Prediction of Temperature and Thermal Stress in Plasma Sprayed Coatings

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Introduction: Plasma spraying is one of the prominent technologies for wear, corrosion and high temperature resistant coatings. The coating quality characteristics depend on many plasma process parameters. Hence, it is necessary to study the mechanisms of stress development to predict and control the temperature and stresses.

1-D model is developed using COMSOL® to predict the thermal history and stress distribution of substrate/ coating during plasma spraying. The mathematical model includes plasma and particle heat flux as well as temperature dependent thermo-physical properties to predict the temperature distribution of substrate/coating by considering semi-infinite body approximation.

Modelling of Temperature Distribution:

The following assumptions are used to develop the present/current model.

- ✓The substrate is a semi-infinite solid body.
- ✓Particle deposition / coating growth rate is constant during spraying.
- ✓Particles are completely melted before reaching substrate/already built coating.
- ✓Both particle and plasma heat fluxes are constant with time.

The Governing equation is

$$\rho C_p \frac{dT}{dt} = K \frac{d^2T}{dX^2}$$

The total heat flux to the top wall is given by

$$q = q_{conv} + q_{rad} + q_{sol} + q_{cool}$$

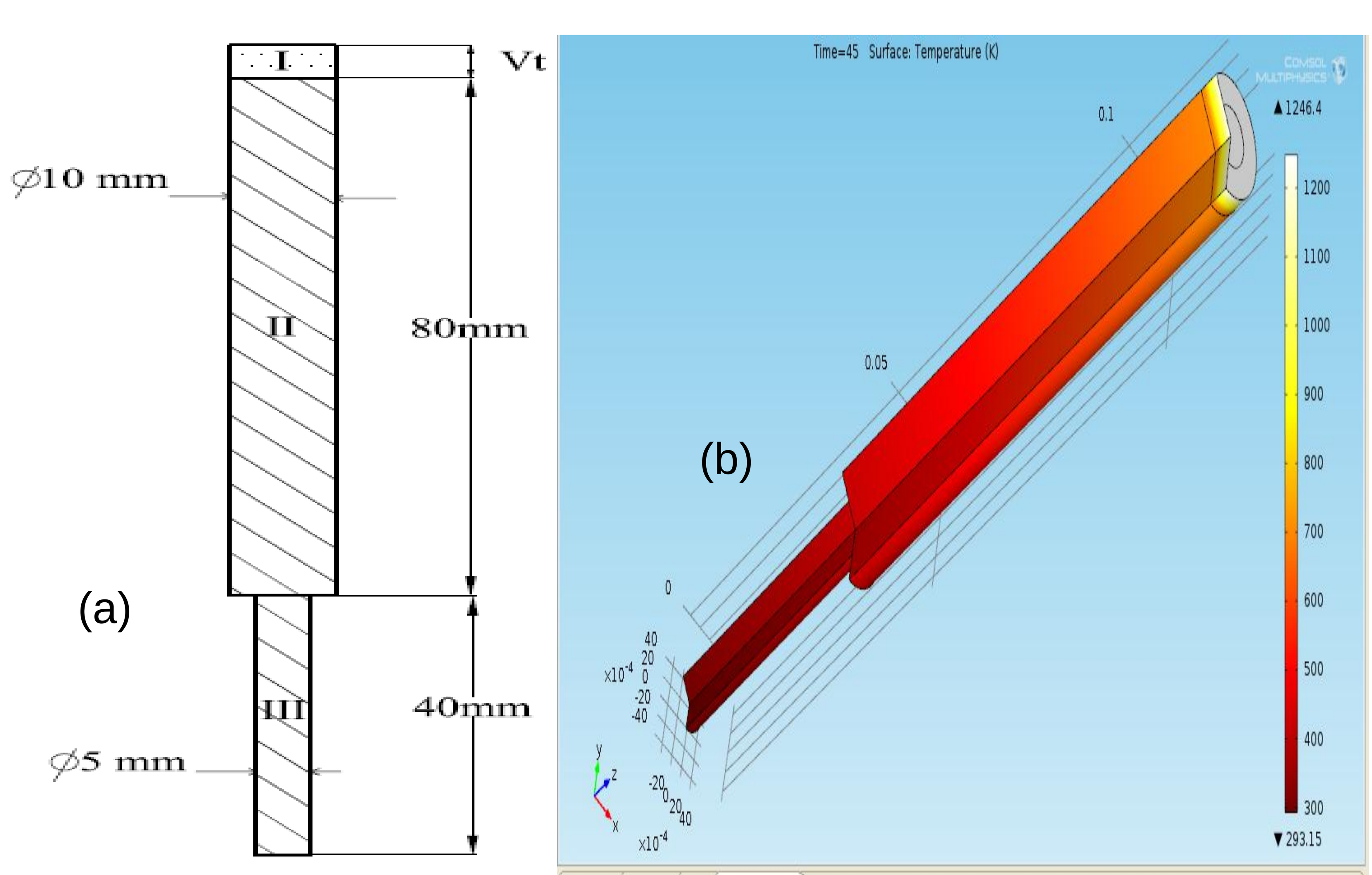

Figure 1. (a) Schematic Representation of Comutational Model (b) Thermal history

Results: The temperature predicted from the previous model varies linearly from the bottom of the substrate holder to top of the coating, which is not realistic.

