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POSSIBILITY OF FAILURE PREDICTION OF ELECTRICAL MACHINES WITH PERMANENT MAGNETS BY POWER SIGNAL MONITORING - A TEST STAND CONCEPTION

Abstract

The paper presents a new vibration diagnostic method and conception of the test stand. This method is used for diagnose of permanent magnets (PM) rotating machines, especially generators. Specific structural properties of machines with permanent magnets are used in this solution - electromotive force (EMF) is generated due to vibrations of permanent magnets. Several issues are discussed in this article: the genesis of the method, the similarity of permanent magnets machines to vibration sensors, the conception of laboratory test stand on which these method will be develop, 3D test stand model strength and vibration numerical analysis. This method is the subject of patent application No P.40566.

1. INTRODUCTION

Tekst During vibration in the machine with permanent magnets in its windings, electromotive force (EMF) is induced. The vibrations in electrical machines are undesirable, their high level, higher than the so called the permissible level, is considered as a symptom of failure. Underestimation of these symptoms entails a real risk of a catastrophic failure, which cost may exceed the cost of a new device. Vibrations that always accompany the work of rotating machines are the cause of the gradual degradation of some components of the device. If you want to know its cause, it is necessary to conduct a detailed analysis of the vibration spectrum. Such procedure allows for the division of the signal generated by the machine into components. Thanks to knowing the basic operating parameters of the machine and its construction it is possible to attribute specific components of the vibration spectrum to the elements or states of the machine [3]. The vibration diagnostics of electrical machines is based mainly on measurements using external sensors and intended for this purpose complicated and expensive apparatus. Attaching sensors to the machine often causes problems, because the machine factory is rarely adapted to this purpose. Installation method affects the frequency response of the measurement signal. Additionally, special attention should be paid to the separation of the measuring circuit from any kind of interference, as it can result in an incorrect display of the measuring apparatus [4]-[6]. The advantage of the described method of detecting the mechanical vibrations in electrical machines with permanent magnets is the fact that the measurement system does not require the use of sensors for measuring vibrations. Excitation circuit and winding armature perform a function of the vibration sensor in the same time. Vibration measuring sensors are used once for measurement scaling of the specific type of the machine. Vibration measurement by this method can be performed on-line during normal operation of the machine [7], [8].

1. SIMILARITY OF (PM) MOTOR TO ELECTRODYNAMIC SENSOR

Tekst The similarity of the machines with permanent magnets (PM) to electrodynamics sensor used to measure vibration as in Figure 1a), was noted. Such sensor is characterized by:

- a simple construction, spring-suspended magnet inside the coil, as due to vibrations, the magnet moves through the coil and generates a proportional signal to the vibration velocity (there are also structures where the coil is movable and magnet is rigidly fixed to the housing),
- sensitivity depending on the number of turns in the coil,
- the lack of power supply from an external source.

While comparing permanent magnets machine as in Figure 1b) with electrodynamic sensor as in Figure 1a) the following properties can be observed:

- similar construction – windings are built like a coil; due to vibrations EMF is generated in the windings, as well as a signal which can be used for vibration analysis,
- higher number of pole pairs and coils induces the higher measuring signal and the sensitivity is dependent on the number of winding turns - in analogy to the electrodynamic sensor.

