17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

Eddy probe system on the basis of new technology

Alexander A.Kirpichev, Andrey V.Klushev, Evgeniy P.Groshkov
Globaltest, Youth Str., 6, Sarov, Nizhny Novgorod region, 607183, Russia
Tel.: (831-30) 4-02-44, Fax: (831-30) 4-38-55
E-mail: globaltest@mail.ru, Web: http://www.globaltest.ru

Shkatov P.N.,
Moscow state university of instrument making and informatic,
Moscow, Russia
E-mail: petr_shkatov@mail.ru

The mode of functioning of the majority of eddy probe system is grounded on the active oscillator method that gives the parameter instability at the effect of environment temperature on the components of eddy probe system (non-contact eddy probe, extension cable and probe driver). GlobalTest has developed a new way of eddy current monitoring grounded on excitation in a probe of damped oscillations by an impulse power source for decrease of environment temperature effect on the components of eddy probe system. The discrete excitation process made possible measurement of a current probe heat-resistance and also measurement of an extension cable during measurement of displacement and an automatic response correction depending on heat-resistance value.

The way used in a sensor allows to reduce an error at the effect of environment temperature on active resistance of a non-contact eddy probe and an extension cable and to obtain height displacement sensitivity. The driver circuitry is grounded on an optimal combination of analog and digital components. It provides height temperature stability of sensor parameters and height time stability of sensor parameters. In is not necessary to have the tuning elements.

At present time we are conducting development work on creation of universal eddy probe displacement system of a new generation on the basis of registered eddy current monitoring way [1]. In this system user can set (through PC):

- material type of device under test;
- eddy probe system type;
- extension cable length;
- diameter of rotary device axis (for an error offset at the measurement of a transverse outrun);
- measurement and sensitivity range.

The essence of the excitation method is that an eddy current transducer as a parallel oscillatory circuit intermittently is connected to dc supply for generating damped oscillations, which are described by following expression:

$$U(t) = I\sqrt{\frac{L}{C}}l^{\frac{t}{\tau}}\sin 2\pi ft ,$$

where L – coil inductance;

C – connection cable capacity;

τ = 2L/R – time constant (R – active resistance of the coil and the connection cable);

f – resonance frequency of the parallel circuit with the R, L, C parameters.

Eddy current influence reduce to equivalent change of R and L, i.e. change of a quality factor and circuit resonance frequency, which is used as an informative parameter.

Thus there are 2 phases: phase of dosing energy feeding to the circuit (“pumping” phase) and a phase of damped vibrations when the informative parameter is released. Accuracy compensation due to temperature influence on the R resistance realized by amendment of a current value feeding the circuit during the “pumping” phase.

General technical date of some certain eddy probe system and similar eddy probe system of GlobalTest are represented in the *Table 1* (diameter probe coil – 8 mm, system length – 5 mm) [2, 3, 4, 5].

Eddy probe systems (eddy probe proximity sensor systems) are designed for non-contact measurement of the vibration, display and rotation frequency of conducting objects. They are used for diagnostics of the industrial turbines, compressors, electric motors. Axial displacement and radial rotor shaft vibration are the main subject to control this way.

Eddy probe system (proximity sensor system) consists of non-contact eddy probe, extension cable and probe driver (Fig.1). Eddy probe is a metal probe with dielectric tip at the end and some piece of the coaxial cable at the other end. The probe is connected to the driver by the coaxial extension cable. Driver is the electronic block which produces probe excitation signal and selects informative parameter.

Output signal of the driver is electric signal proportional to the distance between the eddy probe flange up and object under control.

