SOME TRANSITION AND CAVITATION INCEPTION OBSERVATIONS ON A 1.5 CAL OGIVE

by

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SUMMARY: Transition observation on a 1.5 cal ogive were carried out by Schlieren technique of flow visualization up to Re_D of 1.26×10^6. Good agreement is found between computed position of transition by Smith method and those observed by Schlieren technique for tunnel velocities greater than 50 fps ($Re_D > 7.85 \times 10^5$). Cavitation under desinent conditions at tunnel velocities of 30 fps and 40 fps was found to occur within the transition region of the boundary layer. At 50 fps good agreement is found between the present value of inception cavitation index, the value of desinent cavitation index measured by Parkin and the negative value of the pressure coefficient at both predicted and observed positions of transition. These observations strongly suggest that cavitation inception is closely related to transition on smooth bodies at supercritical Reynolds numbers.

2. Transition Observations.

Present experiments were carried out in the axisymmetric (14 inch diameter) test section of the California Institute of Technology High Speed Water Tunnel Facility. The nominal turbulence level of this tunnel has been measured by Dr. S. Barker to be 0.2 percent. The boundary layer transition observations were carried out on a two inch 1.5 cal ogive with a cylindrical afterbody by Schlieren technique of flow visualization (Arakeri and Acosta, 1973, Arakeri, 1974). Typical Schlieren photographs of the thermal boundary layer on the bottom side of the test body are shown in the photographs (a) and (c) of Fig. 1. For present purposes the starting position of the spatial waves clearly visible in the photographs was taken to be the point of transition. Estimated position of transition from the Schlieren photographs as function of tunnel velocity, U_T, is shown in Fig. 2. For U_T less than 50 fps the observed position of transition is downstream of the predicted point ($S/D = 1.32$) of laminar separation on the ogive by Thwaites method. However, the Schlieren photographs of Fig. 1 do not indicate the existence of laminar separation at U_T less than 50 fps. Recent observations have indicated the existence of laminar separation at $S/D = 1.26$ even at a velocity of 65 fps on the top side of the test body. Thus, it may be concluded that a small negative angle of attack measured to be only 0.067 degrees may be responsible for preventing laminar separation on the bottom side of the model for U_T less than 50 fps.

3. Transition Calculations.

An outline of the present method of transition prediction as first suggested by Smith and Gamberoni (1956) is provided in the appendix of (Arakeri, and Acosta, 1974). From this method the critical Reynolds number based on diameter, Re_D, was found to be 6.3×10^5 i.e., below this Re_D laminar separation should prevail. However, as discussed earlier during present experiments critical Re_D was less than 6.3×10^5 on the bottom side of the model and was more than 6.3×10^5 on the top side of the model. Nonetheless, for tunnel velocities greater than 50 fps ($Re_D > 7.85 \times 10^5$) very good agreement is found between the computed position of transition and that observed from the Schlieren photographs as shown in Fig. 2.

4. Cavitation Inception Observations.

From the photographs of Fig. 1, cavitation bubbles on the bottom side of the test body under desinent conditions are observed to exist within the transition region of the boundary layer. Present cavitation inception measurements based on visual observations at an air content value of 10 - 11 ppm are shown in Fig. 3. Also shown on the same figure are σ_d measurements by Parkin (1956) at an air content value of 8.6 ppm. Comparison of σ_i and σ_d measurements with the negative value of the pressure coefficient at computed and observed positions of transition are also shown in Fig. 3. The agreement between σ_i or σ_d and $-Cp_{tr}$ is found to be quite poor at lower velocities but is found to considerably improve with increase in velocity.

