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WELDING AUTOMATION FOR MATERIALS USED IN HIGH CORROSIVE SERVICE

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Abstract

L&T Heavy Engineering is amongst very few global manufacturers licensed to manufacture critical high pressure equipment like Urea reactors, Urea strippers, Carbamate Condensers & Carbamate Separators for urea service under various Process licensors. Inside surface of these vessels are lined with liner materials to prevent direct contact of corrosive hydrocarbon fluid with substrate base metal. The most commonly used liner materials for such application are urea grade SA240 TP310 MoLN & SA240 TP316 L-UG etc. Thickness of these liner materials varies between 5 to 8 mm depending upon the operating conditions. Out of these equipment Urea Rector involves huge amount of liner welding of the order of ~150-200 kg per equipment. Major part of this weld deposition is attributed to liner circumferential & longitudinal seams. Hitherto, this liner welding is carried out by manual Gas Tungsten Arc Welding (GTAW) process which fairs very low in productivity & thus higher cycle time. To meet stringent corrosion properties liner welding calls for clean & slag free welding process along with dust free atmosphere, hence GTAW process is best suited for this application. However, in order to improve productivity & to reduce cycle time, we took up the challenge of exploring variants of GTAW which will yield higher productivity while at the same time comply with stringent quality requirements. Thus the idea of implementing semi-automatic GTAW welding was conceived which is expected to improve productivity drastically for such liner longitudinal & circumferential seam welding. The paper captures the challenges faced during trial & development of semi-automatic GTAW and its implementation for the first time in Urea reactor.

Keywords: Semi-Automatic GTAW, Liner welding, Urea Reactor

1. INTRODUCTION

Urea, a nitrogenous compound, is the most produced fertilizer in the fertilizer industry [1]. Production of Urea involves treatment of ammonium carbamate solution in different types of equipment, i.e. Urea reactor, Urea stripper & Carbamate condenser [2, 3]. The urea equipment consists of inner lining to prevent it from high corrosive operating fluid [4, 5]. The formed liners are mostly made up of corrosive resistant material like Austenitic SS, Duplex or Super Duplex SS & Titanium [6]. Hence liner welding is the most critical activity in Urea equipment and no defects are tolerated in these welds. The schematic diagram of typical urea reactor with the liner plates is shown in Fig. 1.

Sequence for liner attachment welding on shell Inner surface is as follows (Fig. 2):

1. Buttering of SS309 done inside the shell and dish end.
2. Placing of formed liners inside the vessel.
3. Welding of liner to SS buttering.

Figure 1: Schematic diagram of typical urea reactor with the liner plates

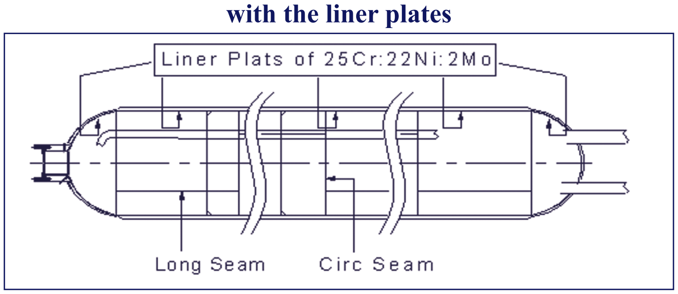
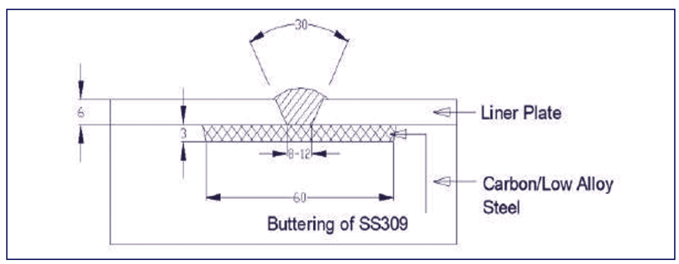


Figure 2: Weld joint configurations for liner attachment weld (all dimensions are in mm)



The current practice followed is welding these liners with manual GTAW process due to its ability to meet the stringent requirements of the Urea Process Licensor. But the cycle time involved in welding by manual GTAW is substantially high considering the amount of welding involved in fabrication of these liners. Moreover, fully automation of these welds is not feasible in view of the varying liner gap during setup as these liner shells are fabricated. Hence the need for an alternate welding process was felt so as to improve productivity, repeatability as well as to obtain a good bead finish.

