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Helical Submerged Arc Welded (HSAW) Pipe Manufacturing & Equipment Configuration

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1. Introduction

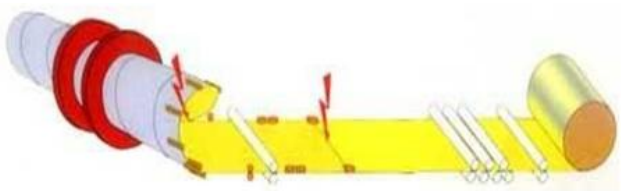
In the early seventies, the sharp rise in energy consumption, particularly that of Natural Gas, has influenced 'The Development of Transmission of Oil and Gas through Pipelines' and this development has necessitated the use of Large Dia Spiral Weld Pipes with High Strength Pipe Materials of Improved Weld ability and Toughness.

Spiral Weld Pipes have been and are being extensively used worldwide. For instance, in Canada, Middle East, Germany, Turkey and the South East Asian Countries, these pipes are being used for thousands of kilometers of high pressure gas transmission pipelines of dia up to 48" and grade X80, successfully; hence their quality is indisputable. The quality assurance factors that merit special attention are no different in Spiral Weld Pipes than that of Longitudinal Pipes.

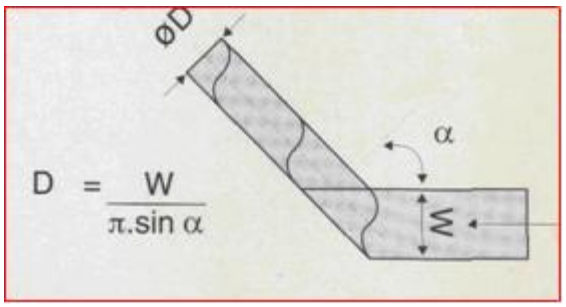
International Oil and Gas Corporation in the Far East had initiated a reappraisal of Spiral Weld Pipes (HSAW) technology and as a consequence of the technical evaluation and appraisal, HSAW Line Pipes have gained acceptance for excellent applications based on an independent assessment of the manufacturer's technical capabilities**.**

Spiral Pipemill Plant

2. Production Methodology



- Coil input clearance
- Geometry monitoring
- Welding procedure qualification tests
- Visual inspection
- Chemical, mechanical and metallurgical testing
- Hydrostatic pressure test
- Ultrasonic test (Pipe end, Body and Seam)
- X-ray test and Fluoroscopy
- Final dimensional and acceptance



The Making of Helical Spiral Welded Pipes

Nowadays many new developments have undertaken in Line pipe manufacturing with new technologies and equipments being introduced but in this heading we shall discuss the basic process of Line pipe (spiral) manufacturing. First, a coil of hot rolled wide strip is mounted into the straightening machine. The strip is positioned to the correct helix angle. Smaller pipes require greater angles than larger pipes manufactured from the same width coil. Before passing the strip through, the leading and trailing ends of the incoming and already inserted coil strip respectively are welded

together. Shears/Plasma cutting trim the edges that are then machined simultaneously on both sides by an edge miller. In the forming section, a 3-roller bending device along with a Jacuator (powered screw jack) bend the strip helically into a cylindrical pipe. Then the longitudinal edges of the incoming strip are brought into low point contact and the resulting butt joint is continuously welded using the Submerged Arc Welding process, first internally and then externally after a half-turn of the pipe. Finally, it is cut off to the desired length with a plasma torch. The machine on which above process is carried out is referred as "Spiral Pipe Mill" and most of the processes are automatic or semi-automatic. It is a continuous process.

Spiral Pipemill-Basic Component & Its Usage

The mill is a single integrated unit comprised of four main components: Entry Line Section/feed table, formation table, ID &OD welding station with seam tracking arrangement and Exit Bench/pay-off table. Other than this there is Coil Preparation Stand to Open the front end of coil.

a) Coil Preparation Stand (CPS)

The Coil is lifted by an EOT crane and placed on the Coil Preparation Stand. At CPS the Coil Front End is opened by using Hydraulic pressure.

