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Interim Report on the Compu-
tation of Helicopter Rotor
Wake Geometry

by

M.P. Scully

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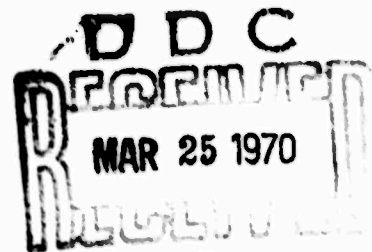
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The wake of a helicopter rotor consists of a relatively concentrated tip vortex generated by the rapid decrease in bound circulation at the tip of the rotor blade and distributed vortex sheets generated by the spanwise variations of bound circulation over the inboard portion of the blade (the inboard trailing wake) and by azimuthal variations of the bound vorticity (the shed wake). The tip vortex, because of its concentration, is responsible for the sharp peaks in the rotor airloads distribution. Thus accurate geometry is much more important for the tip vortex than for the rest of the wake and effort has been concentrated on the accurate and efficient computation of the tip vortex geometry.

The computation of the tip vortex geometry involves the integration over time of the induced velocity at various points on the tip vortex. Since the computed tip vortex geometry changes as the computation proceeds (converging on the actual geometry), the induced velocities must be recomputed (updated) periodically to account for these changes. Since most of the computational effort goes into computing induced velocities, finding techniques to minimize the amount of updating required is very important.

Any point P on the tip vortex can be identified by its azimuth and its age (time elapsed since point P was trailed from the rotor) at any instant. Tip vortex geometry computations generally proceed by computing the geometry of all azimuths at age $\Delta\theta$ (typically $\Delta\theta = 15^\circ$) then at age $2\Delta\theta$, $3\Delta\theta$, and so on up to an age of 4π or 6π). This computation is repeated iteratively until satisfactory convergence is achieved. In Ref. 1 the induced velocities used to compute the geometry were updated every $n\Delta\theta$ in age (typically $n = 6$) at all azimuths. Since the geometry changes at some azimuths much more rapidly than at others this resulted in updating

too often at some azimuths and not often enough at others. This suggested updating each azimuth independently.

To test independent updating a new tip vortex geometry program was developed which updated the induced velocity at any given azimuth whenever the distortion (geometry change due to the induced velocity) accumulated at the azimuth since it was last updated exceeded a preset value (D_m , typically 0.05 to 0.10 rotor radius). This program proved to be very slow because of the complicated logic required to implement independent updating. Extensive development was undertaken to streamline and minimize this logic and substantial improvements were made. Using the efficient program various values of D_m were investigated. It was found that, even using values of D_m so small that the new independent updating computation took much longer than the old uniform updating, the geometry of certain portions of the tip vortex did not converge. This is believed to be because even a small amount of distortion can cause a point which happens to lie near to a tip vortex to be shifted from one side of the tip vortex to the other, with the resulting reversal in the direction of the induced velocity. One way to avoid this problem would be to combine the two methods of updating by requiring that the induced velocities at any azimuth be updated at least every $n\Delta\theta$ in age. The only payoff this could provide compared to using only uniform updating at all azimuths every $n\Delta\theta$ would be an increase in the value of $n\Delta\theta$ for a given accuracy. Considering the extra logic required for independent updating based on the amount of distortion accumulated, the net saving in computation by combining the two types of updating compared to using only uniform updating at all azimuths every $n\Delta\theta$ was expected to be small. It was therefore decided to abandon independent updating based on the amount of distortion accumulated and concentrate on the development of a promising new technique.

This new technique involves breaking the wake up into a near wake and a far wake relative to any point P on the tip vortex at which induced velocities are computed. The near wake is defined to include any vortex line segment or vortex sheet which generates an induced velocity greater than V_m (a parameter to be chosen by experiment) at point P and the far wake is defined as all the rest of the wake. Only the induced velocities generated by the near wake are updated because the far wake is so far away from point P that normal amounts of distortion are negligible by comparison. This saves a great deal of computation but it requires a lot of extra core memory to store a map of the near and far wakes for each point P on the tip vortex. The development of this new updating technique including the reduction of the required core storage to fit available computer facilities will be undertaken under contract N00019-68-C-0150. This will be discussed in detail in the final report on wake geometry, Ref. 2.

In addition to the work on improved updating development of a vortex sheet representation for the inboard trailing wake the shed wake was undertaken. Closed form expressions were derived for the Biot Savart relation for induced velocity integrated over a rectangular, planar vortex sheet with either constant or linearly varying circulation. A subroutine was written to compute induced velocities using this expression and the results were checked against vortex line computations. The vortex sheet computation used 5 to 6 times as much computer time as the corresponding vortex line computation. Since most of the computer time used in a wake geometry computation is spent computing induced velocities and since wake geometry computations were already using up too much computer time it was decided to concentrate on improving the efficiency of the vortex sheet computation and reducing the amount of updating required in the wake geometry computation before the use of vortex sheets in a wake geometry computation was attempted. This development will be done under contract N00019-68-C-0150 and discussed in detail in the final report on wake geometry, Reference 2.

REFERENCES

1. Scully, M.P., A Method of Computing Helicopter Vortex Wake Distortion, Massachusetts Institute of Technology, Aeroelastic and Structures Research Laboratory, ASRL TR 138-1, June 1967.
2. Scully, M.P., Computation of Helicopter Rotor Wake Geometry and its Influence on Rotor Harmonic Airloads, Massachusetts Institute of Technology, Aeroelastic and Structures Research Laboratory, ASRL TR 157-1 (to be published).