The International Journal of Engineering and Science (IJES)
|| Volume || 7 || Issue || 10 Ver.IV || Pages || PP 45-52|| 2018 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Design of the Geomagnetic Sensor Case in Aggressive Environment Conditions

M. Ayaz Ahmad[1], Svitlana Sotnik[2], Tetiana Sinelnikova[3], Vyacheslav Lyashenko[3]

[1]*Physics Department, Faculty of Science, University of Tabuk, Kingdom of Saudi Arabia.*
[2]*Department of Computer-Integrated Technologies, Automation and Mechatronics, KharkivNationalUniversity of RadioElectronics, Kharkiv, Ukraine.*
[3]*Department of Informatics, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine.*
Corresponding Author:M. Ayaz Ahmad

---***ABSTRACT***---
Work is devoted to design of the geomagnetic sensor case in aggressive environment conditions.The choice of material for the case is carried out. 3D model of the geomagnetic sensor case is offered. On the basis of received 3D model the analysis "temperature fields" influence on case surface which showed that the created case from the chosen materials meets requirements of heat conductivity was carried out. The received 3D model can be used further for optimization of existing analogs that will allow to reduce significantly time for project works and to increase cases quality.
KEYWORDS -*Design, SolidWorks, Flow Simulation, Case, Geomagnetic, Sensor*

Date of Submission: 17-10-2018 Date of acceptance: 03-11s-2018

I. INTRODUCTION

Industrial measurements and the control instrumentation, are applied in all areas, geology, by search of minerals; archeology, at archeological excavations; navigation at the sea, in space and aircraft; to military investigation for identification of the shipped submarines; to biology and medicine; seismology (forecast of earthquakes) scientific experiments; magnetic geochronology [1].

Depending on the measured size distinguish devices for measurement of field tension (erstedmeter), field direction (an inklinator and declinators), a gradient of the field (gradiometer), magnetic induction (teslameter), a magnetic flux (fluxmeter), the coercive force (coercimeter), magnetic permeability (mu-meters), magnetic susceptibility (kappa-meters), the magnetic moment [2].

Modern geomagnetic sensors (magnetometers) are devices for measurement of magnetic field characteristics and magnetic properties of materials [3].

World leader in production of geomagnetic sensors – PNI Sensor Corporation. PNI technologies are used in consumer electronics, robotics, automobile, military and other branches. PNI sensors use in products such companies as Nintendo, Samsung, iRobot, Sony, STMicroelectronics, General Motors and Ford [1-3].

Geomagnetic sensors – in a revolutionary way the new functionality of consumer devices, is a new class of devices for magnetic field measurement, such sensors allow to expand navigation functions of portable devices [4].

II. MATERIALS AND METHODS

2.1. Related work

For today there is a number of works in which kinds of geomagnetic sensors and materials for them, features of their design are considered.

In [5] a potential geomagnetic-field sensor is proposed on the basis of an optimal 2D configuration of magnetoelectric Ni-based Metglas/PZT laminates. This sensor can perfectly serve to measure both the strength and the orientation of the earth's magnetic field.

In [6] design and error analysis of geomagnetic measurement circuit based on triaxial magneto-resistive sensor are presented. Error analysis of the hardware circuit was presented. Analysis results showed that larger errors were brought about with increasing geomagnetic field intensity. Finally, static sampling was finished, through which the geomagnetic field was measured to be 52848 nT, as well as 53520.24 nT gained by high-precision triaxial fluxgate magnetometer FVM400.

In [7] a structure of Ta/MgO/NiFe/MgO/Ta was designed and synthesized, which combines the advantages of both tunnel magnetoresistance materials with high magnetic field sensitivity and anisotropic magnetoresistance materials with high directional sensitivity.

An alternative design of resonant cavity based on the birdcage coil structure is proposed in [8] to make the resonant frequency in accordance with the polarization frequency of the working substance. The structure and equivalent circuit of resonant cavity are analyzed. The model of resonant cavity is established, and S-parameter is calculated. Overall, this design has the advantages of high performance and strong anti-interference.

