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KINETICS OF THE COLLISION OF METALLIC PLATES IN A MULTILAYER PACKET DURING EXPLOSION WELDING

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The achievement of high strength in the compounding of metallic plates in layered composite material (LCM) during explosion welding (EW) in accordance with the "simultaneous" scheme requires strict and precise dosing of energy input on all of its interlayer boundaries [1], which can be achieved through the creation of specific conditions, during each act of collision in the packet, characterized by the properties of the metals being combined and by the kinematic parameters of the EW, the most important of which are usually considered to be the collision speeds V_l of the layers. However, the task of the computational evaluation of the layer collision speeds in a multilayer packet corresponding to the actual physical picture of the process, in view of the complexity and transience of the phenomena occurring during welding, remains at present unsolved in many of its aspects.

The present article investigates the true character of kinetics of the layer-by-layer collision ofmetal plates in a multilayer packet during its explosive welding in accordance with the "simultaneous" scheme, which is frequently used in practice.

Existing models of the collision of plates during the explosion welding of multilayer composites [2, 3] for an entire range of reasons do not reflect the actual phenomenology of the process and, consequently, do not permit reliable evaluation of the character of the acceleration of an arbitrary i-th plate involved in the interaction. In this connection a new kinematic collision model has been proposed (Fig. 1), for the elucidation of which we will examine a single act of the interaction of a thrown plate with a second, separate plate located beneath it at a gap of h_1. If it is assumed that the flight speed of the packet consisting of these two plates that have interacted with one another is determined by the speed of the rear surface of the second plate of the packet (ultimately it is this speed that will determine the conditions of the collision at the following interlayer boundary), and if the fact that this surface in some cross section is at rest right up to the emergence onto it of the compression wave [4] is taken into account, then the acceleration of the packet of two plates after their interaction may be regarded and as beginning at the zero value of the speed and as ending at some final magnitude depending on the initial conditions. Thus, the layer-by-layer variation in the speeds is clearly not step-wise [2] but in jumps, with the function $V_c = f(h_\Sigma)$ being not a broken curve, but a family of independent acceleration curves (Fig. 1).

In order to test the adequacy of the proposed kinematic model, a series of experiments in the EW of multilayer model composites was carried out in accordance with an improved method (Fig. 2) with continuous recording of the variation in the kinematic parameters at the selected interlayer boundary with the aid of the rheostat [5] (using a S9-8 digital oscillograph and a current generator, designated in Fig. 2 as OSC and CG) and electrocontact [6] (using a Ch3-34 frequency meter, designated in Fig. 2 as FM) methods. The initial conditions of the experiments are given in Table 1.

The experimental curves of the variation in the flight speed of a packet consisting of aluminum plates 2-10 mm thick, obtained during modelling of the collision process at the second interlayer boundary for various phases of acceleration, are shown in Figs. 3 and 4 (for model plate thicknesses of 2 and 10 mm, respectively) by curves 2-5 (curves 1 and 1′ reflect the acceleration process of aluminum plates 2 and 4 mm thick for Fig. 3 and 10 and 20 mm thick for Fig. 4) and illustrate the correctness of the proposed kinematic model. They establish that the acceleration process of a packet of plates welded during flight after each collision occurs in at least two stages.

In the first stage an intense increase in the speed of the packet that has interacted is observed over a quite short time interval (1-1.5 μsec) or, if we consider the acceleration process in the more usual coordinates V_c — h or V_c/D — h/H, during an insignificant change in the distance from the rear surface of the packet (as a function of the initial conditions of the EW, this distance is in the 0.5-2 mm range). At the second stage of acceleration, the flight speed of the packet increases less intensively (curves 2-4 in Figs. 3 and 4), reaching, at small relative gaps at the first boundary (a ratio of the magnitude of the

