechanization of loading, unloading, setting etc.

## REFERENCE

[1] Henon BK (2010); Automated hot wire TIG with positioner for high productivity quality welding, www.arcmachines.com/news/case-studies/advances-automatic-hot-wire-1 gtaw-tig-welding.

[2] Mustafa FF and Mustafa IR (2016); Automatic welding machine for pipeline using MIG welding process, International Research Journal of Engineering and Technology, 3(12), 1448-1454.

[3] Kitano K, Ikebe M, Shiraishi H and Kasatani T (1996); Development of fully automatic both-side welding (GMAW) for pipeline, Proceedings of the 13th International Symposium on Automation and Robotics in Construction, Tokyo, Japan, June 11-13, 1996, 239-246.

[4] Baskoro AS, Rahman AZ and Haikal (2017); Automatic welding speed control by monitoring image of weld pool using vision sensor, ARPN Journal of Engineering and Applied Sciences, 12(4), 1052-1056.

**Annexure - 1**
**MACHINE SPECIFICATION**

| | |
|---|---|
| SPM | Circumferential Welding Machine. |
| Weld Type | Mechanized Welding using Pulsed TIG welding process with hot wire feed. |
| Features of Pulse TIG Welding Power Source. | Pulse TIG power source with 400A welding current and 100% duty cycle and following features:<br>1. Controlled Fusion.<br>2. Controlled penetration.<br>3. Synergic TIG Welding program.<br>4. Pulse TIG Welding Program.<br>5. Double Pulse Welding Program.<br>6. Spatter less welding.<br>7. Special Welding Program for thin sheet. Welding of Steel. |
| Welding torch and Wire Feeder | 1. Hot Wire torches & welding cables (5 meters).<br>2. Wire feeder & contact tips feeding for Ø 0.8, Ø 1.0 and Ø 1.2 wires. |
| No of torches | Two (Optional). |
| Pulsed GTA welding power source with Hot wire feeder | Two (Optional). |
| Welding Slides | High precision welding slides with 1000x1000mm stroke and accuracy of 0.2mm for fine tuning for precise setting of the electrode tip with respect to the seam. |
| Speed of Welding | 50 to 300 mm/m. |
| Type of job holding & clamping arrangement. | Fixed Head stock & movable Tail stock type |
| Loading & unloading of the motor body | Roller type conveyor with ejector arm for loading and unloading. |
| Automation Steps | 1. Loading of motor Body.<br>2. Positioning of motor Body.<br>3. Welding of motor body.<br>4. Un-Loading of motor Body. |