An all-metal material for high-sensitivity geomagnetic sensors with improved magnetic stability by magnetostatic coupling are considered in [9]. A Ta/NiFe(I)/IrMn/NiFe(II)/NiFeCr/NiFe(III)/Pt/Ta structure is designed and synthesized for high-sensitivity geomagnetic sensors. When the material is fabricated into sensor elements, the magnetic sensitivity reaches $3.1\ mV\ V^{-1}\ Oe^{-1}$ which is close to that of some tunnel magnetoresistance elements.

2.2 Features of geomagnetic sensor realization

Depending on the nature of the measured size magnetometers are graduated in these or those units (magnetic field tension, units of magnetic induction, direction of magnetic field, etc.). The main physical quantity of geomagnetic sensors is magnetic induction which characterizes power influence of magnetic field in each its point, both on value, and in the direction.

Let's consider the main types of modern geomagnetic sensors.

Such sensors are distinguished on the principle of work: proton, quantum, ferroprobe, cryogenic, inductive, on Hall's effect and others, however are widely applied the first three types [10].

Proton magnetometers (Fig. 1) of a free precession are widely used to high-precision magnetic investigation [11], geological researches and also as supersensitive metal detectors. For carrying out measurements by proton magnetometers it is necessary to foreknow the magnetic induction direction as majority sensors of the modern proton magnetometers are sensitive to it.

The sensor of such magnetometer is ampoule with diamagnetic liquid which molecules contain hydrogen atoms (for example, water or benzene). The magnetic moments of molecules are caused only by the magnetic moments of atomic nuclei of hydrogen – protons (electronic magnetic moments in molecules of such liquids are compensated.

Figure 1: Example of the proton magnetometer

Quantum magnetometers (Fig. 2) for measurement of magnetic fields tension, based on the quantum phenomena. As such phenomena serve the free ordered precession of nuclear or electronic magnetic moments (a magnetic resonance), quantum transitions between magnetic subtotals of atoms and also quantum changes of a magnetic flux in a superconducting contour [12, 13]. Such magnetometers are used mainly to measurement of weak magnetic fields tension.

Figure 2: Example of the quantum magnetometer

One of the most widespread geomagnetic sensors types are ferroprobe magnetometers (Fig. 3). Such magnetometers are intended for constant magnetic fields measurement in the range of 0.001... 0.5 oersted and also are intended for measurement of ferromagnetic products residual magnetic field. The simplest ferroprobe consists of a permalloys core on which the drive coil is placed, fed by alternating current, and detector coil [14].

Figure 3: Example of the ferroprobe magnetometer

III. RESULTS AND DISCUSSION

3.1 Design of the geomagnetic sensor case in aggressive environment conditions

As an analog for geomagnetic RM3100 sensor case development (Fig. 4) which consists of three parts was chosen: case and its cover, plug.

Result of modeling: cases are presented on Fig. 5; covers of the case it is presented plug (Fig. 6); plug it is presented in Fig. 7.

For creation of new three-dimensional model the SolidWorks environment was chosen because this system has the following advantages [15-17]:

- provides full development of any appointment, any complexity products;
- allows to realize solid-state and superficial parametrical modeling;
- full associativity between details, assembly and to drawings;
- possesses "rich interface" for import and export of the created details geometry;
- express realizes the analysis of details durability and kinematics of mechanisms;
- has flexibility and scalability;
- has potential of drawing up any documentation;
- simplicity in studying of SolidWorks modules and high functionality;
- observance of uniform system for design documentation requirements at drawings execution.

