A model of two cylindrical plane wall layers exposed to oscillating temperatures with different amplitudes and frequencies

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Keywords:

Oscillating Temperature, Temperature amplitude, Thermal conductivity, Thermal diffusivity

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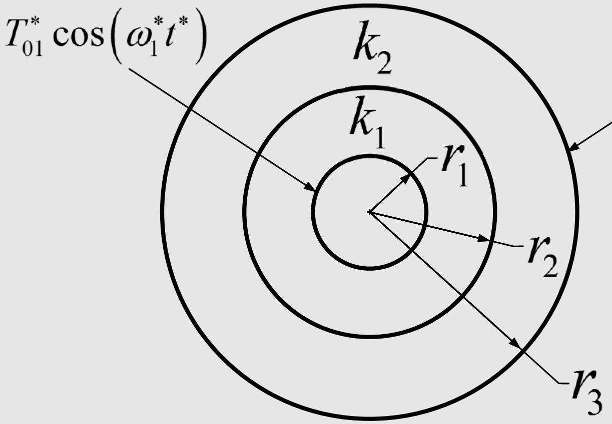
Motivation

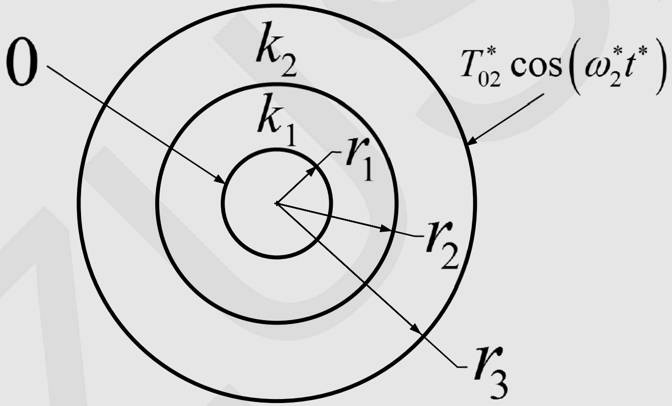
Heat transfer into a cylindrical wall is an important issue in some engineering areas. For example, there is a focused effort in investigating the temperature distribution in the cylinder walls of combustion engines. Studies of temperature distribution are needed for predicting the thermal and fatigue stresses produced in the cylinder wall. Fatigue stresses may be produced as a result of boundary temperature oscillations due to the cyclic operation of the engine.

Method

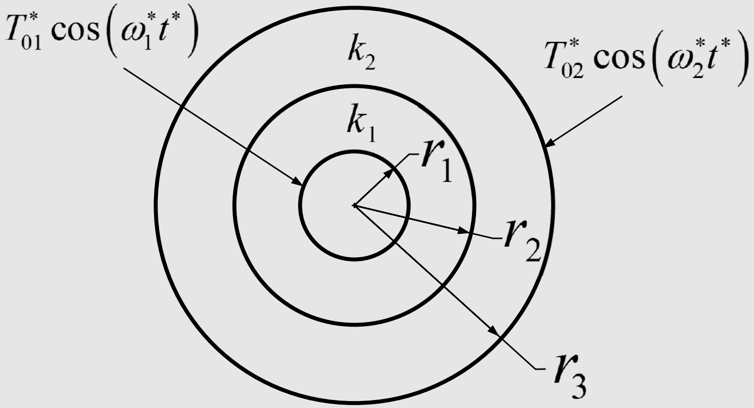
- A physical superposition of stage 1 and stage 2 to receive the general problem solution.



The first stage problem



The second stage problem



The general problem

- The general complex solution into every cylindrical shell

$$T^* = c_1 e^{i\omega^* t^*} I_0(b^* r^*) + c_2 e^{i\omega^* t^*} K_0(b^* r^*)$$

