Рис. 2. Расчетная схема привода (стержня)

Используя (2) и (3), по классическим уравнениям Лагранжа II-го рода [3] найдём уравнения колебаний системы под действием приложенных усилий в матричном виде:

$$\|a\| \cdot \{\ddot{q}\} + \|c\| \cdot \{q\} = 0, \quad (8)$$

где $\|a\|$ – матрица коэффициентов инерции; $\|c\|$ – матрица коэффициентов жесткости.

Представляя частные решения уравнений (8) в виде гармонической функции

$$q_i = A_i \cdot \sin(kt + \beta), \text{ получим } \ddot{q}_i = -k^2 \cdot A_i \cdot \sin(kt + \beta) = -k^2 \cdot q_i. \text{ Обозначив } \lambda_i = \frac{1}{k_i},$$

$$\text{получим: } \lambda_i \{q\} = \|B\| \cdot \{q\}. \quad (9)$$

Раскрывая (9), получим частотное уравнение:

$$\lambda^6 - I_1 \lambda^5 + I_2 \lambda^4 - I_3 \lambda^3 + I_4 \lambda^2 - I_5 \lambda + I_6 = 0, \quad (10)$$

где I_i – миноры, которые получают из общего определителя системы путем вычеркивания i -й строки и j -го столбца. Решая полином (10) путем разложения, можно

найти все значения λ_i , а значит и собственные частоты: $k_i = \sqrt{\frac{1}{\lambda_i}}$.

***

1. Пат. №120599 РФ, МПК В25J1/00. Пространственный механизм / П.Д. Балакин, А. Х. Шамутдинов Заявка №2011153160/02, 26.02.2011. Оpubл. 27.09.2012, Бюл. №27.
2. Пат. №170930 РФ, МПК В25J1/00. Пространственный механизм с шестью степенями свободы / П.Д. Балакин, А. Х. Шамутдинов Заявка №2016115295, 19.05.2016. Оpubл. 15.05.2017, Бюл. №14.
3. Яблонский А.А. Курс теоретической механики. Ч.2. Динамика. – М.: Высшая школа, 1966. – 411 с.

Hovhannisyan A.T., Krmoyan N.M., Arzanyan R.G., Khachatryan V.H., Azatyan R.G.
Algorithm of machine calculation of magnetoelectric induction generator with the
change of the magnetic flux direction and the results of the research (III)

National Polytechnic University of Armenia
(Armenia, Yerevan)

doi: 10.18411/lj-02-2019-133

idsp: ljournal-02-2019-133

Abstract

Designed algorithm of machine calculation enables calculation and optimization of the parameters of magnetoelectric induction generator with the change of the magnetic flux direction. ZOHO software system was used, calculation process is in conversational mode, and the results are presented in numeric values.

Keywords: algorithm, permanent magnet, winding, induction, generator, voltage, autonomous, dialog mode, optimization.

Аннотация

Разработанный алгоритм машинного расчета позволяет рассчитывать и оптимизировать параметры с изменением направления магнитного потока магнитноэлектрического индукционного генератора. Использовалась программная система ZOHO, процесс расчета осуществляется в диалоговом режиме, а результаты представляются в числовых значениях.

Ключевые слова: алгоритм, постоянный магнит, обмотка, индукция, генератор, напряжение, автономный, режим диалога, оптимизация.

The structure, working principals, features of the magnetic system, main characteristics, and the principle of connecting with the load of the magnetoelectric induction generator (MIG) with change of the magnetic flux direction and also the calculating mathematical apparatus are presented in details in the previous publications of this journal.

Combining the opportunities of calculating technique and ZOHO software system, using a corresponding computer program algorithm of machine calculation (AMC) was designed. The operator calculates and develops the parameters of the MIG in a dialogue mode with the machine and gets the needed final information when changing the initial and elective parameters in forms of numerical values of the parameters [1].

Let's briefly describe the work of the AMC. When entering the corresponding address and password the first window opens on the screen of the computer, on the left side of which initial data is imported in the section "Initial data": the brand of the PM's material, ℓ_{PM} length of the PM, a_{PM} width of the PM, b_{PM} thickness of the PM, U_l value of the load's voltage amplitude, R_l resistance of the load, ℓ_{IW} length and h_{IW} height of the IW's window (Fig. 1).

According to the brand of PM's material the machine record corresponding parameters from the library: H_c coercion force, B_r remainig induction, $(BH)_m$ maximum value of the magnetic energy, or the operator imports the parameters in the right side of the window using a directory. In the same side of the window the value of ε and the Δ_{ss} step dimension of k 's change (Fig.1).

The letter notations on the windows are in Armenian.

Նախնական տվյալներ		Նախնական տվյալներ	
l շՄ *	0.022	l փ *	0.026
a շՄ *	0.011	h փ *	0.005
b շՄ *	0.023	B _r *	1.20
U _{բեռ} *	4	H _c *	48000
R _{բեռ} *	2.00	BH *	36000
		DeltaK _պ *	0.10
		Էպսիլոն *	1.10

Fig. 1. The window to enter the initial data and the elective values

After pressing the "Calculate" button on the bottom of the window the second window is opened where the initial data, chosen values and the calculated main results (ε EMF value

of IW, w number of IW's spirals, d_w diameter of the copper wire, r_{IW} active resistance of IW, I_{cl} calculating of the current in the IW-load chain, η energy conversion efficiency, P_{cl} calculating power of the load are presented in one line (Fig. 2).

