Prying Action in a Bolted Connection and Its Relation to Fatigue Failure

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Introduction

The case that we investigate is the very common example of a bolted joint. By the mating of screw threads, two parts are fastened together. Tension joints and shear joints are the main types of such designs. Here we will focus on tension joints subjected to repeated prying actions. The term "prying" is used to indicate that the bolt force is greater than the applied force. Hence such joints are prone to failure especially due to fatigue under repeated loading.

[Fig. 1 Schematic of prying action.]

[Fig. 2 T-stub in which the bolt force is much greater than P/2.]

[Fig. 3 Rigid T-stub in which the bolt force is equal to P/2.]

Results

Bolt force is pretty similar using two different beam theories. From Fig 5, we can conclude that the separation distance is zero at first when the moment is not large enough. When the shear deformation is considered, the moment should reach a certain value to lift the beam up.

[Fig. 4 Bolt force vs applied beam moment (Euler-Bernoulli Beam Theory).]

[Fig. 5 Distance vs applied beam moment (Timoshenko Beam Theory).]

[Fig. 6 Bolt force vs applied force (T-stub with Euler-Bernoulli Beam Theory).]

Approach

In the American Institute of Steel Construction Manual [1], the design procedure is based on certain simplifying assumptions of a tension joint. In our analysis we analyze this configuration as a statically indeterminate contact problem which allows for a more accurate prediction of the bolt force. We use Euler-Bernoulli and Timoshenko beam theories to analyze the cantilever beam with an end-moment (Fig. 1), and learn about the effect of shear deformation. For a T-stub connection (Figs. 2 and 3), we use Euler-Bernoulli theory. The design parameters are the joint dimensions, material properties, the bolt pre-load, and the applied force. The flexural deformation of the joint induces prying forces that results in an increase in the bolt force. The results of our analysis for the bolt force are then incorporated into the Goodman diagram, which provides a means to predict fatigue life of a material under fatigue loading.

[Fig. 7 Normalized high yield stress on Goodman diagram for different normalized preload and applied force.

Goodman diagram

The abscissa represents the ratio of the midrange stress to Young’s modulus. The ordinate is the ratio of the alternating stress to Young’s modulus. The blue solid line represents the Goodman criterion of failure. Points above the respective line indicates failure whereas points below the line are safe (Fig. 7).

Impact

- Value Proposition
  The unique feature about my research is: We analyze this configuration as a statically indeterminate contact problem in order to better determine the force in a bolted connection. Contact mechanics is the study of the deformation of solids that touch each other in an initially unknown. This study is part of a more general investigation of structural connections.

This addresses the problem of: Prying action in a bolted joint.

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