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Plane Problem of an Interaction of Narrow Stamp with Base with A Triangle Shape Welded Joint in Elastic-Plastic Formulation

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Abstract

A generalized approach was developed for solving contact problems in a dynamic elastic-plastic formulation. For the design of metal constructions, a technique for solving dynamic contact problems in more adequate an elastic-plastic mathematical formulation is used. To consider the physical nonlinearity of the deformation process, the method of successive approximations is used, which makes it possible to reduce the nonlinear problem to a solution of the sequences of linear problems. The problem of a plane strain state of a beam which has a welded joint with triangle shape is being solved. The narrow hard body hits from above in the centre of welded joint. The beam which has the welded joint is rigidly linked to an absolutely solid base.

Keywords: Plane, strain, state, impact, welded, joint, elastic-plastic, deformation.

Introduction

The use of a generalized approach to solving dynamic contact problems in an elastic-plastic formulation makes it possible to use it to solve contact problems for a body of arbitrary shape, which is subjected to an arbitrary distributed over the contact zone or shock loading.

Current constructions have welded joints of different shapes and types.

In (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024), a new approach to solve the problems of impact and nonstationary interaction in the elastoplastic mathematical formulation was developed. In these papers like in non-stationary problems (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024), the action of the striker is replaced by a distributed load in the contact area, which changes according to a linear law. The contact area remains constant.

In (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024) dynamic interaction process of plane hard body and many layers reinforced composite material was investigated and the fields of summary plastic deformations and normal stresses arising in the base are calculated using plane strain (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024) and spatial (Bogdanov, 2024) states models. In (Bogdanov, 2023) and (Bogdanov, 2023) the problems of plane strain state of two-layer and four-layer composite reinforced base were solved corresponding. In (Bogdanov, 2024) the solution of the three-dimension problem of non-stationary interaction of narrow stamp and two-layer reinforced composite base is described. In (Bogdanov, 2024) the problem of plane strain state base which has a welded joint of rectangle shape was investigated. A narrow stamp acts from above in the centre of welded joint.

In contrast from (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024) and (Bogdanov, 2018; Mahnenko, 1976; Mahnenko, 2003; Mahnenko et al., 2009), in these papers, we investigate the non-stationary process of interaction of narrow hard body with base containing a welded joint of triangle shape and use dynamic elastic-plastic mathematical model.

The formulation of the problem does not take into account the significant degradation of the strength properties of the material in the heat-affected zone near welded joint. It is also assumed that the weld is free of martensites, which weaken the strength of the weld, and which are formed as a result of rapid cooling of the weld material. The composition of martensites includes crystalline impurities, which, during crystallization of the material, are forced out into the region close to the crystallization front of the molten material.

Problem Formulation

Deformations and their increments (Bogdanov, 2023), Odquist parameter $\kappa = \int d\varepsilon_i^p$ (ε_i^p is plastic deformations intensity), stresses are obtained from the numerical solution of the dynamic elastic-plastic interaction problem of infinite composite beam $\{-L/2 \le x \le L/2; 0 \le y \le B; -\infty \le z \le \infty\}$, in the plane of its cross section in the form of rectangle. It is assumed that the stress-strain state in each cross section of the beam is the same, close to the plane deformation, and therefore it is necessary to solve the equations for only one section in the form of a rectangle $\Sigma = L \times B$ with two materials: main material is steel $\{B/B_1 * y \le |x| \le L/2; -\infty \le z \le \infty; 0 \le y \le B\}$ and weld material $\{|x| \le B/B_1 * y; -\infty \le z \le \infty; 0 \le y \le B\}$. The contact between steel and weld material is ideally rigid. The base contacts absolute hard half-space $\{y \le 0\}$. We assume that the contact between the lower surface of the base and the absolute hard half-space is ideally rigid.

From above on a body the absolutely rigid drummer contacting along a segment $\{|x| \le A; y = B\}$. Its action is replaced by an even distributed stress in the contact region, which changes over time as a linear function $P = p_{01} + p_{02}t$. Given the symmetry of the deformation process relative to the line $x = 0$, only the right part of the cross section is considered below (Fig. 1). The calculations use known methods for studying the quasi-static elastic-plastic (Bogdanov, 2023; Mahnenko, 1976; Mahnenko, 2003; Mahnenko et al., 2009) model, considering the non-stationarity of the load and using numerical integration implemented in the calculation of the dynamic elastic model (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024).

