Design of Automatic Welding System for Process Pipes

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Abstract— The increase in pipeline manufacturing for process industries calls automation of welding system (AWS) in tune with today's demand for accuracy in welding, increased productivity with lesser resources and enhanced profit. Manual welding results in more manpower requirement, low productivity, and low weld quality etc. Automatic welding removes all above problems thus making system itself superior to manual welding system. In this paper, automatic welding system is designed and developed for welding of 'V' Groove in Pipes. AWS based on Embedded / Microcontroller with mechanized output control system is developed for Gas Metal Arc Welding (GMAW) technique. Moreover, system is simple and economical.

Key words: Automatic Welding System, Carbon Steel Pipes, Embedded System, Gas Metal Arc Welding Technique, Sensor

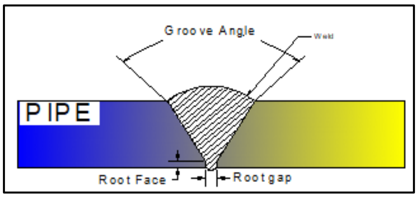
I. Introduction

The Pipe welding is key factor in the manufacturing pipelines used in process industries. Pipe is used to transfer fluid or gases. Manual welding requires high labour strength, low productive efficiency and low quality and leads to weld problems. The arc welding process emits ultraviolet radiation, the high temperatures of molten metal hazardous to human, the current is also unsafe and sparks and smoke makes the environment unsafe to the operator.

As a result of these difficulties, Robots is programmed to perform a sequence of arc welding operation. However, significant technical and economic problems i.e. variations in the components, dimensions of the parts etc. of work piece limits its application and justified in mass production. Vision and laser sensor used to detect weld line of butt joints are affected by noise resulting from arc lights, fumes and spatter [5]. The arc light intensity in GMAW is much higher and influences quality of images by visual sensor, so it is difficult to get weld seam information by visual sensing techniques [3.6].

GMAW welding is most common welding technique and still holds the large scope welding due to low equipment costs, versatility, ease of setup, low maintenance, simple in operation, arc stability, sound fusion, low weld problem etc. [10].

Pipes and connectivity can be joined by Butt Joint i.e. V groove joint. Fig. 1 illustrates the type of pipe i.e V groove joint.



(a) Butt Joint

Fig. 1: Illustrations of Butt joint

As demands on pipeline manufacturing are increasing and to counter labour intensity problem, improve efficiency, quality and productivity, we have designed and developed the new automatic welding system (AWS) based on Embedded/microcontroller system for process pipes. It is by partially mechanized automatic system for multi pass welding. The design of AWS of pipe is based on principle in which job rotates and welding torch moves in fashion on weld joint assigned to it by control unit. The system has accelerometer sensor for data acquisition and Embedded controlled operation. System consists of welding source equipment's, wire feed, auto control system, welding carrier, jobs etc. Gas Metal Arc Welding Technique is used. Embedded based system is preferred over PLC as the PLC is expensive and require much space with specific design. Embedded can be used with multiple products by changing only running code on microprocessor Embedded uses simply System C while PLC uses ST and other things.

Gyro sensor / accelerometer of Embedded system is used for seam tracking collects information about the work piece geometry and manual weld progression of torch w.r.t. work piece. The manual weld progression of certified welder information is collected by sensor. The output of sensor is fed to the stepper motor and when power starts the torch will do welding in the fashion assigned to the machine. Our low cost embedded microcontroller based system results in development of economical design of AWS.

II. Literature Review

Huilin Zeing and et.al [1] They did automatic welding of X-80 pipeline for long distance on U groove type of weld. SMAW technique is used here and PLC controlled in built on machine itself. They did not explain for other joints as V, T, J etc. which are very important in pipeline. The equipment is designed without sensor, so if variation in weld size is there, there can be problems in automation of such systems. Two PLC is used and many mechanical parts such as welding carrier and travelling mechanism etc. is involved thus making design is complicated.

Ai-min Li and et. al [2] Thy had carried automatic welding for roller used in coal mines for bigger diameter. CO_2 gas welding techniques is done for faster production but only one positions of weld can be carried out. Structural designed for AWS is done carrying torch and PLC system. Fixed position welding can be done only as job is fixed at 45 degrees. Only Fillet weld is carried out. It is suitable for mass production only. Again, cost is high as stepper motors leads and switching circuits as control system though design is simple. Only fixed type of job can be carried out.

Kim Young-Back and et.al. [3] SAW welding is used over 60 mm plate which is used in large ship containerships. DSP based and microcontroller system is designed for automatic welding. Touch sensor is used for controlling weld database. Again, only fillet weld on plate is carried out. It is quite suitable for heavy metal plates and large production. Vision or arc sensor is complicated to apply thus for making small job, system cannot be applied. It can go costly for production run.

