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Coil End Welds In Helical Seam Pipes – Automated Process Control For Quality

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Abstract: The process of joining coil ends using the submerged arc welding process is widely used in the manufacturing of HSAW pipes. To improve productivity, quality, and reduced rework, automation of internal and external welding processes were carried out using in-house modifications to enhance the manufacturing capabilities to supply API 5L grade line pipes with coil end welds.

In the present work, the requirements of internal and external welding processes were studied for assessment of capability and the scope of improvement. Various devices such as laser sensors, cameras, HMIs, control panels and motors were assembled, tested, and connected to a central monitoring dashboard to keep an eye on the current welding parameters and other attributes like flux temperature. After several trials, a few minor adjustments were done to properly synchronize the internal and external welding heads with the grooves as per different coil widths and pipe diameters. Automatic laser seam tracking and spot laser were employed in external welding set-up to prevent bead-off in internal and external weld beads.

The system has been made flexible enough to accommodate coils of any width and pipes of outside diameters ranging from 24” to 120”. The system is established with SOPs and work instructions. The performance of these automated internal and external welding set-ups has been demonstrated in an internal project of grade API 5L X65M PSL2 grade with significant improvement in yield and quality as compared to the past projects without automation. The system also has the capability to be monitored from remote locations. Both the destructive and non-destructive tests showed that the quality of coil end welds was of a higher level in all respects.

***Index Terms* - API, HSAW, X65M, SOP, LASER, HMI, SAW**

I. Introduction

HSAW line pipes are widely used in transportation of oil, gas, and other fluids such as iron ore slurry.HSAW pipes are manufactured from HR steel coils as per API 5L and other pipeline specifications toachieve the required mechanical properties and dimensions as per the service condition and application. The manufacturing process (Figure 1) involves forming, welding, finishing and testing. To ensure thedesired quality of pipes, several non-destructive and destructive tests are performed. Dimensions areverified based on a quality assurance plan before releasing a lot of pipes for coating or dispatch.

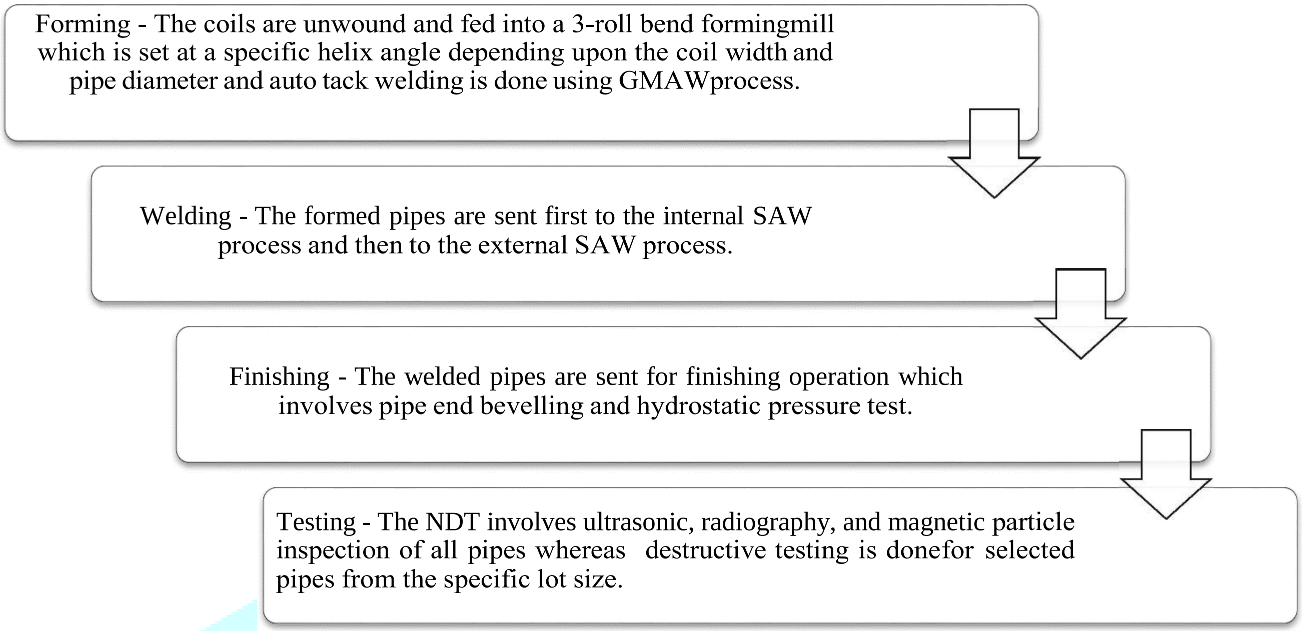


Fig. 1 Process flow for manufacturing of HSAW linepipes

ACCEPTANCE CRITERIA [1]