Coil Preparation Stand (CPS) Comprises of:

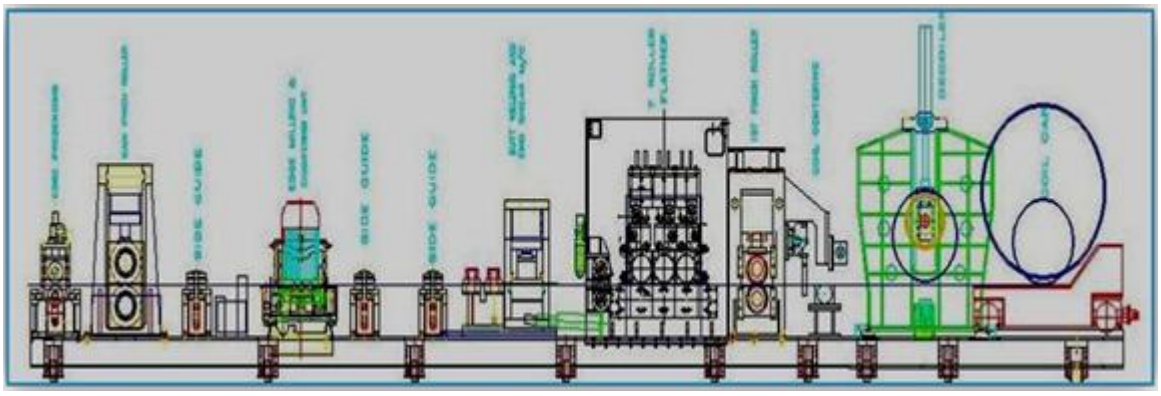
- Coil Rotators
- Coil Clamping Device
- Strip Opening Wedges with hydraulic cylinders
- Clamping Frame
- Plasma Cutting Machine (Optional)
- Hydraulic power pack

Coil Preparation Stand

b) Feed-in or Entry Line Section:

The feed table unrolls coil in the same direction and prepares edge levels and provides for the helix of the pipe by the angle at which the coil enters the forming table. Many parts are assembled on a Heavy H-beam section which is mounted on rollers so that the entire feed table can be given a required helix angle through a hydraulic cylinder. General design of Feed table include:

- Entry Line Beam – 1 No.
- Coil Car – 1 No
- Decoiler – 1 No.
- Strip Centering Device- 1 No.
- Pinch roll – 1 No
- Flattener- 1 No.
- Strip Clamping, Shearing/Plasma cutting & Butt welding device - 1 No.
- Side Guide- 5 No. (may change as per length of Entryl line section)
- Edge Milling device – 1 No.
- Main Pinch roll assembly- 1 No.
- Edge prebending device – 1No.
- Half side guide – 1 No.



Entry Line Section

- **Coil Car:** Coil mostly of 28 to 30 metric tons is loaded on the coil car by the help of EOT.
- **Decoiler Unit:-** The Coil is lifted on the Decoiler Unit with the Hydraulic cylinders. During Operation, Coil gets unwound continuously through the Decoiler station and is centered utilizing the Coil centering unit.
- **First Pinch Roll or Auxiliary drive** is used to put in the front end of coil into the mill. Drive is given through the geared motor and utilizing the hydraulic pressure.
- **Flattener** is used to straighten the Coil for proper butt joint using hydraulic pressure. It is a 7 roll Flattener.
- **Edge Cutting Station**: - It allows cutting the end of the strip using shearing system or a plasma cutting system.
- **Skelp Joining Station**: - It allows joining 2 coil ends by help of submerged arc welding.
- **Milling Station**: - As the coil is feed for the mill the milling cutter prepares the accurate width of strip and both the strip edges. The use of milling and chamfering

cutter depends on strip thickness and contract requirement.

