Energy Saving Electric Winding Machine

Aleksandr Litvinenko, Evgeniy Evtushenko and Denis Baranov

ABSTRACT

Modern electrical engineering is impossible to imagine without transformers, electromagnetic relays and solenoids. The base of this device is an electric coil. Quality of this component depends on the uniformity of winding and compliance with the limits of deformation of the wire. Winding machines are used to create electrical coils on an industrial scale. Their improvement is a priority. Advanced precision devices require high-quality winding of thin wires.

INTRODUCTION

Modern electrical engineering is impossible to imagine without transformers, electromagnetic relays and solenoids. The base of this device is an electric coil. Quality of this component depends on the uniformity of winding and compliance with the limits of deformation of the wire. Winding machines are used to create electrical coils on an industrial scale. Their improvement is a priority. Advanced precision devices require high-quality winding of thin wires.

PROCESS DESCRIPTION

The operation of the machine for winding coils occurs by starting an electric motor that the intermediate shaft rotates. On the belt shaft, there is a friction clutch, which performs the clutch. The clutch begins its work after turning the lever into the plug. This method of starting gives you the opportunity to start work and turn off the machine, without jolts. Next, the gear pair begins to rotate the spindle with the frame.

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The winding machine starts to wind the wire onto the coil. The basis of any winding machine is a coil-wire-frame technological system. This system includes the following elements: 1) the margin of wires required for winding an electric coil; 2) tension control mechanism; 3) Wire motion devices 4) winding devices 5) receiving frame. Figure 1 shows the winding machine model [1].

MODEL DESCRIPTION

Model winding machine consists of: 1 - coil; 2 - cylinder limiter; 3 - the guide roller; 5, 6, 7 - guide rollers; 4, 8, 10 - asynchronous motors; 9 - wire feeder.
The electric winding machine works as follows, the wire winding from the coil 1, passes through the cylinder limiter 2, which protects the rotating loop of the wire. The guide roller 3 provides the movement of the wire at a right angle. The guide rollers 5, 8, 9 determine the trajectory of the wire. The tension of the wire is provided by rollers 4,8,10 mounted on the shaft of induction motors.

![Figure 1. Model of the winding machine](image)

ENGINE PARAMETERS

Tables I, II, III show Engine parameters.
TABLE I. CHARACTERISTICS OF THE ENGINE TENSION DEVICE DID-5TV.

<table>
<thead>
<tr>
<th>engine's type</th>
<th>Maximum shaft power, Wt.</th>
<th>Starting torque, g cm, not less</th>
<th>Starting currents, mA, not more</th>
<th>Idle speed, rpm, not less</th>
</tr>
</thead>
<tbody>
<tr>
<td>DID-5TV</td>
<td>5.0</td>
<td>220</td>
<td>1200</td>
<td>530</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>excitation</td>
<td>control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Power

<table>
<thead>
<tr>
<th>Power supply, V</th>
<th>frequency Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the excitation circuit</td>
<td>In the control circuit</td>
</tr>
<tr>
<td>36±2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>400±8</td>
</tr>
</tbody>
</table>

TABLE II. CHARACTERISTICS OF THE MOTOR WINDING UNIT AIR-63-0.37 KW.

<table>
<thead>
<tr>
<th>engine's type</th>
<th>Power, kw</th>
<th>Synchronous frequency rotation, rpm</th>
<th>Nominal current, A</th>
<th>Nominal twisting moment, kgm</th>
<th>Efficien cy %</th>
<th>Cos φ</th>
<th>Slip %</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR63B4</td>
<td>0.37</td>
<td>1500</td>
<td>1.37</td>
<td>0.26</td>
<td>68.0</td>
<td>0.70</td>
<td>8.7</td>
</tr>
</tbody>
</table>

TABLE III. CHARACTERISTICS OF THE ENGINE LAYOUT UNIT.

