SCOPE FOR FORECASTING ALLOY PIERCING RESISTANCE

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There are various serious difficulties in deriving the physicomechanical characteristics of constructional materials at elevated deformation rates if traditional test methods are used. Practical interest attaches to deformation rates over 10^3 $\sec^{-1}$, and this has led to the development of a phenomenological approach. The first attempt was made in [1] to relate the mechanical characteristics at deformation rates of 10^4-10^5 $\sec^{-1}$ to the piercing characteristics.

Piercing curves are the most widely used of the phenomenological relationships for obstacle piercing, which relate the critical piercing speeds to the parameters of the target and projectile [2]. The post-critical behavior of the projectile-target pair has been represented [3-6] as relationships between the exit velocity v_- and the entrance velocity v_+, or the velocity loss $\Delta v = v_+ - v_-$ as a function of v_+ for various target thicknesses and projectile dimensions.

Also, in [1] we find dimensionless relationships of v_-/v_* or v_+/v_*.

Here we make a systematic study of the relationships for alloy piercing at postcritical speeds in order to demonstrate that one can forecast piercing resistance in various coordinates, which provides a connection with the strength characteristics at high deformation rates. The studies were made for D16T aluminum alloy and VT-20 and OT-4-1 titanium alloys. Normal piercing of targets of thickness from 2 to 10 mm was provided by ball projectiles made of ShKh15 steel of diameters 6.37, 10.3, and 16.0 mm at speeds up to 800 m/sec.

It has been shown [1] that the $v_-/v_*(v_+/v_*)$ curves are independent of target thickness h and projectile diameter d. It was considered that this enables one to assign these curves as a form of strength characteristic, which can be related to traditional strength characteristics in the form of the dependence of the stress—strain σ—ε relationship as a function of the strain rate $\dot{\varepsilon}$. Particular interest attaches to the curves tending to asymptotes, which may be related to the saturation shown in groups of σ—ε curves constructed for various $\dot{\varepsilon}$ when one uses the traditional approach to mechanical characteristics. In fact, according to the conception of [1] the dependence of the resistance force on the incident velocity v_+ indicates that there is a limiting value of $\dot{\varepsilon}$ beyond which the σ—ε curves become insensitive to $\dot{\varepsilon}$ because the main contribution to the resistance arises from the plug of plastically deformed or brittle-crushed material in a comparatively thin cylindrical stabilization layer (this is seen as the piercing curves tending to asymptotic form). The physical approach to this phenomenon may be as follows: When large incidence velocities are attained, the material is in a fluid state, which determines the linear dependence on incidence velocity for the attenuating action of a target of a given material.

On account of the considerable interest in titanium and aluminum alloys, the piercing resistance asymptotes were examined for VT-20 and OT-4-1 titanium alloys and D16T aluminum alloy used as targets of thickness from 2 to 10 mm struck by ShKh15 steel balls at speeds up to 800 m/sec. The relationships are also of independent interest.

We give the experimental curves for $v_-(v_+)$ (Fig. 1) and $\Delta v(v_+)$ (Fig. 2) for VT-20 (a), OT-4-1 (b), and D16T (c) for piercing by balls of diameter 6.37 mm (dot-dash lines drawn through the experimental points indicated by crosses), 10.3 mm (solid lines drawn through the points indicated by circles), and 16.0 mm (dashed lines drawn through the points indicated by triangles) for targets of thickness 2.0, 4.0, 6.0, 8.0, 10.0, 2.8, 4.2, 12.7, and 7.4 mm (correspondingly curves 1-9). All the curves for D16T tend to single asymptotes at speeds of about 800 m/sec. A similar tendency occurs for VT-20 and OT-4-1, so we suggest that for these materials there is an incidence velocity for which the $v_-(v_+)$ curves (Fig. 1) and the $\Delta v(v_+)$ curves (Fig. 2) become invariant with respect to changes in the sizes of the projectiles and the target thickness, naturally for certain ranges in the first and

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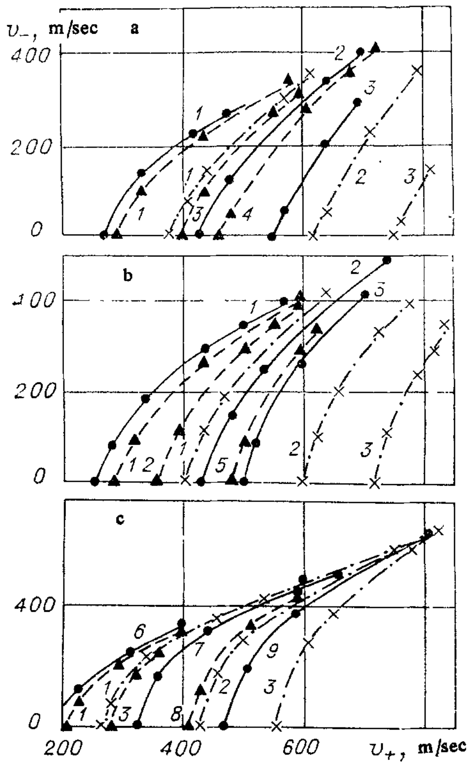

