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Engineering Notes

Frequency Dependence of ZONA6

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Introduction

ZONA6 is an oscillatory subsonic lifting-surface theory [1] based on the oscillatory supersonic lifting-surface theory ZONA51 [2]. ZONA51 is a panel method that uses the assumptions of a constant pressure on each panel (box) and a collocation point on the centerline at 95% of the box; ZONA51 is available in ZAERO [3] and MSC Nastran [4]. ZONA6 is similar in its assumption of a constant pressure, but with the collocation point at the 85% chord.

The assumptions of ZONA6 have been shown [5] in the steady case to predict an aerodynamic center that is too far aft of the quarter-chord and therefore unconservative for predicting subsonic flutter speeds. The vortex-lattice method (VLM) (the steady case of N5KQ) [6] does not have this inaccuracy.

In the interest of forcing ZONA6 to agree with the quarter-chord prediction of the VLM, a new parameter, the force-point (FP) location, was introduced [1] in spite of the basic assumption of the constant-pressure panel. As pointed out in [7], the constant pressure on each box must act at its 50% chord, in accord with elementary static principles. It was also pointed out in [7] that ZONA6 is not a higher-order solution than the VLM. However, for reasons not understood by this commentator, the force-point parameter $FP = 0.25$ does improve the low-frequency prediction and it agrees with the doublet-lattice method (DLM), as shown in Figs. 1–5 for the BAH wing bending and torsion modes; the BAH wing is an example analyzed extensively in MSC Nastran [4]. However, there is no reason to expect that this "improvement" should extend to the higher reduced frequencies of concern in aeroservoelastic analyses, and a discrepancy at the higher frequencies is seen in the figures for the generalized aerodynamic forces in the bending and torsion modes.

Results

Figure 1 shows the idealization of the BAH wing idealized into 50 spanwise strips and 30 chordwise boxes; the 30 chordwise boxes are required for convergence at the high value of $k = 5.0$. Figure 2 shows the real and imaginary parts the generalized forces in bending for the two aerodynamic theories at $M = 0.0$. Figure 3 shows the real and imaginary parts for the generalized forces in torsion for the two aerodynamic theories, also at $M = 0.0$. Figures 4 and 5 show similar results in the compressible case at $M = 0.8$.

Note that the basis for the DLM is found in the derivation in the original paper [8], which was based on the VLM of Hedman [9] and the kernel function method of Watkins et al. [10].

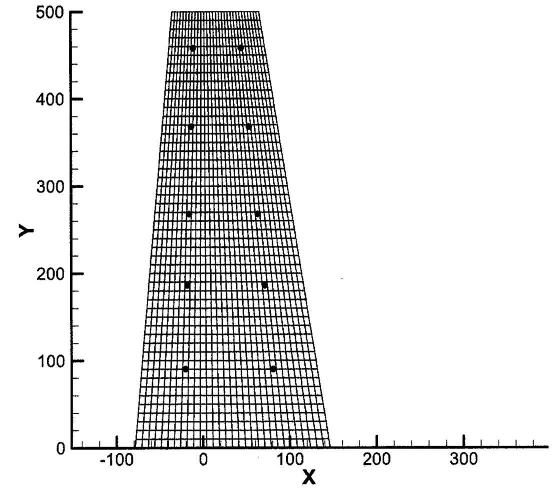

Fig. 1 BAH wing doublet-lattice (N5KQ) and ZONA6 box layout.

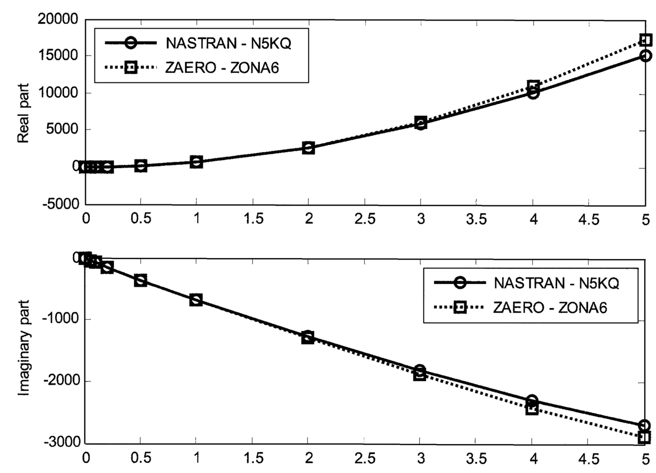

Fig. 2 BAH wing generalized lift due to bending, $Q(1,1)$ at $M = 0.0$.

