Risk Assessment of Atmospheric Pressure Storage Tank Groups Based on AST RBI

Yeping Gao

{dy8060063@163.com}

Dongying Vocational Institute, School of Petroleum and Chemical Engineering, Dongying 257091, Shandong, China

Abstract: With the rapid development of the petroleum industry, the development of petrochemical technology has shown a trend of being larger and more integrated than storage tanks, and the safety of storage tanks has become increasingly important.The theoretical approach of RBI for storage tanks is studied and a model for analysis of the possibility of tank floor failure is established. The results of the risk analysis are analysed and discussed in a practical engineering application study of RBI for storage tank groups in petrochemical enterprises. Tanks with different risk levels were selected and inspected using magnetic leakage detection methods. Localised corrosion perforation was observed in tank 100, which shows that risk analysis cannot be exhaustive in terms of details and contingencies. Therefore, more attention should be paid to daily supervision and maintenance to prevent the occurrence of incidental factors to the maximum extent possible, in order to reduce risk and ensure safety.

Keywords: RBI technology, atmospheric storage tank complex, risk assessment, petroleum storage tanks

1. Introduction

The oil and its products stored in petroleum storage tanks are flammable and explosive, so once a fire occurs, the consequences can be very serious [1]. Currently, there are a large number of storage tanks in China, but due to historical, technical and management factors, the country lacks sufficient attention to them, leaving them in an overdue state for a long time, and lacking effective inspection means and scientific assessment methods, their safety is not optimistic. Based on the above risk assessment, we can predict the possible safety hazards of storage tanks and the possible future risks, and accordingly develop corresponding inspection plans and inspection strategies, so as to make the inspection methods more targeted and also make the inspection and management behaviour more efficient, thus reducing costs while also improving the safety and reliability of storage tanks.

Based on the analysis of a large number of tank failures in the domestic petrochemical industry, Rasyimawati Mat Rashid developed a quantitative risk assessment software system based on a B/S architecture with reference to API 581, API 653 and other relevant standards. Through quantitative calculations, it is possible to determine the

ICSETPSD 2023, November 17-18, Coimbatore, India

DOI 10.4108/eai.17-11-2023.2342620

probability of tank failure, the consequences of failure and the level of risk, as well as the trend of tank damage factors [2]. To reduce the operational risk of metal storage tanks, effective testing of metal atmospheric storage tanks is required. satish S. Salunkhe proposed an effective testing method using leakage detection and acoustic emission detection techniques, based on the actual situation and the development process of the standard. The test results were validated using this method and a treatment method for detection defects was proposed. The test results show that the method is feasible in practical applications [3]. Therefore, it is important to implement scientific safety management of storage tanks and to inspect them effectively so that they can achieve the unity of economy and safety, and to transform preventive inspection into predictive inspection [4-5].

In this paper, by combining the periodic inspection project of an oil reserve base with the RBI-based risk assessment study, the predictive defects and risk development trends of storage tanks are analysed to make up for the unbreakable nature of the fixed periodicity, fixed inspection content, methods and ratios in the traditional periodic inspection regulations, and the inspection strategy is decided by the predictive defects according to the risk size and damage mechanism of the equipment. The main content of this article is as follows:

The first part discusses the importance and significance of risk assessment for atmospheric storage tank groups.

The second part provides an overview of the comprehensive facilities and risk assessment techniques for atmospheric storage tanks, including large-scale atmospheric storage tank complexes and risk based inspection methods.

The third part is a comprehensive risk assessment case of atmospheric storage tanks, including the wind of the Ma'anshan Petrochemical storage tank installation

Risk assessment, possibility of tank bottom failure.

The fourth part is a case study of risk assessment for atmospheric tank farms, including tank farm risk analysis results, magnetic flux leakage detection results, etc.

The fifth part discusses the research limitations and future prospects of risk assessment for atmospheric storage tank groups.

2. Overview of Atmospheric Storage Tank Complexes and Risk Assessment Techniques

2.1 Large Atmospheric Storage Tank Complexes

A group of atmospheric storage tanks is a collection of several atmospheric storage tanks for the storage and handling of liquid or gaseous substances [6-7]. These tanks usually have a similar structure and function to meet specific industrial requirements. To support and stabilise the tanks, groups of atmospheric storage tanks often include support structures or bracing systems. These structures can be metal pillars, frames or foundations to ensure the stability and safety of the tanks. The tanks in an atmospheric tank farm are connected to each other by piping to allow for the flow and transfer of material. Pipelines are often used to transport raw materials, finished products or to handle waste [8-9].

