РАЗДЕЛ XVI. ЭЛЕКТРОТЕХНИКА

**Hovhannisyan A.T., Bareghamyan G.W., Melkonyan T.R., Khachatryan V.H.,
Arzanyan R.G., Azatyan R.G.**

Types and comparative analysis of windings of electromagnetic field sources

*National Polytechnic University of Armenia
(Armenia, Yerevan)*

doi: 10.18411/lj-05-2020-58

idsp: ljournal-05-2020-58

Abstract

The results of research on control windings used in electromechanics that are the source of magnetic fields are presented in the work. In particular, the magnetic fields of types with rectangular, trapezoid cross-sections and of types coming from the combination of these two were researched. The results and characteristics were analyzed.

Keywords: winding, electromagnetic field, induction, rectangle, trapezoid, combination.

Аннотация

В работе представлены результаты исследований обмоток управления, используемых в электромеханике и являющихся источником магнитных полей. В частности, были исследованы магнитные поля типов с прямоугольными, трапециевидными поперечными сечениями и типов, происходящих от сочетания этих двух типов. Результаты и характеристики были проанализированы.

Ключевые слова: обмотка, электромагнитное поле, индукция, прямоугольник, трапеция, комбинация.

Purpose of work

Investigation of magnetic field characteristics along the length of the control winding used in electromechanical systems as magnetic field sources. In particular, windings of rectangular, trapezoidal sections and types with their combination. Analyze the values of the induction B and the induction gradient $G=\Delta B/\Delta X$ in different parts of the winding, as well as the possible axial movement of the ferromagnetic point inside the winding.

The following parameters were kept identical in the researched types of winding: winding length, surface of winding window, flux density in wire.

FEMM 4.2 program package was used to research winding's magnetic field, which uses the finite element method to model the field.

Results of the research

1. The basic version was a winding with a rectangular cross-section (RCW). Such winding (traditional) is the most used in electromechanics. When electric current passes through it, magnetic field is created, where B induction has disproportional distribution across X symmetry longitudinal axes, reaches its maximum value in the center of the winding, and the minimum in the edges.

The cross-section of RCW a), powerlines of the magnetic field b) and induction $B(X)$ characteristic c) are given in fig. 1.

Fig. 1. The cross-section of RCW (a), image of the magnetic field (b), $B(X)$ characteristic (c)

Let's analyse the results we got. The maximum induction value of $B_{\max}=10,11\text{mT}$ is at $X=0$, and at the right and left wings of the winding at $X=\pm 30\text{mm}$ $B=5,64\text{mT}$, at $X=-20\text{mm}$ $B=8,72\text{mT}$, and at $X=-10\text{mm}$ $B=9,81\text{mT}$. In $X=-20\div-30\text{mm}$ section $G=0,31\text{T/m}$, in $X=-10\div-20\text{mm}$ section $G=0,11\text{T/m}$, in $X=0\div-10\text{mm}$ section $G=0,03\text{T/m}$, and in $X=\pm 30\div 0\text{mm}$ section $G=0,15\text{T/m}$. The maximum movement of the ferromagnetic point from the edge of the winding (left or right) was $\Delta X=30\text{mm}$.

2. We have imported trapezoid cross-sectioned winding (TCW) into the electromechanic system, with its the cross-section of winding a), powerlines of the magnetic field b) and induction $B(X)$ characteristic c) given in fig. 2.

Fig. 2. The cross-section of TCW (a), image of magnetic field (b), $B(X)$ characteristic (c)

The analysis of the results show that at $X=10\text{mm}$ $B_{\max}=10,68\text{mT}$, at $X=-30\text{mm}$ $B=4,26\text{mT}$, at $X=30\text{mm}$ $B=6,74\text{mT}$, at $X=-20\text{mm}$ $B=7,13\text{mT}$, and at $X=-10\text{mm}$ $B=8,87\text{mT}$. In $X=-20\div-30\text{mm}$ section $G=0,29\text{T/m}$, in $X=-10\div-20\text{mm}$ section $G=0,17\text{T/m}$, in $X=10\div-10\text{mm}$ section $G=0,09\text{T/m}$, in left side $X=10\div-30\text{mm}$ section $G_l=0,16\text{T/m}$, and in right side $X=10\div30\text{mm}$ section $G_r=0,2\text{T/m}$.