- **Main Pinch Roll**:-The coil is driven through to main pinch rollers. First Pinch Rolls shall be stopped and raised. Main pinch rolls shall be lowered to engage strip. Main pinch shall then be activated to drive strip through to formation table using combination geared motor and hydraulic pressure.
- **Edge Pre-Bending**: - Then the coil passes over Pre-bending rolls at both the edges to introduce some amount of pre bending to avoid peaking at the weld joint at the time of welding.

Feed In Section (Entry Line)

c) Forming Station

It includes:

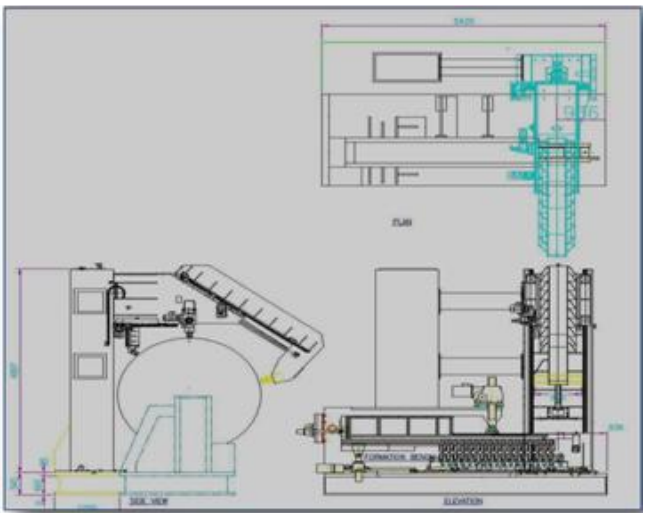
- Forming table base – 1 No.
- Lower forming bench Rolls (Craddles) – 1 No.
- Upper forming bench Rolls (Boom) – 1No.
- Pipe caging unit – 1 No. (Optional)
- Half side guide – 1 No.
- SAW welding equipment- 1 Set

Formation Section

Forming station is a table wherein the 3-roll bending system is fitted. Generally it comprises of 2 rows of rollers on a table which are called front and rear cradles having about 17 rollers each with diameters of 180mm and from the top is a boom having the same rollers 17 in nos and the boom is connected to a jacuator (screw jack) so that required force can be applied in the three roll bending process.

Strip is feed into formation table slowly until it is positioned below formation boom. Strip is stopped and boom is positioned and tightened down securely using a Screw jack (Jacuator) 500mm strip length is feed through three rows for motion roller and pressed continuously till the desired curvature of pipe is obtained. As the strip is being formed into a pipe, the operator continuously checks the initial form by means of the steel template until the pipe travels the full circumference. Once the pipe has been formed and found to be acceptable in size, the formed section of pipe shall be hand tacked at bottom ensuring that the required pipe circumference is attained using a measurement tape and subsequent conversion into the actual diameter.

The formed pipe is hand tacked through the first and second gate frame assembly by MMA process until is approximate 4-6 meters in length. This allows the pipe to be controlled in the longitudinal plane by two sets of gate roller assemblies. The invert roller shall be positioned under the internal welding position at correct height and angle of strip feed at bottom center of formed pipe.



Formation Section

Welding Station

The welding station is basically a part of the formation section and is mounted on a column for the outside welding and on the boom for inside welding. For normal Spiral weld process the inside welding is first done as the pipes rolls spirally and then after 1.5 pitch the outside welding is done. The internal and external welding heads shall be positioned on weld seams along with wire feeder assembly and flux

feeding assembly once Pipe is crossed the gate section.

Once the formation is over, automatic welding starts at internal welding point followed by external welding at the same point after rotation of 15 pitch from the outside resulting the penetration of weld seams by around 10% of wall thickness of the strip.

Automatic Joint Tracking System (Laser Vision Tracking) is being used to control the misalignment (overlapping) of inside and outside weld seams. The weld gap is controlled using the gap control cylinder on the run off table.

Inside and outside welding are carried with welding parameters mainly current, voltage and welding speed established during mill qualification test/ as per approved Procedures.

