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Study on The Dimensional Measurement Method of Bogie Frame Based on Arm Coordinate Measuring Machines

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ABSTRACT: Using CMM to do general detect to key dimensions of Various bogie frames. In measurement method, using least square fitting to fit the plane of frame and the processing converting the nonlinear equations into the linear equations with the use of generalized inverse matrix of system of linear equations to fit the coordinates of hole heart . Based on the measurement method of frame, we designed a frame universal detection platform to meet the detection of different types of frame during overhaul. By contrast experiment it is proved that the universal measurement method of bogie frame are feasible.

Keywords: frame；dimensional measurement；least square fitting；study on measurement method

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I. THE INTRODUCTION

Heavy passenger traffic in rail transit has kept the vehicles overloaded for a long time, especially during rush hour.Bogie frame as the bearing course of locating, installation and bearing of parts of the carrier, keep good state of size tolerance is to ensure that the direction of the premise of normal, collaborative work between components, and prevent the course of fatigue fracture, the core component of vehicle overturn or derailment [1]. Currently, the vehicle manufacturers and metro operators in many countries of the world have tested the bogie performance as an important step to ensure the safe operation of vehicles [2-4].

Existing domestic and foreign truck frame is not alone on the test-bed architecture itself, but in view of the overall bogie, function mainly measuring bogie dynamic performance, and the domestic existing single frame detection methods, can only be measured a type of architecture, at the same time due to the restriction of measuring equipment, only for a few frame size is measured, due to the special properties of the rail transit operational enterprises, the existing framework model is varied, the existing frame detection platform can't satisfy the rail transit operations enterprises on the structure performance growing demand for scientific evaluation, put forward the framework of general testing platform ideas and research and development is imperative.

This paper puts forward a kind of coordinate measuring machine based on joint arm type bogie frame size measurement method, and the design and cooperate with the general test platform of the bogie frame, frame for rail transit overhaul key size measurement stage.

II. ANALYSIS OF KEY DIMENSIONS OF BOGIE FRAME

2.1 basic structure and parameters of the frame

In the case of A type A vehicle bogie frame, it mainly includes two types of dynamic bogie and non-dynamic bogie frame, the two types of bogie frame are the same and can be interchangeable.The bogie frame is the overall welding structure, consisting mainly of two side beams and two beams, as shown in figure 1.The structure of the frame of the frame is u-shaped, a closed box structure, and the seat of the rubber spring is installed on the side of the end of the end, and the air spring seat is installed on the top of the center.Frame beam also adopts a closed box structure, on the outside of the skew symmetric set lift motor and gear box, in the lower part of the skew symmetric set traction rod, set between two beams horizontal stop [5, 6].

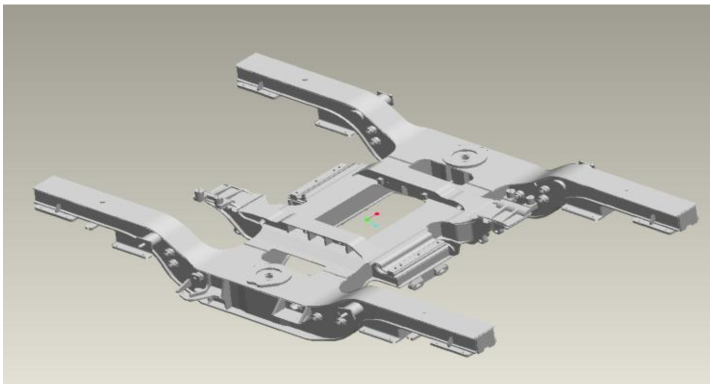

Figure 1 3D model of a A type bogie frame

The structural parameters and material parameters of the bogie are required to be obtained before the finite element model of the bogie frame is established. The main modeling parameters of the bogie are shown in table 1.

