Engineering Notes

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Nonplanar Doublet Lattices

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UNSTEADY lifting surface solutions are commonly obtained as influence matrices relating a lattice of forces to a lattice of normalwashes. The forces usually have been assumed spread along spanwise line segments or over trapezoidal patches, but may sometimes be considered simply as points.[1] The nonplanar formulation is especially simple for the latter case. A nonplanar formulation with comparable simplicity plus compatibility with assumed loadings other than the point doublet is presented here.

Equations (1 – 3) are exact for a point doublet at any Mach number or frequency. K is normalwash at (x,y,z) with direction cosines $(0,\mu_i,\nu_i)$ due to a force at (0,0,0) with direction cosines $(0,\mu_j,\nu_j)$. F is downwash at (x,r) from a coplanar doublet at (0,0), where $r=(y^2+z^2)^{1/2}$. The derivative F_r in Eq. (1) is not required when μ,ν,y, and z define a coplanar lattice pair. When needed, F_r may be obtained numerically. (Supersonically, a nonzero F will always be continuous toward decreasing r.)

$$K=\lfloor A \rfloor\,[B]\left\{\begin{matrix}(F)\\(rF_r)\end{matrix}\right\} \tag{1}$$

$$\lfloor A \rfloor = \lfloor (\mu_i\mu_j)\,(\mu_i\nu_j+\nu_i\mu_j)\,(\nu_i\nu_j) \rfloor \tag{2}$$

$$[B]=\begin{bmatrix}(1) & (y^2/r^2)\\(0) & (yz/r^2)\\(1) & (z^2/r^2)\end{bmatrix} \tag{3}$$

The author has obtained completely satisfactory nonplanar lattice elements by using Eqs. (1), (2), and (3) but with a spread coplanar doublet used for F instead of a point coplanar doublet. Lattice element sweep (Λ, right-handed about the normal) is redefined by Eq. (4) and patch centers are used for x and y. The procedure has been used with both area-averaged (constant pressure) patches and line-averaged (conventional) doublet lattice elements.

$$\begin{aligned}\tan(\bar{\Lambda}) &= \tan(\Lambda), \quad r=0\\ &= (\mu z/r+\nu y/r)\tan(\Lambda), \quad r\neq 0\end{aligned} \tag{4}$$

Lattice elements thus obtained are "smeared" in a manner that is intermediate between a point doublet and a true integration (spreading), but always become exactly integrated in the coplanar limit. The improvement over a point doublet is especially important for adjacent or close lattice elements. Exactness in the coplanar limit is desired for a continuously changing dihedral, as a ring wing representation of a nacelle.

This method should be considered whenever two or three evaluations of a coplanar lattice element are more desirable than one evaluation of a nonplanar element.

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References

[1] Ueda, T. and Dowell, E. H. "A New Solution Method for Lifting Surfaces in Subsonic Flow," *AIAA Journal*, Vol. 20, March 1982, p. 348.