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Use of composite materials to increase the effectiveness of variable-geometry aircraft

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Use of composite materials to increase the effectiveness of variable-geometry aircraft

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Abstract. The results of mathematical modeling of the functioning of the charges using composite materials forming high-speed aircraft of variable geometry are presented. The directional formation of a folded fin in the tail part of the element, providing the aerodynamic stability of the element on the trajectory, is considered as a way to increase the efficiency. The effect of charge parameters on the effectiveness of the action is shown. At the same time, steel claddings of variable thickness and claddings of polymeric material for the formation of a folded fin were considered. The effectiveness of the charges was determined by the shape of the element and its speed. It is found that with an increase in the width of the petal cladding the speed of the element decreases, a linear relationship is presented between the relative width of the cladding and the relative speed. It is revealed that the elongation of the element when varying the width of the cladding varies nonlinearly and there is a range of sizes of the cladding at which the elongation is minimal.

Keywords. Numerical simulation, high-speed aircraft with variable geometry, composite materials, dynamic deformation processes,metal cladding

Introduction

The advanced missile technology uses explosive formed projectile (EFP) [1-3]. With the explosion of such a charge, a high-speed elongated element is formed, changing its geometry during the flight [4-7]. This type of charges is also used in engineering charges for the destruction of concrete and brick buildings, while located at a certain distance from the charge. High-speed elongated elements are formed by high-speed deformation of metal claddings, made, as a rule, of ductile metals, by means of an explosive charge explosive (EX) [8-14]. Aerodynamic stability of high-speed elongated elements is ensured at the location of the center of mass of the element in front of its pressure center. This requirement is usually met by expanding the tail section of an element formed by the explosion, called the fin [15-18]. An additional stabilizing element are folds in the tail part of the element - stabilizers. The directional formation of stabilizers and the analysis of the conditions of their formation is of great scientific and practical importance, since it will allow the creation of high-speed elongated elements that are stable in flight. Abroad, similar elements are created using the claddings on the cladding [15-19]. The effectiveness of the action of projectile-forming charges is increased not only from the standpoint of changing the design parameters, but also by improving the manufacturing technology of cumulative cladding [20, 21], which is the most important part of the charge, as well as charge assembly technologies [22-24]. To study high-speed explosive processes, in order to reduce the

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cost of experimental research, methods of mathematical modeling of the functioning of the EFP are actively used [7-9, 25-28]. This paper presents the results of a study performed using numerical methods of continuum mechanics, which determines the influence of the structural parameters of the PFC on the shape and stability of high-speed elongated elements obtained from claddings based on the use of composite materials.

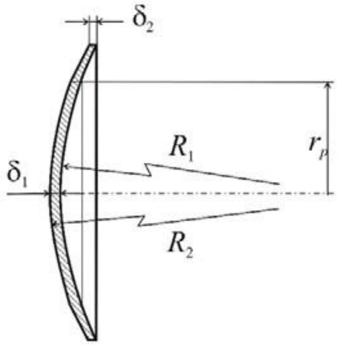


Fig. 1. Spheroconic cumulative cladding **Fig. 2.** The shape of the elongated high-speed element [1]:

EFP , as a rule, consists of a metal cumulative cladding (Fig. 1), explosive charge, body and detonator. The advantages of the elongated form of the element are its greater penetrating ability compared to compact elements of the same mass (Fig. 2). The effect is achieved due to greater length and less loss of speed when moving over long distances. Another important characteristic of a high-speed element is its fullness (Fig. 3) [8]. It is obvious that the higher the fullness of the element, the greater its penetrating effect. For the formation of stabilizers, it is proposed to use a cladding composition of a metal segment cladding and a polymer multilobe cladding installed on the outer surface of the cladding, from the side of the explosive charge.

To determine the parameters of the EFP that provide high-speed elongated elements of greater elongation (ie, greater efficiency) with developed stabilizers, a computational experiment was conducted based on the numerical solution of problems of continuum mechanics.

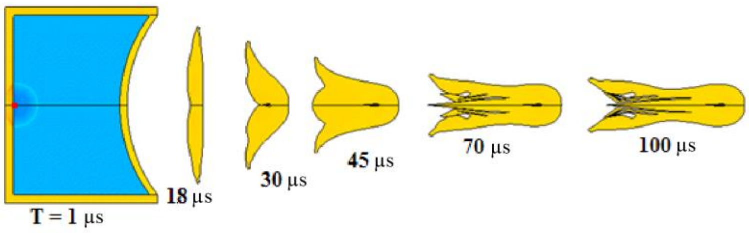


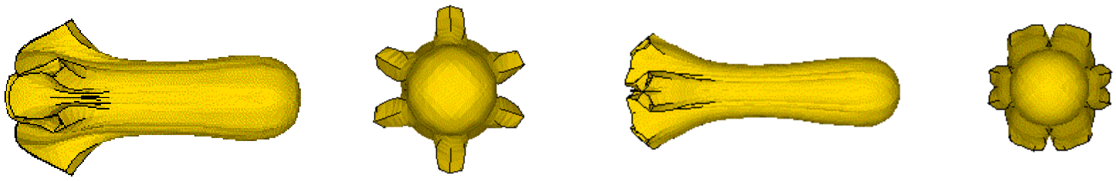
Fig. 3. The process of formation of high-speed elongated elements by the EFP explosion

