Calibration for Dynamic Balancing Test System of Motorcycle Crankshaft

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Abstract—This paper introduces a calibration method used in dynamic balancing test system of motorcycle crankshaft, which referred to but improved influence coefficient method. The magnification and position deviation compensation for reference signal of the test system can be calibrated by using standard component of crankshaft and reference block. The calibration process is divided into four steps. The signal processing of calibration is completed by software. It needn’t manually adjust hardware system. The application result shows that this method of calibration is simple, vivid, procedure automation and satisfied the request of accurate calculation and solution.

Keywords—calibration, dynamic balancing, crankshaft, influence coefficient method

I. INTRODUCTION

CALIBRATION is a compensation for hardware unbalance by software in dynamic balancing test system, and determines the system gain and phase compensation. The calibration method frequently-used is influence coefficient method in dynamic balancing test. This method has many advantages comparing with other method, such as high accuracy, simple theory and high balance efficiency. It doesn’t need to know the complex information of rotor system, and computer-aided balancing is easily realized[1]-[3]. But influence coefficient method relates to not only complex calculations but also complex division used in calculating influence coefficients, which makes testing and calculation process very complex.

The unbalance of motorcycle crankshaft existed when designed and manufactured, and it affects engine greatly. The dynamic balancing test doesn’t relate to removing mass. The expression of unbalance only requires the magnitude and phase of unbalance force in dynamic balancing test of motorcycle crankshaft[4]. This paper refers to but improved influence coefficient method. The application result shows that this calibration method is simple and satisfied the requirements of accurate calculation and solution.

II. INTRODUCTION TO CALIBRATION METHOD

The magnification and position deviation compensation for reference signal of the test system can be calibrated by using standard component crankshaft and reference block. The calibration process is divided into four steps. The signal processing of calibration is completed by software. It needn’t manually adjust hardware system.

The structure of standard component of crankshaft is shown in Fig.1. The reference block represented in black block is shown in Fig.2.

1. spindle connector 2. semicircle key 3. coupler 4. standard component of crankshaft

III. CALIBRATION PROCESS

The calibration is divided into four steps. The first step: testing the first vector \( \vec{E} \) on the condition that the standard component of crankshaft, without reference block, is installed in upside direction. The second step: testing the second vector \( \vec{G} \) on the condition that the standard component of crankshaft, with reference block, is installed in upside direction. The third step: testing the third vector \( \vec{H} \) when the standard component of crankshaft, with reference, is installed in anti-direction. The
forth step: testing the forth vector $\vec{F}$ when the standard component of crankshaft, without reference block, is installed in anti-direction. Calculating the four vectors, you can obtain the gain and phase compensation. Then the calibration is completed. After calibrating, you can test the unbalance of crankshaft under test which is installed in upside direction. In Fig.1, the standard component of crankshaft is in upside direction. The semicircle key is installed in spindle connector in upside direction. Otherwise, it’s called anti-direction, shown in Fig.2(c), (d). There are two key slots in spindle connector. The upside one is upside direction, shown as in Fig.1. The underside one is for anti-direction. The spindle connector is connected with spindle system. When the spindle stops, the upside key slot is upward. The other one is downward. The spindle connector is shown in Fig.1, the standard component of crankshaft is in upside direction. In Fig.2(c), (d). There are two key slots in spindle connector. The upside one is for anti-direction, shown as in Fig.1. The underside one is upside direction, shown as in Fig.2(c). From Fig.2(b) and Fig.2(c), we know that the magnitudes of unbalance caused by standard component of crankshaft are the same, but the angle difference is $180^\circ$. Vector $\vec{B}_1$ represents the vibration vector caused by standard component of crankshaft shown in Fig.2(c). Similarly, we use vector $\vec{C}_1$ to represent the vibration vector caused by reference block. Then, 

$$\vec{C} = \vec{G} - \vec{E}$$

(6)

Then the gain of the system is 

$$k = \frac{mR|\vec{C}|}{|\vec{G} - \vec{E}|}$$

(7)

The angle compensation is 

$$\theta = 180^\circ - \angle \vec{C} = 180^\circ - \angle (\vec{G} - \vec{E})$$

(8)

Eq.(3) reducing Eq.(4) gets 

$$\vec{C}_1 = \vec{H} - \vec{F}$$

(9)

Eq.(6) reducing Eq.(6) gets 

$$\vec{C} - \vec{C}_1 = \vec{G} + \vec{F} - \vec{E} - \vec{H}$$

(10)

There have three requirements for reference block: 1) It must have accurate mass. 2) The distance (i.e., $R$) between point $O$ and its center of gravity must be measured accurately. 3) The unbalance angle of it must be accurate $180^\circ$. Then its unbalance can be written as $\vec{U}_1 = mR\angle 180^\circ$.

