The calculation of a thermal field in the surface of a processed part under the influence of a low-temperature plasma

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Abstract: This paper presents the results of the calculation the thermal field distribution on the surface of processed part under the influence of a moving heat source (of the low-temperature plasma).

1. Introduction:
The most widespread task in the treatment with low-temperature plasma is to obtain specified characteristics (depth, width, heat treatment, etc.) depending on parameters of the heat source, i.e. the current, the arc voltage, the conveying speed, and other parameters of the regime. Moreover, as a rule, a necessity appears to receive the heat treatment with certain physical and mechanical properties [1].

2. Purpose:
In selecting of the treatment conditions is necessary to analyze of the nature heat distribution in detail, the evaluation of the characteristics of the thermal field is determined by the quality of the detail received. A method for determining the interconnection of parameters in complex processes is a mathematical modeling. This method is based on the fact that the study is not subject to the phenomenon of interest to us or a process, the study is subject a mathematical model - the image of a real object or display, building by means of mathematical relationships that establish a link between the defining characteristics of the object. Another important factor is the relatively low cost of the computational experiment as compared to physical.

3. Simulation:
Due to high temperatures and flows with a high concentration power the detailed experimental study and visualization of the temperature field distribution on the surface of processed part is associated with considerable difficulties. The visualization of the temperature distribution on the surface of processed part is necessary for quality control, and the heat treatment process. In the MathCAD was created by the distribution model of the temperature field on the surface of processed part by moving the heat source. Initial data for this model is the thermal characteristics and size of the material, the heat treatment parameters like the current, the voltage and the efficiency of the plant, which in turn affect the capacity of the heat source \( q \), the processing speed. The heating period in a moving coordinate system is not only a function the coordinates but also of the time. The temperature field in the heating stage is described by the formula [3]
\[
\Delta T(x, y, t_H) = \frac{q}{4\pi\lambda d} e^{-\frac{\nu x}{2a} t_H} \left[ 1 - e^{\frac{-v^2 t_H}{4a} \frac{r(x, y)^2}{4at}} \right]
\]

where
\begin{itemize}
  \item \(\lambda\) - the thermal conductivity;
  \item \(t_H\) - the duration of the heat source;
  \item \(q\) - the power the heat source;
  \item \(v\) - the conveying speed of the heat source;
  \item \(a\) - the thermal diffusivity.
\end{itemize}

The results of the model of the temperature distribution on the surface of processed part shown in Figure 1.

\textbf{Figure 1.} Computer modeling of the temperature field distribution on the surface of processed part in the program Mathcad. a - after 1 c, i - after 2 c, c - after 3 c, d - after 4 c.

According to the calculated data revealed that on the surface of the metal steel 40 formed a region in which the temperature is about 2000 K. Then conducted field tests confirm the theoretical calculations (Fig. 2) in particular band is observed with melting the metal from the plasma. Having a graphical representation of
the temperature field on the metal surface of the heat affected zone is defined and the structure of the metal after influence of the heat source.

Figure 2. Traces of melting on the surface of processed part after the low-temperature plasma treatment.

4. Conclusion:
On the basis of the above mentioned model, after receiving the picture of the distribution of the temperature field on the surface of processed part have the opportunity to choose the desired mode of processing, without conducting field experiments to determine the optimal treatment regime.

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