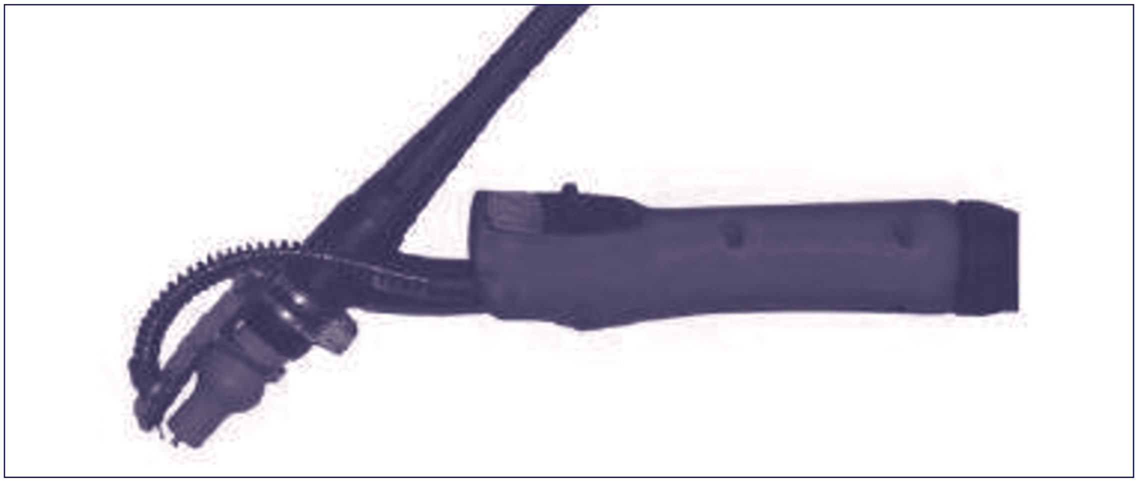
Different welding processes such as SMAW, GMAW & Hot wire GTAW [7] were tried in past to improve productivity. However, each of these processes had their own disadvantages. Both GMAW and SMAW welds showed poor bead finish in comparison with GTAW. Hot wire GTAW was eliminated in view of high precision joint setup requirement.

Semi-Automatic GTAW

Market study was done to find out the various suppliers of semi-automatic GTAW systems. The assessment criterion was based on the various parameters such as operational friendliness, reliability, service and cost effectiveness. Out of the various systems available, extensive trials were carried with few of these machines before a suitable system was short listed based on the better performance.

The semi-automatic GTAW equipment consists of an inverter based power source, controlling unit, wire feeder and a torch [8]. The power source has automatic cooling-unit, cut-out touch-down ignition / HF switch-selectable, over temperature protection, 2-step/4-step mode, spot-welding / pulse mode, etc. It also has the state of art digital control which helps in increasing the accuracy of the parameters to be maintained. In semi- automatic GTAW, the wire feeder is attached to the TIG torch which gives continuous supply of filler wire. The wire feeder is fully digitally regulated and bus-controlled feed system. Semi-automatic GTAW torch (Fig. 3) is a hand-held torch and this process is a blend of both manual and automation. The current can be varied while keeping other parameters constant. The wire speed varies between 0.1m/min. to 11m/min.

Figure 3: Semi-automatic GTAW Torch



The semi-automatic torch has compact construction with internal and external wire feeding hose. It reduces the number of start stop points by producing continuous weld as required for the application. Also the bead profile has a good surface finish and gives higher productivity than manual GTAW process. Refer Table. 1 for details.

