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STUDY OF THE MICROSTRUCTURE OF A COMPOSITE AFTER DYNAMIC FRACTURE

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Variations in the structure and phase composition of a composite of the hard-facing alloy type subjected to dynamic loading are studied by the methods of metallography and x-ray structural analysis at different scale levels. The dynamic action on the composite by a steel impactor led to the redistribution of the structural components with the formation of separate regions with different contents of a hardening agent, the formation of local sites with a structure different from the initial one, and the emergence of new phases.

The wide use of heterophase materials under the conditions of high-speed loading (forging, stamping, impact loading, etc.) requires a thorough study of the evolution of the structure and phase composition of these materials.

The goal of the present work is to study the change in the microstructure of a composite of the type of a hard-facing alloy after its dynamic fracture. The composite had the following composition: 54% (hereinafter, volumetric content) tungsten carbide (WC) and 46% high-manganese steel 110G13. The binding phase was in a metastable state of austenite (γ-solid solution), which was formed by hardening in saltpeter from 1370 K [1].

This study is a continuation of [2], which reflects the evolution of the composite structure at the micro-, meso-, and macrolevels in the transverse cross section of the target which was a disk of diameter 60 mm and thickness 4.5 mm in the initial state. The target was punched by a steel cylindrical impactor moving at a velocity of 1200 m/sec.

The samples were the fragments of the target after its fracture, which were then polished in the transverse and longitudinal planes. The longitudinal planes of the target were studied layer by layer. To do this, they were subsequently polished to a thickness equal to 10 μm, which corresponds to four average sizes of the initial WC grain ($d = 2.5$ μm) [3]. The structure and phase composition of the material were studied with an NEOPHOT-21 optical microscope and a DRON-UM1 x-ray diffractometer with filtered copper radiation.

Metallographic investigations of the region adjacent to a site in which an impact-formed hole becomes a spalling crater revealed an unusual structure, which consists of several alternating sections (Fig. 1).

Section 1 is a structure whose binding phase is free from carbide grains (Fig. 2a). There were few WC grains, whose mean size is smaller than in the initial state ($d = 1.9$ μm) and is 11% of the total composition of the composite, only at the very edge of the spalling surface. The x-ray structural analysis of the spalling surface allowed us to determine the structure of these carbide sites. They have a face-centered cubic (FCC) lattice with the parameter a equal to $4.965 \cdot 10^{-10}$ m. We note that, upon in the initial state, there was no carbide with the FCC lattice. Section 2 is separate binding-phase formations located in the cells of the "carbide network" (Fig. 2b). The mean size of the carbide grains decreased more than twofold compared with the initial size, i.e., $d = 1.3$ μm. In contrast to the preceding sections, section 3 is characterized by a larger content of the hardening phase (Fig. 2c). The carbides have no distinct frontiers and are packed so close to each other that, merging, they form a skeleton. The histogram of the distribution of the carbide grains

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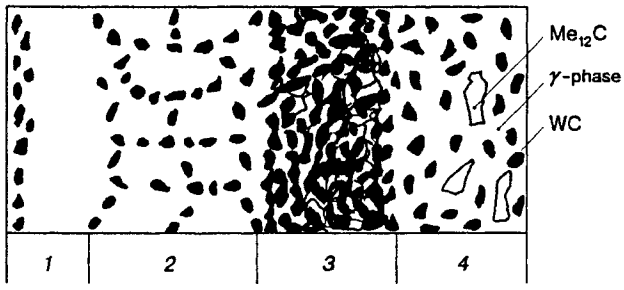

Fig. 1

indicates the increase in their sizes to 3.6 μm. The binder is located between carbides as separate inclusions, and constitutes only 20%. The structure of section 4 is almost the same as the initial structure. The only difference was the fact that inside the binding phase one can observe light sections which are complex carbides of the $Me_{12}C$ (Fe_6W_6C) type identified by chemical etching. The amount of the released carbide $Me_{12}C$ is much greater than in the initial material (1%) and is equal to 5%.

