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Amplitude inspection of the large crawler crane without the marker of turning center

According to the requirement of monitoring and management system for large lifting machinery in the national safety inspection regulations, safety monitoring and management system should be installed for crawler crane with a capacity of exceeding 100 tons. There is an inspection requirement for the amplitude accuracy of the crawler crane. It requires that the sensors should be tested accurately during operation and within the allowable range of the operation instructions. However, it is difficult to measure the amplitude without the marker of turning center on the spot. as the crawler crane has been assembled,the revolving center is covered by the end cover, etc. Therefore, it is necessary to consider other ways to test the relevant parameters. In this paper the method is resorted to the technical and precision advantages of the Total Station,so as to obtain the key amplitude plane and turning center level. The amplitude is calculated by MATLAB programming, and more accurate measurement values are obtained. This method is universal in use, which can thoroughly solve the problem that the amplitude of large equipment cannot be accurately detected, and the accuracy is relatively high.
Keywords: *Slewing Cranes, Safety Monitoring and Management system, Amplitude inspection*

1. INTRODUCTION

In recent years，along with the continue expansion of domestic construction scale， the demand of large crane is increasing.As an indispensable equipment for loading and unloading in construction works,crawler crane plays an important role in infrastructure construction and social development. However, crane accidents have brought many negative effects because of their frequent occurrence.So,crane safety work becomes one more noticeable problem.Additionally,the national special equipment safety supervision bureau also in the book of the supervision and inspection of hoisting machinery regulations proposes it should be equipped with safety monitoring devices for some large crane,such as,the crawler crane hoisting weight exceeding 200t should be installed safety monitoring device.

2. PRINCIPLE OF VARIABLE AMPLITUDE MONITORING SYSTEM

Crawler crane is a special operation equipment used in large-scale construction and industrial control occasions. It is not only necessary to accurately realize the functional action required by the system, but also an important prerequisite to ensure the safety of people and equipment. Therefore, its safety and reliability are the premise of all functions. Only under the premise of ensuring safety, can functional design be carried out. Therefore, the crane luffing monitoring system is an important part of the crane control system.

It mainly monitors the amplitude change system in real time, transforms and analyses the necessary data, and then displays them on the monitoring equipment. At the same time, there are faults which need real-time alarm output.Under the premise of perfect system communication, the ability to solve some faults remotely is realized.

The realization steps of the variable amplitude monitoring system are as follows:

(1) Sensor signal acquisition

This part mainly collects all kinds of signals through sensors. The signal of angle sensor is analog signal, and the signal of height limit switch is switching signal.

Angle sensor (mounted on the bottom arm) - Real-time measurement of the working angle of the boom;

Height Limit Switch - Real-time limit the maximum lifting height of heavy objects.

(2) Data processing and calculation

The measured signal is input to the PLC controller. The PLC controller calculates the real-time load and moment percentage of the crane according to the data collected by the sensor, the parameters required for the crane's amplitude change are preset by the system, the crane's working principle and moment calculation formula, and stores the calculated data.

(3)state display alarm

The alarm and parameter setting of status display are realized by display and buzzer. The parameters of crane, such as structure, working condition, alarm and so on, are set by human-computer interaction interface on the touch screen display. In order to be easy to understand, these parameters are displayed graphically. The buzzer is mainly used to realize sound and light alarm under different working conditions.

(4) Output safety protection control signal

The actual load is compared with the rated load, and the percentage of comparison is divided into four sections. Different color icons are shown on the display of different sections, which is divided into four states:

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normal operation, yellow warning, orange warning and cut-off dangerous action.

(5)System Communication

The system communication between the controller, PC and other serial devices is realized by RS232. The field bus communication between Profibus devices is realized by Profibus bus.

The purpose of inspecting the amplitude monitoring system is to verify whether the system's indication and accuracy of the amplitude are correct and meet the requirements of the national hoisting machinery regulations.

3. The Characteristics and Measuring Process of Leica TPS1200

After doing some reference research on the domestic and foreign existing crane safety protection monitoring devices, based on current inspection method of crane safety monitoring system stability, reliability and precision and system function of the shortage, this paper puts forward an amplitude inspection method based on Leica TPS1200 Total Station system.

