Reclamation of Inner Telescopic Tube-Vacuum Arc Degassing Unit of Continuous Casting Unit

By
M. Hussain[1], S. Sikdar[2]
[1]Manager, Recl. Shop
[2]AGM, CCS Bhilai Steel Plant
(Winner of MD-BSP award in NWS 2005 for this paper)

1.0 Introduction

Steel Authority of India Limited is one of the major quality steel producers in India. It is having annual capacity of more than 11 million tons of crude steel. Bhilai Steel plant is one of its four integrated steel units.

With the recent demand for extra low hydrogen content in steel, Vacuum arc degassing and other secondary refining processes have achieved special significance.

2.0 Vacuum Arc Degassing

It is a commonly used process to reduce hydrogen content in Steel. Bhilai steel plant has achieved H_2 contents < 1.5ppm. VAD ladle (Figure-1) containing molten steel is purged from bottom by argon. Argon is used to maintain the temperature of melt uniform. Heat shield, a water-cooled and refractory lined (dome shaped) unit covers the VAD ladle. Vacuum of the order of 0-65 milli-bar is created in the ladle through separate arrangement. Now the heat is ready for degassing.

Telescopic tube assembly sits on the heat shield (Figure-2). Telescopic tube assembly consists of outer tube and an inner tube. The inner tube (Figure-3) slides inside the outer tube. The whole assembly of telescopic tube consists of three such tube assemblies. Three graphite electrodes protrude through inner tubes for arcing. Intense arcing of the melt (currents of the order of 30000 amps) produces agitation in the molten Steel. Ferro alloys are also added at this stage. Thus gases are evolved from this agitated mass, removing hydrogen along with it.

3.0 Problem

The inner telescopic tube (fig-3) is made of austenitic stainless steel grade **X6 Cr Ni Ti 18 10** (table-1) Equivalent **AISI 321** grade. It is a water-cooled tube. Due to agitation in the mass, some splashing of molten metal takes place. This molten metal stuck to the inner wall of tube and punctured it.

- Area of damage 60 mm X 20mm. (Inside surface)
- The damaged portion was irregular in shape.
- The location of damage was around 1000mm from one side of the tube.
- Poor accessibility of the area to be repaired.
- Weld filler metal to be non-magnetic and so the ferrite content had to be minimum.

4.0 Development of Repair Scheme

Weld ability is dependent not only on the grade of steel but also on the conditions during welding, on the design and the operating conditions of the structural component.

Thus the repair scheme was finalized after due consideration was given to each of these:

4.1 Selection of Welding procedure

4.2 Selection of filler metal (factors affecting the choice of filler material)

- Inter-granular corrosion cracking
- Stress corrosion cracking
- Hot Cracking
- Delta ferrite content of weld metal
- Non-magnetic character of Base metal and weld metal.

4.1 Selection of Welding Process

As the area to be welded (repaired), had poor accessibility (ID of pipe/tube= 608 mm) and it was located at distance of 1000mm from one end of tube. (Fig-3)

Thus only one person could crawl inside with difficulty. Among the various processes SMAW was selected because in GTAW, filler wire had to be fed separately and the narrow space didn't allow a person to do the job of feeding the wire from one hand and holding the torch in another. Due to the confined narrow space available only SMAW was the process of choice.

4.2 Selection of Filler Metal

Once the process of SMAW (MMAW) was selected, filler metal selection was an important step before actually carrying out the welding. The telescopic tube operates under conditions of high temperatures (due of heat radiated by molten steel), oxidizing atmosphere due to gases evolved due to Ferro-alloy additions. Following factors were under consideration for selection of filler metal-Inter granular corrosion cracking (IGCC), Stress corrosion cracking (SCC), hot cracking, effect of delta ferrite and retaining the non-magnetic character of the weld (similar to base metal).

5.0 Discussion based on the factors affecting choice of Filler Material

It is widely known fact that in SMAW, some loss of elements takes place while the metal is transferred across the arc. The base metal is of 18Cr-1 0 Ni type. To compensate for the losses it was decided to use 25Cr/20 Ni type of electrode.

