COMPACT AND ACCURATE PHUGOID MODE APPROXIMATION WITH RESIDUALIZATION

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Abstract

Literal approximations to the phugoid mode are systematically derived by a process of residualization with fast-slow modal decomposition. Approximations with a static residual alone and another including a dynamic residual as well are obtained. The two sets of approximations are shown to be analytically identical to each other, therefore previous attempts by some researchers to obtain "improved" literal approximations by introducing a dynamic residual are seen to be redundant. Our static residualization yields new expressions for the phugoid mode parameters which include an "inertia" term and a "phase damping" term not generally observed in previous approximations. In fact, the "phase damping" term is seen to be the second-most numerically significant damping effect after the drag and is always found to detract from phugoid damping. A third term involving the pitch damping derivative C_{mq} is relatively insignificant but interestingly is found in many cases to undamp the phugoid motion. Approximations are derived with and without compressibility effects in the form of the derivative C_{mMa} to highlight the contribution of this derivative in obtaining accurate estimates of the phugoid frequency, even at low speeds. Finally, recommended literal approximations to the phugoid frequency and damping are presented which are compact and whose numerical accuracy is established for ten different combinations of airplanes / flight conditions.

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