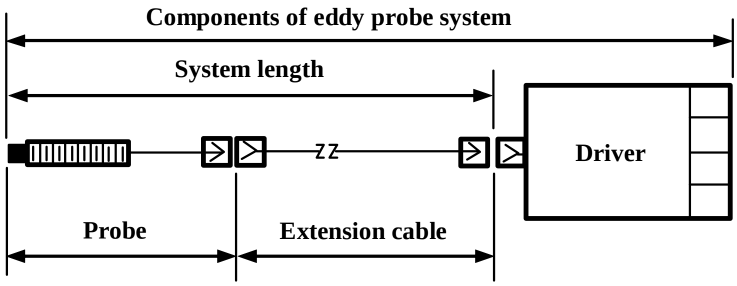

Fig.1

Inductance coil is placed at the flange of the dielectric tip of the addy probe *(Fig.2)*.

The driver produces high-frequency vibration of the induction coil and electromagnetic field influencing the material of the object under control.

In case of conductive material eddy currents occur on the surface. These currents change the value of coil resistance and inductive impedance. The parameters are changing when the gap between controlled object and transducer flange are change.

The driver converts these changes to the electric signal and processes it, providing the linearization and scaling.

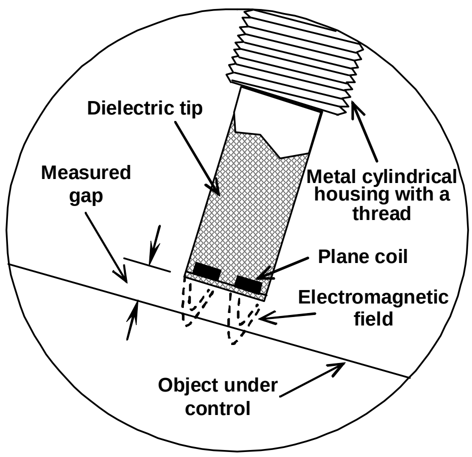

Fig.2

Since probe design is dependant of the mounting point there are many different versions of probe design.

The use of connecting cable, which consists of two parts - cable of probe and extension cable is advantageous for technological effectiveness. With the use of standard set of extension cables of different length it is convenient to select the system's total length. All cable and its separate parts are armored to provide mechanical damage protection.

The driver is designed as a hermetic metallic box with coaxial connector for connection cable, power supply clamp, ground, common and output signal terminals

Eddy probes have good frequency response (reaction on distance change between flange of the probe and object under control). Generally frequency range is *0 – 10 000 Hz*. Non-linearity of the frequency response is less than *0.5 dB*.

The input parameter of the eddy probe is the size of gap between the flange of the probe and conducting object. The size of measured gap is equal to several millimeters and depends on the diameter of the inductance coil placed at the flange of the dielectric tip. Output signal is proportional to the measured gap and may be presented as a voltage or cur rent signal, or in the numeric format (it depends on the control system type).

The driver sensitivity (transfer ratio of the gap to the electric signal) for drivers with the output signal in the form of voltage is usually equal to *8 mV/µm*. It is usually specified. For the junction of the eddy probe and typical monitoring systems quite often the additional transformation of the output voltage to the format of *4 – 20 mA* current circuit or to the numeric format is needed.

Drivers having additional transformation function are called *transmitters*.

The prior field of eddy probes application is the control of axial displacement and transverse run out of turbine shaft in large turbines, compressors and electric motors, having plain bearings. Velocity transducers and accelerometers are used for these purposes, but this is unjustified because of poor response on low frequency (less than *10 Hz*) and high vibration absorption by the massive body of the plant, so the result shows a high error, while eddy probe method provides exceptional accuracy because there is no lower limit for the frequency and it does not require mathematical processing of measurement results due to direct correspondence of output signal to current displacement of the shaft or the measuring bead aside the machine housing.

Weight of body in small turbines, compressors, generators, using rolling bearings is not very high, the vibration spectrum is positioned in high-frequency range. In this case velocity transducers and accelerometers placed on the housing are used for measuring the vibration of the shaft.

For measuring the radial vibration two transducers mounted perpendicular to the shaft and positioned at the angle 90^0 (*Fig.3*) are usually used.

