

MORE ON THE MECHANISM OF POLYMER DISINTEGRATION UNDER THE ACTION OF A RADIATING PLASMA JET

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Experimental investigation into the mechanism of disintegration of certain polymer films by shock wave and radiant plasma jet in high-power pulsed discharge are described. Obtained results confirm the conclusions arrived at in [1, 2] and the pattern of disintegration described in [3, 4]. We note that results of investigations of the disintegration pattern in depth and on the surface of certain polymer films subjected to supersonic plasma jets in a high-power pulsed discharge are given in [1, 2, 5, 6] and that in [1, 2] the stream of radiant plasma was considered to be the fundamental factor in the mechanism of disintegration.

1. The experimental discharge chamber is shown diagrammatically in Fig. 1. Cube 1 of dielectric material holds metal electrodes 2 supplied with high voltage (current) from a battery of pulse condenser 3 which is charged from a high-voltage rectifier 4. The discharge in the gap between electrodes is initiated by the igniting pulse generator (IPG) 5, and the plasma stream generated by the discharge is emitted through nozzle 6. The distance between the nozzle face and the specimen is such that along it the velocity of the plasma jet remains supersonic.

Experimental conditions were approximately the same as given in [1]. However, in order to increase the share of the radiant stream, the electrical parameters of the discharge circuit were altered. The battery of pulse condensers had a capacity of $400 \mu\text{F}$ and the charging voltage was 3 kV. The configuration of the discharge lasting 120 sec remained unaltered, and the emission rate of plasma streams, determined by the slope of bands on time exposures, was 10–12 km/sec.

The structure of compression jumps generated by the impact of the supersonic plasma jet on certain polymers was investigated by the method of mirror filming with a CFR-2M ultra-high-speed camera. The speed of film was 1500 m/sec and the exposure frequency was 500,000 frames/sec. A continuous time exposure of the region of compressed plasma taken at $C = 400 \mu\text{F}$ and $u = 3 \text{ kv}$ is shown in Fig. 2a. It will be seen from it that the impact of the supersonic plasma jet on a solid obstacle generates at the surface of the latter a region of intense luminosity of a thickness of the order of 2.0–2.5 mm which is present virtually throughout the duration of a pulse. The bright region, whose temperature according to some estimates is $40,000^\circ\text{K}$, corresponds to the region comprised between the surface of the obstacle and the detached shock wave. (Several simple methods for obtaining high temperatures at a compression jump in high-power pulse discharges are described in [7].)

Temperature in the region of plasma compressed by the shock at the surface of a solid obstacle was determined by the method described in [8] and, also, from the halfwidth of spectral lines. It was additionally checked by an EV-39 pulsating master light source [9, 10].

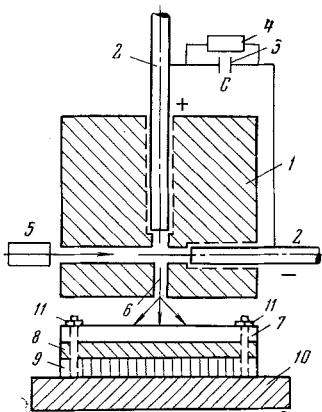


Fig. 1

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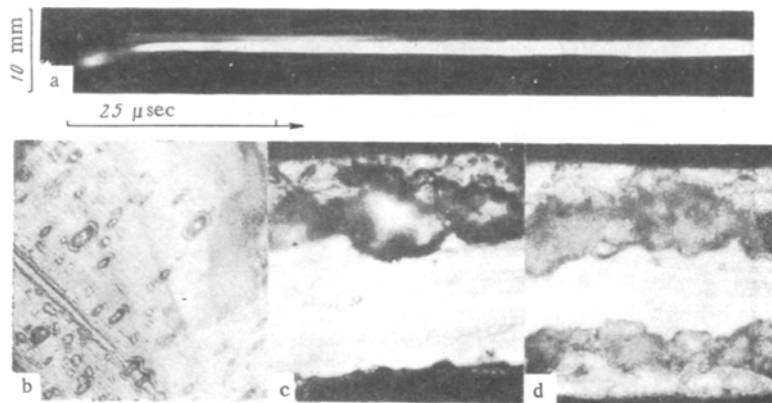


Fig. 2

Certain preliminary experimental observations had shown that the pattern of disintegration of polymer films depends to a considerable extent not only on the structure of the latter but, also, as noted in [1, 2, 6], on parameters of the discharge circuit, the number of pulses, the distance from the obstacle to the nozzle face, and on a number of other experimental conditions.

2. The effect of the plasma jet on the surface of material was investigated separately on specimens 8 mounted on a dielectric support 10 (Fig. 1) in the path of a plasma beam.

Examination of the patterns of surface disintegration of materials shows that:

- 1) even under identical experimental conditions these patterns differ for different materials;
- 2) the disintegrated part is generally in the form of a circle of a diameter which for different materials may vary from a few to 10 mm;
- 3) among the polymer films considered here teflon is the least susceptible to disintegration (at the surface and in depth).

The impact of a supersonic plasma jet leaves on the surface of all materials products of disintegration of the chamber material and of the metal electrodes. The specimen surface is thus subjected not only to the action of air plasma but, also, to that of liquid drops and dispersed particles of metal of the electrodes impacting on its surface at supersonic speed. Holes of various diameters and the tearing away of a certain mass of material from the specimen surface can be observed on some materials subjected to pulsed discharge. Approximate dimensions of liquid drops of metal ejected by the electrodes can sometimes be estimated from the size of these microholes. (The presence of liquid drops can be observed even by naked eye, particularly clearly on metal plates.)

