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Partial Load Detection System Design of Container Crane

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Abstract. Container crane is a lifting and transport equipment, has been widely used to ship containers in numerous depots. As a direct bearing body of container crane, spreader performance is critical to the success of container cargo transportation, it often works in heavy-duty and off-load state, thus prone to arise premature failure. This paper committed to design partial load detection system of spreader, which can improve the spreader mechanical characteristics to ensure the safe transport, but also to maximize avoid the earlier structure failure phenomenon under continuing high stress, thereby reducing the transport costs..

Introduction

Container crane is a logistics handling machinery, mainly used for the completion of transport and stacking 20ft and 40ft ISO containers, as shown in Fig.1. It has large lifting capacity, flexible, high stacking layers. It has different models, a high adaptability in small and medium sized docks. Furthermore, it can also be used as an auxiliary device in large docks. Spreader is a direct bearing body of the container crane, which often in a heavy-duty and off-load state, thus it easily prones to arise premature failure[1].

Partial load of cargo containers undoubtedly can cause the unbalanced bearing on wheels, in this way, container crane has poor stability when it through the uneven pavement or cornering, and the upper and lower amplitude becomes large, which easily lead to immeasurable accidents[2]. In addition, partial load makes discontinuity on each hinge point of spreader connections, accelerating the production of structural cracks and reducing crane’s lifetime. Unbalanced load detection devices of containers commonly include weighbridge, rail scales, crane scales, etc[3]. They are maneuver, big investment, low efficiency and required to hand operation. In general, the existing weighing apparatus has the following disadvantages: Inconvenience use, single function, more investment and low detection efficiency[4]. So there is no effective partial load detection device in international transport process, partial load detection system installed on the spreader is particularly necessary. Which can achieve the dynamic monitoring and control the patial problem from source.

1. electrical components;
2. railing;
3. outrigger;
4. wheel group;
5. beam;
6. telescopic spreader;
7. girder;
8. control cabinet

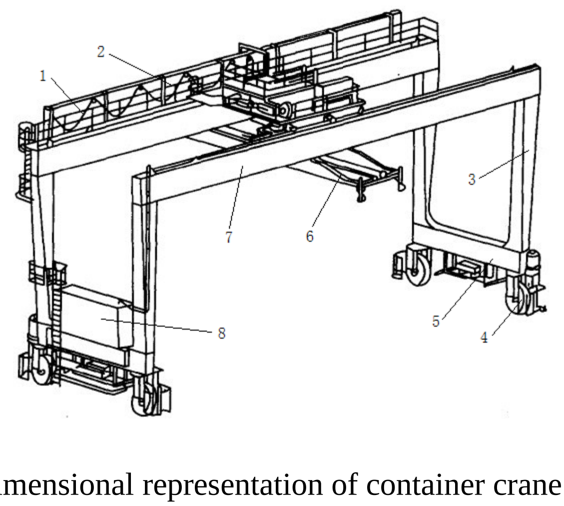

Fig.1 Three-dimensional representation of container crane

Feasibility Analysis

Nowadays, spreader mechanism commonly use the telescopic form which can quickly switch between 20ft and 40ft ISO containers, it is with telescopic, lateral displacement, rotation and other movements, the structure is arranged in the form of four lifting points[5]. Four latches arranged in the four corners of container goes deep into the corresponding hole affiliated to container in hanging process, then the lock cylinder drive the latches rotating $90°$, it will not be separated in the process of cargo transportation, container and spreader can be integrated in this way.

Spreader is always in a horizontal state when it complete the telescopic, lateral, rotation and other movements, in addition, it is made of high strength steel welding, which makes it have good rigidity, because of this, structural deformation affects the accuracy of pressure sensor is negligible, and four latches arrangement are vertically downward and parallel to each other, thus the entire spreader mechanism can be regarded as a stable platform to meet the disposed requirements of pressure sensors on the bearing spin-lock support assembly. Based on the foregoing analysis, pressure sensors were installed on the four bearing spin-lock support assembly of spreader, load of the twist locks can be considered only in vertical direction. weight of the four container corners can be transfer to twist lock nuts by latches, and twist lock nuts transfer the force to weight sensors, then central processor converts the electrical signal of sensors into the digital signal which familiar with us. So container crane can complete the unbalanced load detection quickly in the process of loading and unloading.

Four latches carrying the total weight of container and goods when container is lifted from the bearing surface, in order to eliminate the effects of unbalanced force in circumferential direction, the lower portion of twist lock nuts should be processed into a convex spherical, and the upper portion of sensor is processed into a concave spherical, so twist locks can turn around the globe center for trace swing. According to the arranged form of pressure sensors, spreader also can ensure that loads suffered on the twist locks transfer to sensors evenly even when the crane lifting a small deformation container[6](it will not affect the measurement accuracy of sensors when twist locks swing within $\pm 5°$). Latch weighing form is shown in Fig.2.

