Salvaging of Large Bell of D Furnace of TATA Steel

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ABSTRACT

Large bell is an integral part of the top charging system of blast furnace. It ensures periodical raw material charging inside the furnace. During midterm relining of D furnace of TATA Steel, it was observed to be badly damaged while in service. The magnitude of worn out of bell wall thickness was up to 90 % against the drawing size. Because of cost and lead live (minimum 8-9 months), reconditioning of the bell of D furnace needed to be done within 2 months. Innovative ways was adopted to salvage the existing damaged large bell. The total cycle time taken to salvage was 45 days which was well within the requirement. The large bell after salvaging was assembled with large bell hopper and leak tested. The leak test observed only 25 droplets of water/minute came out from the seating area against the norms of 50 droplets/minute. The bell is in now service and has contributed to timely completion of shutdown with minimal cost.

Key Words: Top charging system, large bell, midterm relining, leak test

1.0 INTRODUCTION

Top charging system of blast furnace ensures raw material throughput inside the blast furnace. There are two type of top charging system :

1. Bell less top charging system
2. Two bell top charging system

One of the most important part of the two bell charging system is large bell. Raw material enters the furnace as and when required through the large bell. The typical 4 step raw material charging in the blast furnace is shown in **Fig.1** below:

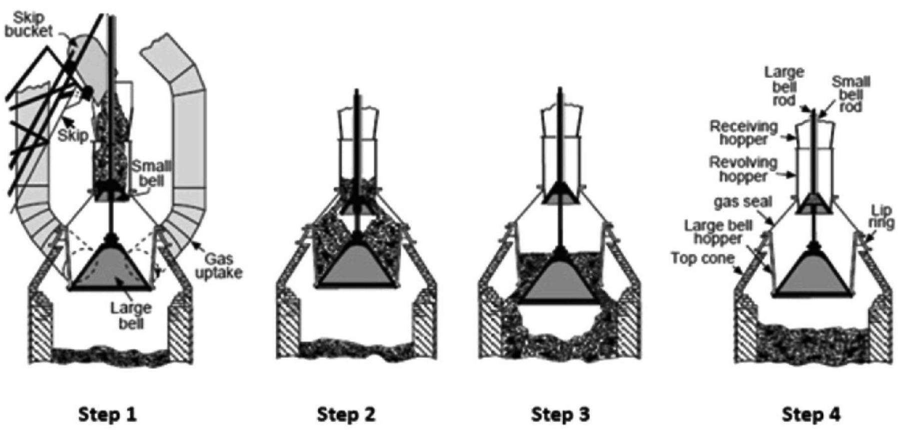

Fig.1 : Schematic diagram of the 4 step raw material charging in blast furnace

Various components of top charging system are depicted in **Fig. 2** below:

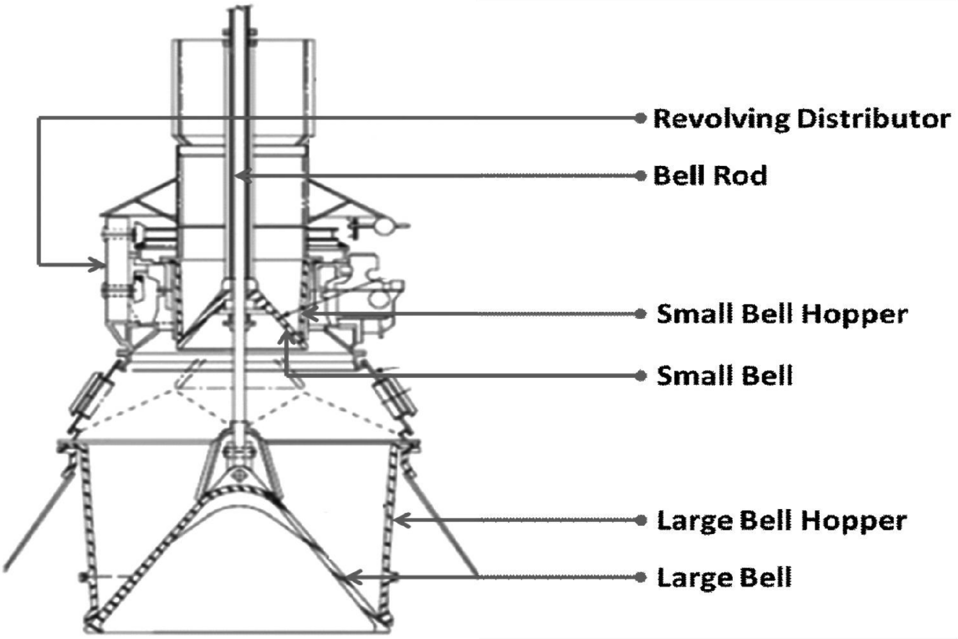

Fig.2 : Components of top charging system

During midterm relining after opening of the top charging system it was observed that the large bell (shown in **Fig. 3**) was badly damaged in service. The extent of damage was varying in nature all over the surface area. Puncture was observed in the multiple locations in the burden portion. The magnitude of damage after measurement was up to 90% of the original drawing size. New procurement of the bell is a costly affair and the lead time of procurement is 8-9 month. The large bell is a single piece casting weighing approximately 20 ton. The major shut down was limited to 60 days only. The challenge was to salvage this existing badly damaged large bell within 60 days' time and make it as good as new one.

