Thermo-elastic characteristics due to influence of thickness in thermal barrier coatings

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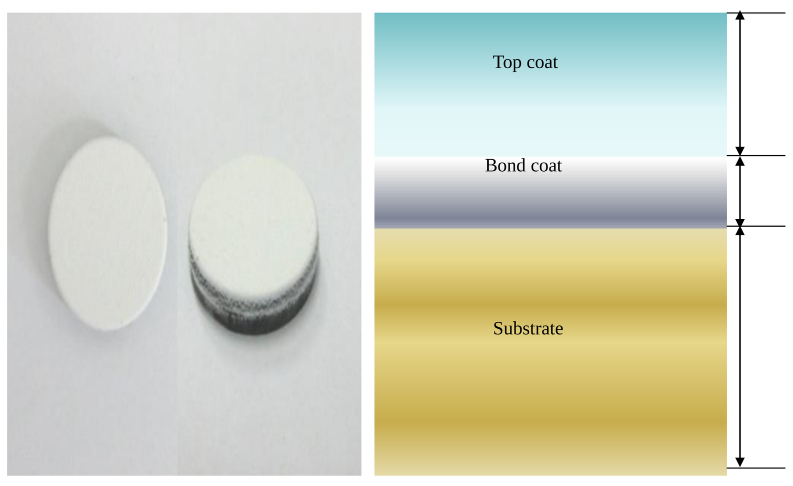
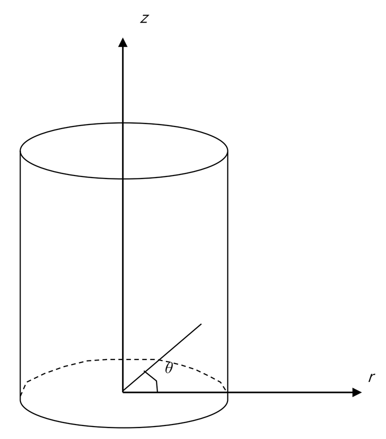
TBC Model – Circular Disk

Circular Disk





Differential equations

1. Temperature distribution

$$\frac{\partial^2 T}{\partial z^2} = 0$$

General Solution :

$$T(z) = D_1 z + D_2$$

$D_1,\ D_2$: integral constants

2. Thermoelastic characteristics

$$-K(1-\nu)r\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right) + Gr^2\frac{\partial}{\partial z}\left(\frac{\partial u}{\partial z}\right) + K(1-\nu)u = 0$$

$$-K(1-\nu)r\frac{\partial}{\partial z}\left(\frac{\partial w}{\partial z}\right) + (G-K\nu)\frac{\partial}{\partial r}\left(\frac{\partial u}{\partial z}\right) + \left(\frac{G}{r}-\frac{K\nu}{r}\right)\frac{\partial u}{\partial z} + K\alpha(1+\nu)\frac{\partial T}{\partial z} = 0$$

