ELIMINATING THE ADDITIONAL INERTIA IN MEASURING THE NATURAL FREQUENCY OF A TORQUE SENSOR

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ABSTRACT

In measuring the natural frequency of a torque sensor, one must apply excitation through some mechanism which produces additional inertia coupling to sensor that the original or instinct data can not be gotten. A method was developed which can eliminate these inertia by testing and calculating. The principle, experimental method, instrumentation and results were described in detail in this paper.

Introduction

The most application field of a torque sensor is in dynamic machinery to measure power and load which are usually variable. The natural frequency is one of the most important and basic parameter of dynamic performance of a sensor,as it can decide and calculate the other parameter, but there are some difficulty to measure it directly. In measuring one must apply some exciting. And there are many devices such as arm, lever, weights, coupling and the moving part of excitation mechanism etc. will be connected to sensor. Their inertia will affect the measuring results. The original or instinct natural frequency of sensor can not be gotten. A method which can eliminate these affect by testing and calculating was developed and described in following.

Principle

The natural frequency f_0(Hz) of a torque sensor can be calculated with following equation from mechanics or physics:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{c}{I_0}} \qquad (1)$$

where: c-torsional stiffness(Nm/rad)

I_0-mass moment of inertia (kgm^2)

In measuring or calibrating, torque sensor must be connected between power machinery or exciting mechanism on one end and loaded on the other end. The original natural frequency f_0 will be changed to measured natural frequency f_a of the mechanical arrangement depended on following equation:

$$f_a = \frac{1}{2\pi}\sqrt{c(\frac{1}{I_1}+\frac{1}{I_2})} \qquad (2)$$

where :I_1,I_2 -mass moment of inertia of connected rotating masses on two ends.

In metrology lab, the aim is to get the

original or instinct natural frequency, so we must eliminate the affect of I_1 and I_2 and to get I_0, c and f_0. A measuring installation was developed. The measured sensor was fixed in one end with a fixture having very large mass and rigid stiffness comparing to sensor and exciting mechanism. Then the item I_2 can be neglected in equation, we get

$$f_b = \frac{1}{2\pi}\sqrt{\frac{c}{I_1}} \qquad (3)$$

Where : $I_1 = I_0 + \Delta I_1$,

ΔI_1-The additional mass moment of inertia of exciting end.

Some mass moment of inertia ΔI_2 which could be calculated exactly by its regular geometric shape was added to I_1 ,then the f_b was changed to f_c

$$f_c = \frac{1}{2\pi}\sqrt{\frac{c}{I_2}} \qquad (4)$$

Where : $I_2 = I_0 + \Delta I_1 + \Delta I_2$

From equation (3)and (4) c could be gotten

$$c = 4\pi^2 \Delta I_2 \frac{f_b^2 f_c^2}{f_b^2 - f_c^2} \qquad (5)$$

Another device with regular geometric shape such as a cylinder or axis etc. with mass moment of inertia ΔI_3 and torsional stiffness c_1 were designed and displaced the measured sensor in arrangement, then we get f_d

$$f_d = \frac{1}{2\pi}\sqrt{\frac{c_1}{I_3}} \qquad (6)$$

Where: $I_3 = \Delta I_1 + \Delta I_3$

When ΔI_2 was added on I_3, f_d was changed to f_e

$$f_e = \frac{1}{2\pi}\sqrt{\frac{c_1}{I_4}} \qquad (7)$$

Where: $I_4 = \Delta I_1 + \Delta I_2 + \Delta I_3$

From equation (6)and (7), c_1 could be gotten:

$$c_1 = 4\pi^2 \Delta I_2 \frac{f_d^2 f_e^2}{f_d^2 - f_e^2} \qquad (8)$$

Then ΔI_1 could be gotten by equation(6) or (7) and (8)

$$\Delta I_1 = \frac{f_e^2}{f_d^2 - f_e^2}\Delta I_2 + \Delta I_3 \qquad (9)$$

And I_0 could be gotten by equation (3) and (9)

$$I_0 = \left(\frac{f_c^2}{f_b^2 - f_c^2} - \frac{f_e^2}{f_d^2 - f_e^2}\right)\Delta I_2 - \Delta I_3 \qquad (10)$$

Substituting c and I_0 in equation(1), f_0 could be gotten.

