ISSN: 2664-9640

Research on Real-time Signal Stability of Computer Monitoring Bridge Structure Health Sensor

Jun Guo[1,2,3,4], Leilei Zhang[1,2,3,4], Hong Jiang[1,2,3,4]

[1] JSTI Group, Nanjing 211000, China;

[2]State key Laboratory of Safety and Health for In-service Long Span Bridge, Nanjing, 210012, China;

[3]Key Laboratory of Large Span Bridge Health Inspection & Diagnosis Technology Ministry of Communications, Nanjing, 210012, China;

[4]Center of Data Measured by Structural Health Monitoring System of Long-span Bridge in Province of Jiangsu, Nanjing, 210012, China

Abstract

Small and medium bridges have a large volume and a wide range. Compared with large bridges, the frequency of problems is higher. However, due to cost and other factors, health monitoring systems are generally not installed, and its technical status and operational safety are difficult to effectively monitor. The bridge structure health monitoring system monitors and evaluates the health status of the bridge structure by collecting various bridge status information such as strain, displacement, deformation, dynamic response, and temperature. At the same time, various signal equipment and sensor equipment are also widely used in various fields. The use environment of the eddy current sensor is generally harsh, especially when it is applied in an environment with large temperature changes, its stability performance is severely tested. This article discusses the eddy current sensor, and explains its working principle and temperature

Keywords

Monitor the health of the bridge structure, sensors, and signal stability.

1. Introduction

In the century when human society has fully entered the era of electronic information, the sensor and detection technology as the forefront of information science and technology will become a commanding height in the field of information science and technology in this century, [1]. The eddy current sensor is manufactured by using the eddy current effect and has a wide range of uses. It can be used to measure various physical quantities such as displacement, vibration, speed, temperature, differential expansion and thickness, and has a simple structure, good reliability, and high sensitivity. , No oil pollution, strong anti-interference ability and many other advantages. Therefore, eddy current sensors have been widely used in the detection of parameters such as displacement, size, vibration, speed and thickness. Sensor is an application technology in the field of engineering information detection. Today, with the rapid development of microelectronics and computers, this non-electricity detection technology presents many obvious advantages and is the main body of modern detection technology [2]. But in the high temperature range (for example, above 100C), there are serious measurement errors, and people are very concerned about it. The current common method is to use temperature compensation technology. In the past ten years, the output and demand of the world sensor market have been developing continuously and steadily, and the annual growth rate has reached more than that. The total annual sales of global sensors have exceeded 100 million U.S. dollars, and this sales will continue to grow.

2. Eddy sensor

2.1. Coil impedance characteristics

The sensor made according to the eddy current effect is the electric vortex sensor. When the eddy current sensor works in amplitude modulation mode, a flat coil L is connected in parallel with a capacitor to form a resonant circuit as the oscillator load. Using the above-mentioned eddy current effect, some non-electricity parameters are converted into the change of sensor coil impedance or inductance, and the change of quality factor value coil loss, so as to realize the accurate measurement of non-electricity [3]. When there is no DUT, the loop resonates at a certain frequency. After the sensor coil is excited by the high-frequency crystal oscillator, a high-frequency magnetic field is generated around it. When a metal object to be measured approaches the coil, the magnetic field of the coil induces eddy currents in the object to be measured. In terms of its composition, the eddy sensor is mainly composed of three links, including the measured body, the probe and the detection circuit. The structure diagram of the eddy sensor is shown in Figure 1.

