mode of pneumatic percussion device operation. Sharp change in air consumption of МО-9П hammer at pressing force less than 260 Н is explained by relative shift of helve, spring-loaded valve and case during operation. Decreasing pressing force helve and valve withdraw from hammer intermediate link, because of this efficient square of admission port reduces.

Conclusion

The regularities of changes in energy parameters and compressed air consumption of hand hammers at changing air parameters in the system and pressing force have been experimentally stated.

When increasing the temperature of compressed air, the energy characteristics, maximum and per-exhaust air pressure in the back chamber grow. The lower the pressing degree and maximum air pressure in the back chamber, the higher the growth of stroke energy and power. Among the types of hammers under study the most significant growth of energy power is observed in hammers of M types having relatively large volume of clearance space and low degree of air compression in the back chamber.

At heating the compressed air its consumption decreases sufficiently. The degree of saving in compressed air is not the same for different types of hammers, the more the payload volume and the less the stroke frequency, the higher the degree of saving in compressed air.

In production and operation of pneumatic percussion mechanisms of hammers and drills the influence of temperature of compressed air on its consumption and device operation should be taken into account.

Using hot compressed air or its special heating is characterized by high energy efficiency, for hammers of M type in particular.

Increase in pressing force on hammer helve is accompanied by the growth of compressed air consumption to the definite level. This level which corresponds to beginning of quasi-stationary operation mode is mainly determined by the value of shaking force in hammer. In hammers having valve intake in the helve, air consumption changes sharply and significantly at changes in pressing force up to limit value.

REFERENCES

1. Karabin A.I. Compressed air. – Moscow: Machinostroyeniye, 1964. – 343 p.
2. Hand pneumatic hammers / Edited by V.F. Gorbunov [et all]. – Moscow: Machinostroyeniye, 1967. – 184 p.

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DYNAMIC MODEL OF ELASTOPLASTIC CONTACT INTERACTION OF SMOOTH BODIES

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Dynamic model of introducing rigid smooth sphere into homogeneous elastoplastic hardenable solid body has been considered. On the basis of the model numerical-analytical dependencies describing the behaviour of solid body in elastoplastic region of contact interaction were suggested. The numerical-analytical dependencies allow us to take into consideration additional approach of contacting bodies owing to dynamic loading.

Demands of modern technology for construction design possessing mechanical reliability at low material consumption lead to development of optimal design in strength taking into account contact deformation. In terms of improvement of physical and mechanical concept on destruction mechanism of solid bodies the section of deformable body mechanics called fracture mechanics has been formed within the last three decades.

Creation of fracture mechanics made possible to interpret the processes of contact interaction from absolutely new point of view. Geometric localisation (in the contact region) of all forms of deformation (elastic and plastic) and destruction is known to be characteristics for contact interaction of solid bodies. Being at first local, destruction can then progress catastrophically and result in break of a sample or a detail. At present it is generally accepted that more than 80 % of failures in mechanisms, machines and devices are conditioned by the processes taking place in the contact zone of solid bodies. Investigations in this field as well as in strength tests are concerned with study of behaviour of material surface layers at impression of one body (indenter) into another. The strength tests provide information on mechanical properties of material and in study of this phenomenon significant success has been achieved. Investigations of fracture mechanics is wrongly paid little attention, which is obviously explained by complexity of formation and growth processes of surface fractures and absence of corresponding theoretical methods of analysis. However, study of contact destruction is of great scientific and practical importance.

The case of contact of spherical indenter of R radius with elastic half-space under the action of force P, the so-called Hertzian contact or Hertzian loading (Fig. 1) is the best studied and widely used one in practice.

