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VERIFICATION OF THE COMPUTER DESIGN PACKAGE ELCUT ON THE EXAMPLE OF THE PROBLEM OF HEATING AN INDUCTOR WITH A TWO-LAYER INWALL

Abstract. The actual problem of researching the thermal field of an induction heater with a two-layer inwall for four pairs of inwall materials is solved; verification of the ELCUT automated design package using pictures of temperature fields, isotherms and diagrams comparing the average temperature of the inwall in the outer and inner layers was carried out.
Key words: automated design package, ELCUT, thermal calculation, temperature, induction heater, inwall.

Introduction. To solve differential equations and their systems describing thermal processes in complex structures and devices, automated design packages, which include ELCUT, are increasingly used. However, this raises the question of the reliability of the obtained results, which can be answered by verifying the used algorithm by comparing the obtained results with the known data of other authors.

Analysis of recent research and publications. The application of the ELCUT automated design package to the solution of actual complex differential problems can be found in articles [1-8].

The paper [1] presents the results of the study of increasing the energy efficiency of the acoustic magnetic device due to the joint solution of three problems: electrical, magnetic, and thermal. For the experimental investigation of the hypothesis, a model of the acoustic-magnetic device was developed using the ELCUT 6.1 software, which allowed to obtain satisfactory results.

The article [2] is devoted to the study of the strength properties of a sand-cement rod under conditions of a thermal gradient. A comparison of the results of the simulation of the problem in the ELCUT Pro package with the experimental data shows minor deviations of the studied parameters.

The purpose of the article [3] is to determine the temperature and correct cutting conditions during flat grinding of a combined form consisting of metal-polymer and metal. The heating of the part surface using the finite element method in the

ELCUT 6.1 was studied. The results of the experiment and discussion are presented, which confirms the previously obtained theoretical and numerical results.

In [4], the methodology for calculating the coefficient of heat transfer of fences for soil massifs that have an infinite thickness, which greatly complicates the task, is developed. The solution of the differential equation of thermal conductivity by the methods of integral transformation, which was confirmed by the results of the finite-element calculation in the ELCUT software simulation, was obtained.

Papers [5-6] are devoted to the analysis of the tool base in the field of horticulture and optimization of the magnetic system of the linear motor of electric secateurs. The task is complicated by the lack of a theory of designing magnetic systems for hand-held electrified tools. Chain methods of calculating magnetic systems have a high error, which does not allow determining the optimal design at the stage of calculations. The use of the modern ELCUT computer program based on the finite element method at the design stage made it possible to increase the force created by the magnetic field of the linear electric motor of the hand-held electrified tool, and thereby obtain the optimal design of the magnetic system with the specified accuracy.

The article [7] provides a description of the developed electric generator designed for the generation of electricity by the magneto-electric method and the conversion of mechanical energy from a rotating wind engine, and the study of the distribution of magnetic fluxes in the area of the magneto conductor of the generator, which were carried out in the ELCUT computer simulation environment. Due to the improved redistribution of the magnetic flux, a 60% increase in electric current at the output of the generator was obtained; 10% reduction in battery charge time, which leads to accelerated use of the energy storage. The obtained results made it possible to improve the mass and overall design parameters of the magnetic system.

The paper [8] presents a comparison of the results of the research on the problem of heating a cylindrical inductor with two inwall layers using the ELCUT and SOLIDWORKS automated design packages.

Thus, the review of the latest research shows that the automation of the complex procedure of integrating differential equations and their systems with the help of modern systems makes it possible to obtain results much faster and in more detail and to determine the fields of the sought functions.

The purpose of the study: verify and prove the feasibility of using the ELCUT automated design package to solve the problem of determining the thermal field of an induction heater with a two-layer inwall for four pairs of inwall materials.

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Presentation of the main material of the study. Estimated cases of location of materials in the layers of the inductor inwall and their thermal conductivity are given in table 1.

Table 1

Numbering of inwall layers materials
and their thermal conductivity coefficients λ_I, W/(m·K)

Inwall layers	**1**	**2**	**3**	**4**
internal	chamotte, 1,33	cement slabs, 1,92	slate, 2,1	asbestos-cement slabs,0,35
external	asbestos, 0,175	bakelite, 0,23	asbestos-cement slabs, 0,35	slate, 2,1

The statement of the problem and the equations system can be found in [9-10], the scheme of the inductor with two-layer inwall is given in [10].

