Investigation of corrosion in evaporator syrup pipes in sugar plant - Case Study

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Abstract

Corrosion in the machinery of the sugar industry is main problems in the worldwide. Acidic nature of the initial extract, high temperature, high velocity fluid motion, and the addition of alkali and acidic compounds in various stages of production ، types of corrosion in plant systems provides. In this study the corrosion of pipes in the evaporator syrup and practices to prevent or reduce the pay. According to the experiments and studies conducted in the raw syrup evaporator pipes on the outer wall of the tube is in contact with the steam and water condensation، General and uniform corrosion and erosion observed. However, corrosion in this area is not due to the destruction of the pipes. The inner wall of the tube is in contact with raw syrup ، pitting type corrosion leads to the destruction of the sedimentary layers were detected. Pitting produced because of thick sediments around the pipe, thus reducing the amount of oxygen in the sediments and the appearance of anodic areas and finally the tube is perforated. The corrosion rate was calculated 24/289MPY according to the experimental weight loss that is very high. The solution, replaced with pipes made of stainless steel type 304L (L grade was selected for welding), which has good resistance to pitting caused by a shortage of oxygen and its application in food industry and also allowed regular use of anti-fouling agent was advised.

Keywords: pitting corrosion، weight loss ، Stainless Steel 304L، raw syrup Pipes.

Introduction

Corrosion is considered as a serious problem in sugar plants. In the early sugar plants, most parts used to be made of plain carbon steels. However, in time and due to the appearance of local and biological corrosion as well as considerable wear in various parts resulting from acidic pH values of the existing compounds in sugar syrup, carbon steels in sugar plant equipment were gradually replaced with stainless steels. In the following paragraphs, we review the literature regarding the history of corrosion in the sugar industry and other relevant subjects in this regard [2] .

An important reason for using stainless steel tubes and pipes in food industries was that they prevented contaminating ions from entering water and other food stuffs [2].

Wesley et al. [5] studied biological corrosion in three steels, namely, AISI 304, AISI 439, and AISI 444. They concluded that AISI 444 and AISI 439 had the highest and lowest corrosion resistance respectively. The high corrosion resistance of AISI 444 is due to the presence of molybdenum in its chemical composition. These researchers also showed that, as compared with the plain carbon steel AISI 1010, the AISI 444 and AISI 1304 stainless steels exhibited much greater resistance against pitting and groove corrosion caused by sugar syrup. This observation is completely justifiable due to the high chrome content as well as the passivity of the AISI 444 and AISI 304 steels.

Increasing the chrome and molybdenum content of stainless steels improves both their passive layer characteristics and their resistance against pitting. Another solution is adding inhibitors such as chromates and molybdates in the environment. Through changing the passive layer and the solution inside the pitting area, these inhibitors can stop the pittings from spreading. One solution for reducing corrosion is to use stainless steels with high corrosion resistance. For example, two-phase 2205 steels or ferritic steel 904 L are more suitable solutions in this regard (Eghbali and Ilevbar) [4,8].

If the design or operating conditions lead to recurrent sedimentation in the system, then the best solution would be to wash away these sediments with water vapor at high pressure (Thushil) [6].

kain et al. [9] showed that in applications where there is the possibility of groove corrosion, the first thing to be considered by engineers should be the chlorine content of water since chlorine content plays an effective role in the groove corrosion resistance of stainless steels and is an easy parameter to measure.

Thushil et al. [11] showed that the best efficiency for stainless steels is obtained under clean running water conditions at velocities exceeding 1.5-2 ft/s (0.5-0.6 m/s). Under high water hardness and unpurified water conditions, a minimum water velocity of 3 ft/s (1 m/s) is recommended to prevent sedimentation.

Kebrin et al. [10] showed in their laboratory research that in most natural waters with a pH value of 6.5-8.0 and chlorine concentrations of less than 200 mg/lit, stainless steels L304 and 304 are rarely corroded. They also found that groove corrosion of stainless steels 310 and 316L very rarely occurred in natural waters with a pH range of 6.5-8.0 and chlorine concentrations of less than 1000mg/lit. However, to be very conservative and to ensure that groove corrosion would never happen, it is better to use stainless steels 304 and 304L for chlorine concentrations of less than 50 mg/lit and stainless steels 316 and 316L for chlorine concentrations of less than 250 mg/lit. Where chlorine content in water exceeds 1000 mg/lit, it is advisable to use stainless steels with high molybdenum content or combined stainless steels.

