Rigid Dynamic Load of the Crane Lifting Mechanism When the Series Resistance Starts

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Abstract. With the development of economy, industry and manufacturing industry play an important role in China's economy. As the most extensive machinery in the industry and manufacturing industry, the development of crane will inevitably affect the development of the whole industry, so how to improve the performance of crane and how to carry out a wide range of analysis has become the current problem to be solved. Starting from the crane, this paper focuses on the study of the rigid dynamic load coefficient when the series resistance of the lifting mechanism of the crane starts, and analyzes the influence of these coefficients on the performance of the crane. In this paper, the big data analysis method is put forward firstly, and the change of rigid dynamic load coefficient when the chain resistance of crane hoisting mechanism starts in China's industry and manufacturing industry in the past 10 years is analyzed. Secondly, the concept and classification of crane are briefly summarized. The crane is mainly divided into two types, one is tire crane, the other is bridge crane. Then this paper establishes the system model and the mathematical model of the crane lifting transmission system. Through the analysis of the system model, we can get the relationship between the rigid dynamic load coefficient $\alpha$ and $\varphi$, and the relationship between $\beta$ and $\varphi$. Their relationship is that the growth rate of the rigid dynamic load is slowed down after $\alpha$ is greater than 5, and the starting torque multiple and the rigid dynamic load coefficient are linear.

Keywords: Crane, Coefficient of rigid dynamic load, Lifting mechanism, Series resistance

1. Introduction

Crane is the most important part of industry and manufacturing industry, because crane can be started many times, and can lift and carry heavy objects vertically and horizontally within a certain range, which brings many conveniences to industry and manufacturing industry. Therefore, the design and manufacturing technology of crane research is becoming more and more important.

The research on crane can not only improve the performance of crane, but also further promote the progress of industry and manufacturing industry. Now there are many scholars studying crane. In [1], the model proposed by the author takes the structure and working principle of industrial crane as a
metaphor to explain the function of human shoulder. Because the crane consists of a base, an axial tower, a suspender and a suspended cascade to move and position loads in space, the base consists of a pelvis platform, and the outriggers (legs) provide stability in the human body. In [2], the author mainly studies two comprehensive coastal operation problems: berth allocation and quay crane allocation. The calculation of several kinds of test cases shows that the problem of 40 containers can be solved at most. In [3], the configuration modeling of YC with limited resources is studied. First, the basic configuration model of the yard crane is proposed, including the basic network flow model and the basic mathematical model. Secondly, the extended model is established, which can be used to deal with the allocation of multi yard cranes. Finally, the effectiveness of the proposed model is verified by numerical experiments, such as functional testing, performance analysis and scenario analysis. In [4], the author discusses the finite time stabilization of a hybrid PDE-OD system, which can be used as the motion model of a bridge crane with flexible cables. The results show that the platform and cable of the whole system are stable in finite time. In [5], in order to ensure the operation safety of the lithium battery hybrid rubber tire gantry crane, the dynamic power control of the lithium battery hybrid rubber tire gantry crane is studied. This paper introduces the structure and switch mode of the lithium battery hybrid RTG crane. The cost of battery charging is analyzed. The results show that the new RTG is 70% less than the traditional RTG crane. In [6], three kinds of mixed gases (HGA) are proposed to treat dynamic and discrete BAP (DDBAP) and dynamic QCAP (DQCAP) simultaneously. The experimental results show that the fitness values of three HGA are better than that of traditional gas. Especially hga3 with THOROS mutation operator has the best performance. In [7], the author studies the crane scheduling problem of single yard to minimize the expected total tardiness of the task, and studies the uncertain release time of the recovery task. The results show that the heuristic algorithm based on rules is better than GA and SAA in solving quality and running time. In [8], the author proposes a nonlinear model predictive control (NMPC) scheme to overcome the sudden peak tension and impact load of lifting wire rope caused by the change of lifting speed in the process of wind turbine blade lifting. Its purpose is to improve the installation efficiency and ensure the operation safety. In [9], the author studies the influence of different boundary conditions on the numerical results of container crane under earthquake. The results show that when the seismic intensity is large enough, the choice of boundary condition model has a great influence on the dynamic response of container crane. In [10], the authors aimed to determine the efficacy of MBIS in children and adolescents through a randomized controlled trial (RCT) design. The results showed that this study enhanced the efficacy of MBIS in improving mental health and well-being of adolescents evaluated by the gold standard RCT method. Future RCT assessments should include an expanded final trial design to further assess the robustness of young MBIS, with a focus on operational mechanisms.

Starting from the crane, this paper focuses on the study of the rigid dynamic load coefficient when the series resistance of the lifting mechanism of the crane starts. Firstly, this paper puts forward the big data analysis method, and summarizes the crane and the category of the crane. Secondly, it puts forward the system model. The specific analysis method is as follows.