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Vector $\vec{\bar{C}}$ can be obtained by Eq.(2) reducing Eq.(1), that is 

$\vec{\bar{C}} = \vec{G} - \vec{E}$

(6)

Then the gain of the system is 

$$k = \frac{mR}{|\vec{C}|} = \frac{mR}{|\vec{G} - \vec{E}|}$$

(7)

The angle compensation is 

$$\theta = 180^\circ - \angle \vec{C} = 180^\circ - \angle (\vec{G} - \vec{E})$$

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Eq.(6) reducing Eq.(6) gets 

$$\vec{C} - \vec{C}_1 = \vec{G} + \vec{F} - \vec{E} - \vec{H}$$

(10)
The relationship of vector $\vec{C}$ and $\vec{C}_1$ can be represented in Fig.4.

In the Fig.4, the angle $\alpha$ is

$$\alpha = \arccos \frac{|\vec{C} - \vec{C}_1|}{2 \times |\vec{C}|}$$

$$= \arccos \frac{|\vec{G} + \vec{F} - \vec{E} - \vec{H}|}{2 \times |\vec{G} - \vec{E}|}$$

Eq.(1) reducing Eq.(4) gets

$$\vec{B} - \vec{B}_1 = \vec{E} - \vec{F}$$

According to the similarity of ge relationship shown in Fig.4, the magnitude and angle of vector $\vec{B}$ can be induced as

$$|\vec{B}| = \frac{||\vec{B} - \vec{B}_1||}{2 \times \cos \alpha} = \frac{|\vec{B} - \vec{B}_1| \times |\vec{G} - \vec{E}|}{|\vec{G} + \vec{F} - \vec{E} - \vec{H}|}$$

$$= \frac{|\vec{E} - \vec{F}| \times |\vec{G} - \vec{E}|}{|\vec{G} + \vec{F} - \vec{E} - \vec{H}|}$$

$$\angle \vec{B} = \angle (\vec{B} - \vec{B}_1) - \alpha = \angle (\vec{E} - \vec{F}) - \alpha$$

From Eq.(1), we know

$$\vec{A} = \vec{E} - \vec{B}$$

From Eq.(5), we may write

$$\vec{X} = \vec{I} - \vec{A}$$

Summarizing all the results, the unbalance of crankshaft under test can be obtained as following

$$|\vec{U}| = k \times |\vec{X}|$$

In Eq.(18), the angle $\theta$ is phase compensation angle. The slot placing reference block has machining errors, so there must have a position error. We can calculate angle $\theta$ by sample crankshaft, and compensate it by software.

IV. CALIBRATION IMPLEMENTATION

LabVIEW[5][6] provides a best platform to develop the measurement system for measuring dynamic balancing of motorcycle crankshaft. The modularity structure of LabVIEW makes software design easy. Calibration module as a subVI can run by itself and be used as part of the test software. The subVI of system calibration is to obtain the gain and inherent unbalance value of the measurement system. Fig.5 shows the front panel of system calibration.

V. CONCLUSION

The bearing system, used in dynamic balance test system of motorcycle crankshaft, belongs to not only soft bearing system but also hard bearing system. The system has the features of high rigidity and high measuring precision[2]. By analysing ABC coefficient method usually adopted by hard bearing system and influence coefficient method often used in soft bearing system, we developed a new calibration method based on the influence coefficient method. The signal processing of calibration is completed by software. It needn’t manually adjust hardware system. The application result shows that this method of calibration is simple, flexible, procedure automation and satisfied the request of accurate calculation and solution.

REFERENCES