Table1 Basic parameters of bogie

parameter	numerical value
axle load	16.0 t
wheel base	2.5 m
• Curb Weight （AW0 state）	24000 kg
Passenger weight（AW3working condition）	25000 kg
Power steering frame quality	7500 kg
wheel diameter	840/770 mm
Composition quality of motor	635 kg
Vertical stiffness of each axle box	1.22 MN/m
Transverse stiffness of each box	5.8 MN/m
Longitudinal stiffness of each axle box	5.8 MN/m
Brake shoe pressure	40 kN

2.1 structure finite element discrete model

When the finite element calculation is carried out for the overall structure of the frame, the frame main body adopts the plate element, the gearbox and the motor seat adopt the physical element.The total model has 23820 nodes, 21,326 plate units, 574 three-dimensional entity units and 3,216 boundary yuan (7,8). In finite element calculation, the model of constraint condition using elastic boundary element, vertical, horizontal and vertical elastic boundary element on the side of frame beam axle box spring seat, the boundary element stiffness according to the parameters in actual bearing part of the suspension components to exert more. The load of the frame strength is determined by the uic615-4 [9] specification, which is used to assess the static strength of the frame.The loading position of the load is applied according to the actual position of the load.The load of the motor is applied to the center of the electric motor in the form of concentrated load, then the center of the motor is connected to the motor base by the rigid rod unit.The brake load is applied to the brake shoe, and the load is transmitted to the unit brake cylinder mounting block of the frame side by the rigid rod unit, and the frame stress is shown in figure 2.

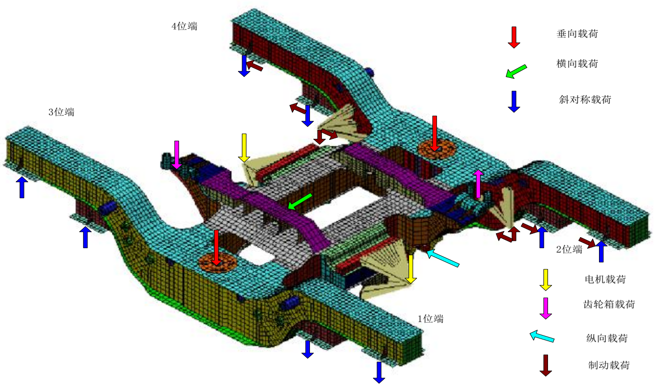

Figure 2 Schematic diagram of bogie stress

Applying exceptional load, reference standard UIC615-4 vertical load is applied, the larger stress parts mainly concentrated on the side of the beam, the central (103.4 Mpa) maximum load of cover plate, and the axle box spring seat position (maximum load 87.7 Mpa);When transverse load is applied, the main stress part is on the side girder and the transverse stop (maximum load 96.9 Mpa).When the oblique symmetric loading is applied, the main stress area is concentrated under the beam under the beam.When the longitudinal loading is applied, the large stress part is mainly concentrated under the beam under the center (maximum load 247Mpa).When the motor suspends load, the large stress part mainly focuses on the upper cover plate of the motor hanger and the lower hanging seat (maximum load 200.7 Mpa);When the gearbox loads, the major stress areas are mainly concentrated in the lower bend of the beam and the center (maximum load of 129.5 Mpa) under the side girder.

The yield strength of the frame material was 345Mpa, and the applied stress of the weld was 313.6 Mpa.According to uic615-4, the strength requirements of the frame under the normal load condition are met.But, in the actual process of rail transit train running, there will be a very special conditions, such as track irregularity, carrying more than AW3, etc., in a very special working conditions, easy to cause stress more than architecture material yield strength, plastic deformation, where under various operating conditions in this we believe that the maximum stress location for structure deformation of dangerous points, namely as the key frame size, including a series spring seat diagonal dimension;The position size of the motor elevator (three directions);Position dimension of gear box (three directions);The brake seat (three directions);The transverse and longitudinal center distance of a series spring.