2. METHODOLOGY

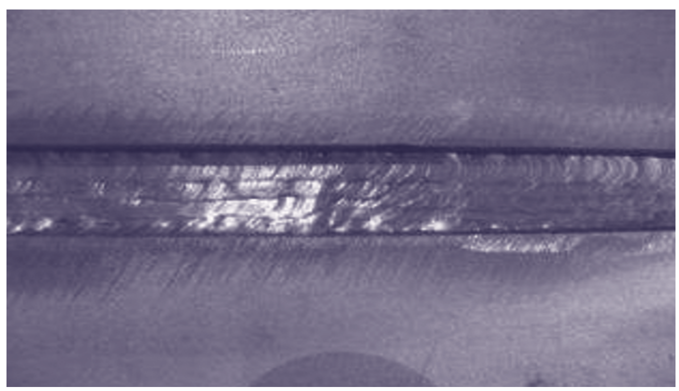
Typical Urea Reactor involves 12 to 15 liner shells in long and circumferential forms to be welded by GTAW process. At present welding is performed by manual GTAW using 1.6 / 2.4mm Ø filler wire. Trials were done by semi-automatic GTAW in both vertical and horizontal positions using 1.6mm Ø filler wire. Root pass of the coupons were welded with manual GTAW. However, subsequent passes were welded with semi-automatic GTAW. Coupons were subjected to corrosion tests & macro examination.

Procedure Qualification

Based on the satisfactory trials, procedure qualification was taken up as per Process Licensor specification. 6mm thick liner plate was weldedto a carbon steel block buttered with SS 309L. The welded coupons were subjected to the following tests:

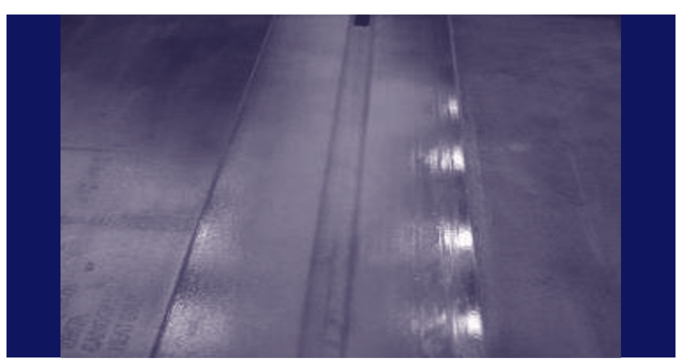
Visual Examination: Examination was carried out on the welded sample to check the bead surface as well as the finish. The welded surface had uniform ripples and acceptable bead profile. (Fig. 4)

Figure 4: Bead Appearance



Non Destructive Test: Dye penetrant test was carried out and no surface defects were observed. (Fig. 5)

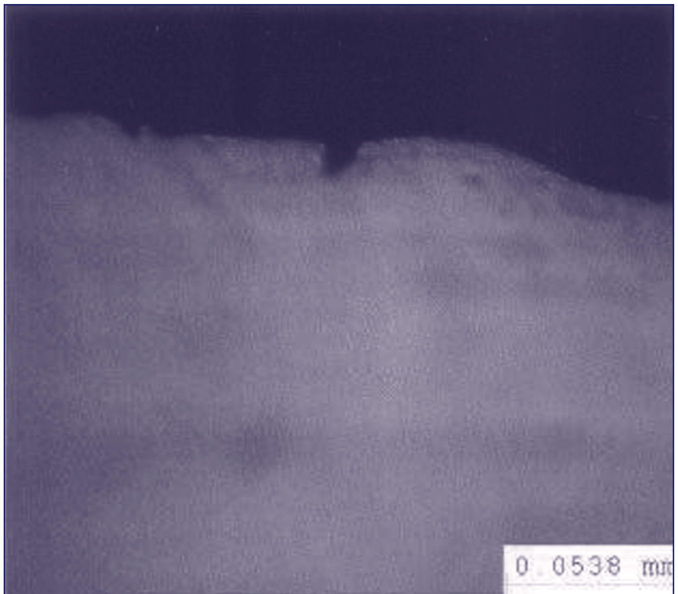
Figure 5: Dye Penetrant Test



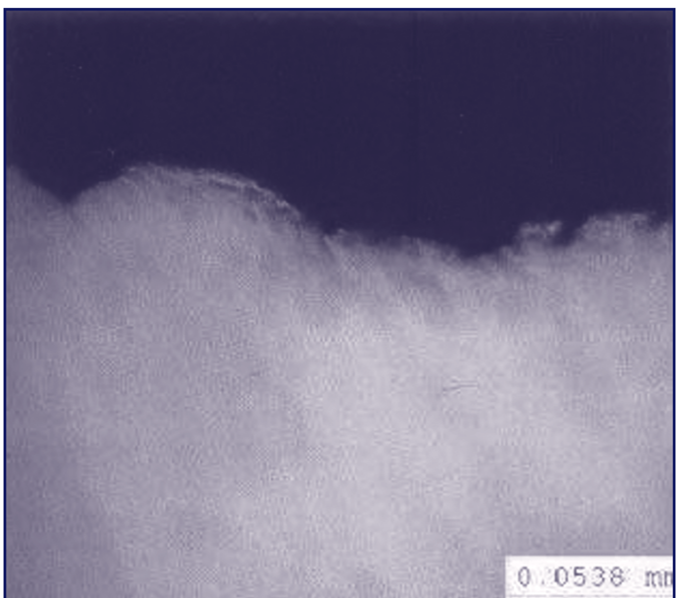
Chemical Test: Chemical composition at a depth of 3mm from the top surface was checked and found to be satisfactory. (Cr: 24.33%, Ni: 21.68%, Mo: 2.31%, C: 0.016, Mn: 5.60)

