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MAGNETIC FIELD IN THE SURROUNDINGS OF INDUCTION MOTORS

Summary: High reliability is one of the most important requirements in technical operations and can be assessed by estimation of the actual operational state. This operation is called technical diagnostics. The magnetic induction around an induction motor is taken as a value indicating the state of its functional properties. The modelling of the magnetic field around an induction motor is performed by means of the ANSYS program in order to get information about the shape of the magnetic field and about the size of magnetic induction both outside a faultless induction motor and inside a motor with an eccentric air gap. The results are checked by measuring the outside magnetic field of the induction motor during its operation by means of the MAGNET-PHYSIK apparatus.

Key words: AC machines, induction machines, modelling, software, diagnostics, measurement

1. INTRODUCTION

In electrical machines electric energy is transformed into mechanical one through a magnetic field. Stator and rotor windings are sources of the magnetic field in every electrical machine. These windings are placed either in slots or on poles. Electromagnetic transformation e.g. in induction motors is made possible by mutual influence of the magnetic field produced by stator windings and by the rotor windings in which the electric current flows. There are two kinds of magnetic field in a motor: the main and the leakage field. The main field magnetic flux is closed by a magnetic circuit. Since the leakage magnetic field is closed and also outside the magnetic circuit it can be used for the research in processes within the machine. This enables to watch the processes taking place in the machine and observe the state of its functional properties during its normal operation. This diagnostic requires no dismantling, is not destructive and has no harmful effects on any part of the machine. The shape and course of magnetic fields have then a direct influence on mechanical quantities, especially on the machine torque. The torque can either positively or negatively influence function, reliability and service life of the driven mechanism.

2. USE OF THE MOTOR MAGNETIC FIELD FOR DETECTION OF ITS ACTUAL CONDITION

As already mentioned, the torque of an electrical machine depends on electromagnetic quantities especially in an air gap. Courses of magnetic fields in a machine are very complicated and are influenced by many factors, especially discrete distribution of conductors in slots, non-linear magnetic characteristics, complicated construction of the magnetic circuit, non-uniformity of the air gap, etc. Quantitative diagnosis of the magnetic field in a rotating electrical machine is therefore very difficult. This may be partly due to the machine construction, non harmonic voltage or electric power supply or any possible defects of electric and mechanical parts of the machine.
For this reason we studied and verified the possibility of obtaining information about defects and failures of induction motors by measuring and analysing leakage magnetic fields on the casing surfaces of these motors.

The frequency spectrum of the leakage magnetic field up to 100 Hz is shown in Figs.1 and 2. The spectrum was measured on the casing surface of a 4 pole induction motor by an exploring coil. The spectrum has a lateral band when the magnetic field of the stator or the air gap are asymmetrical. This will cause a change of the magnetic field during one revolution. This frequency

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will appear in the isit. It depends on the type of the machine and especially on the number of its poles whether the spectrum can be evaluated or not [1].

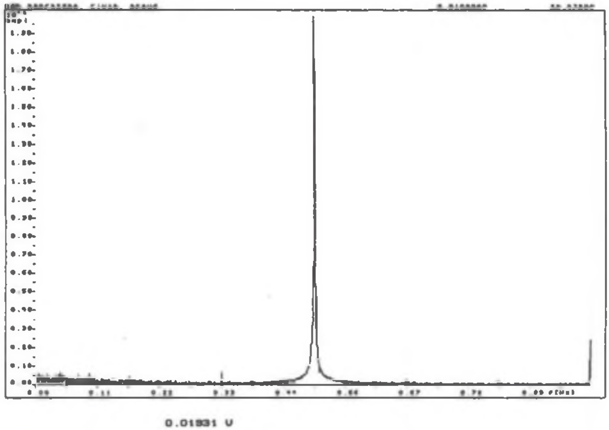

Fig.1. Magnetic field frequency spectrum of a 4-pole induction motor without a symmetric failure

