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Eddy current analysis of shipped stainless steel heat exchanger bundle

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ABSTRACT

In this paper, we present the results of a failure analysis done on new heat exchanger tubes, which shows loss of thickness during a EC inspection to stablish a prior loss of thickness base line aiming guarantee fitness for service during its working life. The root cause analysis indicates that there is intergranular corrosion due a differential concentration caused by seawater evaporation inside the tubes during the ship transit from the port of origin in China to the destination port in Brazil.
The intergranular corrosion depth showed by root cause failure analysis is smaller than that showed by EC inspection. We attribute the EC inspection results deviation to a tube magnetisation due to mechanical stress and to a secondary phase due to an incomplete solubilisation after tube conforming and welding.
Traditionally, these tubes are visually inspected and deemed acceptable but our conclusions reveal that eddy current testing is capable of detecting some corrosion anomalies which makes the tubes unfit for service.

Introduction to the case study

Ensuring the integrity of industrial equipment operating under pressure such as heat exchangers is a global concern to the owners of such equipment [1]. Failure in service can cause severe accidents involving loss of life, environmental damage, damage to property and to the reputation of the owner of the equipment, interruption to the production and maintenance costs [2].

It is common practice for all tubes manufactures to protect both tubes end with plastic caps to prevent the ingress of water and other materials, which can cause damage to the internal tube surface [1], as shown in Fig. 1 below.

A heat exchanger manufacturer based in Brazil was expecting a shipment of heat exchanger tubes from China. The heat exchanger owner contracted Technotest to perform an NDT inspection prior to receiving the heat exchanger at their site aiming stablish a base line for loss of thickness for subsequently inspection during the equipment working life. It is however common practice before the commissioning to inspect the equipment to ascertain its fitness for service regarding corrosion and other damages to guarantee a secure in-service life according ASME code [3]. The inspection NDT method used for this depends on the construction standards. The most often used NDT method for stainless steel heat exchangers

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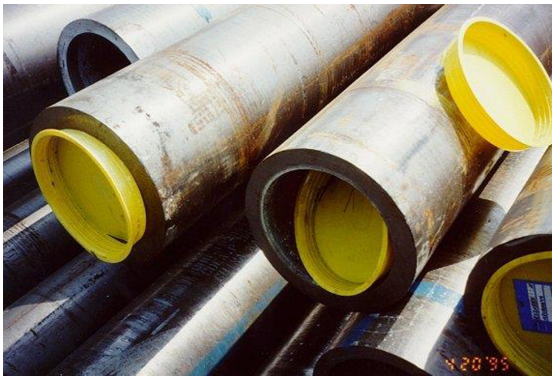

Fig. 1. Plastic caps cover at the end of the tube prior to shipment.

Table 1
Differential channels parameters.

Essay parameters	Channel 3	Channel 4	Parameters (Mixer 1)	Mixed channel 1 (Mixer 1)
Frequency	60 kHz	40 kHz	Gain	300
Phase angle	81°	324°	In Phase	00
Gain	95	115	Out Phase	24
Horizontal Sens. – H	1.00	1.00	H Weight	87
Vertical Sens. – V	1.00	1.00	V Weight	51
Filter LP	70	70	H (Sens.)	1.00
			V (Sens.)	1.00

Table 2
Parameters relation between loss of thickness and phase angle.

Percentage loss of thickness	Phase Angle Channel 3	Phase Angle Mixed Chanel 1 Mixer 1
Through hole 100%	35°	35°
External hole 80%	56°	50°
External hole 60%	75°	69°
External hole 40%	106°	93°
External hole 20%	111°	100°

tubes bundles is eddy current testing [3]. This NDT method is sensitive to localised corrosion, general corrosion and cracks on both tube surfaces, internal and external [3].

Method and results

The NDT method used to carry out this first inspection was eddy current. The heat exchanger tube bundle was made from a seamless stainless steel ASME-SA 213 TP 304L, with 25.4 mm internal diameter and 2.77 mm thickness prior to receiving it at the manufacturer's site. The eddy current inspection was performed according ASME code, section V, article 8, and appendix 1 [3], using conventional internal probe with 85% fill factor with the test parameters showed in Table 1 and Table 2.

After completion, the heat exchanger tubes inspection shows a loss of thickness to the internal tube surface as shown in the tube sheet in Fig. 2.

The tube sheet map received from Technotest shows many tubes with general corrosion between 0 and 20%, some tubes with general corrosion between 61 and 80%, 3 tubes obstructed and one tube with general corrosion between 81 and 100%.

These results were not expected for new tubes, specially one tube with general corrosion between 81 and 100%, and it required an in-depth analysis by other methods to determine the root failure cause. Aiming to determine the root cause, two tubes were removed from the tube bundle. One of the tubes has no loss of thickness is identified as sample 2 and the other which shows a loss of thickness between 81 and 100% under eddy current test is identified as sample 1. Both samples were put through a mechanical, chemical and metallurgical analysis. The tubes were cut in the middle and examined for indications of corrosion.

The analysis undertaken were:

- Visual inspection to verify any possible indications of corrosion