2.0 EXPERIMENTAL

2.1 Visual inspection of large bell

After dismantling the large bell was received at shops in highly damaged condition. Extent of damage was optimum at the certain area in the burden portion. Open cracks were observed in multiple locations of burden portion. Size of these open cracks ranged from 800-1100 mm in length and 100-125 mm in height.

Holes were also observed at multiple locations in the burden area. The seat area also was highly worn out. The extent of the worn out seat was highly heterogeneous in nature. After visual observation of the bell the first remarks was "had it been in service for some more period, it would have been parted in two halves". The magnitude of damages is shown in the **Fig. 3**.

3.0 ANALYSIS

3.1 Analysis of the wall thickness

To understand the magnitude of damage of large bell, wall thickness was measured at various locations in the large bell. Wall thickness was measured by UT method. Three zones were selected top, middle and bottom. Bottom portion was on the seat portion, the middle portion was in the burden area and top portion was just above the burden area. The parameters of UT are given in **Table 1**:

Table.1 : Parameters of UT measurement of wall thickness

Instrument:	USM-33	Probe Size :	24 mm
Gain:	64-70 db	Probe Type :	Normal
Couplant:	Oil	Probe Frequency:	4 MHZ

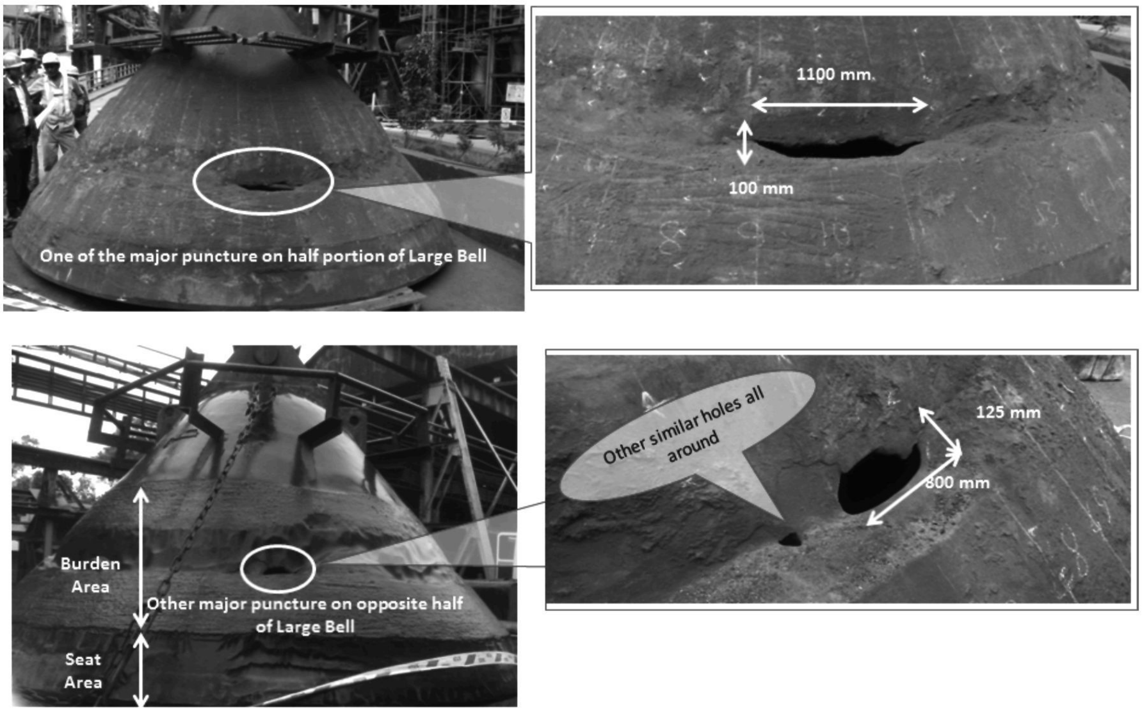

Fig.3 : Magnitude of damage of large bell

Fig.4 : Wall thickness measurement by UT

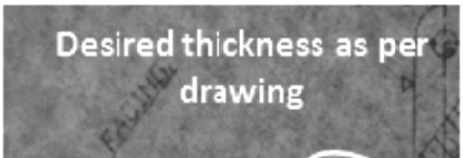

Fig.5 : Wall thickness requirement (Drawing)

The required wall thickness as per drawing (**Fig. 5**) was 80±6 mm and measured thickness varied from 9-90 mm. The variation in wall thickness was 15-60 mm in some portions of the burden area. The seat area wall thickness was 9-10 mm. Only 90% of the wall thickness of the seat area was worn out in service. From the measurement of the wall thickness at various locations, it was concluded that worn out magnitude does not have any pattern and the variation is too high across the large bell.