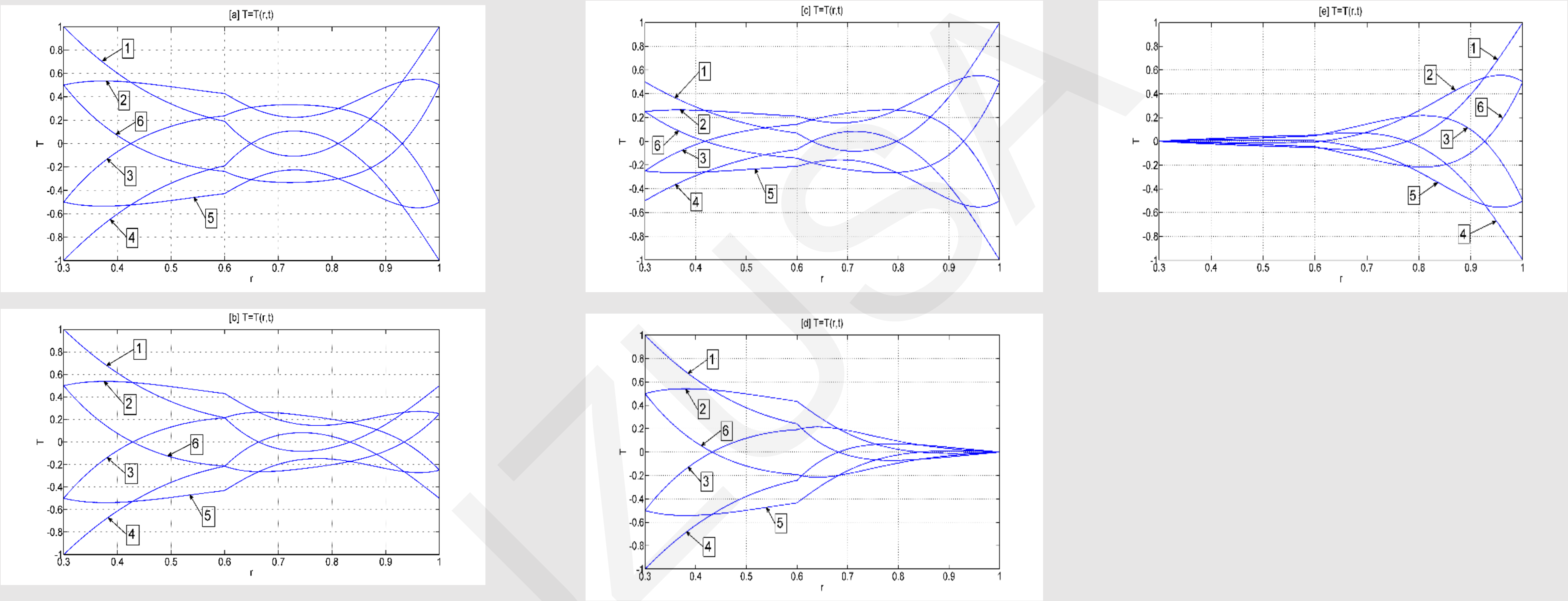
- Boundary conditions of stage 1

$$T_1^*\Big|_{r^*=r_1^*} = T_{01}^* e^{i\omega_1^* t^*} \qquad T_1^*\Big|_{r^*=r_2^*} = T_2^*\Big|_{r^*=r_2^*} \qquad k_1^* \frac{\partial T_1^*}{\partial r^*}\Big|_{r^*=r_2^*} = k_2^* \frac{\partial T_2^*}{\partial r^*}\Big|_{r^*=r_2^*} \qquad T_2^*\Big|_{r^*=r_3^*} = 0$$