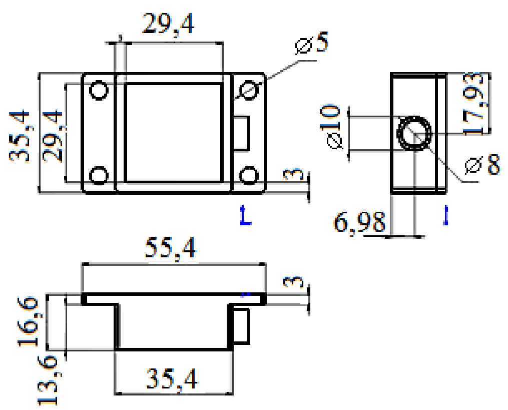


Figure 4: Drawing of the geomagnetic sensor case

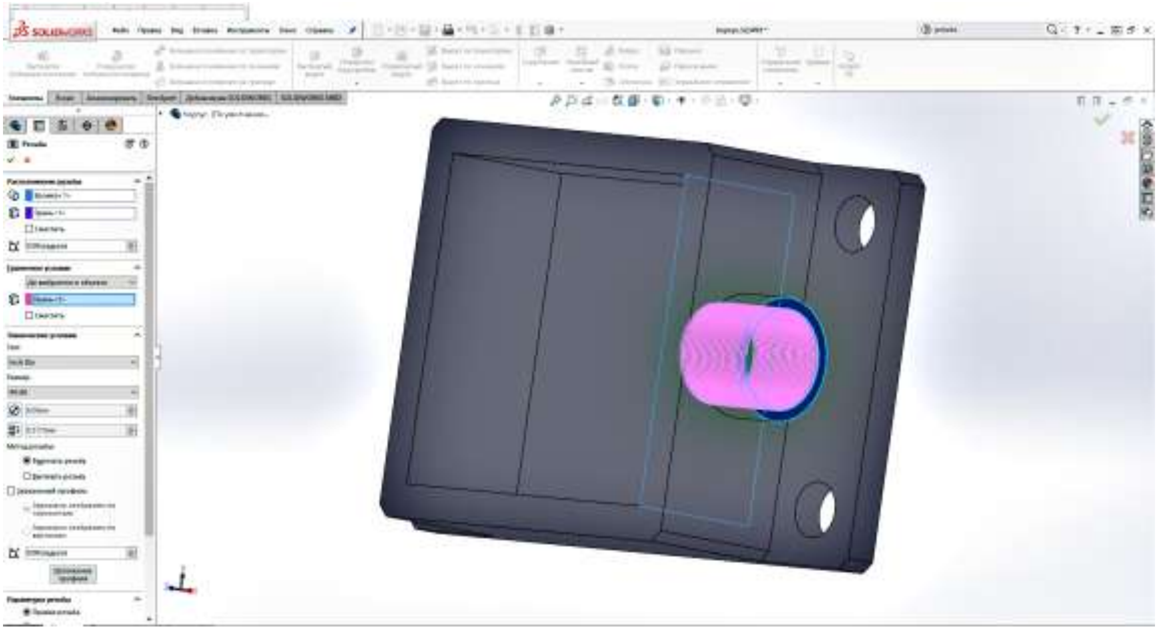


Figure 5: Modeling of the geomagnetic sensor case

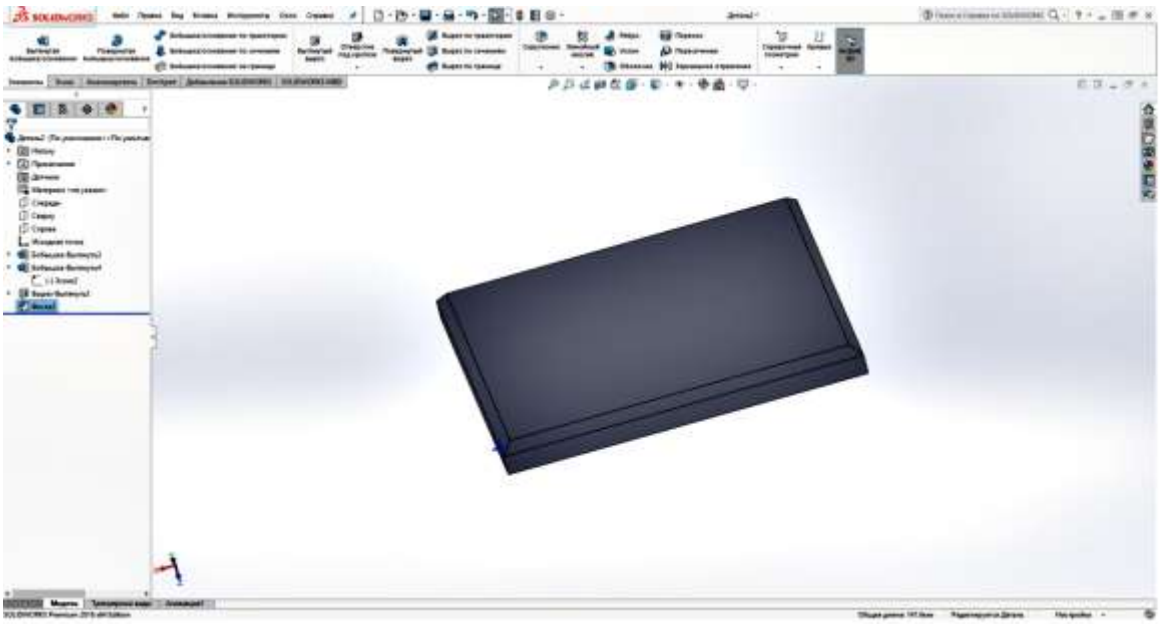
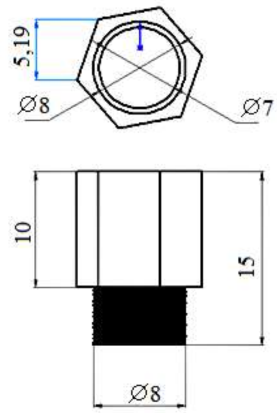


