Research on the dynamic windproof and antiskid ability guarantee of port crane

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Abstract: This paper introduces the windproof and antiskid safety, types and working principles of dynamic windproof and antiskid devices in normal working conditions, analyzes the dynamic braking capacity and points out the deficiencies in the design, and puts forward relevant suggestions to provide basis for the subsequent evaluation of windproof and antiskid performance of port cranes.

1. Introduction
Port crane is designed according to the characteristics and requirements of port loading and unloading operation, which has the characteristics of fast working speed, high loading and unloading efficiency, frequent starting and braking, and so on. Modern ports are equipped with various types of port cranes, engaged in the transfer and loading and unloading of goods. Due to typhoon or gust of wind disaster accidents of port cranes continue to occur, the occurrence of accidents not only directly affects the normal production order of wharf, but also causes serious economic and production losses to port enterprises, but also causes casualties. Therefore, it is of great significance to ensure the safety of port crane against wind and skid.

One of the common characteristics of wind disaster accident is that the crane suffers from sudden gust in the working state or temporary stop state, and the windproof and antiskid device can not work in time, which leads to the overturning accident caused by the collision with the adjacent crane or the stop stop at the end of the track under the action of strong wind. If timely measures can be taken to stop the movement of cranes, the occurrence of these accidents can be avoided.

This paper discusses the safety of working state windproof and antiskid, the types and working principle of dynamic windproof and antiskid devices, combined with the analysis of dynamic braking ability, points out the shortcomings in the design of manufacturing units, and puts forward some relevant suggestions, which provides a reference for the subsequent evaluation of dynamic windproof and antiskid performance of port cranes.

2. Safety of windproof and antiskid in working state
The normal working state of the crane is set to run and brake with load, tailwind and downhill. At this time, the windproof and anti-skid safety is calculated according to the lower check.

\[ P_{Z1} \geq 1.1P_{WII} + P_a + P_D - P_f \]  

(1)
Where:

- $P_1$ — The braking force produced by a brake on a wheel tread $l$ in Newton (N).
- $P_{wI}$ — Working state wind load of crane in Newton (N).
- $P_a$ — The self-weight load of the crane and the sliding force produced by the lifting mechanism in the direction of the ramp, in Newton (N).
- $P_d$ — The inertia force of stopping and slowing down of crane in Newton (N).
- $P_f$ — Operating friction resistance of crane in Newton (N).

\[ P_f = \omega \times (P_Q + P_G) \]  

$\omega$ — Running friction resistance coefficient.

$P_Q + P_G$ — The total wheel pressure generated by rated lifting load and self-weight load in Newton (N).

When the braking force is greater than the adhesion between the brake wheel and the track (that is, friction), the adhesion between the brake wheel and the track is replaced by the adhesion force between the brake wheel and the track. When only part of the wheel is greater than the adhesion between the wheel and the track, it should be calculated according to the wheel under different conditions.

It says that the brake can no longer guarantee the requirements of anti-wind and anti-skid, should try to increase the pressure of the active wheel to increase the adhesion, or take other anti-wind and anti-skid measures (such as stop iron shoes, rail clamps, etc.). The anti-wind and anti-skid safety of crane under normal working condition should generally meet the requirements of empty crane and full load.

At the same time, when working normally, the braking distance of crane is deduced through the standard of crane design code [1]. The specific provisions are as follows:

\[ \frac{v}{15} \geq S \geq \frac{v^2}{5000} \]  

Formula in

$v$ — Rated running speed of large car in meters per minute (m/min).

$S \geq \frac{v^2}{5000}$ is to limit the minimum braking stroke of the large car, that is, the braking torque should not be too large (the brake can not be adjusted too tight), in order to prevent the excessive braking inertia force and affect the motion performance of the large car and the harm to the crane bridge.

$S \leq \frac{v}{15}$ is to limit the maximum braking stroke of the large car, that is, the brake can not be adjusted too loose and the braking torque is too small to ensure that the crane can stop safely within the prescribed allowable range. To prevent collision accidents.

When the sliding distance of the large car exceeds the specified value of the above type after the normal operation and power outage, the brake should be adjusted immediately so that the braking stroke meets the requirements of the above type.

