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TRANSONIC VISCOUS INTERACTIONS

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FINAL REPORT

TRANSONIC VISCOUS INTERACTIONS

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by

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Th problem to which work under these grants addressed itself is, briefly, how can one predict the aerodynamic characteristics of airfoils at transonic speeds simply while at the same time including the effects of fluid viscosity. Previous work by R. W. Truitt had indicated that by assuming the normal viscous stresses to be relatively small a term related to them could be included in a two-dimensional quasi-potential flow equation which, with suitable boundary conditions, can be used to describe flow over airfoils. Sichel had earlier studied a more restricted from of the equation in considerable detail. Truitt found that his formulation would predict the location of shockwaves on the airfoil surface as a function of airfoil geometry at M = 1.0.

Originally it was hoped that the analysis could be extended to lower Mach numbers, thicker airfoils, and lower Reynolds numbers. To provide some guidance for these studies and some data against which to compare predictions, a number of airfoil models were built and tested in the NCSU Transonic wind tunnel. This facility was new at the time and

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several shakedown problems, among them excessive noise, had to be overcome before the tests could be conducted. There was the additional disadvantage that the size of the test section would permit models no larger than 2.5" chord to be tested. This means that the boundary layer on the model was always laminar and relatively thick; in flight hardware the boundary layer is mostly turbulent and relatively thinner. Thus the comparison with data on flight articles could not be exact. Nevertheless several sets of data were obtained which are believed to be quite reliable considering the test conditions. Of particular interest are the detailed studies made of the flow velocity in the field outside the boundary layer. These results were published in technical reports which were sent to the monitor.

The parallel analytical studies did not progress as had been hoped, in that no way was found to extend the Mach number to less than unity and preserve Truitt's approach. Evidence did indicate that it could be extended to axisymmetric bodies, but since the primary interest was airfoils that opening was not pursued. It was then decided to resort to semi-empirical data correlations to treat certain aspects of the problem. If successful, this could be in keeping with an original objective of the work: to find a simple, yet accurate, means of predicting aerodynamic characteristics of airfoils at transonic speeds. This approach had been tried by others. Success depends upon the correlations used, how they are incorporated into the analytical model, and the validity of the analytical model.

The approach evolved is described in detail in the attached paper.

Since the preparation of the paper it has been possible to investigate two of the details in which improvements are fairly obvious. The method uses an inviscid technique to obtain the basic M = 0 pressure distribution. A simple, well-known technique for such calculations was used with the thought that if the overall idea gives promise this portion of the method could easily be upgraded. The upgraded computer-based method, installed after considerable effort, gave results for the thin symmetrical airfoils on which it was tried very little different (or better) from those obtained with the simpler technique. Thus the use of the upgraded technique does not appear to cost effective at least for simple symmetrical airfoils.

The second improvement considered was the shape of the pressure rise through a shock wave. The technique presented in the paper used a simple linear rise over fifty boundary layer lengths. The literature was reviewed extensively for semi-analytic techniques and empirical correlations which give better representations of reality. Unfortunately, no technique which gives the form of the pressure rise solely in terms of the Reynolds number, shock strength, and shock location was found. Further, the form of the pressure rise most often found in the literature may be considered just a perturbation on the linear rise model. It is concluded therefore that the improvement in accuracy possible with this modification requires excessive effort and is therefore not a fruitful path to travel. The prediction method, in the form presented in the Journal of Aircraft paper, appears in consequence of these results, to have reached the accuracy/cost limits of which it is capable. If one is permitted a speculation growing out of this experiance with this

work it would be that a more accurate prediction method will combine (a) a family solutions of solutions of the one-dimensional viscous transonic equation, each valid along a given streamline with (b) a momentum integral boundary layer equation using a sixth order polynomial representation for the velocity profile. By iterating through this system of equations it should be possible to obtain a rather reliable, self-consistent picture of the gas velocities away from the surface and then the surface pressures and skin friction.

Personnel participating in the activity in addition to the Principal Investigator were

Dr. James A. Daggerhart who assisted with the experimental investigation.

Mr. Donald P. Knepper, full-time research assistant who was responsible for conducting the tests and developing the details of the method reported in the J. A. paper. (He earned his M. S. from this activity.)

Mr. Ronald K. Carden and Mr. Neill S. Smith, research assistants, aided in mounting the more involved computer program.

Mr. Glenn L. Martin, research assistant, performed the investigation of the more accurate representation of the pressure rise through the shock wave.

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13. ABSTRACT

The problem to which work reported here addressed itself is, briefly, how can one predict the aerodynamic characteristics of airfoils at transonic speeds simply while at the same time including the effects of fluid viscosity.

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