An analysis of the structure at the edge of the profile of the spalling crater indicates the existence of similar inhomogeneities as separate nonetched sections whose phase components are distributed quite uniformly over their area (Fig. 3a). These sections are either elongated along the profile of the spalling crater or almost equiaxial.

The volumes of material which are more distant from the impact-formed hole and the spalling crater are characterized by a region of transition from the basic to a cup-shaped structure (in the transverse cross section of the sample) or toroidal (in the longitudinal cross section) structure in which mesocracks oriented in a special manner were found [2, 4]. The dynamic loading did not change significantly the morphology of WC in this transient region, and its initial form is preserved. However, the martensite ε-phase was revealed in the binder in the narrow carbide interlayers and in the form of small-sized inclusions in the matrix itself (Fig. 3b). In addition, the martensite α-phase, the metallography of which showed up as dark sites of various shapes located between the carbide particles, appeared. The amount of this phase is insignificant and is not greater than 5%.

Just as in the transient region, the metallographic and x-ray structural studies of the toroidal zones allowed us to fix α- and ε-phases in the matrix. In these zones, the ε-martensite plates are rougher; on the metallographic photography, they are shown as needles which can be as long as 100 μm and 1.5 μm wide (Fig. 3c). Here, the morphology and amount of the martensite α-phase remain the same as in the transient region.

Thus, the appearance of inhomogeneous structures in the form of separate white nonetched inclusions near the spalling crater, the formation of sites with an ordered redistribution of the structural components, and the occurrence of new phases point to pronounced phase-structural changes which occurred in the composite after the action of the steel impactor. The regular character of the redistribution of the structural components of the composite shows up in the emergence of alternating sections of different microhardness, which is due to the presence of the sections free from carbide grains or with a large content of them. In addition, the regrouping of the grains of the hardening agent leads to the formation of a specific carbide structure which resembles a network in the cells of which there is a carbide-free binding phase. Alongside with this, the carbide grains are refined, and this causes an abrupt, nearly twofold decrease in their size. The formation of separate nonetched sections is, apparently, connected with the fact that a spalling impulse is generated during the formation of a spalling crater. Undergoing repeated reflections from the rear surface, this impulse leads to termination of the propagation of a plastic wave and, finally, to localization of the strain on separate sites.

X-ray structural analysis has allowed us to reveal a carbide phase different from the initial phase and having a FCC lattice. The formation of this carbide is, probably, connected with the formation of its nonequilibrium state during impact. Indeed, it was established that during stepwise heating the carbide transforms into WC with a hexagonal close-packed (HCP) lattice having the following parameters: $a = 2.9163 \cdot 10^{-10}$ m and $c = 2.8371 \cdot 10^{-10}$ m, which well agrees with the literature data. The temperature of the