Kebrin et al. [10] showed in their laboratory research that stainless steels exhibit good resistance to groove corrosion even in deoxygenated sea water containing 18,000 mg/lit chlorine. Their obtained data showed that stainless steel 304L was very vulnerable to groove corrosion in highly oxygenated environments with a chlorine residue of as little as 3-5 mg/lit, whereas we expect stainless steel 316L to exhibit better resistance to corrosion under similar conditions of chlorine and oxygen contents. oxygen content of the syrup also increased the rate of corrosion.

Materials & Methods

The study was conducted according to the following steps

(A) Specify the type of pipe and its physical and mechanical properties,

(B) Specify the characteristics of sugar syrup such as pH and temperature,

(C) Measuring the exact dimensions and weight of a square cm of healthy tube,

(D) Specify the exact time to start applying to the destruction of the pipe,

(E) Select one of perforated pipes in accordance with paragraph (d),

(F) Photography and studied visual outer surface,

(G) Incision and evaluate the inner surface of the pipe

(H) Sediment removal and photographed with a stereo microscope.

(I) sampling a square centimeter of the hole in the pipe deposits precise and accurate weighing

(J) Microscopic examination includes polishing, mounts, and metallographic etching of the same region,

To determine the chemical composition of the steel and pipe quantometre sampling and analysis were performed. Then taking the time to extinction was calculated. To determine the characteristics of sugar syrup, various tests such as pH and temperature and pressure were measured. Then tested according to ASTM G-1 to healthy weight loss value of a square centimeter of the sample tube was measured. Then a square centimeter of sediment samples and cut holes in the sediment removal and photographed and weighed. Then mounted and polished for metallographic examination and were etched in a solution Naytal. Then were analyzed using optical microscopy. For descaling the tubes completely, we put and wash them for more than one hour in 15% sulfuric acid pickling solution having 1 gram urotropin inhibitor per liter.

Discussion and results

Based on the analysis performed, the type of pipe used is mild steel ST37. Chemical composition, mechanical and physical properties in Table (1) are shown.

Table 1- The chemical composition and physical and mechanical properties of the tube

Steel	Yield stress N/mm²	Tensile strength N/mm²	Density Gr/cm³	C	Mn	Si	S	P	Cu
ST37	235	360	7.850	0.26	0.75	0.40	0.05	0.04	0.20

Studied in our factory, there are six evaporators. In the first evaporator, condensate is produced and the steam temperature of the steam oven, for subsequent injection into reservoirs decreased. View other bodies in Table 2 are shown.

Table 2- Characteristics of juices

Number of bodies	second	third A	third B	fourth A	fourth B
Temperature (°C)	97	95	92	90	85
Vacuum pressure (condensate production) mmhg	400	400	400	400	400

Condensing pressure input bar	2.5	2.5	2.5	2.5	2.5
pH	6.9	7.1	7.1	7.2	7.3

Measurement and weighing of samples of healthy tube in Table (3) can be seen. Level Metal for the calculation of standard ASTM G1 will be a square centimeter. Preparation of the samples was performed in the following steps.

(A) Wash with water samples (normal grease) and

(B) A final wash in acetone for fat.

Table 3- details the healthy sample tube

The weight of one square centimeter gr	Thickness mm	the outer diametermm	inner diameter ofmm
1.59	2	33	29

Applying to perforation the tube was calculated as follows:

T= 25*24+29*24+31*24+31*24+31*24+31*24+31*24+31*24+30*24+30*24+9*24=**7416h**

All tubes were examined surface. Surface rust orange and black, it was found to be uniformly.

No cracks or holes visible on the exterior of the pipe were observed. But it is necessary to take a closer look at the cut pipe and the inner surfaces of the study. Pictures in Figure (1) are shown.