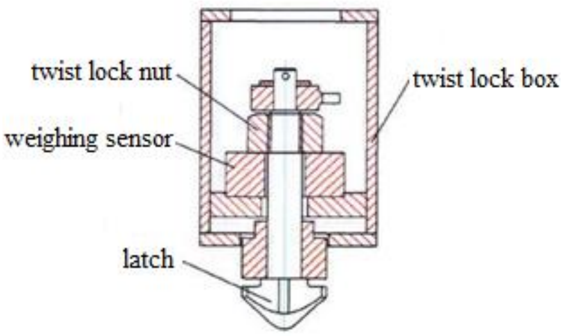

Fig.2 Latch weighing form

Calculation Model

Spreader controller can converted the measured data of sensors into total weight of the container and partial load proportionally, and output it. Fig.3 illustrates a schematic representation of load calculation model. Among it:

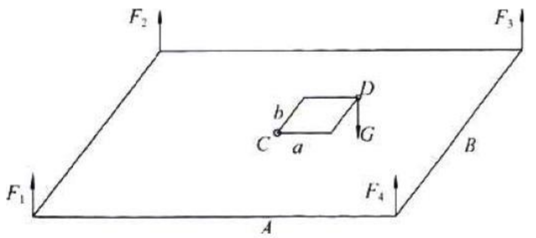

Fig.3 Load calculation model

F_1, F_2, F_3, F_4 —Measured force of each sensor; G —Gravity of cargo and container； C —Geometric center of container; D—Gravity center of container; A—Lateral distance between container angular holes (For 20ft ISO containers, $A = 5853mm$, For 40ft ISO containers, $A = 11985mm$); B—Longitudinal distance between container angular holes (For 20ft and 40ft ISO containers, $B = 2259mm$); a—Lateral offset of the container gravity center; b—Longitudinal offset of the container gravity center.

We can obtaine the following equation according to the mechanics balance knowledge:

$$G = F_1 + F_2 + F_3 + F_4 \quad (1)$$

$$(F_1 + F_2)(\frac{A}{2} + a) = (F_3 + F_4)(\frac{A}{2} - a) \quad (2)$$

$$(F_1 + F_4)(\frac{B}{2} + b) = (F_2 + F_3)(\frac{B}{2} - b) \quad (3)$$

Integrating the foregoing three equations, we can get the lateral and longitudinal offset:

$$a = \frac{A}{2} - \frac{(F_1 + F_2)A}{G} \quad (4)$$

$$b = \frac{B}{2} - \frac{(F_1 + F_4)B}{G} \quad (5)$$

Partial load detection system can perform the following functions:

(1) If 20 ft ISO containers meet the following requirements at the same time: $G = F_1 + F_2 + F_3 + F_4 \le 450kN$, $|a| \le 600mm$, $|b| \le 100mm$; which indicates that container load meet the requirements, otherwise the buzzer alarms;

(2) If 40 ft ISO containers meet the following requirements at the same time: $G = F_1 + F_2 + F_3 + F_4 \le 450kN$, $|a| \le 1200mm$, $|b| \le 100mm$; which indicates that container load meet the requirements, otherwise the buzzer alarms;

(3) For 20 ft and 40 ft ISO containers, if $|a| > 80mm$, operator press the automatic buttons, pilot lamp is on when the spreader sway in place, reminding operator to carry out the next movement;

(4) For 20 ft and 40 ft ISO containers, if $|a| \le 80mm$, pilot lamp is on, reminding operator to carry out the next movement;

(5) For those containers which does not meet the requirements, the operator can see the offset direction and distance of gravity center, and will print out the testing data through an external micro-printer, because of this, the operator can mark the container timely and easily.

System Design

The most effective is digital terrestrial detection devices among the successfully developed equipments, it requires specialized sites, and need to ship all the testing containers to designated location, which apparently unable to complete the dynamic monitoring of container. For large quantities of container detection, it is consuming and labor-intensive. As we know, even though the operator can determine the qualitative partial load empirically, when you cannot provide the reliable data, you don't have right to require the client unpacking container and rearranging goods. Accordingly, it will not be able to eliminate safety hazards timely, partial load problem give rise to a great risk to the safe transportation of containerized cargo.

4.1 Block Diagram

Partial load detection system of spreader includes four major parts: spreader controllers, sensors, actuators and control panel. This paper draws the block diagram of control system in Fig.4.

