FURTHER DEVELOPMENT OF KO DISPLACEMENT THEORIES FOR DEFORMED SHAPE PREDICTIONS OF COMPLEX STRUCTURES

Summary

Formulated Ko displacement theories are further developed for nonuniform cantilever beams, seen in figure 1, under bending, torsion, and combined bending and torsion loading. The displacement equations are expressed in terms of strains measured at multiple equally spaced strain-sensing stations on the lower (or upper) surface of the beam. The bending and distortion strain data can be input to the displacement equations for the calculations of slopes, deflections, and cross-sectional twist angles of the beam for generation of the deformed shapes of the entire beam. The displacement equations developed were successfully validated for their accuracy by the finite-element analysis. The displacement theories developed could also be applied to calculate the deformed shapes of simple beams, plates, aircraft wings, and fuselages. The displacement equations with the associated strain sensing system using fiber-optic sensors form a powerful tool for in-flight deformed shape monitoring of the flexible aircraft wings. The calculated displacement data could ultimately be visually displayed before the eyes of a ground-based pilot to monitor the in-flight deformed shape of unmanned aircraft wings.

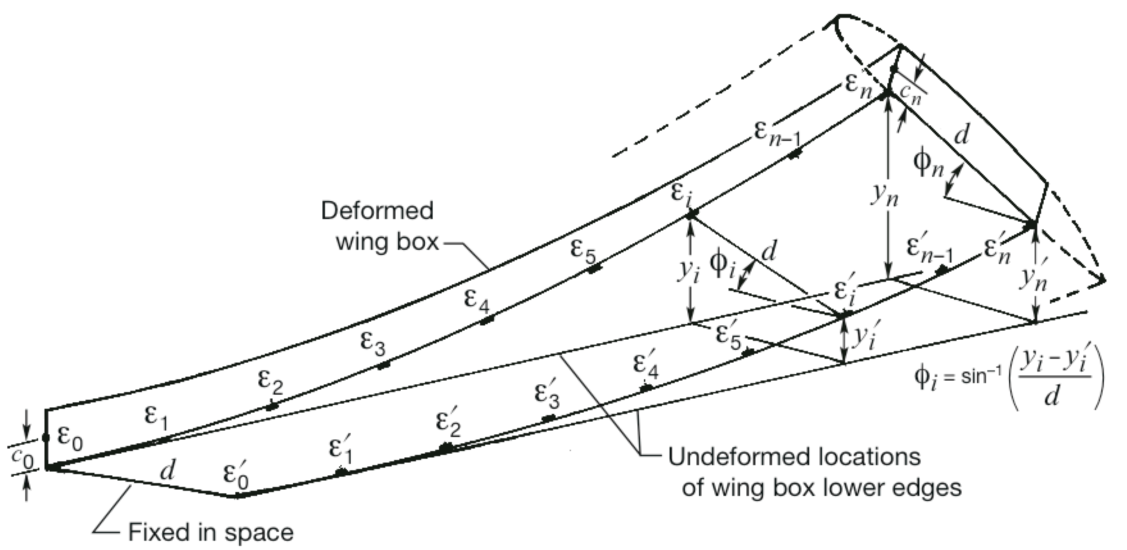

Figure 1. Tapered cantilever wing box.

Objective

By installing multiple strain sensors at discrete sensing stations on a cantilever wing, it is possible to use those strain sensor data as inputs to Ko displacement equations to calculate the deflections and cross sectional twists of the aircraft wings during flight. The purpose is to predict the in-flight deformed shapes of flying vehicles.

Approach

The formulation of the Ko displacement theory for the nonuniform beams is based upon the modified beam differential equation. Using a piece-wise linear assumption and dividing the beam domain into *n* sections, the beam slope and deflection equations for each beam section were then formulated in terms of measured strains at *n* + 1 strain sensing stations at the bottom (or top) of the beam

Status

The Ko displacement theory for nonuniform beams is being tested with the aid of structural performance and resizing (SPAR) finite-element computer program. Cases tested were 1) tapered tubular cantilever beams, 2) un-swept and swept tapered wing boxes, 3) trapezoidal plates, 4) unmanned aerial vehicle (UAV) wing. Partial results, seen in figure 2, show high accuracy of Ko displacement theory in the structural deformed shape predictions. The Ko displacement theory and the associated fiber optics strain sensing system form a powerful tool for monitoring the in-flight deformed shapes of the aircraft wings. This innovative method: Real-time Structural Shape Sensing Techniques using Surface Strain Sensor Measurements, is currently patent pending.

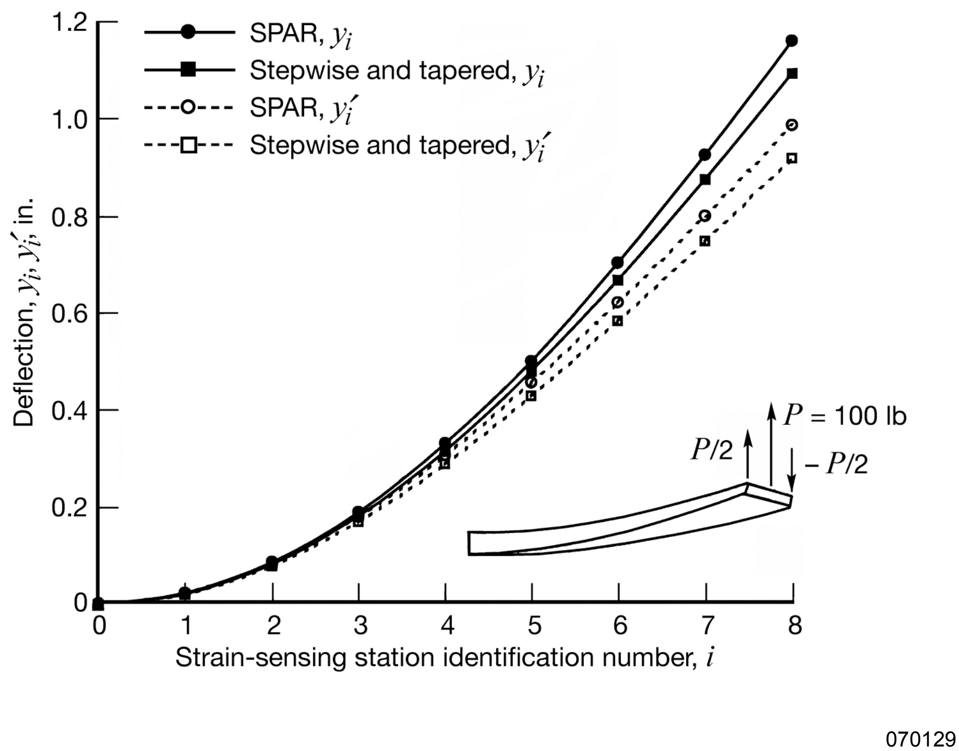

Figure 2. Wing-box deflections predicted from Ko displacement theory and calculated from SPAR finite-element code.

Contacts

Dr. William L. Ko, DFRC, RS, (661) 276-3581
Dr. W. Lance Richards, DFRC, RS, (661) 276-3562