

16.50 Propulsion Systems

HWK#8

Consider a simple supersonic internal-compression inlet, consisting of a convergent-divergent duct designed to accept all of the incoming flow at $M_0 = M_{0,D} = 1.5$ and decelerate it isentropically to $M_2 = 0.5$.

- (a) Calculate the area ratios A_t / A_2 and A_1 / A_2 , where A_1 is the mouth area, A_t is the throat area, and A_2 is the compressor-inlet area.
- (b) During the acceleration of the aircraft to $M_2 = 1.5$, a normal shock appears ahead of the engine, with two effects: (i) To spill some of the flow around the engine, and (ii) To introduce some total pressure losses. Nothing is done about it until the flight Mach number reaches $M_0 = 1.25$. At this condition, assuming M_2 is kept at 0.5, calculate the Mach number M'_0 right after the shock, the total pressure loss P'_{t0} / P_{t0} , and the fraction of flow that is spilled. For the latter, impose isentropic flow continuity between the subsonic conditions right after the shock and the compressor inlet, and calculate the flow area right after the shock, which will be $A'_1 < A_1$.
- (c) The pilot decides to ingest and reposition the shock at this $M_0 = 1.25$ condition. As a first step, the center body is moved such as to increase the throat area to a new value $A'_t > A_t$ such that the shock is brought right up to the engine mouth, and no spillage occurs any more. Assume that at this point, the throat just reaches sonic conditions, the flow being subsonic both before and after the throat. Calculate the required A'_t / A_2 and also the new value of M_2 ; this should be larger than 0.5, because more flow is now accepted, with still the same total pressure losses.
- (d) With the next small throat area increase, the shock pops in, past the throat, to the location on the divergent section where the local Mach number is again 1.25 (so as to continue passing the same full flow at the same engine conditions). The flow is now fully supersonic all the way to the new position of the shock. Calculate the Mach number at the throat.
- (e) The pilot now manipulates the throttle so as to reduce M_2 , and since the flow is still the same, this requires smaller total pressure losses, and in turn, a position of the shock closer to the throat, where the Mach number is lower. Assuming this is continued until the shock is at the throat (a bit beyond, really, but ignore this), calculate the new M_2 and the new total pressure loss across the shock.

Concept questions

- (1) In Part (c) above, the throat area is being increased. What else does the pilot (or the control system) need to do at the same time?

(2) Once the process above is completed and the shock is near the throat, the inlet has minimum losses at $M_0=1.25$. Suppose the aircraft continues to accelerate to $M_0=1.5$. Describe what control actions need to be taken in order to maintain the shock at the throat during the acceleration.

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