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Crossflow Instability Control on a Swept Wing: Preliminary Studies

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The pressure distribution on a swept wing causes the streamlines at the edge of the boundary layer to be curved. This pressure gradient normal to the external streamline creates a velocity component normal to the external streamline within the boundary layer which is referred to as the crossflow velocity. Because the crossflow velocity profile perpendicular to the wing surface has an inflection point, the profile is unstable. The stationary instability mode takes the form of crossflow vortices. Under these conditions, the boundary layer on the wing is extremely unstable and transition to turbulent flow takes place much closer to the leading edge of the wing than it would on an unswept wing. Higher skin friction drag is associated with turbulent flow, and so better aircraft performance could be obtained if the crossflow could be eliminated

One method of controlling crossflow that is being investigated is boundary-layer suction. An extensive airfoil suction experiment in the 8' Transonic Pressure Tunnel (TPT) at NASA Langley Research Center will begin late in 1994. Because of the size, complexity, and expense associated with this test, a number of "risk-reduction" tests are currently being conducted. The 20"x28" Shear Flow Control Tunnel at NASA Langley is being used for some of these tests. Prior to the summer of 1994, a flat plate with a swept leading edge was installed in the 20"x28" tunnel, with a displacement body mounted on the tunnel ceiling that created a pressure distribution on the plate similar to the pressure distribution on a swept wing. The flow over the plate was investigated during the summer of 1994 using a laser Doppler velocimeter (LDV) system. The LDV measurements indicated the possible presence of multiple disturbance modes, a rarely-seen phenomena, since in most tests, one disturbance mode dominates. A number of difficulties were encountered in using the LDV system, however. The material used to seed the flow accumulated on the leading edge of the plate, causing the boundary layer to transition to turbulent flow at the leading edge. This in itself was a positive result with regards to the large 8' TPT experiment, in that the time and effort that would have been required to clean the model after each run (or worse, during a run) validated the choice made previously to use hot-wire anemometry as the velocity diagnostic tool in the 8' TPT test. The possible existence of multiple disturbance modes in the flat plate boundary layer, however, means that the flow in the 20"x28" tunnel is of interest itself, and will be investigated more thoroughly in the future. With a view to these investigations, the boundary layer traverse mechanism in the 20"x"28 tunnel was modified to improve its performance, and strain gauges were mounted on the traverse in order to monitor its deflection during a test. Other preliminary work conducted in the 20"x28" tunnel included the use of an infrared camera system. Previous work with this system showed that transition indeed could be detected, but the signal produced by the crossflow vortices was too weak to be detected. It was hoped that spraying the flat plate with naphthalene would augment the heat transfer associated with the crossflow vortices so that they would show up in a IR image; however, experiments showed that this would not work.

Another set of tests were conducted in the 20"x28" tunnel to determine the tripping requirements for a set of airfoil-shaped struts that will be used in the 8' TPT experiment. Since the Reynolds number associated with these struts is small, a laminar boundary layer would separate early, causing large fluctuations in the flow field. A turbulent boundary layer would remain attached further back, but tripping from laminar to turbulent flow at low Reynolds number is very difficult. However, trip strip configurations were found that should effectively trip the boundary layer at the required conditions.

Currently underway is an investigation of the data acquisition requirements for the 8' TPT experiment, with the purpose of the finding the minimum amount of data needed to characterize sufficiently the swept-wing boundary layer. This study is being conducted using a numerically-generated data set.