Experiment

A measuring installation developed to verify the principle was showed in fig(1) and (2)

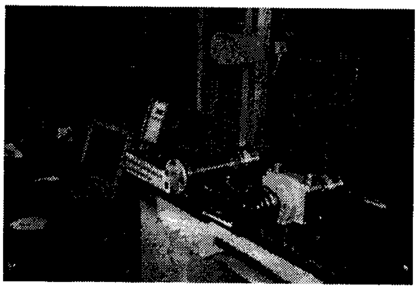


Fig1

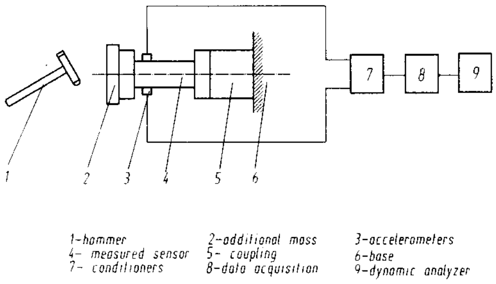


Fig 2

A HBM T30FN/200Nm was used as a measured sensor which one end was fixed on a hard and heavy base with its coupling and another end was freed for exciting. Using a hammer KISTLER 9724/A5000 to apply exciting and two accelerometers KISTLER 8734A500 attached on sensor in 180° position and their sensing axises in same clockwise and perpendicular to the direction of exciting for to measure response and identify the torsional frequency . A disc showed in fig3 as an additional mass which mass moment of inertia $\Delta I_2=0.1729\times10^{-7}kgm^2$

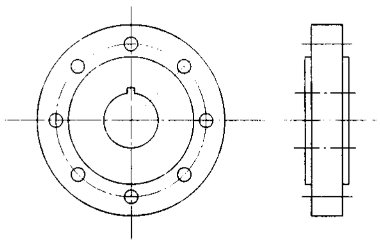


Fig 3

A cylinder showed in fig4 as a simulate sensor which mass moment of inertia $\Delta I_3=21741.5\times10^{-7}kgm^2$

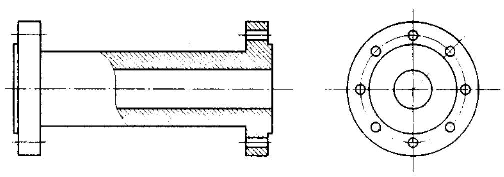
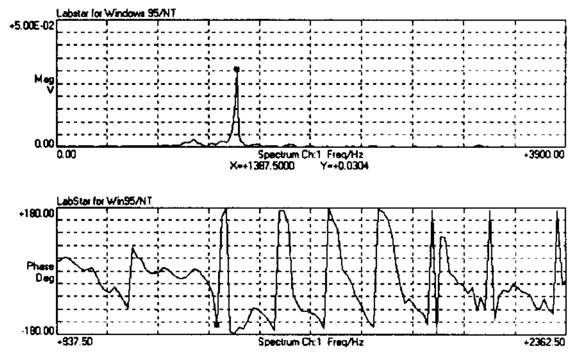


Fig4

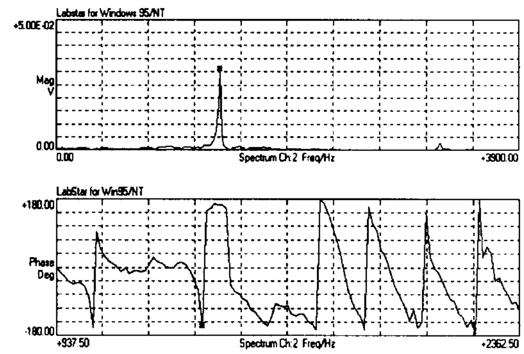
The output of accelerometers were acquired and processed by micro computer based data acquisition PCM3000 and dynamic analyzer LABSTAR through conditioner KISTLER 5134 A

Result

The fig 5 was the Fourier amplitude and phase spectrum of acceleration responses when the free end of measured sensor was excited. From fig5 we could get f_b =1387.5Hz discriminated by their same phases. The fig 6 was these spectrum when the exciting end was attached an additional disc showed in fig3. from fig6 we could get the f_c =1237.5Hz.

