Latest Trends in Fabrication of High Thickness Reactors

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1. Introduction:

Larsen & Toubro Limited is in the business of manufacturing Heavy-walled Reactors, Super Heavy Tubular Reactors, High pressure exchangers and other critical equipment weighing up to 2000MT for Refinery, Petrochemical, Fertilizer, Nuclear, Marine and other such applications. Continuous technological developments in these industries demand more severe operating temperatures and pressure conditions for Reactors, Vessels and Heat Exchangers. To cope up with this demand, new generation materials are being developed worldwide, design aspects are becoming increasingly complex and the quality requirements are becoming extremely stringent. In addition, the delivery time is being squeezed very hard to minimize the project cost. All these developments continually pose new challenges to fabricators worldwide connected with Heavy Engineering industries. This paper discusses various manufacturing technology developed at Larsen & Toubro Limited to overcome these challenges.

2. Developments in Manufacturing Technology:

Heavy equipment manufacturers are continuously facing challenges to meet three most important project requirements—Quality, Cost & Delivery. Mechanization of manufacturing technologies helps in achieving all the three benefits together – the best of the quality as a result of lesser human intervention, faster delivery due to reduced cycle time as well as better productivity and finally lowest cost of production due to lesser rework & faster production.

There have been continuous developments in the field of manufacturing technology at Larsen & Toubro Limited to remain competitive among heavy engineering companies in the world. Some of these developments are briefly discussed below:

2.1 Narrow Gap-SAW for Longitudinal and Circumferential Seam welding of Shell / Channel

- NG-SAW capability to weld joints (with 1° included angle) up to 475mm thick has been developed in-house using bi-axial seam tracker. NG-SAW of Longitudinal seams is an unconventional technique and requires meticulous fabrication procedures.
- Both Single wire (4mm & 5mm diameter) as well as DC-AC Tandem SAW technique is being used extensively for welding of these joints.

2.2 Hemispherical Head Welding by NG-SAW

- Petal # Petal welds as well as Crown # Petal welds of hemispherical heads are being welded by NG-SAW.
- Specially developed non-metallic backing ensures single side welding thereby avoiding any back chipping from inside surface.
The head is mounted on a heavy-duty manipulator and welding is carried out from outside sequentially on various petals thereby controlling distortion of heads.

2.3 **'Continuous' Wide Strip Electro Slag Welding for Shell & Head Overlay:**
- Shell courses in reactor / exchanger with highly corrosive service fluid call for complete weld overlay on the inside surface of them.
- Developed wide strip ESW (120*0.5mm strip) for the first time in India – currents up to 2400Amp and deposition rate up to 42Kg/ arc-hr.
- Welding is carried out by either Single layer (Chemistry of SS 308L or SS347 achieved in one layer weld overlay by using modified strip chemistry) or Two-layer (Barrier layer: SS309L/309Cb & Subsequent layer of required chemistry like SS 308L / SS347) or depending upon customer requirements. Single layer ESW technology using 120*0.5mm strip has been developed for the first time in India.
- Welding is carried out continuously on shell cans with 'step over' technique till a strip spool (typically 250Kg) gets fully consumed, thereby raising the daily productivity and reducing stoppage time. This is achieved by fine tuning synchronized movement of welding head (longitudinally) and circular rotation of cylindrical shell courses.
- Weld overlay on heads is carried out by 90*0.5mm strip.

2.4 **Mechanized Nozzle # Shell / Head Welding by Orbital SAW nozzle welder:**
- Special Orbital SAW nozzle welders have been developed in-house for welding of nozzles. All Nozzles with diameter >200mm are welded by SAW for thick reactors / exchangers.
- New SAW nozzle welder for welding of nozzles with sagita (varying plane generated when a big diameter nozzle sits on a vessel of similar or bigger diameter) more than 30mm have been developed in-house and successfully implementation for the first time in India (probably in the world too).
- This results in higher weld deposition and consistent quality.

2.5 **Shape Welding Technology for Support Ring Build-up**
- Shape welding technology enables creation of specially configured shapes by weld build-up. The technology restricts the liquid weld metal flow progressively and achieves desired shape. Since the weld metal volumes are very high (typically 500-1200Kg), automation and use of high productivity process like Tandem SAW using higher diameter wire (5mm) is necessary.
- Support rings of rectangular cross section are built-up on inside surface of shells for Process Plant reactors using this technology. These support rings are generally required in each reactor to hold heavy load of catalysts and their support trays.
- Special 'shape welding' reduces the weld deposition by 30% coupled with substantial reduction in man and machine hours. This was achieved by elimination of taper weld deposit on both sides of the nubs. These tapers are required to be machined / ground off while welding using conventional method.

2.6 **Tube Sheet Manufacturing for High Pressure Exchangers / Heavy walled Tubular Reactors:**

2.6.1 **Gas cutting of heavy thickness**
Parameters and technique are developed indigenously for oxy-fuel gas cutting of up to 450mm thick Tube sheet forging with machining like finish.