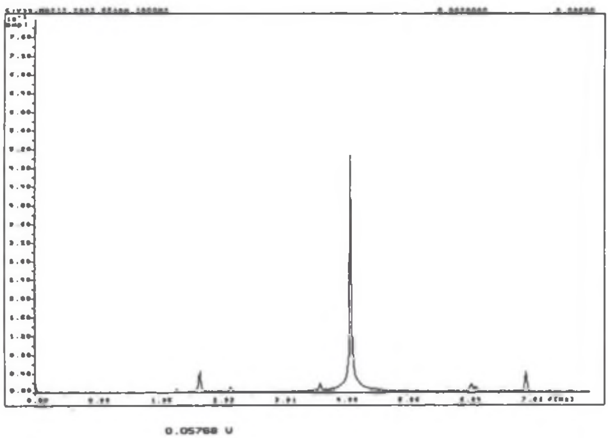

Fig. 2. Magnetic field frequency spectrum of a 4-pole induction motor with a symmetric failure

The above mentioned measured results required more detailed research of the leakage magnetic field in the surroundings of an induction motor. We study this field on a motor without any electrical or mechanical defects as well as with an eccentric air gap. It is obvious that the results can also be used in the field of electromagnetic compatibility.

3. VERIFICATION OF EXPERIMENTALLY DETECTED RESULTS BY MODELLING

We practised modelling of the magnetic field in surroundings of an induction motor by means of the ANSYS 5.5.3 program, which solves problems by means of the finite element method (FEM). The finite element method is an effective method for the solution of all boundary problems of engineering practice described by differential equations. The method was developed with the appearance of digital computers to solve problems in elasticity and strength in the aircraft industry at the end of the fifties.

Nodes and node potentials are introduced into an area where the field is calculated. The nodes can be distributed in the area unevenly and thus they can follow the shape of the boundary areas. The bigger density of the mesh is established in places where the acute change of the field is expected. The system of equations is set for unknown nodal values. The coefficients of the matrix of the system of equations and the right sides are not calculated by using differences substituting derivatives but as definite integrals over elementary areas or volumes, in whose peaks the nodes are placed. These elementary forms are called finite elements. We used areal elements in the shape of quadrilaterals and trilaterals for the calculation of our 2D model.

We model the magnetic field in the surroundings of a three phase wound rotor induction motor with a frame made of cast iron. The induction motor has the power rating of 5,5 kW and 6 poles. We made a cutting plane of the motor so that it went through the motor magnetic circuit (outside the terminal board). We omitted the motor frame cast-iron bases and cooling ribs. By means of preprocessor commands of the ANSYS program we created motor 2D model. The kind of material and element was then fitted to the model areas. The model was covered with elements. The current densities were matched to the stator and rotor sheet metal slot elements. We made static calculation of the 2D model [2].

4. THE RESULTS FOR AN INDUCTION MOTOR WITH SYMMETRIC AIR GAP

The shape of the magnetic field in the surroundings of an induction motor is shown in Fig. 3. The frame is made of cast iron, the induction motor has a symmetric air gap and the motor runs on no-load. 2D flux lines are shown in Fig. 4.

For the calculation of the external field we used the same motor model as for no load, however, we determined the current densities into slots, in the stator and rotor for the load motor. The shape of the magnetic field in the surroundings of the induction motor is shown in Fig. 5.

5. RESULT FOR AN ECCENTRIC AIR GAP

The motor model was adapted by moving the rotor to the right by 0,2 mm. The calculated shape of the magnetic field outside the induction motor is shown in Fig. 6. The frame is made of cast iron, motor has an eccentric air gap end the motor runs on no-load.

The motor model was adapted by modelling the frame cooling ribs. The calculated shape of the magnetic field outside the induction motor is shown in Fig. 7.