2.2 Risk-based Inspection (RBI) Methods

(1) Storage tank RBI method

RBI (RiskBasedInspection), i.e. risk-based inspection, is an equipment integrity management technique with a wide range of applications internationally, which integrates techniques such as device flaw detection, failure modes and damage mechanisms, and is a management method that combines reliability and economy.The RBI technique assesses the risk level of the evaluation object, focusing on the higher risk level of The RBI technique assesses the risk level of the target, focusing on the higher risk equipment, and optimises the allocation of maintenance resources according to the risk ranking. The successful assessment of the risk level of the equipment requires detailed information on the construction of the equipment, the type of material and the structure of the process, as well as the cooperation of basic disciplines such as corrosion research, damage research and materials research, making it a huge technical project [10-11].

According to the API581 specification, the risk R(t) is defined as a function of time, and its calculation formula is Equation (1), because the damage factor DF (DamageFactor) in the equipment causes the accumulation of damage over time, so the probability of failure POF(t) (ProbabilityofFailure) also changes over time, and also due to the process The probability of failure POF(t) (ProbabilityofFailure) also varies with time and can also be due to changes in process parameters such as temperature, pressure and fluid corrosion. The COF (ConsequenceofFailure) is divided into the consequence impact area CA, i.e. the area consequence, and the economic consequence FC, as shown in equations (2) and (3), in area and economic terms respectively.

$$R(t) = POF(t) \bullet COF \tag{1}$$

$$R(t) = POF(t) \bullet CA \tag{2}$$

$$R(t) = POF(t) \bullet FC \tag{3}$$

The POF and COF values are plotted on a risk matrix, with the two values increasing from the origin to the X and Y axes respectively, and the assessor develops an appropriate inspection plan for the equipment based on the risk level corresponding to the matrix.

(2) Comparison of RBI technology with traditional inspection

Typically, equipment is inspected at fixed inspection intervals based on experience and relevant regulations. The potential mechanisms that cause equipment failure and the possible failure modes that correspond to the damage mechanisms are not considered, and the specific content of the inspection is not classified, which leads to a waste of resources and increased costs.

In contrast to the RBI method, traditional inspection: all equipment needs to be inspected regularly in accordance with the corresponding regulatory requirements; the inspection period is relatively fixed; and the inspection items are too complete and unfocused, resulting in high input inspection costs. RBI technology, through risk analysis, to identify high-risk areas, and key testing, can effectively reduce inspection costs, the process is targeted. While traditional risk assessments have focused on safety-related issues on site, RBI technology focuses on integrated risk management, including: off-site risks, business interruption risks, environmental damage risks, etc. RB1 technology can analyse any combination of these risks and can be extended to additional equipment such as instrumentation, control systems, power distribution and critical utilities.

Using RBI techniques for risk assessment has the following advantages.

1) Identify equipment and piping that should be prioritised or prioritised for the next inspection.

2) Identify equipment that can be inspected at longer intervals.

3) Provide a scientific basis for optimising traditional testing protocols.

RBI does not aim to extend the testing time, but rather to design an optimal testing strategy that combines safety and economy. The RBI method is used to determine the inspection cycle in order to meet the needs of long-term stable operation of the equipment as far as possible, while ensuring the essential safety of the equipment.

3. Atmospheric Pressure Storage Tank Complex Risk Assessment Case

3.1 Risk Assessment of the Mshan Petrochemical Storage Tank Fleet

The assessment covered 400 storage tanks in use at Mshan Petrochemicals Refinery, Chemical Plant 1, Chemicals Division, Polyester Division, Rubber Division and Power Division. Among them, the refinery and chemical plant were the main ones. Since the information of this assessment is too large to list in detail, this paper takes the Power Division as an example to conduct risk assessment and analyse the assessment results. The basic parameters of the storage tanks of the Power Division are shown in Table 1.