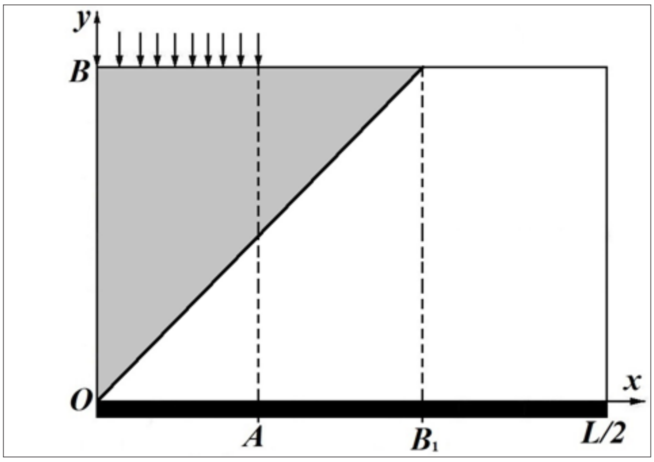

Figure 1: Geometric scheme of the problem

The equations of the plane dynamic theory are considered, for which the components of the displacement vector $u = (u_x, u_y)$ are related to the components of the strain tensor by Cauchy relations:

$$\varepsilon_{xx} = \frac{\partial u_x}{\partial x}, \quad \varepsilon_{yy} = \frac{\partial u_y}{\partial y}, \quad \varepsilon_{xy} = \frac{1}{2}\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right).$$

The equations of motion of the medium have the form:

$$\frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} = \rho \frac{\partial^2 u_x}{\partial t^2}, \quad \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} = \rho \frac{\partial^2 u_y}{\partial t^2}, \tag{1}$$

where p − material density.

The boundary and initial conditions of the problem have the form:

$$\begin{aligned} & x = 0,\ 0 < y < B: \ u_x = 0,\ \sigma_{xy} = 0, \\ & x = L/2,\ 0 < y < B: \ \sigma_{xx} = 0,\ \sigma_{xy} = 0, \\ & y = 0,\ 0 < x < L/2: \ u_y = 0,\ \sigma_{xy} = 0, \\ & y = B,\ 0 < x < A: \ \sigma_{yy} = -P,\ \sigma_{xy} = 0, \\ & y = B,\ A < x < L/2: \ \sigma_{yy} = 0,\ \sigma_{xy} = 0. \end{aligned} \tag{2}$$

$$\begin{aligned} & u_x\big|_{t=0} = 0,\ u_y\big|_{t=0} = 0,\ u_z\big|_{t=0} = 0, \\ & \dot{u}_x\big|_{t=0} = 0,\ \dot{u}_y\big|_{t=0} = 0,\ \dot{u}_z\big|_{t=0} = 0. \end{aligned} \tag{3}$$

The determinant relations of the mechanical model are based on the theory of non-isothermal plastic flow of the medium with hardening under the condition of Huber-Mises fluidity. The effects of creep and thermal expansion are neglected. Then, considering the components of the strain tensor by the sum of its elastic and plastic components (Bogdanov, 2023; Mahnenko, 1976), we obtain expression for them:

$$\varepsilon_{ij} = \varepsilon_{ij}^e + \varepsilon_{ij}^p, \ d\varepsilon_{ij}^p = s_{ij} d\lambda, \quad \varepsilon_{ij}^e = \frac{1}{2G} s_{ij} + K\sigma + \varphi. \tag{4}$$

Here $_{ij} = \sigma_{ij} - \delta_{ij}\sigma$ – stress tensor deviator; δ_{ij} – Kronecker symbol; E – modulus of elasticity (Young's modulus); G – shear modulus; $K_1 = (1-2\nu)/(3E)$, $K = 3K_1$ – volumetric compression modulus, which binds in the ratio $\varepsilon = K\sigma + \phi$ volumetric expansion (thermal expansion $\phi \equiv 0$); $\sigma = (\sigma_{xx} + \sigma_{yy} + \sigma_{zz})/3$ − mean stress; $d\lambda$ – some scalar function (Mahnenko, 1976), which is determined by the shape of the load surface and we assume that this scalar function is quadratic function of the stress deviator s_{ij} (Bogdanov, 2023; Mahnenko, 1976; Mahnenko, 2003; Mahnenko et al., 2009).