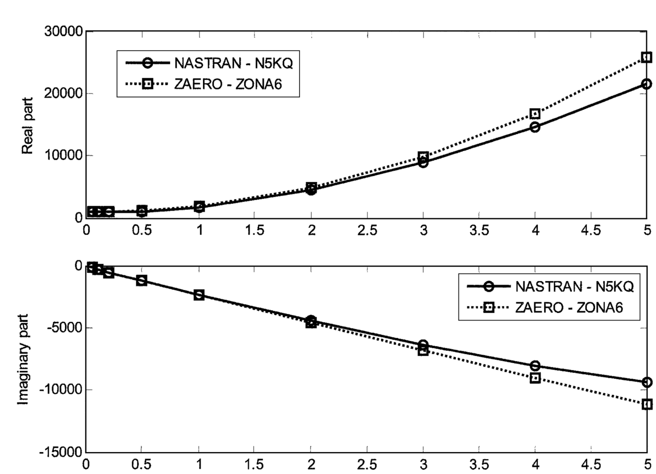

Fig. 3 BAH wing generalized pitching moment due to twisting, $Q(2,2)$ at $M = 0.0$.

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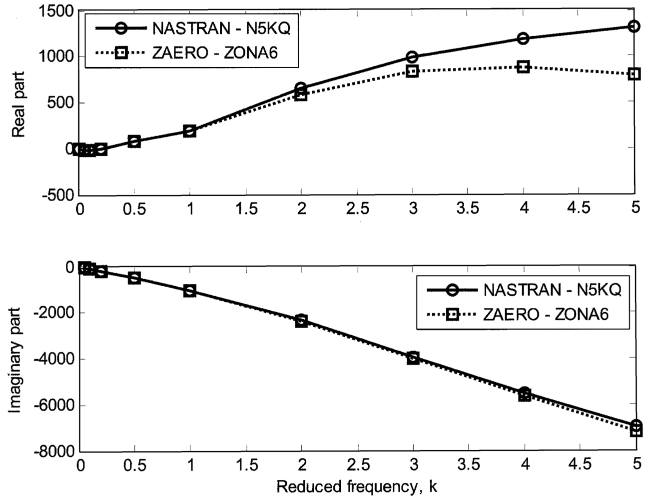

Fig. 4 BAH wing generalized lift due to bending, $Q(1,1)$ at $M = 0.8$.

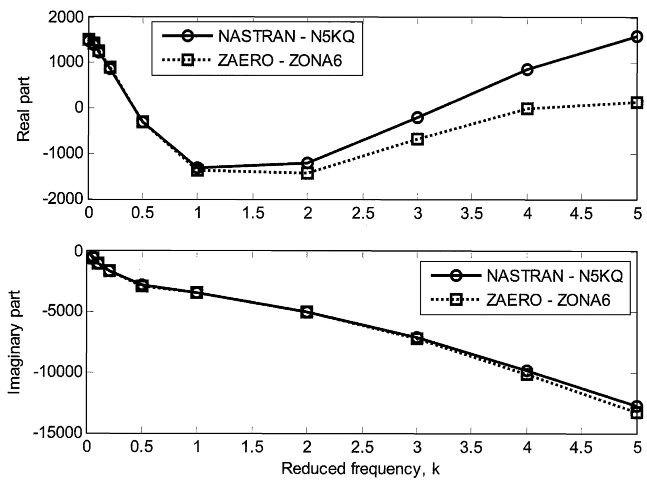

Fig. 5 BAH wing generalized pitching moment due to twisting, $Q(2,2)$ at $M = 0.8$.

Conclusions

The ZONA6 results with $\mathrm{FP} = 0.25$ agree with the DLM at low frequencies. The agreement up to $k = 1.0$ demonstrates that ZONA6 is probably capable of accurate predictions of low-frequency subsonic flutter. However, as the reduced frequency increases, the agreement degenerates, as is to be expected considering that the FP parameter has no rational basis in subsonic unsteady flow theory. In the compressible case of $M = 0.8$, although the imaginary parts are reasonably close, the real parts become substantially different.

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