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Block-Module Electric Machines of Alternating Current

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Abstract. The paper deals with electric machines having active zone based on uniform elements. It presents data on disk-type asynchronous electric motors with short-circuited rotors, where active elements are made by integrated technique that forms modular elements. Photolithography, spraying, stamping of windings, pressing of core and combined methods are utilized as the basic technological approaches of production. The constructions and features of operation for new electric machine – compatible electric machines-transformers are considered. Induction motors are intended for operation in hermetic plants with extreme conditions surrounding gas, steam-to-gas and liquid environment at a high temperature (to several hundred of degrees).

1. Introduction

Flat disk asynchronous electric motors with short-circuit rotor are manufactured in some countries and occupy a certain niche for many mechanisms. Small axial dimensions, open active slot-tooth area offers solutions for design problems of integrating motors without use of any intermediate mechanisms, as well as afford implementation of advanced technologies for making windings and magnetic cores [1-4]. They include: printed wiring and photolithography, vacuum sputtering, stamping of windings, pressing of core etc. that allows to avoid coiling operations from making winding. This is of special importance for microminiature motors [5, 6]. The author of the paper has patented some of constructive and technological solutions [3, 7, 8] described below.

High-speed (8000 rpm) disk induction motors can serve one of examples of embedding a three-high bloomer construction small-section rolling mill (figure 1).

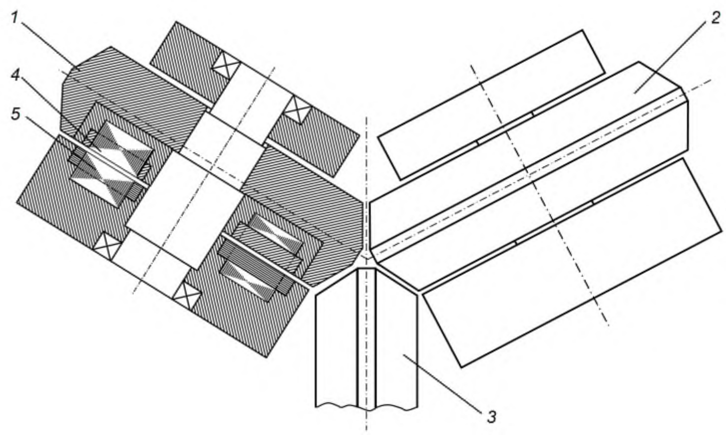

Figure 1. The construction arrangement of a three-high bloomer with embedded disk induction motors. ***1***, ***2*** – auxiliary rolls with embedded rotors; ***3*** – basic roll, rotated by the basic power electric motor; ***4*** – disk rotor with a short-circuited winding; ***5*** – disk stator with a stamped-welded winding.

Such solution gives 1.5-2 times increase in roll speed and, at the same time, reduces the dimensions of the stand.

In addition, the motor is cooled by the technological water in the rolling mill, what increases of current density in the windings [6].

2. General dimensions of modular block motors and induction distribution

Properties of disk motors substantially depends on the relation outer (D_{out}) and inner (D_{in}) diameters of active parts: $a = D_{out}/D_{in}$.

The diameters equation is:

$$(D_{out}+D_{in})^2(D_{out}-D_{in}) = V_A,$$

where

$$V_a = \frac{48{,}8P'10^5}{\alpha_\delta k_f k_{W1} AB_\delta n_1},\ \mathrm{m}^3$$

– active volume of machine, defined from machine constant by initial data and electromagnetic loads; P' means electromagnetic power; AB_δ – electromagnetic loads; n_1 – rotation frequency; α_δ – coefficient of the pole zone; k_f – factor of form of induction curve; k_{W1} – winding factor.

In view of relationship between outer and inner diameter, equation becomes:

$$(aD_{out}+D_{in})^2(aD_{out}-D_{in}) = V_A.$$

This expression defines of inner diameter D_{in} – dependence for given initial data and electromagnetic loads:

$$D_{in} = \sqrt[3]{\frac{1}{(a+1)^2(a-1)}}\sqrt[3]{V_a} = k_{in}\sqrt[3]{V_a}.$$

Dependencies of outer D_{out} and inner diameters values, as well as of active length and are expressed as:

$$D_{out} = \sqrt[3]{\frac{1}{(a+1)^2(a-1)}}\sqrt[3]{V_a} = k_{out}\sqrt[3]{V_a};$$

$$D_{mid} = 0{,}5\sqrt[3]{\frac{(a+1)}{(a-1)}}\sqrt[3]{V_a} = k_{mid}\sqrt[3]{V_a};$$

$$l_d = 0{,}5\sqrt[3]{\left(\frac{a-1}{a+1}\right)^2}\sqrt{V_a} = k_l\sqrt[3]{V_a},$$

where k_{out}, k_{mid} and k_l are respectively, coefficients of outer and inner diameters, and of active length.