$$d\lambda = \begin{cases} 0 \quad (f \equiv \sigma_i^2 - \sigma_S^2(T) < 0) \\ \dfrac{3d\varepsilon_i^p}{2\sigma_i} \quad (f = 0, df = 0) \\ (f > 0 - \text{inadmissible}) \end{cases}, \tag{5}$$

$$d\varepsilon_i^p = \frac{\sqrt{2}}{3}\left(\left(d\varepsilon_{xx}^p - d\varepsilon_{yy}^p\right)^2 + \left(d\varepsilon_{xx}^p - d\varepsilon_{zz}^p\right)^2 + \left(d\varepsilon_{yy}^p - d\varepsilon_{zz}^p\right)^2 + 6\left(d\varepsilon_{xy}^p\right)^2\right)^{1/2},$$

$$\sigma_i = \frac{1}{\sqrt{2}}\left(\left(\sigma_{xx} - \sigma_{yy}\right)^2 + \left(\sigma_{xx} - \sigma_{zz}\right)^2 + \left(\sigma_{yy} - \sigma_{zz}\right)^2 + 6\sigma_{xy}^2\right)^{1/2}.$$

It should be noted that the developed algorithm makes it possible to use the function f in (5) not only in the form of a quadratic function (in this case, we obtain the plastic fluidity condition in the Huber-Mises form), however also in the form of a function containing terms of third and higher degrees. This statement requires further research.

The material is strengthened with a hardening factor η^* (Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2023; Bogdanov, 2024; Bogdanov, 2024; Mahnenko, 1976):

$$\sigma_S(T) = \sigma_{02}(T_0)\left(1 + \frac{\kappa(T)}{\varepsilon_0}\right)^{\eta^*}, \quad \varepsilon_0 = \frac{\sigma_{02}(T_0)}{E}, \qquad (6)$$

where T – temperature; κ – Odquist parameter, $T_0 = 20\ ^oC$, η^* – hardening coefficient; $\sigma_S(T)$ – yield strength after hardening of the material at temperature T.

Rewrite (4) in expanded form:

$$d\varepsilon_{xx} = d\left(\frac{\sigma_{xx} - \sigma}{2G} + K\sigma\right) + (\sigma_{xx} - \sigma)d\lambda, \ d\varepsilon_{yy} = d\left(\frac{\sigma_{yy} - \sigma}{2G} + K\sigma\right) + (\sigma_{yy} - \sigma)d\lambda,$$
$$d\varepsilon_{zz} = d\left(\frac{\sigma_{zz} - \sigma}{2G} + K\sigma\right) + (\sigma_{zz} - \sigma)d\lambda, \ d\varepsilon_{xy} = d\left(\frac{\sigma_{xy}}{2G}\right) + \sigma_{xy}d\lambda, \qquad (7)$$

In contrast to the traditional plane deformation, when $\Delta\varepsilon_{zz}(x, y) = \text{const}$, for a refined description of the deformation of the specimen, taking into account the possible increase in longitudinal elongation $\Delta\varepsilon_{zz}$, we present in its form (Bogdanov, 2023; Mahnenko, 1976):

$$\Delta\varepsilon_{zz}(x, y) = \Delta\varepsilon_{zz}^0 + \Delta\chi_x x + \Delta\chi_y y, \qquad (8)$$

where unknown $\Delta\chi_x$ and $\Delta\chi_y$ describe the bending of the prismatic body (which simulates the plane strain state in the solid mechanics) in the Ozx and Ozy planes, respectively, and $\Delta\varepsilon_{zz}^0$ – the increments according to the detected deformation bending along the fibres $x = y = 0$.

Solution Algorithm

Let the nonstationary interaction (Bogdanov, 2023) occur in a time interval $t \in [0, t_*]$. Then for every moment of time t:

$$\varepsilon_{xx}^e = \frac{\sigma_{xx} - \sigma}{2G} + K\sigma, \ \varepsilon_{yy}^e = \frac{\sigma_{yy} - \sigma}{2G} + K\sigma, \ \varepsilon_{zz}^e = \frac{\sigma_{zz} - \sigma}{2G} + K\sigma, \ \varepsilon_{xy}^e = \frac{\sigma_{xy}}{2G},$$
$$\frac{d\varepsilon_{xx}^p}{dt} = \left(\sigma_{xx} - \sigma\right)\frac{d\lambda}{dt}, \ \frac{d\varepsilon_{xy}^p}{dt} = \sigma_{xy}\frac{d\lambda}{dt}, \ \frac{d\varepsilon_{yy}^p}{dt} = \left(\sigma_{yy} - \sigma\right)\frac{d\lambda}{dt}, \ \frac{d\varepsilon_{zz}^p}{dt} = \left(\sigma_{zz} - \sigma\right)\frac{d\lambda}{dt}. \qquad (9)$$