III. STUDY OF THE FRAME SIZE MEASUREMENT ALGORITHM

According to the frame key size table obtained by the finite element analysis of the previous chapter, the dimension of the frame need to be determined includes: the size of the diagonal line of a series of spring;The position size of the motor elevator (three directions);Position dimension of gear box (three directions);The brake seat (three directions);The transverse and longitudinal center distance of a series spring.In order to facilitate the design of measurement methods and fitting methods, the above measurements are classified according to the reference datum and the measuring point properties, which are divided into: point-to-point distance (axis fitting);Point - surface distance (for the fitting of the hole fitting and fitting);Surface - plane distance (plane fitting).Based on classification, the method is designed and fitting.

3.1 spatial plane and hole fitting

(1) space plane fitting

In the measurement of the architecture, some of the hanging vertical position size block surface mainly by crane to a benchmark of distance is defined, and often hung under the seat surface is not flat, due to such problems as using need to adopt the method of least square method to carry on the plane fitting [10].The equation of the lower plane equation of the motor lifting seat is given as an example $Ax + By + Cz + 1 = 0$, First, use the measuring machine to collect N points, for the N points to be fitted, there are the following equations:

$$
\begin{aligned}
&Ax_1 + By_1 + Cz_1 + 1 = 0 \\
&Ax_2 + By_2 + Cz_2 + 1 = 0 \\
&\cdots\cdots \\
&Ax_N + By_N + Cz_N + 1 = 0
\end{aligned}
\tag{1}
$$

To form such as $Ax = b(A \in R^{m \times n}, b \in R^m)$ can't solve for one of the overdetermined equations $x \in R^n$ The residual vector of the equation $r = b - Ax = 0$, Therefore, we need to compute the least 2-norm solution of r by using least square method, for the above space plane fitting equations, the simplified equation is obtained:

$$
\begin{bmatrix}
\sum_{i=1} x_i^2 & \sum_{i=1} x_i y_i & \sum_{i=1} x_i z_i \\
\sum_{i=1}^{N} x_i y_i & \sum_{i=1}^{N} y_i^2 & \sum_{i=1}^{N} y_i z_i \\
\sum_{i=1}^{N} x_i z_i & \sum_{i=1}^{N} y_i z_i & \sum_{i=1}^{N} z_i^2
\end{bmatrix}
\begin{bmatrix} A \\ B \\ C \end{bmatrix}
=
\begin{bmatrix}
-\sum_{i=1} x_i \\
-\sum_{i=1}^{N} y_i \\
-\sum_{i=1}^{N} z_i
\end{bmatrix}
\tag{2}
$$

You can just find the A, B, and C values of the fitting plane.In this way, the relative position dimension of the frame is calculated by combining with other measurement results.
(2) the spatial orifice fit

At the same time in the process of measuring, some location size is by mounting holes of the architecture to a baseline definition, heart position for hole size measurement also need fitting, first of all samples and fitting of the mounting holes on the surface, the plane known N for fitting the space point （x_i, y_i, z_i）, according to the plane fitting method can P the plane fitting out, and the equation for the standard $Ax + By + Cz + 1 = 0$.
And then we're going to put all the points on that surface, and we're going to project N points to that plane, and the projection point is going to be (X_i,Y_i,Z_i), if A, B, and C are not zero $\frac{X_i - x_i}{A} = \frac{Y_i - y_i}{B} = \frac{Z_i - z_i}{C} = t$,
The coordinates of the hole centered (X, Y, Z) that are to be fitted can be obtained through the coordinates of the measured points:

$$(X_i - X_j)X + (Y_i - Y_j)Y + (Z_i - Z_j)Z = \frac{(X_i^2 + Y_i^2 + Z_i^2) - (X_j^2 + Y_j^2 + Z_j^2)}{2} \quad (3)$$