At present, in the process of crane debugging and testing, manual tape is often used to measure the amplitude, which requires visual measurement of the corresponding position and reading data, so that the measurement accuracy is poor and the efficiency is low. moreover, visual measurement of the corresponding position by manual tape requires that when the crane is debugging the lifting weight, people work under the boom, which has a great potential safety hazard. In order to accurately measure the amplitude,improve the efficiency. and eliminate potential safety hazards, Leica TPS1200 Total Station system can be used to accurately measure the crane's amplitude with an accuracy of 2 mm+ 2 ppm[1].

3.1 Characteristics of TPs 1200

The TPS1200's precision angle-measurement system operates continuously to provide instant horizontal and vertical circle readings that automatically corrects for any "out of level" by a centrally located twin-axis compensator.

Figure 1. Leica TPS1200 instruments

Distance Measurement (average atmospheric conditions)

Range Round prism (GPR1): 3000 m

Range 360° reflector (GRZ4): 1500 m

Range Mini prism (GMP101): 1200 m

Shortest measurable distance: 1.5 m

Accuracy (standard deviation, ISO 17123-4): Standard mode: 2 mm + 2 ppm

Measurement Time: ~ 1.5 s

Display resolution: 0.1 mm

Method: Phase measurement (coaxial, invisible infrared laser)

Leica TPS1200 instruments is shown in the figure 1.

3.2 Measurement and calculation methods

Figure 2. the crawler crane

(1) Obtaining geometric dimension data of side steel structure based on instructions.

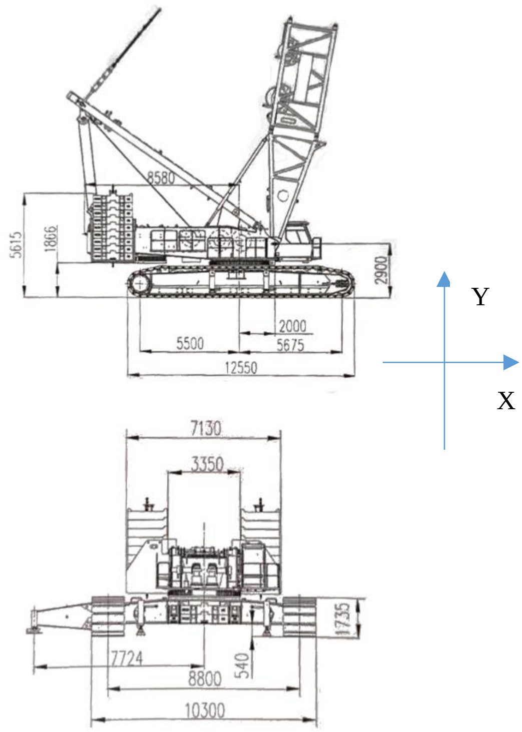

Figure 3. Geometric dimension data of side steel structure of the crawler crane

The crawler crane is tested for amplitude is shown in the figure 2.First, we should read the instructions of the crawler crane, each crawler crane should have the operating manual, geometric dimension data of side steel structure can be obtained from the technical description pages of instructions. The dimension data is shown in the figure 3.

(2) Determining the measuring points of ①,②,③,④

The geometric dimension data of the crawler crane are known.We can determine the middle point ① of the steel structure of the crawler traveling mechanism. This point has the same X coordinate value as the revolving center of crawler crane,which is the key point and shown in the figure 4,then we can find a point ③ of Plane of steel structure, which is in the vertical direction of ①. Ensuring the plane composed of the line of ① and ③ points and the revolving center of crawler crane is consistent with the normal plane of the side of tracked steel structure.the points of ② and ④ are arbitrarily decided side plane of steel structure, which is to determine and verify the lateral plane of this steel structure.

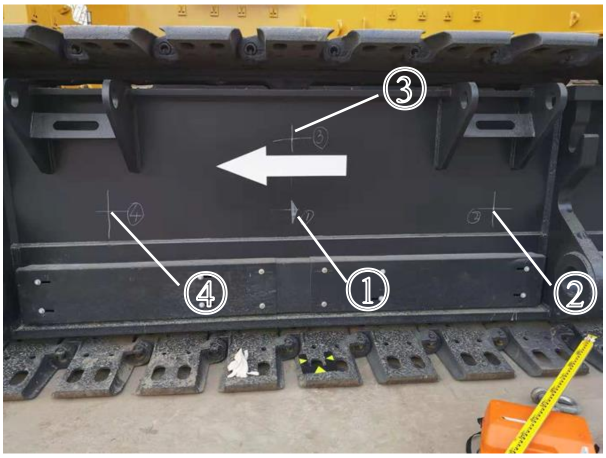

Figure 4. Determining the measuring points of the crawler crane

(3) Gauging data of points ①,②,③,④ & Lifting point with Total Station.

