PROPAGATION OF DISTURBANCE WAVES ACROSS RIGID AND POROUS PANELS

by

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To my parents and my teachers.

CERTIFICATE

This is to certify that the thesis entitled "**Propagation Of Disturbance Waves Across Rigid And Porous Panels**", being submitted by **Mr. Anish Ranjan Paul**, for the award of the degree of Doctor of Philosophy, to the **Indian Institute of Technology Delhi**, is a record of bonafide work carried out by him under our guidance and supervision. The material embodied in this thesis, unless acknowledged otherwise, has not been submitted in part or in full for any other Diploma or Degree of any University.

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ABSTRACT

Propagation of two-dimensional small amplitude Tollmien-Schlichting (TS) waves has been investigated over a rigid panel followed by a porous panel in the presence of cross-flow. In the present work two problems have been solved, viz., (i) boundary layer flow over alternate rigid-porous panels in which suction is applied through the porous panel; and, (ii) flow through an alternate rigid-porous channel in which cross-flow is applied through the porous panel. Thus in case of the channel, there is injection through one wall and there is equal suction through the other wall.

A general space marching solution has been discussed for calculating the mean velocity profile for the above two cases, in the developing region of mean flow in the porous panel, following the rigid-porous junction. Numerical solutions are obtained using a finite difference method for the suitably simplified boundary layer equations, using appropriate boundary conditions. Mass flux has been kept constant while calculating the mean flow field for the channel case.

Detailed two-dimensional analyses have been done for the disturbance waves using both the quasi-parallel (QP) approximation, and more accurately, using the non-parallel (NP) approach. In fact, a new methodology has been developed, from the rigid wall boundary layer flow case, for handling non-parallel effects. Two new concepts have been discussed viz., *additive augmentation* and *optimal normalization*, to take care of the forcing term in the non-homogeneous differential equations corresponding to the non-parallel case. The same non-parallel like methodology also carries over to the developing mean-flow region of the porous panel, following the rigid-porous junction.

Numerical solutions have been obtained using extensions of the Thomas (1953: Phys. review, 91(4)) algorithm using a 7-point finite difference discretization technique, based on the Gauss-Noumerov transform. In some of the cases results have been validated with the available results from the work of Fransson (2001: Ph. D. Thesis, KTH Sweden), and, Fransson and Alfredsson (2003: POF, 15(3)). Finally,

the jumps in the amplitude of the disturbance waves across the rigid-porous junction were calculated using the theory of Carpenter and Sen (2003: IUTAM).

The important outcome from this work is in optimizing the porous panel, following the rigid-porous junction. It is seen that, as compared to the length required to approach the asymptotic mean flow state to within 99%, only a very short porous panel length is sufficient to stabilize the disturbances.

The propagation of disturbance waves has been analysed in detail. The application of cross-flow is an energy consuming process. Hence instead of using a long porous panel (which would be needed to approach the asymptotic mean-flow state), a short length of porous panel is sufficient to stabilize the flow. Thus, the energy requirements for inducing cross-flow can be drastically reduced.

Hence, it is foreseen that alternate long rigid panels, with in-between short porous panels, could be a very effective way of stabilizing the disturbances, and thus delaying laminar to turbulent transition.

Contents