The materials of the inwall layers in cases 1 and 2 of table 1 were chosen to coincide with cases 1 and 11 in [10] for comparison and verification two methods. Cases 3 and 4 contain the same layer materials: "slate" and "asbestos-cement slabs"; cases differ in their sequence and location relative to the inner cavity of the inductor.

Pictures of thermal fields in the inductor for the four studied cases, respectively, table. 1 in fig. 1-4 are presents.

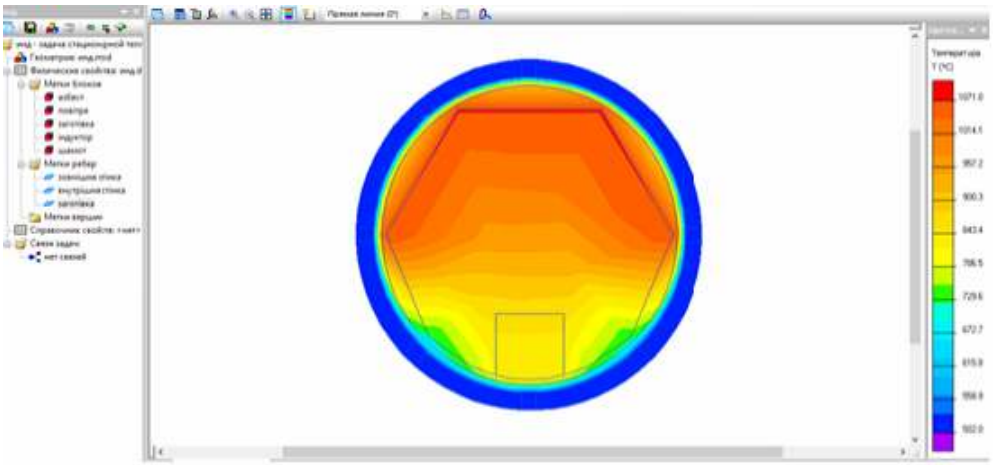

Figure 1 - Thermal field in the inductor for inwall "chamotte-asbestos"

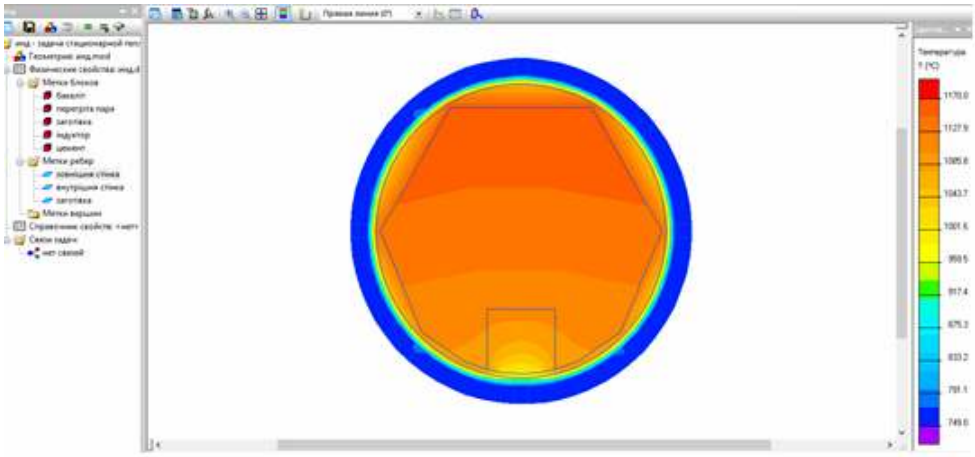

Figure 2 - Thermal field in the inductor for inwall "cement slabs-bakelite"

