Analysis of unbalanced sensor in eddy current method of non destructive testing

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Introduction

The different types of sensors use in eddy current method of non-destructive testing. The choosing of sensor type depends on forms and material of testing object.
For example, rods are tested by encircling sensor, the pipes are tested as by encircling so by through sensor, a surface of large objects are tested by scanning sensor.
But the different types of sensors can have the identical scheme of connection to device for creation of information signal of defect. For different schemes of connection of sensor are accorded different forms of information signal of defect.
Most simple and frequently employed scheme of connection of sensor is bridge joint. Information signal from defect, which sensor of bridge joint make, is a residual (differential) signal, if a measuring bridge joint has a full of balancing. But if a measuring bridge joint does not have a full of balancing, then an information signal from defect summarizes with unbalance voltage. Unbalance voltage is a hindrance for information signal and diminishes proportion signal/hindrance.
During testing a sensor on different causes can lose capacity to work. A faulty sensor for continuation of testing replace by spare sensor. But absolutely identical sensor to make impossibly, therefore an unbalance voltage will be other after a connection of spare sensor.
In accord above stated necessary, that a device had a network balance of measuring bridge or by other methods to take into consideration an unbalance voltage.

Calculation of output voltage of unbalanced sensor

Scheme of measuring bridge shown on Fig. 1. The elements R1 and R2 are external resistors and can be select sufficiently exactly. The elements _1 and _2 are capacity of wires connecting sensor with device. These capacities always different and to get identical impossibly without additional compensating condensers. Introduction of additional condensers complicates a network and it is tuning. If sensor connect to device by coaxial cable, difference _1 and _2 amount not more 1%.
Elements r1, L1, r2, L2 are parameters of sensor coils, which have the identical diameters and number of turns. These parameters take into account brought impedance of

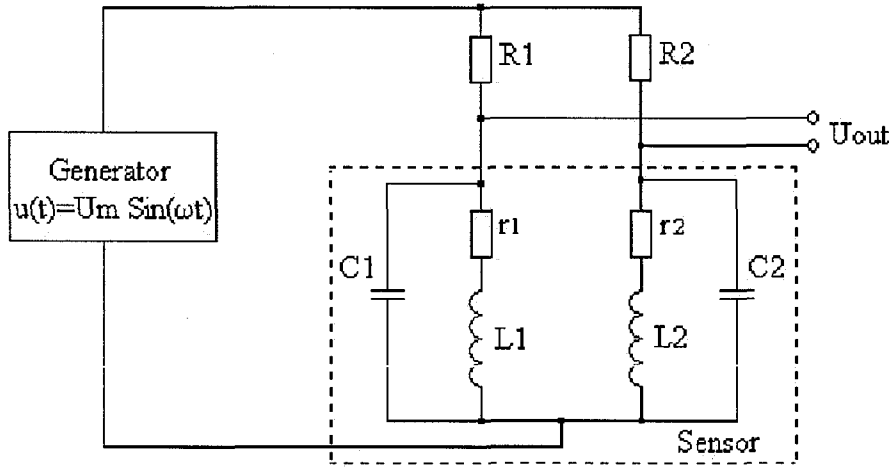

Fig. 1. Scheme connection of sensor

testing object when the sensor is on a segment, which has not defects. Difference between r1, r2 and L1, L2 exists, but does not exceed 1%.
Voltage output of measuring bridge determines by following expression:

$$U_{out} = U_G\left(\frac{z_1}{R_1 + z_1} - \frac{z_2}{R_2 + z_2}\right), \qquad (1)$$

where

$$z_1 = \frac{r_1 + j\omega L_1}{1 - \omega^2 L_1 C_1 + j\omega C_1 \cdot r_1}, \qquad (2)$$

$$z_2 = \frac{r_2 + j\omega L_2}{1 - \omega^2 L_2 C_2 + j\omega C_2 \cdot r_2}. \qquad (3)$$

Equation (1), in view of small value different between elements, will solve making use of increment method, that is R1 = R, R2 = R±ΔR; _1 = C, _2 = C±ΔC; r1 = r, r2 = r±Δr; L1 = L, L2 = L ±ΔL.

