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A NUMERICAL STUDY OF MECHANICAL BEHAVIOUR OF MULTILAYER COMPOSITES UNDER DEPTH-SENSING INDENTATION

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ABSTRACT

Multilayer coatings with nanometer scale layer dimensions are attractive to specific engineering requirements, due to their extremely high strength and flexibility, relatively to conventional laminated composites[1]. The evaluation of hardness and Young's modulus of multilayered thin films is coupled with difficulties induced by the influence of substrate and constituent layers on the measured properties of multilayered composite. Application of the finite element method is an effective way for quantifying mechanical properties of multilayered materials and providing detailed data for better description of their mechanical behaviour under depth-sensing indentation.

In the present study, numerical simulation of nanohardness test of multilayered coatings based on TiAlN with interlayers of ductile metals was carried out, in order to describe the mechanical properties of these coatings. Specific three-dimensional numerical simulation home code, HAFILM, was used[2]. This was specifically developed to simulate hardness tests with any type of indenter shape, taking into account contact with friction between the indenter and the sample and the offset of the Vickers indenter. The substrate material simulated was high-speed-steel M2 (AISI). The coating's thickness was 3.5 μm and the copper interlayer thickness was of 0.1 μm. The mechanical properties of substrate and interlayers materials are presented in Table 1:

Material	σ_y (GPa)	ν	E (GPa)	H (GPa)
M2	2.57	0.3	210	6.5
TiAlN	12.05	0.2	460	27.1
Copper	0.49	0.33	140	1.7

Table 1. Mechanical properties of hard and ductile layers, and substrate.

The mechanical properties of TiAlN coatings with copper interlayers are summarised in Table 2 and the respective load-indentation depth curves obtained in numerical simulations for the coatings with different number of interlayers are shown on Fig. 1. The introduction of copper interlayers results in a decrease of the hardness of the coatings as it is seen on Fig. 2. Moreover, the hardness of the coating decreases

gradually with increasing of the number of copper interlayers. The load – indentation curves tend to approach to each other as the number of the layers increases.

Number of layers/interlayers	H (GPa)	E (GPa)
1/0	27.7	380.3
3/1	26.8	379.8
7/3	25.6	384.1
11/5	23.8	393.2
15/7	22.7	378.5

Table 2. Mechanical properties of multilayer coatings, up to 4 µm penetration depth.

The Young's modulus of the multilayer coatings does not vary with increasing the number of interlayers and attains the value close to the Young's modulus of TiAlN.

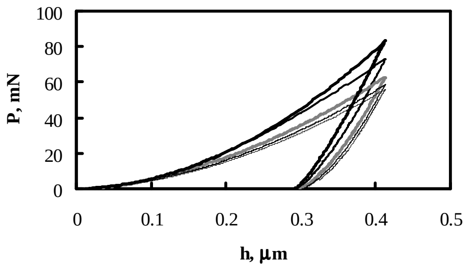


Fig. 1. Load – indentation depth curves for multilayer coatings

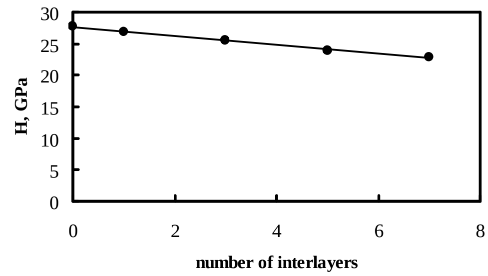
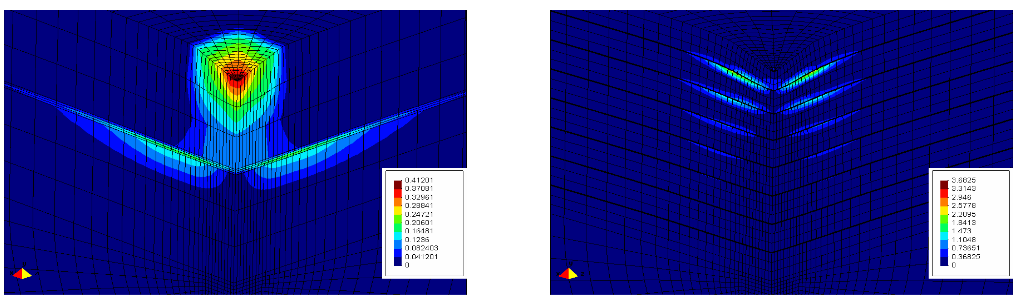


Fig. 2. Hardness of multilayer coatings *versus* the number of interlayers

The strain distribution in multilayer coatings under indentation was also examined. It was observed that for coatings with 7 or more layers the maximum plastic strain regions are located at a deepness value under the indentation surface near the ductile interlayers.



a) b)

Fig. 3 The equivalent plastic strain distribution in TiAlN multilayer coatings composed by: (a) 3/1 layers/interlayers; and (b) 15/7 layers/interlayers.

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