In-situ repair of multiple cracks present in the RTJ groove of high pressure hydrogen bearing DHDS reactor by welding

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ABSTRACT

This article describes a detailed repair procedure with necessary heat treatment involving the repair of multiple cracks in the Ring type joint (RTJ) groove of top man-way flange observed during the first internal inspection of the Reactor (25-R-01). Detailed site inspection and laboratory investigations, including visual inspection, thickness measurements, metallographic analysis, hardness testing of RTJ groove and RTJ gasket, Dye Penetrant testing, cladding disbonding testing by ultrasonic method, ferrite number measurement etc., were performed to identify the cause and mechanism of damage. Various factors like Stress corrosion cracking, Hydrogen induced cracking, sigma phase formation, have been involved with respect to the operating conditions of the equipment. In view of the above observations and ascertaining the severity of the overall damage of the Reactor, the in-situ repair methodology by welding was developed & repair jobs were successfully undertaken.

Keywords: Disbonding testing, Cladding, Dye penetrant testing, ferrite number

1.0 INTRODUCTION

Diesel Hydro De-Sulphurisation (DHDS) unit in Haldia Refinery removes the Sulphur from the sour diesel feed coming from the atmospheric distillation units (Crude distillation units). In DHDS unit, two numbers of reactors (25-R-01 and 25-R-02) are present. During the first internal inspection of the Reactor (25-R-01) at the time of Maintenance and Inspection (M&I) shut-down of DHDS, since the commissioning (after 10 yr) the multiple cracks with Circumferential and transverse branches were observed in the RTJ groove of top man-way flange locations. Detailed internal inspection, including thorough visual inspection, thickness measurements, metallographic analysis, hardness testing of RTJ groove and RTJ gasket, Dye Penetrant testing (DP testing), cladding disbonding testing by ultrasonic method, ferrite number measurement etc., were carried out to identify the cause and mechanism of damage.

In view of the above observations and ascertaining the severity of the overall damage of the reactor, repair methodology by welding was developed for suitable in-situ repair of observed multiple cracks in the RTJ groove.

2.0 TECHNICAL SPECIFICATIONS

The technical specifications of 1st reactor (25-R-01) are as follow:

Manufacturer	M/S Larsen & Toubro Ltd.
Design Temperature °C	440/177 (Internal/External)
Operating Temperature °C	410 Max
Design Pressure, Kg/Cm^{2}g	52 / Full vacuum at 177 °C
Operating Pressure Kg/ Cm^{2}g	44
Corrosion allowances	NIL (3 mm cladding)
Linings	SS-347 Cladding (3 mm)
Shell	SA 264(SA 387 Gr. 11 CL.2 + SA 240 TP 347)

3.0 OBSERVATIONS

The reactor was offered for inspection after unloading of catalyst and completion of passivation. Apart from thorough visual inspection, the Non Destructive Testing (NDT) like D.P. testing and hardness measurements of RTJ groove, gaskets, Ultrasonic Examination of welds and cladding disbonding testing by ultrasonic method, In-situ metallography were carried out. During the dye penetrant testing (DP test) of RTJ groove after opening of man way flange and RTJ gasket, multiple cracks with circumferential and transverse branches in the RTJ groove location were observed (**Fig. 1**).

As the presence of multiple cracks of such dimension cannot be allowed to operate at the high pressure hydrogen bearing reactor with respect to the operating conditions, the multiple cracks at the RTJ groove were repaired by in-situ welding and machining in urgent basis to minimize the shutdown time of unit.

4.0 PREPARATION FOR WELDING PROCEDURE

The developed repair procedure was qualified, before applying in reactor was tested with a test coupon, as per the recognized code such as ASME sec IX, using an experienced welder. The records of procedure qualification as well as performance qualification were duly maintained. The procedure qualification test coupon was made using the same P-Number base metal, cladding, and welding process, and filler metal combination, as per ASME Sec-IX. The dye penetrant test (DP test) was carried out under the supervision of ASNT level-II certified inspector with the acceptance criteria of Appendix 8 of ASME Sec. VIII Div 1.

In view of the above observations and ascertaining the severity of the overall damage of the Reactor with the help of some expert's views, welding procedure was finalized and qualified for repair of defects.