The value of TCW's $B_{\max}$ is greater by 5,6%, G_l is greater by about 7%, and G_r by 33%. By the influence of electromagnetic force the movement of the ferromagnetic point from the left edge of the winding is $\Delta X_l=40\text{mm}$, which is greater by 33%, and from the right edge is $\Delta X_r=20\text{mm}$ which is less by 33%.

Other results of the research on magnetic field with trapezoid cross-section winding are presented in the published works [1÷9].

Using TCW in some electromechanical apparatus, mainly in linear electromagnet without a stop, in electromagnetic accelerator, reed relays and electromagnetic relays, linear induction sensor has advantages compared to RCW. In particular, sensitivity of the system, movement of the anchor, and electromagnetic retraction force increase. These conditions result in decrease in size and weight of the system. Hence, it is advisable to replace RCW with TCW in systems of some electromechanical apparatus [10÷13].

3. RCW - TCW combined version. In this case, the surface of the window for each was $S/2$. The cross-section of winding *a)*, the powerlines of the magnetic field *b)* and induction $B(X)$ characteristic *c)* are given in fig. 3. The analysis of given results show that the magnetic field has two maximum values: at $X_1=-10\text{mm}$ $B_{\max1}=9,46\text{mT}$, and at $X_2=13\text{mm}$ $B_{\max2}=9,37\text{mT}$. At $X=-30\text{mm}$ $B=5,56\text{mT}$, at $X=30\text{mm}$ $B=6,17\text{mT}$, and at $X=-20\text{mm}$ $B=8,58\text{mT}$. In $X=-20\div-30\text{mm}$ section $G=0,3\text{T/m}$, in $X=-10\div-20\text{mm}$ section $G=0,09\text{T/m}$, in $X=-10\div-30\text{mm}$ section $G_l=0,19\text{T/m}$, in $X=13\div30\text{mm}$ section $G_r=0,19\text{T/m}$, $\Delta X_l=20\text{mm}$, and $\Delta X_r=17\text{mm}$.

In this system the value of $B_{\max1}$ is smaller by 6%, and $B_{\max2}$ by about 7%, the value of G_{06} in left and right wings is greater by about 27%, but it concedes the first type by the rest of the parameters.

Fig. 3. The cross-section of winding combined RCW-TCW (a), powerlines of magnetic field (b), $B(X)$ characteristic (c)

4. TCW-RCW combined type. Here the surface of the window for each was $S/2$. The cross-section of winding *a*), the powerlines of the magnetic field *b*) and induction $B(X)$ characteristic *c*) are given in fig. 4. The analysis of given results show that at $X=0$ $B_{\max}=10,52mT$, at $X=-30mm$ $B=4,87mT$, at $X=30mm$ $B=5,68mT$, at $X=-20mm$ $B=8,2mT$, at $X=-10mm$ $B=10,1mT$, at $X=10mm$ $B=10,1mT$. In $X=-20\div-30mm$ section $G=0,33T/m$, in $X=-10\div-20mm$ section $G=0,19T/m$, in $X=0\div-30mm$ section $G=0,19T/m$, in $X=0\div30mm$ section $G=0,16T/m$, and $\Delta X=30mm$.

Compared to the first system, this one concedes the value of the left wing induction by around 14%, but is advantageous by the rest of the parameters. So, right wing induction is greater by around 7%, the value of $B_{\max}$ is greater by 4%, and the value of G in left and right wings is greater by around 27%.

Fig. 4. The cross-section of combined TCW-RCW (a), powerlines of magnetic field (b), $B(X)$ characteristic (c)

5. RCW-TCW combined version. Here the ratio of the window surfaces was $S_2/S_1=5$. The cross-section of winding *a*), the powerlines of the magnetic field *b*) and induction $B(X)$ characteristic *c*) are given in fig. 5. The analysis of given results show that at $X=10mm$ $B_{\max}=10,26mT$, at $X=-30mm$ $B=5,06mT$, at $X=30mm$ $B=6,53mT$, at $X=-20mm$ $B=7,51mT$, at $X=-10mm$ $B=8,55mT$, at $X=0$ $B=9,58mT$, at $X=20mm$ $B=9,8mT$. In $X=-20\div-30mm$ section $G=0,24mT/m$, in $X=-10\div-20mm$ section $G=0,1T/m$, in $X=0\div-10mm$ section $G=0,1T/m$, in $X=10\div0mm$ section $G=0,1T/m$, in $X=10\div-30mm$ section $G_l=0,13T/m$, and in $X=10\div30mm$ section $G_r=0,19T/m$, $\Delta X_l=40mm$, and $\Delta X_r=20mm$.

