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Study on Anti-sway Performance of V-shaped Structure of 50t Multipurpose Gantry Crane

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Abstract: In order to improve the anti roll performance of multipurpose portal crane, a new type of hoist structure is adopted. An additional anti rolling plane of V-shaped structure is constructed by adding four supporting rollers which can swing with the hoist to increase the anti roll performance of the hoist. The new structure was modeled by SolidWorks and then introduced into the ANSYS Workbench for transient dynamic analysis. The comparison of the simulation results shows that the new structure with the increase of wheel are compared with the traditional structure, the swing amplitude of each direction and reformed time have been greatly reduced. The feasibility of the new structure is verified by increasing the anti roll performance of the hoisting gear by increasing the supporting roller.

Introduction

Sway of slings is a problem that has been besetting designers and commissioning personnel in the lifting industry all the time. To ensure the stability of slings in the case of sudden stop and rise, it is necessary to study the anti-sway performance of slings. When slings suddenly stop after moving at a certain speed, they will make compound pendulum motions due to inertia [1]. On the one hand, the generation of complex pendulum motions will make it difficult for the slings to go up and down before the motions stop, and on the other hand, it will also pose a lot of safety problems [2]. There are quite a lot of anti-sway systems for crane slings, and they can be roughly divided into three major categories. The first category is anti-sway systems based on mechanical structures. Such systems use relevant mechanical and physical principles and methods to realize stabilization and anti-sway of the slings. This category can be further divided into rigid anti-sway and flexible anti-sway subcategories. Because of the low cost and good anti-sway effect, mechanical anti-sway is highly widely applied in practice. The second category is hydraulic anti-sway systems, which deliver the anti-sway effect by applying hydraulic damping principle [3-4]. In recent years, with the development of electronic technology and automation technology, the third category of anti-sway systems has gradually produced, which use computers to prevent sway [5].

New Sling Structure

V-shaped anti-sway system is an inverted triangle anti-sway system. The system uses the geometrical principle that triangle is a stable structure and it makes slings have anti-sway performance on the plane by creating a V-shaped plane [6]. The anti-sway structure adopted by the new structure is a V-shaped four-rope anti-sway structure, and it is the first time that such a structure is applied to multipurpose gantry cranes. The structure of traditional multipurpose gantry cranes is relatively simple (as shown in Figure 1), and the sling system only consists of four fixed pulleys and steel wire ropes. The ropes are winded by arranging two steel wire ropes on both right and left axially in each winding drum. There are a total of four steel wire ropes, which independently go out of the winding drum almost vertically, then pass through a pulley on the sling, and return to the winding drum almost vertically. The four fixed pulleys are directly fixed on the sling. V-shaped anti-sway system is constructed on the XY plane. Depending on the V-shaped plane, the sling has certain anti-sway performance in X direction. Although traditional gantry crane slings feature a simple structure and a low production cost, they have obvious disadvantages in anti-sway performance. (1) The V-shaped included angle is small, and the anti-sway performance in Z direction is limited. (2) They have no anti-sway measure on the YX plane, and thus there is basically no anti-sway performance in X direction. (3) Due to the poor anti-sway performance, for the sake of safety, during the work, it is necessary to wait for the slings to be stable before the next step, which leads to low work efficiency. (4) Pulleys are few, the force acted on each steel wire rope is greater, and the torque requirement for the motor is high, which increases the cost of motor selection. Compared to the traditional structure, the most important structure change of the new multipurpose gantry crane (shown in Figures 2 and 3) is the addition of four supporting pulleys that can sway with the lifting up and down of the sling.

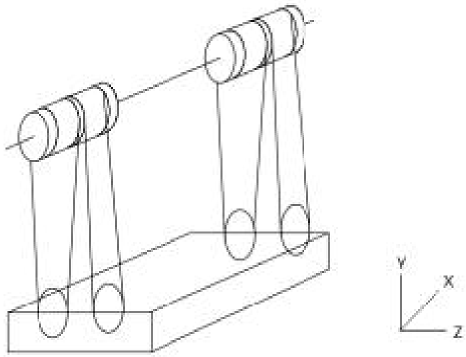

Fig. 1 Winding of ropes in the sling structure of a traditional gantry crane.

