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Automated System of Design and Calculation of Linear Electromagnet without the Stop (part 2)*

Hovhannisyan A.T., Grigoryan A.Kh., Yenoqyan K.R., Babayan A.N., Khachatryan V.H.
National Polytechnic University of Armenia
Yerevan, Armenia
andranik.hovhannisyan@yandex.ru, Grigoryan@seua.am, karine.yenokyan@mail.ru, artbab95@mail.com, vaharpa@mail.ru

Abstract. **The developed system of automatic design allows to calculate, design and optimize the parameters of a linear electromagnet without a stop with an external magnetic circuit or without it with any armature (cylinder, ball, etc.) with an estimate of the magnetization of the armature. The system works in a dialogue regime and the results are represented in the forms of numerical values.**

Keywords: **automat system, calculate, project, linear electromagnet, winding, magnetic wire, anchor, interactive mode, optimization.**

Introduction

This work is the continuation of the article “System of design calculation of linear electromagnet without the stop (part 1)” [1], hence th eletter notations and their physical meanings will not be discussed here.

The program package of automated development system of the LEWS was designed by the programming language C#, where the program interface consists of a window,on the left side of which the preliminary starting data is imported, and the existense of the external magnetic wire is noted, and on the right side the values that need to be chosen are defined, and the limiting values are recorded. On the botton of the window the main preliminary results are exported into one line.

During the work the developer has the opportunity to participate in the process of calculation and design choosing the values that belong to a certain interval. He\She also checks the impact of the parameters’ values on the calculated parameters of the LEWS and makes corresponding decisions. Thus, the developer directly impacts the final results of the calculations depending on their professional knowledge and experience, and during the design process gets the opportunity to “speak” with the computer, during the calculations to compare and analyze values and, if needed, upgrade the calculating parameters.

During the automated design of the LEWS the following problems are being solved according to the preliminary starting data [2].

1. Deciding the dimensions of the electromagnet’s CW;
2. Determining the value of the calculated F_c MMF;
3. Determining the induction value of the magnetic field created by the CW in a specific point of b_a of the CW’s X axis.

In case of having an external magnetic wire K_B dimension of its impact on the induction value of the magnetic field according to the K_w coefficient of the CW’s window is calculated by the following expression

$$K_B = 0{,}137\cdot10^{-4}\cdot K_w{}^4 - 0{,}992\cdot10^{-3}\cdot K_w{}^3 + 2{,}515\cdot10^{-2}\cdot K_w{}^2 - 0{,}261\cdot K_w + 2{,}264. \quad (1)$$

4. Determining the electromagnetic dragging force. In this process the value of the anchor’s demagnetization coefficient N, the value of which depends on the λ coefficient of the form of magnet’s part is decided by the following expression [2]:

- if $\lambda>1$

$$N = \frac{\frac{\lambda}{\sqrt{\lambda^2-1}}ln\left(\lambda+\sqrt{\lambda^2-1}\right)-1}{\lambda^2-1}, \quad (2)$$

if $\lambda<1$

$$N = \frac{1-\frac{\lambda}{\sqrt{1-\lambda^2}}arcos\lambda}{1-\lambda^2}, \quad (3)$$

if $\lambda=1$

$$N=0{,}333.$$

The calculating value of the electromagnetic dragging P_c force is checked, which should not be less than the preliminary starting P_e value, and the relative mistake should not exceed the allowed value of ε_1.

5. Detremining the main parameters of the CW.
6. Determining the working F_w MMF of the CW.

The working F_w MMF of the CW is checked, so that it’s not less than F_h, and the relative mistake doesn’t exceed the value of ε_2.

7. Determining the active power and the calculating θ_{ov} overheating of the CW.

The value of the θ_c is checked, so that it doesn’t exceed the allowed value of θ_{ov}.

8. Determining the parameters of the external magnetic wire and the Q_c weight of the copper in the CW.

In automat design system-ADS, all the mentioned problems are solved with a mutual agreement and, if needed, with the chance of further adjustments of the values.

The controlled parameters in the process of calculating and designing the LEWS may be the K_w coefficient of the CW window, the ℓ_w length of the winding or the d_c diameter of the copper wire.

P_e, F_w and θ_c are the controlled values, the adjusted values of which compared with the starting data must not exceed the limiting relative ε_1 and ε_2 values, and θ_c should not exceed the overheating θ_{ov} value of the winding.

Targeted functions expressing the efficiency standards can be P_w power of the CW, Q_c weight of the copper, etc.

Thus, the problem of the calculations, design and adjustments of the LEWS is formulated in the following way: such a change in the values of the K_w coefficient, ℓ_w or d_c, that the targeted function or functions expressing the efficiency standards of the electromagnet can satisfy the requirements, such that Q_c and P_w are minimized.