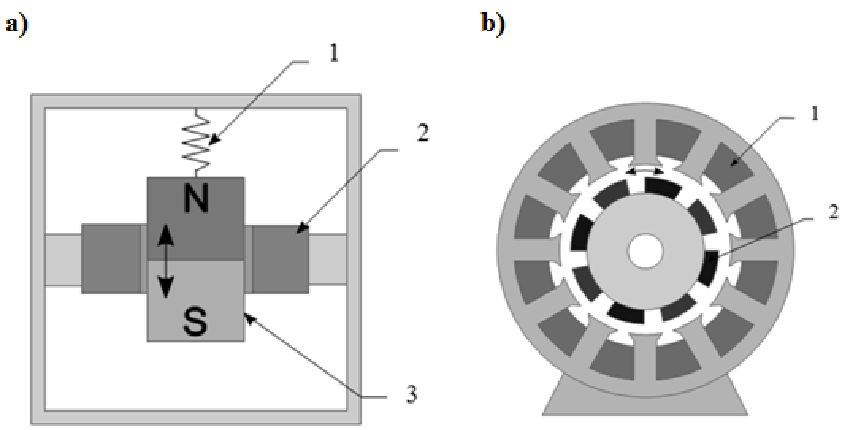

Fig. 1. a) Electrodynamic sensor (1-spring, 2-coil, 3-magnet), b) Machine with permanent magnets (1-winding, 2-magnet).[4]

The following important sources of harmonics that can be observed in generate voltage or current during the operation of the machine are:

- unbalance,
- radial or axial geometry asymmetry between the stator and the rotor,
- bearing damage.

2. 3D TEST STAND MODEL

Fig. 2. 3D Motor model with adjustable discs which allow for the regulation of the gap

The designed test stand lets for every configuration of the rotor to the stator position.To adjust the gap between the rotor and the stator, special bearing disc as in Figure 3, was designed. Discs regulations allow for the rotor position changes in a radial and axial plane as in Figure 4. Discs also allow for encoder assembling by using a special adapter as in Figure 3.

This construction of machine (test stand) will enable to carry out extensive research on the influence of the improper position of the rotor or bearing damage on electrical signals.

3. TEST STAND MECHANICAL SIMULATIONS

The mechanical strength of the test stand was simulated in Autodesk Simulation Multiphysics program. This program uses the Finite Element Method and allows to perform a wide range of analysis especially static and dynamic stress analysis. This software is based on a properly prepared 3D models. As a native environment it uses 3D models prepared in the spatial modeling Autodesk Inventor program.

Three-dimensional computational model was based on previously developed structural model (Figure 2). The structural model is too complex for the calculation using FEM. It has many elements that have no effect on the simulation results, but they make simulation impossible to conduct. They are for example: bolts, washers, bearings, terminal box. These parts haven‘t got a significant impact

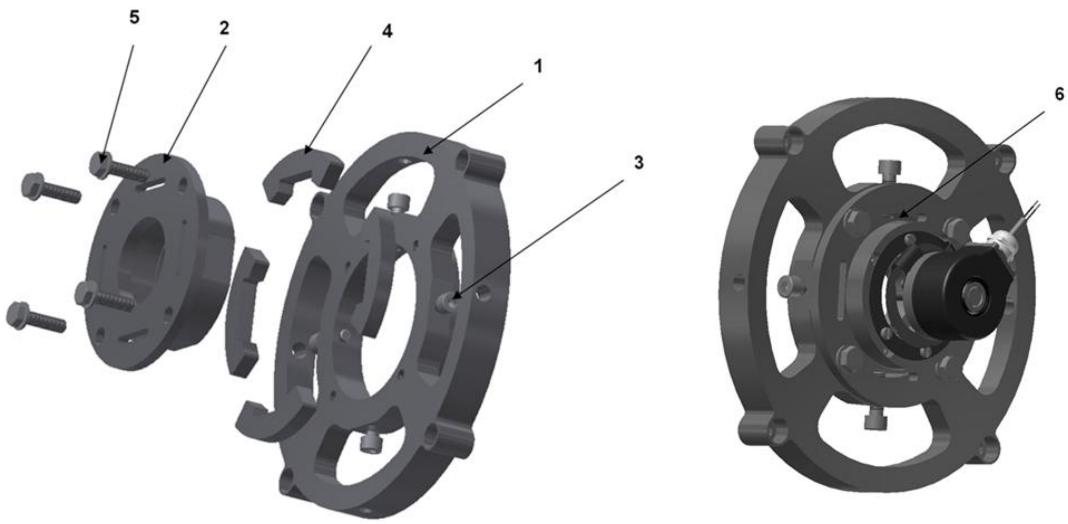

Fig. 3. Components of adjustable motor's bearing disc: 1- main disc, 2 - a mobile hub, 3 - adjusting screws, 4- washers, 5 - locking screws, 6 - encoder's adapter.