As per clause **8.10 Coil/Plate End Welds** of API Spec 5L, following criteria are applicable:

8.10.1 Coil/plate end welds shall not be present in finished longitudinal seam pipe.

8.10.2 For finished helical seam pipe, junctions of coil/plate end welds, and helical seam welds shall be at least 300 mm (12.0 in.) from the pipe ends.

8.10.3 If agreed, coil/plate end welds in helical seam pipe may be present at the pipe ends, provided that there is a circumferential separation of at least 150 mm (6.0 in.) between the coil/plate end weld and the helical seam at the applicable pipe ends.

8.10.4 Coil/plate end welds in finished helical seam pipe shall have been:

a) made by submerged arc welding or a combination of submerged-arc welding and GMAW

b) Inspected to the same acceptance criteria as specified for the helical seam weld.

THE SETUP

Welspun has been supplying linepipes having coil joints for the water sector for the past many years; hence, we already had the capabilities to manufacture the same. The Spiral-02 plant has three dedicated machines for producing the best quality coil joint; Strip Cross Cutting Machine (SCCM), Fly Cross Seam Welding machine, and OD Cross Seam Welding machine.

The **Strip Cross Cutting Machine** (Figure 2 and 3) is used to trim the front and tail ends of the coil and prepare a single bevel using a milling cutter. This machine can be operated in automatic, semi- automatic, and manual modes as per requirement. This machine syncs with the forming mill’s speed and clamps the coil ends so that it can trim the ends and prepare the bevel in online mode without stoppingthe forming mill with increased productivity.