Figure 6: Modeling of a geomagnetic sensor case cover

At first the case model according to the drawing (Fig. 7, a), then volume model of Fig. 7, b was created. To begin geomagnetic sensor assembly, it is necessary to open ready models in the new document. To add on working area the created models (Fig. 8, a, b).



a)

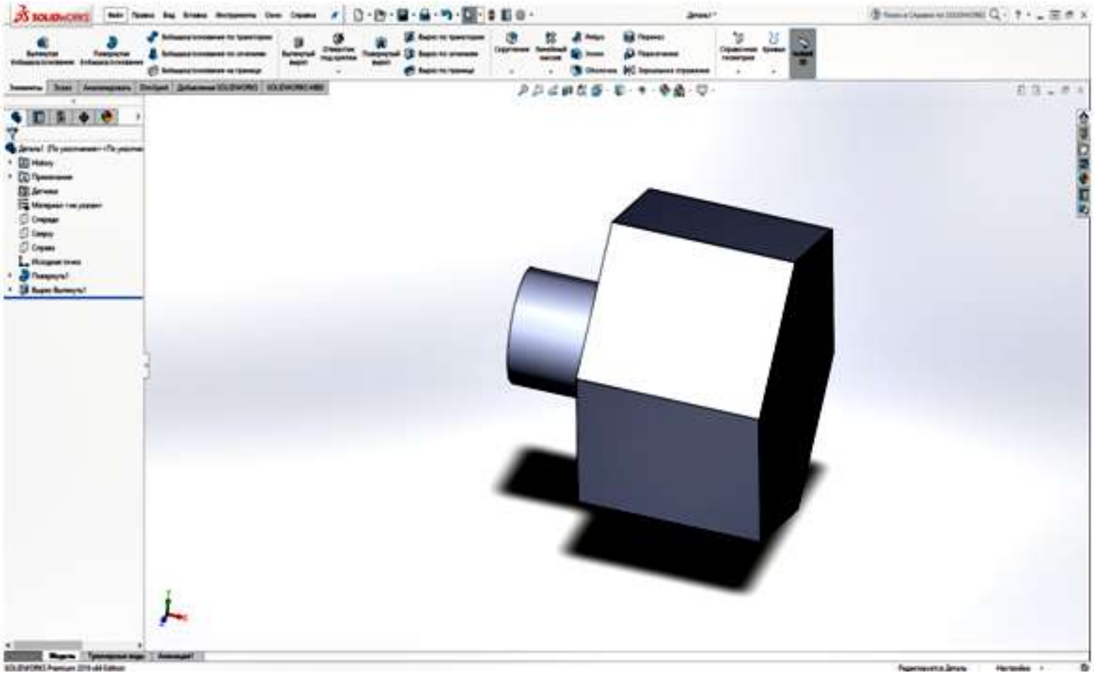
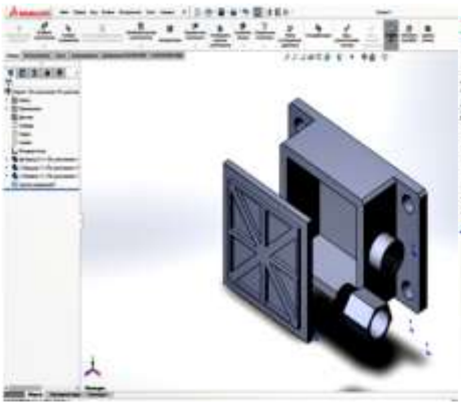
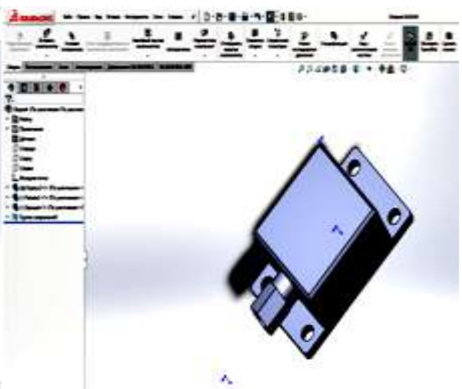