Bae K.Y and et.al. [4] they applied GMAW as welding technique with optical system is used on steel pipe V grove weld. They used Vision sensor using CCD camera for automatic weld seam tracking. V grove welding is used. Sound weldment resulted on different gap sizes of welding. Costly set up as for CCD camera, Image processing, manipulator, fuzzy logic controller etc. Not suitable for medium unit. Pipe range sizes is not considered. It is complicated design in its own sense.

B-H You and J-W Kim [5] Automatic weld seam detection by electromagnetic sensor is done for sheet metal. No separate sensor is used. An analytical approach is considered for welding. System can be affected by current and welding. Typical Design of system consists of signal, controller, bridge circuit, mathematical manipulation etc. No description about thickness of sheet and variation of sizes of weldments is discussed.

J, GAO and et. al [6] Here Vision based automatic welding system is developed for plate welding. GMAW Process is used. CCD camera, image processing algorithm is used for weld parameter detection. ID controller is developed for system. I type of groove is used. Costly set up. Algorithm technique is used. No discussion about variation in gap sizes of weld. Also complicated to understand and carry out although seems easy.

K. Morten and et. al. [7] They developed vision arc welding system using GMAW process and Fuzyy controller. V groove joint is considered. They studied the variation effects of root gap and root width on welding. Here again system is complicated as robot is implemented and further cost is increased. It is suitable for large scale company.

A. Literature Gap

In short Automatic welding system is designed using GMAW/SMAW technique, which is simple but implementation of robotic system and different optical sensor and CCD with controllers and mechanical system makes system complex and can be optimized in large scale production of similar type of job and more cost to be compromised. Automatic welding on doing variation job sizes and orientation is itself a question. For the above we need to develop simple and low budget AWS for medium scale production run and economically effective.

III. Problem Statement and Objectives

The problem lying with manual welding are more manpower required, cost and time consumption in production and low output, weld problem, poor quality of weld. Implementation of robotic system and different optical sensor and CCD with controllers and mechanical system makes system complex and can be optimized in large scale production. However, the objectives of this paper are as follows.

The objectives are to design AWS for the automatic guided welding of 'V' groove weld in Pipes. To select suitable Embedded. microcontroller for AWS over previous PLC design. To evaluate the cost of production of manual welding against automatic welding and quality of weld.

The present paper is the design relates to a new improved (AWS) the present paper leads to the welding system based on Embedded and Microcontroller system rather than previous Programmable Logic Controller (PLC) based to achieve low budget product economically and more productivity.

A. Mechanical Design of AWS and its components.

Our present AWS is simple in construction and economical in design as shown in Fig. 2 consists of Welding machine, embedded system, stepper and dc motor, rack and pinion arrangement welding torch etc. Embedded/microcontroller control System uses the Arduino UNO REV 3 is a microcontroller digital input and output pins, a USB connection, a power jack, an IPSC header etc. Gyro sensor / accelerometer is used, collects information about the work piece geometry and manual weld progression of torch w.r.t. work piece. The accelerometer that is used here in this project is AD×L335 model and is small, thin, low power with three axes controlled that contain signal conditioned with the voltage output system. The accelerometer has three analog output for all three axes i.e. X, Y and Z axes and it require an ADC microcontroller that is provided by the analog function of ARDUNIO board circuit.

The manual weld progression of certified welder is fed to the stepper motor and when power starts the torch will do welding in the fashion assigned to the machine. Welding torch hold on carrier which to be guided through Rack and pinion arrangement as shown in Fig 2. Rollers carries pipe and provides automatic rotation of work piece. The electrode feed mechanism has electrode reels that is pulled and pushed in the conduit up to the welding torch (gun). This unit is composed of a direct-current motor.

The CAD model for working demonstration and analysis purposes as shown in fig 2 and actual model sis shown in fig 3. The model consists of parts as shown in fig.

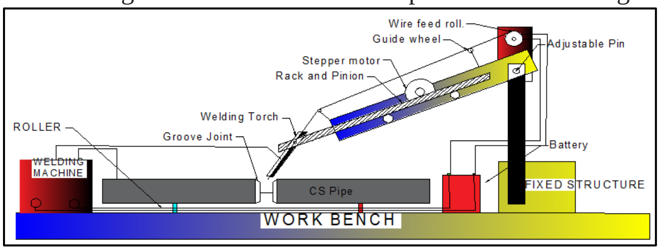


Fig. 2: System configuration of AWS.

The stand which carries the wire feed and stepper moor structure is made wooden as adjustable in size and length for vertical torch movement. For liner movement, the length for horizontal movement frame is given. The Vertical stand is fixed to the base plate and horizontal stand component is bolted to top of vertical plate. For the horizontal torch movement, there is rack and pinion arrangement. Again, for up and down adjustment of torch and further to and fro motion of torch a control mechanism by height controller and rack and pinion adjustment is given. The model has three no dc motor, stepper motor, DC motor for roller and wire feed. A consolidated specification is shown in table 1.