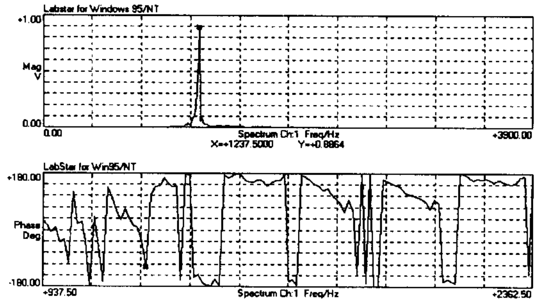


No	Freq	Mag	Phase
111	1387.50	0.0304	-154.278

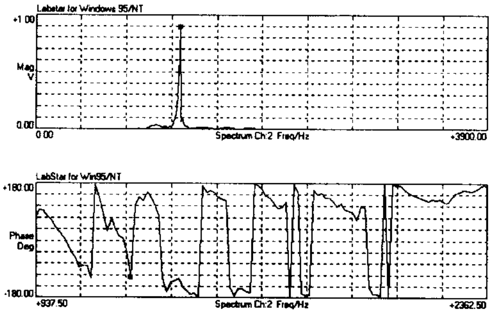


No	Freq	Mag	Phase
111	1387.50	0.0310	-152.932

Fig5



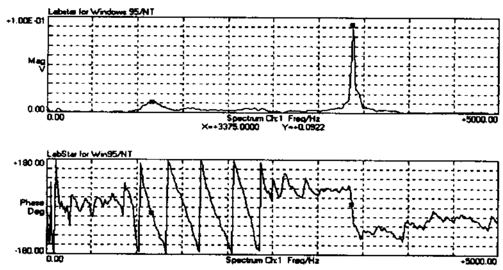
No	Freq	Mag	Phase
99	1237.50	0.8864	-117.621



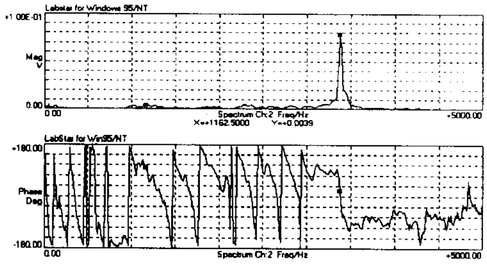
No	Freq	Mag	Phase
99	1237.50	0.8927	-116.8176

fig 6

Fig7 and 8 were these spectrum of simulate sensor when it displaced measured sensor. From fig7 and 8 we could get f_d and f_e corresponding no or additional attached mass, f_d=3375Hz and f_e=3137 Hz

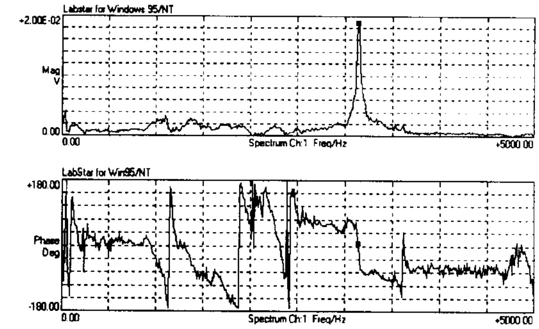


No	Freq	Mag	Phase
93	1162.50	0.0922	-23.2562
270	3375.00	0.0106	10.4848

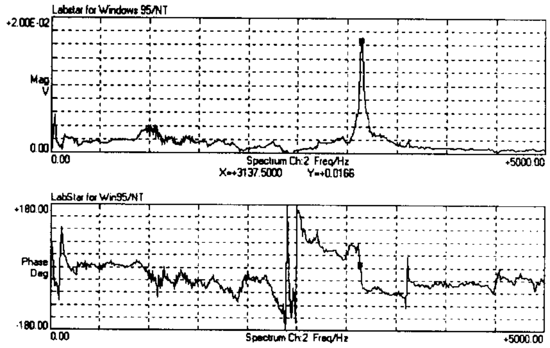


No	Freq	Mag	Phase
93	1162.50	0.0039	97.7121
270	3375.00	0.0783	17.6851

Fig7



No	Freq	Mag	Phase
251	3137.50	0.0188	5.6973



No	Freq	Mag	Phase
251	3137.50	0.0166	9.5681

Fig8

The original or instinct natural frequency f_0 of measured sensor could be gotten by equation(5),(10) and (1), f_0=1320Hz.The value could be verified by comparing to the results of other calculating of same sensor described in paper[3]. In that experiment, the measured natural frequency was 1180Hz which was affected by many unknown additional masses.

Conclusion

The natural frequency of a torque sensor is one of most important dynamic parameter but it is more difficult to measure as affected by many miscellaneous mass in measuring. In this developed method, using a special designed mass and simulate sensor which mass moments of inertia were known, these affect could be eliminate and the original or instinct natural frequency would be gotten.

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