Figure 7: Modeling of the geomagnetic sensor plug: a) drawing; b) 3D model





a) b)

Figure 8: Assembly of the case geomagnetic sensor: a) assembly process; b) result of assembly

3.2 Modeling of the geomagnetic sensor temperature conditions

To realize modeling of temperature conditions for the geomagnetic sensor it is necessary to choose material of case from which it will be.

The choice of materials was carried out proceeding from three basic principles: operational, technological and economic which in total define economic and technical feasibility of material use.
At the choice of materials treat the basic principles:
- nature (metals, nonmetals) chemical structure and structure;
- thermodynamic characteristics;
- physical and chemical properties;
- mechanical properties;
- technological properties;
- properties of a working environment;
- economic feasibility.

As a result, it is defined that users of the geomagnetic sensor are people, professions which can be connected with extreme working conditions. In this case at the choice of materials it is necessary to consider all possible service conditions of a product [1].

Thus, we will allow the geomagnetic sensor it will be used in the aggressive environment conditions, then material has to possess high firmness characteristics to physical impacts, such as blows, pressure, sliding on rough surfaces, etc. Therefore the nomenclature of materials for cases is rather extensive, it can be solid metal, polymer or a composite.

However, proceeding from technological principle geomagnetic sensors do not demand materials with high esthetic properties where the idea of practicality, convenience and reliability is on the first place, it is rational to choose polymeric material.

On the basis of materials types and their characteristics analysis, it is defined that use of polymers allows to simplify and reduce the price of the production technology. Most of producers use this material, varying case thickness, its internal design applying various constructive decisions to increase in product rigidity and giving of the product set properties, etc.

Thus, it is defined that the polymeric case as metal though is stronger will be rational, but has small corrosion resistance in aggressive environment.

More rationally when modeling covers and cases of various electronic devices to choose materials, making a start from their properties which can influence in a varying degree operational characteristics of the device, from functions and service conditions of the designed electronic device.

Therefore are chosen: polybutylene-terephthalate, ABS + PC plastic and polyurethane.

To start modeling in a tab of the Flow Simulation module it is necessary to choose "Additions of SolidWorks". Further to select SolidWorks Simulation item, after addition of simulation the new Simulation tab will appear. In this tab it is necessary to create a new research and to choose type (for these researches thermal was chosen).

Then to set the reference temperature of a product or surface in the “Thermal Loadings” point (Fig. 9).