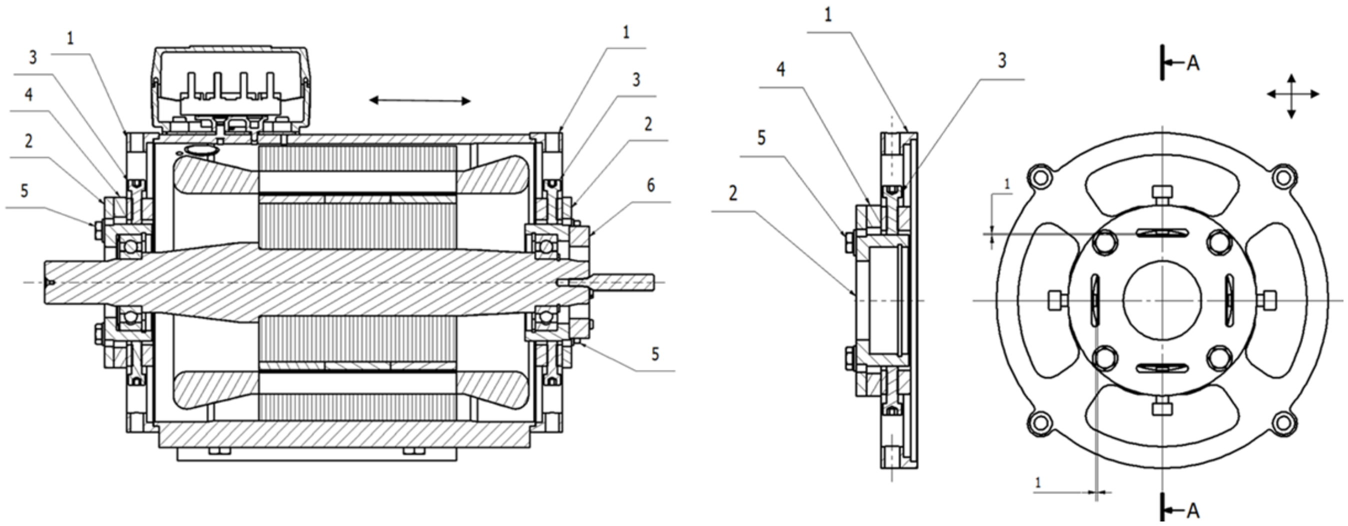

Fig. 4. Adjustable motor's bearing disc - adjustable in the axial and radial plane.

on the results and they cause an increase of the size of the computational model. Proper simplified 3D test stand model was imported to Autodesk Simulation Multiphysics. In the first step, to each element of the model, material properties has been given. In the next step, the proper linkages between elements were loaded. The contact boundary condition between the shields and the body surface and between the stator and the body was established.

The most important thing in simplifying the discrete model was the correct modeling of the rotor bearings. Bearings are modeled by the RIGID elements. These elements are characterized only by stiffness parameters, which were adopted, on the basis of literature, at 150000 N/mm (corresponding to the size of the bearing stiffness). These elements are shown in Figure 5 as rods. Bearing plate grid nodes with the nodes of the shaft are connected by RIGID elements in one central node. A prepared discrete model with a mesh and exemplary force acting on the rotor surface is shown in Figure 5. Such prepared computational model allows to conduct different strength analysis for all kinds of test stand loads. The exemplary simulation stresses results from the asymmetric arrangement of the rotor are shown in Figure 6.

