

THE CONSTRUCTIVE ELEMENT CALCULUS OF THE 'IN CASING , CONTINUOUS CURRENT ELECTROMAGNET'S COIL

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Abstract. This paper include the thoertical considerations, the stage of constructive element calculus of the 'in casing' countinuos current electromagnet's coil and discussion concerning the factors that influence the working of these equipments. This paper is based on concret case studyes t5hat was meeted in repair operation of 'in casing 'electromagnet in ELECTOROSERVICE s.r.l. Bacau, for equipements used to elevate and transport. This paper is useful to the engineers who design, use and repair thus ecquipements.

Keywords. Electromagnet, continuous current, elevation ecquipement, coil.

1. THEORETICAL CONSIDERATIONS

The electromagnet is an temporary magnet that attract or release an ferromagnetic element if, in excitation circuit, an current is present. Like basisi constructive elements, the electromagnet have a coil, that is placed on a ferromagnetic core, formed by a fixe armature and a mobile armature. When the excitation current pass through the coil, the mobile armature is moved by active forces or torques. The value of current is establish by the voltage supply and the excitation coil resistance. The static electromechanical characteristics establish the relation between active force F_a , initially an finally, and values of working gap clearance δ ; that can take values between initial value δ_i and final value δ_f . When the electromagnet work, by the decreasing of gap clearance values, the working point is moveing on the working characteristic to the section coresponding to the feromagnetic core saturation section; the iron range reluctances increase and limit the useful flux value Φ_δ . In thisconditions, the real static electromechanic characteristic is situate under theoretic characteristic (figure 1). The electromagnetic specific woeking in continuous current is the variation in large limits of the active force, the F_{af}/F_{ai} ratio touching from 10 to 15 values.

The 'in casing' electromagnet is characterised by a small displacement of mobile armature (in case study, the armature role is taken by the piece that is elevated or transported) and a big attraction force; the electromagnetic circuit are a very short size and the poles areas is big.

As previussely shown, the gap clearance value is established for active force value of electromagnet, that is the attraction force of electromagnet. In theoretic force computation, the mobile armature is considered homogene and uniiform, therefore the initially and finally gap clearance values is considered like distance between polar peces surfaces and mobil armature surface.

In application, this values is valable only in case that the electromagnet elevate or transport a piece with perfect plane surface without interruption – like a iron sheet. In practice, the electromagnet is used to elevate and transport many pieces simultaneously (many sheet or slab lilets). In this case the distances between pieces must be considered like a gap clearance; in this zone, the useful magnetic flux decrease and implicitly the active force value.

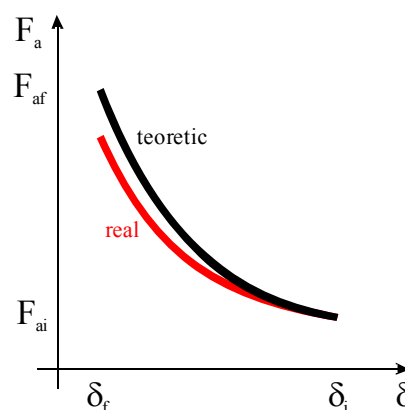


Figure 1

In electric equipments there are forms of energy which transform themselves in heat when electric current passes, like that: Joule Lentz, loss in magnetic circuits through turbionari currents and through phenomena of histerezis, loss in insulation and electric arc. In electromagnets, high temperatures appear when electric current passes, in the volume of coil with ferromagnetic middle. These transformations of energy into heat lead to the directly proportional growth of the coil's resistance and implicitly to that diminution of the active force of electromagnet's attraction.

For the study of thermal solicitations for these coils there are considered the following simplifying hypothesis: there is considered the coil with homogeneous (homogene) body middle under thermal aspect and there are considered the average value for the global thermal transmissivity α_t , at the surface of temperature giving up. The calculus relation of average temperature in this case is:

$$\theta_{\text{med}} = \frac{RI^2}{\alpha_t S} \quad (1)$$

where: R – is the coil's resistance at the work temperature;

I – is the current intensity that crosses the coil:

α_t – is the global thermal transmissivity;

S – is the surface of heat giving up.