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TABLE 1

Experiment series number	Thickness of thrown plate, mm	Thickness of intermediate plate, mm	Engineering parameters of explosion welding: EC type	charge height H, mm	detonation speed D, m/sec	gap between plates h_1, h_1/H	relative gap
1	2	2	AT-1	70	2580—2720	1,5	0,0214
2						6	0,086
3						10	0,143
4						20	0,286
5	10	10				1,5	0,0214
6						6	0,086
7						10	0,143
8						20	0,286

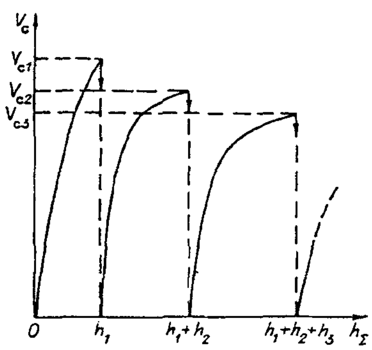

Fig. 1

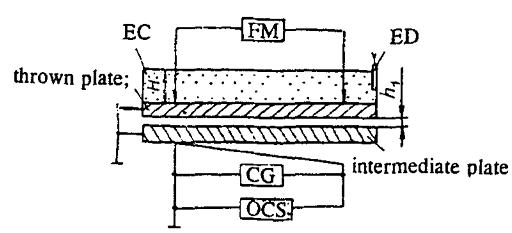

Fig. 2

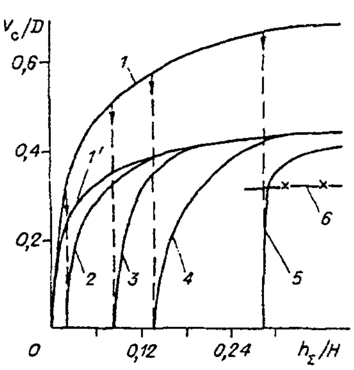

Fig. 3

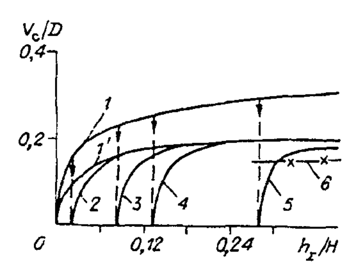

Fig. 4

initial state between the plates to the height of the applied explosive charge (EC) of $h_1/H < 0.15$) in a time interval that is a function of h_1/H, the theoretical values shown in Figs. 3 and 4 by the curves 1' and computed from the equations of the physics of the explosion [7] for the case of a one-dimensional throwing of a metal plate the mass of which is equal to the sum of the masses of the first two colliding plates.

For $h_1/H > 0.2$, at the first interlayer boundary of the packet the acceleration of the two colliding plates occurs at the second stage up to values of V_c (curve 5, Figs. 3, 4) differing from the ones calculated from [7] on the low side, but approximately 20% of the large speeds represented in Figs. 3, 4 by curve 6 and computed from the law of conservation of quantity of motion, which, evidently, is associated with the energetic "make-up" of the system of interacting plates by the residual pressure of the products of the detonation of the EC even with sufficiently large initial gaps, although this pressure is insufficient to accelerate the packet up to the theoretical speed computed on the assumption that a plate of unitary mass equal to the sum of the masses of the two colliding plates in our experiments is being thrown.

Examination from the energetic point of view the process of the collision of two plates and their further common motion leads to the conclusion that depending on the phase of the acceleration of the thrown element, there occurs either a complete (in the case of small values of h_1/H at the first boundary), or partial (in the case of large h_1/H) compensation of the energy expenditure on plastic deformation and cumulation due to the energy of the products of the detonation of the EC.

The experimental data first obtained in this way serve as a starting point for the creation of a reliable mathematical model of the kinetics of the layer-by-layer collision of plates in a multilayer packet during EW on the basis of the proposed kinematic model of the interaction of the plates, and for the development of appropriate methods of computing the conditions of the collision at the interlayer boundaries of LCM, which are the subject of a separate publication.

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