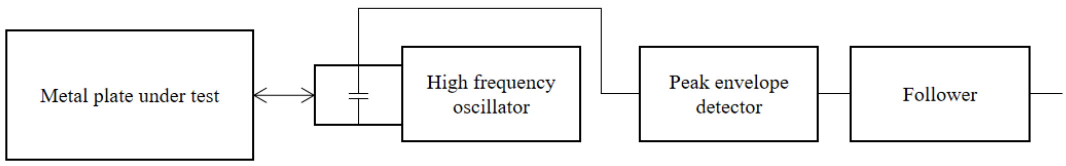

Fig. 1 Structure diagram of eddy sensor

2.2. Page Numbers.

The coil value of the eddy current sensor probe is an important factor in the design of the sensor. It is related to various factors such as the high-frequency skin effect and the dielectric loss of the skeleton. It is also affected by inductance and resistance. Factors, optimize the coil parameters [6]. The coil impedance of the eddy current sensor consists of two parts, the AC resistance and the impedance of the coil. For single-strand guide

Wire coil, at the audio frequency operating frequency, general resistance>inductive reactance. The main factor affecting impedance (inductive reactance) is resistance. , So the impedance increases as the temperature increases. Temperature drift has been proven to be the most important error of eddy current sensors. Both inductance and resistance will drift when temperature changes. However, theory and experiments have proved that temperature has a much greater impact on impedance than inductance. In order to obtain the most optimized coil parameters and the smallest temperature error.

(1) The sensor is arranged parallel to the beam axis and measures the axial force and bending moment at the corner or midpoint of the beam surface. The axial stress:

$$\sigma = \zeta E \tag{1}$$

In formula (1), ζ represents strain; E represents elastic modulus, in MPa.

The sensor is arranged at 45° on the beam axis, and only the shear strain is measured. The specific relationship between the maximum shear stress and the principal strain ζ_m is as follows:

$$r_{\max} = \left|\sigma_{45^\circ}\right| = \left|\frac{E}{1+\mu}\xi_m\right| \tag{2}$$

In formula (2), E represents the modulus of elasticity; μ represents Poisson's ratio; ζ_m represents the strain in the 45-angle direction.

The sensor is equipped with 45° strain rosettes, which mainly measure the specific values of axial force, bending moment and shear stress. The calculation formulas of principal strain ζ_1, ζ_2 and principal strain direction angle θ are:

$$\theta = \frac{}{2} arctg \frac{2\zeta_{45} - \zeta_0 - \zeta_{90}}{\zeta_0 - \zeta_{90}} \tag{3}$$

The calculation formula of principal stress σ_1 and σ_2 is:

$$\frac{\sigma_1}{\sigma_2} = \frac{E}{2}\left[\frac{\zeta_0 + \zeta_{90}}{1-\mu} \pm \frac{\sqrt{2}}{1+\mu}\sqrt{(\zeta_0 - \zeta_{45})^2 + (\zeta_{45} - \zeta_{90})^2}\right] \tag{4}$$

When working under medium and high frequency, the resistance is generally less than the inductive reactance. If the flat coil can be kept unchanged, the AC resistance can be reduced significantly, so that the AC resistance is less than the inductive reactance. Then the influence of the coil resistance and the AC resistance on the impedance will be reduced to a secondary factor, so that even if the temperature change will cause the change of the AC resistance, the impedance will be affected by the temperature change to a very low level, so as to achieve the purpose of suppressing the temperature drift of the impedance. , That is, the coil impedance can remain stable in a large temperature range [7]. The AC impedance is also affected by many other factors: 1. The size, shape, thickness and surface flatness of the metal material to be tested. 2. The material properties of the tested metal, especially the conductivity and resistivity. 3. The DC resistance of the coil and its own shape parameters, etc. 4. Ambient temperature. 5. Working frequency.

3. Temperature stability of eddy sensor

3.1. The effect of temperature on the probe

When the eddy current sensor is working, the probe is in the working environment, and it is more susceptible to the influence of environmental temperature changes [8]. Put the sensor probe in a thermostat, heat it to different temperatures and keep it warm for half an hour. It can be seen that the sensor probe has sensitivity temperature drift and zero temperature drift. If you use the two indicators of zero drift and full scale drift to calculate, The drift value is very high [9]. At present, the main methods to reduce the influence of the probe on the temperature drift are the use of differential probes, multi-strand identification and other methods.

