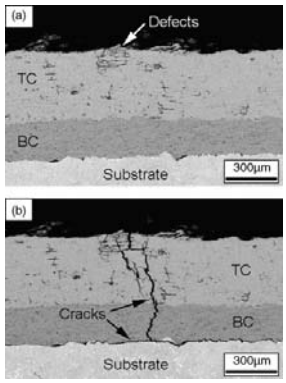
Use of Functionally Graded Interlayer to Improve Bonding in Coated Plates

Introduction

Coatings play an important role in a variety of engineering applications protecting metallic or ceramic substrates against oxidation, heat penetration, wear and corrosion.

Conventional coatings usually consist of one or two homogeneous layers deposited on a substrate; they are susceptible to cracking and debonding due to the mismatch of thermo-mechanical properties between the coating and the substrate.

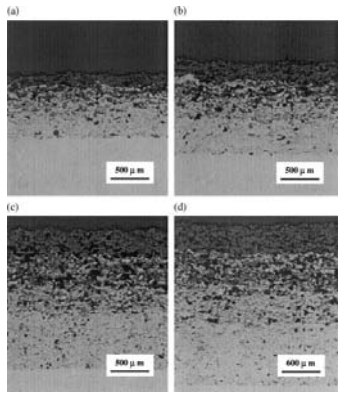


Conventional coating/substrate system

[Z.X. Chen et al. Materials Science and Engineering: A 2008; 483-484, 629-632]

The concept of Functionally Graded Material is currently actively explored in coating design to increase resistance of coatings to functional failure.

Functionally Graded Material (FGM) refers to a heterogeneous composite material with gradient compositional variation of the constituents from one surface of the material to the other which results in continuously varying material properties.

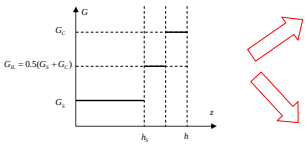


Functionally graded metal/ceramic coatings

[H.-P. Xiong et al. Surface and Coatings Technology 2005; 194 (2-3), 203-214].

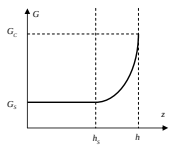
Theoretical Modelling

Coating design incorporating FGM concept



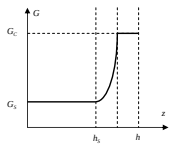
Conventional coating with homogeneous interlayer and homogeneous top coat

(H-H coating)



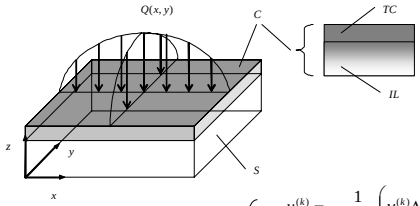
Single layered FGM coating without interlayer

(FGM-coating)



Coating with FGM interlayer and homogeneous top coat

(FGM-H coating)



$$G^{(k)}(z) = g^{(k)} \exp\left[\gamma^{(k)}\left(\frac{z}{h}-1\right)\right],$$

3-D displacement field

$$u_x^{(k)} = -\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial x} + \frac{\partial N^{(k)}}{\partial y}$$

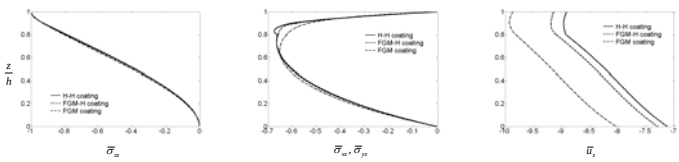
$$u_y^{(k)} = -\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial y} - \frac{\partial N^{(k)}}{\partial x}$$

$$u_z^{(k)} = -\frac{1}{G^{(k)}}\left(\Delta - \frac{\partial^2}{\partial z^2}\right)\frac{\partial L^{(k)}}{\partial z} + \frac{\partial}{\partial z}\left[\frac{1}{2G^{(k)}}\left(\nu^{(k)}\Delta - \frac{\partial^2}{\partial z^2}\right)L^{(k)}\right]$$

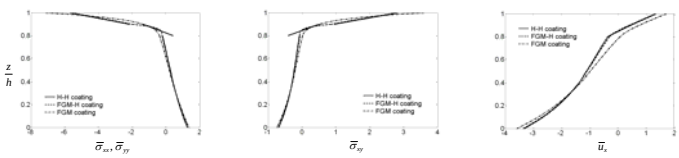
For 3-D stress field use constitutive equations

Numerical Results

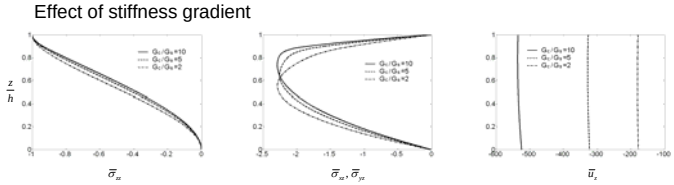
Out-of-plane stresses and displacements

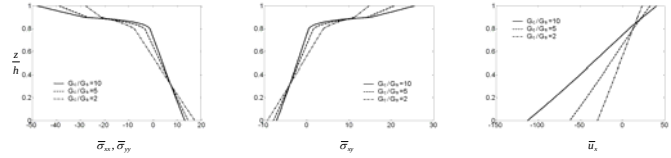


In-plane stresses and displacements



Effect of stiffness gradient





The benefits of using FGM interlayer and homogeneous top coat instead of a single layered FGM coating:

- stress discontinuity is eliminated without increasing stresses at the top surface
- increase in transverse displacement is significantly smaller

REFERENCES

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