Fig. 1

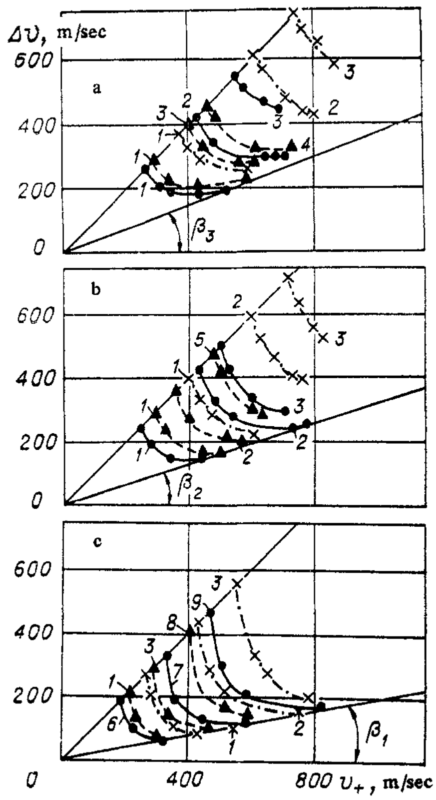

Fig. 2

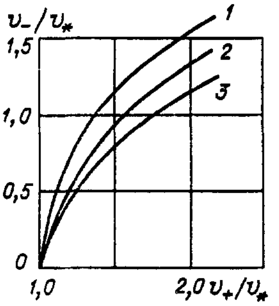

Fig. 3

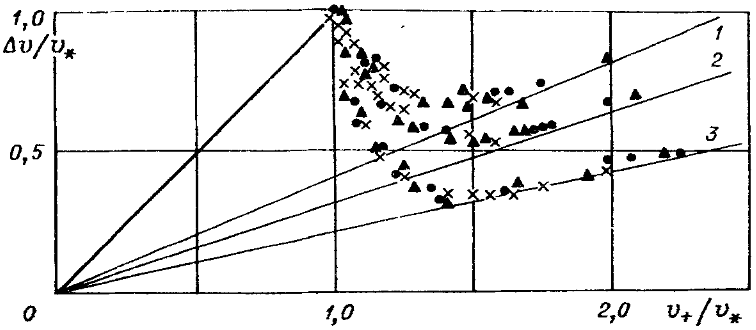

Fig. 4

second, which enables one to forecast the piercing resistance, including at higher speeds, and evidently up to speeds at which the plastic deformation of the projectile has an effect on the piercing. The inclinations of the asymptotes can be interpreted as certain strength characteristics related to the strain rate $\dot{\varepsilon}$, which is determined by v_+. The $v_-(v_+)$ curves were converted to $v_-/v_*(v_+/v_*)$ (Fig. 3), and it was found, as would be expected [1], that the curves in the new coordinates corresponding to different target thicknesses and projectile diameters group into fairly narrow bundles (the bundle for D16T is shown in Fig. 3 as the single curve 1, while that for OT-4-1 is shown as curve 2 and that for VT-20 as curve 3), which indicates that the curves in these coordinates are invariant under change in the target thickness and projectile diameter throughout the speed range, not merely when a certain speed is attained.

Analogous plotting in the new coordinates was also used for the phenomenological $\Delta v(v_+)$ curves; the resulting $\Delta v/v_*(v_+/v_*)$ curves are shown in Fig. 4. The data form pronounced bundles for each material, which tend to asymptotes (1 for VT-20, 2 for OT-4-1, and 3 for D16T).

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EFFECTS OF STRAIN HISTORY ON THE DAMAGE ACCUMULATION RATE IN NONMONOTONE ELASTOPLASTIC LOADING

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1. The determination of the failure instant under conditions of nonmonotone elastoplastic loading may involve determining the number of cycles to failure in few-cycle fatigue [1, 2] and determining the plasticity reserve in complicated technological operations in pressure working of metals [3] as contrasting particular cases. Here we describe the accumulation of distributed damage, not the localized damage occurring after the formation of macroscopic cracks. Therefore, by the term failure we mean the generation of a crack of a certain fixed but small length. Although the superficial pictures of fatigue failure (few-cycle failure) and quasistatic failure are different [2], there are close similarities in the dislocation substructures, which define the damaged state of the material at the stage where delocalized damage accumulates [4], which indicates that a unified description may be possible. We assume that the ranges in strain rate and temperature are such that the choice of time scale is unimportant.

One way of providing a phenomenological description of damage accumulation is to introduce objects of scalar or tensor nature that describe the damage state. These objects are either specified as functionals of the loading path [5] or else their variations are defined by kinetic equations [6-8]. In [7, 8], the kinetic equation for the damage parameter Ω was written as

$$d\Omega/dL = \lambda P, \qquad (1.1)$$

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