The zero drift is mainly caused by the resistance of the wire, the electromagnetic loss of the electrolyte of the probe frame, and the drift of the coupling degree between the sensor coil and the measured body. From the principle of the eddy current sensor, the probe uses an induction coil and the coil frame to pass through. Adhesive bonding. Sensitivity drift is caused by the temperature drift of the ratio of coil inductance to the measured body inductance, and the temperature drift of the ratio of coil resistance to measured body loss resistance [10]. The resistance, inductance and capacitance components are not greatly affected by temperature, and their consistency is good, while transistors are more sensitive to temperature. The temperature compensation network designed in the circuit is generally composed of transistors. Controlling the drift at the maximum linear range of the probe greatly improves the temperature stability of the sensor probe. Therefore, the temperature drift of the sensor we mentioned is the temperature coefficient at the maximum linear range of the backbone [11]. When working, the Proximitor is placed in a room temperature environment, which is not affected by the temperature. It can be seen from the above experiment that even when the temperature is high, the sensor output does not change sharply with the increase in temperature, and the temperature drift is not large. The built-in temperature compensation circuit in the proximitor circuit mainly compensates for the temperature drift of the probe.

3.2. Temperature compensation technology

For specific needs, in the closed-loop control system, the eddy current sensor provides the position feedback signal. The control system controls the position of the measured target surface. The measured target surface is required to be in a balanced position and remain relatively stable, that is, the measured target surface is required The relative position with the sensor probe remains unchanged. The measurement of displacement and temperature compensation are completed by the basic modulation circuit and temperature compensation circuit at the same time. The modulation circuit realizes the basic measurement and output of displacement, but the temperature drift in the output signal is very obvious [12]. Ideally, if there is no displacement change between the eddy current sensor probe and the measured target surface, the output voltage of the sensor will not change, and the change of the position feedback signal is zero, and the control system will not change the relative displacement of the measured target surface. Location. The temperature compensation circuit compensates the sensitivity and signal base value for the displacement signal with temperature drift, and finally suppresses the temperature effect within the allowable range. The principle of the excitation signal generator is shown in Figure 2.

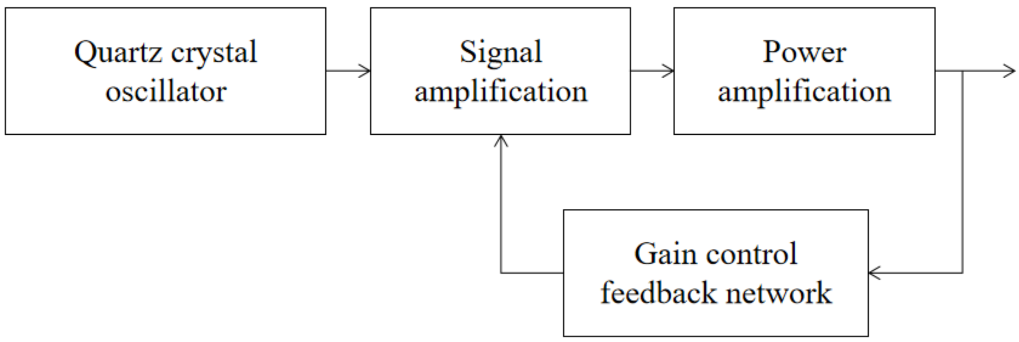

Fig. 2 Principle diagram of excitation signal generator

In practical applications, the ambient temperature varies from -40 ℃ to 60 ℃, and the sensor's own temperature drift will cause measurement errors. This error will be regarded as caused by the change in the distance between the measured target surface and the sensor probe. The control system Close-loop control will be carried out on the measured target surface, and the actual position of the measured target surface will be changed, resulting in the control of situations that should not be controlled. The test circuit of ordinary eddy current displacement sensor can be roughly divided into three categories according to the principle: constant frequency amplitude modulation circuit, variable frequency amplitude modulation circuit and frequency modulation circuit. When there is temperature compensation, the response is that the distance between the sensor and the target surface to be measured remains relatively stable, and the corresponding relationship between the output voltage and temperature; but without temperature compensation, it cannot truly reflect whether the output voltage of the sensor is affected by temperature or affected by temperature. The voltage change caused by the thermal expansion and contraction of the probe or the target surface under test.