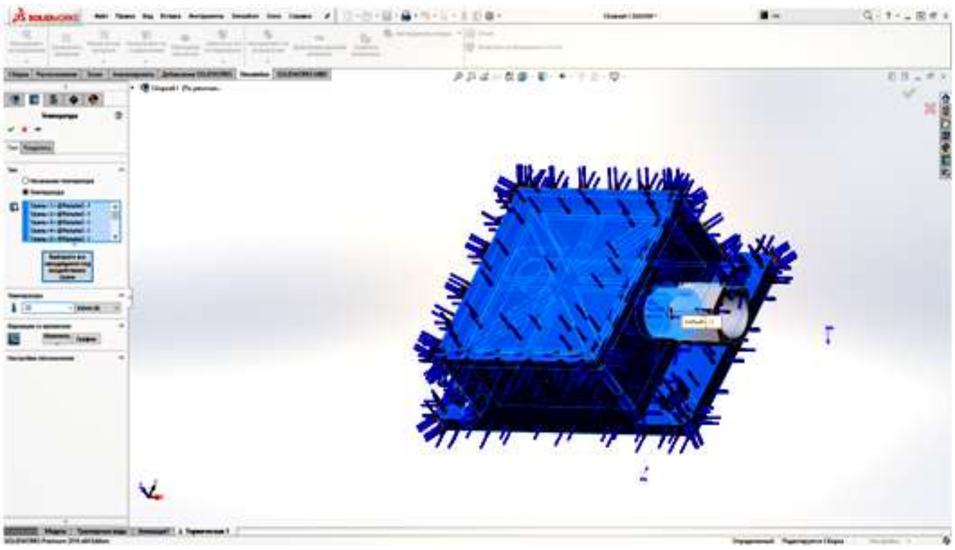
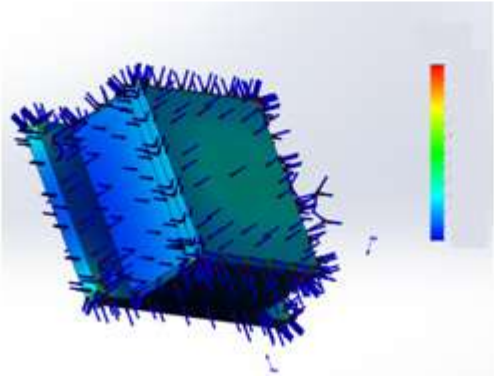


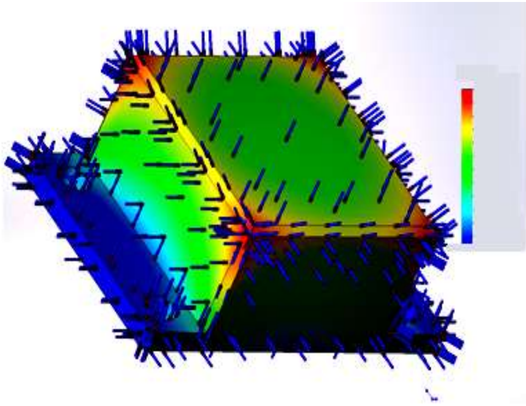
Figure 9: Exposure of reference temperature for simulation

In the “Thermal Loadings” point we set “Thermal Stream” property and we choose the square to which the thermal stream will extend (we set value of 2000 watts). After the creation procedure of a research we receive ready result with the chart (Fig. 10).

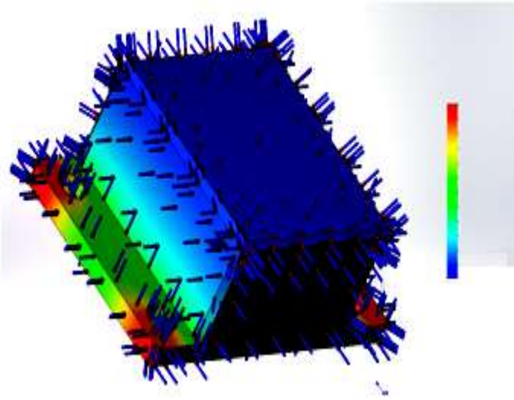
`Results of a research provided that cases of the geomagnetic sensor will be from the polybutylene-terephthalate (Fig. 10, a).