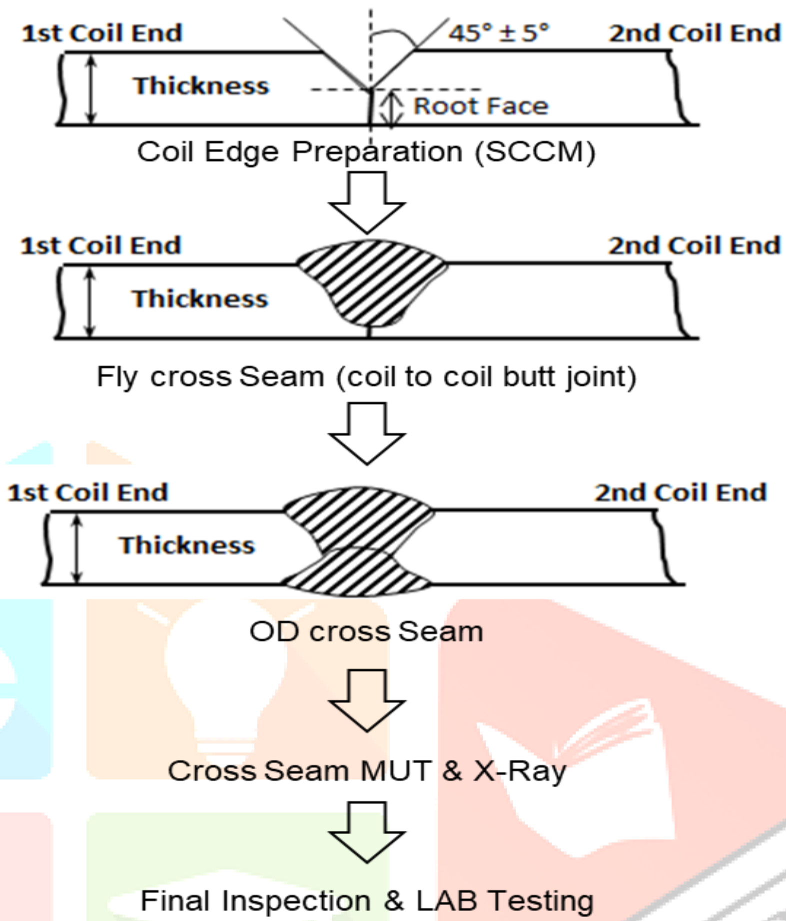
Fig. 2 Strip cross cutting machine

Fig. 3 Control panel of SCCM

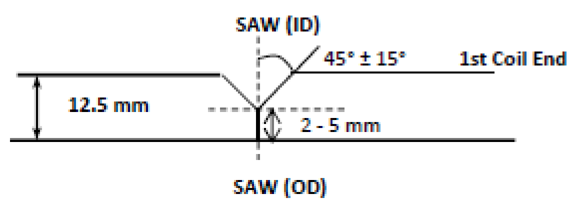
The **Fly Cross Seam Welding machine** (Figure 4) is used to weld the coil ends together. The tail end of the firstcoil and the front end of the second coil are abutted together using hydraulically operated clamps resulting in a single V groove weld geometry. The tandem SAW process used for welding the edges is controlled semi- automatically (machine welding) by the operator. This machine also syncs with the speed of the forming mill so that the welding operation is done in online mode without stopping the forming mill.

Fig. 4 Fly Cross seam welding machine

Preparation of **T- Joint Bevel Geometry**



T - Joint Bevel Geometry for 12.5 mm WT pipe



The **OD Cross Seam Welding machine** (Figure 5 and 6) is used to weld the coil joint from the external surfaceafter it has got formed into a pipe from a coil. This machine uses a single electrode configuration for welding atlow traveling speeds and high heat inputs. This machine has a well-assembled setup of rotators and lead-screwsfor linear movement. The machine is controlled and operated by manual interventions by the operator for minoradjustments of rotational speed for proper syncing and seam tracking.

Fig. 5 OD cross seam welding machine

Fig. 6 Welding head setup

ANALYSIS

Since SCCM is already operable in automatic mode for all thicknesses and widths of coils, there was no scope of improvisation for it. Based on the past orders executed for the water sectors following observations were found out (Table 1):

Table 1. Observations on Fly Cross seam and OD Cross seam welding Operations

Sr. No.	Observation	Description
01	Seam-out while welding	Weld metal not filling the groove properly and moving out of it
02	Intermittent lack-of-penetration	Insufficient penetration due to misalignment between welding head and center of the groove while operation
03	Lack of sidewall fusion	Rarely found lack of fusion due to misalignment
04	Zigzag welding	Welding in zigzag fashion due to manual control of the welding heads by the operator
05	Bead-off	Mismatch in internal and external weld beads due to poor tracking of grove while welding especially from the external side by the operator

Additionally, trials were carried out using the present setup targeting compliance with API 5L X70MPSL2 grade pipes of size 760 mm OD x 12.7 mm WT and the following results were obtained (Figure7):

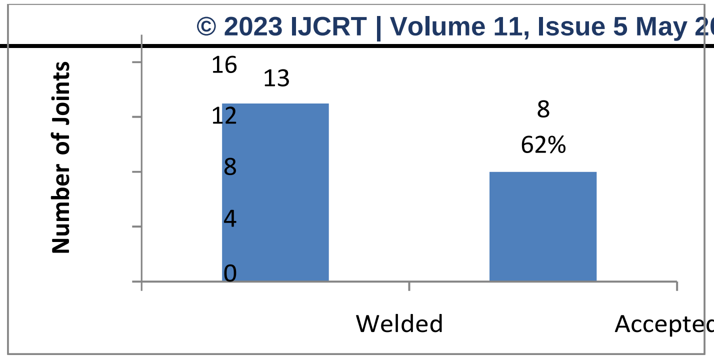


Fig. 7 Comparison between coil joints welded and accepted before modifications

After analyzing the type of defects and their probable causes, it is concluded that the majority of these defects are due to the control and manipulation of welding heads. During semi-automatic or machine welding, the operator is manipulating and regulating the movement of the welding heads using mechanical arrangements. Due to lack of repeatability in manual operation, the above-stated defects that appeared with no regular frequency whatsoever may be the size of coils and pipes.

Therefore, it may be deduced from the above discussion that if the manual control of the operation is replaced with automated control consisting of laser seam tracking aided by the camera to facilitate the operator for remote visual control, consistent results are achievable.

MODIFICATIONS

Fly Cross Seam Welding Machine

For welding head movement in a straight line following the groove, laser seam tracking was deployed in the setup (Figure 8). A laser sensor identifies the groove extremities and shows the exact groove profile scanned on the HMI. The welding head is set in line with the laser sensor so that both remain at the center of the groove while welding. The HMI shows the width of the ideal grove and the scanned profile of the actual groove, so in case if the welding head moves out of the groove, the operator can easily seethe anomaly and take immediate corrective actions.