TABLE I. BASIC PARAMETERS OF STORAGE TANKS

Tank location number	**Medium**	**Volume (m3)**	**Structural style**	**Bottom plate materia l**	**Wall panel material**
Power Station 1#	Blended residual oil	700	vault	A3F	A3F
Power Station 2#	Blended residual oil	500	vault	A3F	A3F
Power Station 3#	Vacuum residue	3000	vault	A3F	A3F
Power Station 4#	Vacuum residue	3000	vault	A3F	A3
Power Station 5#	Cracked residue	700	vault	A3	A3

3.2 Potential for Tank Floor Failure

The theoretical corrosion rate on the soil side can be determined by equation (4).

$$CR_S = CR_{SB} \cdot F_{SR} \cdot F_{PA} \cdot F_{TD} \cdot F_{CP} \cdot F_{TB} \cdot F_{ST} \cdot F_{SQ} \tag{4}$$

The determination of the soil side base corrosion rate CRSB should be based on actual test data. Soil condition adjustment factor FSR - the soil resistivity of the lower part of the tank foundation will affect the corrosion rate of the tank base plate.

Drainage adjustment factor FTD - rainwater accumulation around the tank foundation will lead to an increase in the corrosion rate of the foundation, greatly increasing the corrosion of the tank.

Operating temperature adjustment factor FST - the operating temperature of the tank may affect external corrosion.

The theoretical corrosion rate on the media side can be determined by equation (5).

$$CR_P = CR_{PB} \cdot F_{PC} \cdot F_{PT} \cdot F_{SC} \cdot F_{WD} \cdot F_{PQ} \tag{5}$$

The determination of the media-side base corrosion rate CRP should be based on actual inspection data. If data is not available, the media-side base corrosion rate can be estimated at 0.05-0.125 mm/y (2-5 mpy).

Operating temperature adjustment factor FPT - same as soil-side operating temperature adjustment factor.

The coating condition adjustment factor FPQ - whether the substrate media side is protected by a coating, the material used for the coating, the quality of the coating and the age of the coating will affect the internal corrosion.

The damage factor of the substrate is determined by the parameters ar/t (a is the service life, r is the corrosion rate and t is the original thickness), the number of inspections and the validity of the inspection. A number of tests with a lower validity level within a certain time period can be converted to a higher validity level by the following relationship, but the case of no test is not included in this equation for converting to a higher validity.

4. Analysis of Risk Assessment Cases for Atmospheric Storage Tank Farms

4.1. Results of the Risk Analysis of the Tank Fleet

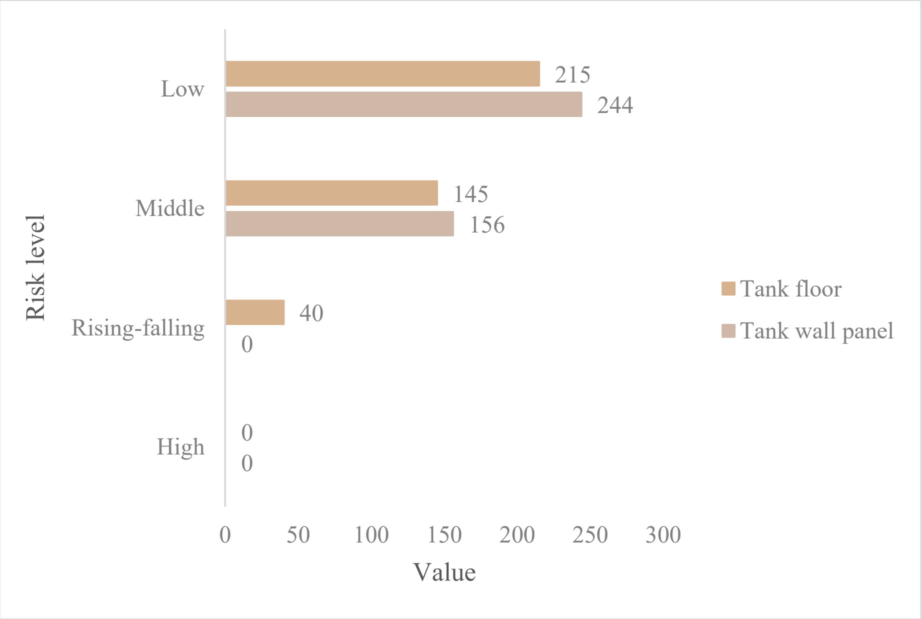

Fig. 1. Statistics of Risk Analysis Results for Storage Tank Group

The results of the risk analysis of the 400 tanks are as follows: there are no high-risk equipment items, 40 base plates for medium-high risk equipment items, 145 base plates and 156 wall plates for medium risk equipment items, and 215 base plates and 244 wall plates for low-risk equipment items. The results of the risk analysis of the 400 tanks in Mshan Petrochemical are shown in Figure 1.

