Research about a Kind of Gantry Type Single-side Drive Straight Line Motion Mechanism

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Abstract: The article mainly has conducted comparison to three kinds of frequently-used long-span gantry type mechanism that do straight line motion, which thereby has obtained that the gantry type single-side drive mechanism has possessed relatively prominent advantage in the smoothness, assembly debugging, reliability and maintenance aspects of the motion and it has conducted reason analysis and structural improvement to problems existed in occasions of its application in large scale equipment, long span or heavy load with impact, which therefore has guaranteed the need for high precision and high stability in practical application.

1. Advantage and Existing Problem of Gantry Type Single-side Drive Straight Line Motion Mechanism

In the automation equipment structural design, it often has adopted gantry mechanism as the mechanism to execute round-trip of the rectistraight line motion, which can complete motion and position required by processing, assembly, detection, etc\textsuperscript{[1]}. This kind of mechanical engineering generally has three kinds of driving methods, below table will conduct comparison from stability of mechanical structure, assembly debugging, reliability of the mechanism, maintainability as well as cost, etc aspects.

From analysis and comparison of the above table, it has obtained that the gantry type single-side drive mechanism has possessed rather prominent advantages in smoothness of the motion, assembly debugging, mechanical reliability and maintenance aspects, which is optimal among the three design schemes. But in the actual application, as the load end of the single-side drive mechanism has existed effect of rotating the torque by winding the Z axis, the range that limits its application has mainly lied in gantry structure or small span gantry (ie., gantry whose width of guiding structure at both sides is no bigger than 600mm) or occasions whose heavy load has had impact cannot fall down on its job, which has mainly existed effects of below two aspects.
I. When the mechanism is in non-motion static status, if the span or the load is too big, it has had higher and harsher requirement to the rigidity as well as installation precision of the guiding system at both sides of the gantry, especially the guiding precision and rigidity of the drive side[3].

II. When the mechanism is in motion status, if the span is too big, as the driving power is only designed at the single-side, the cantilever domino effect of its load to the driving system will be very obvious, the pulsation of its moving speed as well as impact acting force of the load will generate-
torque on the beam, therefore rigidity of the beam as well as the smoothness of the operation are problem that must be solved.

| Type                                      | Double-drive of dual-motor | Single-side drive | Transmission synchronous drive |
|-------------------------------------------|----------------------------|------------------|--------------------------------|
| Schematic diagram                         | ![Diagram](image1)         | ![Diagram](image2) | ![Diagram](image3)             |
| Explanation                               | Two sides of the gantry all have designed drive motor and transmission-guide mechanism to realize synchronous movement via the control. | One side of the gantry has designed the drive motor and transmission-guide mechanism; the other side has designed support and guide structure, the power is provided by the single-side. | One side of the gantry has designed the drive motor and transmission-guide mechanism, the other side has designed the transmission-guide mechanism, there is no drive motor, the power has guaranteed the drive synchronization of two sides with method of power synchronous transmission. |
| Smoothness of the motion is mainly decided by below factors: | Smoothness of the motion is mainly decided by below factors: | Smoothness of the motion is mainly decided by below factors: | Smoothness of the motion is mainly decided by below factors: |
| Guiding precision of two sides            | ①Guiding precision of two sides; | ①Guiding precision of two sides; | ①Guiding precision of two sides; |
| Precision of mechanical transmission in two sides | ②Precision of mechanical transmission in two sides; | ②Precision of mechanical transmission in two sides; | ②Precision of mechanical transmission in two sides; |
| Smoothness and synchronization of dual-motor motion in two sides; | ③Smoothness and synchronization of dual-motor motion in two sides; | ③Smoothness and synchronization of dual-motor motion in two sides; | ③Smoothness and synchronization of dual-motor motion in two sides; |
| Kinematic accuracy of bilateral drive motor, especially the synchronization of bilateral drive motor motion. | ④Kinematic accuracy of bilateral drive motor, especially the synchronization of bilateral drive motor motion. | ④Kinematic accuracy of bilateral drive motor, especially the synchronization of bilateral drive motor motion. | ④Kinematic accuracy of bilateral drive motor, especially the synchronization of bilateral drive motor motion. |
| Quantity of the structural parts are very large, mechanical assembly and precision debugging difficulty is common, but two sides are two power and drive system, debugging difficulty of electric control is relatively high. | Quantity of the structural parts are very small, mechanical assembly and precision debugging is very easy. At the same time, its transmission is only a set of system, debugging of electric control is also very easy. | Quantity of the structural parts are very large, in order to guarantee the synchronism and stability of motion in two sides, debugging difficulty of its overall motion system is very big, but the debugging of electric control is relatively very easy. |
| In order to guarantee the synchronism of motion in two sides, it needs corresponding detectors, if the reliability has extent guarantee, it needs to periodically maintain the electric control and two sets of drive transmission structures, the maintaining difficulty is general. | In order to guarantee the motion precision and reliability of the single-side drive, the guide precision and rigidity requirement of its driving side is very high, which needs to periodically maintain the drive transmission structure and the rigidity of the guiding, the maintenance is relatively very easy. | In order to guarantee the synchronism of motion in two sides, it has had extent transmission precision and rigidity requirement to the power transmission structure, at the same time, if it is to guarantee the precision of the drive and transmission position, the periodical maintenance it needs are synchronous transmission structure, drive transmission structure, especially the maintaining frequency of the transmission structure is very high, which relatively is the most difficult. |
| Cost                                      | Very high                  | Rather low        | Rather high                  |
2. Optimal Design of Large Span Gantry Type Single-side Drive Straight Line Motion Mechanism