Corrosion Tests: The liner welds were subjected to Inter Granular Corrosion (IGC) test according to the ASTM A262 Practice C in 5 cycles [9]. In this test, each cycle consists of a period of 48 hours and the corrosion rate is calculated on the basis of the weight lost during the exposure of the sample to the corrosive environment. The corrosion rate observed was 0.06 gm/m2hr, which was well under acceptance limits of 0.54 gm/m2hr. (Fig. 6)

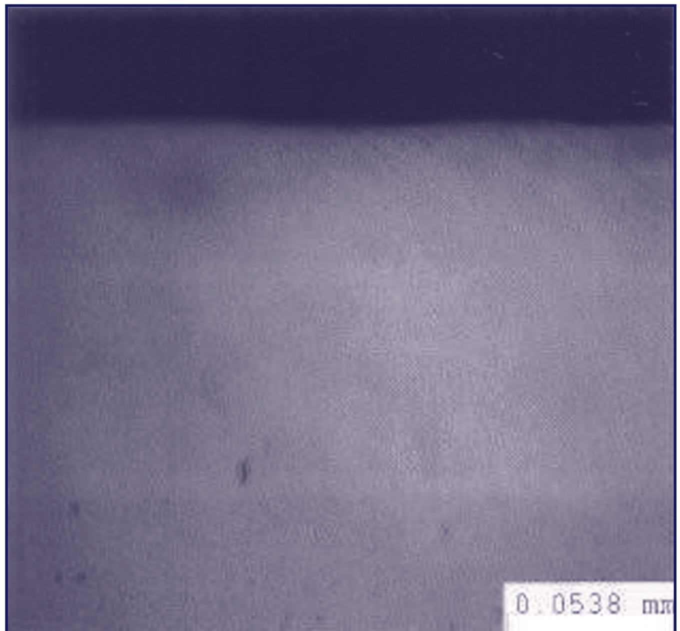
Figure 6: Corrosion Test: Depth of attack on the welded sample



Base Metal



HAZ



Weld Metal

Metallographic Tests: Macro examination was carried out to study the integrity of the weld. Complete fusion between weld metal and base metal was observed and no cracks or porosities were seen as shown in Fig. 7 [10]. For good corrosion resistance, the microstructure should not be of dual structure, ditch structure or inter- dendritic ditches. The microstructures showed absence of sigma phase, metallic carbides or any other inter dendritic structure as shown in Fig. 8.

