ACCURACY OF THE SLIP-RING MEASUREMENT

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ABSTRACT

This paper deals with the accuracy judgement of the distance measurement of the rotating electrical conducting objects by the induction probe. The ovality and the bars protrusion of the slip-ring or commutator are the results of the measurement. The measuring chain of the measurement workstation is described in the text. It is also connected with material and shape properties of the rotating object influence to measurement accuracy. The paper shortly describes the transform characteristic absolute shift influence and the other effect, too.

1 INTRODUCTION

The commutator machine is one of the often use electrical machine. This machine could be constructed as a DC machine or a universal motor for AC supply. The simple construction and the easy speed regulation are the advantages of the universal motors. The commutator is the main construction part of the motor. The commutator with brushes and brush holders create the sliding contact. The sliding contact could obtain a slip-ring in place of the commutator. The slip-ring is used in the other machines with wounded rotor (synchronous motors, generators, alternators, asynchronous machine). The sliding-contact provides the electrical energy to a machine rotor. The commutator of the rotor has the same function as the mechanical rectifier. It is secured the same rotor magnetic field. The machine lifetime and service time is set by the lifetime of the sliding contact. The friction and the current cause the temperature stress of the sliding contact of the working machine. The sliding surface quality of the brush and especially of the commutator is very important for the low wear of the sliding contact. The commutator shape must be circular and commutator bars can't have any protrusion of the surface. In the present, the commutator surface is usually monitoring on a standstill machine. It is important to detect the surface of the working machine to secure the quality of sliding contact. It is necessary to use some of the contactless method for distance sensing. The induction method utilizing the eddy current effect create basic element of the measurement workstation. The measurement workstation using the induction probes has developed on our department UVEE FEKT VUT in Brno. There are new and old probes. The old probes are in Fig.1 and have the amplification modulation or the phase modulation. The new probes have PWM modulation. The properties of the new and the old probes are described in this paper. It is important to secure the maximal accuracy, the error and uncertainty of measurement.

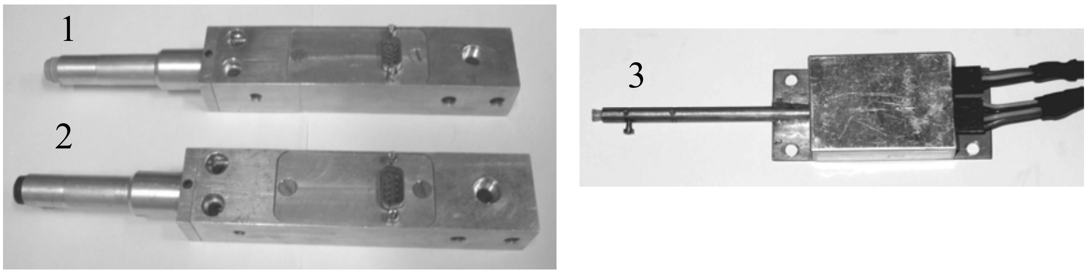

Fig. 1: *Image of the measuring induction analog probech*
Legend: 1- probe AM, 2 - probe PM, 3-new PWM probe.

2 WORKSTATION DESCRIPTION

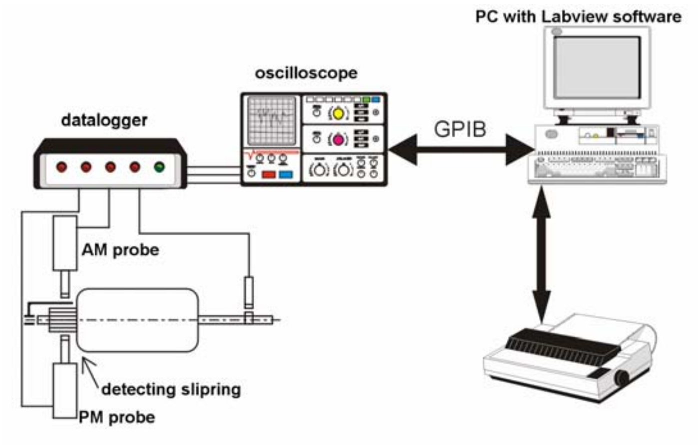

Fig. 2: *Image of the measuring chain of the workstation for the contactless sensing.*

