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Shock-induced structural instability and dynamic strength of brittle solids

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Abstract

Three kinds of brittle material – gabbro-diabase, gray iron of two modifications and fused quartz – have been tested under uniaxial strain conditions of shock loading. The local probing of the free surface of targets by using interferometric technique allows to determining the criterion for initial stage of brittle damage in the form of threshold value of local stress. This stress corresponds to appearance of horizontal step at the front of compressive pulse which evidences the nucleation of local source of damage.

Keywords: shock tests, brittle materials, localized damage, dynamic compression, spall strength**.**

1. Introduction

The initial dynamic fracture is an important stage of deformation process which defines the macroscopic strength of material. Nucleation and development of initial sources of damage is closely associated with the structural instabilities of dynamic deformation process. In their scale, the structural instabilities belong to mesoscale, which supposes that experimental study of response of material on shock loading should be carried out at the mesoscale as well. In the present work, the results of studying the dynamic fracture of brittle materials, namely, gabbro-diabase, gray iron and fused quartz are presented. The goal of research was a determination of the criterions for nucleation of localized structural instabilities as sources of initial stage of dynamic fracture of brittle materials.

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2. Experimental technique and results

Shock tests of specimens were carried out under uniaxial strain conditions (plane collision) by using light gas gun of 37 mm bore diameter, (Meshcheryakov and Divakov, 1994). The time resolved free surface velocity profiles were registered with the velocity interferometer, the laser beam of which was focused on the free surface of target up to 60-70 μm, so all strength characteristics inferred from the velocity profile concerns to mesoscale. In a heterogeneous material, the shock front has a complex space-velocity configuration which reflects a hierarchy of scales. In Fig.1 the qualitative picture of shock-wave front consisting of two scale levels - mesoscale-1(0.1-10 μm) and мезоscale-2 (50-500 μm) - is shown. In our experiments, the registered time-resolved velocity profile corresponds to response of single structural element of mesoscale-2. At the same time, the laser spot at the free surface of target contains about hundred structural elements of mesoscale-1 which velocities are chaotically distributed.

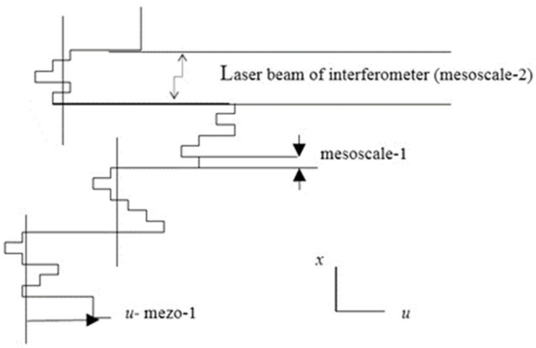

Fig.1. Qualitative picture of structured shock front.

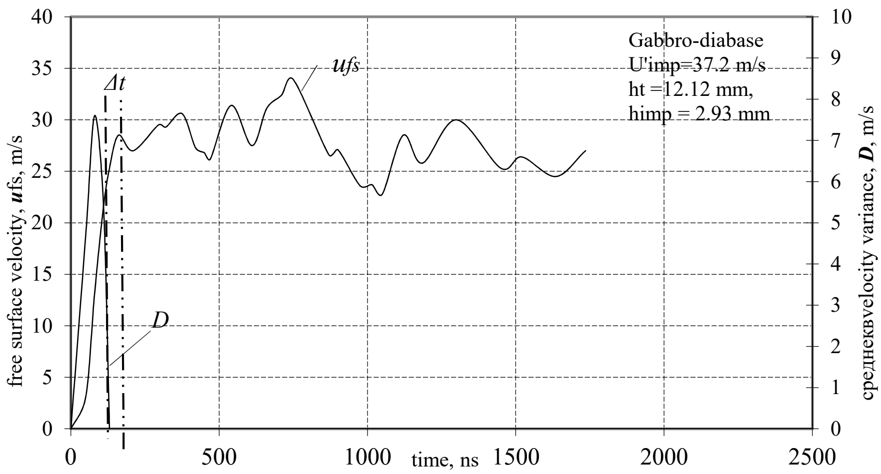

Fig.2. Free surface velocity profile for gabbro-diabase target loaded at the impact velocity of 37.2 m/s

2.1. Gabbro-diabase

Gabbro-diabase under investigation has the following characteristics: density ρ = 3.05 g/cm^3 and sound velocity C_l = 6.25· 10^5 cm/s. The specimens for shock tests were in the form of parallelepiped of 52 mm in size and 12.2 mm in thick. They were polished and covered with aluminum layer of 25 μm, which provides a mirror reflection of laser