Calculations were carried out for a model EFP with the following parameters: the diameter of the explosive charge (or the internal diameter of the shell) $d_з$= 62 mm, height H = 50 mm, thickness of the shell $\delta_к$ = 3 mm. The cladding diameter is d=$d_з$=62 mm, the cladding deflection is h = 10.45 mm. There werer used claddings of variable spheroconic thickness (Fig. 1) with such dimensions [8, 9]: with thickness in the central and peripheral parts was $\delta 1$ = 2.5 mm and $\delta 2$ =2.25 mm, respectively, the radius of transition of the central spherical surface in into the peripheral conical rp = 26 mm. The thickness of the cladding was $\delta_н$ = 1.0 mm, and the width was varied and was s = 2 ... 14 mm.

The following parameters were used in materials models: cladding - steel grades 08кп,

11кп (density ρ0 = 7.85 g / cm3, bulk compression modulus K0 = 175 GPa, dynamic yield strength Y = 0.6 ... 0.9 GPa, shear modulus G = 80 GPa, spall strength σ * = 1.65 GPa , the relative narrowing of the

material ψ = 0.45 ... 0.75); housing - steel 45X; EX - TG40 (density ρBB = 1.68 g / cm3, detonation velocity D_{BB} = 7.85 km/s, heat of explosive transformation Q_{BB} =4.61 MJ / kg); cladding - plexiglass (density ρ0 = 1.15 g/cm3). In the charge, single-point initiation was applied at a distance of 49 mm from the cladding face.
As a result of the charge functioning, the pad degrades, forms an uneven pressure field on the surface of the cladding and stabilizers are created in high-speed element in those places of the cladding that are located opposite the cladding sections (Fig. 4).



(a) (b) (c) (d)

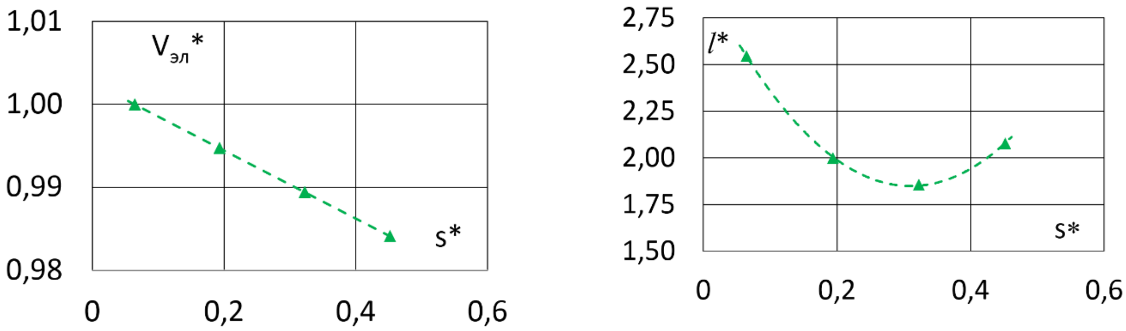
Fig. 4. Options for the shape of high-speed elongated elements when using claddings of various widths

On the basis of mathematical modeling, high-speed elements with a velocity Vel ≈ 1.9 km / s (Fig. 4, a, b) and elongation l*=lэл/dэл ≈ 4 (ratio of the length of the element lel to its diameter del) were obtained (Fig. 4 , c, d) Figure 5a shows the dependence of the relative velocity of the element Vel * = Vel / Velmax (Velmax = 1.9 km / s) on the relative width of the cladding section s * = 2s / d. It is shown that with an increase in the width of the cladding section, the speed of the elongated element decreases by 1.5%, and the height of the stabilizers increases, which has a positive effect on the stability of the element movement. The elongation of the element also decreases with an increase in the section width, but after a certain width value, the elongation begins to grow again (Fig. 5, b).
The regression dependence between the relative width of the cladding section s * and the relative velocity of the element Vel * is described linearly

$$Vel^* = -0.041s^*+1.0026. \quad (1)$$

The relationship between the relative width of the petal cladding s * and the elongation of the element l * is described in quadratic form

$$l^* = 11.49s^{*2} - 7.1306s^* + 2.9557. \quad (2)$$



(a) (b)

Fig. 5. The dependence of the velocity of the element (a) and elongation (b) on the relative width of the cladding section

Thus, the controversial effect of the polymer cladding with straight lobes on the efficiency of high-speed aircraft of variable geometry has been revealed. In particular, increasing the width of the cladding section leads to a decrease in speed, but at the same time to an increase in the height of the stabilizer fold. In turn, a decrease in speed leads to a decrease in the depth of the obstacle overcome by such an apparatus, and an increase in the height of the stabilizer increases the accuracy of hitting the barrier from a long distance. Therefore, further research in this area should be continued in the direction of studying the influence of other parameters of the cladding (geometrical, physicomechanical) in order to increase the efficiency of the charges that form the aircraft of variable geometry.

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