The results of the risk analysis of the 10 tanks in the Power Division are: no high-risk equipment items; medium-high-risk equipment items have 5 base plates; medium-risk equipment items have 5 base plates and 2 wall plates; low-risk equipment items have 8 wall plates. The higher risk items are mainly in the base plate and the lower risk items are mainly in the wall plate.

4.2. Results of Magnetic Leakage Testing

For 100 and 105 except for mechanical obstacles the entire bottom plate for 100% magnetic leakage detection (detection area of about 1853m2), the statistics show that 100 equivalent corrosion depth in 40% to 50% of a total of 30 parts, 50% to 60% of a total of 5, 60% or more 4; 105 equivalent corrosion depth in 40% to 50% of a total of 114 parts, of which 50% to 60% of a total of 31 The total number of sites with corrosion depths between 40% and 50% is 114, of which 31 sites are between 50% and 60% and 11 sites are above 60%. Specific data statistics are shown in Figure 2.

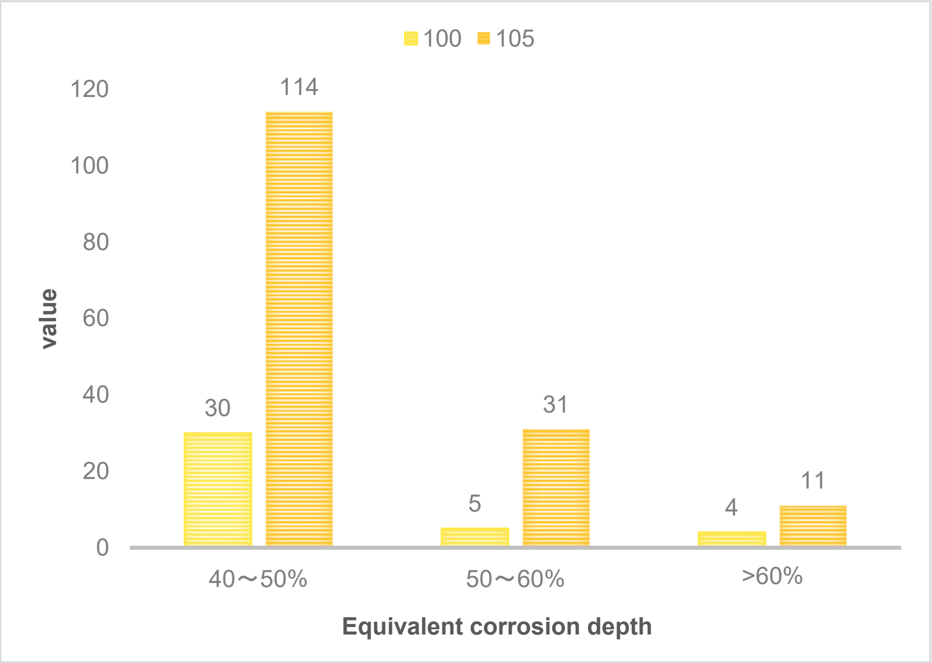

Fig. 2. Comparison of Statistical Data of Magnetic Leakage Results

From the comparison of the sweep results, it is obvious that the overall condition of the bottom plate of tank 100 is better than that of tank 105, but there are corrosion perforations in both tanks. As the overall corrosion condition of the bottom plate of 100 is better, from the on-site inspection and practical experience, it is likely that the perforation is caused by local defects in the bottom plate material itself (e.g. bubbles, inclusions, etc.) or local coating failure leading to accelerated corrosion and other incidental factors, which cannot be controlled during the risk analysis process.

A statistical analysis of the results of the magnetic leakage test shows that the annual corrosion rates for 100 and 105 are 0.176mm/y and 0.295mm/y respectively.

Analysis of the test results led to the following conclusions.