The measuring chain is in the fig.2. First element of the chain is the measuring probe detecting commutator surface and vibration. The analog probe signal is connected to the datalogger and the signal of the IR speed sensor is also connected to datalogger. The signals from the datalogger are connected to the digital oscilloscope. The oscilloscope provide stable digital image of the measured signals. The IR speed sensor signal is used to the oscilloscope synchronization. The shown waveforms are transfer to the PC as a digital signal. The software makes the evaluation of the signals and creates the output to the file or to printer. The first part of the measurement is the relation between the measuring coil and the electrical conducting material. The value of the coil impedance is dependence on the many effects. These are the parameters affecting this part of the measurement:

- oscillator frequency - require constant,
- parameters of the electrical conducting material - specific resistance ρ, magnetic properties, shape ,dimensions,
- minimal influence of the electromagnetic disturbance,

- distance between the measuring coil and the object surface - our measured quantity.

The electrical processing of the measuring coil parameters to the output DC voltage is the next step of the measuring chain. Requirements are:

- zero time and temperature drift,
- minimal influence of the electromagnetic disturbance,
- minimal noise level added to the output signal.

The output voltage signals are displayed on the screen of the scope. The signal of the speed sensor is used to the synchronization. There is a small level of the noise in the output voltage. Therefore the averaging function of the scope is used to stifle this noise. The averaging could be in the range 1 to 512 samples. The old probes have the higher noise level, therefore the higher averaging level was set up. The high averaging level is connected with the quality of the synchronization signal and the constant speed. If the synchronization signal is changed through the sensor quality or difference of the speed, the phase of the each sample of the averaging was changed. Averaging in this case create quite big distortion of the result waveform. The digital transfer of the signal to the computer is errorless. The transform of the measured voltage waveform to the distance between the measuring coil and the surface of the material is very important step. The transformation function must be exact to the transform characteristic.

3 THE RESULTS OF THE MEASUREMENT

The set of the influencing quantities are affected to the measurement. It is vibration, electromagnetic disturbance, shape and material of the measured object for example. Some of the influencing quantities are connected with the systematic error, and these errors can be eliminated. The vibration of the measurement workstation has big influence to the measuring accuracy. It is presented in fig. 4. There is big influence of the vibration on the 6000 rpm speed level. The vibration of the measuring area is producing error up to 25 µm. This critical vibration of the measurement has been verified in each case of the measurement. The vibration analysis confirmed the resonance frequency on speed 6000 rpm.

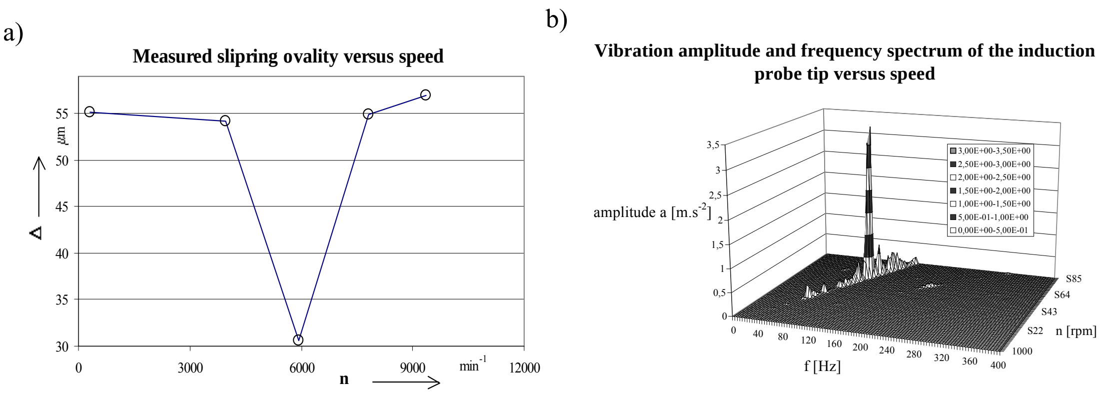

Fig. 3: *Image of the error examples of the contactless measurement*
a) The ovality of the slip-ring versus speed (critical speed 6000 rpm)
b) The frequency spectrum versus the speed range up to 10 000 rpm (critical speed 6000 rpm)

The time and temperature drift of the measuring probes are also influencing quantities. These drifts can shift the transform characteristics, and the result can be different in the time.

