FME 401

UNIVERSITY OF NAIROBI
DEPARTMENT OF MECHANICAL ENGINEERING
FME 401: SOLID & STRUCTURAL MECHANICS I
STRUTS EXPERIMENT

Objective:

The aim of the experiment is to examine the validity of Euler's equation for the crippling load in columns (struts).

Introduction:

A long, slender member that is loaded in compression is termed a column or strut. Such a member will fail by elastic instability or buckling if the load reaches a critical load, P_{cr}. Buckling is a sudden change in configuration of the strut from a straight line. According to the equation first derived by Euler, the load required to cause buckling is given by the equation below:

$$P_{cr} = \frac{N\pi^2 EI}{L^2}$$

where I is the least second moment of area of the cross section, L is the length of the strut, while E is Young's modulus of the material from which the strut is made. The factor N depends on the end support conditions: N = 1 if both ends are pinned; N = ¼ if one end is fixed while the other end is free; N = 4 if both ends are fixed; while N = 2.05 if one end is fixed and the other end is pinned.

In this experiment, the validity of Euler's equation is examined experimentally by loading struts made of various materials which have varying cross section properties. The experimental values are compared with theoretical predictions.

Apparatus:

1. The main apparatus is illustrated in Figure 1. The load is applied to the strut (1) by the adjustable horizontal loading beam (2). The beam is pivoted at the left end and its vertical position may be adjusted to fit the length of the strut by the threaded split sleeve, (3). The load is applied via a spring balance (4) to which is connected a loading wheel (5). The clamps (chuck jaws) (6) enable you to change the nature of the end support from pinned to fixed.
2. Several rectangular struts each 600 mm long made from steel (E = 200 GPa); an aluminium alloy (E = 69 GPa); brass (E = 105 GPa) and wood (E = 10 GPa). The struts have a 60° machined at both ends for pin joined condition.
3. Other equipment include vernier callipers and Allen keys.

Procedure:

1. Use the vernier callipers to determine the cross section properties of the steel strut.
2. Set the dial gauge on the support column (7) so that it is set at 300 mm on the scale provided. This ensures that the deflection is measured at the mid point of the strut.
3. Adjust the vertical position of the loading beam using threaded split sleeve (3) to fit the 600 mm long strut.
4. Fit the chuck jaws (6) with the grooved face exposed (so as to achieve pin jointed support) on both the loading bar and the base plate.
5. Fit the spring balance (4) together with the requisite connecting link (8) while the stop nut (9) is tightened.
6. Fit the counterbalancing weight (10) over the pulley (11). The counterbalancing weight counteracts the dead weight of the loading bar, spring balance, connecting link, etc, so that this load is not supported by the strut.
7. Fit the strut (1) in place. Attach the small weight (12) (use 150 g for the steel strut, 50 for the other struts) over the small pulley (13). This small weight ensures that the strut deflects to the left.
8. Attach the loading wheel (5) to the connecting link (8). Ensure that the loading beam is still horizontal by checking the spirit level on it. If not, adjust the position of the bar using the capstan (14). Adjust both the spring balance and the dial gauge to read zero.
9. Apply the load to the strut by turning the loading wheel (5). Ensure the loading beam is level before taking readings of both the load (spring balance) and mid-point deflection, δ (dial gauge). Increase the load and repeat the procedure until you have at least five readings. Space your loads so that the maximum value of δ is about 25 mm.
10. Repeat the steps 1 to 9 for the other struts.

Analysis of results

For each strut, plot a graph of δ against δ/P. The result should be a straight line. Determine the gradient, m of the straight line. The crippling load is the reciprocal of m. The crippling load may also be estimated as the load at which a large increase in δ follows from a small increase in load. Compare the values of P_{cr} obtained by the two methods.

Calculate the theoretical crippling load using Euler's formula, and the dimensions and properties of each strut. Compare the theoretical and experimental results and comment on any differences.

FIG. 1