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Method of qualitative impregnation of electric motor windings

***Abstract**. The reliability of electric motors depends on the insulation of the windings, which is determined by the quality of the materials used and the correct impregnation of the windings. Impregnation of the stator winding is an important technological process to increase the quality and longevity of electric motors. As a result of impregnation, air pores between windings and spaces in fiber insulation are filled with impregnating composition, which ensures reliable operation of the engine. There are various methods to ensure that pores and voids are well filled. The article provides general information about varnishes used for impregnating windings of electric motors according to their composition. The article shows the scheme of rotating the stator and absorbing it by moving it with the camera. The proposed method implementation mechanism is also given. As a result of the change in the direction of the force vectors affecting the absorbent constituent element with our proposed method, the pores between the coils and the spaces of fibrous insulation are better filled.*

Streszczenie.** Niezawodność silników elektrycznych zależy od izolacji uzwojeń, o której decyduje jakość zastosowanych materiałów i prawidłowa impregnacja uzwojeń. Impregnacja uzwojenia stojana jest ważnym procesem technologicznym zwiększającym jakość i żywotność silników elektrycznych. W wyniku impregnacji pory powietrzne pomiędzy uzwojeniami oraz przestrzenie w izolacji włókien wypełniają się kompozycją impregnującą, co zapewnia niezawodną pracę silnika. Istnieją różne metody zapewnienia dobrego wypełnienia porów i pustych przestrzeni. W artykule przedstawiono ogólne informacje na temat lakierów stosowanych do impregnacji uzwojeń silników elektrycznych ze względu na ich skład. W artykule przedstawiono schemat obracania stojana i pochłaniania go poprzez przesuwanie go za pomocą kamery. Podano także proponowany mechanizm realizacji metody. W wyniku zmiany kierunku wektorów sił działających na element składowy chłonnego zaproponowaną przez nas metodą następuje lepsze wypełnienie porów pomiędzy zwojami i przestrzeniami izolacji włóknistej. (**Metoda jakościowej impregnacji uzwojeń silników elektrycznych)

Keywords: electric motor, stator winding, impregnation method, impregnation lacquer, fiber insulation, electric strength, heat resist
Słowa kluczowe: silnik elektryczny, uzwojenie stojana, metoda impregnacji, lakier impregnacyjny, izolacja włókien,

1.Introduction

Impregnation of windings of electric motors greatly increases the reliability of these machines. As a result of soaking and drying, the following properties of electrical insulation are improved:

- Heat resistance increases;
- As a result of the reduction of the air gap between the wires and the walls of the stator wedge, the thermal conductivity of the coils increases;
- As a result of the filling of the pores and the formation of the varnish film, the insulation, especially the fibrous insulation, increases its moisture resistance due to the decrease in its hygroscopicity.
- As a result of the electric strength of the impregnating materials being greater than the electrical strength of the air between the fibers of the impregnated materials, the electrical strength of these materials increases;
- The mechanical strength of the insulation increases, because in this case the impregnated winding has well "cemented" windings that are tightly and firmly located in the stator wedges. For this reason, the displacement of the wires due to vibration and the related damage to the insulation by friction is prevented.

After drying, the outer surfaces of the windings are painted with coating enamels and varnishes. The resulting hard and smooth film 50-60 μm thick protects the insulation well from moisture, lubricating oils and dust accumulation.

The above-mentioned properties depend on the impregnating varnishes. According to their composition, varnishes applied to impregnate windings of electric motors are divided into three groups:

1. Oil-based varnishes - These varnishes are used for impregnating windings of electric motors with heat resistance classes A, B and E. The most commonly used oil-based absorbent is bitumen varnish. It should be taken into account that oil-based varnishes take a long time to dry (360 minutes at 1050 ^{0}C and 1100 ^{0}C).

2. Synthetic varnishes (based on polymers of artificial origin) - these varnishes do not have the above mentioned defects. In addition, they have high cementing properties and good hardening quality in thick layers. Synthetic varnishes are very diverse, they differ in operational characteristics and areas of application. Synthetic oils are the absolute majority in impregnation of windings of electric motors.

3. Natural varnishes (based on resins of natural origin) – These varnishes are rarely used. Practice shows that when using these varnishes, the same operating properties are obtained, their price is cheap.

It is known that there are various methods of impregnation of stator windings of electric machines [1-6]. During impregnation with one of these methods, an impregnating composition is inserted into one of the forehead parts of the uterus under the influence of mechanical forces.

