

TENSION IN FLUTTERING FLAGS

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ABSTRACT

The tension dynamically induced by the two-dimensional vibratory motion of a fluttering flag is obtained by approximate analysis, using a Computer Algebra System. The dynamic process, involving the centrifugal forces due to the curved path of the trailing edge, is similar to the whipping of an oscillating rope, and accounts for most of the drag-force observed at the flagpole. Conversely, the induced tension, combined with the curvature of the fabric, opposes the pressure forces from the flow field and extracts momentum from it.

The time-averaged tension depends on the square of the velocity amplitude of the oscillating fabric. The distribution of time-averaged tension along the flag is obtained for a typical flag flutter motion, consisting of a traveling wave, growing in amplitude as it progresses towards the leech edge.

An estimate of the tension fluctuations is also obtained. The fluctuations are small relative to the average tension at locations several wavelengths from the leech, but are important near the leech.

The P.D.E. of motion is obtained from Hamilton's principle, and it is shown that the induced-tension terms derive from the in-plane kinetic energy of the flag motion.

Dynamically induced tension is shown to be significant if the stiffness of the fabric is low; an order-of-magnitude criterion is presented.

The structural stiffening due to dynamically induced tension is applicable to the estimation of post-critical flag and panel flutter amplitudes.

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