Gauging data of points ①,②,③,④(This point is a reserve checkpoint, which is the same fuction of ②) is obtained with Leica TPS1200 Total Station. The measurement process is as follows:

It is very important to level the instrument after installing it. If the Total Station is not leveled correctly, measurements will not be continued.The bubble level above the keyboard can be used to make the major adjustment, which is realized by using the thumbscrews on the tribrach to locate the bubble in the center. The fine adjust must be done using the Total Station. First, press the SHIFT key, After pressing SHIFT arrow in the lower right portion of the display which should be solid.Then press <F12>, which will display the Level & Laser Plummet screen.

Use the thumbscrews to locate the bubble as precisely in the center as possible.

After leveling the instrument the various settings related to the acquisition of targets should be checked.

Select the Config menu from the main menu.

Scroll down to General Settings (or press the number key 3). Press <ENTER>.

Scroll down to Units & Formats (or press the number key 3). Press <ENTER>.The default options for Units & Settings will display.

Next, check the EDM (Electronic Distance Measuring Device) and ATR (Automatic Target Recognition) configuration options and adjust them if necessary.

Select the Config menu from the main menu.

Press <ENTER>.

The first option EDM & ATR Settings should be selected, if not then use the scroll keys to select it (or press the number 1 on the numeric keypad).

Check the other settings including EDM Mode, Automation and ATR Settings to make sure they match the screenshot shown at right. The default settings are shown, adjust as needed.

The initial Survey screen shows the current telescope position. We will need to point the telescope at the prism we wish to measure. Use the crosshair spotting tool at the top of the telescope to more precisely locate the prism or view the prism through the telescope itself. Align the crosshairs of the telescope with the center of the target. It does not have to be an exact alignment because the ATR of the instrument will locate the prism precisely once it's engaged. Use the knobs on each side for fine horizontal and vertical adjustments.

Note the DIST button at the bottom of the display. Use the stylus to select this button or press <F2> to engage the ATR and actively locate and measure the target prism position.

Auto will utilize the ATR system to automatically locate the Target within the search window defined previously, measure the distance using the EDM system and update the Hz, V and distance values.

If the ATR is unable to locate the reference you will need to sight the telescope more precisely and press <F2> again. If unsuccessful after a few attempts then check section 4 for troubleshooting help.

Record the Hz and V values for entry in the MultiLogger Configure Total Station Targets form. The Horiz

Dist measurement value can also be recorded but it is not used for configuring the automation.

As a new technology in the field of Surveying and mapping, Prism-free surveying technology is applied to production, and its accuracy is the most concerned problem. For this reason, we collect two sets of data in IR state with infrared light and prism ranging and RL state (no prism measurement) where the field of vision is wide and the reflective medium is good. Because the measured distance is not more than 500 m, the meteorological correction, multiplication constant correction, tilt correction and projection correction of oblique distance are all very small, and their effects can be neglected.

Measure points are used by the Prism-free measurement technology of Total Station.The measuring points coordinate values are shown：

A=[14.0748,36.4558,5.2339] of point ①;

B=[14.0740,36.4562,5.6192] of point ③;

C=[13.4379,37.4143,5.2236] of point ②;

The equation of plane A,B,C is as follows:

$$Ex+Fy+Gz+H=0 \tag{1}$$

Then the normal vector of the plane is $\overrightarrow{(E,F,G)}$, which could be solved by the determinant equation,

$$\begin{vmatrix} i & j & k \\ (A-B)_x & (A-B)_y & (A-B)_z \\ (C-B)_x & (C-B)_y & (C-B)_z \end{vmatrix} = 0 \tag{2}$$

Then the coefficients of i,j,k are corresponds to E,F,G respectively, and H can also be obtained by introducing the coordinate value of point A into the equation of plane ABC.

(4) From the content of spatial analytic geometry, we know that the determinant of D equals zero, which is a

plane equation[2], D=[ones(4,1),[[x,y,z];A;B;C]]. The basic principles are as follows:

If three points p1, p2, P3 are known, the plane equation is obtained, p1= [x1, y1, z1]; p2= [x2, y2, z2]; p3= [x3, y3, z3]; then the following matrix Q determinants are solved: q= [ones (4, 1), [x, y, z]; p1; p2; p3]; DETB = det (q); finally, q = 0.

