Заключение. Предложен новый подход к построению системы оптимизации параметров технологических операций процесса лазерной резки хрупких неметаллических материалов. Обратные связи по управлению формируются на основании алгоритмов построения нейрорегуляторов с применением интеллектуальной системы нового поколения для поиска оптимальной стратегии адаптации управления оборудованием согласно заданным критериям.

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DETERMINATION OF PARAMETERS OF LASER CUTTING OF DIAMONDS USING NEURAL-FUZZY NETWORKS

The properties of diamonds ensure stable operation of devices created on their basis under critical conditions and opens up new ways in the development of new technology. Laser cutting of diamond crystals is characterized by a number of advantages, which primarily include the ability to obtain narrow cuts combined with high productivity of the dimensional processing and wide the possibility of process automation. The distribution of temperature fields in diamond crystals under laser irradiation is the main characteristic, based upon which the determination of the parameters necessary for high-quality processing of this material becomes possible. Laser processing of diamonds can be modeled using the ANSYS finite element analysis software complex [1–6].

Currently, artificial neural networks provide the ability to effectively model complex relationships between the inputs and outputs of a system, and using the theory of fuzzy sets, it is also possible to reflect an arbitrary "input - output" relationship without using complex mathematical apparatus. At the same time, fuzzy modeling, like artificial neural networks, is effective when the processes under consideration are difficult to analyze using traditional methods. Both artificial neural networks and fuzzy systems are successfully used to study laser material processing processes [7].

It should be noted that neural network models can be overly demanding of data, specifically the volume and quality of data used for trining, and one of the main disadvantages of fuzzy models is that the process of defining fuzzy rules depends on the expert knowledge or experience of the researcher. These circumstances can lead to incorrect estimates and inaccurate results when modeling laser processing processes. These disadvantages of artificial neural networks and fuzzy models can be eliminated by integrating artificial neural networks into a fuzzy inference system. This approach provides the ability to train hybrid systems without involving experts.

Thus, hybrid networks allow combining the advantages of both approaches, while their joint application allows overcoming the main limitations of each of them [8–9]. The ANFIS system is an example of an effective implementation of the neuro-fuzzy approach. In this paper the modeling of laser cutting of diamonds was performed using the ANFIS neuro-fuzzy networks.

To construct neuro-fuzzy models, the results of a numerical experiment implemented in the APDL programming language were used. Finite element calculations in the ANSYS program of temperature fields formed during laser processing of diamonds were carried out in the APDL language using a model consisting of 45418 Solid 87 elements. For the calculations, the properties of diamonds given in the work [10] were used. The calculations were performed for a sample in the form of a rectangular parallelepiped with geometric dimensions of 2 × 3 × 1.5 mm.

In the DesignXplorer module of the ANSYS software complex, a face-centered version of the central compositional plan of the numerical experiment was formed for three factors (P_1–P_3): P_1 – processing speed V (m/s), P_2 – laser beam radius R (m), P_3 – laser radiation power density P_0 (W/m^2). In accordance with the experimental plan, calculations were performed for 15 combinations of input parameters. In this case, the temperature values T on the diamond surface in the center of the round laser beam were determined as the output parameter.

The training of the neuro-fuzzy system ANFIS was carried out for 50 epochs on a dataset obtained as a result of a numerical experiment. Diagrams showing the dependence of the maximum temperature on the processing parameters obtained using the hybrid intelligent system ANFIS are presented in Figures 1–3.

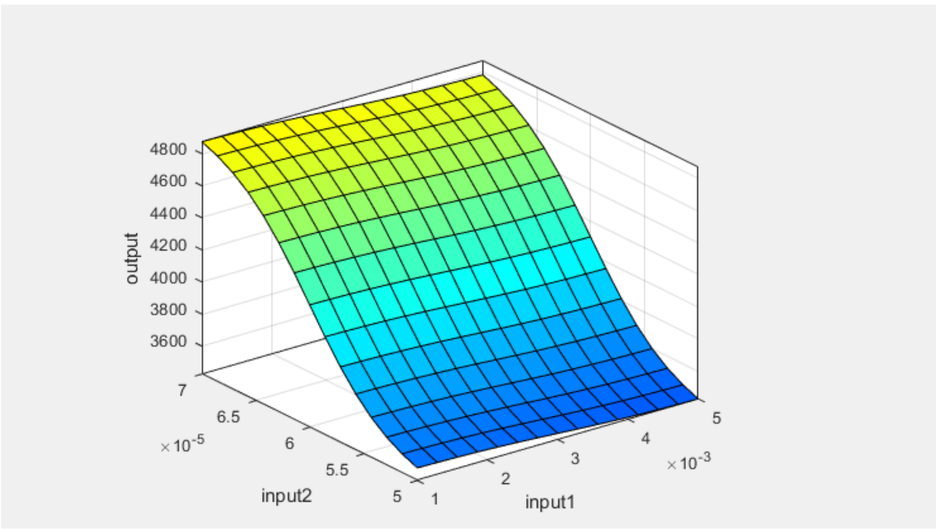

Figure 1 – Dependence of temperature T (K) on processing parameters input2 = R (m) и input1 = V (m/s)