4. DISCUSSION

After visual inspection and analysis of the wall thickness, the salvaging of the existing bell was difficult. It is never recommended to build up 90% of the worn out area on 10 % existing parent material. There was no spare of large bell available in the department. The new bell procurement needs 8-9 month and the cost is too high. The newly procured bell also has to undergo hardfacing process before putting in service. This requires approximate one month cycle time. The mid-term relining was planned to complete within 60 days' time. In a nut sell the furnace won't be available for production for 9 month time and the impact on the production front is huge. Thus having no other option left except to salvage the existing large bell in the shortest possible time frame was considered.

4.1 Design of process of salvaging

Since there was a variation in wall thickness all across the large bell, the biggest challenge was to arrest the welding distortion. The volume of welding involved was huge. The rough calculation was 2500 kg welding consumable to be deposited on the surface. The steps to be followed were as mentioned below:

- Designing ,fabrication and fixing of the stiffener in the large bell
- Designing, fabrication, fixing of the preheating burners
- Preheating the job
- Repairing of the punctured burden area
- Removal of the welding high spots if any and undercut in the seat area
- Preheating the job
- Hardfacing in the burden & seat area
- Finish turning & grinding
- Balancing and leak test in the bell hopper assembly

4.2 Salvaging of Large bell

After chalking out the road maps of salvaging activity started immediately due to shortage in available time frame. Parallel activity carried out to reduce the cycle time.

4.3 Designing and erection of stiffener

The plant design initially proposed for a circular conical as depicted in the **Fig. 6**.

The plate thickness was 6 mm and the whole thing suggested to weld from inside. Based on the practical experience, modification of the plant design was suggested.

With the circular ribs to be placed from inside. These circular members will be supported by number of vertical stiffener to be placed at equal space. These stiffeners were fabricated from 32 mm thick plate of IS 2062. These members after gas cutting and debarring fixed in inner wall of the large bell. The detail of the stiffener drawing is depicted in **Fig. 7** and after erection of the stiffener is shown in **Fig.8**:

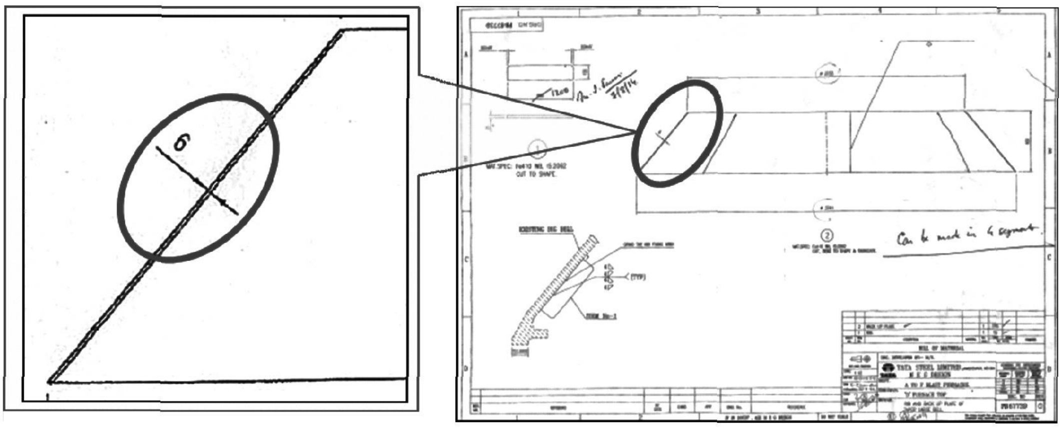

Fig. 6 : Wall thickness requirement as per (Drawing)