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The mathematical model of the problem of calculation and adjustments of LEWS looks like the following

$$\bar{X} = (\ell_w, K_w, d_c),$$

$$0 \le P_c(\bar{X}) - P_e(\bar{X}) / P_e(\bar{X}) \le \varepsilon_1,$$

$$0 \le F_w(\bar{X}) - F_c(\bar{X}) / F(\bar{X}) \le \varepsilon_2,$$

$$\theta_c \le \theta_{ov} \qquad (4)$$

$$Q_c(\bar{X}) \to min,$$

$$P_w(\bar{X}) \to min.$$

The block scheme of ADS is in the Fig. 1.

Lets briefly describe the work of the ADS. When launching the file “Linear elecromagnet”.exe a window appears on the computer screen, on the top left of which, in the section “Imported data” the starting data is imported (Fig. 2). Some indexes of the values in the Fig. 2 are in Armenian.

In the section “Elective values” the developer specifies values from intervals of the following parameters. Those parameters are n=1...10, k_s=1,1…2,5, k_w=1…30, k_f=0,3...0,6, Δ_f=0,5…1mm, Δ_a=0,5...1mm, limiting values ε_1=0,05, ε_2=0,15.

After pressing “Calculate” button the calculated output values of parameters are exported in one line in exit section. If any of the conditions are not met an additional window(missing in the Fig. 2) will show the reasons of the problem, according to which the developer does the needed changes of the parameters in the “Elective values” section.

The developer has the chance to chnage the values of the parameters on a given range in the section “Elective values” and simultaneously follow the chnages of the parameters of LEWS. Due to such method the developer can get design options of the electromagnet in a short time.

For adjustments in the section “Elective values” the developer enters new values, for instance for ℓ_w or d_c in corresponding window, and for adjusting K_w the value is changed in the K_w window. Then pressing the button “Calculate” shows the calculated results of the new version. The developer has the chance to compare, analyze the results and draw corresponding conclusion.

The designing process ends by pressing “Close” button on the right bottom of the window.