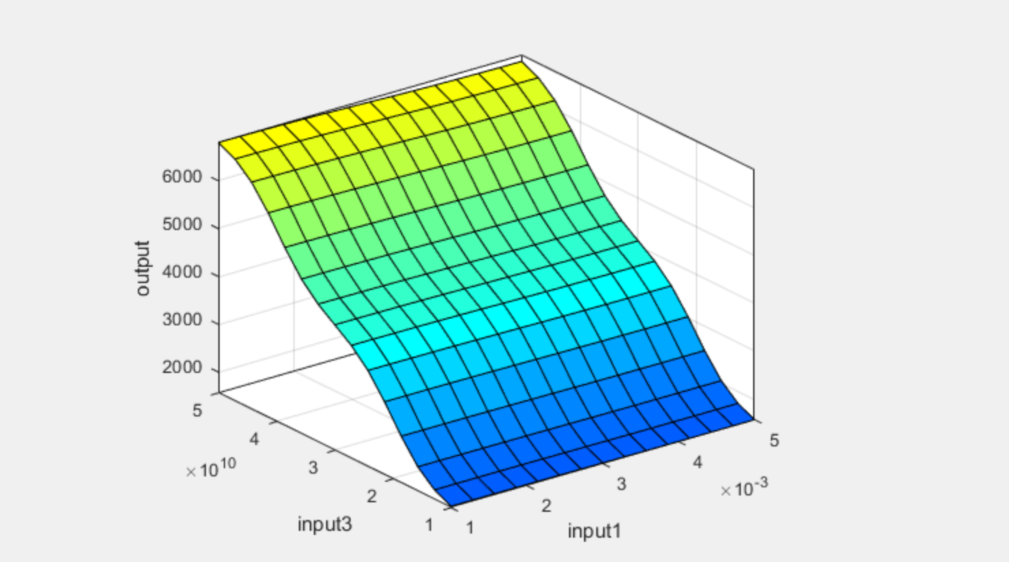

Figure 2 – Temperature dependence T (K) on processing parameters
input3 = P_0 (W/m^2) and input1 = V (m/s)

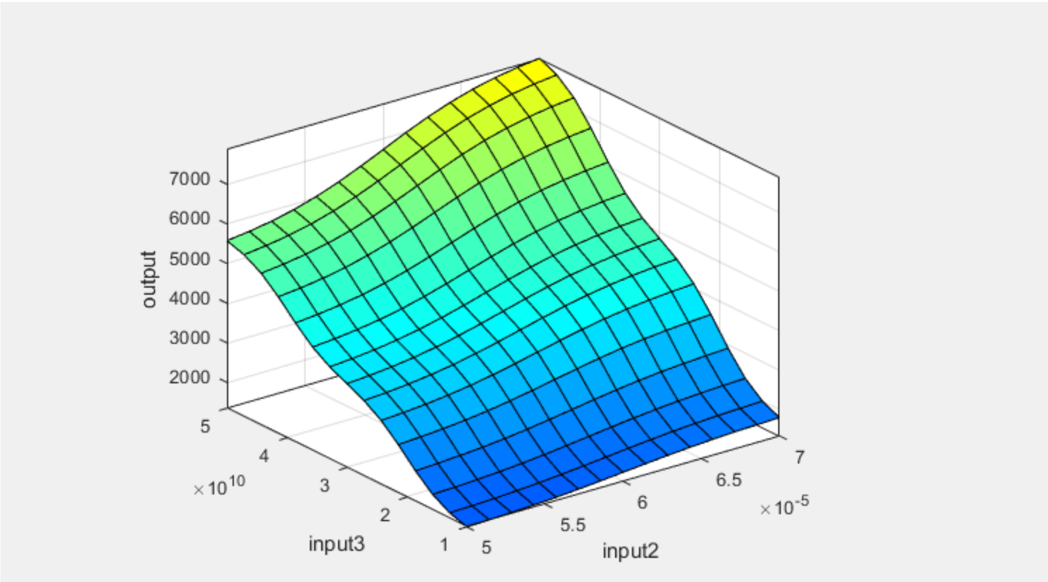

Figure 3 –Temperature dependence T(K) on processing parameters
input3 = P_0 (W/m^2) and input2 = R(m)

The test dataset was formed by solving the corresponding problems using the finite element method in the ANSYS software. The following criteria were used to evaluate the obtained neuro-fuzzy models: the determination coefficient R^2, the mean absolute error (MAE), the root mean square error (RMSE), and the mean absolute percentage error (MAPE).

The following netric values of the neuro-fuzzy model used to determine maximum temperatures were obtained: RMSE = 91.0 K, MAE = 86.7 K, MAPE = 2.0%, R^2 = 0.9961. The presented data allows to conclude that the neuro-fuzzy modeling results correspond to the finite element calculations.

The results of modeling of laser processing of diamonds using artificial neural networks, presented in the work [6], turned out to be somewhat better than the results of modeling using neuro-fuzzy networks. At the same time, an order of magnitude larger training set was required to form neural network models.

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