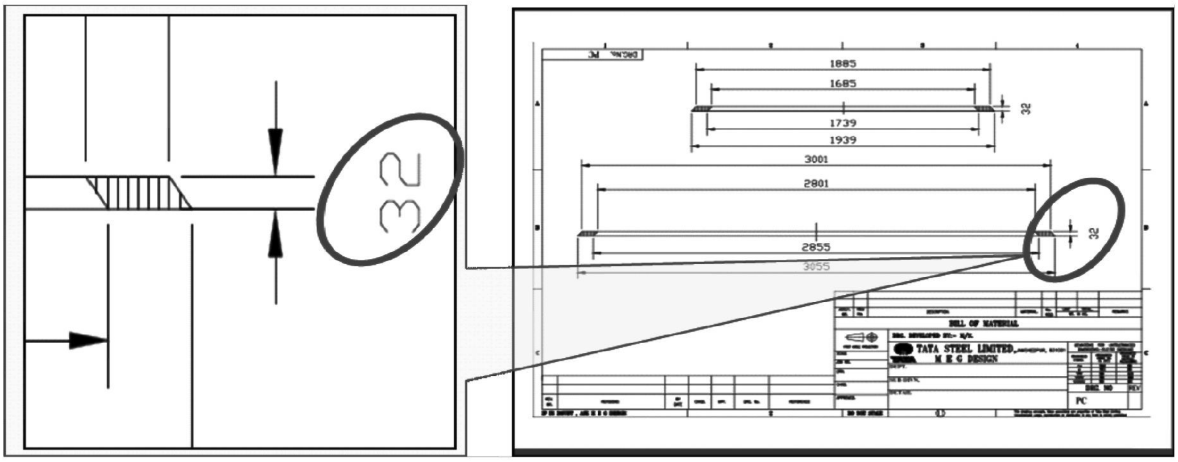

Fig.7 : Modified drawing of stiffene

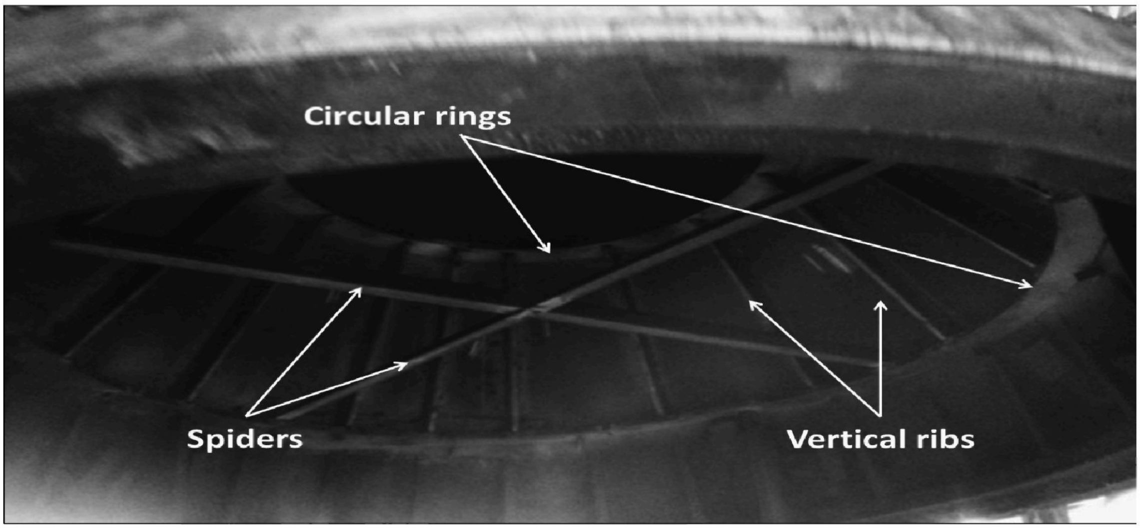

Fig.8 : Stiffener after fixing in the large bell

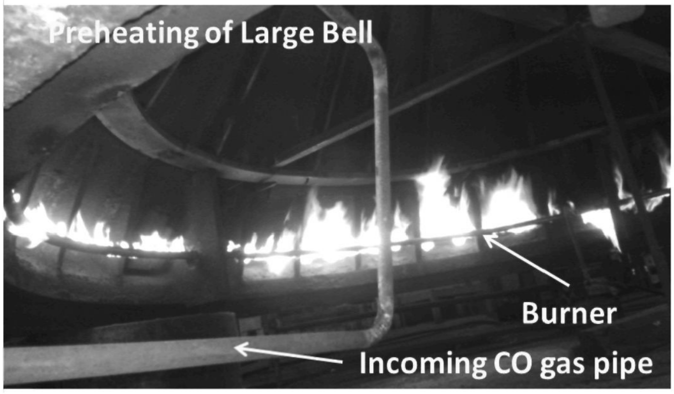

Fig.9 : Preheating of large bell

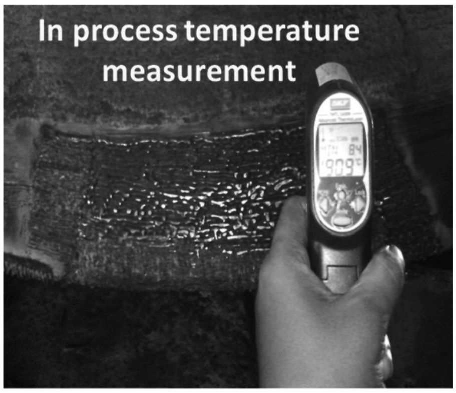

Fig.10 : Temperature measurement

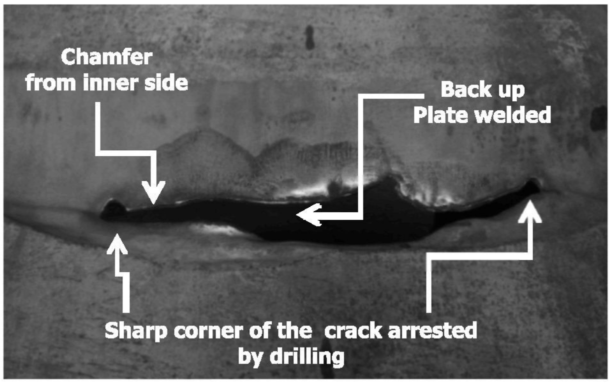

Fig.11 : Temperature measurement

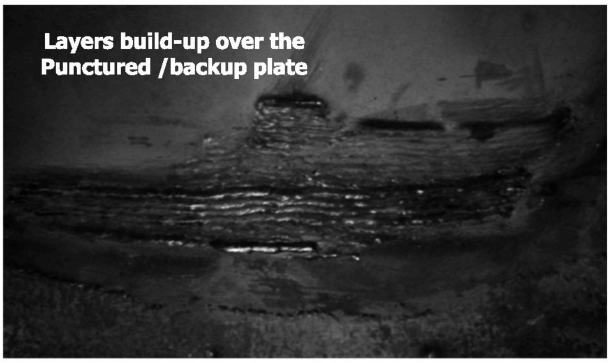

Fig.12 : Layers build up over the backup plate

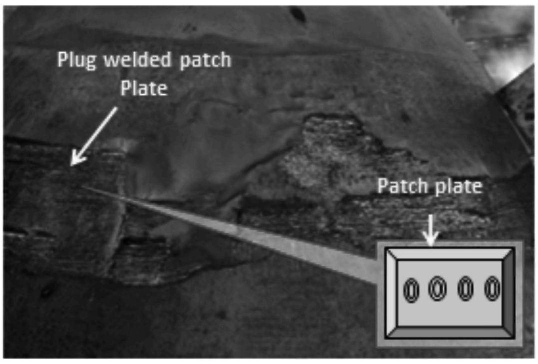

Fig.13 : Plug welded plates

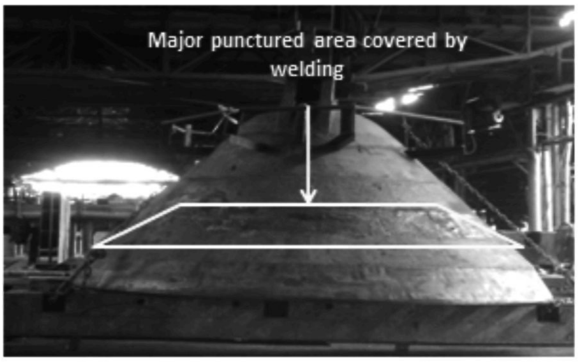

Fig.14 : The major worn out area (after repairing)

4.4 Preheating arrangement

Preheating of the job and maintaining the inter pass temperature during welding is the fore most important parameter during salvaging. Circular burner in semi-circular shape was fabricated from the 1 inch dia mild steel pipe. One side of the pipe was made perforated for gas to come out. The circular parts fixed from inside to make in circular shape. Two pipelines were welded with the pipeline to give separate input of coke oven gas and oxygen. This is then ignited to start the preheating process.

The preheating process is depicted in the **Fig. 9.**

The inter pass temperature was maintained by regulating the gas flow and measuring the temperature by infrared temperature measuring instrument.

4.5 Repairing of the punctured area

Repairing of the highly worn out zone started with repairing of the punctured area. The punctured areas were regularized with gas cutting. The surface area is made chamfered in the direction of the inner wall. The sharp ends are rounded of by drilling to avoid sharp edges.

Back up plate made of 8 mm thick mild steel plate is welded from inside. All the punctured area covered with back up plate. Details are shown in the **Fig. 11**.

After preheating, welding was started to fill up the punctured area. Welding started from the bottom base to the upward direction. This welding was carried out with 7018 electrode. Three layers welding was carried out in same manner to build up a solid bottom base. The details are shown in the **Fig.12**. After completion of the final welding these back up plates were removed by gauging. The solid integral weld pools now became the part of the large bell. Due to shortage of time span and the quantum of build-up on the damaged burden area, plates were cut into different sizes drilled at various length and then plug welded. These plates are made from 32 mm thick mild steel plate. Both ends are chamfered by gas cutting. After that final three layers of 17% Cr-4% Mn welded to make up the uniformity in the shape and also it is the buffer layer of non machinable hardfacing. The details are shown in the **Fig. 13 & 14**.

