Hazard Identification of Portal Crane In-use & Research on Its Application In a Shipbuilding Company

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Abstract: Fatigue damage is always the main cause of the crane damage. The prediction method of fatigue life take far reaching impact on the design and service life of the crane. Therefore, it is extremely important to study the fatigue life prediction method of crane. In this paper, the existing fatigue life prediction methods are summarized systematically. And the fatigue life research was involved in metal material, mechanics, vibration mechanics, fatigue theory, fracture mechanics and so on, which made a difference between the predicted result and the actual life. The emergence and application of new technologies promote the development of the fatigue life evaluation methods, which could debase the risk of portal crane in use significantly.

1. Introduction
The portal crane is an irreplaceable tool for shipbuilding companies due to the large lifting weight and high work efficiency. Though the machine must be strictly inspected before leaving the factory and in use, it is still many reasons to cause the accident in operation such as oversized system, overly complex structure, complex working environment, high working frequency, long-term service, incorrect personnel operation and poor equipment management. In order to reduce, or even avoid such accident, and reduce property loss and casualty, it is necessary to find out the root cause of the accident, and take corresponding measures such as maintenance and replacement of parts before the accident occurs, which could greatly reduce, or even prevent the accidents in operation. Therefore, the risk assessment is also required to carry out on high-risk hoisting machinery, identify the potential hazards and risks, and assess the source of hazards, thus effectively prevents the occurrence of accidents and ensuring the normal operation of the company.

Figure 1. Portal crane in use
2. Hazard identification of high-risk crane

2.1. Hazard identification and identification methods
Hazard identification refers to the identification of potential conditions that may cause the casualties, or the occupational diseases, or the equipment trouble, or the loss of social wealth, or damage to working environment by using appropriate methods at each stage of the life cycle of a product or system. The final result of hazard identification is to identify the hazards existing at each stage of the product, system and project\(^{(1,2)}\).

2.2. Hazard identification method of hoisting machinery
In general, the hazard of hoisting machinery is for the crane as a whole, which contains multiple mechanisms, and each of them is relatively complex. Furthermore, each mechanism is located in different working environment and has different job specification. For a machine with oversized system, it is very important to choose an appropriate method that can comprehensively and completely identify the hazards of the large system, so that we can make more reasonable judgment within the effective time, and then take reasonable improvement measures. In combination with the characteristics of portal crane and the focus of this research, fault tree analysis was finally adopted as the hazard identification method through continuous exploration, repeated deliberation and soliciting the experts’ opinions, so as to find out the risk sources of high-risk hoisting machinery and prevent the occurrence of accidents.

2.3. Fault tree analysis
As one of the important analytical methods of safety system engineering, fault tree analysis refers to starting with the specific accident or fault to be analyzed (top accident), and analyzing its causes layer by layer until finding out the fundamental cause, namely, the bottom event of fault tree. These bottom events are also called elementary events, the data of which is known, or has been calculated, or the result of the experiment. It can identify and assess the hazards of various systems, and can both analyze the direct cause of the accident and reveal the potential cause in depth\(^{(3,4)}\). In addition, it is intuitive and clear to use it to describe the causality of the accident, with clear thinking and strong logic. Both qualitative analysis and quantitative analysis can be achieved.

\[ M_1 = M_2 \times M_3 \times M_5 \times M_4 \]

\[ = (M_{21} + M_{22} + M_{23} + M_{24}) \times (M_{31} + M_{32} + M_{33} + M_{34} + M_{35}) \times (M_{51} + M_{52}) \times \]

\[ (M_{61} + M_{62} + M_{63} + M_{64}) \times (M_{41} + M_{42} + M_{43} + M_{44} + M_{45} + M_{46}) \]

Figure 2. Three-layer diagram of the fault tree
3. Research on hazards of high-risk crane

3.1. Heavy object falling accident
Heavy object falling accident refers to the personal injury and equipment damage accident caused by the falling of heavy objects, such as hoisting objective and lifting appliance, etc., from the air during lifting operation, referred to as falling accident. There are several types of common falling accidents as follows:
   a. Rope-off accident mainly refers to the casualty and damage accident occurred when heavy objects break away from the tied lifting rope and loosen;
   b. Decoupling accident mainly refers to the heavy object falling accident occurred when heavy objects, hoisting rope or special lifting appliance falls out of the lifting hook mouth;
   c. Rope-broken accident mainly refers to the heavy object falling accident by the broken lifting rope and hoisting rope;
   d. Hook-broken accident mainly refers to the heavy object falling accident by the broken lifting hook.