- Boundary conditions of stage 2

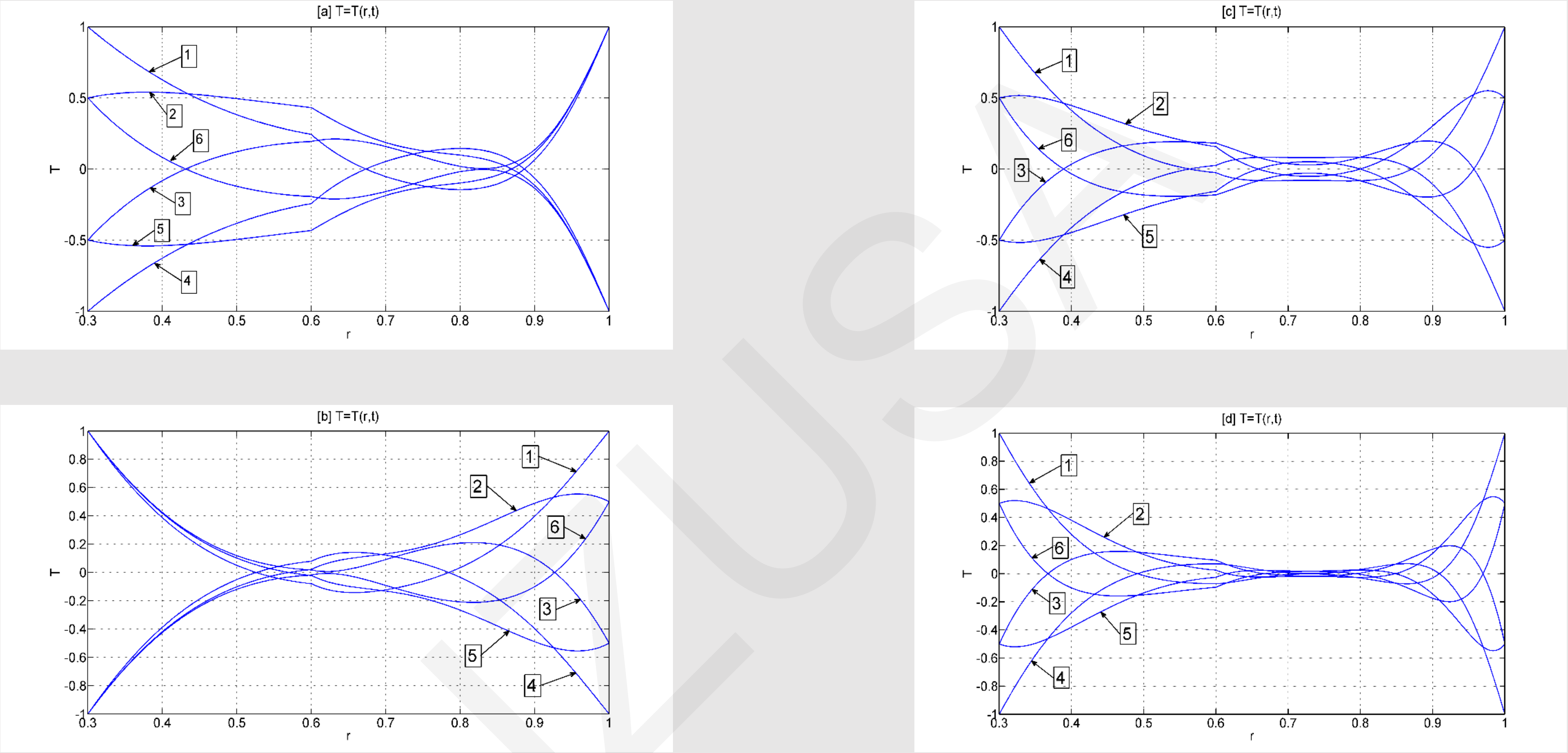
$$T_1^*\Big|_{r^*=r_1^*} = 0 \qquad T_1^*\Big|_{r^*=r_2^*} = T_2^*\Big|_{r^*=r_2^*} \qquad k_1^* \frac{\partial T_1^*}{\partial r^*}\Big|_{r^*=r_2^*} = k_2^* \frac{\partial T_2^*}{\partial r^*}\Big|_{r^*=r_2^*} \qquad T_2^*\Big|_{r^*=r_3^*} = T_{02}^* e^{i\omega_2^* t^*}$$

Amplitude Influence



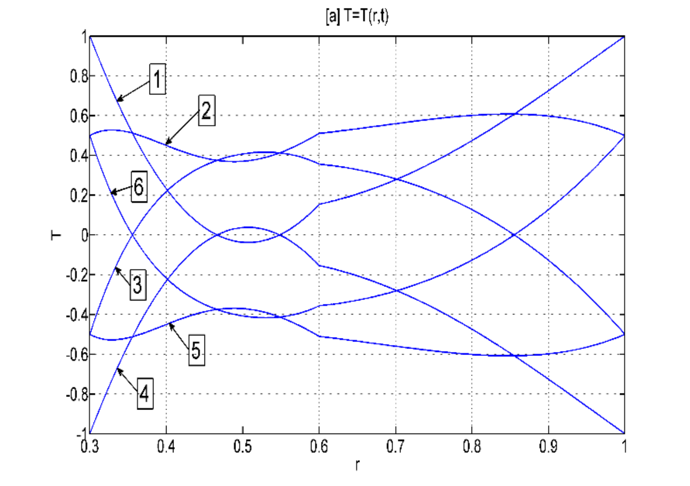
Five temperature distributions for the parameters listed in section 2: $\omega_1^* = 1$, $\omega_2^* = 1$, $\alpha_1^* = 0.05$, $\alpha_2^* = 0.01$, $r_1^* = 0.3$, $r_2^* = 0.6$, $r_3^* = 1$, $k_1^* = 0.05$, $k_2^* = 0.01$ **. The amplitude relations are: case a-** $T_{01}^* = 1$, $T_{02}^* = 1$ **, case b-** $T_{01}^* = 1$, $T_{02}^* = 0.5$ **, case c-** $T_{01}^* = 0.5$, $T_{02}^* = 1$ **, case d-** $T_{01}^* = 1$, $T_{02}^* = 0$ **, case e-** $T_{01}^* = 0$, $T_{02}^* = 1$ **.**

