King Fahd University of Petroleum & Minerals
Mechanical Engineering Department

ME 578: Mechanical Properties of Engineering Polymers

Semester (201)

Homework # 4

Assigned on: 12/11/2020

Due date: 22/11/2020

Kindly, use this page as a cover page for your HW

Name: ______________________________ ID #: ______________________

#	Marks	Grades
1	25	
2	25	
3	25	
4	25	
Total	**100**	

Problem 1:

A plastic component was subjected to a series of step changes in stress as follows:

1) An initial constant stress of 10 MN/m^2 was applied for 1000 seconds.
2) Then, the stress level was increased to a constant level of 20 MN/m^2.
3) After a further 1000 seconds the stress level was decreased to 5 MN/m^2 which was maintained for 1000 seconds.
4) Then, the stress was increased to 25 MN/m^2 for 1000 seconds.
5) After that, the stress was completely removed.

If the material may be represented by a Kelvin-Voigt model in which the elastic constant E = 1.25 GN/m^2 and the viscous constant η= 125 GNs/m^2, calculate the strain 4500 seconds after the first stress was applied.

Problem 2:

If the stress application of Problem 1 is conducted on another polymer at 45ºC, estimate the strain 4500 seconds after the first stress was applied. The plastic used, this time, has a glass transition temperature of -20ºC. The modulus of elasticity, E(t), of this polymer at room temperature (25ºC) was determined to be:

$$E(t) = 1.39\ t^{-0.155}\ \text{GPa}$$

Where t is in seconds.

Problem 3:

The material of Problem 2 is being used as a bolt for joining two rigid plates. The bolt is quickly tightened so that the initial stress is 15.0 MPa. After 48 hours the bolt is retightened to keep the same clamping force. Find the remaining stress value after further one week at 37ºC.

Problem 4:

A straight section of polypropylene pipe is fixed rigidly at its ends. Its tensile stress relaxation modulus at time *t* and coefficient of linear thermal expansion at 20°C are, respectively:

$$E(t) = 2.0\ t^{-0.09}\ \text{GPa} \qquad \text{and} \qquad \alpha = 10^{-4} K^{-1}$$

where *t* is expressed in seconds. The pipe is initially stress-free and at 20°C. Suddenly, there is a rapid rise in temperature to 50°C as a result of passage of some hot water, which continues to flow for one hour. The pipe then returns rapidly to 20°C. Sketch a graph of the thermally induced stress versus time, and calculate the stress in the pipe at 20°C and 100 s after it returns to 20°C. (Assume that the pipe does not buckle, and that polypropylene obeys the boltzmann superposition principle (BSP) and exhibits time-temperature superposition with a_T obeying the Arrhenius equation, with an activation energy ΔH= 145 kJ/mol, and gas constant R=8.314 J/mol.K.)

$$a_T = \exp\left(\frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right)$$