For numerical integration over time, Gregory's quadrature formula (Bogdanov, 2023, Hemming, 1972) of order $m_1=3$ with coefficients D_n was used. After discretisation in time with nodes $t_k = k\Delta t \in [0, t_*] \ \ (k = \overline{0, K})$ for each value k we write down the corresponding node values of deformation increments:

$$\Delta\varepsilon_{xx,k} = B_1\sigma_{xx,k} + B_2\sigma_{yy,k} - \beta_{xx}, \ \Delta\varepsilon_{yy,k} = B_2\sigma_{xx,k} + B_1\sigma_{yy,k} - \beta_{yy},$$
$$\Delta\varepsilon_{zz,k} = \alpha_1\sigma_{zz,k} + \alpha_2(\sigma_{xx,k} - \sigma_{yy,k}) - b_{zz}, \ \Delta\varepsilon_{xy,k} = B_3\sigma_{xy,k} - b_{xy},$$
$$\beta_{xx} = b_{xx} - \alpha_2(b_{zz} + \Delta\varepsilon_{zz})/\alpha_1, \ \beta_{yy} = b_{yy} - \alpha_2(b_{zz} + \Delta\varepsilon_{zz})/\alpha_1, \ \beta_{zz} = -(b_{zz} + \Delta\varepsilon_{zz})/\alpha_1,$$
$$B_1 = \frac{\alpha_1^2 - \alpha_2^2}{\alpha_1}, \ B_2 = \frac{\alpha_2(\alpha_1 - \alpha_2)}{\alpha_1}, \ B_3 = \frac{1}{2G} + D_0\Delta\lambda_k,$$
$$\alpha_1 = \frac{1}{3}\left(K + \frac{1}{G} + 2D_0\Delta\lambda_k\right), \ \alpha_2 = \frac{1}{3}\left(K - \frac{1}{2G} - D_0\Delta\lambda_k\right),$$
$$b_{ij} = \frac{1}{2G}\sigma_{ij,k-1} + \delta_{ij}\left(K - \frac{1}{2G}\right)\sigma_{k-1} - \sum_{n=1}^{m_1} D_n\left(\sigma_{ij,k-n} - \delta_{ij}\sigma_{k-n}\right)\Delta\lambda_{k-n} \ \ (i, j = x, y, z). \qquad (10)$$

The solution of the system (10), gives expressions for the components of the stress tensor at each step [1]:

$$\sigma_{xx,k} = A_1\Delta\varepsilon_{xx,k} + A_2\Delta\varepsilon_{yy,k} + Y_{xx}, \ \sigma_{yy,k} = A_2\Delta\varepsilon_{xx,k} + A_1\Delta\varepsilon_{yy,k} + Y_{yy},$$
$$\sigma_{zz,k} = -\alpha_2(\sigma_{xx,k} + \sigma_{yy,k})/\alpha_1 - \beta_{zz}, \ \sigma_{xy,k} = A_3\Delta\varepsilon_{xy,k} + Y_{xy},$$
$$Y_{xx} = A_1\beta_{xx} + A_2\beta_{yy}, \ Y_{yy} = A_2\beta_{xx} + A_1\beta_{yy}, \ Y_{xy} = A_3 b_{xy}, \ A_3 = 1/B_3,$$
$$A_1 = B_1\Big/\left(B_1^2 - B_2^2\right), \ A_2 = -B_2\Big/\left(B_1^2 - B_2^2\right). \qquad (11)$$

Function $\psi = 1/(2G) + \Delta\lambda$, which is characterizing the yield condition, taking into account (8), (9) and (11) is:

$$\psi = \begin{cases} \dfrac{1}{2G} \quad (f < 0) \\ \dfrac{1}{2G} + \dfrac{3\Delta\varepsilon_i^p}{2\sigma_i} \quad (f = 0, df = 0), \\ (f > 0 - \text{inadmissible}) \end{cases} \qquad (12)$$