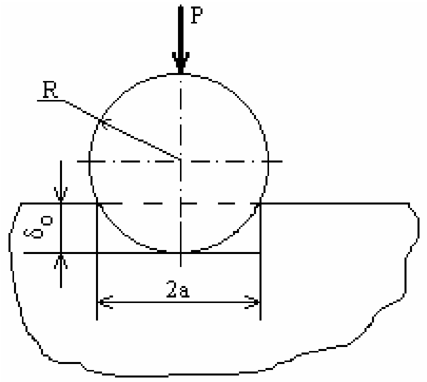

Fig. 1. *Introduction of spherical indenter into elastic half-space (the Hertzian contact)*

According to the Hertzian theory the body approach δ_0 is the power function of contact load P [1], i. e.

$$\delta_0 = kP^{2/3},$$

where $k = 2\frac{(1-\mu^2)}{E}$, E, μ is the elastic constant, elasticity normal module and the Poisson's ratio respectively.

In increasing contact load P there appears plastic deformation for the first time, which then extends gradually both in depth and to the surface of a rider. At some value of load the Hertzian dependence is disturbed on the surface of rider. After removing the load elastic recovery of the rider material takes place and general approach decreased by the δ_y value of rider becomes equal to $\delta_{пл}$ (Fig. 2).

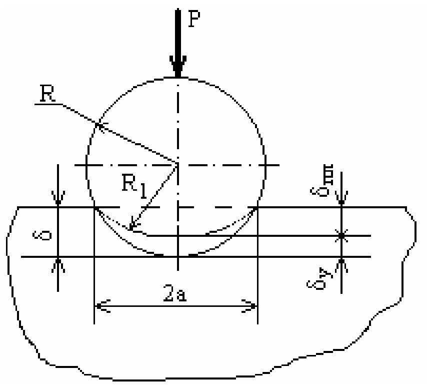

Fig. 2. *Scheme of introduction of rigid ball into flat boundary of elastoplastic rider*

With the advent of residual impression on the contact surface elastic deformations are known to continue following the dependencies of the elasticity theory, however, it is obvious that in this case conventional «elastic» formulas have to be corrected in accordance with new conditions of contact. Fundamental difference of these conditions from those of purely elastic contact of bodies consists in the fact that in the presence of residual impression the circle of R radius contacts not in the point, but with the surface of residual impression, the curvature radius of which is equal to R_1 (Fig. 2).

To determine the magnitude R_1 let us take the following assumptions:

1) after removing load spherical form of imprint does not change;
2) form of impression under load and after unloading in the planes of main curvatures are outlined by the circle of R_1 radius;
3) surface of rider is not deformed without contact.

Based on the proceeding correction to the Hertzian formula, including influence of rider plastic deformation in the contact region on the value of elastic approach, can be calculated by the formula [2]:

$$\Omega = \left(1 + \frac{\delta_{пл}}{\delta_y}\right)^{1/3}, \qquad (1)$$

where δ_y is the elastic constituent of complete approach; $\delta_{пл}$ is the plastic constituent of complete approach.

Finally, we have

$$\delta_y = \frac{\delta_0}{\Omega},$$

or taking into account the formula (1)

$$\delta_y = k^{3/2}\,(P\pi R\mathrm{H})^{1/2}, \qquad (2)$$

Approach, corresponding to appearance and presence of plastic deformation, can be calculated by the formula [3]:

$$\delta_{пл} = \frac{P}{2\pi R\mathrm{H}}, \qquad (3)$$

Complete approach in elastoplastic contact of circle with rider consists of two summands, residual approach $\delta_{пл}$, equal to the depth of residual imprint, and elastic approach δ_y, disappearing after removing the load due to elastic recovery of rider. Thus,

$$\delta = \delta_y + \delta_{пл}. \qquad (4)$$

Substituting the values of elastic and residual approaches from the formulas (2) and (3) into the equation (4) respectively, we obtain:

$$\delta = \alpha P + \beta(\gamma P)^{1/2}, \qquad (5)$$

where $\alpha = \frac{1}{2\pi R\mathrm{H}}$; $\beta = k^{3/2}$; $\gamma = \pi R\mathrm{H}$.

