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VIBRATIONS OF OPEN-SECTION CHANNELS: A COUPLED FLEXURAL AND TORSIONAL WAVE ANALYSIS

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An exact analytical method is presented for the analysis of forced vibrations of uniform, open-section channels. The centroid and the shear center of the channel cross-sections considered do not coincide; hence the flexural and the torsional vibrations are coupled. In the context of this study, the type of any existing coupling is defined in terms of the independent motions which are coupled through mass and/or stiffness terms. Hence, if the flexural vibrations in one direction are coupled with the torsional vibrations, the resulting coupling is called double-coupling. On the other hand, if the flexural vibrations in two mutually perpendicular directions and the torsional vibrations are all coupled, the resulting coupling is referred to as triple-coupling. The study also takes the effects of cross-sectional warping into consideration but, since it is derived from torsional characteristics, the warping is not treated as an independent motion. Wherever necessary, the admission of warping is characterized by the inclusion of warping constraint. The current work uses the wave propagation approach in constructing the analytical model. Single-point force excitation has been considered throughout and the channels are assumed to be of Euler–Bernoulli beam type. Both double- and triple-coupling analyses are performed. The coupled wavenumbers, various frequency response curves and the mode shapes are presented for undamped and structurally damped channels.

1. INTRODUCTION

Open-section channels are widely used in aeronautical structures as stiffeners. In general, they have a cross-section in which the centroid and the shear centre do not coincide. This leads to the phenomenon that the flexural vibrations are coupled with the torsional vibrations.

This complicated problem has attracted scientists for a long time. One of the early analytical works in this field was performed by Gere *et al*. [1]. They determined the coupled, free vibration characteristics of uniform, open-section channels using the Rayleigh–Ritz method. Later Lin [2], again by using the same energy method, analyzed the triply coupled free vibration characteristics of a skin–stringer configuration. In reference [3], Bishop *et al*. compared the effectivenesses of various beam theories in the solution of beams having coupled torsion and bending. Dokumacı [4] developed an exact analytical model for the determination of coupled vibration characteristics of open-section channels which were symmetric with respect to an axis. The warping was not admitted. In reference [5], Bishop *et al*. allowed the cross-sectional warping in Dokumacı's theory and investigated the doubly coupled Euler–Bernoulli beams of open cross-section. All of

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