As example of surface disintegration of isotropic polystyrene is given by the photomicrograph ($270\times$ magnification) in Fig. 2b. Microscopic circular spots of 1 to 5 μ diameter are seen on the specimen surface after it had been subjected to the action of a supersonic plasma beam. A similar picture was observed in [1], where the formation of gas bubbles on the surface of Kapron specimens subjected to the action of a supersonic plasma jet was pointed out. The diameter of gas bubbles mentioned in that paper varied between 10 and 45 μ , in spite of lower discharge circuit parameters than in the experiments described here.

3. Investigation of the pattern of disintegration in depth of polymers was carried out on specimens lying on black paper and protected from the shock wave effect by a 2 mm thick plate of organic glass 7 (Fig. 1) placed on top of it. In this case, as in that described in [1], no signs of any surface deterioration or separation of the carbonaceous layer were observed. A photomicrograph ($450\times$ magnification) of an isotropic polypropylene (specimen) sectioned through the region of disintegration is given in Fig. 2d. It shows that gas bubbles of various diameters, 10 to 30 μ on the average, are formed in the material during disintegration. The virtual absence of damage on the reverse side of the film adjacent to the black paper should be noted.

4. Tests were also carried out on specimens covered by an organic glass plate but with the black paper under it replaced by an aluminum plate with mirror-like surface 9 (Fig. 1). The specimen and the

plates were clamped to a special base by means of bolts 11. A photomicrograph ($450\times$ magnification) of a section of isotropic polypropylene is given in Fig. 2d. It shows that in this case both sides of the film have suffered damage. Results of this experiment show that the radiating jet reflected by the mirror-like surface of the aluminum plate disintegrates the film on the reverse side. Formation of gas bubbles of diameters ranging from 5 to $15\ \mu$ and over was, also, observed here. The nature of their formation is the same as described in [1-6].

The energy of the radiating jet at the film surface behind it was measured at various settings of the electric discharge circuit by calorimetric methods. For example, at $C = 300\ \mu\text{F}$ and $u = 3\ \text{kV}$ with the film (specimen) at $4\ \text{mm}$ from the nozzle face the jet energy at the surface (of impact) was of the order of $2.5 \cdot 10^{11}\ \text{erg}/\text{mm}^2\cdot\text{sec}$, and behind it of the order of $1.6 \cdot 10^{11}\ \text{erg}/\text{mm}^2\cdot\text{sec}$. This shows that the amount of the jet (energy) reflected by the film top surface and dissipated by absorption is small so that nearly all of it penetrates the film.

The obtained values of the jet (energy) may be considered as reasonable if one takes into consideration that even with electric arc simulating equipment it is possible to obtain high-energy radiating fluxes [11].

Thus it is possible to conclude that the shock wave plays the predominant role in the mechanism of destruction of the surface of polymer films subjected to the action of a supersonic plasma jet, while the mechanism of disintegration in depth is essentially affected by the radiating heat flux.

LITERATURE CITED

1. I. K. Dustov and M. A. Sultanov, "Investigation of the mechanism of fracture of some polymers under the action of a radiant plasma flow," *PMTF (J. Appl. Mech. and Tech. Phys.)*, No. 3 (1969).
2. M. A. Sultanov and B. N. Narzullaev, "Investigation of the interaction of shock-compressed plasma volumes formed in high-power pulsed discharge with solid particles," Ninth Intern. Conf. on Phenomena in Ionized Gases, Bucharest, Rumania, 1969.
3. Yu. A. Buevich and M. I. Yakushin, *PMTF (J. Appl. Mech. and Tech. Phys.)*, 9, No. 1 (1968).
4. Yu. A. Buevich, O. K. Egorov, and M. I. Yakushin, *PMTF (J. Appl. Mech. and Tech. Phys.)*, 9, No. 4 (1968).
5. M. A. Sultanov and I. K. Dustov, "Investigation of the interaction of supersonic plasma jets with certain polymer films," Papers Presented at the 2nd All-Union Conference on Low Temperature Plasma Physics [in Russian], Minsk (1968), p. 280.
6. I. K. Dustov, B. N. Narzullaev, and M. A. Sultanov, "Effect of supersonic plasma jets on polymer films," *Dokl. AN Tadjh. SSR [Trans. of the Tadjiky AS SSR]*, 12, No. 3 (1969).
7. M. A. Sultanov, "Effects of collision of supersonic plasma jets," Ninth Intern. Conf. on Phenomena in Ionized Gases, Bucharest, Rumania (1969).
8. L. I. Kiselevskii and M. A. Sultanov, *PMTF (J. Appl. Mech. and Tech. Phys.)*, 7, No. 4 (1966).
9. N. N. Ogurtsova and I. V. Podmoshchenskii, "Spectroscopic investigation of a pulsed discharge through an aperture in a thin insulating plate," Collection: Physical Problems of Spectroscopy, *Izd-vo AN SSSR*, 1 (1962).
10. N. N. Ogurtsova, I. V. Podmoshchenskii, and V. M. Shelemina, "Dependence of temperature and pressure of plasma discharged through a capillary with an evaporating wall on the capillary geometry and the discharge current," *Teplofizika Vysokikh Temperature (High Temperature)*, 6, No. 1 (1968).
11. J. F. Louis, R. Decher, and T. R. Brogan, "Production of intense radiation heat pulses," *AIAA Journal*, 2, No. 1 (1964) [Russian translation in *Raketnaya Tekhnika i Kosmonavtika*, 2, No. 1 (1964)].