Welding system Configuration

Welding system can be of single wire, two wire or three wire. Mostly 2 wire system is followed for internal and external welding of pipes. It will be as follows:

Inside Welding (2 Wire): DC-1500 x 1 No + AC-1200 x 1 No Outside Welding(2 Wire): DC-1500 x 1 No + AC-1200 x 1 No

Instead of DC-1500 we can also use DC-1000-2 Nos for higher heat input.

Flux Recovery System

The Flux used for shielding in ID and OD welding can be recovered by vacuum suction of the extra flux during the continuous welding process. It is one of the major components of a spiral pipe mill wherein the sucked flux passes through a magnetic roller belt to remove debris and through the sieving unit and in turn the flux gets collected in the storage tanks for further use with fresh flux. This is a continuous cycle.

Flux recovery system

Exit Bench/Run off Section

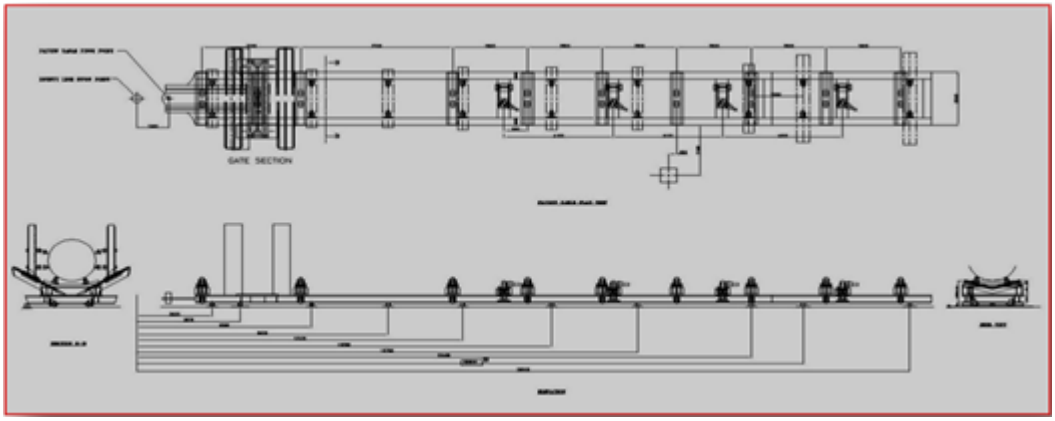
It Includes:

- Run off section Base frame- 1 No.
- Gate section- 2 Nos.
- Plasma cutting unit – 1 Set
- Pipe Support roller frames – 1 Set
- Pipe feed in and Kick out units – 2 Nos.
- Gap Control cylinder – 1 No.
- Hydraulic powerpack- 1 No.

Exit Bench

The Exit Bench is basically the part of pipemill wherein the formed and autoweld pipes exit the production process after being dully cut through plasma cutting. The welded pipes travels spirally through the gate sections (equipment which touches is the pipe from outside through 4 rollers) and then slides through the support rollers on the support roller frames. On the exit bench are mounted 2 rotation rollers which come into action when the pipe is cut. These rollers pull the pipes on the exit bench and finally also kick out the pipes through hydraulic jack. A gap control cylinder is mounted at the bottom and end of the exit bench frame which is used by the operator to maintain the weld gap.

Exit Bench



Exit Bench

Saw Welding

The optimum performances of welded vessels and structures in service have led to the full exploitation of automatic welding processes. Submerged arc welding has been playing a prominent role in this endeavor and it finds application in a variety of components from pressure vessels, structures machine building etc., to hard facing of components exposed to wear. In submerged arc welding process the heat for welding is supplied by an arc, developed between a consumable electrode and the work piece under a blanket of granulated flux.

Principle of Operation

Submerged Arc Welding (SAW) is a Covered Arc Welding Process.

The arc is located below a layer of granular flux and is thus not visible to the eye. The welding electrode, which is fed continuously to the welding point on the work piece burns in a cavity filled with gases and vapors. The cavern is surrounded by liquid slag. The welding flux and the molten slag formed as a result of the melting and vaporization of this flux protect the molten baths of the melting drips of the electrode and work piece within the welding cavern against the harmful effects of the surrounding atmosphere. The effect corresponds approximately to that of the inert- gas welding.