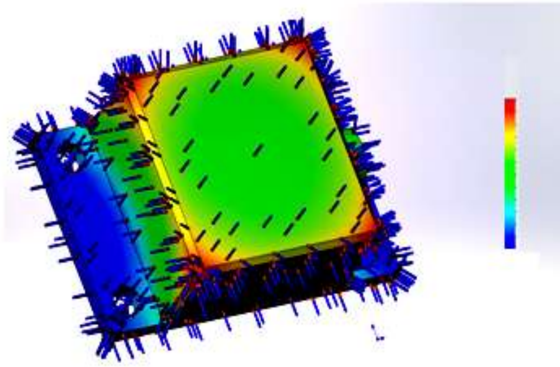
a)



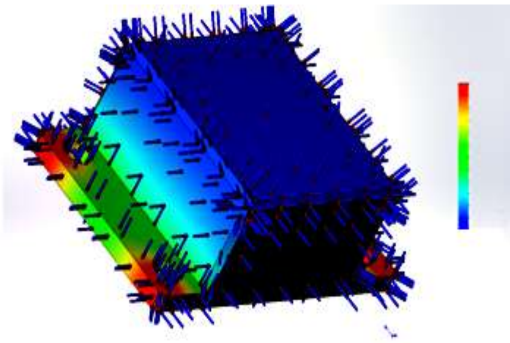
b)



c)



d)



e)

Figure 10: Modeling of temperature conditions

Researches were repeated with material ABS + PC plastic, but only now provided that the thermal stream is directed from above to case (Fig. 10, b).

Results of researches with ABS + PC plastic provided that the thermal stream is directed from below (Fig. 10, c).

Let's choose the following material and we will similarly conduct a research with polyurethane provided that a thermal stream of the directions from above on the case (Fig. 10, d).

Results of researches with polyurethane provided that the thermal stream is directed from below, data did not change (Fig. 10, e).

In fFg. 10, a, b, c, d, e "color scale" on which is located on the right deformations sites of the geomagnetic sensor case(red color) to sites which are practically not deformed under use conditions of such sensor in aggressive environment are specified from the most subject (they are shown on a scale in blue color).

IV. CONCLUSION

In work the 3D model of geomagnetic sensor case in the aggressive environment conditions is offered.

The choice of material for the case on condition of its operation in aggressive environment is carried out. Thus, ABC plastic is chosen as it: heavy-duty, has high stability of the sizes and a plain brilliant surface, the received details from this material; resistance to aggressive environment. Further the second analog – PUR polyurethane is chosen as it has a high stability and durability, resistance to atmospheric actions. PC-HT polycarbonate is chosen as the third analog as it possesses: special durability, impact strength and thermal firmness, this material keeps the properties even at + 100 - 110 °C).

On the basis of received 3D model the analysis "temperature fields" influence on case surface (surfaces the most subject to influence of temperatures – a stream of the directions from above and from below on the case are chosen), which showed that the created case from the chosen materials meets requirements of heat conductivity was carried out.

The received 3D model can be used further for optimization of the existing analogs that will allow to reduce significantly time for project works and to increase quality of cases.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the keen support for this work of the Department of Physics, Faculty of Science, University of Tabuk, Saudi Arabia and also the Department of Informatics, Kharkov National University of RadioElectronics, Kharkov, Ukraine [18-22].

REFERENCE

[1]. S. Tumanski, *Handbook of magnetic measurements* (CRC press, 2016).

[2]. D. Budker, and D. F. J. Kimball (ed.), *Optical magnetometry* (Cambridge University Press, 2013).

[3]. D. Haobin, and Z. Changda, A further review of the quantum magnetometers, *Chinese Journal of Engineering Geophysics*, *4*, 2010, 013-027.

[4]. J. D. Kana, N. Djongyang, D. Raïdandi, P. N. Nouck, and A. Dadjé, A review of geophysical methods for geothermal exploration, *Renewable and Sustainable Energy Reviews*, *44*, 2015, 87-95.

[5]. D. H. Giang, P. A. Duc, N. T. Ngoc, and N. H. Duc, Geomagnetic sensors based on Metglas/PZT laminates, *Sensors and Actuators A: Physical*, *179*, 2012, 78-82.

[6]. Y. Li, X. Zhang, G. Chen, X. Cui, and J. Liu, Design and error analysis of geomagnetic measurement circuit based on triaxial magneto-resistive sensor, In *Control, Automation and Systems Engineering (CASE), 2011 International Conference on* (pp. 1-3). IEEE.