<table>
<thead>
<tr>
<th>engine's type</th>
<th>Angle step, hail</th>
<th>Current phase SM, A</th>
<th>Torque, kg x cm</th>
<th>Inductance / phase, mH</th>
<th>Resistance / Phase, Ohm</th>
<th>The moment of inertia of the rotor, g x cm^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL86ST H80-5504</td>
<td>1.8</td>
<td>5.5</td>
<td>46</td>
<td>4</td>
<td>0.46</td>
<td>1400</td>
</tr>
</tbody>
</table>

WIRE TENSION STABILIZATION

One of the dominant problems is a high reject rate – 50%. This is due to inaccurate control of the stretching of the thin wire during winding. This leads to frequent wire breaks.

The article aims to reduce the percentage of reject and energy costs in the manufacture.

To this end, a mathematic model of the electric winding machine was built in the Mathcad program.
The system is set up for a given tension statically before the machine is started by breaking the wire with a roller 4 with a certain force, which in this case can be determined from the expression [2]

$$T_{st} = T_0 + 2p f_3$$  \hspace{1cm} (1)

With the static setting of the machine, we can approximately assume that the tension of the driven wire branch $T_0 = 0$; from here

$$p = \frac{T_{st}}{2 \cdot f_3}$$  \hspace{1cm} (2)

Let us determine the change in the magnitude of the tension along the entire length of the moving wire and the actual tension with which the winding winds up. To do this, we determine successively the tension of the wire at each section of the schematized technological system. [3]

Section 1. It is known from theory that with the axial winding of wires with a fixed coil in the ballooning part of the passing values at the top of the balloon and can be calculated by the formula

$$T_1 = T_c + \frac{1}{2} m \cdot \omega^2 \cdot R_{max} \cdot \sin^2 (\omega_h \cdot H_c)$$  \hspace{1cm} (3)

The angular velocity of ballooning wire is

$$\omega = \frac{1000 \cdot v_r}{60 \cdot R_k}$$  \hspace{1cm} (4)

The linear mass of the ballooning wire is equal to [3]

$$m = \frac{10 \cdot P}{g \cdot L_\theta}$$  \hspace{1cm} (5)

Substituting the formula, we get

$$m = \frac{\pi \cdot d_M^2 \cdot \gamma}{400 \cdot g}$$  \hspace{1cm} (6)

Determine the value of sine [4]
\[
\sin(\omega_0 \cdot H_c) = \sin\left(\frac{\pi}{H} \cdot H_c\right)
\]  

Substituting the obtained values into the equation, we determine the tension at the top of the cylinder:

\[
T_1 = T_c + \frac{1}{2} \cdot m \cdot \omega^2 \cdot R_{\text{max}}^2 \cdot \sin^2(\omega_0 \cdot H_c)
\]

Section 2. In this section, the wire passes the guide roller 2. By neglecting the rotational movement of the wire and considering only its longitudinal movement, the tension of the leading branch of this section can be determined from the equation

\[
T_2 = T_1 e^{f \varphi_1} + f_1 \cdot m_1 \cdot v_r^2 \cdot \varphi_1
\]

Section 3. In this area with sufficient accuracy can be considered (without taking into account the longitudinal and transverse oscillations of the wire) that the tension is kept constant until roller 3 [5].

Section 4. The tension of the leading branch of the wire is determined from the expression

\[
T_3 = T_2 \cdot e^{f_2 \varphi_2}
\]

Section 5. Tension is kept constant until the wire contacts the tension roller 4. Section 6. The tension of the leading branch will be determined from the expression

\[
T_4 = T_3 + 2 \cdot f_3 \cdot p
\]

Similarly, we will perform the calculation of the remaining sections.

**EXPERIMENTAL RESULTS**

As can be seen from figures 3, 4 - stabilization of the tension allows reducing the tension of the wire by three times. This reduces the power consumption of the machine and increases its productivity. These results were tested experimentally on a real electric drive of a model winding machine (SNP-0.1-150V “Pulsar”), which reduced the reject rate by two times.
CONCLUSION

As can be seen from figures 3, 4 - stabilization of the tension allows reducing the tension of the wire by three times. This reduces the power consumption of the machine and increases its productivity. These results were tested experimentally on a real electric drive of a model winding machine (SNP-0.1-150V “Pulsar”), which reduced the reject rate by two times.
REFERENCES


