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RESEARCH OF MAGNETIC FIELD OF AN AXIAL INDUCTOR MACHINE

MAGNĒTISKĀ LAUKA IZPĒTE AKSIĀLAJĀ INDUKTORMAŠĪNĀ

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Introduction

The calculations of electrical machines are based on the investigation results of their electromagnetic fields. When electrical machines are designed, the main task is the achievement of optimal distribution of a magnetic flux, which depends on the right choice of the parameters of the construction. Difficulties in calculations of fields in electro-technical devices increase with the extent to the complication of forms of the surfaces, separating environments with different qualities. The difficulties mentioned increase even more if non-linearity of the environment, which is reflected through the dependence of the parameters of the environment on the value characterizing the field (for example, magnetic permeability), is taken into account.

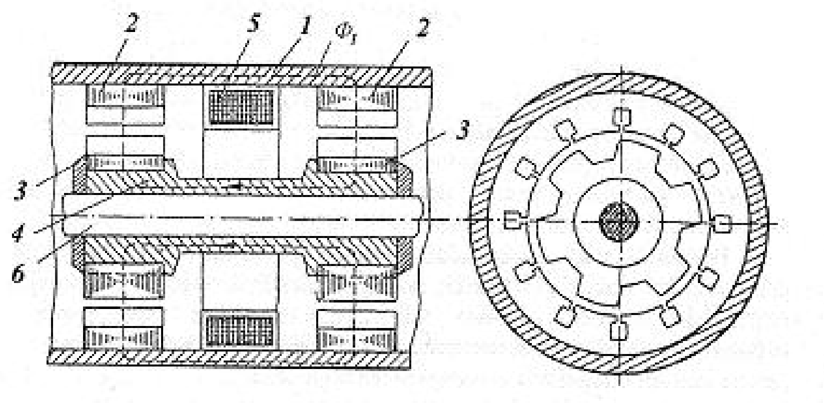

Figure 1. Two-packet axial inductor machine:
1 – body, 2 - armature packets with windings, 3 – rotor packets,
4 – rotor shell, 5 – excitation winding, 6 –shaft,
(Φ is a magnetic flux).

AIM owing simple constructions (Fig. 1) have an electro-magnetic system that principally differs from other synchronous machines and magnetic fields in them and preserves clearly three-dimensional character. However, with the help of some simplifications the solution can be reflected in two two-dimensional tasks: the field in an active zone (a core of the stator, a rotor and a main air gap) is flat parallel, but outside the boarders of the active zone (in an axial core) can be received as symmetrical to the axis. Complexity in modelling of a magnetic field in the active AIM zone is that it is necessary to model an absent source of the excitation field, as the coaxial excitation coil is situated in the space between the packets of the stator and the rotor [3].

The present work shows the results of the investigation of flat parallel magnetic field in a cross-section of the packets of the stator and the rotor. Sheets of electrotechnical steel of the stator and the rotor are presented as environment with non-linear characteristics of magnetization B=f(H).

Purpose function for the calculation of an optimal geometrical tooth zone of the inductor generator

In order to calculate the optimal geometry of the tooth zone we have developed a purpose function, which was gained by transformation of a number of equations.
Power the generator is defined in accordance with the following formula (1):

$$P = mk_U EI = mk_U k_I EI_K \quad (1)$$

where E is an electromotive force (E.M.F.);
m – number of phases;
k_U is the voltage coefficient;
$I = k_I I_K$ is load current, expressed with the help of short circuit current.
E.M.F. of two packets (2):

$$E = 2\frac{Z_1}{m}\sqrt{2}\pi w_K f k_W \frac{\Phi_{max} - \Phi_{min}}{2}, \quad (2)$$

where $f = \frac{Z_2 n}{60}$ is the current frequency;
n is rotational speed;
Z_1, Z_2 is the number of teeth of the stator and the rotor correspondingly;
Φ_{max}, Φ_{min} is maximal and minimal value of the magnetic stream, when the tooth of the stator is opposite the slot of the rotor;
w_K is the number of turns in the tooth coil;
k_w is winding coefficient.
Short circuit current can be defined by ratio (3):

$$I_K = \frac{E}{X_S}, \quad (3)$$

where $X_S = 2\frac{Z_1}{m} w_K{}^2 2\pi \frac{Z_2 n}{60} \times \frac{\Phi_{max} + \Phi_{min}}{2} \times \frac{2}{F_0}$ is synchronous resistance.
Substituting the expression (2) and (3) by (1), we get (4):

$$P = \frac{\pi}{120} k_U k_I k_w{}^2 Z_1 n Z_2 F_0 \frac{(\Phi_{max} - \Phi_{min})^2}{\Phi_{max} + \Phi_{min}} \quad (4)$$