The orthogonal X-Y placement of transducers improves diagnostics possibility because makes it possible to watch the orbit of the shaft movement in the radial plane if there are proper means of monitoring.

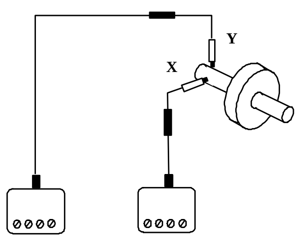

Fig.3

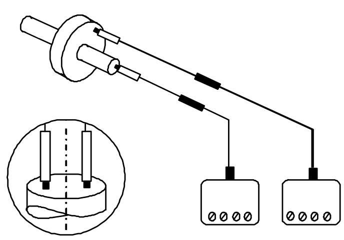
Fig.4

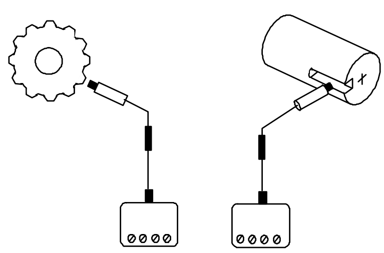
Fig.5

For measuring the axis displacement the transducer is placed parallel to the axis at the flange of the shaft and/or parallel to the testing clamp plane (*Fig. 4*).

In some cases to improve the diagnostic facilities it is recommended to mount two transducers on the flange of the shaft. In additional to displacement it allow to measure the angle of shaft deviation from axis line.

Eddy transducers are often used to measure the rotation frequency and the turn angle of the rotor (*Fig.5*). The re action of the transducer is provided by the small lug or the hollow on the shaft. Such transducer is called phase key (phase mark shaper). It is often used together with *X-Y* transducers of the radial vibration to determine shaft movement or bit orientation relatively to the phase mark. This information allows determine easily the place of mounting of the counterbalance to remove shaft disbalance. To measure angle position of the shaft the cog-wheel is ideal to use. The number of impulses corresponding to the number of the cogs of the wheel if to count from reference point, determines current angle position of the shaft.

The use of the transmitter instead of the driver in eddy proximity system allows receiving the output signal which is directly proportional to revolutions per minute number.

Moreover, eddy proximity systems are used:

- to measure a shaft eccentricity;
- to measure a thickness of a dielectric paint coating on the metal base;
- to measure an extent of the temperature distension of the mechanism;
- to measure an extent of attrition wear of parts and mechanisms;
- as the non-contact limit switch;
- to measure a metallization layer on the dielectric base.

There are several standard system configurations of eddy proximity systems offered with different diameters of the inductance coil of the probe, cable lengths, output signal parameters and measured parameters. The diameter of the inductance coil of the probe determines the range of measurement and the area of the interaction of electromagnetic fie ld with object under control. It is considered that the area of the interaction is within the limits of imaginary circle on the surface of the object. Its diameter is equal to double diameter of the inductance coil of the probe. It is necessary to take into consideration the last circumstance when it is necessary to select the mounting place of the probe and also when transverse vibration is measured because the illuminated area is cylindrical one so systematic error occurs which rises if the inductance coil diameter is increasing and shaft diameter is diminishing.

For each combination *"inductance coil diameter + system cable length"* there is the particular driver or the transmitter which is properly marked. Disparity between system cable length or inductance coil diameter and driver marking or transmitter marking leads to the increase of error.

Base specifications are represented in the *Table 2*. They allow selecting the suitable configuration of the transducer system to solve current application problem.