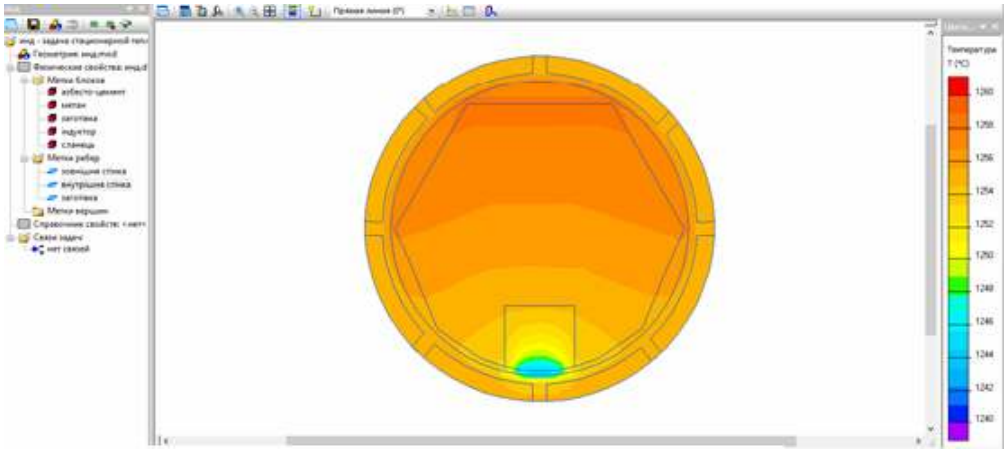

Figure 3 - Thermal field in the inductor for inwall "slate-asbestos-cement slabs"

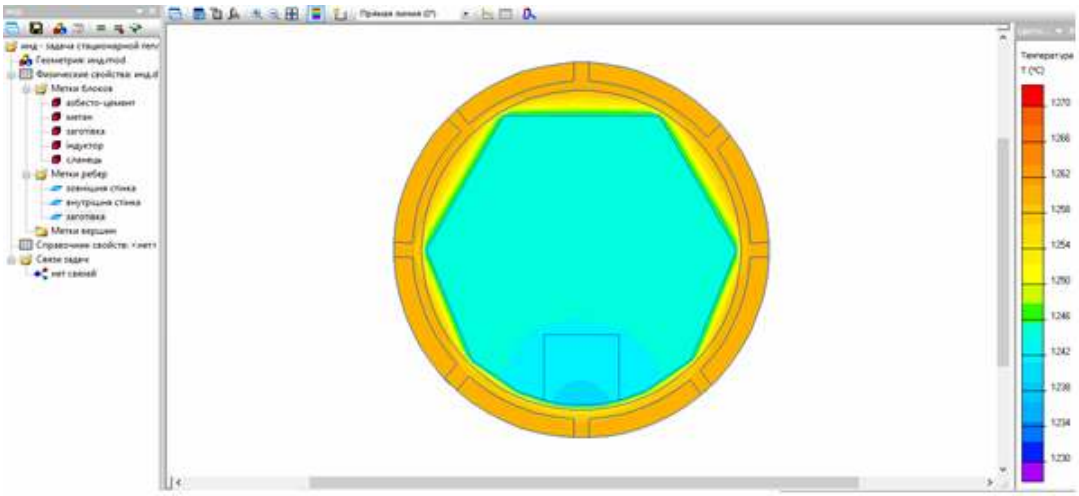

Figure 4 - Thermal field in the inductor for inwall "asbestos-cement slabs-slate"

The comparison of the inwall temperature average values with the corresponding data of [10] for cases 1 and 2 is shown in Fig. 5.

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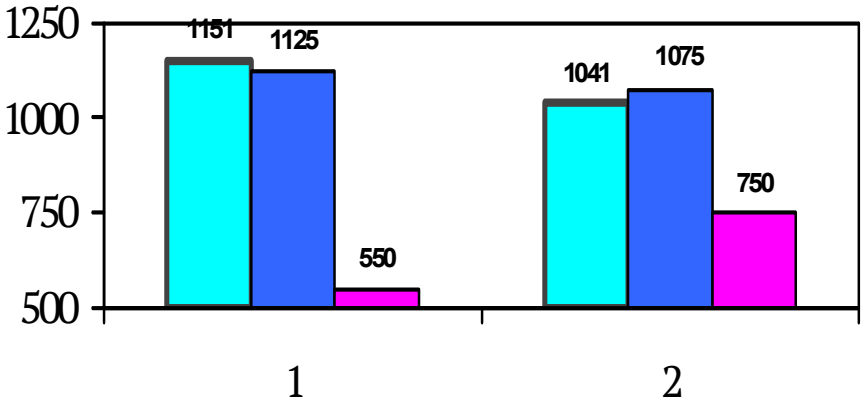

Figure 5 - The average temperature of the inwall: 1 – chamotte-asbestos;
2 – cement slabs-bakelite;
– inner layer [10];
– inner layer, ELCUT;
– outer layer, ELCUT

It should be noted that the difference in temperature values on the inner side of the inner layer of the inwall, obtained by the method [10] and numerically – using the software package ELCUT for pairs of materials "chamotte-asbestos" and "cement slabs-bakelite" (Fig. 5), does not exceed 3%.

