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THE MODEL OF INTERACTION BETWEEN WHEEL AND SOIL WITH RHEOLOGIKAL PROPIETIES

Most of wheeled tractors and field machinery are known to cause physical changes in soil thus damaging its fertility. Modernisation of the wheel propelling agents or even a complete changeover to some more efficient technology having a permissible effect on soil can only be based on thorough studies of the wheel-soil interaction phenomenon. The satisfaction of this problem depends on a right choice of contact bodies rheological models and on an analytical or numerical solution of contact problem.

Until recently the physical and mechanical properties of soil and wheel had been described in terms of one or two parameters. Most of the studies had assumed wheel a rigid body and strained deformation in it was described by a linear ratio. However, experiments reveal that mechanical properties of a tyre and soil in the process of non-elastic deformation can be described by a greater number of values. Therefore, the actual process of body deformation in the contact area in their rheological models can be adequately described only with an account of all basic mechanical properties of wheel and soil. Studies with more complex models of wheel and soil provide a more adequate and true picture of deformation process.

An elastic wheel rolling upon a ground surface with elastic, tensile-strong and plastic properties is described in this study. Figure 1 represents the model of this ground surface.

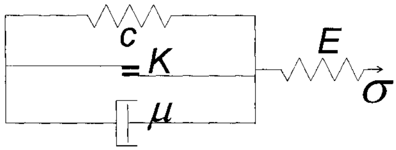

Fig. 1. The model of ground surface

The model is based on three principle mechanisms of ground deformation: elasticity, plasticity and tensile strength. The condition of ground plasticity is assumed of the form

$$\sigma - c\,e_r^p - \mu\,\dot{e}_r^p = k(P); \quad \dot{e}_r^p = \frac{de_r^p}{dt} \tag{1}$$

where:

σ – indicates strain in contact area, e_r^p – indicates plastic deformation, c - is modulus of strengthening, K – is coefficient of plasticity, P – is pressure, t – is time parameter.

Rheological equation describing strengthened and deformed state of ground in this case is assumed of the form

$$\mu\dot{\sigma} + (E_r + c)\sigma = E_r\,c\,e_r + \mu\,E_r\,\dot{e}_r + E_r\,k \tag{2}$$

where:

$\dot{\sigma} = \frac{d\sigma}{dt}$; E_r - indicates Young's modulus, e_r – is complete deformation composed of elastic deformation e_r^e and plastic deformation e_r^p.

The contact line (a_1, a_2) in the loading and unloading areas can be obtained by rotating the radius r in plane xy with a constant angular velocity ω, thus assuming that point M moves along the radius at the velocity proportionate to the distance OM (Fig. 2).

Let the point A correspond to the angles $\alpha = \beta = 0$. Let r_0 indicate the distant from the centre 0 to the point A. According to the assumption made the loading area can be described:

$$\frac{dr_1}{dt} = m_1 r_1 \qquad (3)$$

And the unloading area:

$$\frac{dr_2}{dt} = m_2 r_2 \qquad (4)$$

Provided $m_1 = m_2 = 0$ the problem of a rigid wheel rolling over a deformed ground appear. After integration the equations (3) and (4) take the following form:

$$r_1 = r_0 \cdot e^{m_1 t}; \qquad r_2 = r_0 \cdot e^{m_2 t} \qquad (5)$$

or

$$r_1 = r_0 \cdot e^{\delta_1 \alpha}; \qquad r_2 = r_0 \cdot e^{\delta_2 \beta} \qquad (6)$$

where $\delta_i = m_i / \omega$ is no-size value (i = 1, 2). Relation between r_1 and r_2 can be written down as follows:

$$r_2 = r_1 \, e^{(\delta_2 \alpha - \delta_1 \beta)} \qquad (7)$$

This first equation in (6) can obtain the following form (refer to Fig. 2);

$$r - h_r = r_0 \cdot e^{\delta_1 \alpha} \qquad (8)$$

where h_r is radial transfer of the wheel's point during the deformation process.

