The use of ANSYS for modelling the energy distribution in steady mode with electron beam welding

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Abstract. The article is devoted to solving the problem of modelling the distribution of energy in the steady mode with electron beam welding with the means of ANSYS Academic Student. The authors propose the implementation of the simulation model to allow evaluating the density of the heat field in the assembly unit of the product when it is connected to its elements by means of electron beam welding. Two imitation models are implemented for one of the types of aerospace products, made of titanium alloy and aluminum alloy. Such models allow research to assess the effect of technological parameters of the process of electron beam welding on the heating intensity of the zone near the weld. A series of experiments with visualization of their results for various power values was carried out.

1. Introduction
Currently, the simulation is widely used in the technique to increase the efficiency of technological processes of various subject areas [1-3]. In particular, to improve the quality of the electron-beam welding process, many authors conducted mathematical modelling of this technological process in different modes and with different materials [4]. For example, the authors of [5] considered the multi-criteria optimization of the process of electron-beam welding using experimental data obtained on the basis of real technological processes on the billets of austenitic steel.

Methods of statistical data processing made it possible to obtain fairly accurate models of the process of electron beam welding, which describe the dependence of the geometry of welds on stainless steel on the parameters of the electron-beam welding mode. And, for example, the authors of [6] investigated the processes of the formation of the carriage channel at electron-beam welding with a full propagation of the material. As part of this study, a dynamic mathematical model was proposed, which allows to describe the formation of the reverse roller of the weld depending on the parameters of the technological process of electron beam welding. The mathematical model of evaporation processes, condensation, as well as diffusion of AMG-6 alloy with electron-beam welding with dynamic positioning of the electron beam is described in [7]. The developed model allows predicting the chemical composition of welds with electron beam welding. Verification of the model was carried out by comparison with the results of the analysis of the chemical composition of the regulation zones in the material. The development of electron-beam welding technology, the development of new methods for managing this technological process, spawned a wide range of electron beam effects to the surface of the welded parts. In [8], a differential equation of thermal conductivity is presented, which is a mathematical model of a whole
class of thermal conductivity phenomena. The study demonstrated the possibility of using the Green function to build heat models for electron beam welding with dynamic positioning of the electron beam. 

Also, the use of Green functions for modelling is presented in [9]. The authors of the work [10] developed an approach to modelling, which allows to predict the accumulation of errors in the additive production of large parts. Experimental verification of this model showed its quite high efficiency with a maximum error of 29%. High requirements for the quality of welded compounds in the aviation industry impose serious restrictions on the technologies used to create in-block connections. The use of electron beam welding is preferably in this field of industry, because Electron beam welding provides the narrowest melting area. In [11], modelling the technological process of electron beam welding using the Taguchi strategy with three levels of input values is given. The model is used to predict the tensile strength and hardness strength. Both estimates are optimized using gray relational analysis [12, 13].

Thus, the development of an energy distribution model in the steady mode with electron beam welding and its implementation in the framework of the simulation system to simplify the visualization and further interpretation of the results is an urgent task.

2. Modelling the energy distribution in the steady mode with electron beam welding in ANSYS
In this paper, the power model is applied, which represents the function written in the following form:

\[ Q = I \cdot U \cdot \eta \cdot 0.24 \]  

(1)

where \( U \) is accelerating voltage; \( I \) – beam current; \( \eta \) – efficiency factor.

To implement a simulation model, based on the proposed power function, the ANSYS Academic Student system is used, which is widely used in the study of physical processes in the technique [14-18].

In the process of experimental studies, the energy distribution was simulated in the ELS process for a thin-walled structure. The following technological parameters of the process were taken as the basis:

• Welding current, ma.
• Current focusing.
• Welding speed, rpm.
• Distance to electron-optical system, mm.

As part of the experiments, a change in welding power values in order to determine the effectiveness of pre-selected parameters was made. Products made of two materials were studied:

• Titanium.
• Aluminum.

Figures 1-2 present examples of visualization of the distribution of energy when changing the technological parameters for the design obtained by simulation in ANSYS, respectively, for titanium and aluminum alloys.
Figure 1. Temperature distribution when heating TIT14 titanium alloy and different power.
Figure 2. Temperature distribution when heating aluminum AMG6 alloy and at a given different power.

It can be seen from the figures that when the power changes down the increase, the heating is more intensive, and the temperature field is concentrated in the zone of the energy application - in the weld zone. However, for a thin-walled structure, which is an upper element of the built-in assembly, such a concentration leads to the appearance of defects in the welded joint. This conclusion is fair both for a product from titanium alloy and for products from aluminum alloy.

Reducing the electron beam power in the process of welding, according to the resulting simulation
models, leads to the distribution of energy over the entire surface of the product, including areas located at a significant distance from the welding zone, which leads to a distortion of the geometric characteristics of the welded bath and negatively affects the mechanical characteristics of the connections.

3. Conclusion
The article solved the task of modelling the distribution of energy in the steady mode with electronically radial welding with the means ANSYS Academic Student. During the work, the authors implemented a simulation model to estimate the density of the heat field in the assembly unit of the product when it is connected to its elements by means of electron-beam welding. Two imitation models were implemented for one of the types of aerospace products made from titanium alloy (BT14) and aluminum alloy (AMG6). Such models have allowed research to assess the effect of the technological parameters of the process of electron-beam welding on the heating intensity of the zone near the weld.

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