THE MECHANICAL VIBRATION ANALYSIS OF THE MEASURING WORKPLACE

Ing. Pavel ŠTOREK, Doctoral Degree Programme (2)
Dept. of Power Electrical and Electronic Engineering, FEEC, BUT
E-mail: storek@feec.vutbr.cz

Supervised by: Dr. František Veselka

ABSTRACT

This paper deals with the mechanical vibration measurement. Vibration knowledge is important to eliminate the vibration from acquiring data for better accuracy and for another more stiffness system design. It is sensing the vibration of the contactless measurement workstation for the commutator bars protrusion sensing on the working electrical machine. The electrical machine high speed may cause the vibrations. The modern measurement system with accelerometers is used for vibration diagnostics. The results give the vibration frequency analysis over the whole speed range.

1 INTRODUCTION

The electrical commutator motors are steel very often used machines in many applications. The service live of these machines is very important parameter. The service live is dependent on the quality of sliding contact. The sliding contact is composed of brush, brush holder and commutator (slip ring). The brush lifetime depend on many circumstances. The quality of the commutator surface is one of them. The shape knowledge of running commutator on nominal speed level is useful. It is the reason to developed the contactless measurement workstation with induction probes. The probes use the eddy current effect to sensing the placement of the electrical conducting materials. The distance between the probe tip and the measured surface is equal to DC output voltage. Measuring workplace was developed on Department of power electrical and electronic engineering. Measuring chain is composed of the induction probes, the central unit, the oscilloscope, the personal computer with GPIB card and a printer. The induction probes signal is connected to central unit. The central unit fit level of the probe output voltage for the oscilloscope. The oscilloscope view the waveform of the measured voltage. The optical reflective IR speed sensor is used to the probe waveform synchronization on the oscilloscope. The waveform determine the surface of measured rotating object. The measurement workstation draft is in Fig. 1. There is marked additional stiffness bar for vibration decreasing. The rotating motive motor and clutch cause the spurious vibration. These mechanical vibration makes a little commutator displacement and makes the measuring error and makes lower accuracy, consequently.

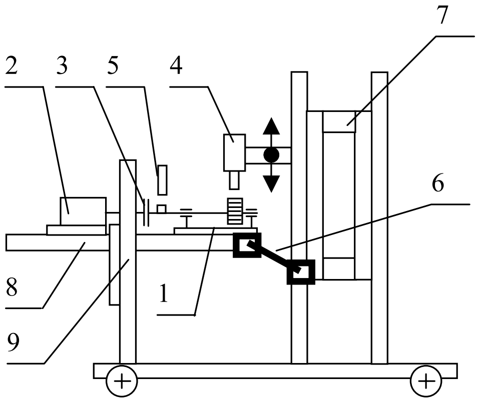


Fig. 1: *The contactless measurement workstation draft*
Legend: 1 - model with commutator and slip-ring on the rotor, 2 - motive machine, 3 - clutch, 4 - induction probe, 5 - optical speed sensor, 6 - additional stiffness bar, 7 - measurement frame, 8 - motor base, 9 - vertical motor base beam.

2 DESCRIPTION OF THE METHOD

The measurement was done in cooperation with Institute of Solid Mechanics, Mechatronics and Biomechanics on Faculty of Mechanical Engineering BUT Brno. It is used the modern mobile measuring system PULSE 3560 for vibration diagnostics of the mechanical systems, Fig.2. The microphone sound sensing and the acceleration sensing using the piezoelectric sensors can be used to diagnostics. Only accelerometers is used in this case. The accelerometers signals are connected to data-logger and to computer, consequently. The software makes frequency spectrum for actual speed. The accelerometers placement on the measurement workstation is following (Fig.3):

- bearing bush of the model
- tip of the measuring probe
- the top part of the measuring probe
- motor base of the measurement workstation

The accelerometers were attached to the surface using the beeswax.
The parameters of the sensing devices:
Acceleration pick ups – piezoelectric accelerometer
Type: 4374, 4374
Freq. range : 0 - 20 kHz
sensitivity: $9.95mV.m.s^{-2}$, $9.87mV.m.s^{-2}$
manufacturer: Brüel&Kjaer, Denmark
serial number: 998247, 99824
freq. range: 0 - 100 kHz
manufacturer: Brüel&Kjaer, Denmark
serial number: 1911379, 1911380
Technical specification is described in [1].

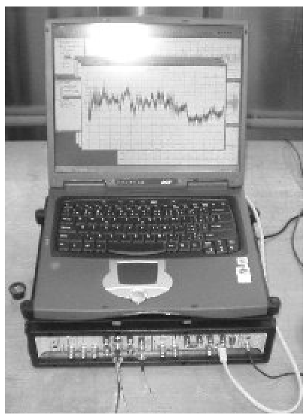


Fig. 2: *The data logger and notebook with OS and the measurement software*

The modal analysis was done in the second step. Modal analysis is the procedure of determining a structure's dynamic characteristics (resonant frequencies, damping values, etc.). This analysis is performed while the workstation is not running. A series of frequency response functions are measured at various geometric locations using either an instrumented impact hammer to supply an input force. There is set seven points on the construction to hit using the impact hammer. Response is measured on the bearing bush with accelerometers. A frequency response function is the response per unit force over the frequency range of interest [2].