The induction analog probes are the deciding factor of the workstation resolution. The eddy current principle is depended on the material electric conductivity and the shape of the object. The probes dependence of the material is describing in [5]. The shape has influence to the transformation characteristic. Therefore the individual transformation characteristic must be measured to the individual measured object.

The series of the measurement have been made on this workstation. The commutator and slip-ring have been measured. The new probes have PWM modulation and temperature stabilization in probe body. This improvements cause the lower EMC dependence and temperature drift is equal to zero. The new probes have also lower noise level in output signal against the old contactless probe. The measurements of the slip-rings have been done on the specimen including two slip-ring of the car alternator and one commutator. The measurement speed range is up to 10000 rpm. The example of the calculated uncertainty is in Tab 1. The example of the uncertainties is calculating from three values of the speed range up to 4000 rpm.

slip-ring 1	slip-ring 2	old probe	new probe	AE2DS	Number of measurement			mean value	stand. deviation	uncertainties			
					1.	2.	3.	$\overline{q}$ [μm]	$s(\overline{q})^2$ [μm]	u_a [μm]	u_b [μm]	u_c [μm]	U [μm]
X				X	51,2	51,1	51,8	51,36	0,14	0,21	0,43	0,47	0,94
X		X			60,21	61,32	59,86	60,46	0,58	0,44	1,15	1,23	2,46
X			X		55,09	54,19	54,91	54,73	0,21	0,26	0,87	0,91	1,82
	X			X	56,4	55,4	57,1	56,3	0,73	0,49	0,87	1	2
	X		X		55,19	53,92	54,88	54,66	0,43	0,38	0,87	0,94	1,88

Tab. 1: *The table of the measured and calculating data.*

- average value

$$\overline{q} = \frac{1}{n}\sum_{k=1}^{n} q_k = \frac{1}{3}\sum_{k=1}^{3} q_k = 54{,}66\ \mu m \tag{1}$$

- standard deviation

$$s^2(\overline{q}) = \frac{1}{n-1}\sum_{k=1}^{n}(q_k - \overline{q})^2 = \frac{1}{3-1}\sum_{k=1}^{3}(q_k - 54{,}66)^2 = 0{,}43\mu m^2 \tag{2}$$

- uncertainty type u_A

$$u_A^2 \approx s^2(\overline{q}) \Rightarrow u_A = \sqrt{\frac{s^2(\overline{q})}{n}} = \sqrt{\frac{0{,}29}{3}} = 0{,}38\mu m \tag{3}$$

- uncertainty type u_B

$$u^2{}_B = \frac{(a_+ - a_-)^2}{12} = \frac{(56-53)^2}{12} = 0{,}75\ \mu m^2 \Rightarrow u_B = 0{,}87\mu m \tag{4}$$

- combined uncertainty u_C

$$u_C = \sqrt{u_A^2 + u_B^2} = \sqrt{0{,}31^2 + 0{,}87^2} = 0{,}92\mu m \tag{5}$$

- expanded uncertainty on 95% confidence level U

$$U = k \cdot u_C = 2 \cdot 0{,}92 = 1{,}84\mu m \tag{6}$$

k .. coverage coefficient

The result of the measurement of the slip-ring is in format mean value ($\overline{q}$) ± expanded uncertainty (U), example for slip-ring2 measured using new probe is 54,7 ±1,88µm. The result of the measurement of the standstill slip-ring2 using contact method is 56,3 ± 2µm. The results of the measurement of the slip-ring2 using the new contactless probes and the contact method give the same results with a very small difference.

4 CONCLUSION

This paper is concentrated to accuracy judgement and effects influencing the measurement error of the contactless probes. The uncertainties and other values calculated in Tab.1 are indicator of the probes qualities. The ovality is difference between the highest and the lowest measured point of the surface. The ovality measurement of the slip-ring2 using new contactless probe has the closer results than old probes. The new contactless probes have the same accuracy of the measured results of the slip-ring2. The contactless method provides higher comfort, short time of measurement and longer time of the preparation against contact measurement. Only the contactless method provides measuring slipring (commutator) surface of the working machine. The most important effect affecting the accuracy of the measurement is vibration between probe and sensing surface. This problem has been solved too.

ACKNOWLEDGEMENTS

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