The coil's resistance is calculated with the relation:

$$R = \rho \frac{l_c}{S_c} \quad (2)$$

where: ρ – is the rezistivity at the work temperature;

l_c – is the conductor's length;

S_c – is the surface of the conductor's section.

It's very clearly that the heating depends directly proportional on the conductor which is used at the coil's manufacturing (also as a material as in section) and on the coil's dimensions (occupied volume, average length of the coil and number of whirls). Also, the coil's heating leads, through direct transfer, to the heating of the ferromagnetic miez. It's known that the heating of the miez leads to the diminution of the active force attraction.

In the specific case of the electromagnet in continuous current 'in casing' type SGP, used in siderurgical industry, the designer found some constructive solutions and applied it, that lead to the diminution of heating effects like this: first of all, the casing has adequate thickness for rapid dispare of heat and a free space inside, between the coil and the exterior walls of the electromagnet, space that allows in air cooling; the application of an asbestos layer between the coil and middle; and the last but not least a plate of refractory steel Mn (different structure than the electromagnet's walls) joined through soldering in the inferior side of the electromagnet, letting free only the polar surfaces of contact. This plate has more than one rolls: it allows heat dissipation from miez, it rapidly demagnetize miezul after electric current is turned off and it protects the coil from casual strokes and impurities.

2. CALCULUS METHOD

The main relation used in the preliminary calculus is

$$F = \frac{B^2 \cdot A}{2\mu_0} \quad (3)$$

in which: B is the magnetic induction [Wb/m²] or [T];

A is the surface of polar piece [m²];

μ_0 is the magnetic constant $4\pi \cdot 10^{-7}$ [H/m]

The selection of the value of induction B is made depending on the constant ce of the electromagnet. From the relation of force results that the linear dimension of the area (the diameter of a circular section for example) is

proportional with the square root of the force. On the other hand, if the interfeerul δ is big, also the length l of the electromagnet's coil increase, being this may be necessary a higher solenation.

As a result, the linear dimension of the cross section of iron and the coil's length determines the consumption of active material of the electromagnet. In [1] the constant of the electromagnet has the following expression:

$$c_e = \frac{\sqrt{F}}{\delta} \quad (4)$$

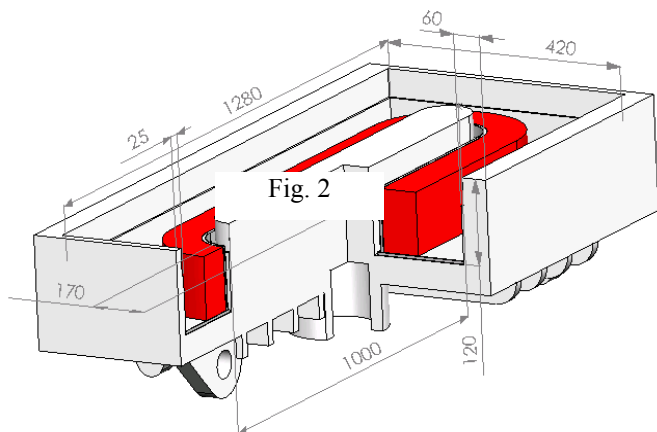
and has as measure unit $[N^{1/2}/m]$ in case of 'in casing' electromagnet with fixed armature, the C_e value is 29000. Normally, for electromagnet calculus there are necessary following initially data: minimum force (for maximum gap clearance), maximum force (for minimum gap clearance), maximum gap clearance, supply voltage, relative connecting time, winding heating, environment temperature and the magnetic core material. In practice, especially in case of electromagnet repair, there are not known all this initially data. The electromagnet repair, generally consists in complete reconstruction of induction coil and is necessary a correct admeasurement of active material volume to maintain the functional parameters of electromagnet and for a economic efficiency of repair.