2. Method and Crane Overview

2.1. Big data analysis method

Big data analysis method mainly has four basic characteristics: special types of data, large amount of data, low value density of data and special speed of data processing. This paper uses big data to analyze the change of rigid dynamic load coefficient of crane hoisting mechanism during the 10 years of 2009-2019 in China's manufacturing industry. The detailed analysis process is shown in Figure 1.
2.2. Overview of crane
Cranes generally refer to the machines that carry heavy objects vertically or horizontally within a certain allowable range. Nowadays, most of the cranes in the industry and manufacturing industry refer to cranes, aerial cranes, etc., which can be seen everywhere. There are many kinds of cranes, but there are only two kinds, one is the tire crane, the other is the bridge crane. The cab of the tire crane is combined with the operation cab of the crane, which belongs to the machinery for handling many kinds of materials. This kind of crane overcomes the damage to the ground caused by the crawler crane. The bridge crane is a kind of lifting equipment which is erected above the workshop and the warehouse. As the name implies, the shape of the bridge crane is similar to the bridge shape. Its track is erected on the viaduct on both sides, and uses the lower part of the track to transfer materials, so it is not constrained. Crane is the most widely used machinery in industry and manufacturing, because its use not only saves human and material resources, but also brings great convenience to industry and manufacturing.

3. Establish System Model

3.1. Motor starting torque
The starting characteristics of the motor can be expressed by mathematical expression:

\[ S_i = S_{i0}(1 - \frac{\phi}{p_x}) \]  (1)

Where, \( p_x \) represents the synchronous speed of the motor, \( \phi \) represents the speed of the motor rotor at a certain time, and \( S_{i0} \) represents the starting torque of the motor.

Wound asynchronous motor is generally started by series rotor resistance. In order to reduce the impact load, a reserve resistance is added to the starting resistance of wound motor. When the mechanism is started, the reserve resistance is added, and the motor will generate a torque equal to 75% of the rated torque of the motor, so as to eliminate the gap in the transmission mechanism and generate a certain pre tightening force. However, the It is not enough to start the mechanism, which can significantly reduce the vibration load.

3.2. Mathematical modeling of crane lifting transmission system
For the calculation of the vibration load of the crane mechanism, the two-mass single degree of freedom system is the most suitable. However, due to manufacturing reasons, there will inevitably be errors in the starting process, and there is always a certain gap in the transmission mechanism. There is clearance in the mechanism, and there is impact in the starting and braking, which results in a large dynamic load. The clearance starting process of the mechanism can be divided into three stages: the first stage: the motor starts and the transmission system idles to eliminate the clearance; the second
stage: the transmission mechanism starts to contact and produce elastic deformation until the elastic torque equals to the external resistance torque; the third stage: the whole system continues to vibrate as a whole.

The first stage: the motor accelerates $A_1$ until the clearance is eliminated, at this time $A_1$ has the initial speed $\phi_0$, but $A_2$ has not yet moved.

The second stage: the contact between $A_1$ and $A_2$ starts and produces elastic force. When the elastic force increases to be able to overcome the static resistance $R_t$, the stage ends, and the angular velocity of the shaft:

$$\phi_1 = \sqrt{\phi_0^2 + \frac{2R_t R_i - R_1^2}{kA_1}} \quad (2)$$

The third stage: the whole system will vibrate from the beginning of $A_2$ participating in the motion. The initial displacement of this stage is: $\phi_1 = R_t/k$, and the initial velocity is $\phi_0$ represented by formula (2).

4. Results

From the above modeling and research, we can get the influence of $\phi$, $\alpha$, $\beta$ and other factors on the rigid dynamic load coefficient. We must determine the other two variables before we can get the relationship between the variables and the rigid dynamic load. Firstly, the relationship between $\alpha$ and $\phi$ is studied. See Table 1 for specific data. It can be seen from Figure 2 that the rigid dynamic load coefficient calculated by the formula derived in this paper and the formula without considering the gap is too large, but the growth rate of the rigid dynamic load obtained after $\alpha$ is greater than 5 slows down. Then study the relationship between $\beta$ and $\phi$. See Table 2 for specific data. From Figure 3, it can be seen that the starting torque multiple has a linear relationship with the rigid dynamic load coefficient.

Table 1. Relationship between $\alpha$ and $\phi$

| $\alpha$ | 1.2 | 2.3 | 3.4 | 4.6 | 5.3 | 6.7 | 7.5 | 8.8 | 9.2 | 10.4 |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Data     | 2.81| 3.06| 3.22| 3.30| 3.37| 3.42| 3.45| 3.49| 3.52| 3.57|

Figure 2. Relationship between $\alpha$ and $\phi$

Table 2. Relationship between $\beta$ and $\phi$

| $\beta$ | 1.35 | 1.45 | 1.55 | 1.65 | 1.75 | 1.85 | 1.95 | 2.05 |
|---------|------|------|------|------|------|------|------|------|
| Data    | 1.84 | 1.93 | 2.02 | 2.16 | 2.25 | 2.31 | 2.37 | 2.48 |
5. Conclusion
Starting from the crane, this paper focuses on the study of the rigid dynamic load coefficient when the chain resistance of the crane lifting mechanism starts. Firstly, it puts forward the research method, i.e. big data analysis method. It analyzes the change of the rigid dynamic load coefficient when the chain resistance of the crane lifting mechanism starts in China's manufacturing industry in the past 10 years. Secondly, it summarizes the concept and classification of the crane. Then this paper establishes the system model, we can get the relationship between α and φ, β and φ, that is, the growth rate of rigid dynamic load will slow down after α is greater than 5, and the starting torque multiple is linear with the coefficient of rigid dynamic load. There are many shortcomings in this paper, which will be solved one by one in the future research.

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