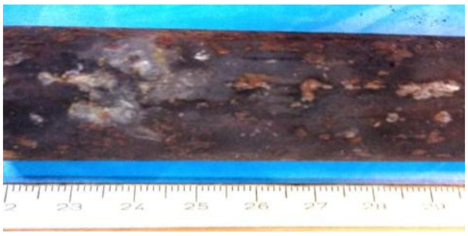


Figure 1- Image exterior perforated pipe

Located on the inner surface of the pipe deposits white. Gender analysis was performed with the salts of calcium, phosphate, oxalate and the silicates. Pictures in Figure (2) are shown

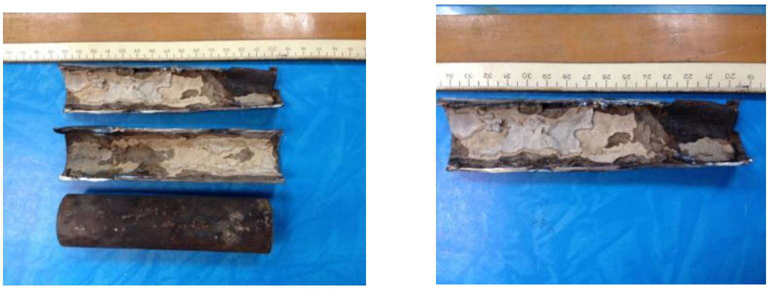


Figure 2 - Images from the inner surface of the tube before removing sediments

Sediment removal and imaging was performed with a stereo microscope. In the pictures, holes and roughness caused by corrosion are marked with circles. Pictures can be seen in Figures (3-4) with different magnifications.

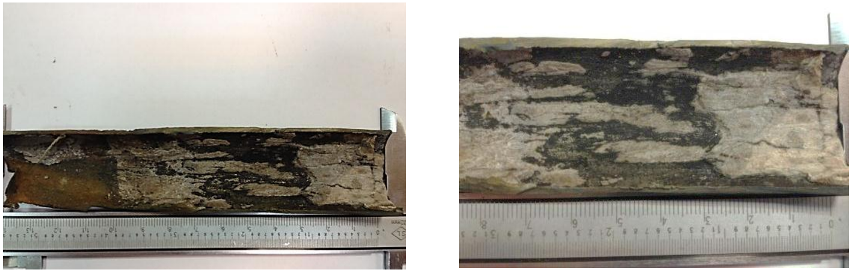
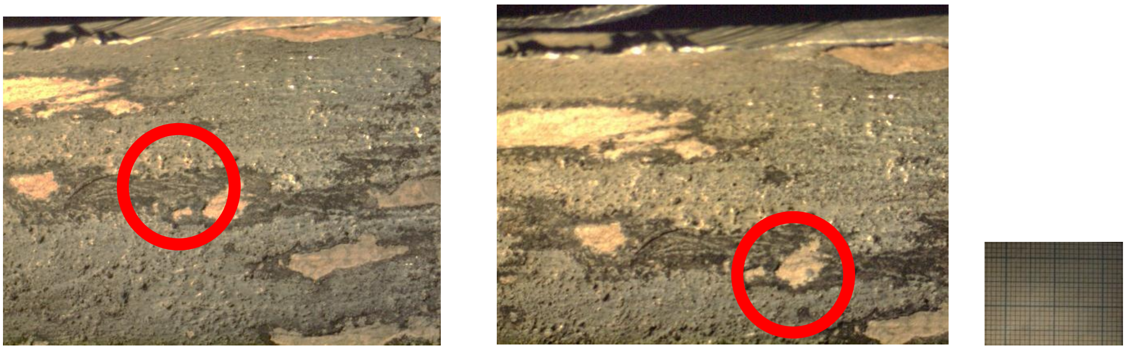


Figure 3- The internal picture tube after removing sediment



1=0.7 mm

1=3 mm

1=5 mm

Figure 4. The internal picture tube with three zoom stereo microscope after removing sediment

Of the sediment that was thin and holes were sampled. Measurement and weighing of samples in Table (4) can be seen. Level Metal for the calculation of standard ASTM G1 will be a square centimeter.

Table 4. Sample characteristics of corroded

weight gr	Tube thickness mm
1.18	**1.55**

Before etching, black holes were found in it. Etched and examined under a microscope, we observed that the microstructure of the tube, ferrite - perlite and has not seen any major structural changes. It is well known that the type of corrosion leads to perforations in the pipe deposits, was the pitting and Crevice corrosion. In the figures(5-6) holes caused by corrosion are marked with circles.