(X, Y, Z) to be coefficient, N the known points on the plug type, can be composed of overdetermined linear equations, for the equation, by using generalized inverse matrix to calculate the least squares solution, the resulting hole coordinates.In this way, the relative position dimension of the frame is calculated by combining with other measurement results.
3.2 calculation of spatial parameters

For space plane $P : Ax + By + Cz + D = 0$, And a little outside the plane $M : (x, y, z)$, The distance from space to plane d can be represented as:

$$d = \frac{|Ax + By + Cz + D|}{\sqrt{A^2 + B^2 + C^2}} \quad (4)$$

For the coordinates of the holes to be fitted out (x1,y1,z1)and (x2,y2,z2), according to the distance formula between the two points of space, the distance between two points can be expressed as:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \quad (5)$$

IV. DESIGN OF THE GENERAL TEST PLATFORM FOR ARCHITECTURE

To meet the full range of different type structure and high precision measurement, the general testing platform to develop high-precision bogie frame, the platform is supported by general frame detection platform, joint arm type three coordinate measuring machine, computer equipment, software system and auxiliary equipment,and so on.

4.1 Joint arm coordinate measuring machine

The joint arm coordinate measuring machine consists of base, measuring arm, joint and head system, as shown in figure 3.The structure of the measuring machine is designed to meet the measuring machine's sufficient measuring space, measuring flexibility and measuring accuracy.The advantage of the joint arm tricoordinate measuring machine is that the structure is portable and can be flexibly arranged in the field, and the universal detection platform can meet the general testing task of the framework. In view of the structural features of the requirements and architecture of 5m by 3m space measurement, the project adopts the RA 7345S joint arm type three-coordinate measuring machine with a range of 4.5 m, which can complete the task of the overall measuring range of the frame.Its arm adopts carbon graphite fiber material, high strength, high temperature stability, low environmental requirements.

Figure 3 Articulated arm coordinate measuring machine

4.2 design of the framework general testing

Through structure analysis of the various model frame, we found that the frame length 3581 mm, maximum the width of 2615 mm, in the process of design examination platform base, not only need to meet the maximum size frame width distance, want to leave some space for operating personnel at the same time.For the choice of the strong point, due to a system of the spring seat frame different type has different structure forms, and the second is the structure of the spring seat is in the form of pin hole, and different types of architecture department of spring seat hole and frame is nearer the distance between the longitudinal symmetry plane, the second is the location of the spring seat holes in the frame lateral central symmetry plane for reference benchmark, so choose two spring seat of strong point, the point can along the lateral movement in order to satisfy different type frame support, at the same time in order to ensure the balance of the architecture, the spring seat adding auxiliary support in four departments. General frame detection platform of general layout as shown in figure 4, supported by 1 platform device, a series of supporting 2 device, 3 frame to be detected, 4 joint arm coordinate measuring machine, 5 department of support device, 6 measuring machine foundation supports, 7 cast iron test platform, 8 auxiliary parts such as step.