Complex of parameters $\frac{\pi}{120} k_U k_I k_w{}^2 n = k$ is a const.
In the total we get function (5) for the calculation of optimal geometry of the tooth zone and mark it as C:

$$C = Z_1 Z_2 F_0 \frac{(\Phi_{max} - \Phi_{min})^2}{\Phi_{max} + \Phi_{min}} \quad (5)$$

Maximal C, in case the parameters of the tooth zone are changed, defines maximal value of the power of the generator [1].

Research results of purpose function for the axial inductor generator

The machine under consideration is produced at plant RER and is used as an under carriage generator. In order to receive the maximum value of a purpose function C some investigations concerning the change of the tooth zone geometry were performed, particularly variations in the number of teeth of the stator and the rotor as well as relation of the slot width of the rotor to the tooth width of the rotor. The calculations were made in the program “Quick Field”, this program allowed to perform modelling taking into account concentration of the magnetic circuit and real geometry of the tooth zone [4]. The results were gained for different ratio of the teeth number of the stator and the rotor, which were analysed with the help of a purpose function.
1.Than the number of teeth of the stator is a Z_1=24, modelling of the magnetic field was performed for the value of the teeth of the inductor Z_2=10;11;12;13;14,16,17 in case of ratio of the width of slot to the width of the tooth of the rotor γ=1,2;1,4;1,45;1,5;1,55;1,7 (Fig. 2).

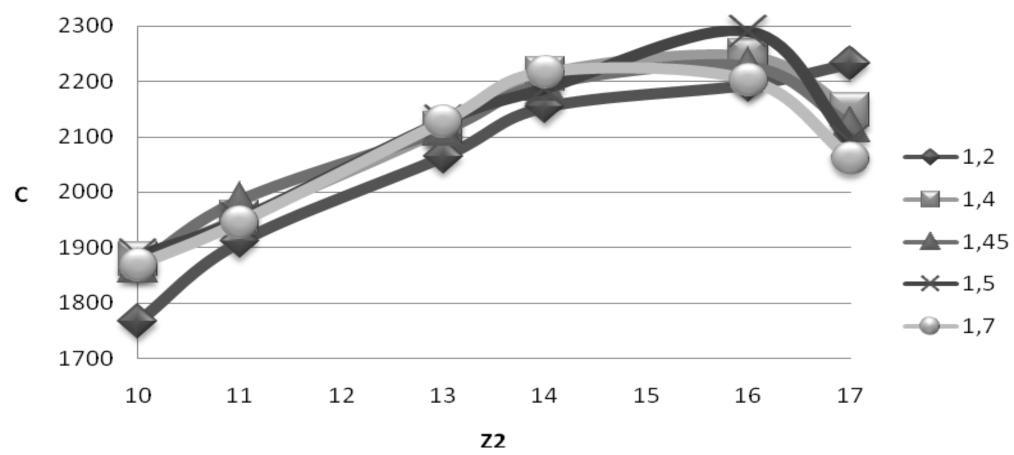

Figure 2. Curves of dependence C=f(Z_2) if γ=1,2;1,4;1,45;1,5;1,55;1,7 for Z_1=24

The graphic chart (Fig. 2) presents a curve of the dependence of the purpose function C on the number of teeth of the rotor in case there is a different relation of the slot width of the rotor to the tooth width of the rotor (γ). Maximal value of the purpose function is present if there are 16 teeth on the rotor. This structure of the tooth zone (Z_1=24, Z_2=16) corresponds to the three-phase inductor machines with the number of teeth for the pole and the phase - q=Z/2pm=0,25. The inductor machine with such tooth zone has a significant distortion of phase voltage and fluctuations of the moment due to significant pulsation of longitudinal magnetic flux density. The optimal variant is a machine with 14 teeth on the rotor and γ=1,55, that allows to increase C for 15-20% in comparison with the basic sample of the generator (Z_1=24, Z_2=10, γ=1,45).

