COMPUTER-AIDED FEM ANALYSIS OF A BEARING PLACED IN A MAGNETIC FIELD

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ABSTRACT

This paper presents a simulated analysis of the influence of the magnetic field upon the bearings. Three different situations are taken into account depending on the position of the bearing and magnetic field axis. The simulation uses a software package based on finite element method.

KEYWORDS: bearings, magnetic field, FEM analysis.

1. INTRODUCTION

The operation of a large number of electromechanical systems is related to the presence of the magnetic field. It acts preponderantly in the areas where there are ferromagnetic materials and has different effects depending both on its type (constant or alternating field) and the electric and magnetic material properties.

The systems that involve rotating movement during the operation are often provided with bearings. The typical example is electrical machines. Usually their magnetic circuit is such a way designed to concentrate the majority of the flux lines. Yet the other ferromagnetic components of the entire building often become part of the flux lines pathways.

The presence of the bearings next to magnetic area could involve appearance of side effects that influence their operation and durability. Especially we talk about supplementary heating generated by eddy currents.

To estimate the particular phenomena related to the presence of the magnetic field in the area where bearings operate we have performed a computer-aided analysis based on finite element method. Three different situations have been taken into account:

- the magnetic filed axis dovetails with the bearing axis;
- the magnetic filed axis is parallel to the bearing axis;
- the magnetic filed axis is perpendicular to the bearing axis;

These situations simulate the possible position of a bearing incorporated in an electromechanical system and placed under the influence of an alternating magnetic field.

2. FEM ANALYSIS

The investigation based on finite element method involves subdivision of the domain that has to be studied in small triangles called “elements”. Each element is characterised by certain points called “nodes” where one of the parameters of the magnetic field, usually magnetic vector potential, is calculated. Then the software gives a general solution by interpolating the results obtained for each node.

The major advantage of the FEM analysis consists in the possibility of establishing with high accuracy the effects of the magnetic field for each point of the domain. However, has to be pointed out that the computation takes into account the following assumptions:

- the magnetisation curve of the magnetic material is single-valued, i.e. hysteresis is neglected;
- the ferromagnetic materials are isotropic;
- the field distribution is the same in any cross-section;
- the field components vary sinusoidal.

As follows the simulation for the three above-mentioned situations is presented.

2.1. Magnetic field and bearing with the same axis

This is a situation similar to a case of a bearing placed on a shaft in which an electric current flows. Figure 1 presents the geometrical structure. The inner (1) and outer (2) rings are characterised by ferromagnetic properties defined by magnetisation curve, which was experimentally determined. The resistivity corresponds to RUL 1V material ($\rho = 2.43 \times 10^{-7} \Omega \cdot m$). The shaft (3) is defined as a conductor. The value of the current is of 1000A.
Figure 2 presents the mesh corresponding to the geometrical structure.

Since the type of the current (a.c. or d.c.) does not influence the magnetic state of the bearing we have performed a magnetostatic analysis. The results, expressed as flux lines distribution (fig. 3) and flux density colour map (fig. 4), put in view the most exposed parts of the bearing. Obviously, the two rings represent the main pathways. As consequence, the maximum magnetic load corresponds to inner ring, slightly lower to outer ring and practically insignificant in the balls.

The values of the flux density, presented in figure 4, have only a symbolic meaning since they depend on the value of the current. As a matter of fact these values express mostly in a comparison way the load degree of the bearing parts.

### 2.2. Magnetic field and bearing with parallel axes

To analyse this case we have taken into account the geometric structure presented in figure 5. A coil with magnetic core, placed next to the bearing, produces the magnetic field. To amplify the effects of the magnetic field upon the bearing, two ferromagnetic plates realise a connection between them. The plates are made of OLC 35 with known magnetic curve. The presence of the plates does not modify the essence of the phenomenon. Practically they replace the real magnetic stray field in a more intense one.

This case required a magnetodynamic analysis and as consequence the elaboration of an equivalent electric circuit (fig. 6). Besides the two parts of the coils (B+ and B-) and the voltage source, the electric circuit contains six particular components representing the outer ring (two components in cross-section), the inner ring and the two balls. These electric components are capable to take into consideration the eddy currents and practically to give a hint about the thermal state of the bearing components.

Figure 7 presents the flux lines distribution. One can see that the bearing components, which are placed closer to the coil (magnetic field source), have a more important magnetic load.

In figure 8 the 3D picture shows clearly the differences and the non-uniform heating state, respectively.

Similar to the previous analysis, the magnetic field has a poor influence upon the balls.
Fig. 5 Geometrical structure and mesh

Fig. 6 Equivalent circuit.

Fig. 7 Flux lines distribution.

Fig. 8 Color density color map.
2.3. Magnetic field axis perpendicular to bearing axis

For this analysis we have used the geometrical structure presented in figure 9. The bearing is placed into a magnetic circuit with salient poles. The coils from the two legs create an alternating magnetic field. Figures 10, 11 and 12 shows the equivalent electric circuit, flux lines distribution and flux density colour map.
In this case the pathways of the flux lines include both rings and some of the rolling balls. It appears some areas where the flux density value is rather high in comparison with the rest of the bearing. As a matter of fact the points displayed in lighter colours has probably a supplementary heating. The confirmation is given by the current density map presented in figure 13 (2D view) and figure 14 (3D view). One can see clearly the appearance of important currents in bearing components, which for the first time affects the balls.

3. CONCLUSIONS

Definitely, the presence of the magnetic field has an influence on the bearing components that can
not be neglected. Mostly the effects consist in the appearance of eddy currents and consequently a supplementary and non-uniform heating.

REFERENCES