Electromagnetic moment that accounts for uneven distribution of induction $B_\delta(R)$ along the radius R:

$$M = C_M\int_{R_{in}}^{R_{out}} B_\delta(R)RdR = C_M R_{mid} l_0 \left(B_{\delta mid} + B'_\delta\right),$$

where R means a current radius, C_M means a proportionality coefficient, R_{mid} – a middle radius, l_0 – an active length, $B_{\delta mid}$ – an induction at the middle diameter, and B'_δ – an additional induction that may be both positive and negative.

The distribution of magnetic induction in a working gap along the active length may be obtained under the calculation block diagram (figure 2) by method of successive approximations, that breaks the active length into n_Δ sections (n_Δ = 5÷10) of $l_{\Delta\delta}$ width and calculation of induction $B_{\delta i}$, average a for each section from its middle radius R_{mid}:

$$k'_\mu(R) = \mu_0 F_\Sigma / B_\delta(R) k_\delta(R) 2\delta.$$

In the process, certain values of $B'_\delta(R)$ are preset and calculations made until the $k_\mu(R)$ and $k'_\mu(R)$ values agree with intended degree of accuracy:

$$\left(k_\mu(R) - k'_\mu(R)\right) / k_\mu(R) < \varepsilon = 0{,}01.$$

Magnetomotive forces of magnetic circuit (F_Σ = const) is obtained at the middle radius R_{mid} (within the limits of section $l_{\Delta\delta}$) by the value B_δ.

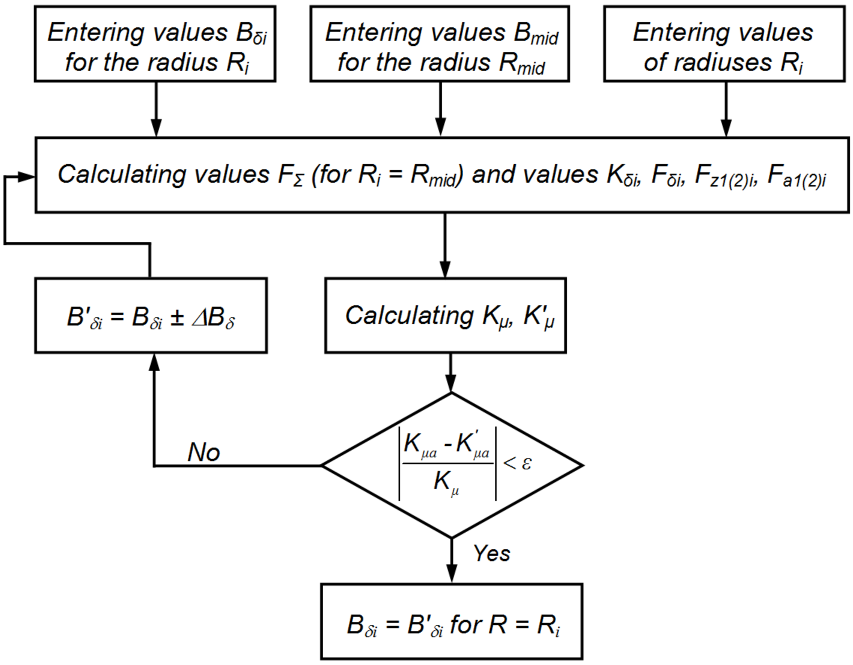

Figure 2. The calculation scheme for induction distribution $B_\delta(R)$ in working gap.

3. Compatible electric machines-transformers

As the compatible construction: the electric machine -transformer it is possible to examine three probable options:

– cylinder-type electric machine (motor or generator) and transformer;
– end (disc) machines (motor and generator);
– mixed: cylinder-type transformer – disc motor.

In every option, the transformer converts the AC voltage and number of phases.

For the first option, electric machines and transformers can be based on serial produced machines either in single-body or two-body modification that provides for standard manufacturing.

Block-module execution of combined electric motors-transformers allows to solve following problems:

– to reduce voltage on electric motor to 1÷2 Volt and practically to remove grooving insulation and electric conductor insulation;

– to raise electric and thermal loads, to increase fill factor of groove stator winding to unit and, thereby, to lower mass and overall dimensions of electric motors.

This option seems to be the best for the electric motor operating in extreme environment. In all known constructions of hermetic motors made for corrosive environment the stator is placed outside the object (environment) and has a sealed wall (screen) that segregates it from the rotor. This increases the gap between the stator and the rotor and reduces energy indicators.

The report offers block-module execution of the combined electric motors-transformers [5-9] which allow to exclude these negative factors.

