INVESTIGATION OF SEPARATION PROCESSES FOR CONSTRUCTION ELEMENTS AND MATERIALS AT IMPULSE LOADING

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ABSTRACT

A combined theoretically-experimental approach to investigate the separation process for materials and construction elements by using impulse energy carriers is briefly described. As mathematical tools for simulation of separation processes are used calculated schemes of a different level of accuracy and complexity that allows to estimate sensitivity of processes to variation of input parameters including their random spread. Experimental studies are conducted by an automated complex of a specially developed bandwidth strain measurement equipment. Data of experiments are used to estimate separation processes and to define parameters of impulse pressure and in the corresponding numerical processes.

KEYWORDS

Separation, impulse loading, simulation, experiment, fracture, estimate

INTRODUCTION

As has been known from literature (Finkel et al, 1982), technological operations and separation systems using impulse energy carriers are widely used in the modern engineering. The efficiency of action of systems of such type significantly depends on state study level, reliability and serviceability of components.

With studying the behavior of separation systems it is expedient to use a complex theoretically-experimental approach.

GENERAL CHARACTERISTICS OF SEPARATION PROCESSES

Elements of plane and cylindrical shape are considered as ob-

jects of separation. A problem on their separation along a given contour(1)with an artificial surface defect (a concentrator)(2)(Fig.1) is stated. Separation occurs due to intensive momentary loading from impulse energy carrier(3) that brings about a development of fracture processes beginning from an area of artificial defect where deformation energy concentration is observed. It is of interest to use not only a bending scheme of separation (Fig.1) but a shear scheme and their different modifications.

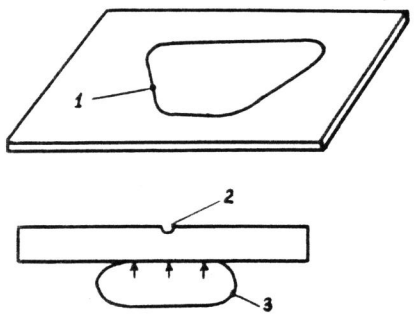

Fig.1. Elements of a separation system

NUMERICAL SIMULATION OF SEPARATION PROCESSES

Mathematical Models. To determine parameters - separation processes the models of different levels of accuracy and complexity are used ,it is very important when studying sensitivity of processes to variation of parameters, reliability estimate and the solution of optimization problems (Vorobiev et al., 1989).

A model constructed on general dependences of mechanics of solids is the most full and exact one. In this case the constitutive dependences reflect the laws of mass and impulse conservation (Ionov et al., 1987)

$$\dot{\varrho} = -\varrho\,\dot{\varepsilon}\ , \qquad \varrho\dot{v}_i = \sigma_{ij,j}\ , \qquad (1)$$

added by the corresponding relationships of a theory of elastic-viscous plasticity including medium damage

$$\nabla \tau^*_{ij} + \lambda\,\tau^*_{ij} = 2G\,e_{ij}, \qquad \tau^*_{ij} = \tau_{ij}\,(1-\omega), \qquad \dot{\omega} = B\,(\sigma^*-\sigma_0)^m\,H(\sigma^*-\sigma_0) \qquad (2)$$

By giving parameters of a material characterising dependences (2) we shall use both the information from literature (Ionov, 1987, Kurran,1985) and data of specially made experiments.

It is of interest to use a theory of plates and shells of Timoshenko type (Vorobiev et al.,1989) the specific peculiarity of which is independence of unknown functions from a singular coordinate. The application of the simplest elastic-massive model (Crouch, Williams, 1988) for the initial estimate of system state.

Consider that fracture process consists of two consequent stages of initiation and growth of a crack. To determine the initiation of fracture the known generalized criteria of strength (Morozov,1990, Ionov, 1987) are used. Besides, to predict fracture initiation we shall use an energetic approach associated with search of a relative minimum of deformation energy density.

The second stage of fracture is connected with microcrack growth. As it has been known(Andrejkiv, 1982, Ionov, 1987)two main mechanisms of fracture processes are possible: brittle and viscous , separation on which is conventional to a certain extent.

A condition of a brittle fracture is to achieve a critical value for a coefficient of intensity for stresses K_{Ic}. The consequent development of fracture model associated with account of plastic effects required to apply the more adequate criterion as J_{Ic}- integral. At last, a deformation criterion of fracture of a type (Ionov et al., 1987) may be used in the area of evident plastic deformations to estimate a limiting state of the separated element.

$$\varepsilon_i > \varepsilon_c \exp(-\kappa\sigma/\sigma_i) \qquad (3)$$

Note that a criterion (3) corresponds to the most power-intensive condition of fracture. Use of the above system, a criterion in the proposed consequence allows to cover not only the possible mechanisms but to give them a limiting estimate. While studying the behavior of the system the energy carrier- the element being separated in the whole two approaches are realized. The first approach is connected with the solution of the corresponding contact problem, the second approach is connected with the application of experimental data according to pressure impulse estimate.