$$\Delta\varepsilon_i^p = \frac{\sqrt{2}}{3}\left(\left(\Delta\varepsilon_{xx}^p - \Delta\varepsilon_{yy}^p\right)^2 + \left(\Delta\varepsilon_{xx}^p - \Delta\varepsilon_{zz}^p\right)^2 + \left(\Delta\varepsilon_{yy}^p - \Delta\varepsilon_{zz}^p\right)^2 + 6\left(\Delta\varepsilon_{xy}^p\right)^2\right)^{1/2},$$
$$\Delta\varepsilon_{xx}^p = \Delta\varepsilon_{xx} - \Delta\varepsilon_{xx}^e, \ \Delta\varepsilon_{yy}^p = \Delta\varepsilon_{yy} - \Delta\varepsilon_{yy}^e, \ \Delta\varepsilon_{xy}^p = \Delta\varepsilon_{xy} - \Delta\varepsilon_{xy}^e, \ \Delta\varepsilon_{zz}^p = \Delta\varepsilon_{zz} - \Delta\varepsilon_{zz}^e,$$
$$\Delta\varepsilon_{xx}^e = \frac{1}{2G}\sigma_{xx} + \left(K - \frac{1}{2G}\right)\sigma, \ \Delta\varepsilon_{yy}^e = \frac{1}{2G}\sigma_{yy} + \left(K - \frac{1}{2G}\right)\sigma,$$
$$\Delta\varepsilon_{zz}^e = \frac{1}{2G}\sigma_{zz} + \left(K - \frac{1}{2G}\right)\sigma, \ \Delta\varepsilon_{xy}^e = \frac{1}{2G}\sigma_{xy}, \ \sigma = \frac{\sigma_{xx} + \sigma_{yy} + \sigma_{zz}}{3}.$$

Considering when calculating the value $\Delta\varepsilon_{zz}^p$, we found that its impact is so small that without reducing the accuracy of calculations can be considered $\Delta\varepsilon_{zz}^p = 0$.

To take into account (Bogdanov, 2023) the physical nonlinearity contained in conditions (12), the method of successive approximations is used, which makes it possible to reduce a nonlinear problem to a sequence of linear problems (Bogdanov, 2023; Mahnenko, 1976; Mahnenko, 2003; Mahnenko et al., 2009):

$$\psi^{(n+1)} = \left\{\psi^{(n)}p + \frac{1-p}{2G}, \text{ if } \sigma_{iS} < -Q; \ \psi^{(n)}, \text{ if } -Q < \sigma_{iS} < Q; \ \psi^{(n)}\frac{\sigma_i^{(n)}}{\sigma_S(T)}, \text{ if } \sigma_{iS} > Q\right\},$$
$$\sigma_{iS} = \sigma_i^{(n)} - \sigma_S(T), \qquad (13)$$

where Q – the value of the largest deviation of the stress intensity $\sigma_i^{(n)}$ in step n from the strengthened yield strength;
n – is the approximation number.

Unknown (Bogdanov, 2023; Mahnenko, 1976) $\Delta\chi_x, \Delta\chi_y$ and $\Delta\varepsilon_{zz}^0$ in (8) are determined from the conditions of equilibrium of even with respect to x normal stresses σ_{zz}.

$$\iint_\Sigma \sigma_{zz}(x, y)\rho dxdy = M_\rho, \ (\rho = 1, x, y), \qquad (14)$$

when $M_1 = M_x = M_y = 0$; where M_1 – projection on the axis O_z of the main vector of contact stresses, and M_x, M_y – corresponding projections of the main moment of the forces acting on the resistance (no torsion, as noted). Given the symmetry of the problem and $\sigma_{zz}(x, y) = \sigma_{zz}(-x, y)$ this equation in case of $p =\ x$ is satisfied automatically.

If we substitute (8) and (11) in (14), taking into account the symmetry of the integration domain with respect to x and the even of functions $\sigma_{xx,k}, \sigma_{yy,k}, b_{zz}$, we have $\Delta\chi_x = 0$. A system of linear algebraic equations is obtained for the calculation of $\Delta\varepsilon_{zz}^0, \ \Delta\chi_y$.

$$\Delta\varepsilon_{zz}^{0} L_{\rho 1} + \Delta\chi_y L_{\rho y} = \bar{M}_\rho, \ (\rho = 1, y),$$
$$\bar{M}_\rho = \iint_\Sigma \frac{\alpha_2\left(\sigma_{xx} + \sigma_{yy}\right) - b_{zz}}{\alpha_1} \rho r dx dy, \ L_{\rho r} = \iint_\Sigma \frac{\rho r dx dy}{\alpha_1}, \ (r, \rho = 1, x, y). \quad (15)$$

The stresses and strains used above were determined for each unit cell from the numerical solution at each point in time $t_k = k\Delta t$.