Impingement is achieved by applying mechanical forces to the impregnating composition and rotating the stator, but in this case the stator is positioned so that its longitudinal axis and the axis of rotation form an angle other than 900 with each other. This allows to increase the force applied to the impregnating composition and to reduce the impregnation time. In this case, the quality of impregnation improves. However, when impregnation is carried out by this method, the impregnation component cannot enter the intestinal pores well, and the quality of the impregnation is relatively low [7].

Another well-known method of impregnation is performed by rotating the stator on one of the front parts of the coil, moving it up and down under the influence of mechanical forces. This method improves the quality of impregnation by better penetration of the impregnating agent into the pores of the pulp during impregnation.

Despite this, it is not possible to obtain high-quality impregnation of deeper layers of wound dressings. In order to further improve the quality of the winding, by placing the winding stator in the chamber and giving the winding composition to one of the front parts of the winding, it is necessary to ensure the rotation of the chamber around the axis perpendicular to the axis of the stator, and to ensure the additional rotation of this system around the second axis passing outside the chamber and perpendicular to the axis of the stator [8-12].

2. Materials and methods

Along with the effect of mechanical forces introduced into one of the faces of the stator winding, generated by rotating the stator, moving it up and down, at the same time, the forces generated by the circumferential rotation of the stator chamber around the other axis also act, which causes the gaps of the stator winding. it leads to complete filling and further improvement of the impregnation quality. Fig. 1 schematically shows the winding absorption during the rotation of the stator and, in addition, its displacement with the cam, and Fig. 2 schematically shows the directions of the forces (F_1 and F_2) acting on the absorbent fluid element in the gaps of the stator windings [13-16].

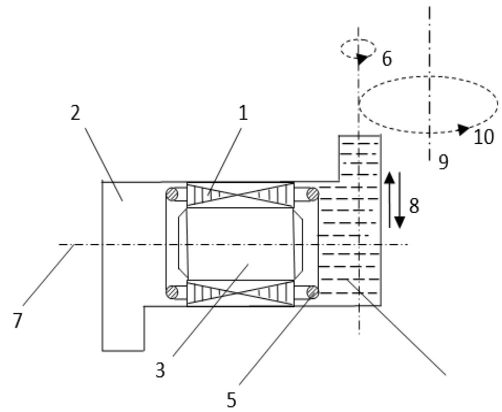

Fig. 1. Rotation of the stator and absorption by moving it along with the cam

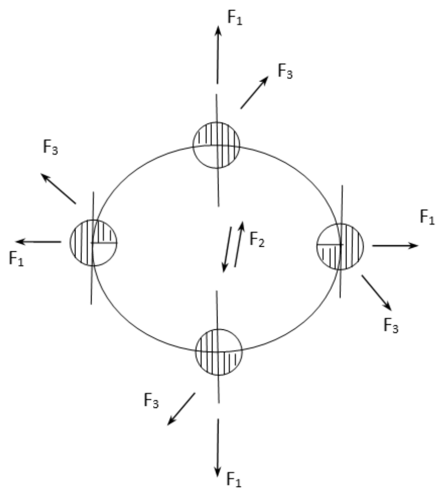

Fig. 2. The directions of the forces acting on the absorbent fluid element in the spaces of the windings of the stator

Figure 3 shows the directions of the third force (F_3) acting on the liquid absorbent element as a result of the rotation of the stator axis itself.

Figure 4 shows the implementation mechanism of the indicated method.

The method of winding the stator winding of an electric machine is performed as follows:

The wound stator 1 is placed in the chamber 2. The surface of the hole intended for the rotor is closed with plug 3. The chamber is filled with absorbent material 4. The absorbent material 4 is delivered to the front part of the ring 5 under the influence of mechanical forces. These forces act on the component during its rotation around the axis 6 perpendicular to the longitudinal axis 7 of the stator 1 together with the stator and pass outside the stator. At the same time, together with the stator, the chamber 2 moves up and down 8 along the perpendicular axis 6 (Fig. 1). Then, in order to improve the quality of absorption, the stator 1, which is absorbed in several chambers, is placed symmetrically on the disk 10, which can be rotated by the engine 9 (Fig. 4). The symmetrical placement of several stators 1 on the disc 10 both stabilizes the balance and increases productivity [17-21].