where $K = \dfrac{E}{(1+\nu)(2\nu-1)}$

u : displacement to the direction r

w : displacement to the direction z

Boundary conditions

1. Temperature distribution

$T(z_0) = T_{in}$ $\quad T(z_1) = T_1$

$T(z_2) = T_2$ $\quad T(z_3) = T_{out}$

2. Thermoelastic characteristics

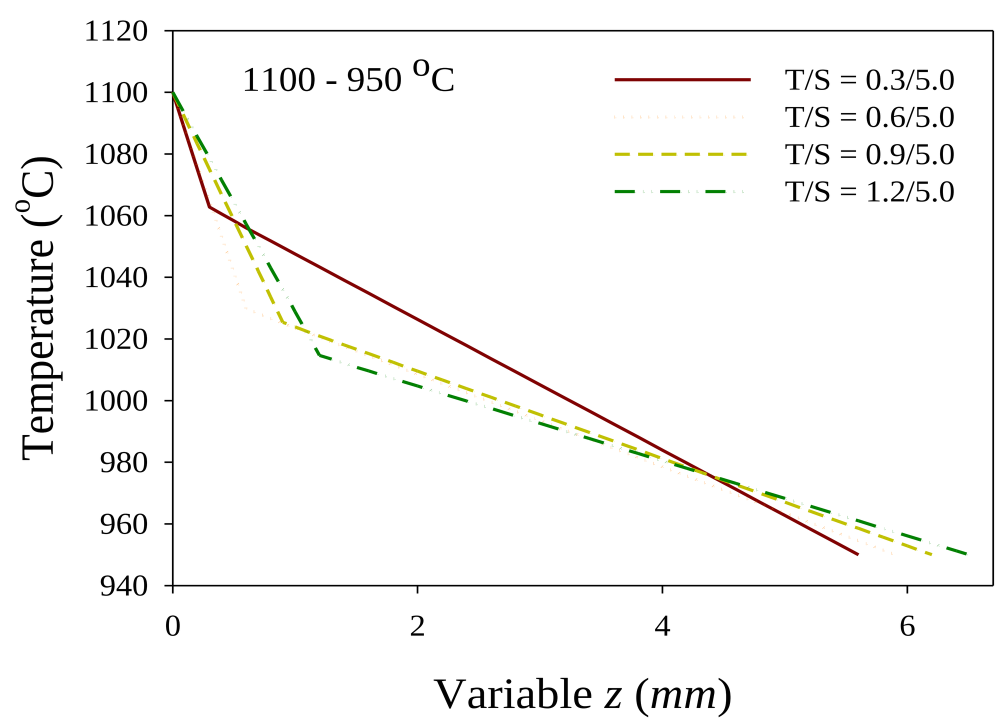
$u(0,z) = 0$ $\quad \sigma_r(R,z) = 0$

$\sigma_z(r,0) = 0$ $\quad \sigma_z(r,z_b) = 0$

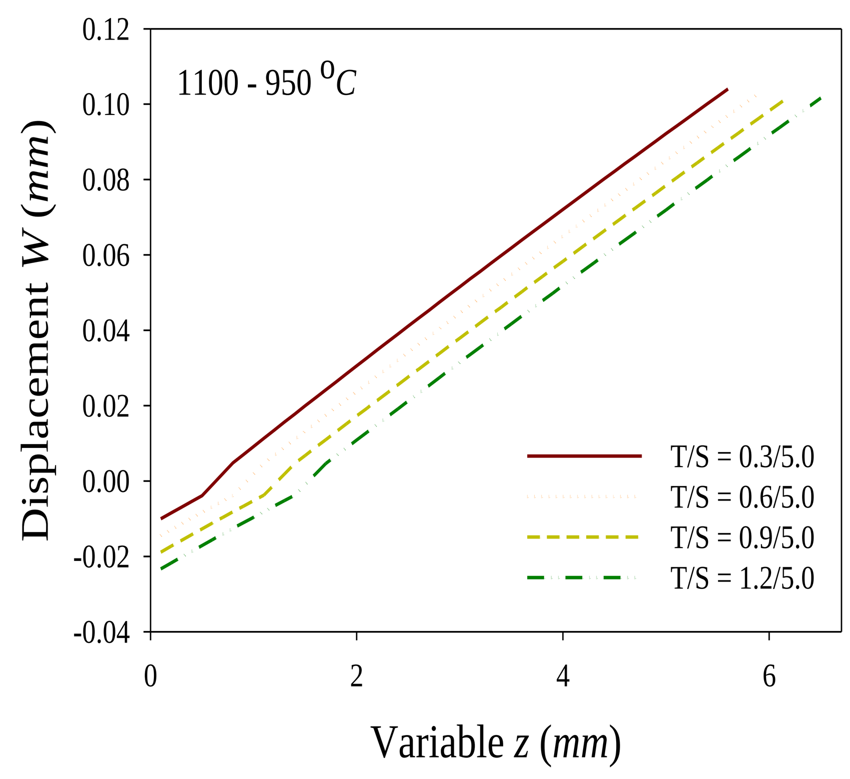
Mechanical and thermal properties

Material	Dense Top coat (204 C-NS)	Dense Top coat (204 NS)	Bond coat (AMDRY 962)	Substrate (NIMONIC 263)
Elastic Modulus (GPa) at room temperature	50	100	200	221
Poisson's ratio	0.315	0.2	0.3	0.3
Thermal Expansion Coefficient (10-6/℃)	11.5 (20-1300℃)	9.5 (20-1300℃)	14	11.1 (20-100℃)
Thermal Conductivity (W/m-℃)	1.5	2.0	11	11.7