Figure 7: Macro photograph (10X) showing bead placement

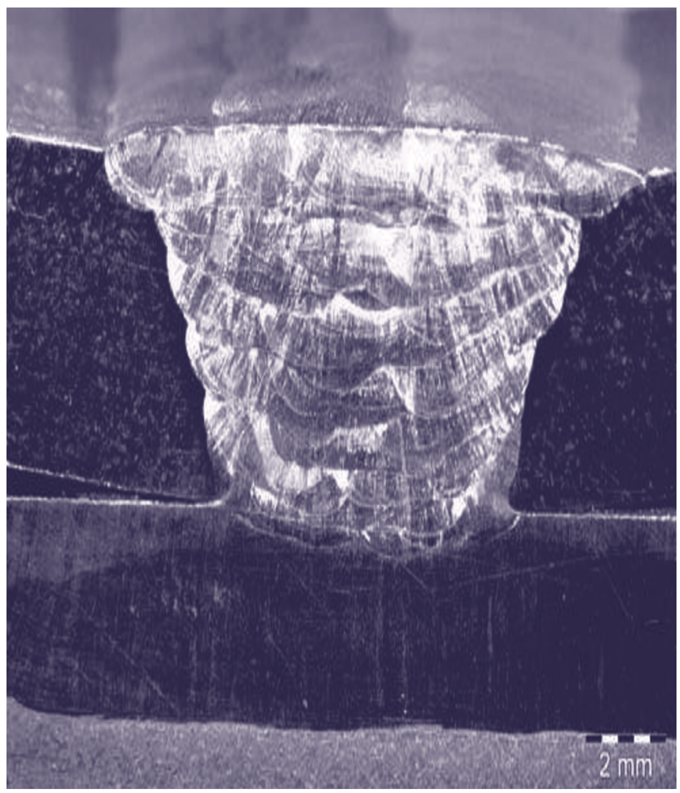


Figure 8: Microstructures (200X)

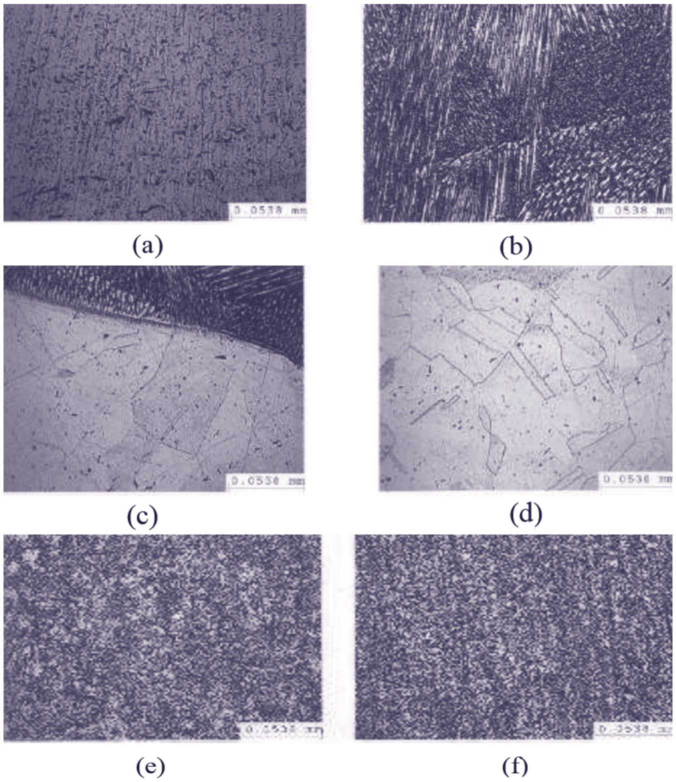


Fig. 8(a) and 8(b) shows microstructure of weld buttering and weld metal respectively. The microstructure shows austenitic dendrites in the buttering and liner.

Fig. 8(c) microstructure shows the fusion line of the liner and weld. The microstructure of Fig. 8(d) shows austenitic structure in the liner metal.

Fig. 8(e), (f) The microstructure shows bainitic structure in base metal and HAZ.

3. IMPLEMENTATION

Developed procedure was successfully implemented in one of the recently executed Urea Reactor. All trained welders were given practice on simulated coupons before they were employed for production. Process was used to weld both longitudinal and circumferential seams of the liner.

Following were ensured during the job implementation:

- In-situ cleanliness with fixture in place.
- Fixture for welding machine & sitting arrangement as shown in Fig. 9.
- Proper fixture arrangement for liner set up.

Deposition rate was found to be 1.3Kg/ welder/ shift against 0.7Kg/ welder/ shift by manual GTAW.