2.1. Countermeasures of the Guide Precision and Rigidity

There are generally two sets of guiding structure in the gantry type single-side drive straight line motion mechanism, among which structure of the driving side has mainly played the guiding role, whose precision and rigidity has played important role in the overall gantry motion system. However, the other side has mainly provided support for the end of the beam and has strengthening the guidance quality of the beam. As is shown by below figure 1, when the span L of the gantry increases, however effective guiding length k1 of the two sliding blocks does not increase, which has directly lead to the decline of specific value for guiding rigidity coefficient k1/L, when specific value of rigidity coefficient k1/L is no bigger than 0.5, rigidity variation of the guiding system will be magnified in multiple by the gantry beam[4]. This means the deviation in rigidity and stability of the system. In order to enhance the stability of the gantry type single-side drive straight line motion mechanism, except by increasing the pre-pressing grade of the ball straight line guideway sliding block, it also must enhance the guiding rigidity coefficient k/L. The most frequently-used practice is to increase the space between two sliding blocks in the straight line guideway, ie., to directly increase k1. Aiming at defects of gantry type single-side drive straight line motion mechanism in large span occasions, except for method of directly increasing space K1 between two sliding blocks, it has additionally had method of adding one sliding block and strengthening block (As parts expressed by imaginary line in figure 1), via this optimal design, it can directly increase the original effective guiding length k1 to k2, which therefore has enhanced the specific value k/L of guiding rigidity coefficient. At the same time, when in installation debugging, the optimal design of this kind of structure can firstly assemble and debug in place via two sliding blocks (as is shown by 2 full line sliding block and beam parts of left side in figure 1), then it has assembled the third sliding block and it has added the guiding ability of the sliding block onto the gantry structure component via the strengthening component, which therefore has strengthened the load ability and motion rigidity of the gantry type single-side drive straight line motion mechanism.

2.2. Power design Countermeasures of the Drive and Transmission

As is shown by the above figure 2, for gantry type single-side drive straight line motion mechanism, the general power design can be distributed at three points, which respectively are ①②③ three points. In order to lower the cantilever beam effect of the large gantry span load to the driving system, via force analysis, it is better to design the application point of transmission and drive onto position ③.
2.3. Design of the Beam Structure
Integrating above analysis to structure, rigidity, loading form, etc of the gantry type, under the premise of guarantee the intensity of beam, for beam plate, the Y direction motion of the loading motion on the Z axis is the impact acting force of Y axis, however, for beam plate, X direction motion of the loading motion on Z axis is the impact acting force of X axis direction and the positive and negative twisting force winding Z axis for rotation. Therefore, when designing the beam, the key point is to increase the ability of beam plate’s resisting Z axis torque, ie., the intensity and rigidity of XY plane. Therefore, it has designed the beam into the flat plate type, whose two dimensional diagram is shown as figure 3:

Finally, its 3D diagram after the design is as follows:
3. Practical Application Cases of Gantry Type Single-side Drive straight line Motion Mechanism

In one set of mechanical equipment, the needed gantry span is 1200mm, by adopting above design method, it has designed the guide of the drive side into three sliding blocks, among which it has strengthened one sliding block onto the gantry structure. Then it has installed the power design onto the position of point ③ of the gantry system, in order to reduce that the weight of beam plate will bring excess loading for the large span gantry type single-side drive straight line motion mechanism and in order to guarantee its intensity and rigidity, it needs to conduct weight losing optimal designs to the beam plate, whose design diagram is shown as figure 5:

4. Conclusion

The article has intensified the rigidity and intensity of the large span gantry type single-side straight line motion mechanism via reasonable design and it has got verification and application in practical application, at the same time, via these two kinds of methods, it has effectively enlarged such simple, practical and stable structure as large span gantry type single-side drive straight line motion mechanism, which has made it to have larger application space.

Research project

Scientific research task of Guangzhou City Construction College (Y201909)
Inner Mongolia Natural Science Funds (2009MS0802), Inner Mongolia Office of Personnel Services Talent Funds, National Natural Science Foundation of China (61563042)
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