DEPARTMENT OF CHEMICAL & PROCESS ENGINEERING

University of Strathclyde Engineering

Degree of BEng/MEng in Chemical Engineering

CP218 Applied Mechanics

Date: Thursday, 29/04/2021 **Time: 09:30 am**
Duration: 02:40 (hrs:mins)

Answer 2 Questions from 2

PLEASE PAY CAREFUL ATTENTION TO INSTRUCTIONS ON MYPLACE FOR UPLOAD OF YOUR ANSWERS

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ANSWER ALL QUESTIONS

Q1. 50 marks

Consider the two-bar truss shown in Fig. 1 below. The truss is composed of two bars, one made of steel, the other of aluminium, which meet together at junction point O. The length of each bar in their unloaded state is L. Both bars have constant cut-areas, which are A_α and A_s for aluminium and steel bars correspondingly. Similarly, the bars have constant Young moduli, which are E_α and E_s correspondingly. The two bars together with the distance between their two ends that are not associated with the junction, form an equilateral triangle. A force P is applied on the junction point O along the horizontal direction, and to the right (Fig. 1). After a transient, the system reaches a static equilibrium, and O has been displaced along the direction of force P by amount Δ_H. You can assume that linear elasticity theory is valid for all processes.

(a) Write an equation describing the energy conservation during the loading process. Discuss the meaning of each term in this equation.

[2 marks]

(b) Write an equation for the mechanical work performed by the force load P on the truss.

[2 marks]

(c) Write a formula for the work performed by a constant force in particle mechanics, and explain the physical origin of any differences between the work performed by a constant force and the work performed by a force load P on the truss.

[6 marks]

(d) If, after the transient, the forces acting *along* the bars (i.e., the axial loads) are P_α and P_s for aluminium and steel bars correspondingly, write expressions for total bar displacements Δ_α and Δ_s.

[2 marks]

(e) Write expressions for the elastic energy stored in each bar after the transient associated with the application of load P has ceased.

[4 mark]

(f) Write equations for the mechanical work performed on each bar by their corresponding axial loads P_α and P_s.

[4 mark]

(g) By employing free body analysis, compute the axial loads P_α and P_s in terms of load P.

[8 marks]

(h) Is the aluminium bar under compression or extension?

[2 marks]

(i) Discuss the reasoning supporting your answer to the question above, by indicating the two major hypotheses that justify your conclusion.

[3 marks]

(j) Is the steel bar under compression or extension?

[2 marks]

(k) Discuss the reasoning supporting your answer to the question above, by indicating the major hypothesis that justifies your conclusion.

[1 marks]

(l) Derive an expression for the horizontal displacement Δ_H of junction point O.

[4 marks]

(m) Assume both bars are made of the same material. Compute the ratio Δ_H/Δ for each bar, where Δ is the total displacement of a bar.

[5 marks]

(n) Assume both bars are made of the same material. Compute the length of each bar after the transient associated with the application of load P has ceased.

[4 marks]

(o) Assume both bars are made of the same material. Calculate the ratio of the sum of the bar lengths before the application of load P over the sum of the bar lengths after the transient associated with the application of load P has ceased.

[1 marks]