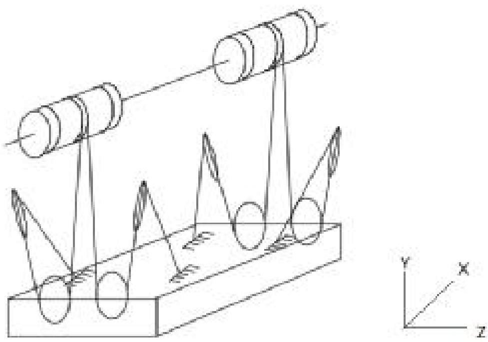

Fig. 2 Winding of ropes in the sling structure of a new gantry crane.

As an anti-sway system for slings of multipurpose gantry cranes, this new active anti-sway device comprises small frames, main lifting winding drums, lifting motors, brakes, speed reducers, pulleys, slings, supporting pulleys, steel wire ropes, and so on. The sling is characterized in that on the frame of the trolley, two lifting motors are symmetrically arranged on the right and left and perpendicular to the lengthwise direction of the trolley. They are connected to the gear box with the brake respectively, axially parallel to the main lifting winding drum in the direction of the trolley's track. Due to such arrangements, the main weight of the trolley is distributed symmetrically, which increases its stability during the operation and delivers an auxiliary anti-sway effect. In order to make the left and right motors rotate synchronously, the pulleys on both sides are rigidly connected to each other so as to avoid the balance of the entire sling from being affected by the rotation differences between the motors on both sides.

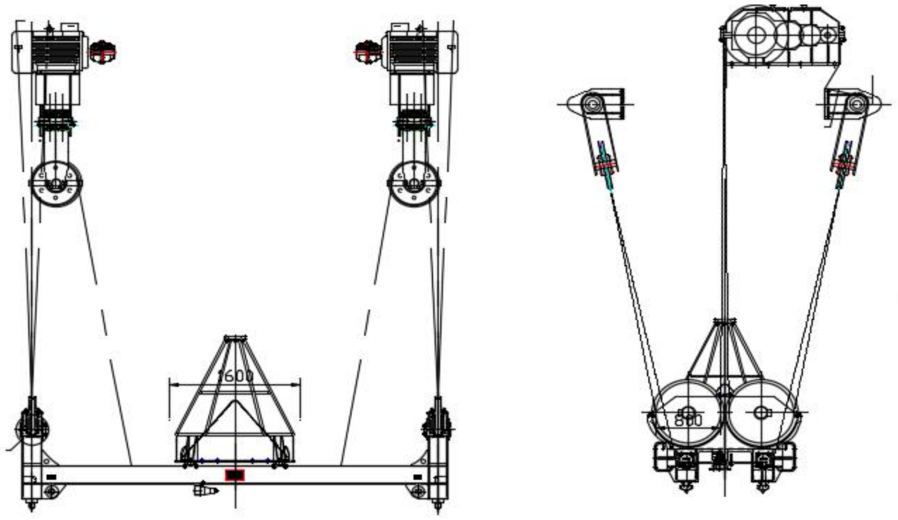

Fig. 3 Drawings New Sling Structure.

In each drum, two steel wire ropes are arranged on both left and right axially, and there are four steel wire ropes in total. Each of the ropes goes out of the drum almost vertically, passes through a pulley on the slings, and then goes upward and passes through an anti-sway supporting pulley at a certain angle. At last, the ropes are fixed down to the lower sling at a certain angle. The schematic diagram of the winding of the two steel wire ropes on one side is shown in Figure 4.

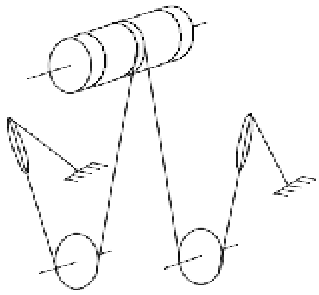

Fig. 4 Schematic Diagram of the Winding of the Steel Wire Ropes on One Side.

