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Corrosion Damages of 2205 Duplex Steel on Chemical Tanker Carrying Mineral Acids

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History on corrosion of tanks

The chemical tanker started exploitation in February 2000. The cargo acid tanks have been constructed from 22 % Cr, 5,5 % Ni, nitrogen enhanced duplex stainless steel 2205. The cargoes that have been shipped were sulphuric acid (12 journeys), caustic soda (1 journey) and phosphoric acid DFL or MGA (15 journeys). Voyages were mostly along the western American coast.

The vessel passed guarantee repair work one year after construction. Ship designing was not satisfactory. The cargo acid tanks got external reinforcement of some transverse bulkheads, got internal stiffeners and passed second mineral acid passivation. After two and a half years after construction external reinforcement of some transverse bulkheads and pad eyes for hanging stages were fitted.

Trace weld leakages were discovered in two tanks (two and a half years after construction). Small openings at transversal bulkhead/bottom weld in one tank were found eight months later. Weld repairs and third mineral acid passivation were performed. At that time heavy grinding work to remove rust was carried out. After four years of exploitation cracks of welds connecting main deck with transverse bulkhead of the most corroded tank and a crack in one tank bottom were found. Corrosion around welds of eye pads, rust stains over top and ceilings in all tanks (15% in the most corroded tank) and some small pits were also registered. Besides overheated strips after welding bulb plate elements from external side of transversal bulkheads started to rust four years after ship construction.

The author survey on tank corrosion was performed 5 years after ship construction during a shipping brake for repairs done in a Panama shipyard. The purpose of a survey was to

evaluate corrosion of ship tank walls. Time period for a survey was limited. Testing of wall thickness was not included to the investigation. The survey based mostly on potential measurements performed using 175 True RMS Multimeter FLUKE.

Corrosion damages

Some of corrosion damages were serious ones that could bring catastrophic effects.

One or two thick rust strips at the transverse corrugated for-bulkhead up to 100 mm wide existed over reinforcing stiffeners welded on the other side of the bulkheads.

Several fragments of the welds were completely rusted; some of them joining plates at the tank ceiling, the other joining walls with the ceiling. Several fragments of the welds were completely covered with rust or a number of rust spots were over or around the welds between the tank ceiling and the walls. Rust was located mostly around the welds at some distance but in some cases close to the welds. Single shallow pits were under rust spots in places that were heavily ground some time ago. There was no bottom weld corrosion.

When welds joining the ceiling plates were completely covered with heavy rust the surrounding surface of the plates was covered with superficial rust.

The edge sides of nearly all vertical and bottom stiffeners were covered with heavy rust spots. The edges under rust were smooth, they were not ground before. In many cases rust was concentrated at one edge side of the stiffeners. At some stiffeners weld slugs were over welds. The large surfaces of the stiffeners were with no rust at all.

Most of the ladder steps were covered with small rust spots. All the railings were covered with small rust spots. Both of them steps and angles had potentials over 1000 mV against zinc/zinc sulphate electrode. There was no rust on the ladder sides (angles having wide surface), neither on ladder welds.

Heavy rust was situated within and around of the inspection manhole. The nuts and bolt heads at a single manhole were partly covered with rust. Eye pads and the ceiling around their welds were covered with rust.

The slope part of longitudinal starboard side bulkheads was at some cases covered with rust spots. A single filling pipe was covered with rust spots.

Reasons of corrosion

Active potentials values (around 500 mV against zinc/zinc sulphate electrode) of certain number of plates at the top part of some tanks suggested that they were made from different steel than duplex 2205. These potentials values suggest that the quality of the steel is lower compared to duplex 2205 (potentials over 900 mV).

Rust on welds could be a result of slight corrosion in the case of some overheating, heat input not high enough, application of lower grade electrode, imbedded external iron. The potential values after passivation of below 600 mV of a few weld segments means structure change or improper welding material quality. The duplex steel becomes sensitive to corrosion in the case of enriching ferrite content over 60% (too small concentration of austenite). Overheating, that is too long time of high temperature 300-1000°C increasing ferrite, delta, alpha prime and

intermetallic phases /1,2/ could be seen in form of heat tints. The steel may suffer from embrittlement if was hold at temperatures above 300°C even for short time. Cr,Mo-enriched intermetallic phases precipitate preferentially at δ/γ interface and within δ -ferrite grains at the temperature range of 875 ~ 900°C /3/. Exceedingly low heat input may result in fusion zones and HAZ, which are excessively ferrite. While duplex steel gets change of its metallic structure due to improper treatment, it loses its good toughness and corrosion resistance.

Welding of thick stiffeners from the external side of tank transverse corrugated bulkheads affected heavy walls corrosion from the tank interior side in form of strips around 100 mm wide. An active potential was the reason of overheating that led to the structure changes and diminished stainless steel corrosion resistance. The design welding procedures did not lead to a favorable phase balance after welding to avoid precipitation of detrimental intermetallic or nonmetallic phases. Passivation done after rust removal could increase corrosion resistance but would not be satisfactory because of deep structure change (due to high content of alpha prime and intermetallic phases).

The fact that ladder steps and railings were covered with rust but not angles means that iron was deeply embedded most probably before construction of the ladders (for instance the elements could be situated close to a region of shot iron blasting). Most of the rust spots were present because of external iron contamination that had not been removed by previous pickling/passivating processes or happened after them.

The edge sides of vertical, bottom or ceiling stiffeners were covered with heavy rust spots due to improper cutting technology. The large surfaces of the stiffeners were with no rust at all. Edge corrosion of stiffeners, connected with structure changes, does not create any serious problem.

In some cases rust from the welds could be dispersed around by liquid cargo on over walls or ceilings. This could happen in the conditions when cargo dissolves iron and iron oxides (rust) are formed after drying. Rusted steel having different potential than clean steel surface may affect galvanic corrosion. Activity of the corrosion cells that are formed over the plates is much less dangerous compared to rusted welds.

Conclusions

Corrosion of plate welds is the most dangerous problem as regards tank tightness. It was found that some of weld segments had potentials showing bad quality.

The overheated strips of the transverse corrugated bulkheads at the top part of the tanks, having active potentials, corroded after each passivation. This fact allows drawing the conclusion that there was very deep overheating with the resultant high structure change.

The suspicion that some plates were formed from the steel different than other duplex steel plates could be clear up by metallurgical investigation.

Rusting of ladder steps, railings and edges of stiffeners, is with no importance as regards tank durability, and may be easily and continuously controlled. On the first occasion these elements may be cleaned once more by application of pickling/passivation paste. The mentioned parts could be resistant against rusting after passivating.

References

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