3.2. Crushing accident
Crushing accident refers to the human casualty accident, such as crushing injury, pressing injury and crashing injury, occurred when the operator is squeezed between two objects during lifting operation. Crushing accident mostly occurs to the following operating conditions:
   a. Crushing accident occurred between the lifting appliance, or hoisting objective, and the objects on the ground;
   b. Crushing accident of lifting equipment;
   c. Crushing accident between the machine body and the building;
   d. Crushing accident occurred when the machine body rotates;
   e. Crushing accident occurred during overturning operation.

3.3. Falling accident
Falling accident mainly refers to the falling damage accident occurred when the person engaged in lifting operation falls down to the ground from a height, such as the crane body, as well as refers to the personal injury accident of workers on the ground caused by the falling tools and parts from a height.
   a. Falling damage accident from the machine body;
   b. Crashing and falling accident of machine body;
   c. Falling damage accident of lift car;
   d. Falling and crushing damage accident caused by falling repair tool parts;
   e. Falling accident caused by vibration;
   f. Falling accident caused by sliding brake.

3.4. Electric shock accident
Electric shock accident refers to the personal injury and death accident caused by electric shock especially to the operation and maintenance person. According to different types of cranes in different indoor and outdoor occasions, electric shock accidents can be divided into two types:
   a. Electric shock accident of indoor operation;
   b. Electric shock accident of outdoor operation.

3.5. Crane body damage accident
Crane body damage accident refers to the heavy crane body damage accident and human casualty accident caused by fractured crane body and tipping due to the overload and instability of the crane.
   a. Broken arm accident;
   b. Tipping accident;
   c. Falling crane body accident;
   d. Collision accident.
4. Overall safety assessment

Through the risk assessment of the shipbuilding company in Shanghai, the conclusions are as follows:

(1) In terms of corporate management, the shipbuilding company in Shanghai is able to establish the safety management ledger for special equipment in accordance with the requirements of documents related to equipment safety management, conduct regular inspection and detection for the special equipment, make a plan for equipment inspection and maintenance, manage the lifting equipment in the plant at different levels, and maintain, upkeep and repair the equipment regularly at different levels. As a result, management level and management efficiency are improved significantly. However, there are still problems due to the influence of methods and personnel quality in the implementation process of some policies. For example, there are some cases that the person does not comply with the relevant regulations in the daily implementation process.

(2) In terms of equipment, the overall condition of portal crane is good and the daily, monthly and regular inspections are normal, but the inspection quality still needs to be further improved. For example, in the on-site inspection, it is found that the associated lock of safety accessory is missing and corrosion is existing on the equipment body, especially on some important weld joints. It is easy to induce cracks and cause major risks, so the company should rectify them in time and eliminate the potential safety hazards.

(3) In terms of personnel, the shipbuilding company in Shanghai has gaps between management personnel and maintenance personnel currently. And in the inspection of personnel quality, it is found that there are problems of safety management personnel in professional knowledge and legal knowledge, lower than the average level of large-scale enterprises in Shanghai. Moreover, the operator’s level of management knowledge, professional knowledge and legal knowledge is lower than the average level of large-scale enterprises in Shanghai. Therefore, the company should make up for shortcomings as soon as possible, so as to reduce risks.

(4) In terms of operating environment, the company has a relatively good operating environment. However, there are still hidden dangers in some links. Firstly, the debris is placed in the main beam at will, which affects traffic; secondly, the safety distance between the cab and the boarding platform is too large to cause tripping easily; thirdly, the elevator is easy to overload due to the lack of load capacity signs; fourth, the electric appliance cabinet is not equipped with insulating carpet, which may cause electric shock. The company is suggested to make rectification as soon as possible, so as to eliminate the potential safety hazards.

5. Conclusion

The main risk sources of the equipment of a shipbuilding company in Shanghai is determined by risk assessment adopted the fault tree analysis method. It is found that there are certain hidden safety hazards in almost five parts: “human”, “machine”, “management”, “environment” and “use”. The corresponding suggestions and rectification measures are proposed in the paper and the accident risk of the company is reduced effectively after the measure enforced.

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