Table 2

Model	**Type of electronic block**	**Diameter of probe coil**	**Linearity range**	**Sensitivity, output range**	**System length**	**Measured parameter**
AP2000	Driver	*5 mm*	*0.3 – 2.3 mm*	*-8 mV/µm*	*5/9 m*	Vibration, displacement
		8 mm	*0.3 – 3.0 mm*	*-8 mV/µm*	*5/9 m*	
		19 mm	*1.0 – 8.0 mm*	*-2 mV/µm*	*9 m*	
AP2200	Transmitter	*5 mm*	*0.3 – 2.3 mm*	*4 – 20 mA*	*5/9 m*	Vibration, displacement
		8 mm	*0.3 – 3.0 mm*	*4 – 20 mA*	*5/9 m*	
		19 mm	*1.0 – 8.0 mm*	*4 – 20 mA*	*5/9 m*	
AP2300		*5 mm*	*5 – 30 000 rpm*	*4 – 20 mA*	*5/9 m*	Rotation frequency

Next plans are to conduct development work on creation of eddy current rotation transmitter that allows to set a measurement range and a number of responses on one axis rotation period and creation of eddy probe displacement system and rotation transmitter with interface RS-485 and support of wire protocol ModBus.

References

[1] A.V.Klushev, Patent RF2185617. “Method of eddy current control and device for its realization”. 2002.

[2] Bently Nevada Corporation, USA. Catalogue. 2005

[3] SKF Condition Monitoring, USA. Catalogue. 2006

[4] Henrik Brill. Amazing new Uniprobe^{TM} set to rock thousands of proximity probe users worldwide. Bruel&Kjaer Profile No.3. 1995

[5] LLC GlobalTest, Russia Catalogue. 2008

Table 1

	3300 XL 8mm Proximity Transduser System (Bently Nevada Corp., USA)	**CMSS68/CSMSS668 8mm Eddy Probe System (SKF Condition Monitoring, USA)**	**8320 8mm Eddy Probe System (B&K, Danmark)**	**D200—8.05 (GlobalTest, Russia)**
Linear range	0.25 – 2.3 mm	0.25 – 2.5 mm	0.2 – 2.0 mm	0.2 – 2.5 mm
Incremental scale factor (ISF)	7.87 V/mm ± 5% (up 0 °C to 45 °C)	7.87 V/mm ± 5% (23 °C)	7.87 V/mm ± 5% (20 °C)	7.87 V/mm + 5% (23 °C)
Deviation from best fit straight line (DSL)	± 0.025 mm (up 0 °C to 45 °C)	± 0.025 mm (23 °C)	± 0.025 mm (20 °C)	+ 0.025 mm (23 °C)
System performance over extended temperatures	7.87 V/mm ± 10% (ISF) ± 0.076 mm (DSL) probe temperature (up-35 °C to 120 °C), cable and driver temperature (up 0 °C to 45 °C)	7.87 V/mm ± 10% (ISF) + 0.076 mm (DSL) probe temperature (up -35 °C to 120 °C), cable and driver temperature (23°C)	7.87 V/mm+10% (ISF) ± 0.076 mm (DSL) probe temperature (up -40 °C to 85 °C), cable and driver temperature (20 °C)	7.87 V/mm ± 7% (ISF) ± 0.035 mm (DSL) probe temperature (up -40°C to 120°C), cable and driver temperature (23 °C)
	7.87 V/mm ± 10% (ISF) ± 0.076 mm (DSL) cable and driver temperature (up-35 °C to +65 °C), probe temperature (up 0 °C to 45 °C)	7.87 V/mm ± 10% (ISF) ±0.076 mm (DSL) cable and driver temperature (up -35 °C to +65 °C), probe temperature (23 °C)	7.87 V/mm ±10% (ISF) + 0.076 mm (DSL) cable and driver temperature (up-40 °C to +85 °C), probe temperature (20 °C)	7.87 V/mm ± 10% (ISF) + 0.05 mm (DSL) cable and driver temperature (up -40 °C to +85 °C), probe temperature (up 0 °C to 45 °C)
Frequency response	0-10 kHz	0-10 kHz	0-10 kHz	0-10 kHz
Resolving ability	-	-	-	2 μm
Power	up- 17.5V to-26V	up- 24V to - 30V	up- 19V to-30V	up- 24V to - 30V