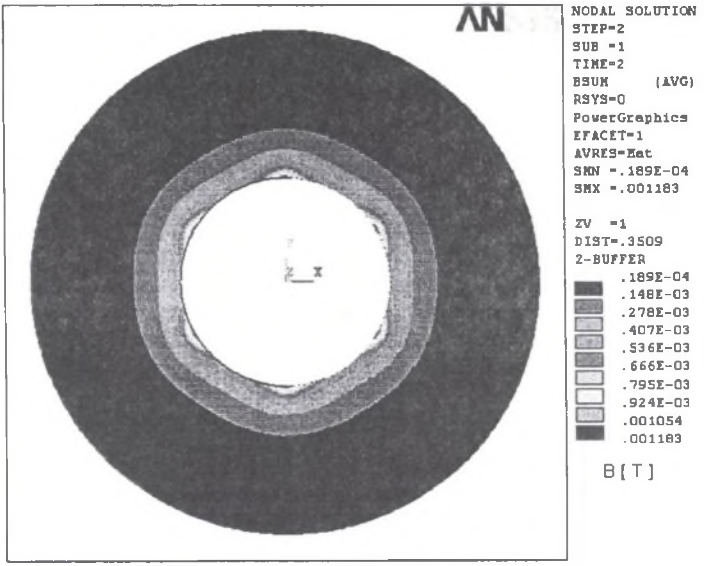

Fig.3. The magnetic field in induction motor surroundings, the frame is made of cast iron, air gap is symmetric, no-load motor

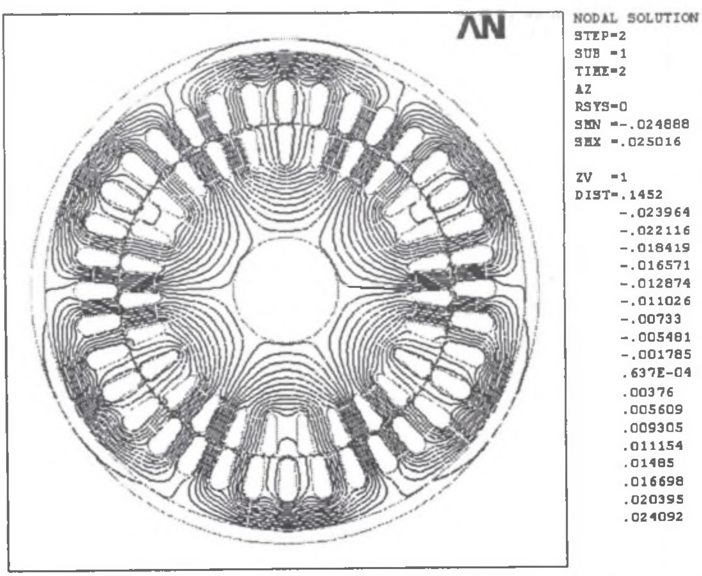

Fig.4. 2D flux lines of induction motor, the frame is made of cast iron, air gap is symmetric, no-load motor

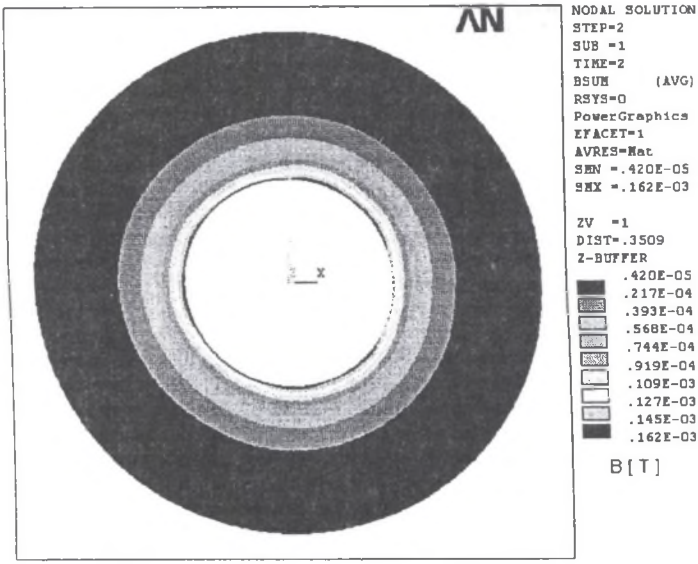

Fig.5. The magnetic field in induction motor surroundings, the frame is made of cast iron, air gap is symmetric, load motor