In this system, the value of $B_{\max}$ exceeds by around 1,5%, G_r exceeds by about 27%, but G_l is less by 3%.

Fig. 5. The cross-section of combined TCW-RCW with ratio $S_2/S_1=5$ (a), image of the magnetic field (b), $B(X)$ characteristic (c)

$B(X)$ characteristics of 5 researched windings are given together in figure 6.

Fig. 6. $B(X)$ characteristics of researched windings

We can also conduct a comparative parameter analysis between the rest of the presented windings using the given features.

Practically we can make other combination joints of windings of different types.

Conclusion

1. The results of the research can assist in choosing the type of combined winding to get the magnetic field of needed characteristics.
2. The choice of the structure of control winding conditions the productive performance of the electromechanical system.

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

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

1. Hovhannisyan A., Grigoryan A., Sargsyan V., Khachatryan V. The Applications of the trapezoid control coil in electromechanics // Wykształcenie i nauka bez granic: Materiały IX międzynarodowej naukowo-praktycznej konferencji.- 2013.- V. 46.- P. 50-55.

2. Оганесян А.Т. Расчет тягового электромагнитного усилия длинноходового электромагнита // Известия вузов. Электромеханика. – 2014. - № 6. – С. 28-30.
 3. Оганесян А.Т., Григорян А.Х., Хачатрян Ш.Д., Хачатрян В.А. Особенности обмотки управления трапецевидного сечения в электромеханических системах // "Научно-теоретический и практический журнал Уральский Научный Вестник". Серия: Технические науки.- 2014, № 21 (100).- С. 79-83.
 4. Оганесян А.Т. Расчет тягового электромагнитного усилия длинноходового электромагнита без стопа // MATERIALS OF THE I INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE «SCIENCE AND EDUCATION - 2014» Volume 20, Technical sciences Belgorod - Sheffield Science and Education LTD. 2014, P. 43-47.
 5. Оганесян А.Т., Григорян А.Х., Хачатрян Ш.Д., Апетян Н.В. Особенности обмотки трапецевидного сечения в электромагнитной системе // Электротехника: сетевой электронный научный журнал.- 2015, Т. 2, №2.- С. 50-52.
 6. Оганесян А.Т., Григорян А.Х., Хачатрян Ш.Д. Влияние внешнего магнитопровода на магнитное поле обмоток прямоугольного и трапецевидного сечений // Актуальные проблемы гуманитарных и естественных наук.-М., 2015.- №12, ч.2.- С. 169-174.
 7. Оганесян А.Т., Григорян А.Х., Хачатрян Ш.Д. Исследование и сравнительный анализ плотности электромагнитной энергии обмоток прямоугольного и трапецевидного сечений / ВЕСТНИК ИНЖЕНЕРНОЙ АКАДЕМИИ АРМЕНИИ.- 2016.- Т. 13, № 1.- С. 44-48.
 8. Hovhannisyan A.T. System of design and calculation of linear electromagnet without the stop (I) / Научный журнал "Chronos". Выпуск 5(21)-М: 2018.- С. 18-24.
 9. Hovhannisyan A.T., Grigoryan A.Kh., Yenokyan K.R., Babayan A.N., Khachatryan V.H. An automated system of design and calculation of linear electromagnet without the stop (II) / Научный журнал "Chronos". Выпуск 5(21)-М: 2018.- С. 24-29.
 10. Patent of RA 2349A. The reed relay / A.T. Hovhannisyan, A.Kh. Grigoryan, V. G. Sargsyan.- H01H 1/00, 51/00, 25.01.2010.- 4 p.
 11. Patent of RA 2572A. The linear electromagnet / A.T. Hovhannisyan.- H02K 41/00, 25.11.2011.- 6 p.
 12. Patent of RA 2609A. Electromagnet / A.T. Hovhannisyan.- H01H 3/00, H01H 50/00, 27.02.2012.- 6 p.
 13. Patent of RA 2708. The electromagnetic linear accelerator / A.T. Hovhannisyan.- F41B 6/00, 25.01.2013.- 6 p.
-