However, the tasks of the welding flux are not only to protect the liquid and solidifying material from the air, but also to shape the welding bead, to prevent rapid cooling of the welding deposit, to compensate for losses due to burning by feeding alloying elements to the welding deposit and to increase the stability of the arc by improving the conductivity of the arc section. After passing through the arc, the liquid slag solidifies and can then be removed from the welding bead as a glass-like, solid substance.

The submerged arc welding process can be carried out using either direct current (DC) or alternating current (AC). In this respect, it is also possible to use power sources with a falling static characteristic or with a horizontal characteristic. In the case of welding with DC, the electrode may be located at the plus pole or at the minus pole.

In this automatic process (i.e. maintaining the constant length of the arc), the welding sequence is controlled by either the Variable Voltage (VV) control system or by the Constant Voltage (CV) control system, depending on the characteristic of the power source.

Advantages of the Process

- **No Radiation Burdens**
  There are no radiation burdens for the surroundings. It is therefore possible to carry out the welding process without any screening.
- **No Cooling Required**
  Since the arc is covered, no heat is radiated either. The device cannot become heated up. It is thus not necessary to cool the device and is possible to move the device as close to the work piece as desired and, in some circumstances, to continue the welding operation for weeks without any interruptions.
- **High Welding-Current Values**
  Since the welding current can be fed to the direct vicinity of the arc, it is possible to use high current densities. With small-diameter electrode wires (2 to 3 mm), values of 100-150 A/mm^2 are by no means unusual. This is fundamentally important for the uniformity of the material transfer in the arc. However, in general, the submerged arc welding process can operate at very high welding currents (up to 2000 A with one wire and up to 3000 A and above with multiple wires) and correspondingly high welding capacities are achieved.
- **Screening against the Atmosphere**
  The submerged arc slag performs important tasks. It ensures complete screening of the molten welding mass against the atmosphere and provides the possibility of utilizing the metallurgical influencing of the molten welding mass by means of favorable slag reactions so that high quality demands can be met.
- **Good Seam Shaping**
  The viscous welding slag is a fluxing agent and a current and heat conductor and, at the same time, serves to shape the seam. Therefore, submerged arc welded seams are normally free from transition notches and, with regard to their external shape and their surface condition, are superior to other molten welding seams.
- **High Quality Weld**
  In addition, there is a high degree of safety against inclusions and fusion defects. Good quality seams are achieved, even in the case of difficult multi-layer welding processes.
- **High Arc Stability**
  The arc is stabilized by those components of the slag

which vaporize in it. This has an advantageous effect on the welding sequence, material transfer and seam shaping and allows a high welding capacity at high welding speeds.

The main uses of Spiral Welded Pipe are:

1) High Pressure Gas Lines
2) High Pressure Oil Pipelines (both land and submerged)
3) Water Pipes (transmission and trunk mains)
4) Piling
5) Irrigation

Additionally, Spiral Weld Pipe is used for the transport of chemicals, slurry etc. Spiral pipe also has applications in other materials, for example Alumimium and also Stainless Steel.

Many studies by independent experts have proved that far from being inferior to other methods, Spiral Welded Pipe is in fact SUPERIOR Indeed, identical bursting tests have been carried out on Seamless, Longitudinal and Spiral Welded Pipe and the results have shown Spiral Welded Pipe to be the strongest.

Advantages

One of the major advantages of Spiral Welded Pipe is the simplicity of manufacture. Hot Rolled Coil (strip) is fed by drive mechanism through a 3-roll forming system at a predetermined angle to produce a given diameter of pipe. This pipe is automatically welded by submerged arc process, both internally and externally.