Inter-granular corrosion cracking is a widely known phenomenon in austenitic Stainless steel grades. Stainless steel grades having 0.08% C or more, are more susceptible. X6Cr Ni Ti 18 10 IS A Titanium stabilized grade. Titanium burns off in the welding arc, thus electrodes are always stabilized with Niobium/ Columbium. Such is not the case with GTAW/GMAW (TIG/MIG) filler wires because both processes take place in an inert atmosphere.

Under conditions of stress and corrosive atmosphere, weld metal is prone to Stress corrosion cracking. During Ferro-alloy additions, the gases evolved are strongly oxidizing in nature. These make the weld metal and the heat affected zone (HAZ) susceptible to SCC. Stress relieving by suitably designed procedures can minimize the chances of SCC. Silicon containing grades improve high temperature oxidation resistance [4]. Grades containing Molybdenum and copper improve general corrosion resistance [4].

After considering corrosion resistance, the avoidance of cracking becomes the underlying theme in filler metal selection and procedure development for the welding of stainless steels [3]. When hot cracking occurs in an austenitic weld metal" a common remedy is to use a mostly austenitic filler metal that includes a small amount of ferrite [1]. Ferrite is 1.5% in the base metal (Schaeffler's diagram). Thus it was decided to keep the ferrite content of weld metal close to 1.5-2.0%. This range was also necessitated by the fact that ferrite is Para-magnetic and the requirement is of non-magnetic weld metal.

At high temperatures, delta ferrite can transform to brittle sigma phase, so that amount of ferrite must be closely controlled. For each SS grade, there exists a specific volume fraction of delta ferrite corresponding to a maximum ductility [3].

Apart from their oxidation resistance, which can be improved by adding Si and increasing Cr and Ni contents, the austenitic SS retrains good mechanical properties at high temperatures. The beneficial effects of molybdenum is due to substitutional solid solution strengthening, which is more stable than that derived from interstitials, the effect increasing with temperature. The principal limitation to the use of molybdenum is the risk of sigma phase formation [2].

Weld puddle shape has a strong influence on hot cracking tendencies. Narrow deep puddles crack more readily than wide, shallow puddles. Low heat input, low pre heat and inter pass temperatures are all beneficial. These factors were kept in mind while designing the weld procedure.

Thus the available literature suggests that AISI 321 grade Ss is easily weldable by AISI 347 or AISI 308L (low carbon filler) but under the present conditions, a niobium-stabilized grade with the following composition was used: (Table 5)

C=0.08%, Cr= 25%, Ni=20%, Mn=1-2%, Si= 0.75%, Cu=0.75%, Mo=0.75%

(S<0.03%, P<0.03%) and Cb=10xC

Which is an equivalent to AISI 310Cb.

6.0 Reclamation Scheme

After the welding process and consumable were selected, trial runs were held using the same grade of steel plate in which a pocket was arbitrarily cut, similar in shape and size to the actual defect.

Welding parameters were selected- Current, Voltage and Welding speed. Heat input was kept to a minimum. (Table-6 gives the actual values)

No separate plate/patch was used for repair. The material was built up layer by layer.

Fig-4 gives the material deposition scheme.

Subsequently weld metal analysis and ferrite content of the trial (dummy repair) runs were done. The values were found to be satisfactory and with in acceptable limits. During actual repair the welder could weld only for a short period, one electrode at a time and then would come out of the tube and took rest. This also allowed the job to cool and heat build up was less.

General precautions regarding welding of Stainless steel welding were taken.

The weld area and adjacent area was pickled and passivated by commonly available agents and later flushed by water.

7.0 Testing

The welded area was finished by grinding and later pickled and passivated. Surface cracks were checked by Dye penetrate test. The job was Hydraulically tested at 10 kg/cm2 for 1 hr was done. No leakage was found.