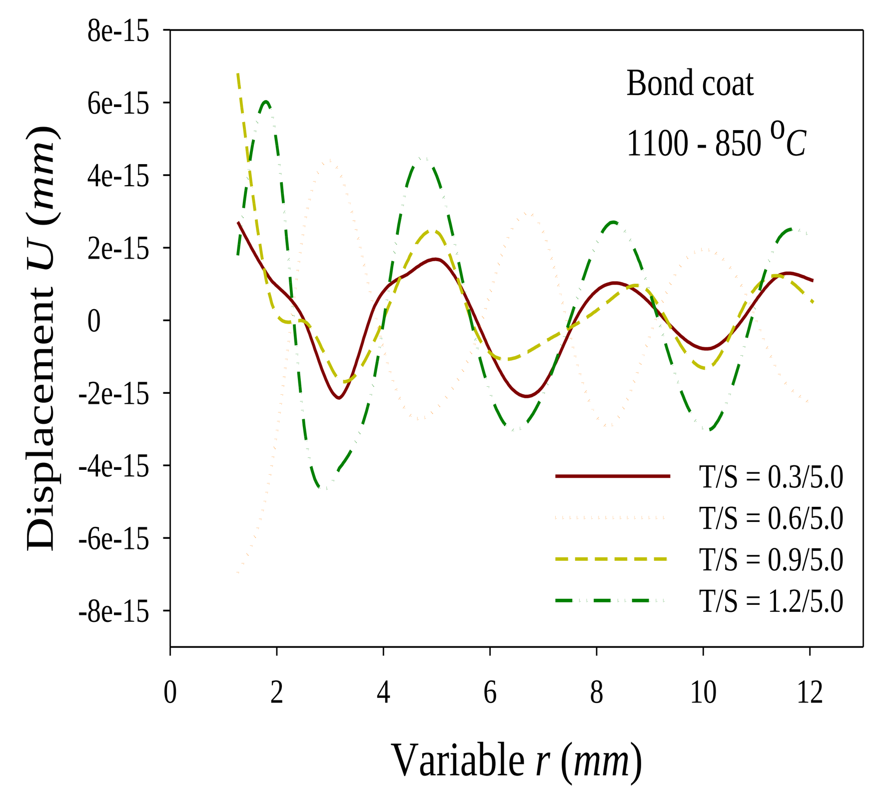
Temperature distribution



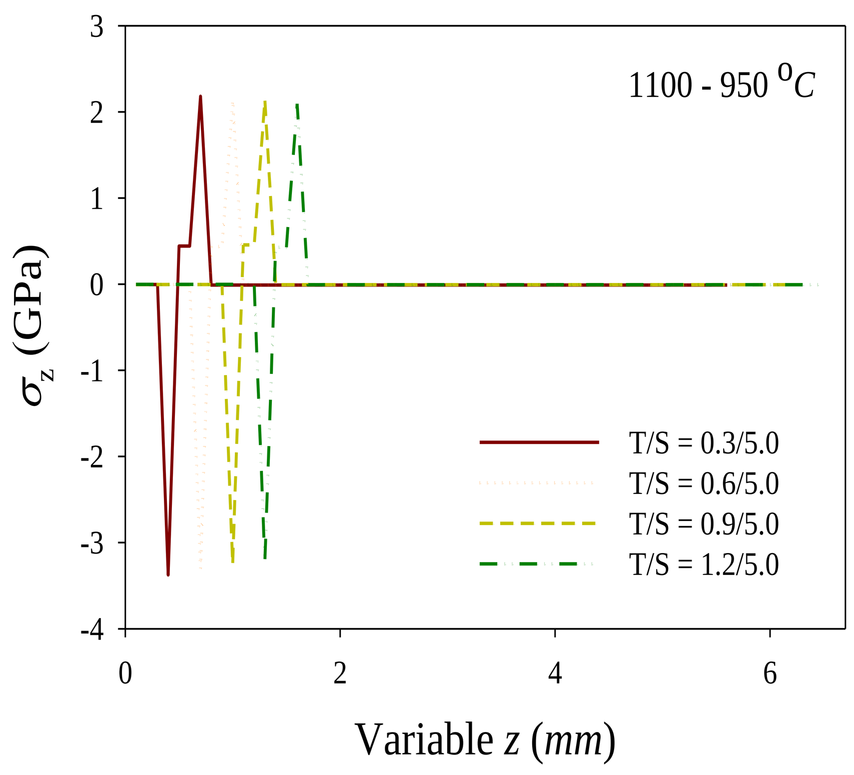
Longitudinal displacement



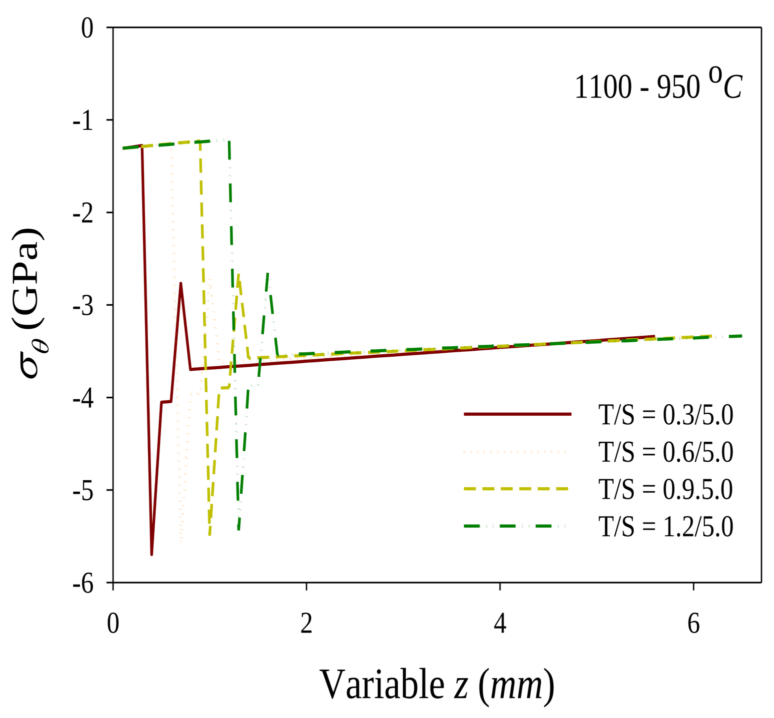
Radial displacement



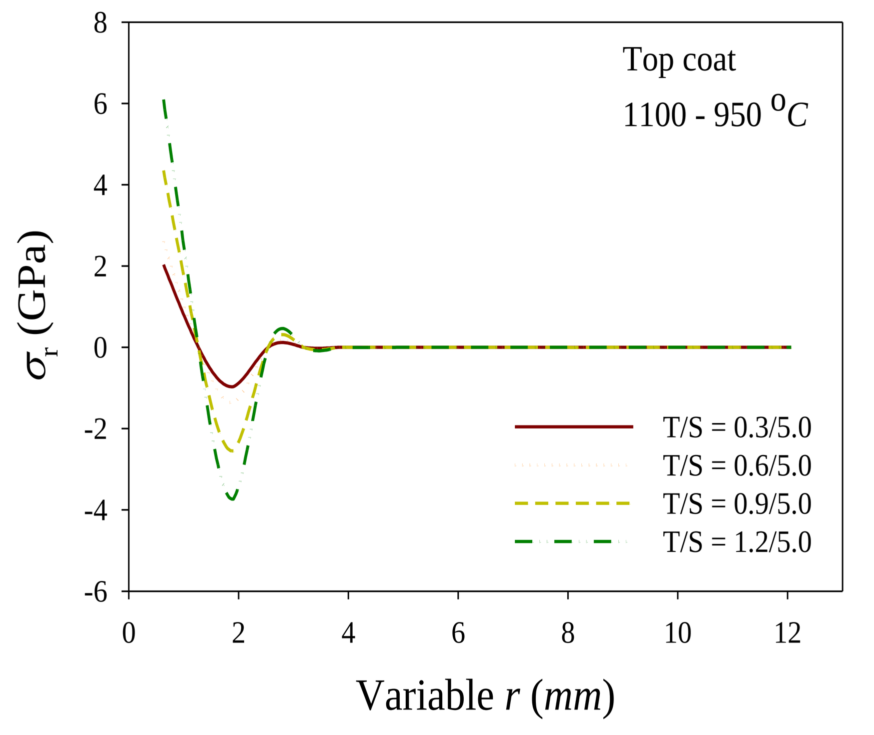
Longitudinal stress



Circumferential stress



Radial stress



Conclusions

1. As the thickness of the top coat increases the bond coat and the substrate are the loading of lower temperature .
2. In the longitudinal direction, larger extension developed as the ratio of the top coat to the substrate decreases, while the displacement to the radial direction smaller.
3. The magnitude of the maximum longitudinal and circumferential stresses (compressive and tensile) gradually decreases the ratio increases.
4. The largest radial stress occurs at the center and the magnitude of fluctuation is getting larger as the ratio increases.
5. Mathematical approach developed is reasonable and the results obtained can be applicable in designing TBC to increase the durability of hot-section components in gas turbines.