The formulas presented above permit the calculation of complete approach in elastoplastic contact at static loading. In some cases contact of solid bodies occurs at dynamic, in particular shock loading. Dynamics of loading is characterised by either shock velocity or deformation rate, or stress rate, which depends on rate of load application. At elastoplastic contact of materials under the condition of dynamic loading additional approach takes place that can result in changes of mechanical properties of the surface. Elastic contact occurs rarely at the initial collision of solid bodies, especially materials. Analysis of stress state of material at dynamic elastoplastic introduction of rigid indenters into it represents a very complex problem; the investigations in this field are being continued. The absence of common methods of construction in solution of non-linear problems leads to necessity of developing efficient approximate numerical-analytical methods.

In many mechanic systems motion is described by non-linear differential equations. The model of contact interaction considered in the paper is non-linear; therefore, differential equation of motion under the condition of free oscillations has the view:

$$m\ddot{x}+P(x)=0,$$

where $x=\delta$, but $P(x)$ is expressed from the formula (5). Taking into account the mentioned above the differential motion equation of rigid plain sphere along elastoplastic half-space at shock will have the view:

$$m\ddot{x}+a_1\sqrt{x}+a_2 x=0,$$

where $a_1=-\frac{\beta\gamma^{1/2}}{\alpha^{3/2}}$; $a_2=\frac{1}{\alpha}$.

Considering that at the initial moment of collision $\frac{dx}{dt}=v_0$, after the first integration one can find the velocity of approach in the form

$$\frac{dx}{dt}=\sqrt{v_0^2-\left(\frac{4a_1x^{3/2}}{3m}+\frac{a_2x^2}{m}\right)}. \qquad (6)$$

The most value of the approach magnitude is achieved at the moment when $\frac{dx}{dt}=0$. Solving the equations (6) one can calculate the value of dynamic approach, maximum shock force and maximum pressure in the centre of contact. To calculate the shock duration division of variables in the equation (6) is performed, and then integration from the beginning of shock to the moment of maximum approach is made

$$t=\pm\int_0^{x_{max}}\frac{dx}{\sqrt{v_0^2-\left(\frac{4a_1x^{3/2}}{3m}+\frac{a_2x^2}{m}\right)}}. \qquad (7)$$

Solving the given dependence and approximating the obtained solution one can plot the dependencies $x(t)$ and $P(x)$ at any moment of collision.

If one takes the value of initial velocity equal to zero ($v_0=0$), then one can calculate static elastoplastic value of approach. Solution has the form:

$$x=\left(\frac{2a_1}{3a_2}\left[\sin\left(\frac{t\sqrt{a_2}}{2\sqrt{m}}-\frac{\pi}{2}\right)+1\right]\right)^2. \qquad (8)$$

Values calculated by the formula (8) are similar to those calculated by the formula (5).

In conclusion it should be noted that the given numerical-analytical method makes possible to calculate the parameters of contact hardness and strength both in the conditions of static and dynamic loading. Application of this algorithm allows estimation in influence of elastoplastic deformation on contact strength for the case of collision of rigid plain ball with plain elastoplastic half-space. The proposed numerical-analytical method of calculation can also be used for design of elastoplastic contact interaction of rough bodies. For this purpose it is necessary to take into account the microgeometry parameters of contacting bodies in the formula (5).

REFERENCES

1. Timoshenko S.P., Gurier J. Elasticity theory. – Moscow: Nauka, 1975. – 567 p.
2. Drozd M.S., Matlin M.M., Sidyakhin Yu.I. Engineering calculations of elastoplastic contact deformation. – Moscow: Machinostroyeniye, 1986. – 220 p.
3. Koteneva N.V. Elastoplastic contact of smooth sphere with flat surface ay dynamic loading // Bulletin of Tomsk Polytechnic University. – 2005. – V. 308. – № 2. – P. 114–116.

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