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The Importance of visual Examination in the Failure Analysis: Case History of a Microbiologically Influenced Corrosion

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In this paper we present a case of microbiologically influenced corrosion interesting several stainless steel storage tanks of a sugar Refinery.

An accurate visual examination of the damage morphology, together with a long experience in failure analysis permitted to recognise the bacteria attack to be liable for damage.

This hypothesis excluded other corrosion phenomena typical of stainless steels.

The microanalysis results obtained on the deposits taken from the surface of the storage tanks confirmed the original hypothesis.

Further metallographic examination by replica technique excluded the presence of stress-corrosion and allowed a feasibility plan for repairing the tanks.

INTRODUCTION

The case, discussed together with technicians of a sugar refinery in Saudi Arabia, concerns a corrosion phenomenon that interests stainless steel vessels.

At the beginning this phenomenon was considered as chloride corrosion on the ground of experience. This interpretation was also justified as the vessels were placed in a seaside environment.

It was requested to determine the type of damage, the stress corrosion phenomenon and the metallographic conditions because of its importance and extension.

The results obtained from the examinations had to establish the possible remedies for keeping the vessels in working conditions.

EXAMINATIONS SCHEDULE

Two initial phases (for the definition of the phenomenon and the type of metallurgical damage) and two final phases (subordinated to the initial results that are linked to the surface neutralisation, in order to stop the corrosion phenomena and to the rehabilitation of the most important corroded areas) were planned.

The examinations performed were the following:

- Visual Examination;
- Metallographic Examination by Replica Technique.

BASIC DATA

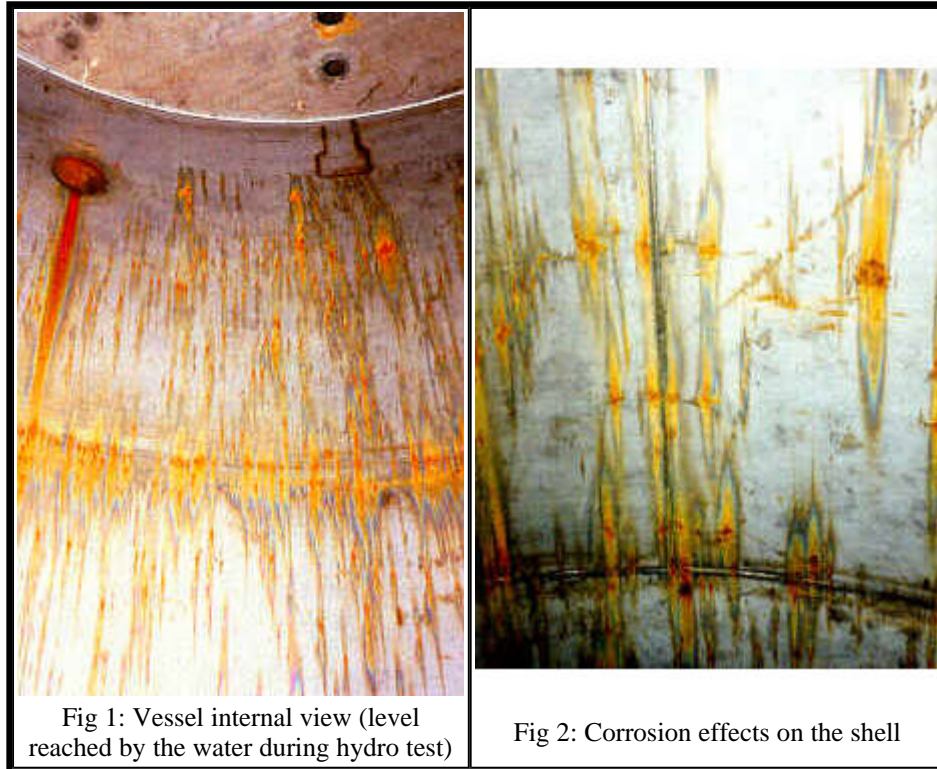
The inspection of corroded plates was performed in refinery complex under construction. The dimensional plates characteristics of some vessels affected by corrosion phenomena were:

- Bottom : 5 ÷ 20 mm (thickness)
- Shell : 4 ÷ 8 mm (thickness)

RESULTS OF VISUAL CHECK OF THE PLATES

Shell plates

The surfaces affected by corrosion phenomena were located between a top line at 30÷80 cm from top cover and the circumferential seam connecting shell to bottom (Fig. 1 and 2).



The aspect of the corroded areas is generally similar to two vertical compass needles (streaks) having the edges in opposite positions and having the core-origin of pitting corrosion - in correspondence of the top edge of circumferential seams.

Additional vertically pitted areas have been visualized in correspondence of superficial incisions, welding circumferential joints and welding anomalies.

Notes:

- a. Top borders of areas including corroded surfaces corresponded exactly to the highest level reached by water during hydrostatic test of vessels.
- b. In the upper parts of the shells (from the highest nozzle up to cover plate) the surfaces were clean and integer.

Bottom plates

The areas affected by pitting corrosion phenomena (Fig. 3 and 4) were spread at random on the plate of the bottom head. They were covered by corrosion deposits having a crest in correspondence of the origin of pitting; the average diameter of corroded zones was about 50 mm; the central height of the pit was in the range of 1÷3,5 mm.



Fig 3: Corrosion effects on the bottom



Fig 4: Detail of a pit near the bottom weld

NON DESTRUCTIVE EXAMINATIONS (BY REPLICA TECHNIQUE)

Non destructive examinations were performed on two of the corroded vessels.

a. Check of pit depths

Depths of 4 pit centre lines were obtained as difference between the actual thickness of uncorroded plate (A), in the surrounding of each test point, and the plate thickness of the pit centre line measured after grinding (B).