(1) 100 tanks: the corrosion of the upper surface of the bottom plate is slight and uniform, the lower surface of a total of 39 corrosion points found equivalent corrosion depth greater than or equal to 40%, the maximum equivalent corrosion depth of the middle width plate is 100% (a total of 1), the maximum equivalent corrosion depth of the edge plate is 50%. After repairing the defects with an equivalent corrosion depth of more than 43%, the maximum inspection period under normal working conditions is 5 years.

(2) 105 tanks: the upper surface of the bottom plate can be seen on a large area of corrosion, part of the bottom plate corrosion is serious, the lower surface of a total of 156 corrosion points found equivalent corrosion depth greater than or equal to 40%, the maximum equivalent corrosion depth of the middle width plate is 100% (a total of 3), the maximum equivalent corrosion depth of the edge plate is 69%, the equivalent corrosion depth of more than 40% of the defects to be repaired, the longest inspection cycle under normal working conditions The maximum inspection period under normal operating conditions is 3.5 years.

5. Conclusions

As China's strategic layout changes from quantity to quality, domestic petroleum refining enterprises have begun to focus on enterprise safety and security work in recent years under government supervision, and are also actively looking for means to improve equipment safety and control risk levels. This paper provides a useful exploration of the prognostic inspection method of large atmospheric storage tanks based on RBI technology, which provides a new technical method for the inspection of risk-reducing operation of storage tanks in petrochemical zones. However, the accuracy of the RBI-based assessment results is closely related to the completeness of the information data, so ensuring the accuracy and authenticity of the original data information is a key issue that needs to be further addressed in this assessment method.

References

[1] Ng'ambilani Zulu, Douglas Kunda: Mining models for predicting product quality properties of petroleum products. Int. J. Bus. Intell. Data Min. 22(3): 359-388 (2023).

[2] Rasyimawati Mat Rashid, Radin Zaid Radin Umar, Nadiah Ahmad: Major hazard industries disaster preparedness: an empirical study of liquefied petroleum gas storage facilities. Int. J. Crit. Infrastructures 19(1): 17-39 (2023).

[3] Satish S. Salunkhe, Ashok Deshpande: Estimation of Fuzzy Reliability: A Case Study for Flash Vessel in Ammonia Storage Tank. J. Multiple Valued Log. Soft Comput. 33(4-5): 471-479 (2019).

[4] André Gonçalves Medeiros, Leandro Colombi Resendo: Mixed integer linear programming approaches to optimising oil production in offshore petroleum fields. Int. J. Math. Oper. Res. 22(4): 468-495 (2022).

[5] Abdulhamit Subasi, Mohamed Fathy El-Amin, Tarek Darwich, Mubarak Dossary: Permeability prediction of petroleum reservoirs using stochastic gradient boosting regression. J. Ambient Intell. Humaniz. Comput. 13(7): 3555-3564 (2022).

[6] Muhammad Akram, Uzma Ahmad, Rukhsar, Faruk Karaaslan: Complex Pythagorean fuzzy threshold graphs with application in petroleum replenishment. J. Appl. Math. Comput. 68(3): 2125-2150 (2022).

[7] Summaya Mumtaz, Irina Pene, Adnan Latif, Martin Giese: Data-based support for petroleum prospect evaluation. Earth Sci. Informatics 13(4): 1305-1324 (2020).

[8] Maryam Ashrafi: Forward and backward risk assessment throughout a system life cycle using dynamic Bayesian networks: A case in a petroleum refinery. Qual. Reliab. Eng. Int. 37(1): 309-334 (2021).

[9] Awsan Mohammed, Ahmed M. Ghaithan, Fahad Al-Yami: An integrated fuzzy-FMEA risk assessment approach for reinforced concrete structures in oil and gas industry. J. Intell. Fuzzy Syst. 44(1): 1129-1151 (2023).

[10] Pelin Toktas, Gülin Feryal Can: A three-stage holistic risk assessment approach proposal based on KEMIRA-M and DEMATEL integration. Knowl. Inf. Syst. 65(4): 1735-1768 (2023).

[11] Ding Zhiqian, Hu Jian, Zhang Zijian, Chai Junhui, Wu Mengmeng, Zhou Xiaotong, Li Yang. Selection of target values for damage coefficient in RBI calculation of atmospheric storage tanks for hazardous chemicals [J]. Chemical Machinery, 49 (6): 863-868(2021)