DEPARTMENT OF AEROSPACE ENGINEERING

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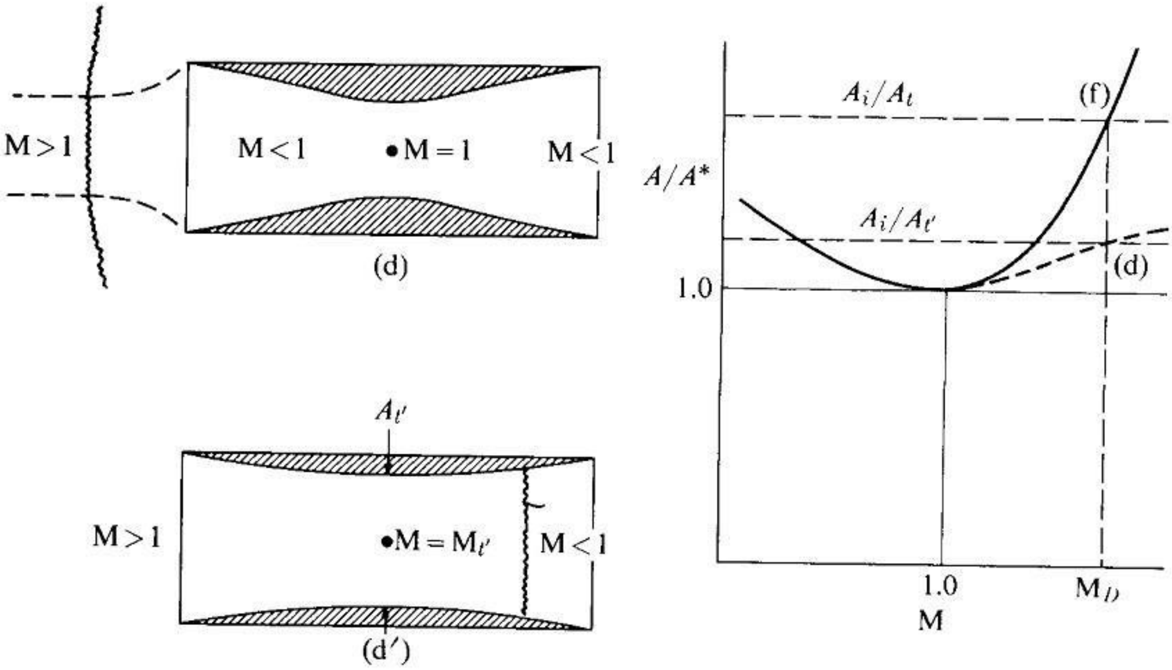
UNIT II - JET ENGINE INTAKES AND EXHAUST NOZZLES

Analysis of Shock Swallowing by Area Variation

The internal supersonic deceleration in a converging passage is not easy to establish. In fact, design conditions cannot be achieved without momentarily overspeeding the inlet air or varying the diffuser geometry. This difficulty is due to shocks that arise during the deceleration process while we examine the starting behavior of a converging-diverging diffuser.



An inlet having A_i/A_t greater than 1 ($A_i>A_t$) will always require spillage upon reaching supersonic flight velocities since Aa/At will always pass through a minimum of 1 just as sonic flight velocity is attained. It is necessary to perform some operation other than simply accelerating to the design speed to "swallow" the starting shock and establish isentropic flow. Overspeeding is one such operation, but there are others.

If overspeeding is not, it might be possible to swallow the shock by a variation of geometry at constant flight speed. The principle is easily seen in terms of simple one-dimensional analysis. Suppose the inlet is accelerated to the design Mach number MD with the starting shock present, as at point (d) in the above figure if the actual area ratio can be decreased from Ai/At to the value that can ingest the entire inlet flow behind the shock, the shock will be swallowed to take up a position downstream of the throat. This variation would normally involve a momentary increase of throat area from At to a new value that we will call At*. Having thus achieved isentropic flow within the convergence, the throat Mach number M is greater than 1, and a relatively strong shock occurs farther downstream. Completely isentropic flow can then be achieved by returning the area ratio to its original value while the operating conditions move from (d) to (f).

If the shock undergoes a momentary motion into the converging section of the diffuser, the shock Mach number will be lowered, and the downstream stagnation pressure will increase. This will increase the mass flow through the diffuser throat, lowering the density and the static pressure downstream of the shock. To accommodate this, the shock must move further down the converging section. From these arguments, there is no location in the converging section at which the shock will be stable, so the shock will move through the throat. If no adjustments are made in conditions downstream of the diffuser, the shock will move to a location in the diverging section of the diffuser at an area corresponding to the test section area, where it will then be stably positioned. This process is known as swallowing the shock. Once it occurs, the shock can be positioned by changing the operating conditions of the exhauster.

In practice, the shock must be maintained somewhat downstream of the diffuser throat because the shock is unstable in the converging part of the diffuser. If the shock moves upstream slightly, the shock Mach number increases, increasing the stagnation pressure loss and decreasing the mass flow capacity of the diffuser throat.