DESIGN AND ANALYSIS OF AN AUTOMOTIVE ALTERNATOR

The article deals with design of the heavy-duty claw-pole automotive alternator. This type of alternator should operate under unfriendly condition, e.g. in agricultural applications. Described development is supported by Ministry of Industry and Trade in frame of the project FI-IM4/194. Required parameters were evaluated and analytic design of magnetic circuit was performed in cooperation with Magneton a.s. Kroměříž company. A laboratory sample was also manufactured in this stage of the project solution. The 3D finite element method model was created simultaneously using the ANSYS program. The model was used to verify the magnetic flux density distribution and it will be used for optimization in following stage of the project.

1. INTRODUCTION

The alternator is a common equipment of the all today automobiles. Their are used not only on small cars but also in agricultural engineering, structural engineering, stationary generators, etc. They are produced in a variety of power and voltage levels and generally are always examined from many points of view, such as reliability, efficiency, dimensions, weight and costs. Special attention is paid to whole service life of alternator.

The method of analytic calculation of claw-pole alternator is based on common design method of synchronous machines with salient poles. However, magnetic circuit geometry is more complex due to claw-pole arrangement (Fig. 1, left) and the leakage flux calculation becomes especially complicated. There is not unique solution of alternator design and it is necessary to estimate some parameters entering to calculation. This estimation was based on experience with previous verified alternator constructions. Design procedure includes several steps shown in block diagram in Fig.1, right.

Designed alternator should attain following nominal parameters: voltage 14 V, current 42 A, speed 6000 rpm, min. speed for accumulator charging initiation 1300 rpm.

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2. FEM MODEL OF THE ALTERNATOR

The alternator design procedure described above should be considered as the initial solution only and therefore verification and optimization of magnetic circuit is advisable. The magnetic flux flows through the claw-poles and rotor yoke in z-direction (direction of alternator axis, Fig. 1, left) therefore the 2D FEM analysis is not sufficient and the magnetic saturation of each part of the magnetic circuit is necessary to verify by the 3D model. Cutaway view of the automotive alternator is shown in Fig. 2. The magnetic circuit geometric structure was built using Autodesk Inventor and it was imported to ANSYS environment (Fig. 2, right).

The mesh generation was the most time-consuming part of the model creation. Mesh layout and quality has significant influence to calculation accuracy. Unfortunately, the number of finite elements is limited by current computing power. Finite elements representation of the alternator magnetic circuit is shown in Fig. 3. There are three elements in radial direction between stator and rotor (in the air gap). The total number of elements is approximately 1.2 million.
Electromagnetic field of the alternator was solved using the general magnetic scalar potential strategy. The stationary field was excited by rotor coil. Calculation was performed for various values of excitation current. The obtained results correspond to 1 A of excitation current and the total magnetomotive force of 435 Ampere-turns. This lower value was chosen because the nominal excitation current 4.3 A causes oversaturation of magnetic circuit under no-load condition and then the critical parts of magnetic circuits are not clear visible.
The magnetic flux density distribution in the alternator core is presented in Fig. 4. The uniform level of magnetic saturation in the whole magnetic circuit is usually required, but it is seen that the magnetic flux density in the claw-poles roots is significantly higher in comparison with other magnetic circuit areas and components (Fig. 5). Improvement of claw-pole design is therefore advisable. On the other side, increasing the cross-section area of the claw-pole root causes reduction of exciting winding space. Optimization will be consequently performed in the next stage of project solution. The magnetic flux density in the air gap is shown in Fig. 5 (right). Visible teeth and claw-poles contact areas confirm the suitable mesh layout.
3. CONCLUSION

The analytic design method of the claw-pole alternator was developed in cooperation with Magneton a.s. Kroměříž company. The automotive alternator of nominal voltage 14 V and current 42 A was calculated and manufactured. The 3D FEM model was created and some results were discussed in previous chapter. The FEM model was used to verify the analytic design results and to check the saturation level of the alternator magnetic circuit. The claw-poles roots tend to be oversaturated and optimization of these areas is therefore advisable. Unfortunately, the measurements results are not available up to now and may not be compared with theoretical results. Modification of the alternator magnetic circuit based on prospective optimization results will be included in design of an alternator prototype which will be introduced in following stage of the project solution.

REFERENCES


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