Determining of the structural schemes and performance of linear DC motor control system for welding equipment development in the layered tapes production

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Abstract
The process of restoration when frayed surface of machine details covering with layer of required thickness with predefined properties that obtained by creation of multilayer tapes for deposition and allows to effectively solve the problem of prolongation of service life of machine details is widely used in repair and recovery works.

Key words: MULTILAYERED TAPES, ELECTROCONTACT MICROWELDING, LINEAR DIRECT CURRENT MOTOR

In conditions of modern production the problem of the development of resource-saving technologies of repair and restoration of machine parts subjected to heavy wear and premature failure, which greatly affects the life of the machines, their performance and the quality of their work is relevant.

Machine control system for the production of multi-layer tape should monitor and control the multiple parameters simultaneously (Fig 1) [1, 6-11]: rotational speed of a welded part; speed of welded tape supply; application force of roller electrode to the workpiece; duration and value of the welding current impulse; value and polarity of the voltage supplied to the fixed coil 6; value and duration of the current pulse of the forward trace reel for the electrode 9; value and duration of the current pulse of the reverse trace reel for the electrode 8.

Let's consider the work of clamping mechanism of proposed machine of contact micro surfacing. Under the voltage supply of corresponded polarity simultaneously on the coils 6 and 9 there is a loading of roller electrode to welded tape. A loading occurs within a short period of time equal to the time for the welding current pulse. Further, from the forward stroke coil 9, the voltage is removed, and on the coil 6 the voltage polarity is changed. Simultaneously, a voltage is supplied to the coil of reverse trace 8 and the roller electrode moves away from the workpiece. This cycle continues with a frequency of 6 ... 7 points on 1 cm of welded tape. Based on the requirements for the welding machine a design of the linear DC motor with a cylindrical inductor and anchor without slots was developed. The structure is shown in Fig.2. The studied design of anchor without slots although increases the air gap between the movable and stationary parts of the engine, however, has many advantages: "smooth" anchor is lighter and, consequently, a smaller moment of inertia and a lower value of inductance, which reduces the time constant of the control circuit. One of the most important characteristics of a developing motor driving force is determined from the following expression [2]:

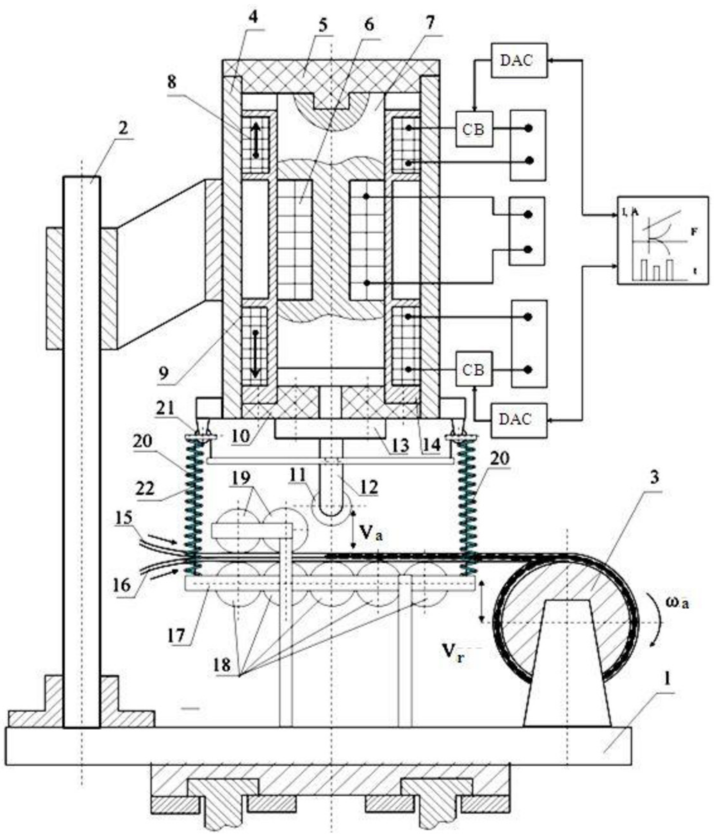

Figure 1. The scheme of equipment for multilayer tape manufacturing

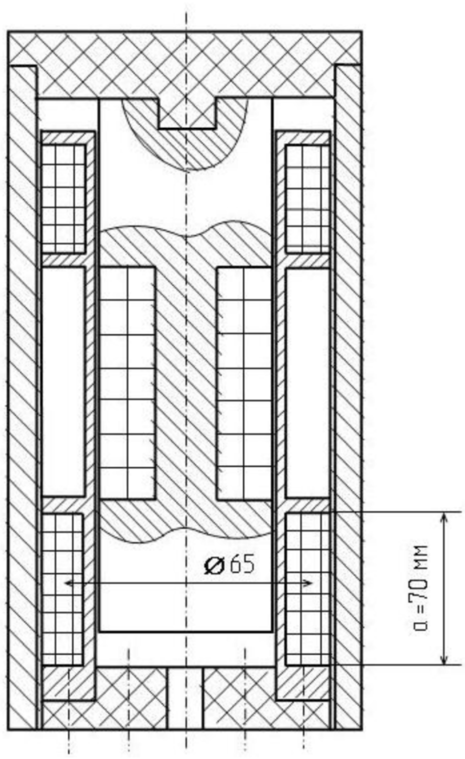

Figure 2. Construction of the linear DC motor

$$P_p = B_\delta l_{av} I_p = 1,2 \cdot 0,204 \cdot 630 = 154,4H, \quad (1)$$

where P_p – pulling capacity on one pole, N; B_δ – induction in the air gap (under pole), Tl; l_{av} – the average length of coil winding of the movable part (anchor), m; I_p – total current of the anchor winding, A (the turns that are in the zone of one pole influence):

$$I_p = I_\beta N_p = 1,2 \cdot 525 = 630A, \quad (2)$$

where I_a =1.2 A – a current of a conductor of the anchor winding; N_p = 525 – number of turns of the anchor winding in the zone of one pole influence.