Spiral Welded Pipe has a surety over ERW and U- and O-ing methods, particularly in terms of flexibility and economy. Firstly, from small to large diameter pipes can be produced on one machine, whereas other systems would demand two or more machines. Economically, a Spiral Pipe Mill gives the following advantages:

1) Holding in stock only a limited number of strip widths with the possibility to produce a complete range of diameters merely by changing the forming angle. Note that U- and O-ing requires a different and exact strip width for every diameter.
2) Capability for production of large diameter pipes simply and without the need for two or three weld seams as in the case of Longitudinally Welded Pipe.
3) Finished pipes are perfectly formed (round) without the need for further mechanical process (expander) as required in the U- and O-ing system.
4) Pipes can be produced in varying lengths limited only by the transportation, whereas most of the U- and O-ing systems are limited to 12 meters by the tooling. Note that in the Oil and Gas industry, 18 meters is a common length requirement in order to save on field jointing.
5) Low cost investment: The conventional steel, due to the high carbon content, indicates a high raise in hardness in the heat-affected zone (HAZ). Significant smaller hardness deviations occur in X60/X70 perlite reduced steel grades. The Impact energy in the HAZ was investigated within the same procedure.

We find higher impact energy and restricted hardness levels with smaller heat input, provided the carbon content is low.

Points of consideration for spiral pipemill equipments

a) The spiral pipemill plant should have a minimum weight of 200 Metric Tons and 300 Metric tons will be much better mill (required for mill stability).
b) Steel of St 52.3 as per DIN standards is the best quality steel for pipemill.
c) Coil preparation stand can do away with the plasma cutting system. A separate Coil preparation stand reduce the time for coil opening if done on pipemill.
d) The coil car should be fitted with PA-6 strip to prevent wear and tear from the Hot rolled coil resting on it. Usage of Angular contact bearings in the coil car for linear drive shows good performance.
e) The decoiler unit frame should be mounted with 20mm M.S plates on the coil mounting mandrel so that the Hot rolled coil sides don't damage the main frame. These can be replaced when required.
f) Coil centering with feedback control through proportional valve should be used as the coil gets automatically centered at the back during operation resulting in less manpower and better controls.
g) The geared motor if used with AC drive for Auxiliary drive and main pinch roller should have planetary gearboxes as these are not bulky and give good torque.
h) Usage of hydraulic flow dividers at the decoiler, auxiliary drive and main pinch rollers is desired for proper controls.
i) The Flattener should be a 7 roll flattener with support rollers at top and bottom. It should be a combination of hydraulic cylinders and jacuators (screw jack with geared drive). The hardening of the rollers is critical as during high grade steel (X-70 & X-80) these rollers can break. Diameter of flattener rollers if 240mm then it gives good straightening in high strength coils when the total capacity (force) is 700 metric tons from the flattener.
j) Good amount of side guides give better control of coil shifting. Atleast 3 are desired in the entry line length of 19 metres. Side guides should be mounted before and after milling unit.
k) Milling unit plays an important role in pipe production hence it should be of good performance. A cutter of minimum diameter 500mm is desired with atleast 30 tools. Slat band chip conveyors should be used.
l) Main drive rollers should have proper case hardening for better life and minimum desired diameter is of 450mm.
m) Formation rollers are one of the critical items of the formation bench which should be of proper material like D2 or 100CrMo7 with HRC of 55 to 60. Rollers should have taper roller bearings with minimum diameter of 180mm. Width should be 60mm minimum, little more the better.
n) Flux recovery system with online heating and vibro sieve unit is desired. The process should be automatic through PLC programming
o) For high heat input DC-1000-2 nos can be used.
p) The hydraulic system for the milling, main drive unit and the exit bench should have the accumulator circuit. For this Vane pumps can be used.
q) Regular usage of filtration unit for hydraulic oil filtration is desired.

Spiral Pipe manufacturing is an interesting process of pipe formation and there are many aspects which can be considered for Spiral pipe plant to get the good quality product.

Spiral Pipes

References

[1] Details & Information's in this article are based on 24 years of experience of the author in Spiral Pipe Manufacturing and Anti-corrosion coating of Line pipes.