The solution here is the determinant of the fourth-order matrix, which can be solved from the determinant of the third-order matrix. That is the conventional solution method: the system of equations is written as [p1; p2; p3] = D, where D= [d, d, d]'represents the constant term of the plane equation, and first the determinant of q= [p1; p2; p3] is obtained, then the determinant of the third-order matrix composed of D and three coordinates is set as q1, q2, q3 respectively. The four parameters of the plane equation are A=q1/q; B=q2/q; c=q3/q; D=d; and the result multiplied by q/d is essentially the determinant solution of the fourth-order matrix above.

(5) Creating a symbolic matrice

detd=det(D);which returns the determinant of square matrix D.

(6) Getting the coefficients of geometric equation

G = coeffs(detd);which returns a structure containing the coefficients of the discrete-normal vector in the Side Plane of Steel Structures.

(7) Coefficient assignment

a=G(4);b=G(3);c=G(2);d=G(1);

vpa (a); vpa (b); vpa (c) ; vpa (d);

The basic effect of VPA function is as follows:

vpa(x) uses variable-precision floating-point arithmetic (VPA) to evaluate each element of the symbolic input x to at least d significant digits, where d is the value of the digits function. The default value of digits is 32.

Assignment of Lifting point is measured by Leica TPS1200 Total Station. The coordinates of the hoisting point are as follows:

p(1)=38.3101; p(2)=8.1980; p(3)=30.0578;

(8) Solving the Normal Vector of a Plane Passing Points of ① & ③

a1=[(A(1)-B(1)) (A(2)-B(2)) (A(3)-B(3))] ; which is the vertical vector in the Side Plane of Steel Structures.

b1=[a b c] , which is the normal vector in the Side Plane of Steel Structures.

c1=cross(a1,b1);which returns the cross product of a1 and b1.

a1 and b1 are matrices or multidimensional arrays, then they must have the same size. In this case, the cross function treats a1 and b1 as collections of three-element vectors. The function calculates the cross product of corresponding vectors along the first array dimension whose size equals 3.

(9) Solving the amplitude from point to plane by Point of ① & the Normal Vector.

La=abs(u×(A(1)-p(1))+v × (A(2)-p(2))+w × (A(3)-p(3)))/sqrt(u^2+v^2+w^2)

Where,u=c1(1); v=c1(2); w=c1(3). (3)

Distance calculation from hanging point to normal plane,the amplitude is 36.9983m.

4. System validation

Let's change the point of ② to the reserve checkpoint of ④, the amplitude is 36.9919m. The error is 6.4 mm,which is acceptable.because the error is the result of system measurement and calcution.

Considering the sag and measurement error of tape in long distance, it can be considered that tape can be replaced within the allowable range of error, and the accuracy is higher than that of tape. Installation of test equipment depends on tooling, and special tooling for installation of test equipment is developed independently, which greatly saves installation time.

5. CONCLUSION

Aiming at the problem of measuring range in the debugging test of crawler crane, this paper completes the measurement of crane amplitude by means of Total Station measuring system. This method has the advantages of high measuring efficiency and high accuracy in practical application, eliminating the hidden safety hazards of manual tape measurement, and achieves the expected effect.

Prism-free measurement technology has many advantages, but it is not omnipotent. Especially for harsh observation conditions in the field, the instrument can not change it, nor can it fully adapt to the conditions in the field. Therefore, operators should fully understand the characteristics of this new technology, take necessary measures to enhance their strengths and avoid weaknesses, in order to better play to the advantages of its advanced technology and equipment, and achieve good observation results. Through surveying and mapping practice, we put forward the following two suggestions for improvement:

(1) In view of the fact that Prism-free measurement is limited by obstacles and easy to cause errors in object surveying, it is suggested that the reflective function of Prism-free ranging range should be enhanced on equipment, and the visual estimation ability of surveyors should be fully utilized. If the object at 500m is to be measured and the range of ranging is set, the refractive object at 300m will not be mismeasured. When the object within 400-500m is to be surveyed, the best place for the line of sight to leave the obstacle is more than 1.5m in the range of 400-500m.

(2) In order to avoid eye damage caused by laser radiation in measurement operation, the author suggests that the instrument manufacturer add a high-power visible light "quasi-star" system.

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