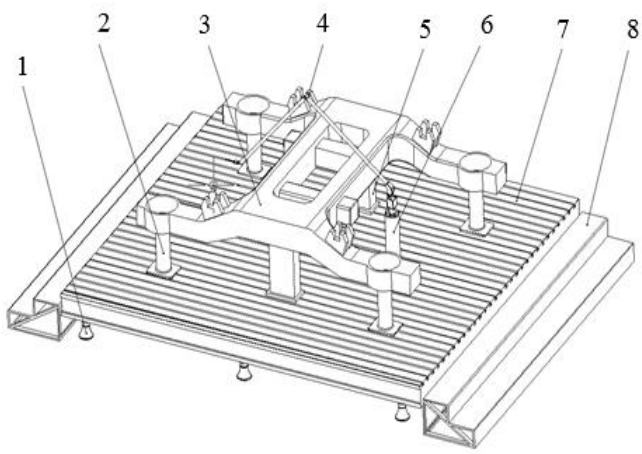

Figure 4 Schematic diagram of frame universal detection platform

V. EXPERIMENTAL COMPARISON AND VERIFICATION

Experiment is the basic idea of verification, that is, by measuring the size of the architecture of the new factory compared with the drawing size of the architecture, to verify the special measurement software used in the mathematical model is reasonable, whether the software function implementation. Experiment, a type architecture in architecture of general testing platform, through the two secondary spring seat hole support, at the same time in the four spring seat is a system for auxiliary fixed, and then use special measurement software architecture to be measured for the computation of the measured data of selected frame size experiment of the spring seat for a series diagonal distance and the calculated results with the architectural factory drawing size do contrast, and defines the special measurement software size for the difference between the calculation results with the drawings∆.

In the inside of the hole, in turn, points out five points, according to the design of the third chapter bore the heart fitting method to get coordinates, in turn to a series of spring seat four hole to hole fitting, and then divided into two groups, according to the spatial distance formula to calculate the diagonal distance between two points, the results are shown in table 2.

Table 2 Experimental result

Measurement Framework	Experimental Result（mm）	Drawing Size（mm）	∆ .（mm）
Framework 1	3264.15	3265.00	0.85
Framework 2	3264.00	3265.00	1.00
Framework 3	3265.30	3265.00	0.30
Framework 4	3265.15	3265.00	0.15
Framework 5	3265.15	3265.00	0.15

Can be seen from the table, for a spring seat diagonal distance, using a special software to calculate the experimental results and the frame factory drawing size error is 0.15 ‰, the accuracy of measurement in the same order of magnitude, meet the design requirements, verify the method is feasible.

VI. CONCLUSION

Coordinate measuring machine based on joint arm type for more general key type bogie frame size and the in plane fitting, using the method of least squares fitting to the spatial hole heart, USES the linearization of nonlinear equations, and USES the method of linear equations of the generalized inverse matrix hole coordinates. At the same time, an architecture universal testing platform was designed to complete the dimensions of the bogie frame. In the comparison test, the measured result and the frame factory size error are 0.15 ‰, which verifies the accuracy and feasibility of the measurement algorithm and test platform.

REFERENCE

[1]. wang jianbing. Research on the structural crack problems of the Shanghai metro vehicle bogie frame Beijing: Beijing jiao tong university, 2004.

[2]. ma qingzhong. Test and analysis of bogie frame virtual test bench [D]. Beijing jiaotong university, 2014.

[3]. zhao xiyong. Three-axis steering wheel I dynamic performance rolling test stand [J]. Locomotive electric transmission, 2000, 5:29-33

[4]. qian kefeng. Multi-channel hydraulic servo loading calibration test bed design [D]. Beijing: Beijing jiao tong university, 2008.

[5]. The structure optimization of a certain type of subway bogie frame [J]. Urban rail transportation research, 2014, (8) : 44-48.

[6]. zhang binyu, zhao honglun. Optimization design of subway vehicle bogie frame based on finite element analysis [J]. Computer aided engineering, 2011 (6), 20 (2) : 82-85.

[7]. Xie Xiongyao; Jin Guolong; Wang Rulu. Evaluation of Bogie Frame Safety of Shanghai Metro Line 1 by 3D FEM Analysis[J]. International Symposium on Computational Mechanics 12th International Conference on the Enhancement and Promotion of Computational Methods in Engineering and science, 2010, 1233(1):1140-1147

[8]. huang xu. Analysis of fatigue analysis and structure optimization of bogie frame based on "flexible coupling" model [D]. Shanghai university of engineering technology, 2015.

[9]. UIC 615-4-2003，Motive power units-Bogie and running gear-Bogie frame structure strength tests[S].

[10]. li mingyu. Research on the method of assembly measurement of an aircraft based on joint arm coordinate measuring machine [D]. Harbin: Harbin institute of technology, 2011.

[11]. http://www.hexagonmetrology.com.cn.

[12]. http://www.Faro.com.

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