The Use of High Resolution Magnetic Flux Leakage for Life Prediction

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Abstract. Several techniques can be used to develop important life prediction information regarding structural conditions of storage tank bottoms. However, there is a limited availability of test that can be obtained from in service structural components. The reasons for applying life prediction methodology to aging storage tanks: more stringent safety and environment regulations, avoid costly forced outages, the limited availability of construction sites for new tanks, the expense of constructing, etc. The cause for applying life prediction methodology in aging tanks is material degradation.

Nondestructive evaluation technique for characterizing and sizing important mechanical conditions in storage tank bottoms have been developed by the Company Rosen Inspection Technologies. The Tank Bottom Inspection Tool (TBIT) is capable to detect, data collecting and sizing in real time oriented flaws defects as well as metal loss features with length of 03 mm and depth of 50%. The technique based in high resolution MFL (Magnetic Flux Leakage) was applied in a petrochemical storage tank and compared with visual and dimensional analysis. The results show accurate information for predicting life.

Introduction

Storage tank are designed for a variety of service conditions. The condition of the complete installation, including maintenance and operation, can often be used by the inspector as a guide in forming an opinion of the care given to the tank. A review of the known history of the tank should be performed, such as:

Operating conditions, date of last inspection, current jurisdictional inspection certificate, types of defects found in last inspection, remaining life, etc.

The type of inspection given to storage tank should take into consideration the condition of the tank and the environment in which it operates.

This inspection may be internal or external, and use a variety of nondestructive testing examination methods. The purpose of an external inspection is to provide information regarding the overall condition of the storage tank. For an internal inspection, a general visual inspection is the first step in making an inspection. When there is doubt as to the extent of a defect or detrimental condition found in a storage tank, the inspector may require nondestructive testing: magnetic particle, liquid penetrant, ultrasonic, radiography, acoustic emission and magnetic flux leakage.

1. Remaining Life Assessment and Tank Bottom Inspection Technology

1.1 Metal Loss

General or local metal loss may occur on the inside or outside of the tank bottom. The Tank Bottom Inspection Tool (TBIT) is capable to detect, data collecting and sizing in real time oriented flaws defects as well as metal loss features with length of 0,3 mm and depth of 50%. The remaining life of a tank bottom with a region of metal loss can be estimated using an assessment procedure based upon condition of a minimum required thickness for intended service conditions, actual thickness and region size measurements from TBIT inspection.

$$T_x = \frac{(e_i - e_a)}{(t_i - t_a)}$$

Where:

T_x	=	corrosion rate,
e_i	=	start up thickness,
e_a	=	actual thickness,
t_i	=	initial date,
t_a	=	actual date.

The remaining life is:

$$V_R = \frac{(e_a - e_{\min})}{T_x}$$

Where:

V_R	=	Remaining life,
$e_{\min}$	=	minimum required thickness

The remaining life may be difficult to establish for some regions of local metal loss in services where an estimate of the future metal loss and enlargement cannot be adequately characterized. In this case, remediation and or in-service monitoring may be required to qualify the assumptions made to establish the remaining life.

1.2 Tank Bottom Inspection Technology

For bottom inspection there are four Non Destructive Testing (NDT) - techniques available: Ultrasonic, Conventional MFL, Eddy Current and High Resolution MFL. The differences between these techniques considering the special requirements for the tank bottom inspection are mentioned in Table 1:

Table 1. Comparison of NDT techniques considering the special requirements for tank bottom inspection

	(Manual) Ultrasonic	**Conventional MFL**	**Eddy current**	**High Resolution MFL (TBIT)**
Tolerance to debris	Low	Medium	Low	Medium
Tolerance to surface conditions	Low	Medium	Low	Medium
Inspection capacity	Only for spot measurements	Full inspection capacity, additional UT spot measurements required	Full inspection capacity, additional / validation UT spot measurements required	Full inspection capacity, no additional spot measurements required
Detect ability of small pittings	High	Low	Medium	High
Data Management program available	-	Limited	Limited	Extended

New developments are ongoing, as well in Eddy current technology as in High Resolution MFL technology. Each tank is unique in geometry, plate condition, susceptibility to corrosion etc. It is extremely difficult to develop a system that can cope with these different local conditions. Although a system can work perfectly on test plates, is does not mean that in a real tank, it can give a realistic view of the integrity of the tank bottom.