2. If Z_1=36, there were performed some calculations for the number of teeth of the rotor equal to Z_2=19;21;22;23;25;26, at the same time an optimal ratio of the slot width to the teeth width (γ) was selected for every separate case (Fig. 3).

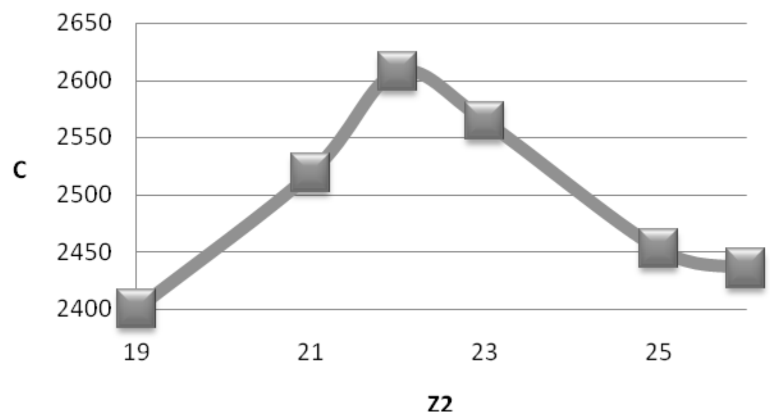

Figure 3. Curves of dependence C=f(Z_2) for Z_1=36

The analysis of the curve (Fig. 3) of dependence of the purpose function C on the number of the teeth of the rotor shows that the maximal index is reached if there are 22 teeth on the rotor and γ=1,8, that allows to increase the value of C for 35-40%.

3. A number of proportions was calculated for 48 teeth, in case Z_2=29;30;31;33;34 (Fig. 4).

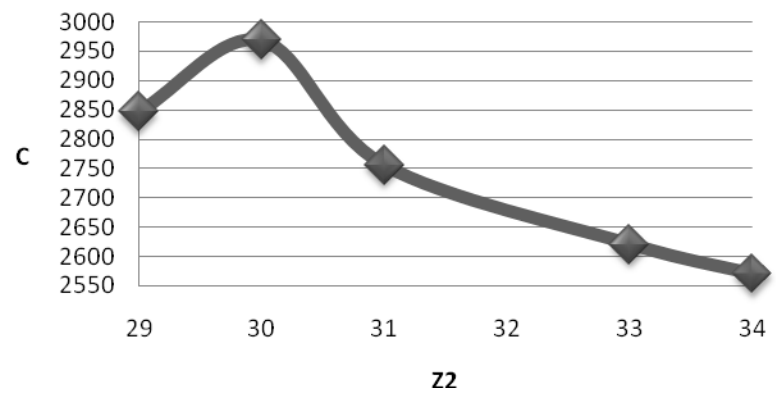

Figure 4. Curves of dependence C=f(Z_2) for Z_1=48

The graphic chart presents (Fig. 4) the dependence showing that the optimum is reached in case Z_2=30 and proportion of the slot width to the teeth width of the inductor is equal to γ=1,65. The present geometry of the inductor generator shows the value of maximal purpose function which is bigger for 55-60% than the basic sample of the generator (Z_1=24, Z_2=10, γ=1,45).

Conclusion

The present work deals with the investigation of magnetic field of an axial inductor machine taking into account real geometry of the tooth zone and saturation of the magnetic circuit. The results of the modelling of a magnetic field with different geometry of the tooth zone gained allowed to increase specific power rating for 55-60%, which is a good basis for further investigations of inductor machines as well as the solution of issues of optimisation of magnetic circuit parameters.

