FORMATION OF SUCCESSIVE SHOCKS IN ABSORBING MATERIAL SUBJECTED TO A LASER EFFECT IN THE ORDERED GENERATION MODE

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The possibility of the formation of moving shocks in a metal subjected to a laser effect in the free generation mode was mentioned in [1]. However, it is not possible to detect shocks reliably during chaotic generation of effective laser radiation, nor to study the mechanism of their formation and the nature of their propagation, which knowledge is necessary to a comprehension of a whole set of phenomena accompanying a laser effect in absorbing materials. To this end, the ordered generation mode was selected, which permits production of relatively homogeneous radiation pulses with a sufficient time interval. A neodymium laser was used, which assured a radiation energy to 150 J. To obtain an ordered generation mode, a plane-sphere type cavity was used; the spherical mirror (R = 2.5 m) had a maximum reflection coefficient, while the plane had 20%. The laser permitted obtaining a series of radiation pulses of bandspread 6 and duration 1 μsec for each pulse. The duration of laser generation was 700 μsec. Focusing the radiation on the absorbing materials (metals and opaque dielectrics) was accomplished by means of a lens with F = 100 mm in a ~2.5 mm diameter spot. Taking account of the pulse bandspread, the radiation flux density reached $\sim 10^7$ W/cm^2. The investigations were conducted at atmospheric and reduced ($\sim 10^{-2}$ mm Hg) pressures by the method of high-speed photographic scanning with the photorecorder slit disposed longitudinally and transversely relative to the plasma flux being formed.

Attention is first turned to a series of successive glow fronts corresponding to the individual pulses of effective laser radiation, in the longitudinal and transverse photoscans of the plasma fluxes formed under the laser effect in absorbing materials (LS-59, brass, for example; Figs. 1a-c, e).

The propagation velocity of these fronts diminishes with distance from the surface (Fig. 2). They are moving shocks. As is known, a shock forms under the condition that the pressure in the surrounding medium is less than the pressure in the moving piston.

In fact, the erosion plasma formed under the effect of each successive radiation pulse moves in the relatively rarefied medium produced by each preceding plasma bunch and performs the role of a piston in the shock formation. The peculiarity of successive moving shocks is that they are formed and propagated in the vapors of the target material produced by the preceding radiation pulses, rather than in the surrounding air (displaced by the first plasma bunches). The front of each of the successive shocks, up to the fixed compression shock formed in the plasma bunch because of supersonic exhaust under under-saturation conditions [2], hence coincides with the glow front of a bunch (Figs. 1a,b). Upon entering the plasma produced by the preceding radiation pulses, the shock is explicitly disclosed behind the fixed compression shock, by the periodic increase in the glow on the longitudinal photoscans. It hence has a higher velocity than the plasma bunch (Fig. 2), which has a jump drop in velocity at the fixed compression shock. The increase observed in the propagation velocity of the plasma bunch (Fig. 2) is related to its being heated in the shock from the next radiation pulse.

At reduced pressure ($5 \cdot 10^{-2}$ mm Hg), a series of successive shocks forms, whose velocity hardly changes with recession from the surface (Fig. 1d). As spectroscopic investigations show, there is no shock-heated plasma of the remaining air and,as in the case of the laser effect at atmospheric pressure, shocks form in the vapors of the target material produced by the preceding radiation pulses.

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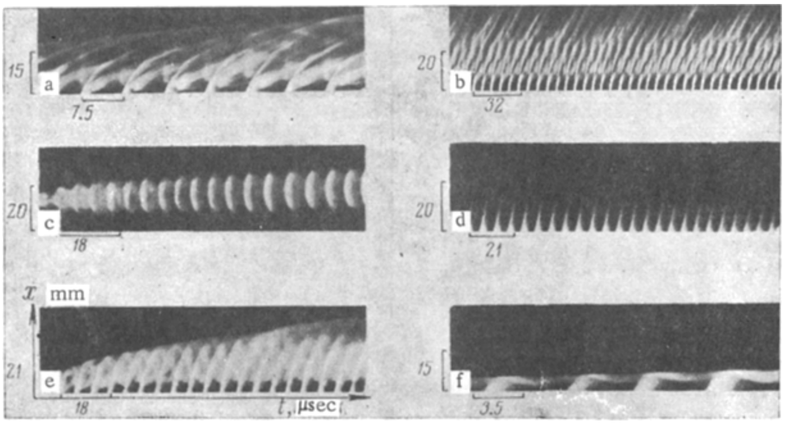

Fig. 1. Fragments of photoscans of the glow process accompanying the laser effect on LS-59 brass (q ~ $5 \cdot 10^6$ W/cm^2): a,b,e) longitudinal photoscans (ambient air pressure p = 1 atm); c) transverse photoscan (p = 1 atm); d) longitudinal photoscan (p = $5 \cdot 10^{-2}$ mm Hg); f) longitudinal photoscan of the plasma jet colliding with an obstacle (p = 1 atm, obstacle 6 mm from the target).

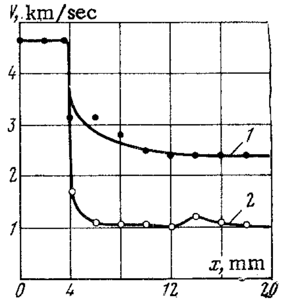

Fig. 2. Change in the propagation velocity of the shock (1) and the plasma bunch (2) with recession from the target surface (q ~ $5 \cdot 10^6$ W/cm^2, p = 1 atm; material – LS-59 brass).

A confirmation of the existence of successive shocks in absorbing materials subjected to a laser effect in the ordered generation mode is the presence of shocks reflected from the air–plasma interface at the beginning of the effect, which interact with the incident shocks (Fig. 1e). Investigations were carried out on the reflection of shocks from an obstacle (a glass plate) disposed at different distances from the target surface. Presented in Fig. 1f is a typical photoscan of the collision process, wherein the reflected shocks can be clearly seen.

Quite definite vertical bands are observed in the longitudinal photoscans of the glow process (Figs. 1a,b), which indicate additional heating of the plasma formed by the succeeding pulses under the effect of the preceding radiation pulses; consequently, partial shielding of the target surface from the effect of the laser radiation occurs. As the process develops, accumulation of the plasma bunches occurs, and shielding of the surface is increased. This is observed in the photoscans as a periodic "deflagration" of the plasma bunches (Fig. 1b). Because of the absorption of radiation in the front of the moving shock, in some cases a glow front is propagated from this zone to the target, which is apparently a shock (Fig. 1a) that interacts with opposing shocks and plasma bunches.

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