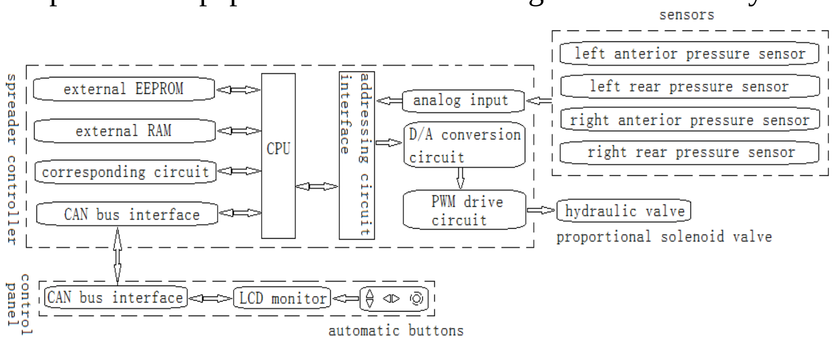

Fig.4 Block diagram of control system

Spreader controller is the key component to achieve a intelligent control, including CPU processor, input and output modules, drive circuit module, correspoding module and interface circuit, etc; Sensors contain left anterior pressure sensor, left rear pressure sensor, right anterior pressure sensor and right rear pressure sensor; Actuator mainly comprises proportional solenoid valve; For the operating panel, we no longer make hardware development alone, borrowing the original manipulation platform instead, as the man-machine interface dialogue, operating panel including automatical button, LCD monitor and other elements.

4.2 Program Flowchart

Good procedures not only can improve the operating speed of system, but also increase the stability of system. Flowchart design is essential to abandon the early parts of the redundancy programming, only in this way can we get the refined and practical procedure. For those packing containers unqualified, program flowchart of alarm system is shown in Fig.5, and Fig.6 shows the program flowchart of lateral sway.

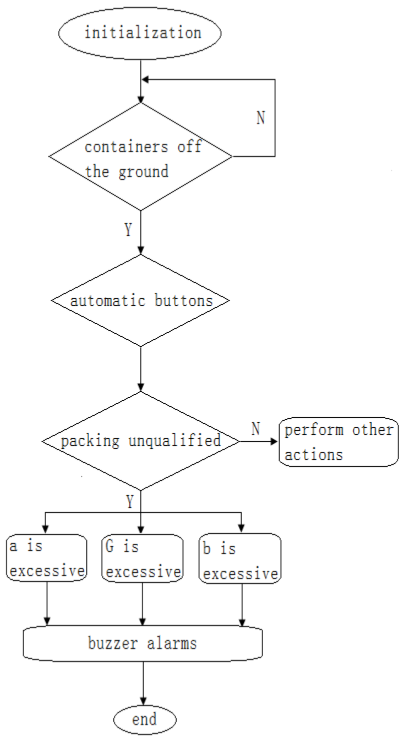

Fig.5 Flowchart of alarm

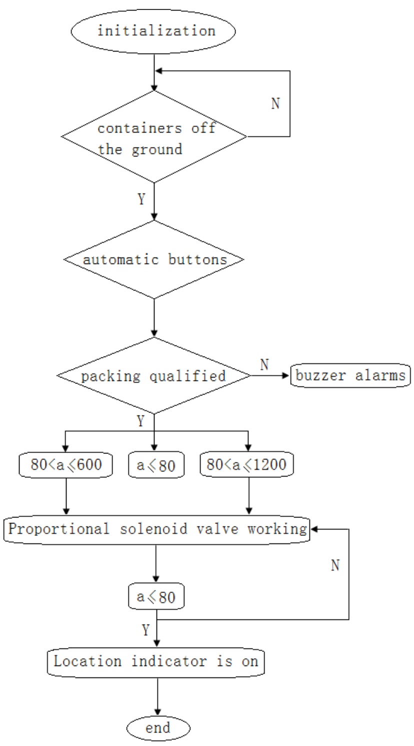

Fig.6 Flowchart of lateral sway

When container is off the ground, driver starts up the Auto buttons, then system begins to detect whether the container meets the packing requirements or not. If any is excessive for G, a and b, this box deemed to be packing unqualified, buzzer alarms in this case; On the contrary, this box deemed to be packing qualified, then system performs other actions.

When container is off the ground, driver starts up the Auto buttons, then system begins to detect whether the container meets the packing requirements or not. If this box is packing qualified, and $|a| \le 80mm$, then location indicator is on which reminds driver to carry out the next operation; If $80 < a \le 600mm$ for 20ft ISO containers and $80 < a \le 1200mm$ for 40ft ISO containers, spreader approximately get to the gravity center of container and cargo by lateral movement, location indicator is on when spreader meet the intended program, which reminds driver to carry out the next operation.

The system is practical, reliable and easy to operate. It not only lower the maximum stress and deformation of spreader in working process, avoid the phenomenon of earlier damage under continued high stress, but also guarantee the subsequent safe transportation and improve the cargo transport efficiency from a long-term sense.

Conclusions

It discusses the installation necessity of partial load detection system on the front hanging spreader, then describes the system feasibility analysis, calculation model, block diagram and flowcharts in detail, which oretically explain the rationality of the control scheme. This system is practical, reliable and easy to operate, improving the mechanical characteristic of spreader mechanism to ensure the safe cargo transportation, but also to maximize avoid early structure failure phenomenon under the continuing high stress, thereby extending the lifetime of crane and reducing the container transportation costs.

Acknowledgements

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