Energy distribution modelling in the weld zone for various electron beam current values in COMSOL Multiphysics

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Abstract. The presented work is devoted to the study of the effect of various values of the electron beam current on the distribution of the energy cross section of the weld when conducting the technological process of electron-beam welding of thin-walled structures. The work is used by the simulation system of COMSOL Multiphysics, in which mathematical models of energy distribution proposed by the authors are implemented with electron beam welding. Imitation modelling was carried out for two materials widely used in the aerospace industry: titan alloy BT14 and AMG aluminum alloy. The values of the parameters for which the simulation was carried out were selected as a result of the predetermined process of optimizing the technological mode of electron beam welding for the construction under study. In the process of the research, a change in the value of the electron beam current is carried out both in less and to the large side. The article presents visualization for the three values of the parameter under study for each material, which makes it possible to judge the effectiveness of the previously formed set of optimal parameter values.

1. Introduction
The enterprises of the rocket and space industry currently apply the most modern technologies at each stage of the process of producing air and space craft [1-3]. In particular, when creating an indefinite compounds, the method of electron beam welding was widely used [4-6]. However, in view of the complexity of such a technological process, enterprises spent large means for improving the quality of welded compounds, expressed in the need to carry out a large number of internally experiments to work out technological parameters [7-9].

One of the ways to significantly reduce the required number of field experiments is modelling the heating process of the welded elements of the equipment. Currently, the authors proposed a mathematical model [10, 11] of the temperature field in the process of electron beam welding, reflecting the distribution of energy and allowing to optimize the technological modes of ELC.

One of the ways to correct the constructed mathematical model is simulation modelling, for the implementation of which a number of software systems have been developed. One of the most popular media simulation tools is COMSOL Multiphysics [12-14]. Such a system is widely used worldwide both for modelling electromagnetic fields and for modelling thermal processes [15, 16]. In particular, Alloul, J et.al. investigated the transition thermal conductivity in a multilayer material [17], Singh D. et.al. investigated the model of a solid ceramic heat exchanger for the concentration of solar power.
plants [18], Zandi S. et.al. conducted numerical modelling of heat distribution in the solar cells from perovskite in contact with RGO [19].

2. Study of the influence of the electron beam current on the energy distribution

In order to study the impact of the behaviour of the mathematical model of the energy distribution proposed by the authors, a series of numerical experiments in the COMSOL Multiphysics system was carried out. As a product, on the example of which the distribution of thermal fields was investigated, 3D model of the assembly unit of the fine-walled aerospace product was implemented.

At the initial stage, a set of effective values of technological parameters of the process of electron-beam welding process (beam current, welding speed, focusing current, accelerating the voltage) of the above product, which realizes the effective and concentrated heating of the material in the weld zone for the formation of symmetric welded Baths without defects was selected. Next, the authors changed the values of the electron beam current to the smaller and most side to study the reaction of the proposed model.

Figure 1 presents visualization of modelling results in the COMSOL Multiphysics system for the product made of titanium alloy, and in figure 2 - for a product made from AMG6 aluminum alloy.

![Figure 1. Temperature distribution when heating TIT14 titanium alloy and different power.](image-url)
From the figures, it can be seen that with a decrease in the value of the electron beam current (figure 1a, figure 2a) relative to the effective (figure 1b, figure 2b), the temperature field becomes more blurred and uniform over the area of the weld zone, which leads to an increase in the width of the formed welded bath, as well as to a decrease in the depth of fusion. This leads to a decrease in the quality of the welded joint in the sense of strength.

With an increase in the value of the electron beam (figure 1c, figure 2c) relative to the effective (figure 1b, figure 2b), an increase in the concentration of energy in the joint zone occurs, which leads to excessive searches of the weld, as well as to the possible appearance of root defects due to the increased depth of the electron beam in the fusion zone. In addition, overheating by a thinner component of the product – cover, takes place.

3. Conclusion
The simulation modelling conducted in the framework of the study for two widespread materials used in the aerospace industry: titanium alloy BT14 and aluminum alloy AMG6 showed the efficiency of the energy distribution proposed by the authors of the mathematical model in the process of electron-beam welding. As a result of visualization by means of COMSOL multiphysics, the distribution of heat
fields in the welded zone for the three values of the electron beam current for each material, one can judge the effectiveness of the previously formed set of optimal parameter values.

The application of the proposed approach will allow in the future to continue to investigate the process of electron beam welding.

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