4. Conclusion

The eddy current sensor can achieve accurate measurement in a normal temperature environment. Temperature is an important factor affecting the performance of eddy current sensors. It is particularly important whether the eddy current sensor can maintain good performance when the temperature changes and in high-temperature environments. However, when the eddy current sensor works in a specific high temperature environment, the magnetic permeability of the measured conductor changes due to changes in the excitation current, the frequency of the excitation signal, and the ambient temperature T of the conductor being measured by the eddy current sensor. Affect the electrical signal output by the sensor, and ultimately make the measurement accuracy of the eddy current sensor drop drastically or even fail to measure normally. Theories and experiments have proved that temperature drift is the most important factor that affects the performance of eddy current sensors. How to reduce the temperature drift error of eddy current sensors has become an issue of increasing concern for sensor manufacturers. With temperature compensation, the amount of voltage change is reduced by nearly 50% compared to when there is no temperature compensation. As a result of temperature compensation measures, the distance between the measured target surface and the probe remains relatively stable.

References

[1] Uren K R, Van Schoor G, Du Rand C P, et al. An integrated approach to sensor FDI and signal reconstruction in HTGRs – Part II: Case studies[J]. Annals of Nuclear Energy, 2016, 87(1):739 - 749.

[2] Moon J, Jung I Y, Yoo J. Security Enhancement of Wireless Sensor Networks Using Signal Intervals[J]. Sensors, 2017, 17(4):752.

[3] Pereira S S, R López - Valcarce, A Pagès - Zamora. Parameter estimation in wireless sensor networks with faulty transducers: A distributed EM approach[J]. Signal processing, 2018, 144(3):226 - 237.

[4] Matsishin M, Rachkov A, Lopatynskyi A, et al. Selective Amplification of SPR Biosensor Signal for Recognition of rpoB Gene Fragments by Use of Gold Nanoparticles Modified by Thiolated DNA[J]. Nanoscale Research Letters, 2017, 12(1):252.

[5] Liu C, Zhu W, Li M, et al. Highly stable pressure sensor based on carbonized melamine sponge using fully wrapped conductive path for flexible electronic skin[J]. Organic Electronics, 2020, 76(1):105447.1 - 105447.8.

[6] Zhang D, Shi P, Zhang W A, et al. Energy - Efficient Distributed Filtering in Sensor Networks: A Unified Switched System Approach[J]. IEEE Transactions on Cybernetics, 2016, 47(7):1 - 12.

[7] Uren K R, Schoor G V, Du Rand C P, et al. An integrated approach to sensor FDI and signal reconstruction in HTGRs – Part I: Theoretical framework[J]. Annals of Nuclear Energy, 2016, 87(1):750 - 760.

[8] Zhao Y W, Wang Y, Zhang X M. Homochiral MOF as Circular Dichroism Sensor for Enantioselective Recognition on Nature and Chirality of Unmodified Amino Acids[J]. Acs Applied Materials & Interfaces, 2017, 9(24):20991 - 20999.

[9] Tai A, Li D J, Currey A, et al. SU - F - T - 525: Monitordeep - Inspiratory Breathhold with a Laser Sensor for Radiation Therapy of Left Breast Cancer[J]. Medical Physics, 2016, 43(6):3584 - 3584.

[10] Hajializadeh D, Obrien E J, AJ O'Connor. Virtual structural health monitoring and remaining life prediction of steel bridges[J]. Canadian Journal of Civil Engineering, 2017, 44(4):264 - 273.

[11] Yonchev D, J Bajorath. DeepCOMO: from structure - activity relationship diagnostics to generative molecular design using the compound optimization monitor methodology[J]. Journal of Computer - Aided Molecular Design, 2020, 34(12):1207 - 1218.

[12] Geudeke, Theo. Monitoring of health of pigs Online Monitor: sneezing in piglets[J]. Tijdschrift voor diergeneeskunde, 2018, 143(1):29 - 29.