[7]. L. Ding, J. Teng, X. C. Wang, C. Feng, Y. Jiang, et al., Designed synthesis of materials for high-sensitivity geomagnetic sensors, *Applied Physics Letters*, *96*(5), 2010, 052515.

[8]. B. Bai, H. Liu, J. Ge, and H. Dong, Research on an Improved Resonant Cavity for Overhauser Geomagnetic Sensor, *IEEE Sensors Journal*, *18*(7), 2018, 2713-2721.

[9]. L. Ding, J. Teng, C. Feng, W. Li, M. Li, et al., An all-metal material for high-sensitivity geomagnetic sensors with improved magnetic stability by magnetostatic coupling, *Journal of Physics D: Applied Physics*, *44*(38), 2011, 385001.

[10]. S. Syisoeva, Datchiki magnitnogo polya, *Komponentyi i tehnologii*, 1, 2012, 19-32.

[11]. P. Ripka, and M. Janosek, Advances in magnetic field sensors, *IEEE Sensors Journal*, *10*(6), 2010, 1108-1116.

[12]. D. Haobin, and Z. Changda, A further review of the quantum magnetometers, *Chinese Journal of Engineering Geophysics*, *4*, 2010, 013.

[13]. J. B. Brask, R. Chaves, and J. Kołodyński, Improved quantum magnetometry beyond the standard quantum limit, *Physical Review X*, *5*(3), 2015, 031010.

[14]. P. Butvin, M. Janošek, P. Ripka, B. Butvinová, et al, Field annealed closed-path fluxgate sensors made of metallic-glass ribbons, *Sensors and Actuators A: Physical*, *184*, 2012, 72-77.

[15]. R. Matarneh, S. Sotnik, N. Belova, and V. Lyashenko, Automated modeling of shaft leading elements in the rear axle gear, *International Journal of Engineering & Technology*, *7*(3), 2018, 1468-1473.

[16]. V. Lyashenko, R. Matarneh, and S. Sotnik, Modeling of Machine Design with Numerical Control in UG NX 7.5 System, *The International Journal of Engineering and Science (IJES)*, 7(7), 2018,: 28-37.

[17]. V. Lyashenko, S. Sotnik, T. Sinelnikova, and M. A. Ahmad, Methodology Modeling of Parts with Replaceable Hard Alloy Plates Types in the SolidWorks System,*Saudi Journal of Engineering and Technology (SJEAT)*, 3(3),2018, 119-126.

[18]. S. Sotnik, R. Matarneh, and V. Lyashenko, System Model Tooling For Injection Molding, *International Journal of Mechanical Engineering and Technology*,*8*(9), 2017, 378–390.

[19]. M .A. Ahmad, V. Lyashenko, V. Lyubchenko, A. Khan, and O. Kobylin, The Methodology of Image Processing in the Study of the Properties of Fiber as a Reinforcing Agent in Polymer Compositions, *International Journal of Advanced Research in Computer Science*, *7*(1), 2016, 15-18.

[20]. R. Matarneh, S., Sotnik, Z. Deineko, and V. Lyashenko, Highlights methodology of time characteristics optimization for plastic products production, *International Journal of Engineering & Technology*, *7*(1), 2018, 165-173.

[21]. V. Lyashenko, M. A. Ahmad, S. Sotnik, Zh. Deineko, and A. Khan, Defects of Communication Pipes from Plastic in Modern Civil Engineering, *International Journal of Mechanical and Production Engineering Research and Development*,*8*(1), 2018, 253-262.

[22]. A. Khan, S. Joshi, M. A. Ahmad, and V. Lyashenko, Some Effect of Chemical Treatment by Ferric Nitrate Salts on the Structure and Morphology of Coir Fibre Composites, *Advances in Materials Physics and Chemistry*,*5*(01), 2015, 39-45.

M. Ayaz Ahmad. " Design of the Geomagnetic Sensor Case in Aggressive Environment Conditions" The International Journal of Engineering and Science (IJES),), 7.10 (2018): 45-52