One of the important features of this investigation is the fact that the contribution from the wake to the total unsteadiness in the subsequent blade row comes equally from the wake turbulence and the defect in mean velocity. Due to physical constraints, it was not possible to investigate the flow regions in the vicinity of the trailing edge ($s/S' < 0.15$) or the boundary layer characteristics at the trailing edge of the rotor blade. Therefore, it is planned to investigate the wake flow fully using a rotating hot wire and conventional probe.

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DISCUSSION

P. Bradshaw[2]

The authors are to be congratulated on the success of a sophisticated experimental technique. The irregularity of the profiles of turbulence quantities seems to be partly due to inadequate sampling time, and it is to be hoped that future work will distinguish the genuine irregularities as well as documenting the initial conditions of the wake—that is, the trailing-edge boundary layers. To make the results more useful as a test case for calculation methods, either the pressure distribution or a complete specification of the machine geometry would be very helpful: it should be possible to deduce the static pressure just outside the wake from velocity measurements because the flow is nominally steady in rotating coordinates, but the data presented are not extensive enough to do this reliably.

The authors' attitude to the eddy viscosity assumption, presented just before equation (1), is not clear, since in a later section they disclaim proposing any Reynolds-stress model: certainly the eddy viscosity as defined in the paper varies wildly across the wake and is often negative. Probably, the best approach to calculating such a complicated flow is to treat the interaction between the two boundary layers explicitly, as was done for some simpler cases in references [13, 14].[3] The method used in these references is basically that of reference [12], but does *not* imply a constant value of $|\tau|/\rho q^2$ in the interaction region. Clearly this quantity is zero on the center line of a symmetrical two-dimensional wake and is likely to behave oddly in a rotor wake—though much of the variation shown by the authors can be attributed to sampling scatter and to 0/0 trouble at the wake edges.

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[3] Numbers in brackets designate Additional References at end of discussion.

Additional References

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Authors' Closure

The authors wish to thank Bradshaw for the discussion of their paper.

Subsequent to the publication of the paper in preprint form, we discovered a rather subtle but important error in the computer programming as well as the location of the measuring stations. Figs. 3 and 5–15, equations (29)–(33) presented in this final version of the paper have been corrected from the earlier version (ASME Paper No. 75-GT-1). Nevertheless, Bradshaw's comments based on the earlier version are still valid, since the results are same, qualitatively.

The irregularities mentioned by Bradshaw are dominant only in the shear stress profiles and not in the intensity profiles. While inadequate sampling may be one of the reasons for this, the irregularities caused by spacial error due to finite spacing of the sensors cannot be overlooked. The authors believe the latter cause to be more dominant. To prove this point, averaging process was carried out with different number of samples, twenty and one hundred. Averaging of hundred or more samples did not improve the quality of shear stress profiles over that of twenty samples, indicating that the scatter may not be due to inadequate number of samples. The shear stress data presented in this paper should be viewed as qualitative.

The determination of the properties of the wake at the trailing edge region is not feasible with the present method due to physical limitation, since the data were taken with a stationary probe while the rotor was in motion.

Specifications on the blade geometry, rotor configuration, and operating conditions are provided in the section on "Experimental Equipment and Method." A NASA report in preparation will provide all the inflow as well as exit flow data at all the spanwise locations.

The authors disclaim to have proposed any modeling of the Reynolds stress equation similar to that proposed in reference [12]. The use of eddy viscosity is certainly questionable. But the technique presented in references D_1 and D_2 are also open to question. The factor G would vary not only across the wake, but also from one rotor configuration to other, since the turbulence properties are affected by rotation and curvature. It is not clear whether the method described in reference D_1 and D_2 would be able to form a satisfactory closure to the rotor wake problem. The variation of G across the wake presented in this paper should be viewed with caution, since the stresses are qualitative even though intensities are accurate.