4.6 Removal of welding high spots & undercut

The welding high spots in the major punctured area are removed by machining in vertical boring machine. Undercutting the seat areas are done in the same machine. The details are depicted in the **Fig.15.**

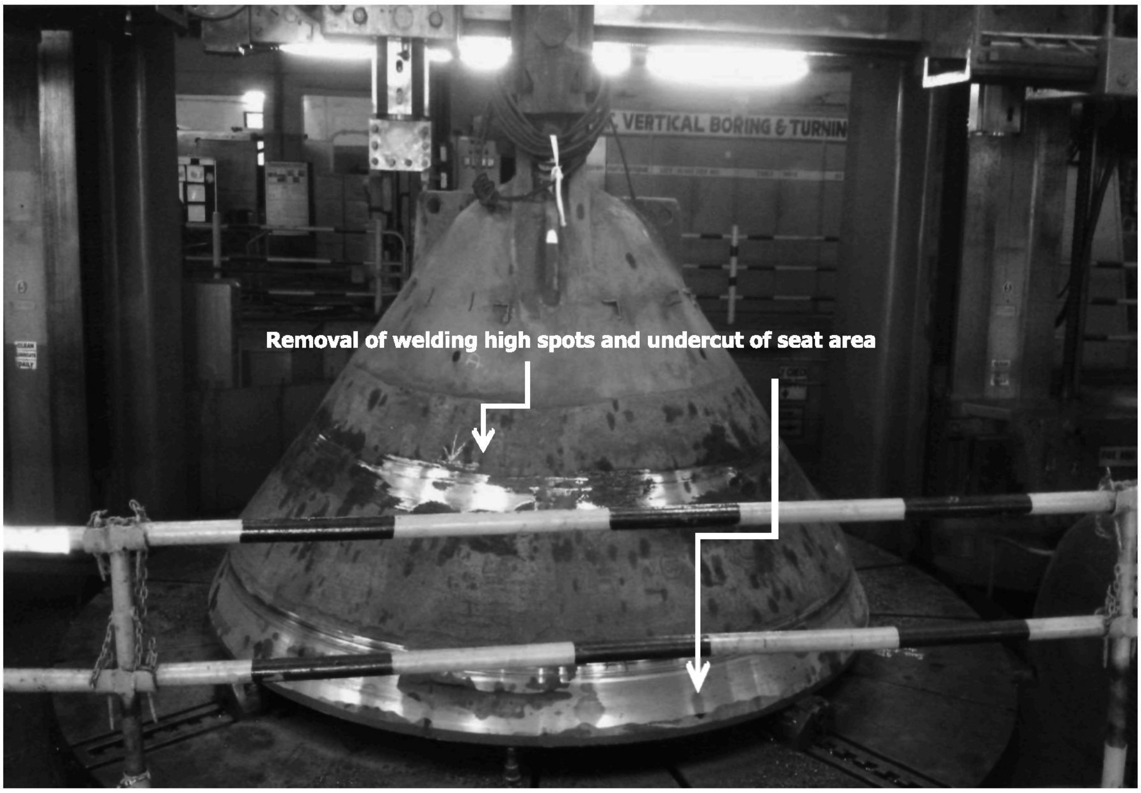

Fig.15 : Undercut and removal of welding high spots

4.7 Final welding of Large bell

After undercut and removal of welding high spots, the job is sent for welding. The preheating burners are set again. After preheating the base wall of the seat portion was build up with 7018 electrode. Four welders were welding round the clock in the 3-6-9-12 clockwise direction. Welders were sifting their place in the clockwise direction. After that 2 layers of buffer applied with 17%Cr-4%Mn electrode which has work hardening characteristics. The weld metal resists impact abrasion and corrosion. This electrode is ideal for buffer before depositing air hardening deposit. The inter pass temperature was measured with the help of an infrared temperature measuring instrument. Inter pass temperature was measured in regular intervals and corrective actions (if any) are taken accordingly. Machinable hardfacing was carried out with air hardening type electrode(C-0.25%, Mo-5.0%, Ni- 5.0%).The weld metal of this electrode possesses high hardness which is retained even at elevated temperature of 5500C.This is suitable for the application where abbrasion in combination with impact is predominant in service condition. The electrodes used were 5 mm diameter. Three layers of machinable hardfacing were applied. The small portion above burden area was also worn out in service. Since the available wall thickness at the area was above 50 mm, FCAW method applied to reduce the cycle time of welding. The wire being used are 17%Cr, 3.5%Mn and the wire dia is 2.4 mm. After putting buffer layer that area was also hardfaced with the air hardening complex carbide deposition. The hardfacing deposition was also carried out by FCAW method. The burden area was hardfaced with air hardening complex carbide type Niobium bearing deposit. Two layers of hardfacing were applied. The entire welding operation had followed the following SOP:

1. Maintaining the inter pass temperature
2. Peening was carried out in between the layers.

4.8 SR of Large bell

Since there was no in house facility available to carry out SR of such big job, it was decided to carry out in-situ. The process applied was at 450 ±10 0C, 4 Hrs+15' (ST).slow cooling upto room temperature. The induction heating method was applied. The large bell was completely insulated by thermal blanketing both from inside and outside. Thermocouples were put at three different zones from outside to measure the temperature of each zone. These three thermocouple output were connected with the online plot and display. Slower rate of heating was adopted to avoid distortion in the job. The details of the process with online plots are shown in the **Fig. 16.**