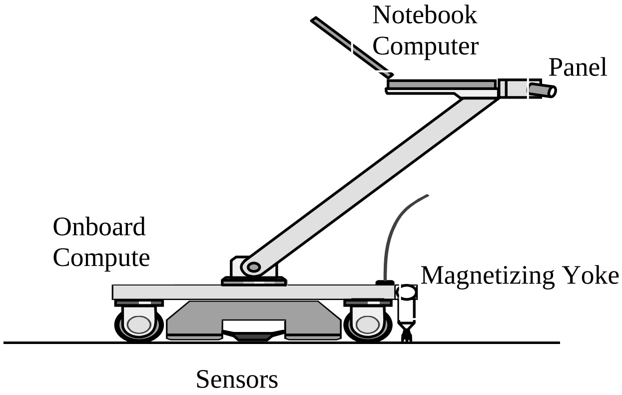
For instance, in case a tool is calibrated for a certain coating on a test plate, it does not automatically mean that the system can cope with the local conditions inside a tank where the coating thickness varies. Therefore a flexible system, less sensitive to different local conditions but with the possibility to adjust the system to the local circumstances is mandatory. These elements have been implemented in ROSEN's High Resolution MFL Tank Bottom Inspection Tool, which is adjustable to local conditions, such as influence of coating.

1.2.1 Tank Bottom Inspection Tool (TBIT): qualitative and quantitative

The Tank Bottom Inspection Tool (TBIT), applies the High Resolution Magnetic Flux Leakage inspection principle. When driving over the surface, the tank bottom is magnetized, creating a magnetic field. The onboard computer evaluates the signals accumulated by the sensors. TBIT immediately sizes every single detected feature. If the depth of the feature exceeds the percentage of the marking threshold, an acoustic signal will inform the engineer and the location of the feature will be marked on top of the bottom plate.

ROSEN has succeeded in not just performing a qualitative inspection but also a quantitative MFL inspection, so the need for UT check ups to quantify the detected features can be omitted. By directly accurate sizing all features without making numerous UT check ups, more detailed information is provided of the length, width a depth and location of the features, while inspection time is reduced to a minimum. By also applying a local power supply in stead of using cables for power supply, and various steering options, the mover ability of the TBIT in site the tank is optimized, which improves the inspection area and reduces down time. The general concept of the TBIT is displayed in Figure 1.

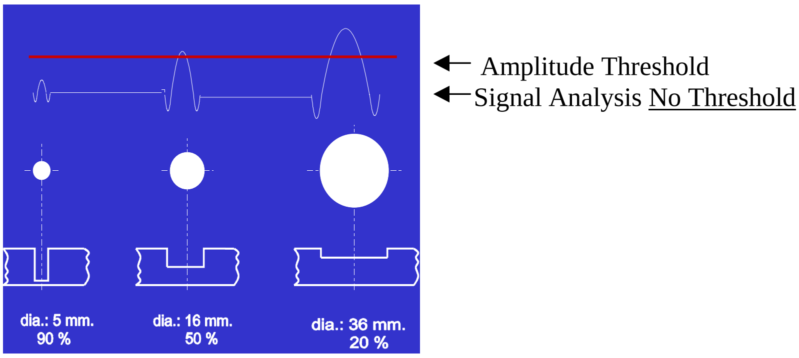
Figure 1: Tank Bottom Inspection Tool (TBIT)



1.2.2 Detection and sizing system

There are two kinds of metal loss depth criteria: Amplitude Based Detection and Signal Analysis. The Amplitude based detection sets a diameter threshold, meaning that any defect below this threshold is not detected and reported, see Figure 2.

Figure 2: Signal Analysis versus Amplitude Threshold



The Signal Analysis has no threshold, meaning that every disturbance in the MFL signal is detected and reported. TBIT calculates the metal loss depth of a detected MFL Signal on line by using a Signal-Analysis module.

