Master of Mechanical Engineering Examination, 2018

(2^{nd} semester)

Design of Structural Elements

Time – 3 hours

Full marks: 100

(Answer any five questions)

Data if missing may be assumed reasonably

1a. Determine the stress function associated with the bending of a slender cantilever beam. Show that the stress boundary conditions are satisfied at the two ends and at the top and bottom surfaces of the beam. Also derive the displacement fields from the stress function.

b. Prove that Euler – Bernoulli theory is valid only where induced bending moment is constant or varies linearly along the axis of the beam.

13 + 7

2a. Explain the concept of limit load of a structural element and hence define limit load factor (LLF).

b. Determine the LLF of the following structural elements assuming 'linearly elastic – perfectly plastic' material behaviour.

a. a slender beam of rectangular cross section

b. a thick walled pressure vessel

c. a high speed rotating steel disk of uniform thickness

3+(5+6+6)

3a. State the basic assumptions of thin plate theory and deduce the governing equation for the deflected surface of a plate subjected to pure bending.

b. Mention the different classical boundary conditions of thin plates, and for a plate with free edge, state how the fallacy of redundant boundary condition was resolved by Kirchoff. Also discuss about the various other plate theories.

10+10

4a. Determine the ratio of bending and shear deflections of a rectangular clamped free beam subjected to a concentrated transverse load at the free end.

b. Discuss the analysis method of thick plates following FSDPT. A thick rectangular S-S-S-S plate is under a transverse load having the distribution,

$$q(x,y) = \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} q_{mn} \sin\{(\pi m/a)x\}\cos\{(\pi n/b)y\}$$

Obtain the expression for the mid-plane of the deflected plate and determine the approximate deflection of the plate at the point ($x = \boldsymbol{a}/2$, $y = \boldsymbol{b}/2$).

7+13

5a. A steel disk ($E = 210\ kN/mm^2$, $\nu = 0.28$) of uniform thickness having inner and outer radii of 75 mm and 400 mm is rotating at 1440 r.p.m. Determine the induced stresses in the disk.

b. If the disk is shrink fitted on the shaft with a radial interference of 0.06 mm, determine the change in the induced stresses. Also determine the rotational speed when the shrink fitting will get released.

10+10

6a. State and derive Von Karman's equations for large displacement non-linear analysis of rectangular plates and express the final equations in uncoupled form.

b. Obtain the deflected shape $w(x,y)$ for large deflection of a thin rectangular plate, simply-supported along each of its four edges, by using energy functionals. The plate is acted upon by a uniformly applied load of magnitude q_0.

10+10

7a. Determine the critical load of a thin rectangular simply-supported plate (a x b x t), subjected to unidirectional uniform compressive load. Plot the buckling coefficients showing its variation with the aspect ratio of the plate. Also indicate the first four transition values of aspect ratios where buckling modes change.

b. How the buckling coefficients will change if the plate is subjected to bidirectional uniform compressive load.

12+8

8. Explain how the dynamic problem of thick beams is analyzed by using Timoshenko beam theory and extend the method for the solution of thick plate vibration problems following Mindlin plate theory.

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