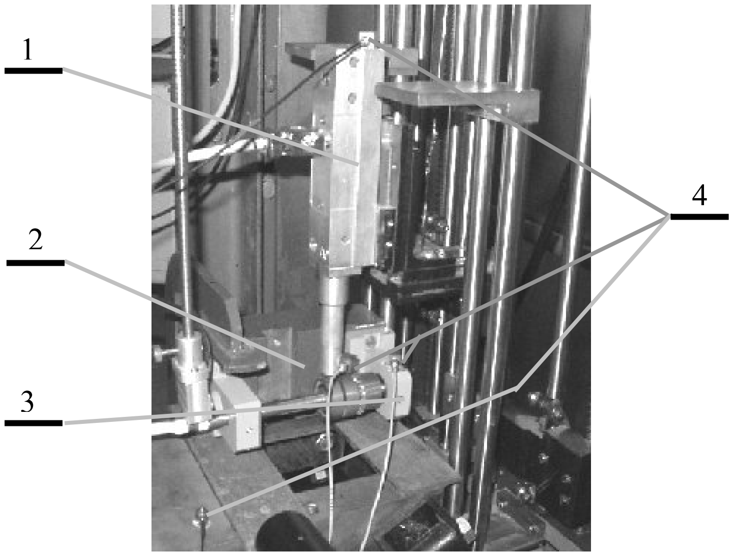
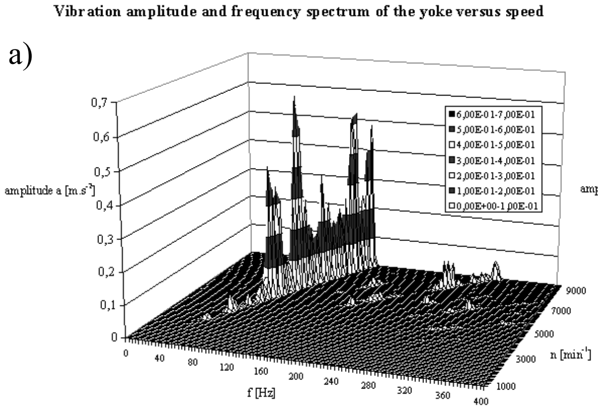


Fig. 3: *The placement of the accelerometers on the measurement workstation.*
Legend: 1 - induction probe, 2 - model with the commutator and slip-ring on the rotor, 3 - bearing bush , 4 - piezoelectric accelerometers.

3 THE RESULTS OF THE MEASUREMENT

Measuring system PULSE 3560 using accelerometers make the frequency diagnostics of the workstation up to 10 000 rpm. The motive motor has this speed range. The differences between the construction with additional stiffness bar and without additional stiffness bar is detected in this speed range. The first type measuring use the accelerometers on four points of the construction as in chap.2. The accelerometers signals give the information about the vibration frequency spectrum for each speed. The acquiring data is saved in format *.xls for MS EXCEL. 3D-graph in fig. 4 is constructed here. The graphs allow their simply comparison. The motor base vibration frequency spectrum graphs with and without the additional stiffness bar are in fig. 4. The most significant vibration frequency spectrum change is in this graphs. The additional stiffness bar decrease the acceleration maximum amplitude to 10 %. It shows that the additional stiffness bar make the motor base more stiffness. On the other hand, the additional stiffness bar make the mechanical connection between the motor base and the measurement frame. This connection make the induction probe vibration increase of 100 %. The bearing bush vibration is without the change. The vibration between the induction probe and the motor base decrease to 60 %.



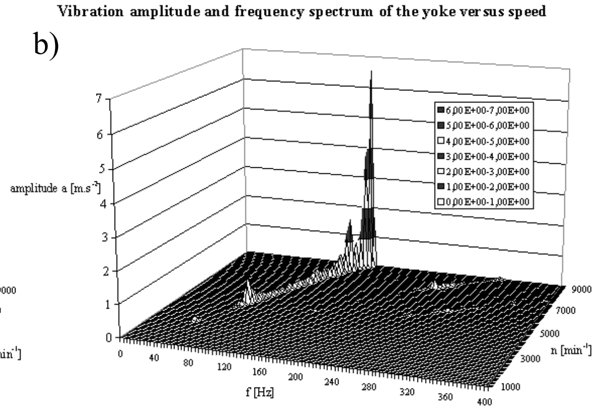
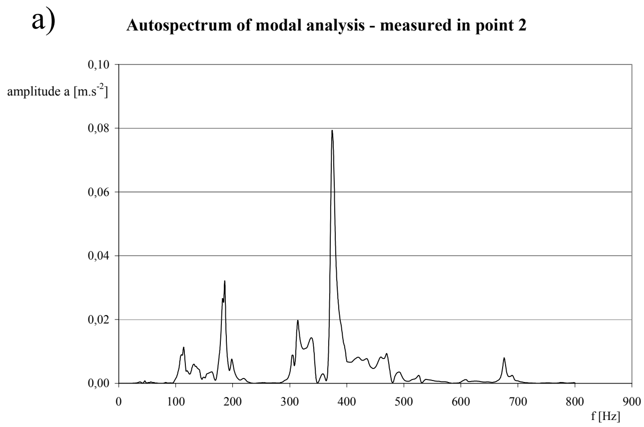