Solution Methods and Software. Including the basic peculiarity of the considered problems - short time of separation processes a complex of hybrid explicit difference algorithms is used (Ionov et al.,1987, Vorobiev et al., 1989).The influence of random spread of parameters on separation process is studied by a method of statistical tests (Monte-Karlo) with the conse-

quent statistic processing of the values obtained.

Software for the solution of the above problems has been realized as a bending integrated system allowing to consider a wide range of problems.

Results of Calculations. A problem on separation of a steel plate of thickness 10^{-2} m with a cylindrical surface concentrator, a radius of which is 10^{-3} m is considered as an example (Fig.1). Parameters of the material corresponding to the steel were specified during dynamic tests. An energy source of an explosive type has been used as an energy carrier. The specific impulse due to its action is 80 N s, the amplitude of pressure is 2 GPa.

Computational experiments showed that a crack was initiated on a free surface of a concentrator where concentration of deformation energy was observed. The following stage of separation is of quasistatic nature and is connected with maintenance of the corresponding level of bending stresses. Fig.2 shows positions of a plate at different stages of separation including loading symmetry and scale 1 : 10 increase of dimensions of fracture area.

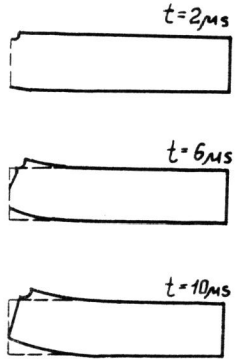

Fig. 2. Separation stages of a steel plate

During calculations the significant sensitivity of separation process to variation of input parameters is defined. The influence of the parameters characterising intensity and application field for impulse effect is more evident. The parameters of the material characterising directly the fracture process, influence to a great extent, i.e. K_{1c}, J_{1c}, ε_c.

Briefly estimating the different schemes of separation note that the bending scheme is the less power-intensive and the less stable to parameters variation. The shift scheme is the less sensitive to parameters change, but the more power-intensive, as the calculations have shown.

EXPERIMENTS ON SEPARATION OF CONSTRUCTION ELEMENTS

Studies are conducted to define a nature of a concentrator deformed in the vicinity of a concentrator and along a trajectory of main crack and parameters of impulse pressure. To solve these problems a method of bandwidth electrostrain measurement consisting of maintenance of a unique dynamic error at all parts of strain signal conversion is applied. For that small resistance strain gauges of a basis $\ell = (0.5...2.0) \cdot 10^{-3}$ m over deformation range $\varepsilon = 10^{-7}...10^{-1}$; strain amplifiers based on a principle of amplitude modulation with feeding measuring bridges by an alternating stress with carrying frequency 2 MHz and the range of operating frequencies $\Delta f = 20...\ 4\ 10^5$ Hz; analog-to-digital converters with cycling frequency $f_c = 40$ MHz; with control, registration and information processing on IBM PC AT.

Fig.3. gives schemes for measurement of parameters of stress-strain state, fracture and loading.

Data of Experiments. From the test results it was determined that the main crack is developed under conditions of plain deformation practically irrespective of curvature of separation contour (that explains a high rate of process propagation at explosive loading)

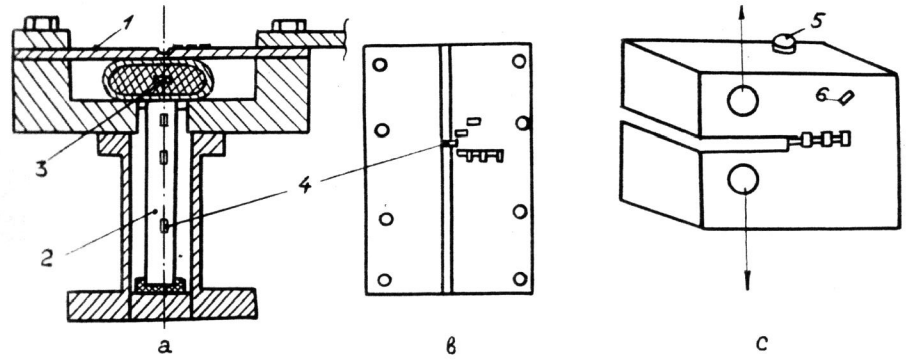

Fig. 3. Scheme of measurement parameters for deformed state-fracture and loading: a) explosive-impact testing machine; b) test specimen; c) fracture-test specimen;
1-test specimen; 2-strain-gauge dynamometer; 3-explosive charge; 4-foil strain gauges; 5-piezoelectric gauge AE semiconductor; 6-strain gauge AE

The nature and maximal deformations are determined in an object of separation at the stage of active loading and relaxation of stress waves with forming a free surface by the development of the main crack and the law of change of impulse pressure on the object of separation at the impulse stand using the elastic strain gauges-waveguides made of a material of high dynamic limit of ductility ($\sigma_s = 3.6$ GPa).

The determination of parameters of impulse loading both by direct tensor strain measurement and calculation-experimental method allowed significantly to increase the reliability of calculations according to the developed mathematical models and to apply them for investigation of technological processes of separation or utilization of metallic constructions.