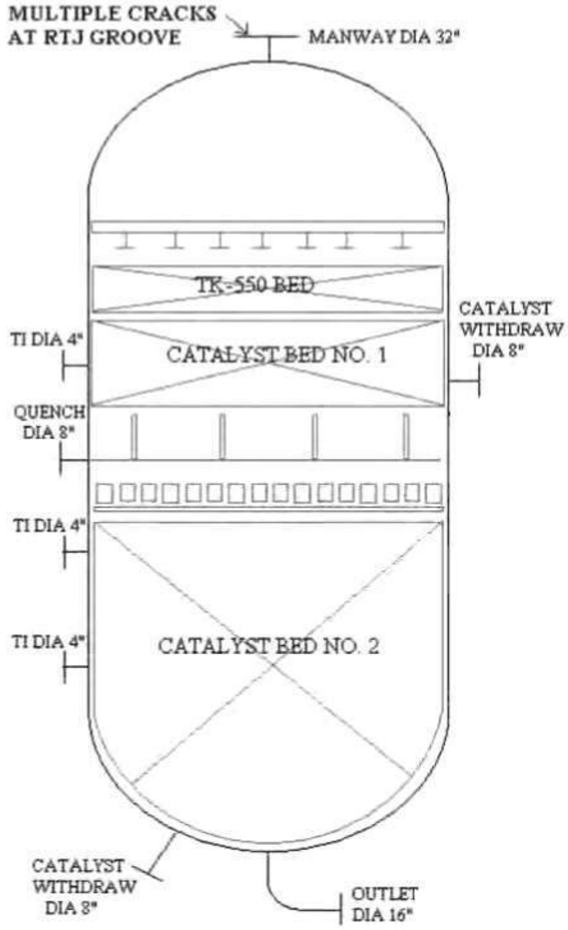

Fig.1: The cracks at RTJ groove in the schematic drawing of Reactor

5.0 REPAIR OF REACTOR AS PER APPROVED PROCEDURE

- Dressing of affected locations by grinding of above mentioned damaged locations was carried out to facilitate further operations. However, necessary precautions were

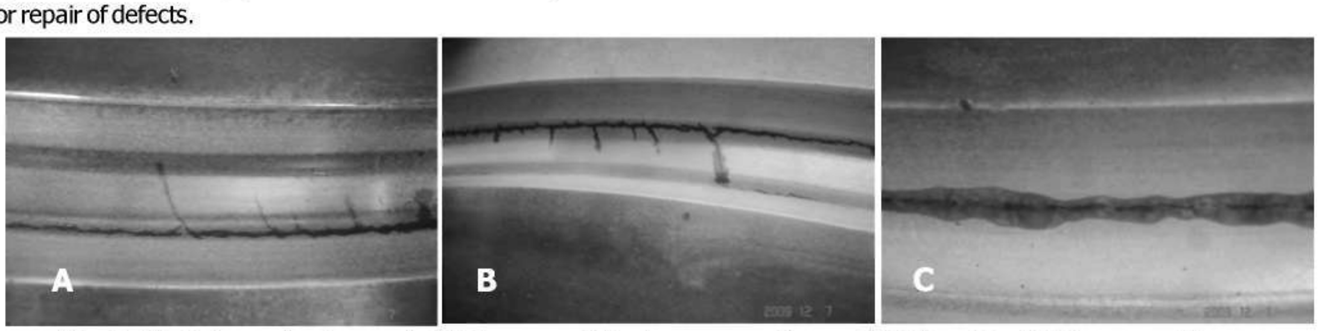

Fig. 2 : Multiple cracks observed at RTJ groove of the top manway flange (A) Outer side of RTJ manway flange- circumferential cracks with transverse cracks (B) Inner side of RTJ manway flange- circumferential cracks with transverse cracks (C) Outer side of RTJ manway flange- circumferential cracks

ensued for not to reduce weld overlay thickness any further during the dressing.

- Then D. P. testing was carried out to assess the nature of defect.
- Progressive machining (maximum 0.5 mm metal removal in one cut) was carried out and subsequent DP test was carried out, after every 0.5 mm of machining, for removal of defects (**Fig. 3**).
- Progressive machining (maximum 0.5 mm metal removal in one cut) was carried out until DP test was clear.
- Checking with $CuSO_4$ solution testing was carried out to confirm the material (stainless steel weld overlay or low alloy steel) at the depth of cutting and measure accurate dimensions of balance groove at the grinding locations.
- Preheating was done at 125 °C using gas burners and hold for minimum one hour (1 hr) before start of welding. Temperature was monitored using temperature crayons.
- Subsequent layer of weld overlay was carried out using E 347 electrode (3.2 mm dia) by SMAW process to achieve required finished groove dimensions and also welded extra thickness to take care of machining allowance. Welding parameter used : current: 80-120 A, Voltage: 22-28 V and interpass temperature of 175 °C .
- Post weld heating was carried out at 300 - 350 °C for 2 hrs before cooling below preheating temperature.
- DP test was carried out before start of machining as per acceptance criteria: Appendix 8 of ASME Sec VIII Div 1.
- After weld build-up and completion of DP test, in-situ machining as per measurement was carried out.
- Post heating was carried out at 300-350 °C for 2 hrs.
- After repaired by welding followed by grinding, final polishing with lapping was carried out (**Fig. 4**). At last, final D. P. testing was carried out to identify significant indications, if any (**Fig. 5**).

Fig. 3: In-situ machining at RTJ groove of man-way flange to remove cracks

Fig. 4 : Final polishing with lapping

Fig. 5 : Final D.P. testing after lapping to identify significant indications, if any

6.0 CONCLUSION

The complete in-situ repair job was carried out as per the developed and qualified welding procedure. After completion of repair, final polishing with lapping was carried out followed by final dye penetrant test for presence of crack in RTJ groove . No crack was observed (**Fig. 5**). After commissioning of the reactor, no leakage was observed from repaired RTJ flange. By employing this in-situ repair methodology, the repair could be successfully accomplished within the scheduled shutdown period of the unit.