Fig. 4: *Vibration amplitude and frequency spectrum of the motor base versus speed:*
a) construction with additional stiffness bar
b) construction without additional stiffness bar

The next measurement is modal analysis. The measuring principle is described in chap.2. The five files are saved for each measuring. First file includes the frequency autospectrum of time response. The send one contains the cross-spectrum. The third file contains the frequency response to unit force. The fourth file contains the time response to unit force and fifth file contains the unit force pattern of the impact hammer. Modal analysis shows the changes of the resonance frequencies of the construction. The most significant change is in the autospectrum of the vertical motor base beam, Fig.5. The impact hammer hit to the vertical motor base beam and accelerometer measure the time response. The computer using software make the FFT analysis. The main difference is on the low frequency about 60 and 200 Hz. The resonance amplitude using the additional stiffness bar decrease to 30%. The next big difference is following. The time response to unit force on the motor base using the additional bar is too small for measuring. The time response is measurable without the additional stiffness bar, only. This result shows the construction higher stiffness with the additional bar. The unit force time response of the probe support shows the more spread frequency spectrum using the stiffness bar. The other autospectra show generally the same results of the resonance amplitude value and the spread of the resonance frequencies.



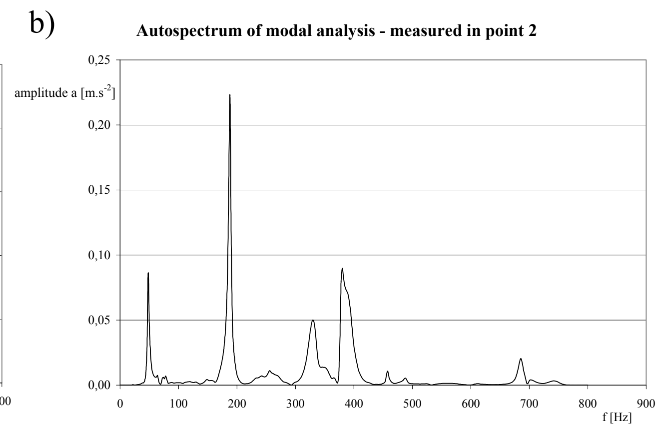


Fig. 5: *The frequency autospectrum of modal analysis, hammer hitting the point on the vertical motor base beam: a) construction with the additional stiffness bar*
b) construction without the additional stiffness bar

4 CONCLUSION

The measured results give the information about system vibration behaviour in the interest speed range. The vibration analysis give advice to resonance frequencies, which can cause some problems. This work judge the using additional stiffness bar, too. The results show that the additional stiffness bar decrease the motor base vibration. It makes the running workstation more safety, and make the smaller accident probability. The vibration decrease corresponds to the lower commutator displacement. The second result is the induction probe vibration increase. The relative vibration between the probe tip and commutator decrease to 60% with additional bar in the end. But vibration is steel here. The vibration has effect to measurement, especially to measuring error. The vibration cause the displacement of the sensing surface. It is reason to sensing the vibration between the probe tip and measuring surface. The vibration can be measured by the other induction probe. The probe and commutator relative dimension forbidden the two probe measuring at one time. The commutator displacement measurement is done after commutator surface measurement. The developed software eliminate the vibration from the measured data, consequently. The new motive machine and magnetic clutch with range up to 50000 rpm will be use in the future. The vibration diagnostics give information of the construction behaviour for high speed machines, too. Only the mass of the machine could make little changes at resonance frequencies and their amplitudes.

ACKNOWLEDGEMENTS

The article is supported by grant MSM 2622 000 10.

REFERENCES

[1] Technical documents of the charge amplifier 2635. Brüel & Kjaer, Dánsko, 1993

[2] www.structuraltechnology.com/modal_analysis.htm

[3] Veselka, F.: Studie bezkontaktního měření a vyhodnocení povrchu komutátoru za provozu [Závěrečná zpráva]. ÚVEE FEKT VUT v Brně, Brno 1993.

[4] Štorek, P.: Bezkontaktní měření vystupování lamel komutátoru elektrických strojů. DP ÚVEE FEKT VUT v Brně, Brno 2002.