Sl. No.	Descriptions.	Dimensions.
1	Pipe	ASME SA 106 Gr. B mat. 100 NB and 4.5 thk.

2	Stepper DC motor	12 V, Voltage controlled, 5W, 200 steps per rev., 2-3 kg-cm torque, 0.200Kg wt.
3	Roller DC motor	12 V, 3 rpm, 3-4 kg-cm torque. Power- 3-5 W, 0.250Kg wt.
4	Feed DC motor	Actual job wire feed mechanism during testing, Here 310 rpm motor with 12 V input, 3W as power.
5	Frame Structure (Wooden material)	Base plate, 300× 200 mm antd 20 thk, Vertical stand 250 mm ht. and 50× 50 mm cross section and horizontal with 150 mm long with 50 × 50 mm cross section.
6	Battery box	12 V with 1.3- 400 milliampere current. Standard dimensions
7	Rack and pinion	No. of teeth on Pinion- 19 No. of teeth on rack- 80 Material – Plastic Face width- 5 mm Pinion rpm-50
8	Weld technique	GMAW
9	Weld joint Set up	RF 1.00-1.5 mm, RG 1.5 -2.5 mm, Bevel angle 60-70 Deg.
10	Consumables	E71T1, size 1.6 mm length. continuous.
11	Deposition rate	1.5 mm per run.
12	Gas	Argon, CO2
13	Work-piece Position	Horizontal
14	Torch Position	Vertical Top down perpendicular to work piece.

Table 1. Specifications of AWS model and welding

IV. WORKING OF AWS MODEL

The following section explains the working analysis of AWS.

Firstly, the battery box button is turned on and power supply is given to the welding machine. Simultaneously the same power is fed to all three DC motor i.e steeper motor, roller gear motor and wire feed motor. Every motor operation is controlled by power button box. Now a rotary motion is given to the pipe through roller and motor arrangement as shown in fig3. The pipe starts rotation on the roller at 3 rpm. The speed can be controlled by voltage regulation mechanism.

At the same time the power is given to the stepper motor and the wire feed mechanism. The wire starts feed to the welding point and the steeper motor controls the motion of welding torch on the groove joint. The movement fashion of welding torch is controlled by gyro sensor and stepper motor control action define under heading subsection control system of AWS. Again, the when the pipe revolves one motion the motor can be stopped for cleaning of weld of previous weld pass and the weld is cleaned off the motor will restart from motor box and do the next pass welding.

All the control mechanism for next pass welding is same.

A. AWS Model Testing and Results

The model working and testing has been carried out with experimental set up has been taken out. The actual model is shown in fig 3.

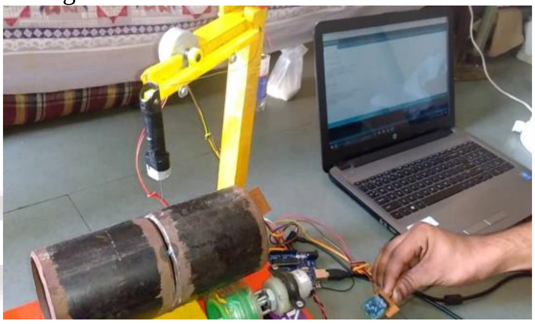


Fig. 3: Model of AWS with Arduino circuit and operation.

The result is summarized as per below table2.

Sl. No.	Quality Check	Required values	Welding	
			Manual	Automatic
1	Physical Check	YS-240	280	300
		TS- 415 Mpa	456-490	485-510
		EL- 22	23	27
2	Face bend	Satisfactory	--------	Satisfactory
3	Side bend	Satisfactory	--------	Satisfactory
4	Chemical check	C-0.30, Mn- 0.29-1.06, P-0.035, Si-0.10, S-0.035, cr- 0.40, Mo-0.15.	----------	C-0.23, Mn- 0. 95, P-0.16, Si-0.02, S-0.12, cr- 0.32, Mo-0.10.
5	Visual Test	Defects free		Satisfactory and continuous weld seam.

Table 2: Quality comparison analysis between manual and automatic welding.

We found that designed and developed AWS is economical and cheaper in design.

The automatic welding improved the weld quality reduce labour intensity and save time of pipeline manufacturing per hour thereby costs.

A quality check has been carried out on the performance AWS and the result shows that the weld quality is far superior than the manual welding and which reduces repair and maintenance costs of faulty joints and further helps in cost reduction

V. CONCLUSIONS

Due to its simple construction and low-cost budget AWS, it will carry out welding on pipe automatically and sound quality of weld is resulted out. Again, cost and time for manual against automatic production is evaluated and compared which shows AWS is much better than conventional welding if designed properly. The accelerometer provided data to stepper motor works properly. The fashion movement of welding torch in x and Y direction works well. The automatic welding improved the weld quality reduce labour intensity and save time of pipeline manufacturing per hour thereby costs.

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