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Analytical and numerical model of laser welding phenomena with the initial preheating

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Abstract

The paper presents the analysis of stress state in flat elements of welded dual-beam laser. One of them (lower power) is used as a source of preheating, the second (main) as a source of welding. The temperature field is determined using the equation of heat conduction, which comprises a convection term and is solved by the Green function method. Temporary and residual stresses obtained from equilibrium equations solutions by FEM using the law nonisothermal plastic flow with isotropic strengthening and Huber-Misses condition plasticity. In the model was taken into account strain of phase transitions and transformation plasticity. The phase transformation model is based on the continuous cooling transformation diagram plotted for steel welded, as well as on the Avrami, Koistinen and Marburger equations. Thermomechanical parameter changes of material as a function of phase contents and temperature are considered.

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Keywords: laser welding; phase transformations; thermal and mechanical phenomena.

1. Introduction

Laser welding is a new technology and, increasingly used. There is no comprehensive numerical models which allow provide reliable assessment of phenomena that accompany to such a process of welding. Large speed welding and specific shape of weld, as the characteristic feature of laser welding, are reasons for the occurrence phenomena

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which are not occur in the conventional welding methods. Laser welding is performed for concentrated heat sources with high power. Near to this sources occurs a high temperature and its considerable gradients [1-4]. Temperature and phase transformations in welding elements are reasons to generated significant thermal and structural strains and in consequently to generate residual and temporal stresses.

Most of the papers dedicated to the technology of laser welding are focused on welding parameters and experimental data. Existing numerical models are concerned of selected phenomena such as temperature field, remelting zone and the heat affected zone [1,2,5]. Although in the works [1,2,6] proposed the models of the mechanical laser welding but has not been included n them the strain transformation.

Evaluation of the impact of structural changes on the strains and generating the stresses in the material welded is an important in technology. Mechanical properties and strength of welded joins are determined by stresses. Such an assessment is possible only when there are informations about the size and type of phase transformations occurring in the thermal cycle. Numerical models of phase transformations and stresses allow to avoid expensive researches in obtaining data for the optimal conduct welding of laser technique.

2. Model of thermal phenomena

Heat transfer equation with convective unit was used to modelling of thermal phenomena. The arguments of searched temperature fields are spatial coordinates (Euler coordinates) and time [7,8]:

$$a\nabla^2 T(\mathbf{x},t) - \frac{\partial T(\mathbf{x},t)}{\partial t} + \nabla T(\mathbf{x},t)\cdot \mathbf{v} = -\frac{Q}{C} \tag{1}$$

where: $T=T(\mathbf{x},t)$ is temperature [K], a is thermal diffusivity, C is specific heat capacity, Q is element of volumetric heat sources that takes into account the heat generation from the laser beam, $\mathbf{v}$ is the vector of velocity of the beam, $\mathbf{x}$ is the vector of position of considered particle (point), t is time [s].

Equation (1) is solved by methods proposed in [5]. This method is based on superposition of Green's functions. This solution applies to the geometry and configuration of sources which is shown in figure 1a.

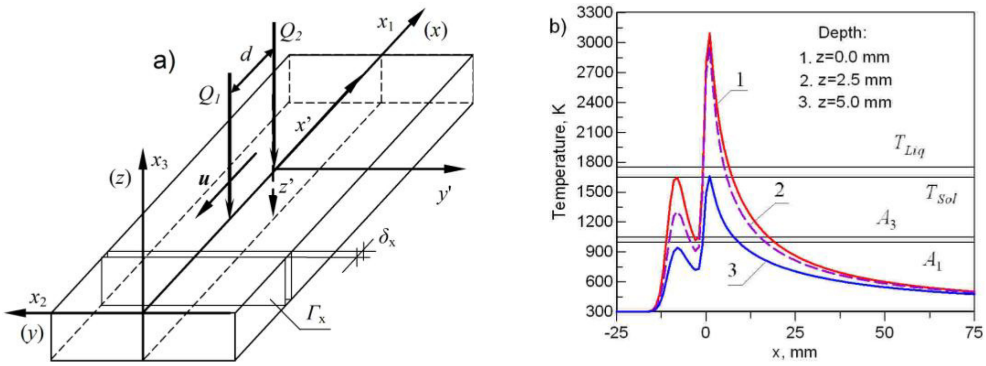

Fig. 1. (a) Scheme of considered system, (b) temperature distributions in central plane of heat source activity zones.

Two sources: first with a Gaussian distribution working at the distance $x' = -d$ from the second source. The distribution of second source has selected linear penetration (h_z), (it is assumed that establishing temperature distribution in consideration area is existed for time t and coordinate system $\{x',y',z'\}$ moves relative to system $\{x,y,z\}$ with speed $\mathbf{v}=\mathbf{v}(u,0,0)$) are determinated of field temperature in selected points.

$$Q_1(\mathbf{x}') = \frac{P_1(1-R)}{2\pi r^2}\exp\left(-\frac{(x')^2+(y')^2}{2r^2} - \beta|z'|\right),\quad Q_2 = \frac{P_2 H(z')}{h_z},\quad H(z') = \begin{cases} 1, & -h_z \le z' \le h_z \\ 0, & |z'| > h_z \end{cases} \tag{2}$$