It needs to be explained that the above is an empirical formula, the calculation is round, the minimum braking stroke is set according to the maximum acceleration, the "crane design code" (GB/T 3811-2008) is specified as 0.67, here set 0.7; the maximum braking stroke is set according to the maximum braking time, the maximum is 8S in Table 13 of the design code, and the value is 8S here [2]. Of course, the above formula is a restriction on conventional cranes. The speed of crane operation should actually be measured by the crane unit according to the specific use situation and lifting structure and working conditions. Some of them should consider the types of hoisting items, whether they need accurate positioning, whether to pursue work efficiency, and so on. Under the premise of ensuring safety, the braking torque is on the large side of the heavy object sloshing is more severe. The braking torque is too small to be accurately located.
\[ S_1 = \frac{v^2}{(3600 \times 2 \times 0.7)} \approx \frac{v^2}{5000} \]  

Formula in

\( v \) — Rated running speed of large car in meters per minute (m/min)

\( S_1 \) — Minimum braking stroke in meters (m)

In order to avoid the lifting mechanism moving too hard and affect the normal operation, two-stage braking can be adopted, the first stage braking can be used for deceleration, and the second stage braking can be used to ensure the safety of wind resistance and skid resistance in the working state. In general, especially large cranes, the automatic anti-wind anti-skid device should be selected to ensure that the crane will not slide in the event of power outage and storm burst. The upper brake action of the anti-wind and anti-skid device should be later than the upper brake action of the operating mechanism brake, and the loosening action of the windproof and antiskid device should be slightly ahead of the loosening action of the operating mechanism brake.

3. Study on the types and working principle of dynamic windproof and antiskid device

There are several main types of windproof and antiskid devices in the working state of port crane, such as brake, clamping gear, rail clamping device, top rail device, anti-climbing boots (wedges) and so on [3][4]. The brake and clamping gear are the braking wheels of the traveling car, which makes use of the weight of the crane to produce friction force between the wheel and the track, thus braking the crane; the rail clamping device and the top rail device can resist the wind force by generating friction resistance opposite to the wind force, the former through their own clamping force on the track, the latter through their own top rail force on the track, only suitable for the situation where the track is higher than the ground. The anti-climbing boot has some effect on preventing the sudden gust under the working condition, but it has great limitations. it is a force-increasing braking device, which needs to make the crane wheel roll up a certain height along the boot surface of the anti-climbing boot before it plays a role; the structure of the self-locking anti-climbing device is similar to that of the rail clamping device, but its action mode is completely different from that of the latter. It uses the clamp mouth of the clamp arm to fasten the rail surface and rail neck. When the crane is blown by the wind, the clamp mouth of the clamp arm is automatically clamped with the rail surface and rail neck to form a self-lock to prevent climbing. Once the self-locking device fails, the crane reaches the connecting plate between the tracks, and the clamp arm will also pull the track to prevent crawling. It is a very safe and simple device.

The design wind load of the above anti-wind and anti-skid device is generally parallel to the working wind speed of 32-35m/s in the track of the traveling car. The most effective measures to resist wind and prevent slippage are to stop all the wheels, such as the active wheel brake and the follower wheel are installed in the walking mechanism of the query-side container crane, so as to realize the braking of all wheels and make the crane achieve the maximum anti-climbing force.

4. Analysis of dynamic braking capacity

Many accidents are caused by wind loads driving cranes along the track and eventually colliding with another crane or with the backstop at the end of the track and causing it to overturn or collapse. Most of these cranes are hit by gusts when they are working, and the windproof device fails to work in time, resulting in the crane being blown by the wind and moving along the track (although the wheels are killed, but still sliding, or rolling belt slippage), a large amount of kinetic energy is accumulated, and once one side of the door leg is blocked, the other side of the door leg may be lifted. Depending on the energy accumulated by the crane before impact, there may be two situations:

1. If the energy is large enough, one side of the door leg is raised very high, and directly tilts and collapses.
2. If the crane is driven by the wind after the movement distance is still relatively short, the speed is small, the accumulated energy is also small, then one side of the crane is lifted by the height of the crane will not make the whole crane capsized and fall, at this time the door leg will be subjected to the impact of the ground and lose stability, leading to the collapse of the crane.

In view of this situation, the design of windproof and antiskid device of port crane should prevent the displacement of crane when it encounters strong sudden gust in working state and temporary shutdown state.