Numerical Solution

For problem solving the explicit scheme of the finite difference method was used with a variable partitioning step along the axes O_x (M elements) and O_y (N elements). The step between the split points was the smallest in the area of the different materials contact and at the boundaries of the computational domain. Since the interaction process is fleeting, this did not affect the accuracy in the welded joint layer, areas near the boundaries, and the adequacy of the contact interaction modelling.

The use of finite differences (Hemming, 1972) with variable partition step for wave equations is justified in (Zukina, 2004), and the accuracy of calculations with an error of no more than $0((\Delta x)^2 + (\Delta y)^2 + (\Delta t)^2)$ where Δx, Δy and Δt – increments of variables: spatial x and y and time t. A low rate of change in the size of the steps of the partition mesh was ensured. The time step was constant.

The resolving system of linear algebraic equations with a banded symmetric matrix was solved by the Gauss method according to the Cholesky scheme.

In (Weisbrod & Rittel, 2000), during experiments, compact samples were destroyed in 21 – 23*ms*. The process of destruction of compact specimens from a material of size and with contact loading as in (Weisbrod & Rittel, 2000) was modelled in a dynamic elastoplastic formulation as plane strain state, considering the unloading of the material and the growth of a crack according to the local criterion of brittle fracture. The samples were destroyed in 23*ms*. This confirms the correctness and adequacy of the developed formulation and model.

Figs. 2 – 10 show the results of calculations of one-layer specimens with triangle shape welded joint with a hardening factor of the materials $\eta^* = 0{,}05$. The steel specimen has in the centre iron welded joint. Contact between steel and iron is an ideal rigid. Calculations were made at the following parameter values: temperature $T = 50^o$C; $L = 60$ *mm*; $B = 10$*mm*; $b = 2B_1 = 3$*mm*; $\Delta t = 3.21.10^{-8}$ *s* ; $p_{01} = 8$ *MPa*; $p_{01} = 10$ *MPa*; $M = 100$; $N = 100$. The smallest splitting step was 0,01 *mm*, and the largest 0,9 *mm* ($\Delta x_{\min} = 0{,}02$ *mm*; $\Delta y_{\min} = 0{,}01$ *mm* (only the first layer); $\Delta x_{\max} = 0{,}9$ *mm*; $\Delta y_{\max} = 0{,}65$ *mm*); contact zone was equal $a = 2A = a_1 = 1.44$ *mm*.

Figs. 2, 3; 4, 5; 6,7 show the fields of the Odquist parameter κ, normal stresses σ_{xx} and σ_{yy} at the moments of time $t_1 = 2.56 \cdot 10^{-6}$ *s* and $t_2 = 2.63 \cdot 10^{-6}$ *s*, respectively.