Considering that multiplication the increments is infinitesimal value and it is possible to neglect it, get:

$$U_{out} = \frac{A + j\omega(B + \omega^2 D)}{[R + r - \omega^2 LCR + j\omega(L + C \cdot r)]^2}, \qquad (4)$$

where

$$A = \pm r \cdot \Delta R \mp R \cdot \Delta r \mp 2\omega^2 L \cdot r \cdot (C \cdot \Delta R + R \cdot \Delta C), \qquad (5)$$

$$B = \pm L \cdot \Delta R \mp R \cdot \Delta L \pm r^2 \cdot (C \cdot \Delta R + R \cdot \Delta C), \qquad (6)$$

$$D = \mp L^2 \cdot (C \cdot \Delta R + R \cdot \Delta C). \qquad (7)$$

Compensation of output voltage

Output voltage of measuring bridge will be equal zero when A = 0 and (B + _^{2}D) = 0. This is executed at condition that:

$$\frac{\Delta R}{R} = \frac{\Delta r}{r}; \quad \frac{\Delta L}{L} = \frac{\Delta R}{R}; \quad \frac{\Delta C}{C} = -\frac{\Delta R}{R}. \qquad \textbf{(8)}$$

At the practice, it is very hard to obtain the execution of condition (8) because it require the synchronous equality of increment of wire resistance to increment of coil inductance. Therefore, the full balance of measuring bridge for account of its elements is very hard.
Really the compensation of unbalanced voltage of measuring bridge is used. The unbalanced voltage is complex value, that is it has real and imaginary components. The real and imaginary components are liable to compensation individual. That compensation can be conducted by electronic method used following functional scheme (Fig. 2).

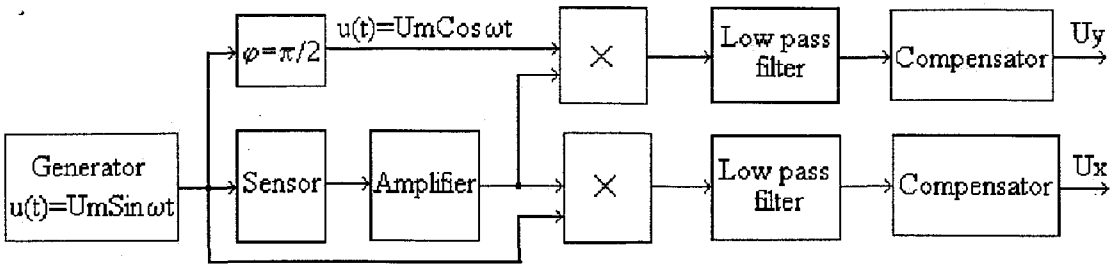

Fig. 2. The functional scheme of electronic compensation

This method of compensation required complicated electronics. A lot of electronics blocks have temperature dependence. This factor made worse on response of testing method.

The modern eddy current testing techniques use the computer methods of processing the signal. With provision for this to the following method of compensation may regard the possibility of decomposition of signal on orthogonal of functions in procedure of computer processing. The algorithm of compensation in this case will be following.

At first necessary to define module of unbalanced voltage and phase shift in relation to voltage generator (this possible do by analog facilities of electronic processing).

Farther function "Sin" and "Cos" calculate from corner of phase shift. Multiplying got value of function "Sin" and "Cos" on module of unbalanced voltage make projections of module on orthogonal coordinates axes. Then subtraction of projections of unbalanced voltage from full signal enables to get the signal from defect. This compensation method more effective and allows to simplify a blocks analog facilities of electronic processing. But it requires the more careful calculation capacity analog-to-digital converter for formation of digital data of signal from defect.

Conclusion

Any sensor (bridge joint) have unbalance, which diminishes response to small defects. It is very hard to do full balance by elements of measuring bridge. Its can compensate the unbalance voltage by electronic or computer method. The compensation of unbalance voltage by computer (on described algorithm) allow simplify analog electronic processing.