Research on Safety performance Evaluation method of Portal Crane based on Reliability Evaluation and Risk Assessment

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Abstract. In recent decades, with the vigorous development of shipping and transportation logistics industry, a large number of portal cranes have been installed in the ports of our country for production, and some of the equipment has approached or even exceeded its designed service life, and there is a great hidden danger of safety in the continued use of the equipment. This paper discusses a safety performance evaluation method of portal crane based on analytic hierarchy process (AHP). Through the determination and measurement of evaluation index, the safety condition of equipment can be obtained. according to the value of equipment safety condition, the safety performance can be classified, and the user and management organization can respond effectively according to the safety performance level of equipment, and the risk caused by long-term service of equipment can be effectively eliminated.

1 Introduction

Shanghai is an important freight and logistics distribution center in the world. Since 2013, Shanghai Port has ranked first in the world in container throughput for seven consecutive years. Among them, lifting machinery loads and unloads containers and goods in time, which ensures the orderly production of the port, which has played a great role in promoting the vigorous development of port and logistics in Shanghai. It is also the solid and reliable equipment foundation for our city to maintain the world's first container throughput.

In the 1980s, the port area built in our city began to install lifting machinery for cargo handling and hoisting (the peak number of installation was from 2003 to 2010). The most typical equipment was portal crane. The service life of portal cranes put into use earlier has exceeded 40 years (the design service life of this kind of equipment is generally 15-30 years), and some of them that exceed the designed service life is more than 40 years. They are still as the main machine to continue to carry out heavy load, high intensity of the operation. However, a large number of portal cranes in our city will reach their designed service life or close to the service life during the 14th five-year Plan period. After the arrival or near service life of this batch of equipment, because of its large weight and high service frequency, there are great uncertainties in the strength of the steel structure (static strength, fatigue strength), electrical system performance and safety protection device. For this country, there are no operational regulations, systems or technical specifications to guide supervision and enterprise to carry out management and disposal, enterprises in the specific response to this kind of problems in a situation where there is no system to follow, this uncertainty, easy to lead to long- term equipment failure or even lead to major safety production accidents, leading to the stagnation of production in the port area, and more important production and means of living in our city come from water shipping. The consequences caused by the inability of lifting equipment to operate in the port area may directly affect the production of enterprises in our city and the normal operation of the public's living order, so it is of great significance to arrange the safety condition of portal cranes in use (especially in excess of service life or close to service life), which is of great significance to its fine supervision according to the safety level.

2 Selection of evaluation methods

At present, several mature methods for risk assessment of special equipment are exponential evaluation method[1][2], fault tree analysis method, Bayesian network method, weight evaluation method[3][4] and so on. The basic principles and characteristics of these methods are shown in Table 1.

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Table 1. characteristics of several risk assessment methods

Approach	Basic principle	Representative method	Main application fields and characteristics
Index evaluation method	According to the evaluation object, the evaluation item is selected, the score range of the evaluation item is determined according to certain principles, the professional evaluator scores the evaluation item, and the total score is obtained through the index operation.	Dow method, Monde method	It is mainly suitable for safety assessment of special equipment or procedures involved in energy conversion in production.
Fault tree analysis	System Security Evaluation Technology based on probabilistic risk Analysis	Fault tree analysis	It is mainly suitable for safety assessment of special equipment or procedures in aerospace industry and newly developed high-techindustry.
Bayesian network method	Based on the method of numerical analysis, the Bayesian network is introduced into the fault tree model for calculation.	Fuzzy analysis method[5][9], fuzzy probability method[6][7][8]	It is mainly suitable for real-time and dynamic evaluation of special equipment in production system, and the calculation cost is very large.
Construction weight evaluation method	The required safety indicators are obtained by modeling and quantifying the evaluation problems.	Analytic hierarchy process AHP method[10]	It is widely used, especially for the safety assessment of special equipment which lacks the necessary statistical data, but its target value is more at the base level

The portal crane has the characteristics of simple and clear structure and mechanism composition, but it lacks the statistical data of its long-term operation, so many mature evaluation methods can not be applied in the portal crane. The construction weight evaluation method is more suitable for the portal crane, mechanism and structure of which is simple and clear, and there is a lack of statistical data. However, it is necessary to overcome the shortcomings that the highest level factors are not sensitive to the change of grass-roots factors when the number of grass-roots factors is large.

3 Determination of evaluation index of gantry crane based on variable weight AHP method

Risk assessment index refers to the factors that can be used to characterize the risk status of the whole equipment in the process of risk assessment of complex equipment. According to the accident incidence of portal crane and the composition characteristics of portal crane in recent years, combined with the degree of influence on the risk performance of the whole machine, the factors that may affect the safety performance of portal crane are put forward, and the structure, mechanism, electrical system and safety protection device are determined as the risk evaluation indexes of this study. That is to say, these four risk assessment indexes constitute the first level of the risk assessment model of portal crane, and the four risk assessment indexes in the same first level can be further decomposed, such as the mechanical properties of the structure can be decomposed into strength, stiffness, stability, corrosion of the whole machine, crack, residual life of equipment and accident damage. The mechanism part can be divided into lifting mechanism condition, variable amplitude mechanism condition, rotating mechanism condition, walking mechanism condition. According to this principle, the evaluation index is arranged from top to bottom according to the subordinate relationship, until the bottom layer, according to this principle, each index is decomposed until the index can be quantitatively represented. The risk index of portal crane is finally divided into four levels, as shown in figure 1 of the decomposition of the mechanical performance index of steel structure to the next level.