Acknowledgement

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Orlova S., Pugačevs V., Ļevins N. Bezsmertnijs A. Magnētiskā lauka izpēte aksiālajā induktormašīnā

Šajā darbā veikta aksiālās induktormašīnas (AIM) izpēte un optimizācija. Aplūkotajai mašīnai ir vienkārša konstrukcija un augsta drošuma pakāpe, jo tai nav rotējošo tinumu un slīdošu kontaktu. AIM ir populāras kā ģeneratori vēja enerģētiskajās ierīcēs, kā arī vilcienu, kuģu un lidmašīnu elektroapgādes sistēmās. Elektrisko mašīnu aprēķini balstās uz to magnētisko lauku pētījumu rezultātiem. Projektējot elektriskās mašīnas, galvenais uzdevums ir sasniegt optimālu magnētiskās plūsmas sadali, kas pamatā ir atkarīga no pareizas konstrukcijas parametru izvēles. Grūtības aprēķināt lauku elektrotehniskajās ierīcēs palielinās atkarībā no virsmu, kas atdala vides ar dažādām īpašībām, formas sarežģītības. Šīs grūtības vēl vairāk pieaug, ja ir jāņem vērā vides nelineārums, kas parādās atkarībā no vides parametru lielumiem, kuri raksturo lauku (piemēram, magnētiskās caurlaidības). Magnētiskā lauka modelēšanas sarežģītību AIM aktīvajā zonā rada tas, ka ir jāmodelē ierosmes lauka avots, jo koaksiālā ierosmes spole atrodas telpā starp statora un rotora paketēm. Darbā sniegti magnētiskā lauka modelēšanas rezultāti dažādu rotora un statora zobu skaita attiecību gadījumā, ņemot vērā reālo ģeometriju un magnētiskās ķēdes piesātinājumu, izmantojot programmu kompleksu "Quick Field".

Orlova S., Pugachov V., Levin N. Bezsmertnij A. Research of magnetic field of an axial inductor machine

The present work is devoted to research and optimization of an axial inductor machines (AIM). The present machines have simple construction and high degree of reliability, owing to the absence of rotating windings and sliding contacts. As a result of that, the advantages of AIM are: their popularity as generators in wind-driven power plants, in the systems of electrical supply of trains, planes and ships. Theory of electric machines is based on the research of magnetic fields by analytical methods in an air gap of the machine, but for the present times there are some rough assumptions: magnetic field in the gap is flat-parallel; the surface of an armature is smooth and flat, magnetic permeability of steel is unchanged. Simple constructions AIM have an electrical magnetic system that is absolutely different from other synchronous machines and their magnetic field has expressively three-dimensional character. However, with the help of some simplifications, the solution can be reduced to two two-dimensional tasks: field in the active zone (the core of the stator, rotor and the main air gap) is flat parallel, but outside the boarders of the active zone can be received as axis symmetrical. The complexity of modeling of magnetic field in the active zone of AIM lies in the necessity of modeling an absent source of excitation field, as the coaxial excitation coil is situated in the space between sets of the stator or the rotor. The work presents the results of modeling of magnetic field in the tooth zone of an axial inductor machine for a different number of teeth of the stator or of the rotor with the account of real geometry and concentration of the magnetic circuit by using "Quick Field" program.

Орлова С., Пугачёв В., Левин Н. Безсмертный А. Исследование магнитного поля в аксиальной индукторной машине

В данной работе проведено исследование и оптимизация аксиальной индукторной машины (АИМ). Рассматриваемая машина имеет простую конструкцию и высокую степень надёжности, из-за отсутствия вращающихся обмоток и скользящих контактов. Благодаря этому АИМ популярны в качестве генераторов в ветроэнергетических установках, а также в системах электроснабжения поездов, кораблей и самолётов. Расчёты электрических машин опираются на результаты исследований их электромагнитных полей. Проектируя электрические машины, основным заданием является достичь оптимального распределения магнитного потока, что в основном зависит от правильного выбора параметров конструкции. Трудности расчёта поля в электротехнических устройствах увеличиваются по мере усложнения формы поверхностей, отделяющих среды с различными свойствами. Эти трудности возрастают в ещё большей степени при необходимости учёта нелинейности сред, проявляющейся в зависимости параметров сред от величин, характеризующих поле (например, магнитной проницаемости). Сложность моделирования магнитного поля в активной зоне АИМ, заключается в том, что необходимо моделировать отсутствующий источник поля возбуждения, так как коаксиальная катушка возбуждения, расположена в пространстве между пакетами статора или ротора. В работе представлены результаты моделирования магнитного поля при различном соотношении чисел зубцов ротора и статора, с учётом реальной геометрии и насыщения магнитной цепи, используя комплекс программ "Quick Field".