2.6.2  Welding of Longitudinal joints in Tube sheet
- Super heavy Tube sheets of up to 444mm thick and 9200 mm OD have been successfully manufactured. The weight was approx. 125 MT for each tube sheet.
- The main challenges in welding of longitudinal joints in tube sheet are as follows:
  - Avoid Restraint Cracking
  - Control of Distortion
  - Defect free weld in deep groove
  - Handling and turning of segments prior to and during welding
- To minimize the volume of weld metal, narrow gap weld preparation was selected. Heavy wall thickness of tube sheet imposes tremendous restraints. Thermal shock on the joint and unfavorable thermal gradient along the joint as well as across the joint further aggravates the chances of cracking in such restrained joint. Zone-wise temperature as well as temperature differential was monitored and controlled throughout the welding operation. Continuous monitoring of flatness and sequential welding controlled the distortion during welding.
- After completion of welding, joints were tested by UT and all the joints were cleared without any defect. The distortion was found well within the acceptable limit of 10 mm.

2.6.3  Weld Overlay on Tube Sheets
- Tube sheets are required to be weld overlaid before drilling. The overlay material varies from CS to SS to Inconel depending upon Process Licensor.
- Typically one to three layers are required to be put depending upon requirement.
- The main challenges involved in weld overlay of Tube sheet is to control distortion (bow effect) and maintain the flatness
- Since the amount of weld metal deposition is quite high, high deposition welding processes (up to 33kg/ Arc-hr) i.e. welding with 90mm / 60mm wide strip is applied. ESW / SAW (Electro Slag or Submerged Arc Strip welding) process is selected for weld overlay on Tube sheets. Single layer ESW process for Inconel weld overlay with 5mm minimum height has been developed & implemented.
- Flatness of tube sheet after weld overlay is achieved within +/- 5 mm up to 10m diameter.

2.6.4  Drilling of Tube holes
- Typically there are several thousands of holes high pressure exchangers / tubular reactors.
- Drilling of such a huge number of holes for so large diameter (up to 63mm) tubes is done on CNC horizontal boring machine. Deep hole drilling is performed in two operations to achieve the required size and surface finish. Specially designed tooling with slenderness ratio more than 7 is used. Drilling parameters are established after extensive trials. To improve the productivity, multi spindle drilling (three spindles) operation is performed.

2.6.5  Tube # Tube sheet Welding:
- Tubular reactors / High pressure exchangers call for Tube # Tube sheet welding of wide range of materials – starting from simple C-Mn steel, Stainless Steel to exotic Ni-alloys, Duplex / Super Duplex SS and so on.
- Many of these applications demand stringent quality requirements for Tube # Tube sheet joints including Radiography and Ultrasonic testing.
Both automatic & manual welding techniques are used to carry out these joints depending upon the requirement.

Procedures have been established and implemented for different types of materials combinations meeting all requirements of Code of construction and Customer specifications.

Welds are subjected to stringent NDT like PT after each pass, Radiography / Ultrasonic check, Helium leak test etc and Destructive tests like Minimum Leak Path test, Pull-out test, Transverse sectioning check etc.

2.7 Quenching & Tempering of hot rolled shell cans:

Heavy thickness Cr-Mo or Cr-Mo-V plates can be bent either in cold condition (approx at Room temperature), warm condition (at approx 600-700°C) or in hot condition (at Austenitizing temperature).

This is true for plates with higher width. If lesser width plates are taken, comparatively thicker plates can be bent with the same machine. However, reducing plate width would increase number of circular joints, which is not desired from cycle time point of view. Therefore, an optimum decision is taken to balance both these contradictory requirements.

Whenever, the plates are to be hot rolled, the bent plates are required to be subjected to the quality heat treatment (mostly Quenched + Tempered or Normalized with Accelerated Cooling + Tempered condition) to restore the original mechanical properties of the material. To meet this requirement, a special quenching facility has been developed at L&T.

The furnace is capable of achieving required Austenitizing temperature for shells up to 8m diameter. A water-quenching tank with specially designed agitation facility has been constructed to quench shells up to 8m diameter.

Material test coupons are being attached at the top and bottom ends of each quenching shell and tested to confirm the required mechanical properties and microstructure. Till date, various grades of Cr-Mo, Cr-Mo-V, Mn-Mo-Ni plates have been successfully quenched and tempered. In addition to meeting required Room temp strength, High temp strength and Impact toughness at (-) 30°C, step cool test requirements have also been met without any problem.

3.0 Conclusion: Manufacturing of High pressure Reactors, Exchangers, Tubular reactors and other equipment involves various critical fabrication and welding operations. Several state-of-the-art manufacturing technology are implemented in the areas of fabrication, handling and welding, some of which are described above. These are the clear examples of converting designer’s dream into reality. Successful implementation of improved technologies has further enhanced the capability of Larsen & Toubro Limited to manufacture such critical equipment meeting global standards and thereby putting India on world map.
Fig- 1: 1500MT Tubular reactor being dispatched from L&T Shop for Equate Petroleum, Kuwait

Fig- 2: Dispatch of 300mm thick 2.25Cr-1Mo-0.25V Hydro-cracking Reactor (970MT) for Helpe, Greece