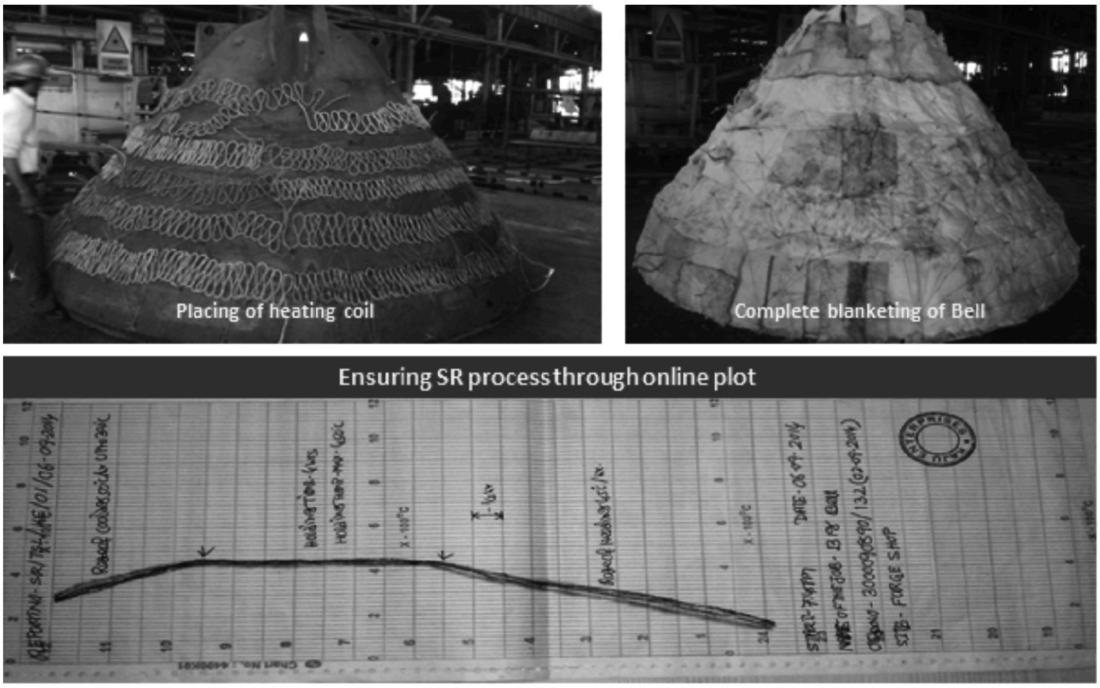

Fig.16 : In situ SR of Large bell

4.9 Finish machining of Large bell

After SR large bell is sent to machine shop for final machining. Finish machining is carried out at the seat area in vertical boring machine. This machine is unique in its nature to have unique gearing facility for taper turning. The requirement of machining at the seat area was to be at 600.The seat area of the large bell hopper was also grinded at 600 for better sealing .After taper turning ,grinding is carried out in the seat portion with the same setting of finish grinding of large bell hopper. This has ensured to have same surface of large bell and hopper. **Fig.18** shows turning and grinding operation of the large bell:

4.10 Final inspection and leak test

The job is visually inspected to find out any crack open to the surface. In the burden portion open hardfacing cracks were observed. The seat area is ultrasonically tested to find out any surface defects. The parameter of the UT testing is shown below in **Table 2.**

Table 2 : Parameters of UT testing of the seat area

Instrument:	USM-33	Probe Size :	24 mm
Gain:	64-70 db	Probe Type :	Normal
Couplant:	Oil	Probe Frequency:	4 MHZ

There was no surface defect detected in the process. Balancing operation is carried out of the large bell. It came within 1.0 mm against the requirement of ±1.5 mm. After balancing the large bell hopper assembly is leak tested. The leak test is most important parameter as this eliminates the probability of gas leakage from the sealing area. In order to carry out the leak test, the large bell hopper is placed over the large bell. Ten litres of water was put inside the assembly and the results are as follows:

- Less than 20 droplets/minute of water came out from the assembly against the requirement of maximum 50 droplet /minute
- Even seating mark was observed in the bell as shown in the **Fig.18.**
- The length of seating portion was 225 mm from the bottom against the requirement of 223 mm

The details of the leak test are given in the **Fig.18**.