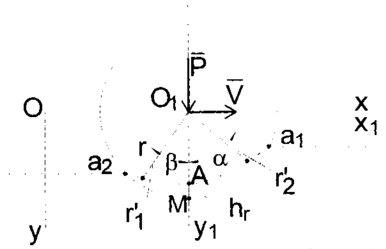

Fig. 2. The schematic diagram of interaction between wheel-soil by using ratios

$$\dot{\sigma} = \frac{d\sigma}{dx}\dot{x}; \qquad \dot{e} = \frac{de}{dx}\dot{x} \qquad (9)$$

and assuming that $\dot{x} = -v$ equation (2) is of the form:

$$\sigma^* = E_r \cdot e_r^* \qquad (10)$$

where $$\sigma^* = \left[(E_r + c) \cdot \sigma - \frac{1}{c} v \mu \frac{d\sigma}{dx} - \frac{1}{c} E_r \mathrm{K} \right]$$

$$e_r^* = e_r - \frac{1}{c} v \mu \frac{de_r}{dx}$$

After necessary transformations:

$$\sigma^* = \frac{\sqrt{(\zeta_0 + a_1) \cdot (a_2 + \zeta_0) \cdot (1 + P_w)}}{N \cdot \pi \cdot \left[r_{1(2)} (1 + P_w) - \Gamma \sqrt[4]{P^3} \right]} \int_{-\alpha_2}^{\alpha_1} \frac{\varsigma \, d\varsigma}{(\varsigma + a_1)(a_2 + \varsigma)} \qquad (11)$$

Where $N = \frac{E_r \, E_{sh}}{12}$ and ς_0 is a contact point. From (10) with respect to (11) true strain is obtained:

$$\sigma = \left(E_r + \frac{\mathrm{K}\, E_r + \mu \omega \sigma^*}{E_r - c} \right) \left[1 - e^{-\frac{E_r - c}{\mu \nu}(a_1 - \varsigma)} \right] \tag{12}$$

Thus the dependence of pressure σ on ground and tyre properties can be expressed by formula (12). Figure 3 represents the graph of dependence of the radius r'_p on the values of the coefficient Γ and the angle α for values of the stress concentration coefficient i.e. $\nu = 3, 4, 5$. Other values assumed are $P_w = 400$ N; $P = 300$ N.

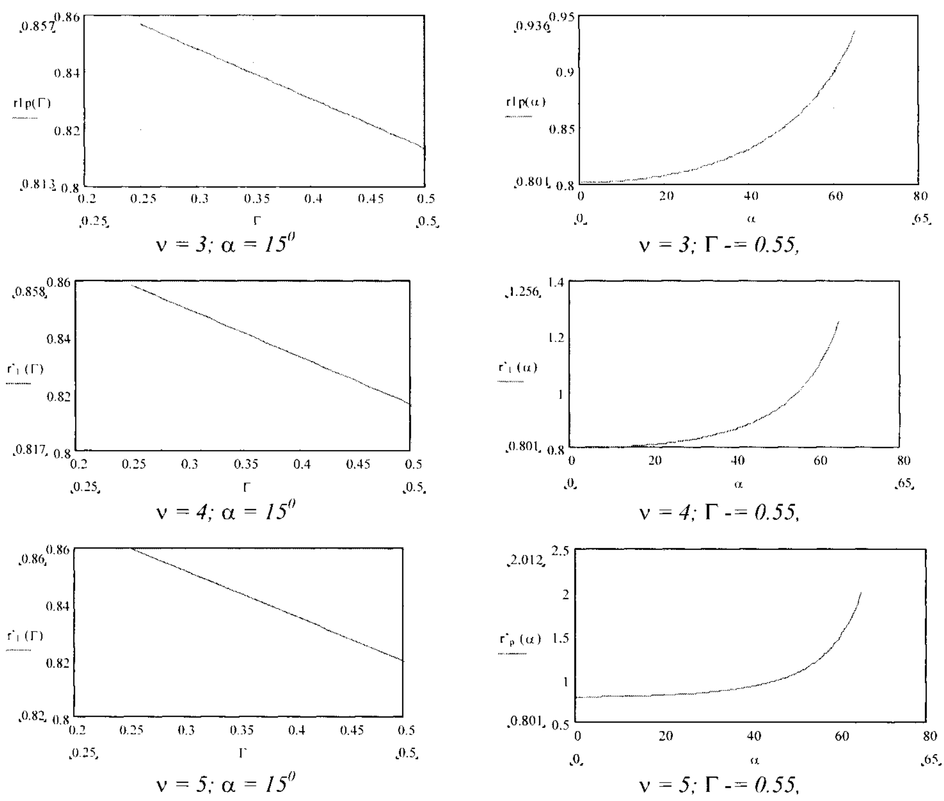

Fig. 3. Dependence of the radius r'_p on the values of the coefficient Γ and the angle α for various values of the stress concentration coefficient

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