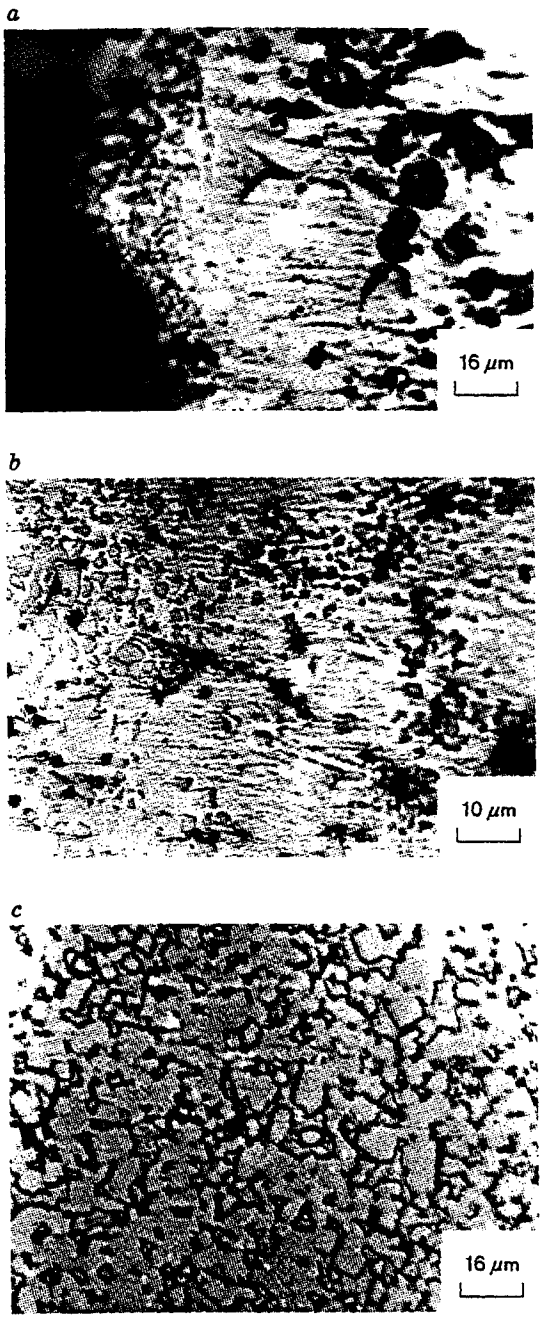

Fig. 2

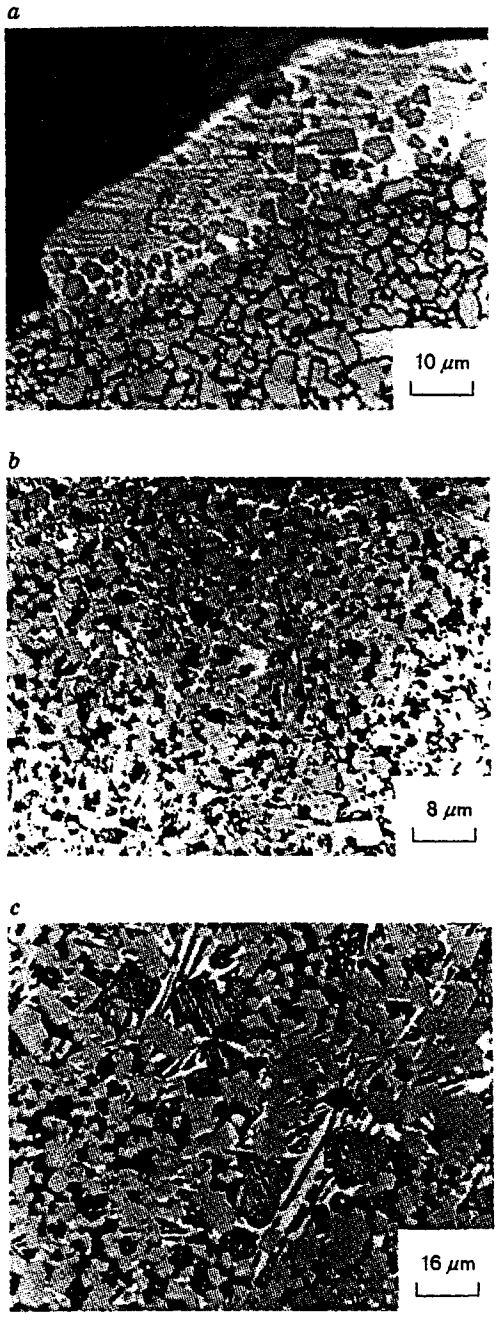

Fig. 3

complete FCC → HCP transformation is equal to 720 K.

The variation in the morphology and dispersity of ε-martensite is associated with the conditions of propagation of and interaction between compression and expansion waves. During reflection of elastoplastic waves from the rear surface of the target, rarefaction waves which interact with the primary wave are generated. In the region of these interactions (near the spalling crater), the target material is subjected to complex spatial-time loads, and this creates conditions for the formation of fine ε-martensite.

Thus, it has been shown that in dynamic fracture of a composite, cardinal changes occur which are connected with the structure and phase composition of the material at macro-, meso-, and microscale levels. These changes are nonuniformly distributed over the material owing to the inhomogeneous internal stresses. A simultaneous involvement of all structural levels in the process of dynamic deformation in similar materials will allow one, apparently, to increase the stability of material to impact fracture.

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