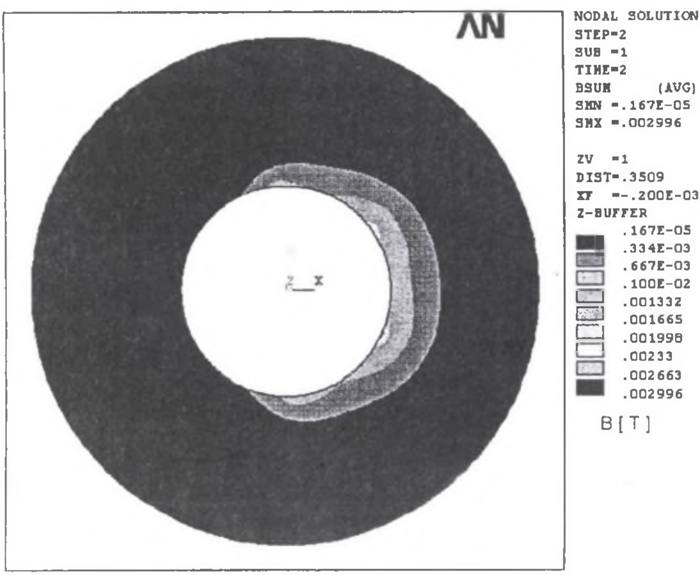

Fig.6. The magnetic field in induction motor surroundings, the frame is made of cast iron, eccentric air gap, no-load motor

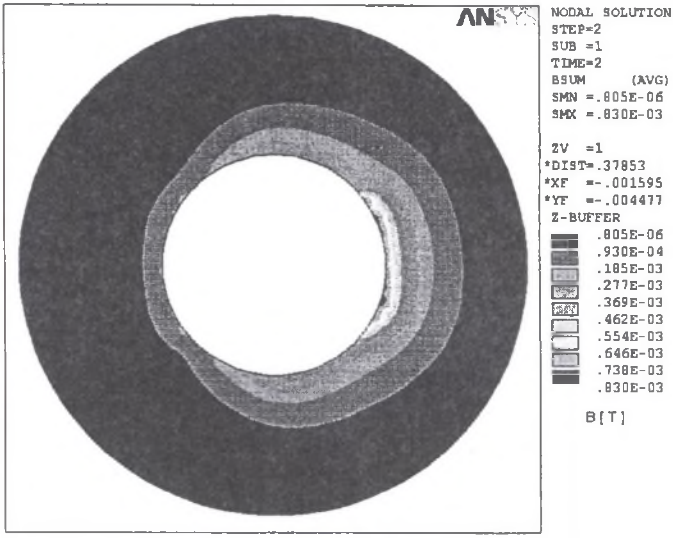

Fig.7. The magnetic field in induction motor surroundings, the frame is made of cast iron, eccentric air gap, no-load motor. Cooling ribs were also modelled

6. VERIFICATION OF THE MAGNETIC INDUCTION CALCULATED VALUES IN SURROUNDINGS OF AN INDUCTION MOTOR BY MEASUREMENTS

The magnetic induction value in the modelled motor surroundings was measured by the MAGNET-PHYSIK measuring apparatus shown in Fig. 8. The apparatus measures magnetic field by means of the Hall probe. We placed the probe into the plane where the motor magnetic field was modelled and we gradually moved the probe away from the motor frame. We compared the magnetic induction measured values with those obtained by modelling in the ANSYS program. The calculated values of magnetic flux density in the induction motor surroundings are shown in diagram no.1. The magnetic induction measured values are shown in diagram no.2.

