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Mechanical characterization of coated systems involving multilayer films

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Mots clé

Elastic modulus, multilayer coatings, nanoindentation, spherical indentation, elastic stresses

INTRODUCTION

The computation of the elastic contact stresses and particularly the determination of the change in the von Mises stress from the surface of a coated system, when it is subjected to spherical indentation, constitutes an important aspect of the tribological performance assessment of such a system.

In the case of coated systems involving multilayer films this task implies a fundamental problem: the description of both the elastic modulus and Poisson ratio of the different layers, which encompass the coated system, with indentation depth. In this way, it would be possible to solve the non-linear equation which relates the contact radius, reduced modulus, load applied and ball diameter, in order to compute the correct value of the contact radius.

Concerning the computation of Poisson's ratio for a given contact radius, which is required in order to determine both the principal stresses and consequently the von Mises stress, a Heaviside step function can be readily employed. However, the description of the change in elastic modulus of a multilayer coated system implies a more elaborated procedure, as indicated in the forthcoming.

CHANGE IN ELASTIC MODULUS WITH INDENTATION DEPTH

Figure 1 illustrates, as an example, the change in elastic modulus with indentation depth for a coated system involving a prototype a-C:Cr,Si/CrCSi coating deposited by PVD techniques.

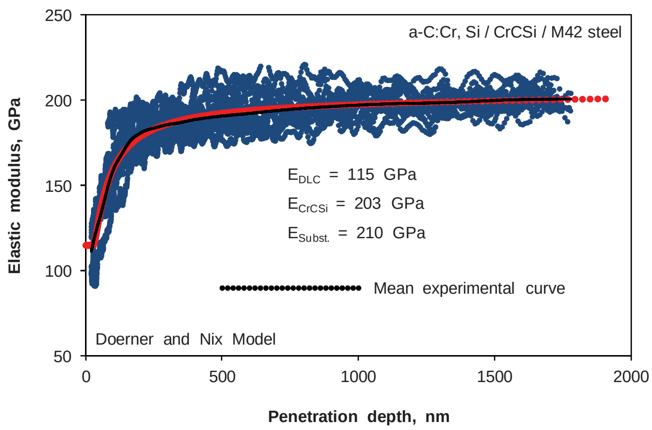

Figure 1 : Change in the elastic modulus of a coated system with indentation depth

The experimental data are encompassed in a wide scatter band. Therefore, together with the experimental data points, the mean experimental curve has also been included in the Figure. Thus, it is possible to model the change in the elastic modulus of the system with indentation depth by means of the extended version of any model developed for such a purpose, in the case of monolayer coatings. In Figure 1, the approach earlier proposed by Doerner and Nix [1] for monolayer coatings and extended by Puchi-Cabrera et al. [2] to multilayer coatings, has been employed.

EXPERIMENTAL RESULTS

Figure 1 clearly illustrates that the extended Doerner and Nix model is able to reproduce quite accurately the trend shown by the mean experimental curve. Therefore, it represents a valuable tool for determining accurate and reliable values of the elastic modulus of the different layers, which compose the coated system. Consequently, the computation of the change in the von Mises stress with distance from the surface can be carried out on the basis of the Hertzian equations, which correspond to the elastic contact between a spherical indenter and a multilayer coating, taking into account the strain compatibility at each interface. Thus, the value of the elastic modulus can be interpolated directly from the results shown in Fig. 1 and the von Mises stress could be computed for the each layer. The results of these computations are shown in Fig. 2 for 1 N of applied load.

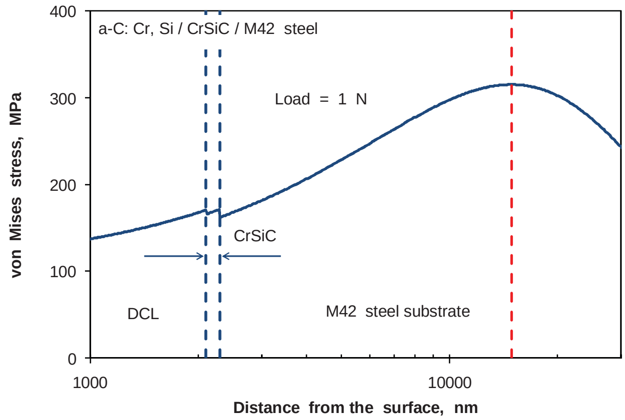

Fig. 2: Change in the von Mises stress as a function of the distance from the surface

CONCLUSIONS

The elastic modulus of multilayer coatings can be characterized experimentally by nanoindentation techniques and modeled by means of different approaches, taking into account their actual architecture, rather than assuming the existence of a monolayer film. In this way, it would be possible to conduct a precise analysis of the elastic stresses developed in the coated system under spherical indentation, as well as determining the maximum contact pressure at which the coated system will perform satisfactorily in service.

References

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