5.0 CONCLUDING REMARK

The large bell after salvaging is sent back to the department within 45 days against the planned 60 days' time frame. The large bell and hopper are in operation for last 3 month from December 2014 and it is working smoothly. This salvaging has eliminated the new procurement of large bell. Furthermore,

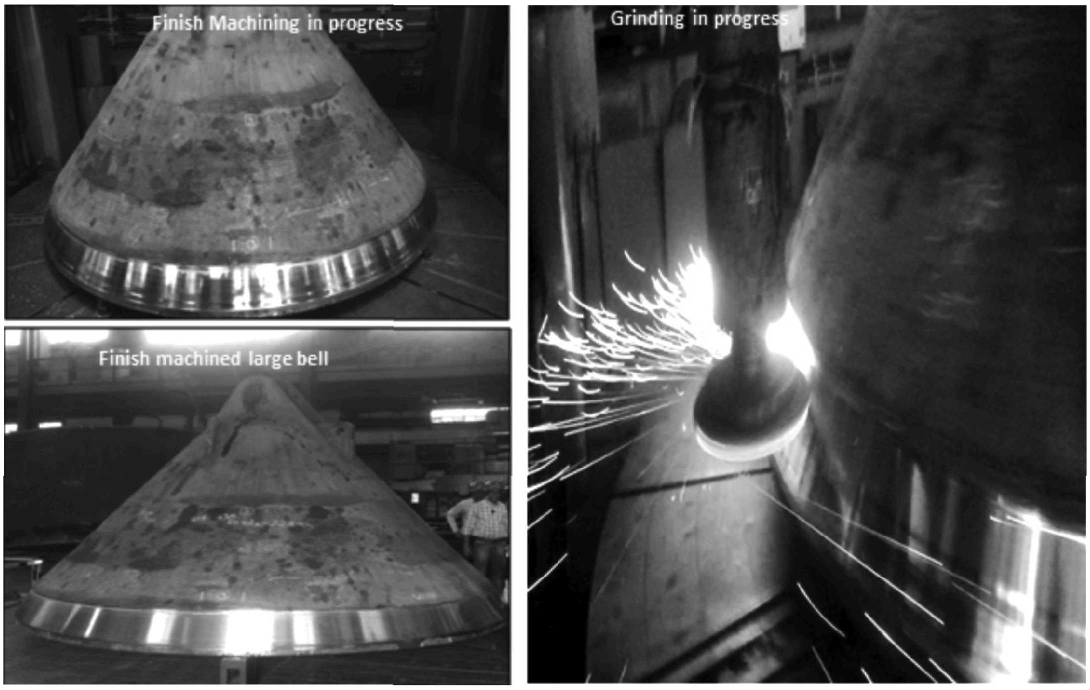

Fig.17 : Finish machining & grinding of large bell

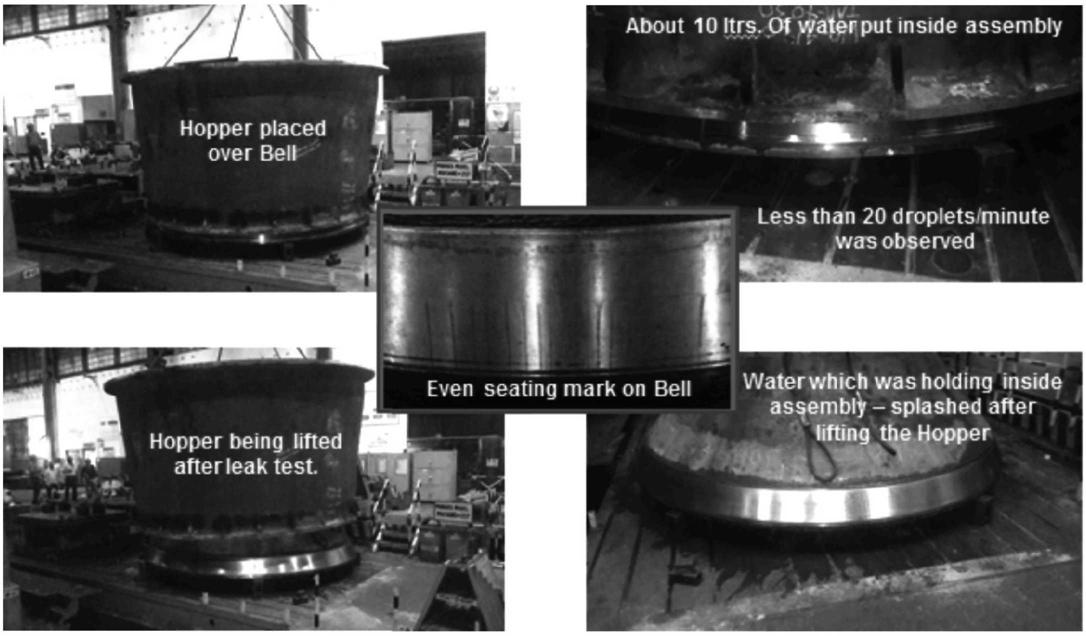

Fig. 18 : Leak test of large bell & hopper assembly

the necessary down time of blast furnace during the lead tome of 8-9 month of procurement was completely eliminated. All of these have resulted in restriction of cash outflow of the organization.

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