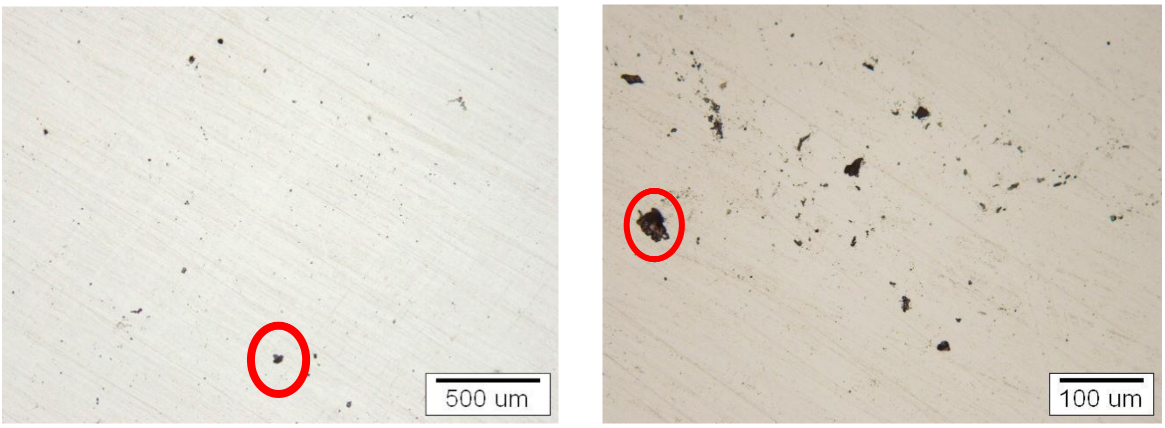
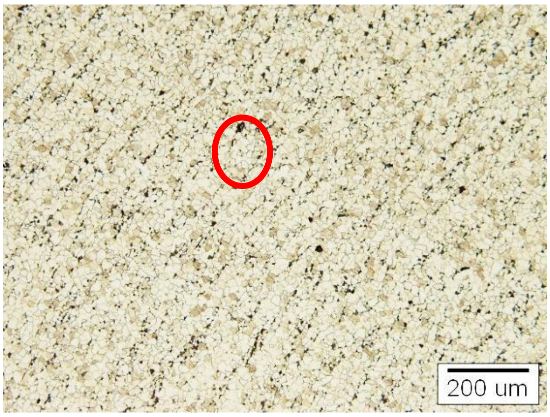


Figure 5 - metallographic image before etching



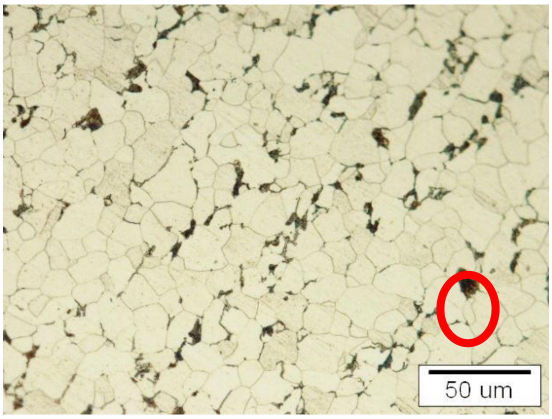


Figure 6. etched metallographic image

The cause of this type of corrosion, forming sediments are thick around the pipe. This reduces the amount of oxygen in the sediments and the formation of the oxygen concentration cell. In the sediments, forming the anode region. Where the iron oxide layer formed is weaker, a small anode is composed of a large cathode and causing severe localized corrosion pitting that would be continues until perforations tube. Due to penetration and retention of the corrosive under deposition , the Crevice corrosion occurs

To calculate the corrosion rate is:

Corrosion rate =LW/D.A.T= $\frac{0/41gr}{100\text{mm}^2\times 7416\text{h}\times 7/850\text{gr/cm}^3}\times\frac{100\text{mm}^2}{1\text{cm}^2}\times\frac{1\text{ inch}}{2/54\text{ cm}}\times\frac{1000\text{mils}}{1\text{ inch}}\times\frac{365\text{ day}}{1\text{ year}}\times\frac{24\text{ h}}{1\text{ day}}=\mathbf{24/289MPY}$

According to our calculations, the corrosion rate is very high.
The amount of chloride in the system analysis was performed with less than 5mg/lit. The amount of oxygen in the system analysis is carried out between 5-8 PPM.

Conclusions and recommendations

A - Corrosion leads to the destruction of the pipes, Was pitting under the sediment
B- Solution, replacing the pipe materials, inhibitors materials and also removing sediment deposits made periodically by the water pressure, recommended
C- With respect to syrup pH, the amount of chloride and oxygen, welding parts and with regard to economic issues and costs, replacement of stainless steel 304 L was proposed.
D- recommended health coverage may be investigated and appropriate use of their sugar industries, to be used

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