A high definition camera (Figure 9) was also installed at the carriage with its display at the operator's desk to assist optimum welding head movement and flux supply.

Fig. 8 Joint setup and welding head

Fig. 9 Control panel with camera setup

OD Cross Seam Welding Machine

Since this operation involves welding in the inclined direction from the longitudinal axis of the pipewhich means 2-dimensional motions is required to achieve welding in the desired direction (Figure 10).To achieve this, the operation was divided into two separate systems; longitudinal movement was achieved using lead screw drive, and the transverse movement, achieved using the rotation of the pipe. The rotators were provided with drive-controlled motors for smooth operation. The linear screw actuator for longitudinal motion is equipped with a servo motor for precise control.

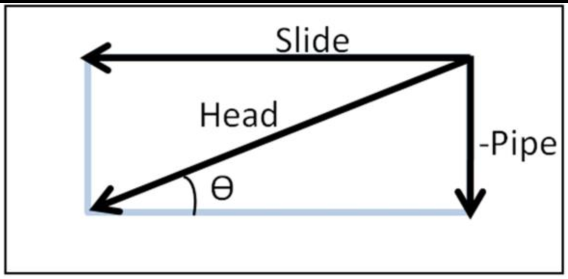


Fig. 10 Synchronisation of linear and rotational speeds (Θ - Helix angle)

To better synchronize the linear and rotational movements, laser seam tracking (Figure 11) using spot sensor and PLC controller are deployed which takes coil width, pipe diameter and desired welding speedas the input to automatically calculate the required speeds (Figure 12). The requirement of the operatorto manipulate speed control knobs have been entirely eliminated which was the major reason for occurrences of the above-stated defects.

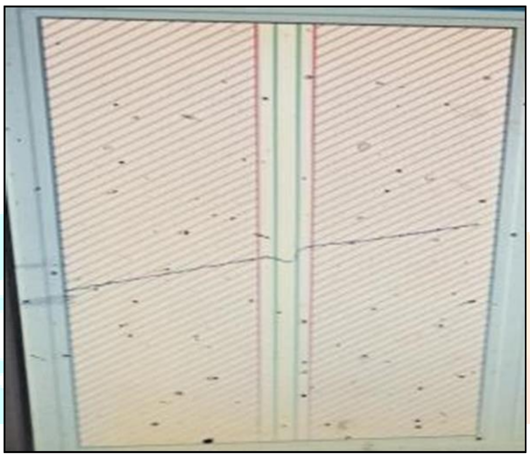


Fig. 11 Laser seam tracking display

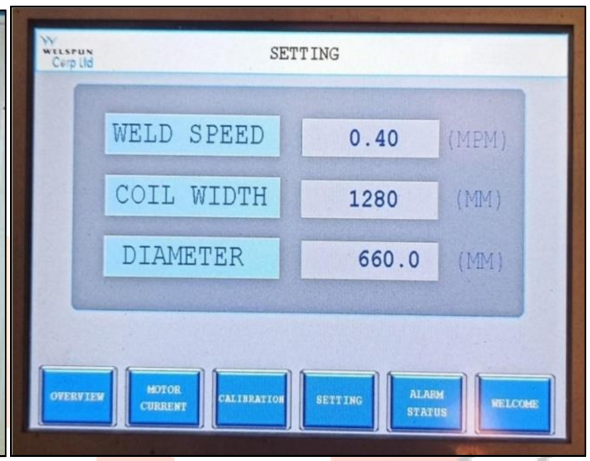


Fig. 12 Inputs to the system

THE TRIALS

The upgraded system was put into trial phase to weld coil joint pipes and the results were obtained asfollows (Figure 13):

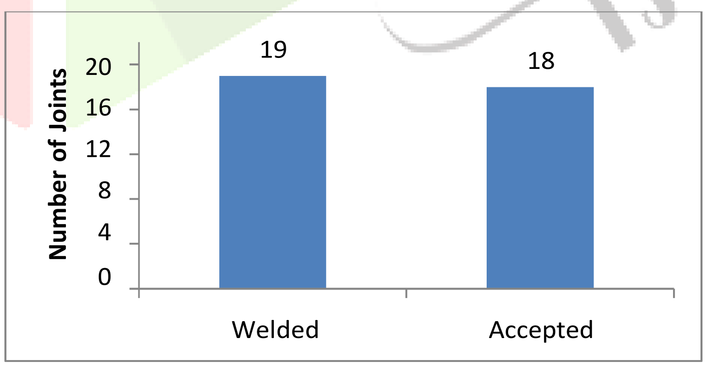


Fig. 13 Comparison between coil joints welded and accepted after modifications

THE EXECUTION

Spiral-02, Anjar plant of Welspun received an order of HSAW linepipes conforming to API 5L X65M PSL2 steel grade pipes of size 660 mm outside diameter with 18-meter length and various wall thicknesses. After analyzing the project requirements, few more modifications were done apart from automation such as making a groove at the junction in the direction of the helical seam using grinding before external SAW to reduce chances of lack of penetration and fusion.