When the sling is going down, the angle between the two steel wire ropes becomes smaller. At this moment, the supporting pulley sways inward. When the sling is going up, this angle becomes larger, and the supporting pulley sways outward. The supporting pulley in this sling anti-sway system is of an independently designed structure. A hole is drilled on the center of the pulley, and a bearing passes through this hole and is fixed to the U-shaped sheet by means of welding. Then, the U-shaped sheet is connected and fixed to the base of the supporting pulley with a bearing, so that the pulley can sway on the vertical plane and construct a supporting pulley structure as shown in Figure 5. Winding of the ropes is changed through addition of the four supporting pulleys so as to create a V shape with steel wire ropes in X direction, further significantly enhancing the anti-sway effect of the sling in X direction. In the meanwhile, with supporting pulleys being added, the original V-shaped angle in Z direction becomes larger, and the anti-sway performance in this direction is also further improved.

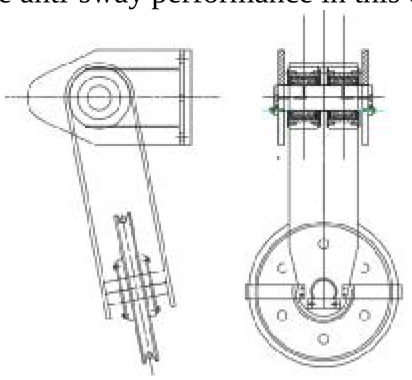

Fig. 5 Structure of Supporting Roller.

Analysis of Anti-sway Performance

To verify that the supporting pulleys that have been added can actually improve the anti-sway performance of the sling system significantly, a contrastive analysis was performed. The advantages and disadvantages of the anti-sway performance of this new structure were tested through simulation and comparison of the anti-sway performance of traditional and new structures. In the simulation, ANSYS Workbench was used, the transient dynamics module of which was employed to simulate the anti-sway performance of two structures in different directions. Angles of steel wire roles when the new structure and the traditional structure were in the same lifting position were selected according to the drawings, and Solidworks was used to simplify the model of its structure and do the modeling work (as shown in Figures 6 and 7). In the process of simplifying the model, the trolley and the pulley were simplified as a sheet. Only the diameter of the pulley was kept as the distance between two steel wire ropes, and the inclination angle of the pulley was taken as the inclination angle and included angle of the steel wire ropes. In the model constructed, the included angle between two steel wire ropes on both sides of the pulley and the inclination angle of the supporting pulley were both 11°.

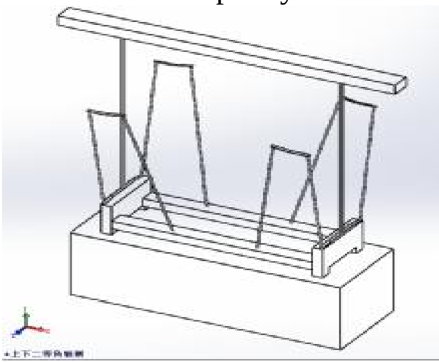

Fig. 6 New Sling Structure Model.

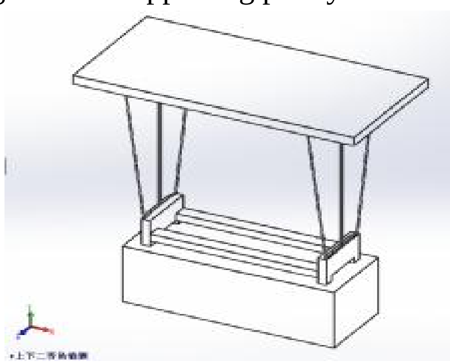

Fig. 7 Traditional Sling Structure Model.

In the process of numerical simulation, to make the simulation results have more comparison values, an acceleration of 4 m/s^2 was used as the excitation source all the time, and there were two steps in total (as shown in Table 1). Step 1 was the stage at which the excitation source was loaded and disappeared, and Step 2 was the stage at which the slings performed compound pendulum motions after the removal of excitation source.

Table 1 Relevant Settings of Steps

Item	Step 1 [s]	Step 2 [s]
Step end time	0.1	40
Initial time step	1×10^{-4}	1×10^{-2}
Minimum time step	1×10^{-6}	1×10^{-5}
Maximum time step	1×10^{-3}	1

Performance Analysis of the New Structure. The constructed model was imported in ANSYS Workbench, and then the following steps were followed. (1) Set the lower sling load as a rigid one and re-set the relevant constraint; (2) divide the grid as required; (3) complete the relevant settings of the simulated steps; (4) set a fixed constraint on the upper model sheet to fix it; (5) on the YZ plane, add a revolute pair on the simplified sheet of the supporting pulley so as to make it sway like the supporting pulley; (5) add an overall gravity in the direction of –Y; (6) add an excitation source in X direction; and (7) extract the required simulation results.