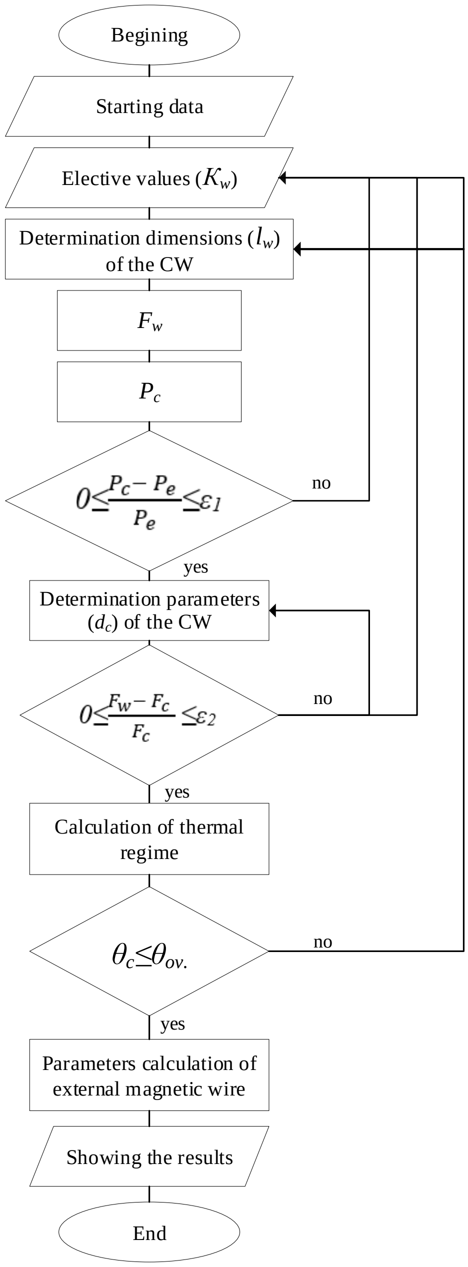

Fig. 1. Block-scheme of ADS

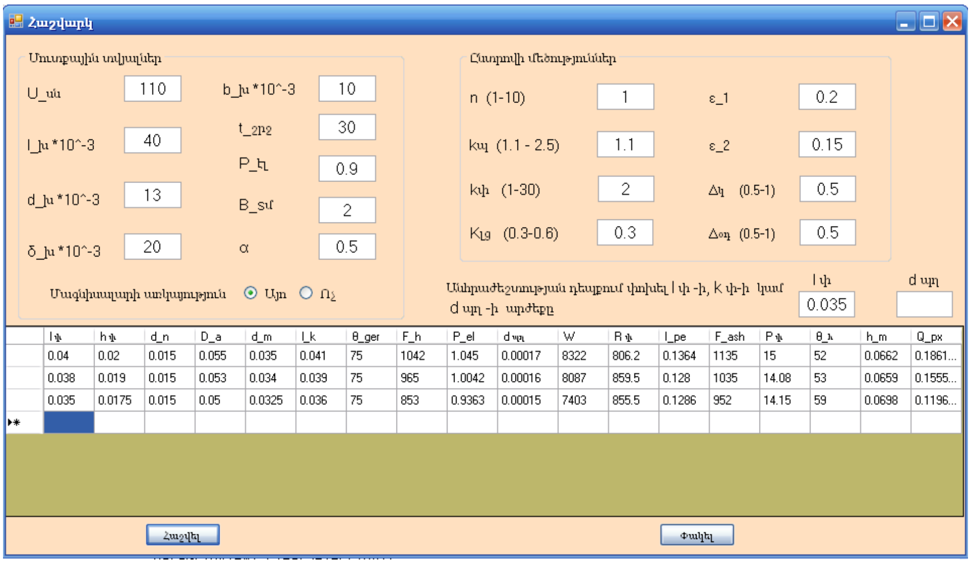

Fig. 2. The window of the ADS of LEWS

THE RESULTS OF THE RESEARCH

Numeric values of the main preliminary data for the calculations and design of the LEWS were d_a=13*mm*, δ_a=20*mm*, b_a=10*mm*, U_n=110*V*, P_e=0,9*N*, t_w=30^o*C*, α=0,5, with presence of the working magnetic wire, B_{Sm}=2*Tl*. The elective values had the following values K_w=2, Δ_a=0,5*mm*, Δ_f=0,5*mm*, *n*=1, k_s=1,1, and limitations were ε_1=0,05, ε_2=0,15.

As a result of the calculations we get the following output data ℓ_w=40mm, h_w=20*mm*, d_i=15*mm*, D_{ov}=55*mm*, d_a=35*mm*, ℓ_c=41*mm*, θ_{ov}=75^0*C*, F_c=1042*A*, P_e=1,045*N*, d_c=0,17*mm*, *w*=8322, R_w=806,2*Ohm*, I_w=0,136*A*, F_w=1135*A*, P_w=15*Vatt*, θ_c =52^0*C*, Q_c=0,186 *kg*, h_m=0,066*mm*.

These results became base for the further versions.

The following problems were analyzed using automat design system.

The problems of adjusting the calculating parameters of LEWS were formulated the following way:

1. Provide such a value for d_c diameter of CW's wire that it is a variable with discrete value and $Q_{c\ c}$ and P_w are minimized.
2. Provide such a value for ℓ_w length of CW that Q_c and P_w are minimized.

For the both problems the output main, elective, and limiting data were unchanged.

In the first problem, according to the standard increase and decrease of the value of d_c in case of elected values, the calculation was not done because the condition ε_2 was not satisfied.

In the second problem, decreasing ℓ_w had a positive result. When ℓ_w=38*mm* the output values were P_w=14,08*Vatt*, Q_c = =0,1555*kg*, and when ℓ_w=35*mm*, P_w=14,15*Vatt*, Q_c =0,1196*kg*.

It turns out that (according to the power of the winding) in the first case the P_w er declined by 6,1%, and Q_c by 16,5%, and in the second case, P_w declined by 5,6%, and Q_c by about 35,7%.

CONCLUSION

The developed ADS gives the chance to calculate, design and adjust the parameters with or without an external magnetic wire, with anchor of any shape (cylinder, ball, etc.) and with different cross-sectional areas. It can be used in educational, engineering and research processes.

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Автоматизированная система расчета и проектирования линейного электромагнита без стопа (часть 2)

Оганесян А.Т., Григорян А.Х., Енокян К.Р., Бабаян А.Н., Хачатрян В.А.
Национальный Политехнический Университет Армении
г. Ереван, Армения
andranik.hovhannisyan@yandex.ru, Grigoryan@seua.am, karine.yenokyan@mail.ru, artbab95@mail.com, vaharpa@mail.ru

Аннотация. **Разработанная автоматизированная система позволяет вычислять, проектировать и оптимизировать параметры линейного электромагнита без стопа с внешним магнитопроводом или без него с любым выдом якоря (цилиндр, шар и т.д.). Система действует в диалоговом режиме и результаты представляются в виде числовых значений.**

Ключевые слова: **автоматизированная система, расчет, проект, линейный электромагнит, обмотка, магнитопровод, якорь, диалоговый режим, оптимизация.**

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