Destructive Testing

As per the requirements of the specification tests such as tensile, guided bend, impact, and macro- hardness were done satisfactorily for each test unit of 50 coil joint pipes. The required minimum mechanical properties were satisfactorily achieved after modified setups.

Non Destructive Testing

As per the requirements of the specification tests such as ultrasonic of 100% length of coil joint and radiography of both the junctions (between coil joint weld and helical seam weld) were done for all thecoil joints. Additionally, as per internal quality objectives, 100% real-time radiography was also donefor all the coil joints. The overall results that were achieved at the end of the project are being presentedas follows (Figure 14):

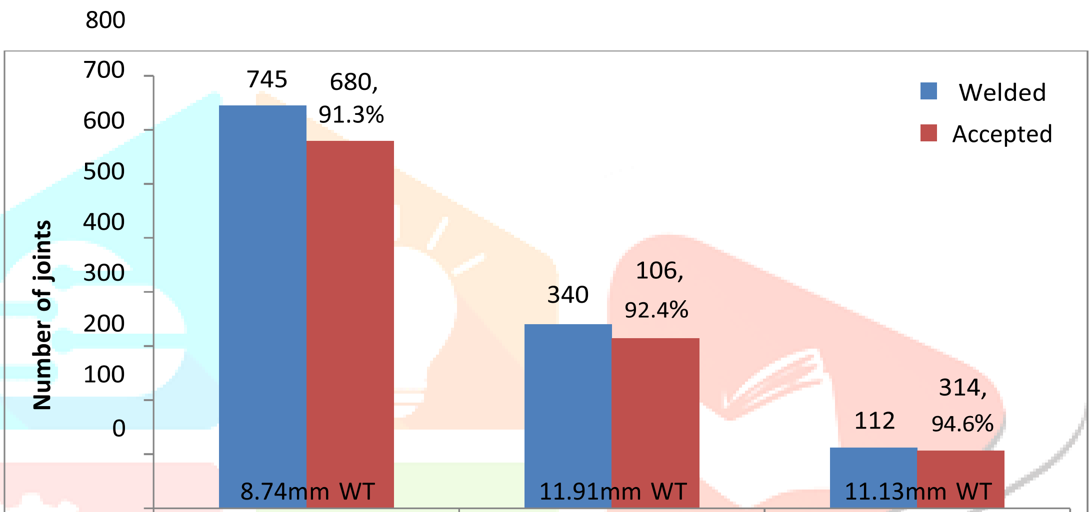


Fig. 14 Comparison between coil joints welded and accepted

DISCUSSION

1. The fly cross-seam machine is capable of remote visual control.
2. The OD cross-seam welding machine has precise control over the movement of welding heads eliminating manual interventions.
3. The major defects like zigzag welding, LOP, seam-out, and bead-off have been significantly reduced with the automation.
4. The objective to achieve automated operation of fly cross-seam and OD cross-seam welding has been realized and demonstrated in real-time for linepipe manufacturing conforming to API 5L X65 M PSL2.
5. It has also been established that there is no impact of automation on the mechanical properties ofthe end product.
6. More control and steady performance has been achieved by automating the manual processeswith significant repeatability and reproducibility.

WAY FORWARD

1. To further enhance system capabilities in order to improve welding quality and achieve betterresults.
2. Implementation of advanced automation techniques to enable the allied operations such as pipehandling to be done automatically.

ABBREVIATIONS

API American Petroleum Institute *HSAW* Helical Submerged Arc Welded *SOP* Standard Operating Procedure

LASER Light Amplification by Stimulated Emission of Radiation

HMI Human Machine Interface

SAW Submerged Arc Welding *SCCM* Strip Cross Cutting Machine *OD* Outside Diameter

PLC Programmable Logic Controller

PSL Product Specification Level

HR Hot Rolled

WT Wall Thickness

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REFERENCES

[1] API Specification 5L, 46th Edition, April 2018 and Errata 1 dated May 2018