Through numerical simulation, the sway result in X direction was obtained (as shown in Figure 8). Then simulation was re-conducted with the direction of the excitation source being changed into Z, and then the sway result of the new sling structure in Z direction was obtained (as shown in Figure 9).

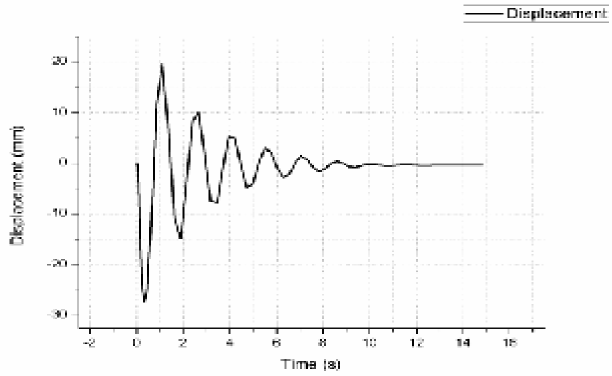

Fig. 8 Sway Result of the New Structure in X Direction.

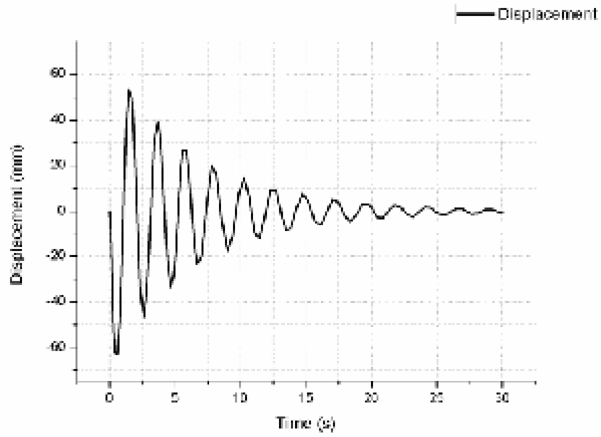

Fig. 9 Sway Result of the New Structure in Z Direction.

According to the simulation results, the greatest amplitude of the new sling structure in X direction was 27.085 mm, the basic restoration time was 11.19 s, and the complete restoration time was 13.52 s. The attenuation of sway amplitude in one cycle was about 50%. In the case of sway in Z direction, the greatest sway amplitude was 63.255 mm, and at around 30 s, the sling was basically restored, with the attenuation of sway amplitude in one cycle being about 23%. Thus, the new sling structure had pretty good anti-sway performance in X direction and it could greatly attenuate the sway amplitude within a short period. It also has fine anti-sway performance in Z direction but that in X direction is more excellent.

Performance Analysis of the Traditional Structure. The steps of simulating the anti-sway performance of traditional structures are basically same as those of the new structure. For the traditional structures, simulation also needs to be done on the anti-sway performance in the directions of X and Z. To make the results have more values in comparison, the excitation source, parameters and so on in the simulation of traditional structure were same as those in the simulation of the new structure. Based on these conditions, the anti-sway performance of the traditional structure in both directions was obtained (as shown in Figures 10 and 11).

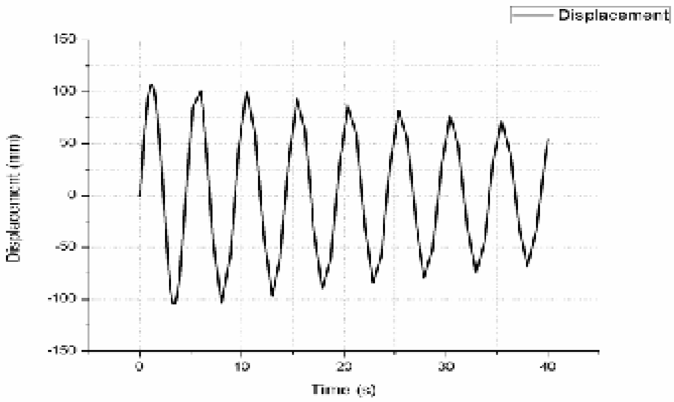

Fig. 10 Sway Result of the Traditional Structure in the Direction of X.