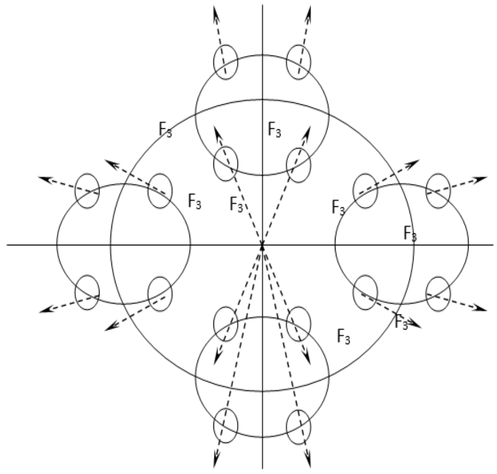

Fig. 3. Directions of the force (F_3) acting on the liquid absorbent element as a result of the rotation of the stator axis

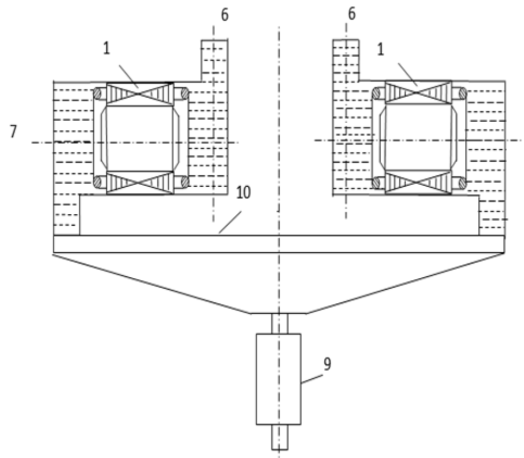

Fig. 4. Implementation mechanism of the proposed method

The stator 1 rotates around the perpendicular axis 6 and moves vertically (up-down) along this axis. In this case, the absorbent composition is affected by 4 known forces F_1 and F_2 (Fig. 2).

When the chamber 2, in which the stator is located, rotates around the second axis 11 - the axis of the disk, which passes outside the chamber and is perpendicular to the axis 7 of the stator, a force F_3 acting on the absorbent composition 4 (Fig. 3) is generated, which causes the absorbent composition 4 to better fill the pores of the stator 1 loop and thus , allows to increase the quality of impregnation.

Thus, the chamber 2 placed on the stator 1 is simultaneously subjected to three types of movement:

- the chamber 2 in which the stator 1 is located rotates around the axis 6 perpendicular to the stator axis 7;
- the chamber 1 together with the stator 2 moves up and down 8 along the perpendicular axis 6;

- the chamber 2 located with the stator 1 rotates on a circle 12 around the axis 11 of the disc, the second axis 7 passing outside the chamber and perpendicular to the stator axis 7.

Figure 2 schematically shows the directions of the forces affecting the absorbent material 4 in the gaps of the stator windings. F_1 is the vertical centrifugal force acting on the fluid, F_2 is the vertical force acting on the fluid. The F_3 force acts on the fluid element in the bladder cavity, moving it in every direction [22-25].

When the system is affected only by F_1 and F_2 forces, the absorbent content cannot fully penetrate into the deep layers of the windings. This is not enough to obtain the required quality of impregnation. In addition to the stator 1 chamber 2, as a result of the effect of the F_3 force, the absorbing composition 4 ensures that the outer parts of the windings also enter the deeper layers. As a result, liquid voids are completely filled and the quality of impregnation improves.

Figure 3 shows the third force F_3 affecting the absorbent material as a result of the rotation of the perpendicular axis 6 of the stator, in addition to the above-mentioned forces F_1 and F_2. From Figure 3, it can be seen that the direction of the force F_3 changes 3600 and causes the stator to absorb well.

True, the force F_1 also changes by 3600 (Fig. 1), but in this case, since the stator rotates around an axis, the absorption is not complete (Fig. 3).

In the proposed method, the stator already rotates around two axes: both the axis perpendicular to its axis (Fig. 1, axis 6) and the axis 6 itself rotates around the defined axis (Fig. 1, axis 11) [26-28].

3. Conclusion

Compared to other impregnation methods, the advantage of our proposed method is that during impregnation, the forces acting on the impregnating composition change in all directions and lead to the complete filling of the spaces of the stator loop, thus further improving the quality of impregnation. The improvement of the quality of the hopper leads to the increase of the quality and longevity of the electric motors. In conclusion, the method offers a promising solution to improve the reliability and performance of electric motors by enhancing the quality of insulation impregnation. Further research and practical implementation of this method could lead to advancements in electric motor design and manufacturing processes.

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