Thus, the heat transfer module ELCUT can be successfully used to model the distribution of temperatures and heat fluxes in industrial problems heat engineering, however in the presence in designs of the cavities filled with air or other gaseous environment, it is necessary to consider heat exchange not only due to thermal conductivity, but also due to free / forced convection and thermal radiation - this explains the difference results.

The presented results at the XXII International Conferences "Human and Space" [8] were tested.

Conclusions. In the course of performance of the set task the following types of works were carried out and conclusions were received:

1) the algorithm for studying the thermal field of an induction heater with a two-layer inwall was created;

2) the created algorithm on problems of the given class with the known solutions received in [10] is carried out was testing;

3) the temperature fields of the induction heater with two-layer inwall for four pairs of inwall materials using software ELCUT complex was calculated;

4) pictures of temperature fields and isotherms for the investigated cases of induction heater inwall materials, and the diagram for comparison of the average temperature of the inwall in the outer and inner layers, obtained using the ELCUT package and using an analytical approach [10] are constructed.

As a result of the conducted research, the maximum difference between the analytical and numerical solution obtained when using the ELCUT automated design system was determined – it did not exceed 3%. Thus, the expediency of using the ELCUT software complex to solve actual and practically necessary problems of industry has been proven.

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Верифікація пакету автоматизованого проєктування ELCUT на прикладі задачі нагрівання індуктора з двошаровим футеруванням

Для розв'язання диференціальних рівнянь та їх систем, що описують теплові процеси в складних конструкціях та пристроях, усе частіше застосовуються пакети автоматизованого проєктування, до яких відноситься ELCUT. Однак, при цьому виникає питання достовірності отриманих результатів, відповісти на яке можна, довівши достовірність використовуваного алгоритму шляхом порівняння отриманих результатів з відомими даними інших авторів. Аналіз останніх досліджень і публікацій свідчить, що система ELCUT може застосовуватись до розв'язання задач з різних галузей промисловості, а саме: підвищення енергоефективності акустичного магнітного пристрою; дослідження міцних властивостей піскоцементного стрижня в умовах термоградієнту; визначення температури та правильних умов різання при плоскому шліфуванні комбінованої форми, що складається з металополімеру та металу; розробка методики розрахунку коефіцієнта тепловіддачі огороджень для ґрунтових масивів, які мають нескінченну товщину; аналіз інструментальної бази в галузі садівництва та оптимізації магнітної системи лінійного двигуна електричних секаторів; опис електричного генератора, призначеного для вироблення електроенергії магнітно-електричним способом і перетворення механічної енергії від вітряного двигуна, що обертається, та дослідження розподілу магнітних потоків на ділянці магнітопроводу генератора. Метою даної роботи є верифікування та доведення доцільності застосування пакету автоматизованого проєктування ELCUT до розв'язання задачі ви-

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значення теплового поля індукційного нагрівача з двошаровим футеруванням для чотирьох пар матеріалів футерівки. В роботі створено алгоритм дослідження теплового поля індукційного нагрівача з двошаровим футеруванням; проведено тестування на задачі даного класу з відомими розв'язками; за допомогою програмного комплексу ELCUT розраховано поля температур індукційного нагрівача з двошаровим футеруванням для чотирьох пар матеріалів футерування; побудовано картини полів температур та ізотерм для досліджуваних випадків матеріалів футерування індукційного нагрівача, а також діаграму порівняння середньої температури футерівки в зовнішньому та внутрішньому шарах, отриманої за допомогою пакету ELCUT та при використанні аналітичного підходу; визначено максимальну різницю між аналітичним та числовим розв'язком, отриманим при використанні системи автоматизованого проєктування ELCUT, – вона не перевищила 3%. Таким чином, доведено доцільність застосування програмного комплексу ELCUT до розв'язання актуальних та практично необхідних задач промисловості.

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