Figure 9: Fixture for welding machine & sitting arrangement

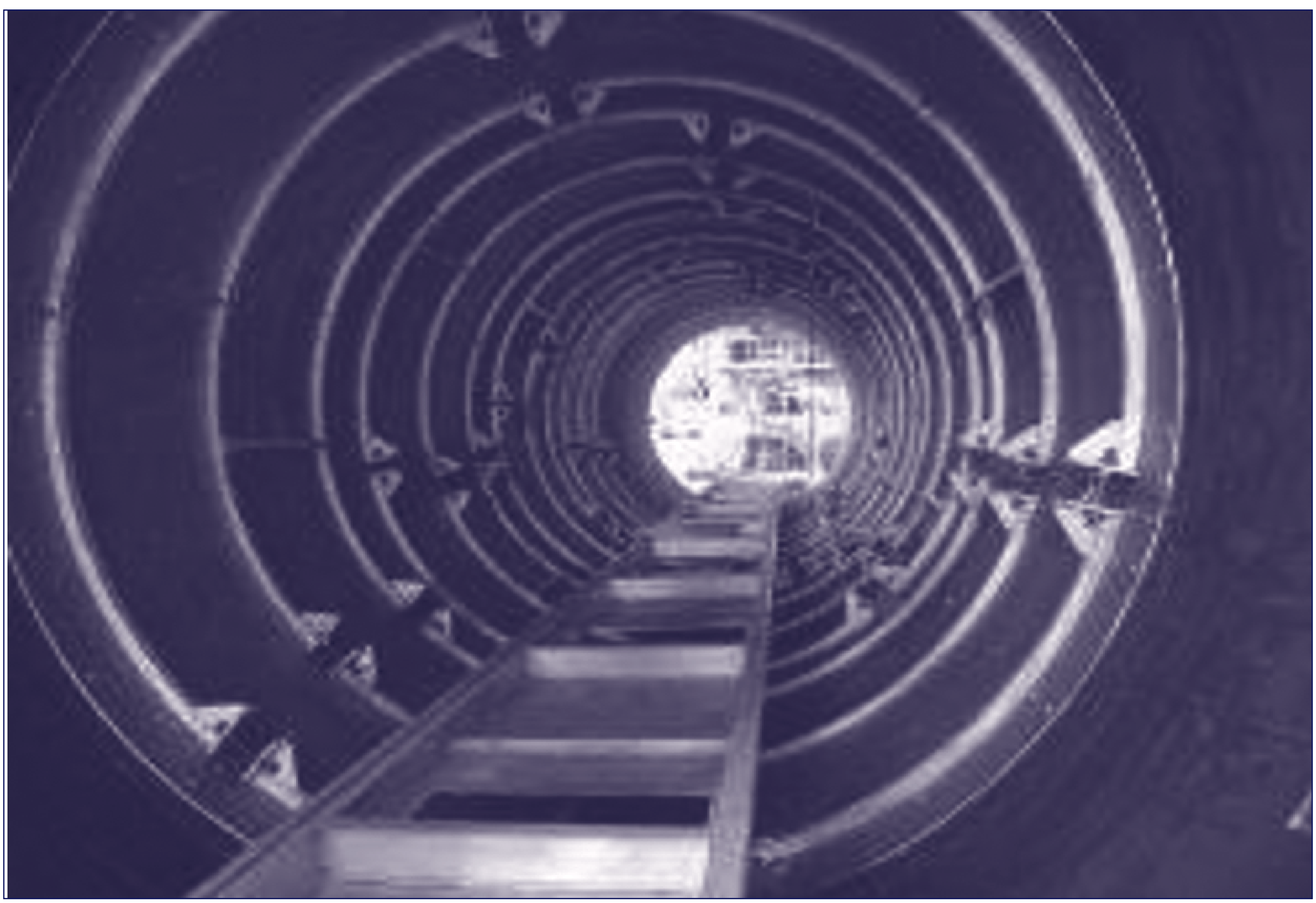


Table 1: Comparison between Manual GTAW and Semi Auto GTAW process

Welding Parameters	Manual GTAW	Semiautomatic GTAW
Dia. Of wire(mm)	1.6/2.4	1.6
Current(A)	100-140	120-170
Voltage(V)	10-15	10-15
Speed(mm/min)	100-130	140-160
Productivity(kg/arc.hr)	0.3	0.45
No. of beads	Same in Both	

4. CONCLUSION

First time application of semi-automatic GTAW for liner attachment welds established. Welding procedure was qualified meeting all the stringent requirements of the specification including corrosion tests. The process was also implemented on one of the Urea Reactors manufactured recently as shown in Fig. 10.

Salient achievements are as follows:

- Heat input with semi-automatic GTAW was found very less when compared with manual GTAW leading to much reduced corrosion rate (0.079 gm/m^2Hr Vs 0.16 gm/m^2Hr) [11].
- Reduction in cycle time by approximately 45%.

Figure 10: Semi-automatic GTAW in action

- Increase in the deposition efficiency due to increased arcing time by approximately 80%.
- Reduction in the number of weld start and stop locations resulted in enhanced joint integrity.
- Increase in the welding operator comfort level.

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