When the braking force is greater than the adhesion between the brake wheel and the track (that is, friction), it means that the brake can hold the wheel to death and the wheel does not produce rolling. When only part of the wheel is larger than the adhesion between the wheel and the track, it shows that some brakes can not completely hold the wheel, and the wheel is in the state of continuous rolling belt slippage, which is the difficulty considered in the design and use process and the place worthy of optimization. Based on the above provisions that the crane should be larger than the minimum braking stroke, the braking torque of the brake can not be selected to be too large. Because the wheel pressure on each wheel is different, the choice of brake on each wheel is still open to question, the model is large, resulting in waste; the model is small, the wheel is in incomplete braking state, and the crane should be less than the maximum braking stroke, so the brake and clamping gear need to be arranged scientifically.

Clamping force produced by rail clamping device

\[ P_Z \geq P_h = P_{fI} - P_m \]  

Formula in

\[ P_{fI} -- \text{non-working state, the wind load acting on the crane along the running direction (N)} \]

\[ P_m -- \text{Friction Resistance (N)} \]

Clamp force

\[ N = K_n P_h / 2 \mu \]  

In the formula, \( \mu \) the friction coefficient between clamp and rail is 0.12~0.15 for non-toothless and unheat-treated steel 50, and 0.30~0.35 for 65Mn and 60SiMn steel with tooth grain and hardened (HRC \( \geq 55 \)). When the steel tooth is not sharp, the coefficient should also be reduced (\( \mu = 0.2 \)).

\( K_n \) is a safety factor.

According to the laboratory test and simulation research on the windproof and antiskid test device in the literature, it can be seen that the contact force of the left wheel is larger than that of the right wheel horizontal and vertical before adding the rail clamping device, and the contact force of the left wheel is smaller than that of the right wheel after adding the rail clamping device, which is due to the clamping force of the rail clamping device, which produces a friction force to prevent the horizontal movement of the wheel. This leads to the change of the contact force of the related wheels [5]. It shows that when the rail clamp is used in the actual use of the crane, under the action of wind force and external load, the rail clamping device will also change the wheel pressure under the self-weight of the crane. This factor will generally be ignored in the traditional design, resulting in the lack of design analysis.

There are also top rail devices, anti-climbing boots (wedges) dynamic braking capacity is similar to the introduced dynamic anti-wind and anti-skid device analysis, so do not repeat.

To this end, the following recommendations are made:

1. The wind speed and direction of the port in previous years and the automatically recorded wind speed and direction, as well as the load and working condition data of hoisting on the monitoring device of large lifting machinery are collected, analyzed and refined, and the typical wind speed and working conditions of each state are selected, and the further analysis and calculation are carried out.
2. Combined with advanced dynamics and finite element simulation software, considering the working state of windproof and antiskid device, the scientific and reasonable calculation results of wheel pressure and safe braking distance are obtained.

3. According to the calculation results, a more scientific and reasonable anti-wind and anti-skid selection and configuration are carried out.

4. The key windproof and antiskid device is tested in the test-bed and practical application field of the windproof and antiskid device, and the feasible dynamic test, detection and analysis, as well as adjustment and perfection are carried out to ensure the safety of use.

At the same time, in the use of port cranes, we should also strengthen the relevant management, the specific suggestions are as follows:

1. Drivers should concentrate on their work and should not operate in violation of the rules. When working, you should be aware of the abnormal noise of the crane. Special attention should be paid to the running speed, hoisting condition and real-time wind speed of port crane, and should have the ability to deal with it in time and calmly when it is dangerous.

2. Timely maintenance of windproof and antiskid device found defects or defective windproof and antiskid devices and supporting facilities should be maintained in time.

3. The relevant rules and regulations should be improved as scientifically as possible.

The user unit should establish the safety management system, which should include: safety operation rules, daily maintenance system, use safety management system, post responsibility system, regular inspection and hidden danger investigation system, accident emergency special plan, transfer shift system and staff training system, and so on.

5. Conclusion

Through the introduction of the dynamic windproof and antiskid principle of port crane and the analysis of its braking device capacity, it is suggested that the following effective and concrete inspection and testing countermeasures should be taken:

1. To obtain the meteorological data of the port and the recording data of the monitoring system of the large port crane, it is necessary to recalculate and evaluate the ability of the windproof and antiskid device required by the port crane for equipment whose configuration is unreasonable and below the new standard and where the same wind disaster has occurred in similar places.

2. According to the evaluation results, the wheel edge brake is reasonably added to the passive wheel of the crane, and other auxiliary windproof and antiskid devices, such as the rail clamping device, are added to the crane which can not increase the wheel edge brake.

3. The dynamic windproof and antiskid device of crane needs to be maintained regularly to keep it in good condition, including brake and clamping gear and rail clamping device, so that the windproof and antiskid ability of port crane is obviously improved.

References
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