The MFL Amplitude is strongly depending on length and width of a feature. Thus an uncritical pit with a large diameter will produce a higher MFL-amplitude than a critical, but small diameter pit. Owing to the force of the magnet, the magnetizing level is very high. Because of the large number of flux lines, also smaller defects are detected. Contrary to other available MFL floor scanners, the ROSEN TBIT detection threshold is set to metal-loss-depth criteria and not to the amplitude of a MFL signal. TBIT will find small, deep pittings and rejects uncritical features by using the metal loss-depth criteria.

The TBIT has several specific capabilities:

- High sensibility to corrosion and being less sensitive to debris;
- Measurement of internal and external corrosion;
- Characteristic information for each detected feature like length, width and depth is provided in real-time;
- Accurate location and sizing of features is reported on-site in order to eliminate additional down time;

- Onsite final reporting allows the operator to immediately start repair work after inspection is completed;
- Comprehensive repair-sheets are provided;
- Even small pittings are detectable and sizeable;
- Tanks with high plate thickness can be inspected;
- Very high inspection capacity, short inspection period;
- ROSOFT, the interactive tank inspection, assessment and maintenance software;
- Remote Control Mode: allows inspection of floor areas underneath heating coils, piping or other restrictive installations.

1.2.3 Specifications

The TBIT system is capable to detect transverse oriented flaws and three-dimensional defects such as cracks, cuts, pitting- and general corrosion. In addition, corrosion with longitudinal orientation will be detected as long as defects have sufficient transverse components to generate detectable magnetic field disturbance. The detection level results from the smallest detectable amplitude above the noise level of the recorded field data. The noise level is determined by the resolution of the TBIT itself as well as by the quality of the non-corroded bottom plates. ROSEN provides a specification how accurate the measurements are, and what effect some local conditions have on the reported measurements. By providing this information, ROSEN is giving a validation to the reported measurements.

1.3 PQU Tank Bottom Inspection

TBIT was applied in Petroquímica União, São Paulo, Brazil in November 09, 2004. The inspection data are mentioned below:

- Tank: FB-53A
- Bottom surface: 113 m2
- Product stored: toluene
- Bottom plate thickness: 6,35 mm
- Material: A-283 C
- Age: 36 years old

The inspected area of tank contained 14 anomalies, of which none with a metal loss over 40 % of thickness. These anomalies can be found and compared with the dimensional inspection on the Table 2:

Table 2: Anomalies found with TBIT and dimensional inspection

Number	X size (mm) TBIT	X size (mm) Dimensional inspection	Y size (mm) TBIT	Y size (mm) Dimensional inspection	Depth (mm) TBIT	Depth (mm) Dimensional inspection
1	24	25,0	10	9,0	6,19	6,0
2	25	25,0	30	30,0	6,11	6,0
3	3	5,0	47	50,0	6,19	6,0
4	12	10,0	7	10,0	5,79	5,6
5	3	5,0	61	60,0	5,71	5,6
6	21	20,0	42	40,0	6,19	6,0
7	16	15,0	7	5,0	6,03	6,0
8	17	15,0	41	40,0	6,19	6,0
9	28	30,0	27	25,0	6,19	6,0
10	8	10,0	8	10,0	5,87	5,5

11	23	25,0	39	40,0	5,79	5,5
12	15	15,0	35	35,0	6,34	6,2
13	12	15,0	40	40,0	6,19	6,0
14	12	15,0	36	30,0	6,26	6,1

2. Conclusion

The remaining life of a bottom may be determined based upon computation of a minimum required thickness for the intended service conditions, thickness measurements from TBIT, and estimate of the anticipated corrosion rate. The assessment procedures are based on a local thickness approach which provides suitable results when applied to local metal loss. The regions that presented anomalies with base in TBIT's results were removed for dimensional analysis. The found results introduced mistakes lower than 6,3 % in the depth. Thus, considering these imprecision, TBIT it introduced as tool adequate for identification of residual life at the bottom of storage tanks.

References

[1] API (American Petroleum Institute) Recommended Practice API-579. - Fitness for Service - First Edition - 2000.

[2] ASM Handbook (American Society for Metals) - Corrosion – Volume 13 – 1987.

[3] Metals Handbook – Failure analysis and Prevention – 8ª Edição -Volume 10 – 1975.