When the primary distributed three-phase winding of the transformer ***1*** with *p* couples of poles gets supply from a three-phase circuit of *f* frequency, the rotary magnetic fields appears. When the secondary *Z*-phase winding of transformer (*Z* means the number of windings) crosses bars ***4***, magnetic fields induces *Z*- phase electromotive force with the same amount of poles 2*p*. Sealed lead-in rods ***7*** and arc-shaped elements ***10*** provide an electrical connection between the winding and the *nZ*-phase bar winding of the stator; the former passes the currents and creates a step curve of magnetomotive forces (MMF) (figure 4) with less component of higher harmonics for the electric motor.

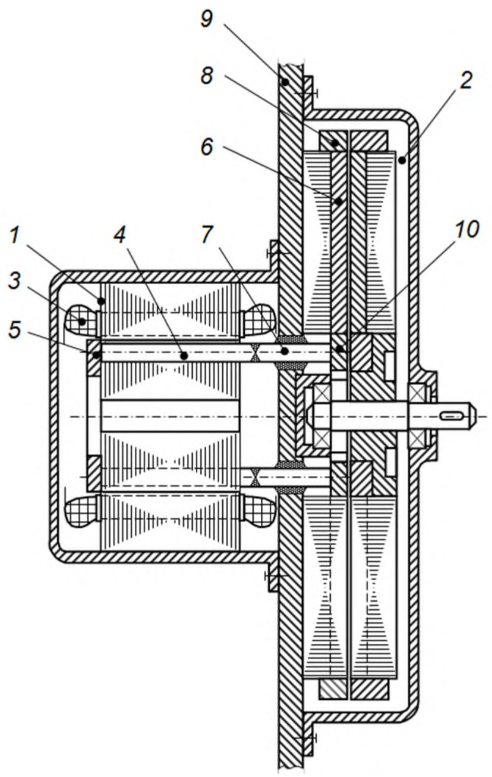

Figure 3. Longitudinal section of the electric machine
1 – cylindrical three-phase transformer with a rotating magnetic field; ***2*** – disk electric motor; ***3*** – primary winding of a transformer; ***4*** – multiphase (z-phase) bar winding; ***5*** – short circuit ring; ***6*** – rod stator winding; ***7*** – sealed lead-in rods; ***8*** – short circuit ring; ***9*** – leakproof partition; ***10*** – arched conductive segments.

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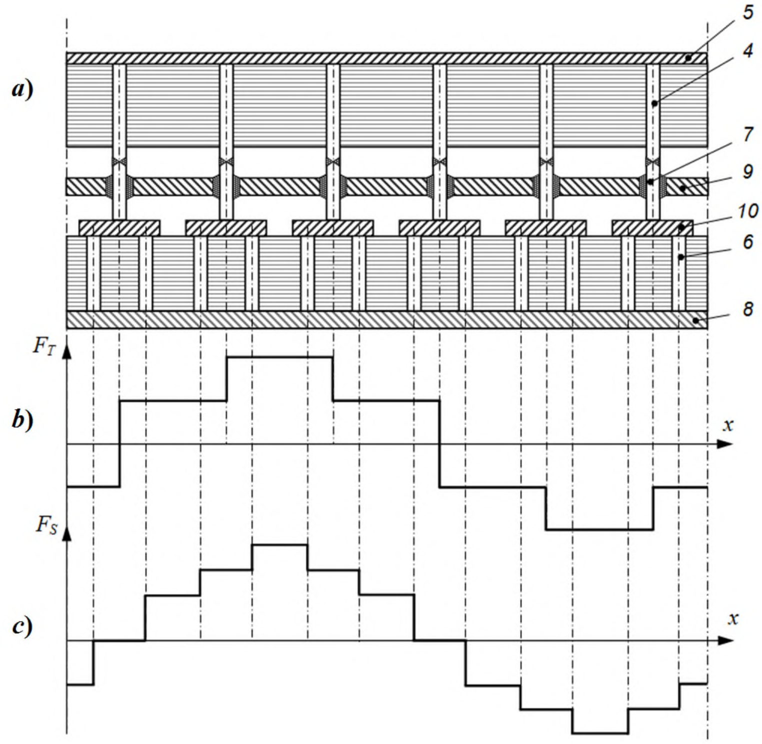

Figure 4. Scanning active surfaces of transformer and stator from outside of rods (***a***): distribution magnetomotive forces (MMF) F_T of transformer (***b***) and MMF *Fs* of electric motor (***c***) on effective diameter.

4. Conclusion

The designs and features of operation for new disk induction motors of block-module type are a part of motors-transformer aggregates for extreme condition environments are considered.

The new patented constructive decisions, allowing to raise technical and economic indicators compatible electric machines-transformers at the expense of *n*-multiple division of rod windings in a motor part of aggregate are offered;

Manufacturing of a disk rotor is offered with double-sided stator with Z/2 the radial grooves, shifted on half beard division and is mutual-cut with cores hexagonal section.

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