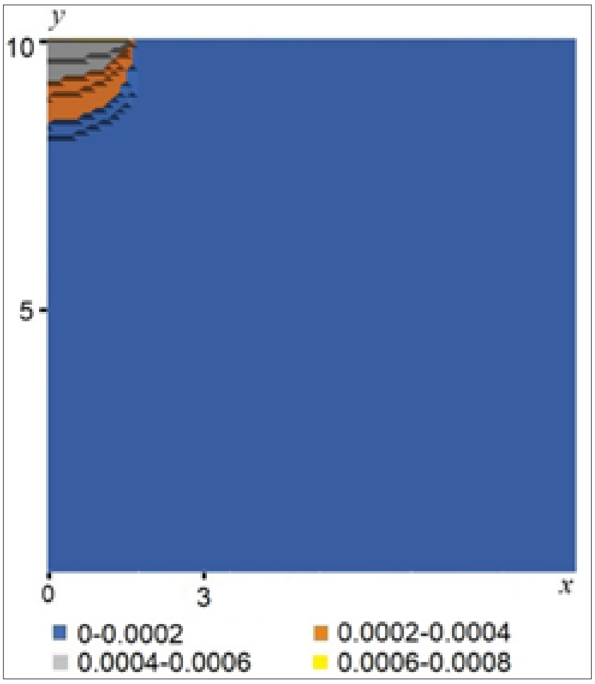

Figure 2: Odquist parameter K when $a = a_1$ and $t = t_1$

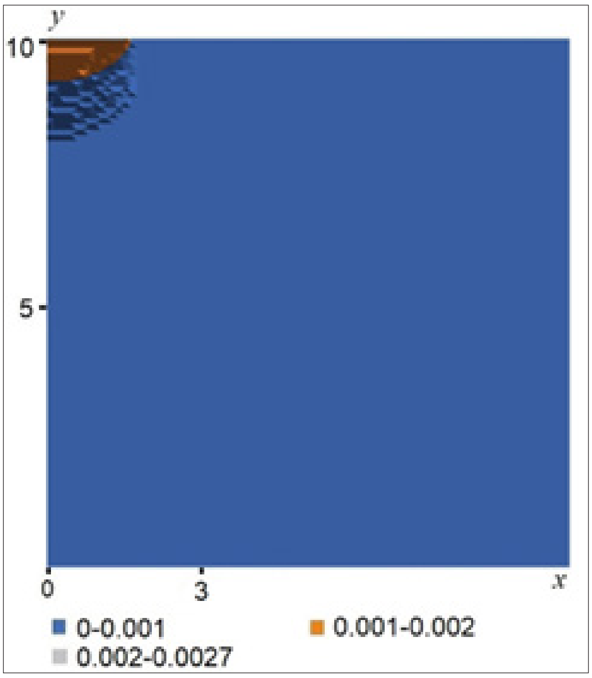

Figure 3: Odquist parameter K when $a = a_1$ and $t = t_2$

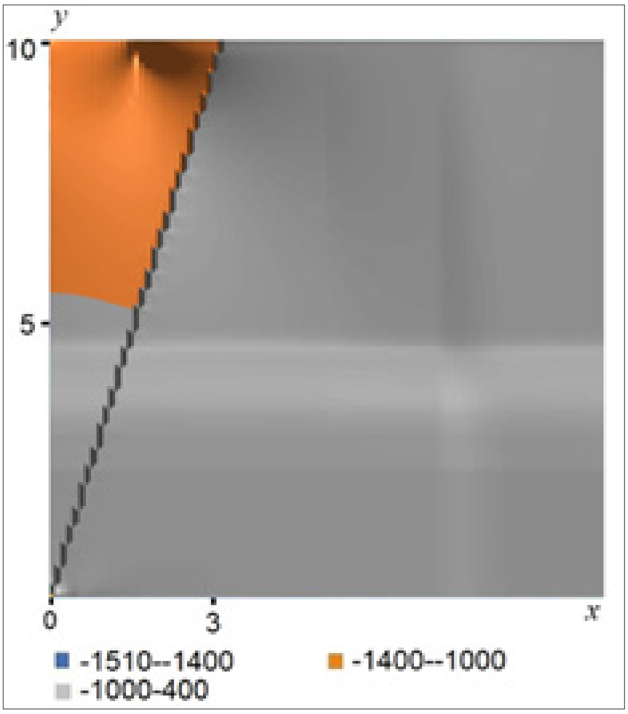

Figure 4: Stress σ_{xx} when $a = a_1$ and $t = t_1$

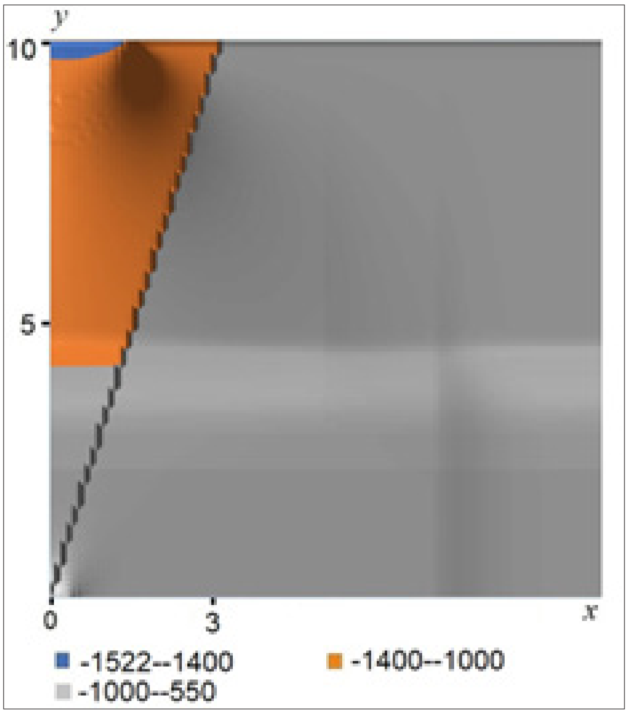

Figure 5: Stress σ_{xx} when $a = a_1$ and $t = t_2$

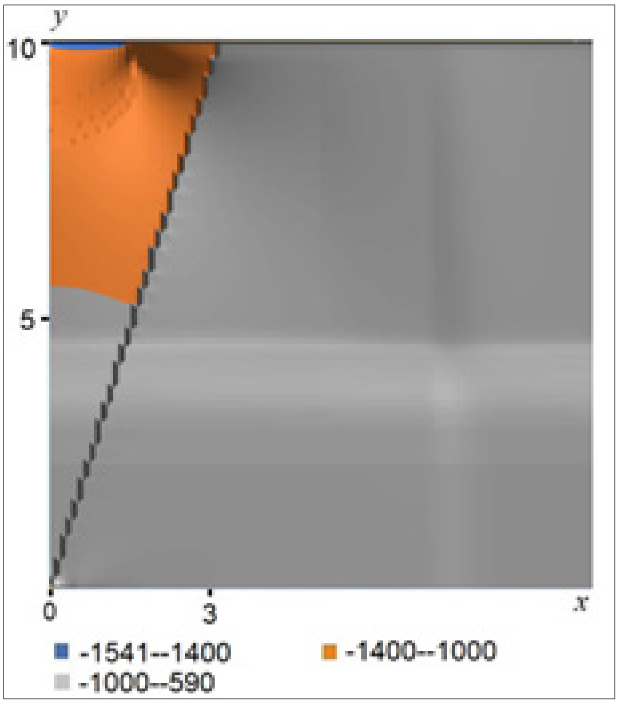

Figure 6: Stress σ_{yy} when $a = a_1$ and $t = t_1$

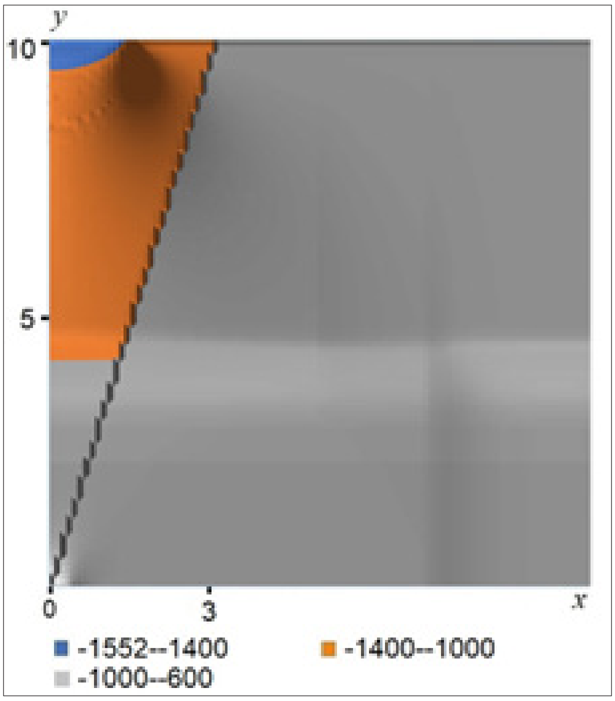

Figure 6: Stress σ_{yy} when $a = a_1$ and $t = t_2$

As can be seen from Fig. 2, 3, the greatest plastic deformations and stresses occur directly under the striker and in the area of welded joint.

Figs. 4 – 7 show that the highest stresses occur in the area close to the upper surface of the specimen and the process of accumulation of plastic deformations is more intense there. If compare base with triangle shape welded joint and base with rectangle shape welded joint [5] the plastic deformations appear earlier in case of triangle shape. This is explained by the fact that reflected waves from the boundary of the weld and the base material have a stronger effect on the process of non-stationary interaction between the stamp and the base.

Normal stresses have a wave nature and can be seen as to the left of the sloping boundary of the contact of materials, where the welded joint is located, the process of propagation of stress waves and resulting plastic deformations is more intense.

Conclusions

The developed methodology of solving dynamic contact problems in an elastic-plastic dynamic mathematical formulation makes it possible to model the processes of impact, shock and non-stationary contact interaction with the elastic base which has welded joint of triangle shape adequately. In this work, the process of non-stationary interaction of narrow hard body with welded joint of triangle shape. The fields of normal stresses and parameter Odquist which characterize a summary plastic deformations in the base are calculated.

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