Starting by a concret case, shall be presented a calculus for some initially data.

2.1. Design data

In figure 2 is presented a 'in casing' continuous current electromagnet, SGP type, used in siderurgical industry, to elevate or transport the semi-finished laminate. The user demande is to make a complete reconstruction of electromagnet winding with copper conductor.

The known design data are: power 3.5KW, voltage supply 110V continuous current, the polare pieces surface is 0,3566m², the core dimensions: 0,17x1m, the useful in internal dimensions are 1,28x0,42x0,12m; the maximum transported pieces weight is 10000kg, the relative connection time is 1200s. Starting with this initially data, it must be established an calculus algorithm for coil constructive elements.



2.2. The design algorithm for coil constructive elements

2.2.1. Necessary force

The most important parameter that must be calculated is the maximum force. This can be deduced by the gravity force expression multiplied by a coefficient established by the technic prescription of ISCIR:

$$F_{\max} = (m \cdot g) \cdot 1,6 = 156.906 \text{ N} \quad (5)$$

2.2.2. The minimum gap clearance corresponding to maximum force

The minimum gap clearance corresponding to maximum attraction force of electromagnet is computed from electromagnet constant relation (eq. 4) using the maximum force value from eq. 5.:

$$\delta_{\min} = \frac{\sqrt{F_{\max}}}{c_e} = 0,0137 \text{ m} \quad (6)$$

2.2.3. The maximum induction value:

The maximum induction value is obtained from relation (3) where the force is maximum force value:

$$B = \sqrt{\frac{F_{\max} \cdot 2\mu_0}{A}} = 1,0513 \text{ T} \quad (7)$$

2.2.4. The solenation

The solenation calculus is based on magnetic circuit law:

$$NI = \frac{B}{\mu_0} \delta_{\min} + \sum_{i=1}^n H_i l_i = 16.333 \text{ A} \quad (8)$$

where $\sum_{i=1}^n H_i l_i \approx 0,3NI$

2.2.5. The coil rezistivity

This step is very important because the rezistivity is computed like a function by temperature and thermal conductivity coefficient. The work temoperture is choosen like a insulated class function, in this case, for F class, the temperature is 155°C, and the resistivity, from 20°C is obtained from dedicated tables, depending on winding material, copper in this case.

$$\rho = \rho_{20}(1 + \alpha_t \theta_T) = 2,89 \cdot 10^{-8} \Omega \text{m} \quad (9)$$

2.2.6. The conductor diameter

The conductor diameter is obtained from excitation voltage relation, where L_m is coiling average size, like a function by the internal dimension is computed:

$$L_m = \frac{(L_{\text{miez}} \cdot l_{\text{miez}}) + (L_{\text{int}} \cdot l_{\text{int}})}{2} = 2,63 \text{ m} \quad (10)$$

$$d = \sqrt{\frac{4\rho \cdot L_m \cdot NI}{U \cdot \pi}} = 3,792 \cdot 10^{-3} \text{ m} \quad (11)$$

2.2.7. The coiling number

The coiling number is computed using the power relation in continuos current:

$$N = \frac{NI \cdot U}{P} = 513 \text{ spire} \quad (12)$$

2.2.8. The current intensity

The current intensity is computed with

$$I = \frac{P}{U} = 31,8182 \text{ A} \quad (13)$$

2.2.9. The coil rezitence

The coil rezistence is computed with following relation:

$$R = \rho \frac{l}{S} = \frac{\rho \cdot 4 \cdot L_m \cdot N}{\pi \cdot d^2} = 3,4571 \Omega \quad (14)$$

It can be verified with:

$$R = \frac{U}{I} = 3,4571 \Omega \quad (15)$$

2.2.10. The current density

The current density in connection period is necessary to explain some phenomena that can appear in electromagnet function:

$$J = \frac{4 \cdot I}{\pi \cdot d^2} = 2,8189 \cdot 10^6 \text{ A / m}^2 \quad (16)$$

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