Since alumina has thermal conductivity much lower than the copper, there should be a larger temperature gradient in the coating than substrate. It is interesting to note that the present model predicts larger temperature gradients in the coating than the same in the substrate as anticipated. This is because the heat flux boundary condition is applied on the built coating surface not on the substrate surface when $t > 0$ in the present model.

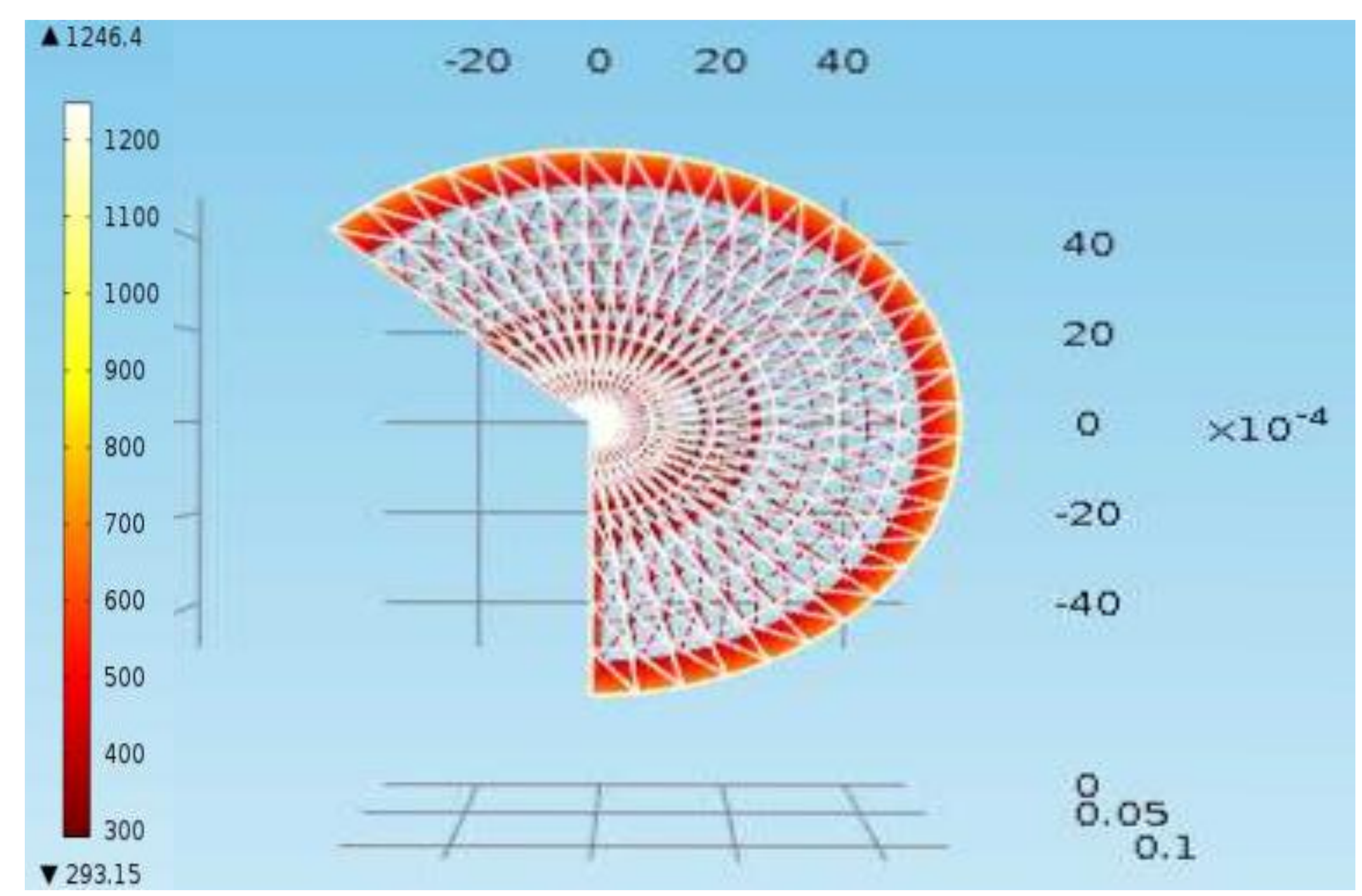

Figure 2. Thermal history of coating region on substrate

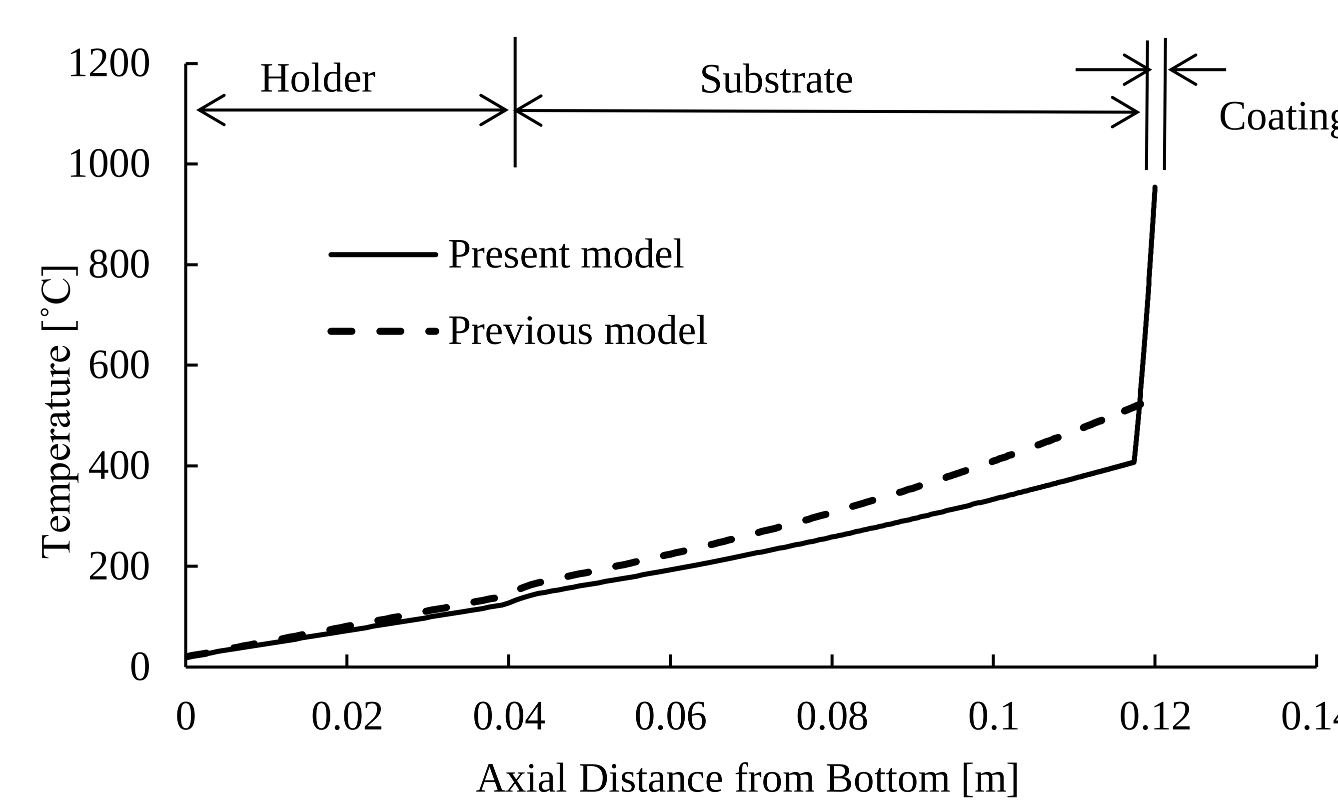

Figure 3. Axial Temperature distribution of coating-substrate-holder

Conclusions: A 1-D model is developed based on the theory of previous model to predict the substrate and coating temperatures of growing alumina coating during plasma spraying. The model is able to predict the temperature gradient of the coating during spraying..

References:

1. Lech Pawlowski, "Temperature Distribution in Plasma-Sprayed Coatings", Thin Solid Films, 81, pp 79-88 (1981).
2. S. Cirolini et al. "Computer simulation of plasma-sprayed coatings I. Coating deposition model", Surface and Coatings Technology, 48, pp 137-145 (1991).
3. M. Ferrari et al. "Computer simulation of plasma-sprayed coatings II. Effective bulk properties and thermal stress calculations", Surface and Coatings Technology, 48, pp 147-154 (1991).

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