chordwise variation of the aerodynamic phase lag data for the first and second harmonics. As is indicated, the first harmonic phase lag data demonstrate that a convected wake traveling at approximately 62 ft/s (18.90 m/s) dominates nearly the entire pressure surface, but not the suction surface. The second harmonic phase lag data, on the other hand, shows that a convected wake traveling at approximately 112 ft/s (34.14 m/s) dominates the entire suction surface, but not the pressure surface. Thus, not only does a convected wake phenomena exist over the entire cambered airfoil vane chord at large negative incidence angles, but these wakes are convected at different velocities along each surface.

Summary and Conclusions

The rotor wake generated harmonic time-variant pressure distributions on both a classical flat plate and a cambered airfoil stator row have been determined over a wide range of incidence angle values at realistic reduced frequency. These dynamic data were all correlated with predictions obtained from a state-of-the-art compressible, zero incidence, flat plate cascade, transverse gust analysis to determine its range of validity and to quantitatively assess the effects of airfoil camber.

This data-theory correlation quantitatively demonstrated the following.

- Compressibility is significant at high reduced frequency and low Mach number values (unit order compressible reduced frequency values).
- The zero incidence flat plate vane data correlate very well with the compressible flat plate predictions.
- The zero incidence cambered airfoil vane row dynamic pressure coefficient data corrleate well with the compressible flat plate prediction over the entire vane chord whereas the phase lag data correlate only over the front portion of the vane, i.e., the effect of airfoil camber is to increase the aerodynamic phase lag over the rear portion of the vane.
- As the incidence angle is decreased from zero, the flat plate and cambered airfoil aerodynamic phase lag were affected prior to the dynamic pressure coefficient.
- As the incidence angle is decreased from zero towards large negative values, a wave phenomenon not modeled by the analysis becomes apparent on both the flat plate and cambered airfoil vane rows. This wave phenomenon first appears at the rear of the vane, and moves forward as the incidence angle decreases.
- At large negative incidence angle values, the wave phenomena exhibits different velocities on the pressure and suction surfaces of the cambered airfoil, a result not modeled in the analysis.
- The value of the dynamic pressure coefficient at the trailing edge was zero for the flat plate and non-zero but finite for the cambered airfoil vane rows, even at large negative incidence angle values. This reflects upon the validity of the Kutta condition for unsteady flows at high reduced frequency values.

Acknowledgment

This research was sponsored, in part, by the Air Force Office of Scientific Research (AFSC), United States Air Force. Acknowledgment is also made to the General Motors Corporation for permission to include the flat plate cascade data.

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DISCUSSION

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Of the several useful aspects of this paper, I am particularly interested in the authors' conclusions related to convected wake segment (rotor wake segment in the present case) transport through a chopping blade row (stater row in the present case). They have shown in this and an earlier paper [8], that the convection of chopped wake segments along a chopping blade section, suction and pressure surfaces occurs at different velocities; they also suggested that this kind of wake action may be important enough to consider if more accurate analytical predictions of the unsteady effects involved are desired. An approproximate description of the wake chopping and transport process in a turbo-machine has been proposed by several investigators [9–14] and detailed measurements including fluid velocities and particle pathlines seem to support the general model involved.

There appears to be an inconsistency between the wake segment convection velocities reported in the present paper and those reported earlier [8] and I would appreciate the authors' comments on this particular matter.

In the present paper, the authors have concluded from chopping blade (stater blade) surface pressure aerodynamic phase lag data that convected wake segments traveling at approximately 112 ft/s (34.14 m/s) dominate the pressure surface while convected wake segments traveling at approximately 62 ft/s (18.9 m/s) dominate the suction surface. In the earlier paper, the authors concluded from individual chopping blade surface pressure transducer signals, unsteady chopping blade surface pressure differential data and timing traces that the chopped wake segment convection velocity was between 60 to 62.2 ft/s (18.3 to 19.0 m/s) on the pressure surface and 105.6 to 110 ft/s (32.2 to 33.5 m/s) on the suction side. In both papers, the authors concluded that the first harmonic of the chopping blade unsteady pressure data is dominated by wake segment transport over the pressure surface of the chopping blade section and that the second harmonic of the unsteady pressure data is dominated by wake segment transport over the suction surface.

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Authors' Closure

We appreciate Dr. Okiishi's interest in this effort and also for pointing out the inconsistency in the reported convected velocities of the wake segments. The inconsistency comes from writing a textual conclusion from a mislabeled plot. Fig. 17 should have a labeled velocity of 62 ft/s and Fig. 18 should be labeled 112 ft/s with the text also reflecting this change. This can be readily checked by obtaining the slope of the phase lag as a function of percent chord and calculating the convected velocity of 70 percent design speed (613 rpm). From the published plots one can easily obtain 65 ft/s for Fig. 17 and 105 ft/s for Fig. 18, which is well within tolerance one may expect for an unlined plot.

The conclusion, for our purpose, remains unchanged in that the apparent chopped wake segments travel at different convected velocities along the pressure and suction surfaces and this difference should be incorporated into the analytical model.