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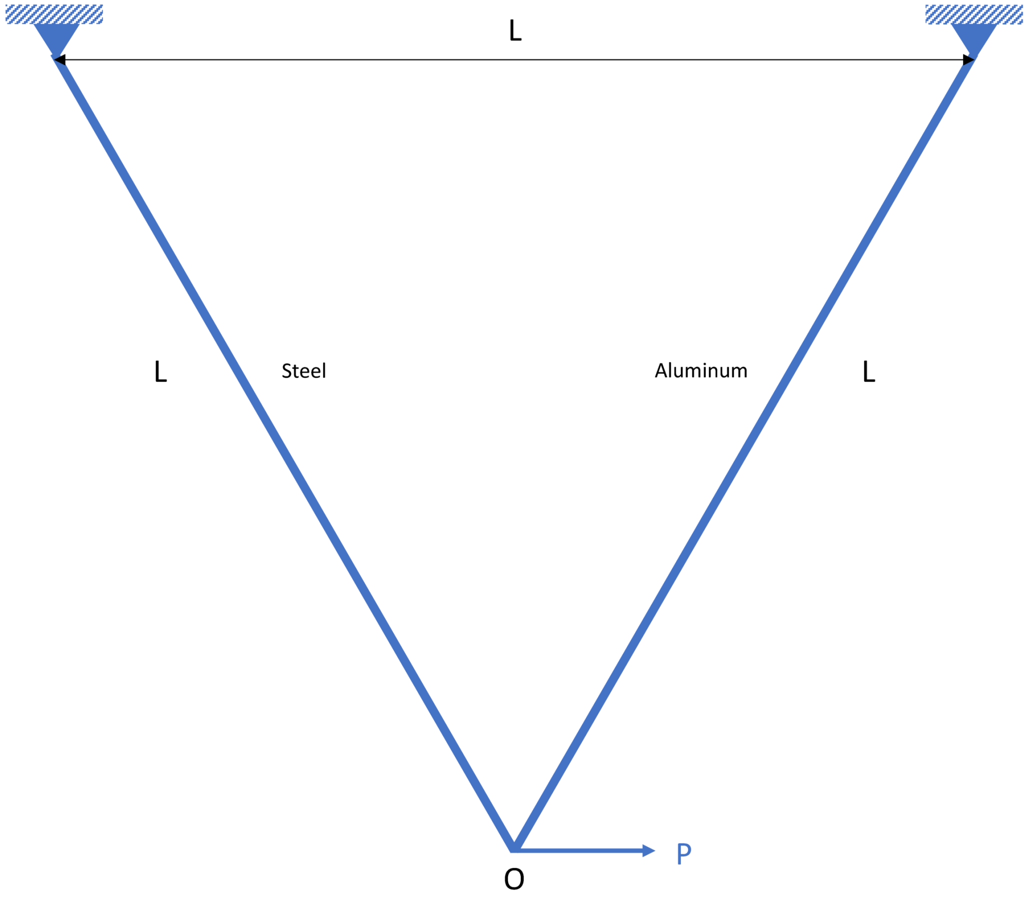

Figure 1: Two-bar truss loaded by a horizontal force P acting on junction O.

Q2. 50 marks

An axial-flow fan operates in sea level air at 1200 r/min. At sea level, the air mass density is $\rho = 1.205$ kg/m^3. The blade-tip diameter is 1 m, and the blade-root diameter is 80 cm. The flow-blade angles in the exit velocity diagram of the stator cascade are $\alpha_1 = 55°$ and $\beta_1 = 30°$, while in the exit velocity diagram of the rotor cascade, it is $\beta_2 = 60°$.

(a) Define and compute the available area A for the flow entering the turbomachine.

[2 marks]

(b) Explain your definition of available area A by comparing it with the corresponding definition for centrifugal turbomachines.

[4 marks]

(c) Define the specific radius r to be employed in your analysis.

[2 marks]

(d) Indicate the approximations that the choice of a specific radius introduces in your analysis.

[5 marks]

(e) If you apply the same (as above) criterion for choosing a specific radius r for the analysis of a similar axial-flow fan with a *larger* ratio of blade-tip radius to blade-root radius, do you improve or worsen the quality of your approximations?

[2 marks]

(f) Justify your answer to the previous question.

[5 marks]

(g) Compute the axial flow velocity in the stator.

[6 marks]

(h) Compute the theoretical volumetric flow rate in the rotor.

[2 marks]

(i) Indicate the main assumption of Euler turbomachinery theory for the flow exiting the stator cascade.

[5 marks]

(j) Indicate the main assumption of Euler turbomachinery theory for the flow exiting the rotor cascade.

[5 marks]

(k) Compute the theoretical angle α_2 in the exit velocity diagram of the rotor cascade.

[5 marks]

(l) Compute the fan theoretical head H.

[5 marks]

(m) Compute the theoretical power P (in both watts and horsepower units) that the fan extracts from the flow.

[2 marks]

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[Compiler: Dr D. Kivotides, [demosthenes.kivotides@strath.ac.uk]]