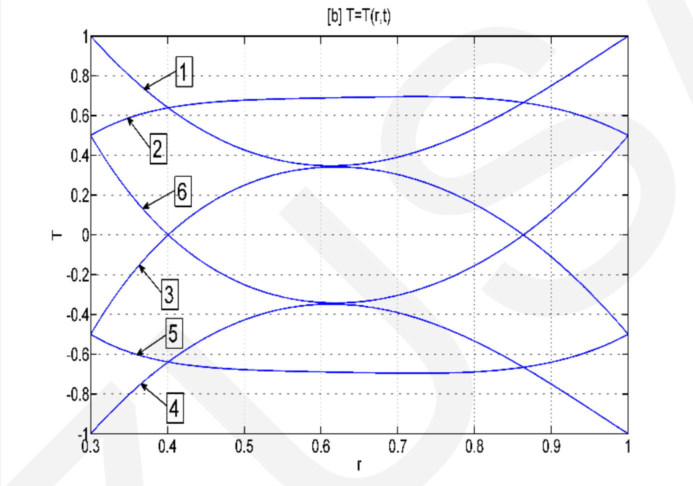
Frequency Influence

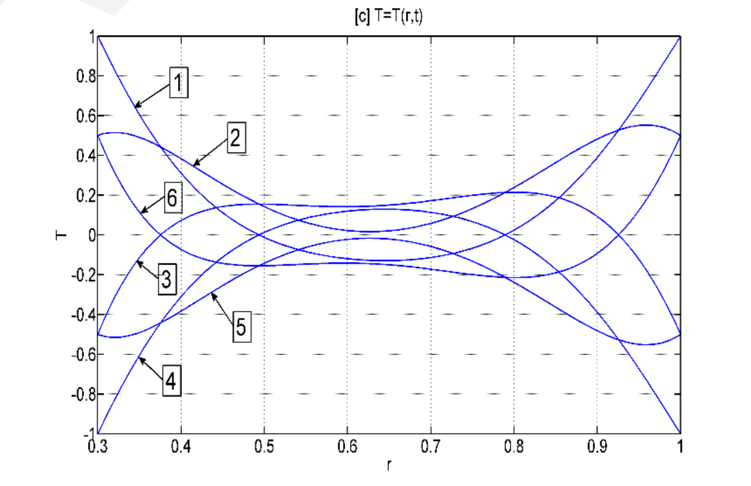


Four temperature distributions for those parameters listed in section 2: $T_{01}^* = 1$, $T_{02}^* = 1$, $\alpha_1^* = 0.05$, $\alpha_2^* = 0.01$, $r_1^* = 0.3$, $r_2^* = 0.6$, $r_3^* = 1$, $k_1^* = 0.05$, $k_2^* = 0.01$. **The frequency relations are: case a-** $\omega_1^* = 1$, $\omega_2^* = 3$, **case b-** $\omega_1^* = 3$, $\omega_2^* = 1$, **case c-** $\omega_1^* = 3$, $\omega_2^* = 3$, **case d-** $\omega_1^* = 6$, $\omega_2^* = 6$.

Conductivity Influence







Three temperature distributions for those parameters listed in Section 2: $T_{01}^* = 1$, $T_{02}^* = 1$, $\omega_1^* = 1$, $\omega_2^* = 1$, $r_1^* = 0.3$, $r_2^* = 0.6$, $r_3^* = 1$. **The specific diffusivity and conductivity relations are:** case a- $\alpha_1^* = 0.01$, $\alpha_2^* = 0.05$, $k_1^* = 0.01$, $k_2^* = 0.05$ case b- $\alpha_1^* = 0.05$, $\alpha_2^* = 0.05$, $k_1^* = 0.05$, $k_2^* = 0.05$, case c- $\alpha_1^* = 0.01$, $\alpha_2^* = 0.01$, $k_1^* = 0.01$, $k_2^* = 0.01$.

Conclusions

- Increasing the frequency constraint on the surface, decreases the temperature penetration depth.
- In systems that are working with high frequency and need insulation, it is possible to save material thickness and insulation.
- Temperature distribution lines showing simultaneous heat flux entry and exit were not found.
- To build this physical model, a physical superposition had to be used.