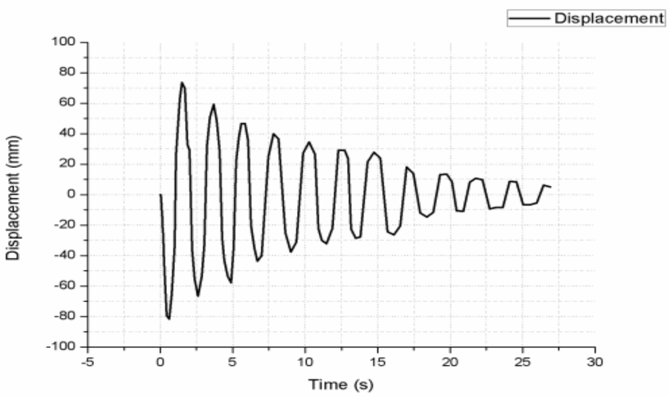

Fig. 11 Sway Result of the Traditional Structure in the Direction of Z.

According to the simulation results, due to the lack of anti-sway measure in X direction, the anti-sway performance of the traditional structure in X direction was extremely poor. The largest sway amplitude was 104.55 mm, and the attenuation of sway amplitude in one cycle was about 3.2 %. Even 40s later, the amplitude was still great. In Z direction, the greatest sway amplitude was 81.544 mm, about 12.5% of the amplitude was attenuated after one cycle, and a small amplitude of sway still remained 30 s later.

Conclusions

After comparing and summarizing the simulation results of the new and the traditional anti-sway systems, the data comparison in Table 2 is obtained.

Table 2 Comparison in Anti-sway Performance

Item	X direction of the new structure	Z direction of the new structure	X direction of the traditional structure	Z direction of the traditional structure
Greatest swing amplitude[mm]	27.085	63.255	104.55	81.544
Attenuation of sway amplitude in one cycle	50%	23%	3.2%	12.5%
Restoration	Restore at 13.52s	Restore basically at 30s	Greatly sway at 40s	Slightly sway at 30s

After the addition of four supporting pulleys, the greatest sway amplitude in X direction was reduced from 104.55 mm of the traditional structure to 27.085 mm, with nearly 74% greatest sway amplitude being reduced, which was a significant improvement to the anti-sway performance in X direction. In the Z direction, the greatest sway amplitude was reduced from the original 81.544 mm to

63.255 mm, with nearly 23% smallest sway amplitude being reduced, which indicated that the anti-sway performance in this direction was also improved to a certain extent. As for the attenuation of sway in one cycle, the new structure was attenuated by almost 50%, a very high degree. However, in X direction of the traditional structure, since a V-shaped anti-sway system nearly existed, the attenuation of the sway in one cycle was only 3.2%, very small. In the Z direction, the attenuated sway amplitude of the new structure was 23%, which was a great improvement compared to 12.5% of the traditional structure. As for the restoration time, 13.52 s later, the sway of the new structure in X direction restored completely while that of the traditional structure in this direction still had very large amplitude even 40s later. The restoration time of the new structure in X direction was far shorter than that of the traditional structure. As for the sway in Z direction, 30s later, the sway of the new structure restored basically but that of the traditional structure still had certain amplitude. Thus in this direction, the restoration time of the new structure was also shorter than that of the traditional structure.

The following conclusions were made based on the summary of all data:

（1）Sway of the new structure in X direction was smaller than that in Z direction in terms of both amplitude and restoration time. Thus the anti-sway performance of this structure in X direction was much better than that in Z direction.

（2） In the traditional structure, due to the general lack of anti-sway structure in X direction, the anti-sway performance in Z direction was better than that in X direction.

（3） With the addition of the supporting pulleys to the new structure, a V-shaped plane was constructed in X direction, significantly improved the anti-sway performance in this direction. In the meanwhile, the anti-sway performance in Z direction was also improved to a certain extent.

Overall, simulation and comparison verified that the new sling structure added with the supporting pulleys could actually greatly improve the anti-sway performance in both its directions and reduce the sway amplitude and restoration time.

Acknowledgements

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