Rheological Modelling of Metal-Polymer-Oxide Ceramics Composite

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EXTENDED ABSTRACT

In the paper fracture of Al-Al_2O_3-Diamonds containing composite coating has been investigated by using rheological models for principal Hertzian contact of a sphere and a plate. Several requirements to the rheological models were formulated regarding adequate strain-deformation state.

Rheological model of the composite coating has been proposed and confirmed by in-suit experiments. The coating was presented as complex elastic-viscous-plastic rheological model and/or a rheological model from two elastic elements and one viscous element that is the Maxwells' model and an elastic element. Structural equation of an integral model is written as (H || N || St-V) - (H-N || H). If $s > s_0$, then rheological model of the former model may be described as

$$\sigma = \sigma_0 + E_1\varepsilon_1 + \eta_1 \frac{d\varepsilon_1}{dt}. \qquad (1)$$

where s_0 is ultimate strain; $?_1$ is Young's modulus; $?_1$ is coefficient of viscosity; e – deformation. If $s > s_0$, then rheological model of the later model is

$$\frac{d\sigma}{dt} + \frac{E_{22}}{\eta_2}\sigma = (E_{21} + E_{22})\frac{d\varepsilon_2}{dt} + \frac{E_{21}E_{22}}{\eta_2}\varepsilon_2 \qquad (2)$$

where $?_{21}$, $?_{22}$ are Young's modules; $?_2$ is coefficient of viscous element.

Under random loading rate integral rheological equation for the joined models will be as follows

$$\frac{\eta_1}{E_{22}}\frac{d^2\sigma}{dt^2} + \left(\frac{E_1}{E_{22}} + \frac{\eta_1}{\eta_2} + \beta\right)\frac{d\sigma}{dt} + \frac{E_1 + E_{21}}{\eta_2}\sigma - \frac{E_{21}}{\eta_2}\sigma_0 = \beta\eta_1\frac{d^2\varepsilon}{dt^2} + \left(\frac{\eta_1}{\eta_2}E_{21} + \beta E_1\right)\frac{d\varepsilon}{dt} + \frac{E_1E_{21}}{\eta_2}\varepsilon$$

The crystallographic and morphologic texture was characterized and the fracture resistance was measured, using fracture-mechanics. Examination of the composite coating shows a hardness value of 25 GPa (about 25% higher than alumina-based layer) and fracture resistance (about 50% higher than for single oxide ceramic layer) as compared to prior alumina-based coatings on a soft substrate.

Experiments revealed ultimate stresses and stress-deformation modes of the coating. Diamonds nanoparticles improve fracture resistance of alumina-based layer. It is also thought that the composite coatings will have higher thermal conductivity and thermal shock resistance than that of alumina-based layer. Such physical characteristics suggest a number of possible commercial applications for the composite coatings, particularly for wear-resistant and related applications. The higher hardness and toughness of the coatings make them very attractive as substitutes for alumina-based and other ceramic-based composite coatings in these applications.