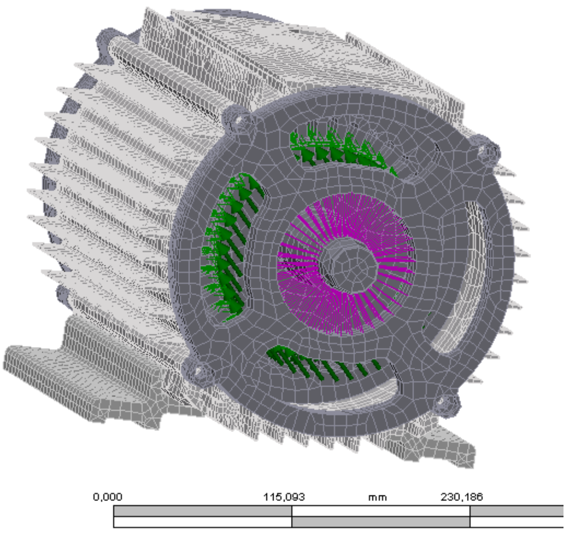

Fig. 5. *Digitized model of the test stand.*

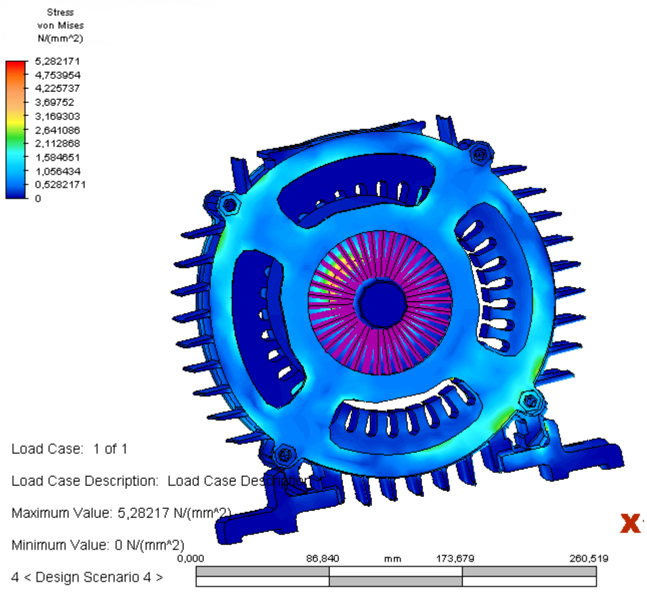

Fig. 6. *The simulation stresses results from the asymmetric arrangement of the rotor.*

SUMMARY

The analysis reveals the possibility to use the machine with permanent magnets as a vibration sensor. This approach is innovative, as such an application for PM generators, where the assessment of the technical terms used in the vibration is signaled by the machine itself, has never been approached. Presented diagnostic method greatly simplifies PM machines' vibratory diagnostics. Thanks to this method, it is not required to use expensive sensors, and diagnostician does not have to care about sensors' assembly which in some cases is an important issue. The method also allows for diagnostics on-line with the usage of additional equipment which enables the analysis of the frequency of the voltage signal or current operated drive. The designed test stand lets for checking the accuracy of this method.

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MOŻLIWOŚCI PRZEWIDYWANIA USZKODZEŃ MASZYN ELEKTRYCZNYCH Z MAGNESAMI TRWAŁYMI ZA POMOCĄ ANALIZY SYGNAŁÓW WŁASNYCH - KONCEPCJA STANOWISKA BADAWCZEGO

Streszczenie

W pracy przedstawiono nową metodę diagnostyczną uszkodzeń wirujących maszyn elektrycznych z magnesami trwałymi, oraz koncepcję stanowiska badawczego *do jej weryfikacji. Metoda ta służy do diagnostyki maszyn z magnesami trwałymi (PM) za pomocą drgań, zwłaszcza generatorów. Wykorzystano w niej specyficzne właściwości konstrukcyjne maszyn z magnesami trwałymi, w których siła elektromotoryczna (SEM) generowana jest w wyniku drgań. W artykule omówiono: genezę metody, podobieństwo w budowie czujnika drgań i maszyny z magnesami trwałymi, koncepcję stanowiska do badań laboratoryjnych, na którym metoda ta będzie rozwijana, model 3D stanowiska laboratoryjnego z symulacjami numerycznymi jego wytrzymałości i sztywności. Metoda ta jest przedmiotem zgłoszenia patentowego nr P.40566.*

INFORMATION

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