8.0 Conclusions

1. The ferrite content of the weld metal was found to be 1.5% although theoretical values were less than 1 %. This might have been due to dilution effects. Although the AISI 310Cb material

TABLE 1
Nominal composition of base metal: according to **DIN**
Material no.: 1.4541 **X6Cr Ni 18 10**

C	Cr	Ni	Ti
0.08%	18%	10.5%	0.4%

(S<0.03%, P<0.045%, Si<1%)

TABLE 2
Mechanical Properties
Tensile Strength : 500-730 N/mm^2
% Elongation: 35% longitudinal and 30% Transverse direction.
0.2% proof stress = 200 N/mm^2
1% proof stress = 235 N/mm^2

TABLE 3
Reduction of 0.2% proof Stress at various temperatures: (to study resistance to ICC)

^{0}C	50	100	150	200	250	300	350	400	450	500	550
N/mm^2	190	176	167	157	147	136	130	125	121	119	118

TABLE 4
Creep Strength according to BIN 17458: N/mm²

°C	10 000 hrs	100 000 hrs
600	115	65
650	70	39
700	45	22
750	28	13

TABLE 5

C	Cr	Ni	Mn	Si	Cu	Mo
0.08%	24.5%	20%	1.8%	0.75%	0.75%	0.75%

S<0.03%, P<0.03% and Cb=10 x C Ferrite = 1% (theoretical)