To obtain the necessary drawing force, as well as to calculate the magnetizing force of winding the activations are set by the value of the inductions in the air gap B_δ, which is taken within 0.8 ... 1.2 Tesla. Significant increase of drawing gives the application to engine design in which the anchor winding is external to the activation winding (due to the fact that l_{av} is increased), as Figure 2 shows. Calculation of active resistances and inductances is shown in relation to the size of the given design of the engine [3].

Active resistances of the anchor winding. The length of the wire of anchor winding:

$$l_{aw} = \pi \cdot D_{a\,av} \cdot N_a, \quad (3)$$

where $D_{a\,av}$ – the average diameter of the anchor winding; N_a – the total number of turns of the anchor winding; for the given construction the number of turns N_a=630 copper wire of PETV-2 type and diameter 0,2 mm:

$$l_{aw} = \pi \cdot 0,075 \cdot 630 = 148\text{m}. \quad (4)$$

Wire resistance of anchor winding:

$$R_a = l_{aw} \cdot r_{sp}, \quad (5)$$

where r_{sp} – resistance 100 m of wire of selected section at temperature t = 15°C.

$$R_a = 148 \cdot 0,08 = 11,88\ \Omega. \quad (6)$$

The resistance of the anchor winding wire by heating to 80 ° C:

$$R_a' = R_a \cdot k_{heat}, \quad (7)$$

where k_{heat} – factor considering increase in resistance when heated;

$$R_a' = 11,88 \cdot 1,3 = 15,44\ \Omega. \quad (8)$$

The minimum voltage for anchor supply:

$$U_{a\,\min} = I_a \cdot R_a^{/} = 1,2 \cdot 15,44 = 18,53 \approx 19\ \text{V}. \quad (9)$$

Supply voltage considering forcing transients:

$$U_{a\,\max} = (2..2,5) \cdot U_{a\,\min} = 47,5\ \text{V}. \quad (10)$$

Range of anchor voltage at motor control:

$$U_a = 19..47,5\ \text{V}. \quad (11)$$

The inductance of the anchor winding. Anchor winding is a cylindrical coil with the height = 70 mm. The diameter of the middle turn of the anchor winding $D_{a\,av}$ = 65 mm. According to [4], the inductance of this coil:

$$L_a = \frac{\mu_0}{4\pi} N_a^2 \frac{D_{a\,av}^2}{a} K_\alpha, \quad (12)$$

where μ_0 – permeability of free space (air gap), μ_0 = 4π·10^{-7} H/m; K_α – factor considering the design of the coil, in accordance with [5] for the ratio $a/D_{a\,av}$ = 1,077; $\frac{1}{\alpha}$ = 0,929, k_{op} = 6.46.

The inductance of the anchor winding:

$$L_a = \frac{4\pi \cdot 10^{-7}}{4\pi} \cdot 630^2 \cdot \frac{0,065^2}{0,07} \cdot 6,46 = 1,01 \cdot 10^{-3}\ \text{H}. \quad (13)$$

Active resistance and inductance of the field winding are similarly calculated [5]. We will carry out the equation of mechanical characteristics of a linear motor. The equation for the equilibrium of the electric motor:

$$U_a = E_a + I_a R_a. \quad (14)$$

Anchor pressure:

$$E_a = B_\delta \cdot l_{av} \cdot N_a \cdot V_a, \quad (15)$$

where V_a – the linear speed of the anchor shift:

$$V_a = \frac{U_a - I_a R_a}{B_\delta \cdot l_{av} \cdot N_a}. \quad (16)$$

The ratio for the motor pulling capacity:

$$P_m = B_\delta I_a l_{av} N_a \Rightarrow I_a = \frac{P_m}{B_\delta l_{av} N_a}; \quad (17)$$

Taking into consideration the latter:

$$V_a = \frac{U_a}{B_\delta l_{av} N_a} - \frac{P_m R_a}{B_\delta^2 l_{av}^2 N_a^2}. \quad (18)$$

By analogy with an electric motor of DC rotating the following notations can be introduced:

$$K_l = B_\delta l_{av} N_a = \frac{\Phi \cdot \left(\pi D_{a\,av} \cdot N_a\right)}{S_\delta}, \quad (19)$$

where F – The magnetic flux volume in the pole; S_δ – sectional area of the air gap under the pole.

Finally, the equation of mechanical characteristics:

$$V_a = \frac{U_a}{K_l} - \frac{P_m R_a}{K_l K_\alpha}. \quad (20)$$

The resulted equation of mechanical characteristics can be used not only for the calculation of the equation of a linear motor, but also for research and development of its mathematical model.

Application of a DC motor, performing the function of the roller electrode clamp and shift allows you to upgrade the welding machine construction for the production of multi-layer metal strip used in electro contact reconstructive surfacing of worn surfaces of parts such as fittings and shafts, which provides high quality of coating material with the possibility of varying the physical and mechanical properties of the final coating in a wide range maintaining the sufficient strength of the coating material adhesion and adhesion of subsequently, weld surface layer of a part according to operating conditions and requirements of the product.

Conclusion

There are examples of calculation inductances and resistances of the motor windings used to determine the structural schemes and performance of its system of control. There is the equation of the mechanical characteristics of the linear motor, which can be used for developing the control system, and in the study of its mathematical model.

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