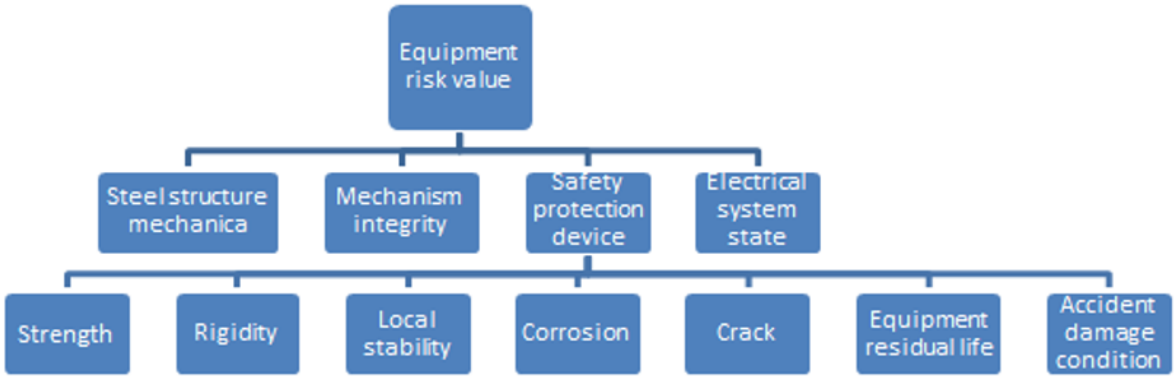

Fig.1. Determination of measurement method of evaluation index for mechanical properties of steel structure of gantry crane

4 Determination of measurement methods for evaluation index

Because the arrangement of risk evaluation index of portal crane is more complicated, this paper only introduces the measurement method of the evaluation index of the mechanical properties of steel structure.

4.1 Strength

When evaluating the strength of the equipment, the maximum static stress of the component is taken as the evaluation object, and compared with the allowable stress of the material used in the equipment, the larger the ratio of the maximum static stress to the allowable stress of the material is, the smaller the strength margin of the steel structure of the equipment is.

4.2 Stiffness

Although the stiffness of the structure can not directly determine the bearing capacity of the structure, the stiffness will affect the performance of the structure, the actual bearing capacity of the structure will be affected. The state value of static stiffness is compared with the allowable deflection measured in practice. The allowable static deflection is selected according to the Code for Crane Design. The larger the ratio of maximum static deflection to allowable static deflection is, the smaller the stiffness margin is.

4.3 Local stability

For the portal crane, the deformation of the main components is mainly investigated: the local deflection of the compression members with local deformation will produce obvious stress concentration phenomenon, which makes the stress on the section of the compressed members extremely uneven, and the maximum stress may even exceed the yield limit, so it is possible to reduce the bearing capacity of the members. Mainly by measuring the waviness of the plate to quantify.

4.4 Corrosion of the whole machine

According to the safety rules and related regulations of lifting machinery, it can be seen that if the corrosion of the section of the main stress components reaches 10% of the designed thickness, if it can not be repaired, it should be scrapped. The ratio of corrosion depth to raw material thickness is taken as the evaluation value, and the larger the ratio of corrosion depth to the thickness of the original plate is, the greater the corrosion is.

4.5 Cracks in steel structures

After a long period of service (especially high frequency and heavy load operation), the steel structure of the equipment is prone to cracks. If it is not properly dealt with, it may lead to the failure of the steel structure or even cause accidents. In the safety evaluation, according to the critical crack length, the method of determining the crack inspection period has strong maneuverability and good effect in practice.

4.6 Residual life of equipment

Combined with the design life, actual service life, field working conditions (load percentage, frequency, service environment, etc.) of the lifting machinery design document, as well as the maintenance situation, the service life is estimated.

4.7 Accident damage

By reading the use records and maintenance record of lifting machinery, the status of crane is determined by summing up the accident (if any), failure and damage.

5 Equipment safety grade classification

The risk classification of portal crane should be based on the evaluation results of the mechanical properties of equipment steel structure, the integrity of the mechanism, the state of safety protection device and the performance of electrical system. According to the international practice, the equipment risk is divided into four grades. The higher the grade, the greater the characterization

risk[11]. In general, the reliability grade should be determined according to the mechanical properties of the equipment steel structure, the integrity of the mechanism, the state of the safety protection device and the performance of the electrical system. When the sub-rating result of mechanism integrity or electrical system performance is the three class, and the mechanical performance of equipment steel structure or the state of safety protection device is the second class, the comprehensive reliability rating of portal crane can be rated as second class, but the unqualified items need to be repaired in time; the mechanical properties of equipment steel structure, the integrity of the mechanism, the state of safety protection device and the performance of electrical system should be guided by the following principles:

(1) When there are no three-level indicators in the rating results and there are not more than two secondary indicators, the individual rating results shall be rated as first-level.

(2) When there are no three-level indicators in the rating results and there are more than two secondary indicators, the individual rating results should be rated as second- level.

(3) When there is a three-level index in the rating result, the individual rating result should be a second or third level.

(4) When there are more than two third-level indicators in the rating results, and there are no four-level indicators, the single rating results should be three-level.

When there are four-level of rating results, the individual rating results should be four-level.

6 summary

The safety performance evaluation method of portal crane based on analytic hierarchy process (AHP) is discussed in this paper. through the determination and measurement of evaluation index, the safety condition of equipment can be obtained. according to the value of equipment safety condition, the safety performance can be classified, and the user and management organization can deal with it effectively according to the safety performance level of equipment, and the risk caused by long- term service of equipment can be effectively eliminated.

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