TABLE 6

Diameter	Current (amps)	Voltage (V)
3.15 mm	90-95	24
4.00 mm	120-130	26

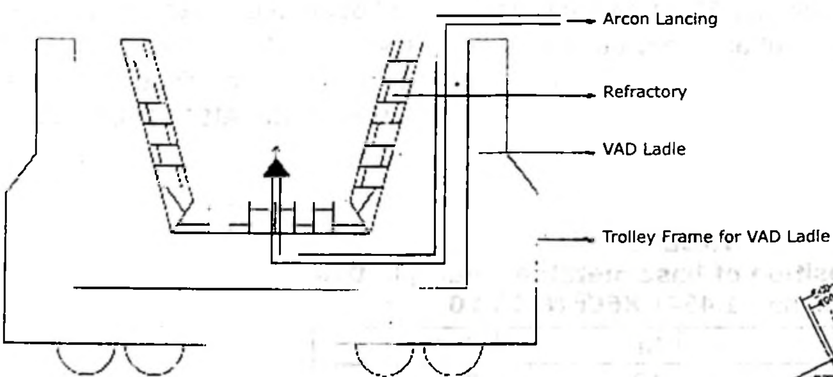

Fig.1 : General Arrangement of VAD Ladle without Heat Shield

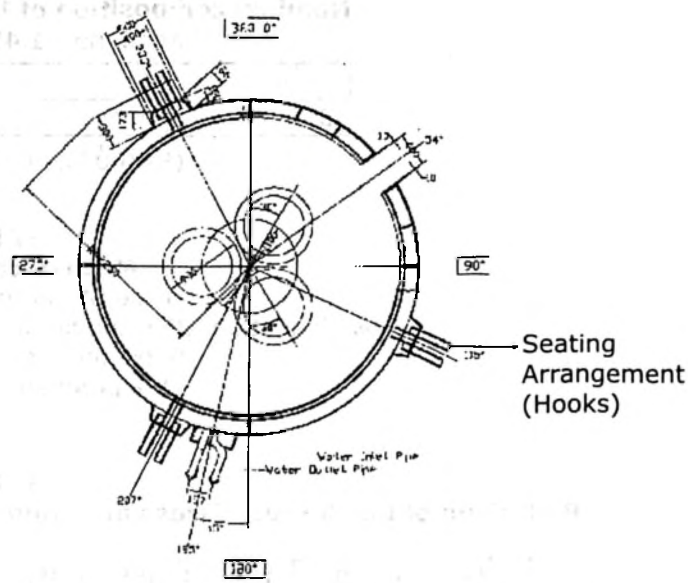

Fig. 2 : Plan Representation of Heat Shield

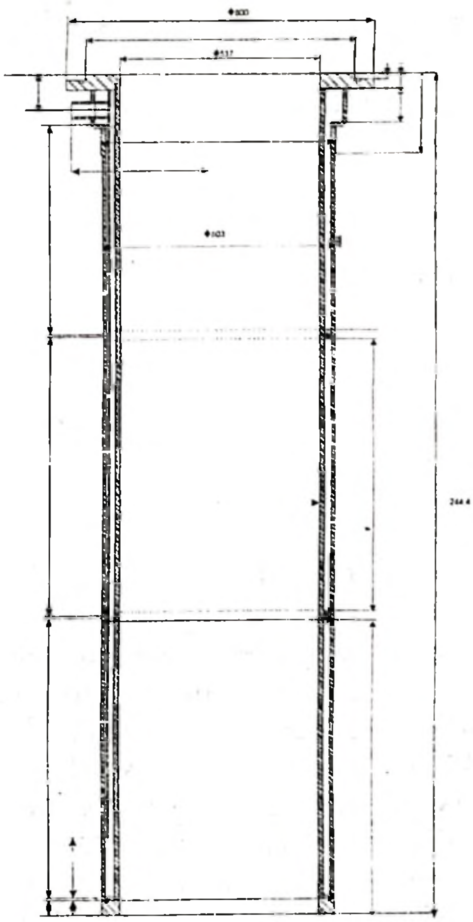

Fig. 3: Sectional View of Inner Telescopic Tube

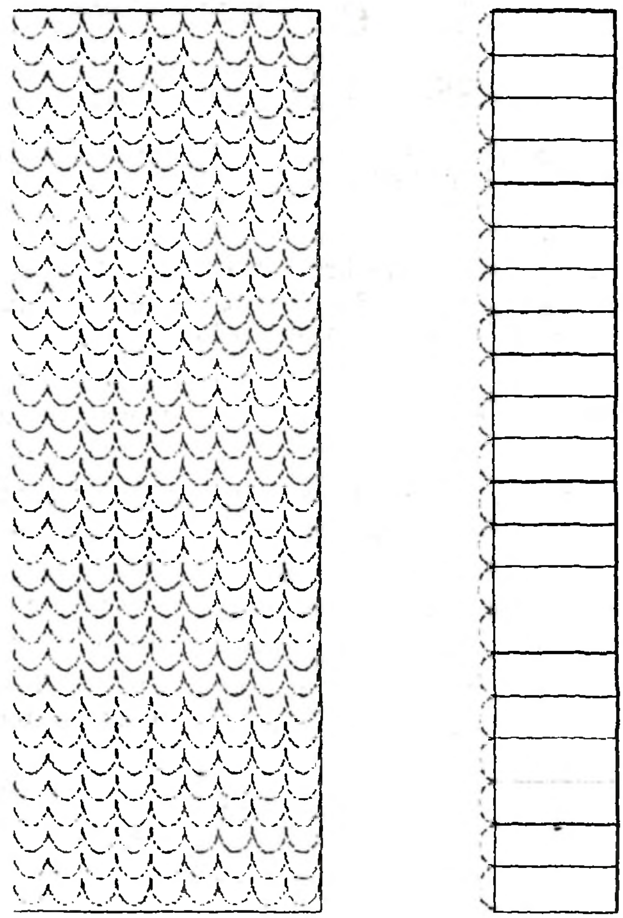

Fig.4: Material Buildup Scheme

gives ferrite content in the range of 0 to 0.5% ferrite.

2. As per the literature available AISI 321 grades are weldable by AISI 347 or AISI321 grades. But here operating conditions necessitated use of AISI310Cb and it proved satisfactory (non-magnetic nature of job).

3. The cost of one assembly of Telescopic tube is around 90,00,000 INR (USD 180000). Single tube orders are not entertained by companies or are charged very highly. Thus, there were savings to the tune of USD 75000 even if one tube was purchased.

4. Production losses due to down time etc have not been added here.

5. At present the reclaimed tube is running satisfactorily.

Bibliography

1. LACOMBE, BAROUX, BERANGER Scientific editors. Stainless Steels Chapter 16 Austenitic Stainless steels by J.C.Bavay (p549-p592) ed-1992.

2. DEGALAIX.S.FOCT J, Nitrogen in Austenitic Stainless Steels (11). Influence on Mechanical properties. Mem.ScLRev Met (1988) 111-123.

3. OLSON.D.L. Prediction of Austenitic weld metal microstructure and properties. Welding Journal (American welding society journal) 1985 p-281 s-295s.

4. Dr.ARUN KUMAR BHADURI, Welding processes and technology for Stainless Steels. Weldi~ Journal Indian institute of welding July 2002(p24-p36)

5. Welding Handbook American Welding society Volume-II, IV 8th editions.

6. Jefferson's welding Encyclopaedia (p- p-) edition.