	1 IW	a IW	b IW	l Φ	h Φ	B _r	H _c	BH	U _l кв	R _l кв	e	w	d	г _ф кв	I _р кв	I	К _{эф} кв	P _{кл} кв	ОЭК
	0.022	0.011	0.023	0.026	0.005	1.43	876000	400000	4	2.00	4.8	66	0.83	0.09	2.00	2.30	1.10	10.6	95.7
	0.022	0.011	0.023	0.026	0.005	1.20	48000	36000	4	2.00	5.6	167	0.83	0.55	2.00	2.20	1.10	9.7	78.4

Fig. 2. The window of initial data, elective dimensions, and output results

In case if any of the values does not meet the conditions, an extra window shows a comment on the reason of that (is missing in the Fig. 2), according to which operator changes the parameters.

During the work operator checks the impact of the initial and elective values on the calculating parameters of MIG and makes corresponding decision. He\She can directly affect the final results of calculation depending on his\her professional knowledge and experience, and can “speak” to the computer during the calculation, compare and analyze the results and optimize the calculating parameters if needed.

K coefficient of EMF or d_w diameter of the copper wire can be manageable parameters in the AMC.

The controlled dimensions are S_{IW} calculating surface of the IW and the measurement of the flux, the relative value of which compared to the initial value should be greater than ε .

Targeted functions expressing the criteria of effectiveness can be P_{cl} calculating power of the load, η ECE, weight of IW's copper, etc. In our case as targeted functions P_{cl} and η were selected.

The problems of optimizing MIG's calculating parameters were formulated in the following way. To provide such a value of d_w diameter of copper wire that is a discrete variable and provides maximum values for P_{cl} and η keeping resulting, elective and limited data unchanged.

Some changes made in the mathematical apparatus are presented in the block scheme. The mathematical model of MIG's calculation and optimization problem looks as the following (k_l is the laying coefficient).

$$\bar{X} = (\text{parameters of PM and load}),$$

$$\begin{aligned} \varepsilon &\leq \frac{I_{cl}}{I_l}, \\ S &= \ell_{IW} h_{IW} \geq \frac{\pi(d_w + \Delta_{iz})^2 w}{4k_l}, \\ r_{IW}(d_w) &\rightarrow \min, \\ P_{cl}(\bar{x}, r_{IW}) &\rightarrow \max, \\ \eta(\bar{x}, r_{IW}) &\rightarrow \max. \end{aligned}$$

The block-scheme of AMC is in the Fig. 3.

Results of the research

First problem. The brand of the PM ЮН14ДК24, $H_c = 48 \cdot 10^3 \text{ A/m}$, $B_r = 1.2 \text{ T}$, $(BH)_m = 36 \cdot 10^3 \text{ J/m}^3$, $\ell_{PM} = 22 \text{ mm}$, $a_{PM} = 11 \text{ mm}$, $b_{PM} = 23 \text{ mm}$, $U_l = 4 \text{ V}$, $R_l = 20 \text{ Ohm}$, $\ell_{IW} = 22 \text{ mm}$, $h_{IW} = 8 \text{ mm}$, $\gamma = 85^\circ$, $\Delta_{ss} = 0.1$, $\varepsilon = 1.1$.

Calculations resulted in the following output data: $e_{IW} = 5.6 \text{ V}$, $w = 167$, $d_w = 0.83 \text{ mm}$, $r_{IW} = 0.55 \text{ Ohm}$, $I_{cl} = 2.2 \text{ A}$, $\eta = 78.4\%$, $P_{cl} = 9.7 \text{ Watt}$.

Fig. 3. Block-scheme of AMC

Second problem. The brand of the PM N52, $H_c=876 \cdot 10^3 \text{ A/m}$, $B_r=1,43 \text{ T}$, $(BH)_m=400 \cdot 10^3 \text{ J/m}^3$, $\ell_{PM}=22 \text{ mm}$, $a_{PM}=11 \text{ mm}$, $b_{PM}=23 \text{ mm}$, $U_\ell=4 \text{ V}$, $R_\ell=2 \text{ Ohm}$, $\ell_{IW}=22 \text{ mm}$, $h_{IW}=8 \text{ mm}$, $\gamma=85^\circ$, $\Delta_{ss}=0,1$, $\varepsilon=1,1$.

Calculations resulted in the following output data: $e_{IW}=4,8 \text{ V}$, $w=66$, $d_w=0,83 \text{ mm}$, $r_{IW}=0,09 \text{ Ohm}$, $I_{c\ell}=2,3 \text{ A}$, $\eta=95,7\%$, $P_{c\ell}=10,6 \text{ Watt}$.

Conclusion: Designed algorithm of machine calculation enables calculation, optimization of the parameters of MIG with the change of the magnetic flux direction, development of the structure by the change of initial and elective parameters being in a conversation mode with the machine. It is applicable in educational, engineering, and scientific research processes.

This work was supported by the RA MES State Committee of Science, in the frames of the research project «Electromagnetic systems» research base laboratory.

This work was supported by the RA MES Science Committee, in the frames of the research project № 18T-2B309.

***

1. Hovhannisyan A.T., Minasyan G.M., Melkonyan T.R., Yenoqyan K.R., Hovhannisyan A.A. An Automated Design System of a Flat Lifting Electromagnet // PROCEEDINGS OF THE REPUBLIC OF ARMENIANATIONAL ACADEMY OF SCIENCES AND NATIONAL POLYTECHNIC UNIVERSITY OF ARMENIA, SERIES OF TECHNICAL SCIENCES, Volume 70, № 2, 2017.- P. 188-196.