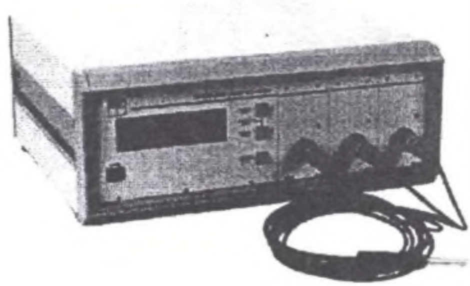

Fig.8. Measuring apparatus MAGNET-PHYSIK FH 47/3, model 9953

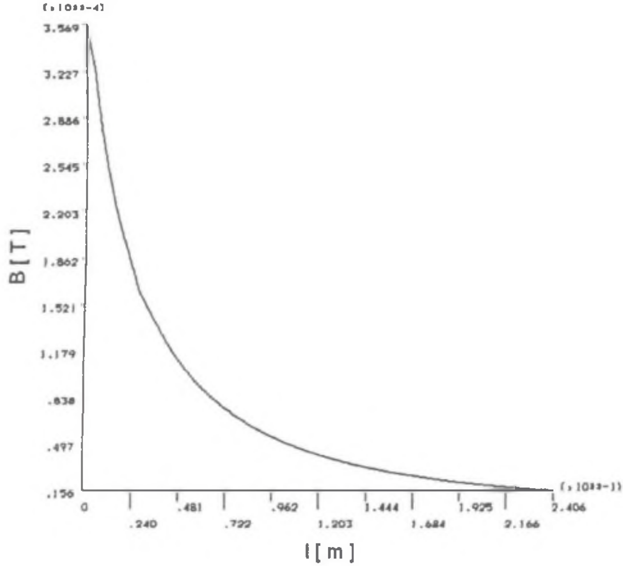

Diagram no.1. Illustration of magnetic induction calculated values in induction motor surroundings vs. distance from the frame (no-load motor, air gap is symmetric, the frame is made of cast iron)

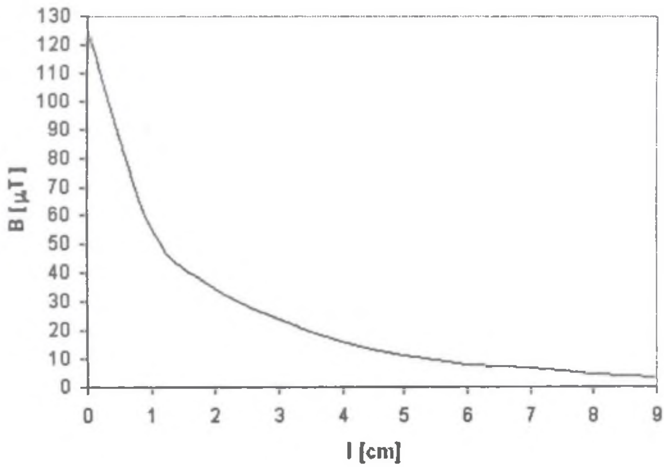

Diagram no.2. Illustration of magnetic induction measured values In induction motor surroundings vs. distance from the frame (no-load motor, air gap is symmetric, the frame is made of cast iron)

7. CONCLUSIONS

Comparing the above mentioned results we came to following conclusions:

1. The magnetic field in the surroundings of an induction motor has higher values for no load motor because the magnetic field of the rotor interacts counter to the magnetic field of the stator when the motor runs on load. Therefore the target field has lower values in surroundings of an induction motor (influence of anchor reaction).
2. The shape of the magnetic field in the surroundings of an induction motor with an eccentric air gap is also eccentric.
3. We can say that the motor fulfills conditions of EMC according to the calculated and measured values of magnetic induction in the surroundings of an induction motor.
4. The shapes of magnetic induction outside an induction motor obtained by modelling and measuring correspond with each other. The magnetic induction values are of the same order but their values are not identical. The both processes were obtained in entirely different ways. The results of magnetic induction obtained by modelling represent the magnetic induction values on the selected net nodes under the ideal conditions of no load motor case (there is no current in the rotor). The magnetic induction values obtained from measurements corespond to those for real no load motor case. We also have to take into consideration that the measurements were taken on a metal dynamometer measuring desk in a test room and their accuracy can therefore be influenced by the various electric gadgets that are placed there.
5. Calculations of the magnetic field in the surroundings of an induction motor that are mentioned here are not final. Modelling the magnetic field in the surroundings of an induction motor will be performed for frame made of aluminum and for other cases of failures of induction motors.

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