A digital ultrasonic meter was used for carrying out the measurements, and the following results were obtained:

Position	Thk A (mm)	Thk B (mm)	Pit depth (mm)
1	8,8	5,3	3,5
2	20,9	17,6	3,3
3	6,4	5,1	1,3
4	8,4	6,9	1,5

b. Metallographic examinations

Non destructive metallographic examinations of some corroded and uncorroded zones were carried out by "reflective metallographic replica" method according to ASTM E 1351/90, in order to verify the presence of carbide precipitation in the microstructure of base materials, welding beads and heat affected zones (H.A.Z.).

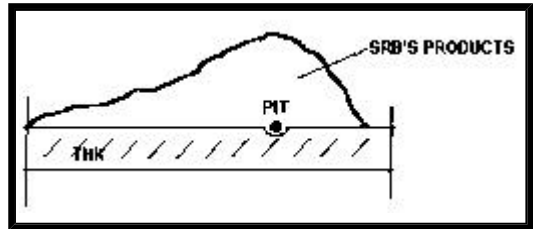
The films obtained by replica test were observed with optical microscope and gave the following results:

- Base material: microstructure formed by austenite grains without carbides precipitation
- Welding bead material: microstructure formed by austenite dendrites with free ferrite

ANALYSIS OF CORROSION CAUSES

The characteristics of the examined corroded areas (shape, extension, pit depth, vertical growth, etc.) are the typical ones normally found in all the cases where corrosion is associated to the

growth of moving microbacteria ("biological corrosion"). The progressive superficial accumulation of deposits (see the following sketch) indicated the presence of Sulphate Reducing Bacteria (SRB):



The growth of microbacteria on the plates was explained only assuming that microbacteria had been in the water used for hydrostatic tests of the vessels and they were not perfectly dried after test completion.

This assumption was confirmed by the absence of corroded areas above the maximum water level during hydro test.

Microbacteria's metabolism produced acid secretions that damage the passivating oxide film and their accumulation led to a shield effect respect to the adjacent areas. The surface of AISI 304L plates was then locally exposed to anodic corrosion with consequent "pitting" effects and accelerated dissolution of the base material inside the pits.



Fig 5: Typical SRB's products.

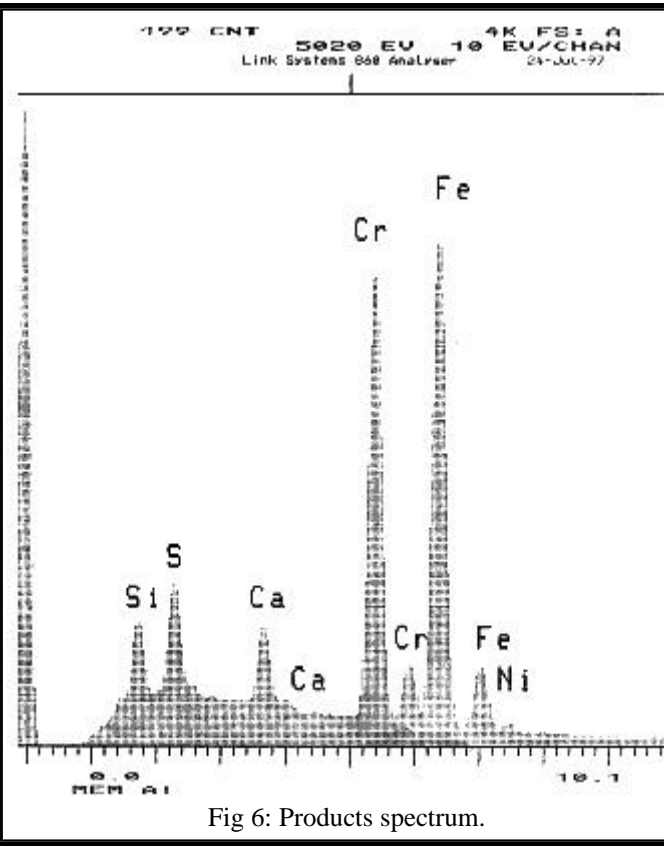


Fig 6: Products spectrum.

RECOMMENDATIONS FOR REMEDIAL WORKS

Remedial works were calibrated in accordance with the actual characteristics of the corroded areas and therefore the steps of the procedures to be used on shell and bottom for restoring a

homogeneous passivating film of metal oxides on the surfaces were partially different.

a. Repairing procedure for shell plates

Since the shell plates were mainly affected by superficial corrosion (low value of pit depth) they were treated as follows:

1. Soft grinding of all corroded areas by stainless steel grinding disk.
2. Application of pickling-passivating paste.
3. Rinsing of the surfaces using demineralized water properly treated. Water injected onto the plates with a H.P. water launcher.
4. Final controlled drying of the surfaces by blowing air with an air fan.

b. Repairing procedure for bottom plates

Bottom plates showed corroded areas with deeper pits that had to be covered with additional metal; thus, the relevant procedure included:

1. Grinding(as previous paragraph).
2. Checked drilling of pits around their central points by using stainless steel drills as follows:

Design plate Thk (mm)	Drill bit Ø (mm)	Grinding max depth (mm)
5-6	8	2
8÷20	10	4

3. Filling the ground areas with additional metal using approved welding procedure.
4. Grinding of surplus welding materials.
5. Dye penetrant liquid examination of weldings.
6. Pickling-passivation (as in previous paragraph).
7. Rinsing (as in previous paragraph).
8. Final drying (as in previous paragraph).

CONCLUSIONS

On the plates, treated in accordance with the producers of par. 5.0 and with the specified water, the passivating metal oxide films was restored to a status equivalent to the original one, so that the corrosion phenomena was permanently stopped.