Learn Concept of Thermal Stress for GATE with Sample Questions - Study Material in PDF!

Thermal stress is stress created by any change in temperature to a material. These stresses can lead to fracture or plastic deformation depending on the other variables of heating, which include material types and constraints. Thermal stress is caused due to Temperature gradients, thermal expansion or contraction. The thermal coefficient of expansion determines the type of stress which varies from material to material. In general, the larger the temperature change, the higher the level of stress that can occur. The material will expand or contract depending on the material's thermal expansion coefficient. As long as the material is free to move, the material can expand or contract freely without generating stresses. They are especially important for GATE CE and GATE ME. Read this article on Thermal Stress for GATE & find some previous year questions too!

Strain & Thermal Stress for GATE

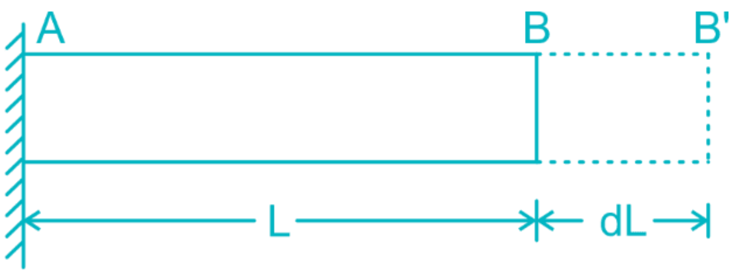
- An increase in temperature produces an increase in length and a decrease in temperature results in a decrease in length.
- If the body is allowed to expand or contract freely, no stress will be set up in the body.
- When the free expansion or contraction is partially or completely prevented then there will be internal resisting force induced in the body i.e. thermal stress will be developed in the body.
- So, change in temperature results in thermal strain and thermal stress, depending upon the boundary condition's.

<u>Case 1:</u> No restriction for expansion/contraction

Thermal strain ϵ_T is proportional to the temperature change ΔT:

$$\epsilon_T = \alpha \Delta T$$

α is coefficient of thermal expansion.



Change in length of the rod (dL) due to change in temperature (ΔT):

$$dL = \alpha . \Delta T . L$$

$$\epsilon \neq 0, \sigma = 0$$

Q: A circular rod of length 'L' and area of cross-section 'A' has a modulus of elasticity '*E*' and coefficient of thermal expansion 'α'. One end of the rod is fixed and other end is free. If the temperature of the rod is increased by Δ*T*, then

(GATE 2014)

1. Stress developed in the rod is **EαΔT** and strain developed in the rod is **αΔT**
2. Both stress and strain developed in the rod are zero
3. Stress developed in the rod is zero and strain developed in the rod is **αΔT**

4. Stress developed in the rod is **EαΔT** and strain developed in the rod is zero

Ans: 3

Case 2: There is restriction for expansion/contraction

When there is some restriction to the bar to expand, thermal stress will generate in the material:

$$\sigma_T = strain \times E = \alpha.\Delta T.E$$

Q: A steel bar is held by two fixed supports as shown in the figure and is subjected to an increases of temperature ΔT = 100°C. If the coefficient of thermal expansion and Young's modulus of elasticity of steel are 11 × 10^{-6}/℃ and 200 GPa, respectively, the magnitude of thermal stress (in MPa) induced in the bar is _______.

(GATE 2017)

Solution:

$\sigma = E\,\alpha\,\Delta T$

$\sigma = 200 \times 10^{3}$ □11 □10^{-6} □100

$\sigma = 220$ MPa

Q: A steel rod of length L and diameter D, fixed at both ends, is uniformly heated to a temperature rise of ΔT. The Young's modulus is E and the co efficient of linear expansion is a. The thermal stress in the rod is

(GATE 2007)

1. 0
2. a ΔT
3. E a ΔT
4. E a ΔTL

Ans: 3

Solution:

$$\epsilon_T = \alpha \Delta T$$

$$\sigma_T = \epsilon_T \times E = \alpha . \Delta T . E$$

<u>Case 3: When support yield by amount 'a'</u>

When support yields or is unable to prevent the expansion completely, then if the yield is ‘a’:

$$dL = \alpha \Delta T L - a$$

$$\epsilon_T = \frac{dL}{L} = \frac{\alpha \Delta T L - a}{L}$$

$$\sigma_T = \epsilon_T E = \frac{(\alpha \Delta T L - a)E}{L}$$

Q: A circular metallic rod of length 250 mm is placed between two rigid immovable walls as shown in the figure. The rod is in perfect contact with the wall on the left side and there is a gap of 0.2 mm between the rod and the wall on the right side. If the temperature of the rod is increased by 200℃, the axial stress developed in the rod is _______ MPa. Young’s modulus of the material of the rod is 200 GPa and the coefficient of thermal expansion is 10^{-5} per ℃.

Solution:

$$\sigma_T = \frac{dL}{L} E = \epsilon_T E = \frac{(\alpha \Delta T L - a)E}{L}$$

$$\sigma_T = \frac{(10^{-5} \times 200 \times 250 - 0.2) \times 200 \times 10^3}{250} = 240\ MPa$$

Thermal stresses in a body come into existence if thermal strains are constrained. They are proportional to the thermal strains, to the appropriate elastic constant E′, and to a factor Sth, which is between zero and one and which depends on the constraint

To reduce thermal stresses, Artificial control of the internal temperatures during placement can be done. This can be accomplished by the use of cooling pipes placed in the interior, allowing chilled water to pass through the structure so as to regulate the internal temperature.

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