Mechanisms of deformation and fracture in coated materials. Multiscale numerical simulation

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Introduction. Presented is the numerical analysis of deformation and fracture in materials with wear resistant iron boride coating and a composite coating (fig. 1) providing oxidation protection. A dynamic boundary-value problem in a plane strain formulation is solved numerically by the finite-difference method. The coating-substrate interface geometry corresponds to the configuration found experimentally and is accounted for explicitly in the calculations (fig. 1). To simulate the mechanical response of a substrate and a coating use was made of the relaxation constitutive equation based on microscopic dislocation mechanisms and a fracture model taking into account crack initiation and growth in the regions of bulk tension. A series of numerical experiments was conducted at different scales and for varying strain rate of tension/compression.

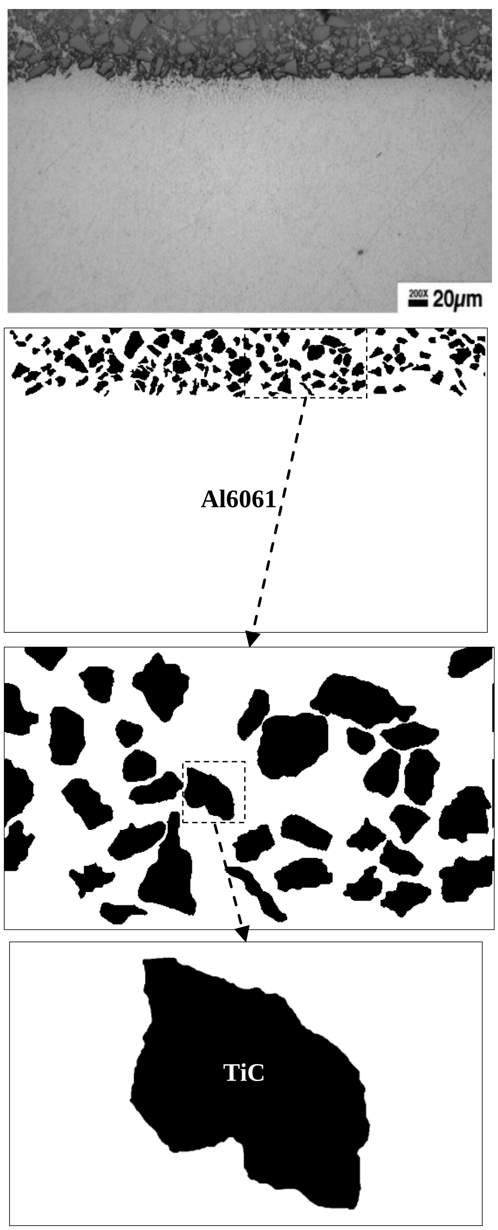

Fig. 1. Composite Al-TiC

The following conclusions can be drawn.

1. The local regions of bulk tension are shown to arise near the metal/ceramic interfaces even under simple uniaxial compression of the composites that controls the mechanisms of fracture at the mesoscale. Both, for tensile and compressive loadings, cracks in the coating tend to originate predominantly in regions of local tension and propagate in different directions.
2. The macroscopic stress increases exponentially with the compression strain rate and changes only slightly under tension because of reduced plasticity.
3. Macroscopic behavior of the Al-TiC composite is shown to be controlled by interrelated processes of localized plastic flow and cracking occurring near the interfaces of two types: “composite coating-aluminum substrate” and “aluminum-TiC”.

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