Acknowledgment

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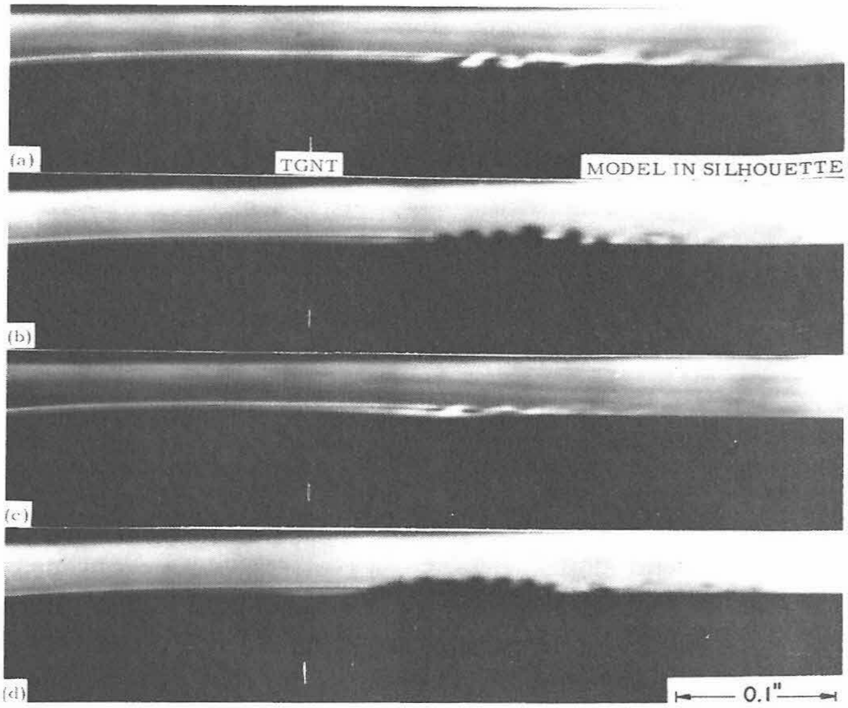

Figure 1 The schlieren photograph (a) illustrates some details of the transition process on a two inch 1.5 cal ogive at a tunnel velocity of 30 fps and the photograph (b) immediately below shows the cavitation bubbles under desinent conditions existing within the transition region at the same velocity of 30 fps. Similar observations at a velocity of 40 fps are shown in the photographs (c) and (d). The flow is from left to right.

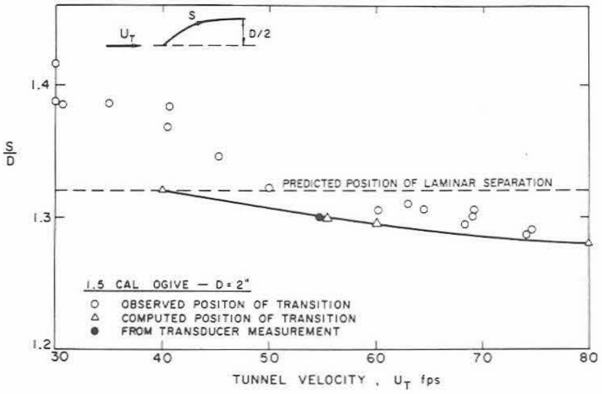

Figure 2 Variation of the observed and computed position of transition with velocity. Also shown is the estimated tunnel velocity at which transition occurs at the location (S/D=1.3) of a pressure transducer (Arakeri 1974).

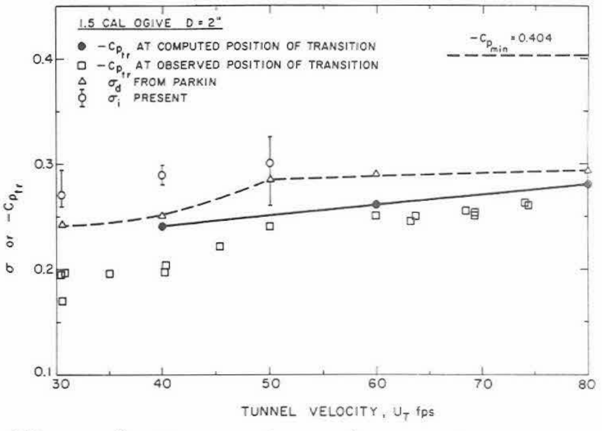

Figure 3 Comparison of present measurements of incipient cavitation index and Parkin's measurement of desinent cavitation index with the negative value of the pressure coefficient at the observed and computed position of transition on a 1.5 cal ogive.