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Mechanical Design 1

01 Assignment

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Class Section 01

12/18/2020

Problem 1

A flat leaf spring has fluctuating stress of σ_{max} = 360 MPa and σ_{min} = 160 MPa applied for 80000 cycles. If the load changes to σ_{max} = 320 MPa and σ_{min} = −200 MPa, how many cycles should the spring survive? The material is AISI 1020 CD and has a fully corrected endurance strength of S_e = 175 MPa. Assume that f = 0.9. Use Miner's method.

Solution:

For this question, we are asked to determine how many cycles should the spring survive.

$$(\sigma_m)_1 = \frac{(360\ \text{MPa}) + (160\ \text{MPa})}{2} = 260\ \text{MPa}$$

$$(\sigma_a)_1 = \frac{(360\ \text{MPa}) - (160\ \text{MPa})}{2} = 100\ \text{MPa}$$

$$\sigma_{rev} = \frac{(\sigma_a)_1}{1 - \left[\frac{(\sigma_m)_1}{S_{ut}}\right]^2} = \frac{(100\ \text{MPa})}{1 - \left[\frac{(260\ \text{MPa})}{(470\ \text{MPa})}\right]^2} = 223.8\ \text{MPa} > S_e$$

$$a = \frac{(fS_{ut})^2}{S_e} = \frac{[(0.9) \times (470\ \text{MPa})]^2}{(175\ \text{MPa})} = 1022.5\ \text{MPa}$$

$$b = -\frac{1}{3}\log\left(\frac{fS_{ut}}{S_e}\right) = -\frac{1}{3}\log\left[\frac{(0.9) \times (470\ \text{MPa})}{(175\ \text{MPa})}\right] = -0.127767$$

$$N_1 = \left[\frac{(223.8\ \text{MPa})}{(1022.5\ \text{MPa})}\right]^{\frac{1}{-0.127767}} = 145920$$

$$(\sigma_m)_1 = \frac{(320\ \text{MPa}) + (-200\ \text{MPa})}{2} = 60\ \text{MPa}$$

$$(\sigma_a)_1 = \frac{(320\ \text{MPa}) - (-200\ \text{MPa})}{2} = 260\ \text{MPa}$$

$$\sigma_{rev} = \frac{(\sigma_a)_1}{1 - \left[\frac{(\sigma_m)_1}{S_{ut}}\right]^2} = \frac{(260\ \text{MPa})}{1 - \left[\frac{(60\ \text{MPa})}{(470\ \text{MPa})}\right]^2} = 298.0\ \text{MPa} > S_e$$

$$N_2 = \left(\frac{\sigma_{rev}/n}{a}\right)^{\frac{1}{b}} = \left[\frac{(298.0\ \text{MPa})}{(1022.5\ \text{MPa})}\right]^{\frac{1}{-0.127767}} = 15520$$

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} = 1 \Rightarrow \frac{(80000)}{(145920)} + \frac{n_2}{(15520)} = 1 \Rightarrow n_2 = 7000$$

Problem 2

A 1-m-long cantilever spring is composed of eight graduated leaves. The leaves are 50 mm wide. A load of 2000 N at the end of the spring causes a deflection of 75 mm. The spring is made of steel with modulus of elasticity of 207 GPa. Determine the thickness of the leaves and the maximum bending stress

Solution:

For this question, we are asked to determine the thickness of the leaves and the maximum bending stress.

$$\delta = \frac{6PL^3}{Enbh^3}$$

$$\Rightarrow h = \sqrt[3]{\frac{6PL^3}{En\delta b}} = \sqrt[3]{\frac{6 \times (2000\ \text{N}) \times (1\ \text{m})^3}{(207\ \text{GPa}) \times (8) \times (75\ \text{mm}) \times (50\ \text{mm})}} = 12.46\ \text{mm}$$

$$\sigma_{max} = \frac{6PL}{nbh^2} = \frac{6 \times (2000\ \text{N}) \times (1\ \text{m})}{(8) \times (50\ \text{mm}) \times (12.46\ \text{mm})^2} = 193.37\ \text{MPa}$$

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