AE2010 Computer Project

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4/16/2021

Introduction:

First, the geometry of the nozzle was determined. This was done by determining the $^{A}/_{A*}$ so that the subsonic flow after the inlet shock at M=2 would not be choked. The area of the throat was calculated to be 0.89 m^2. Then, standard atmospheric conditions were determined at an altitude of 10 kilometers; these static conditions were constant for the airflow. Over the course of speeding up, the reference frame was speeding up as well, so the stagnation conditions changed according to isentropic flow relations. In order to calculate mass flow rate through the engine, spillage, and stagnation pressure loss, the reference frame at various were examined at critical conditions:

- Condition 1: When $0.2 \leq M \leq 0.5574$ (before the choke point)
  - $\dot{m}_\infty = \dot{m}_{Throat}$
  - Can be calculated using $\dot{m} = \rho_\infty v A_T$
- Condition 2: When $0.5574 < M \leq 1$ (after the choke point)
  - $\dot{m}_\infty \leq \dot{m}_{Throat}$
  - Spillage is relevant
  - Can be calculated using $\dot{m} = \rho_T v A_T$
    - v is a calculated for M = 0.5574
    - ρ_T changes isentropically so that M = 0.5574
- Condition 3: When $1 < M \leq 2$ (with a shock)
  - $\dot{m}_\infty \leq \dot{m}_{Throat}$
  - Spillage is relevant
  - Stagnation pressure is lost over the shock
  - Temperature increases over the shock
  - Can be calculated using $\dot{m} = \rho_T v A_T$

The following plots were produced:

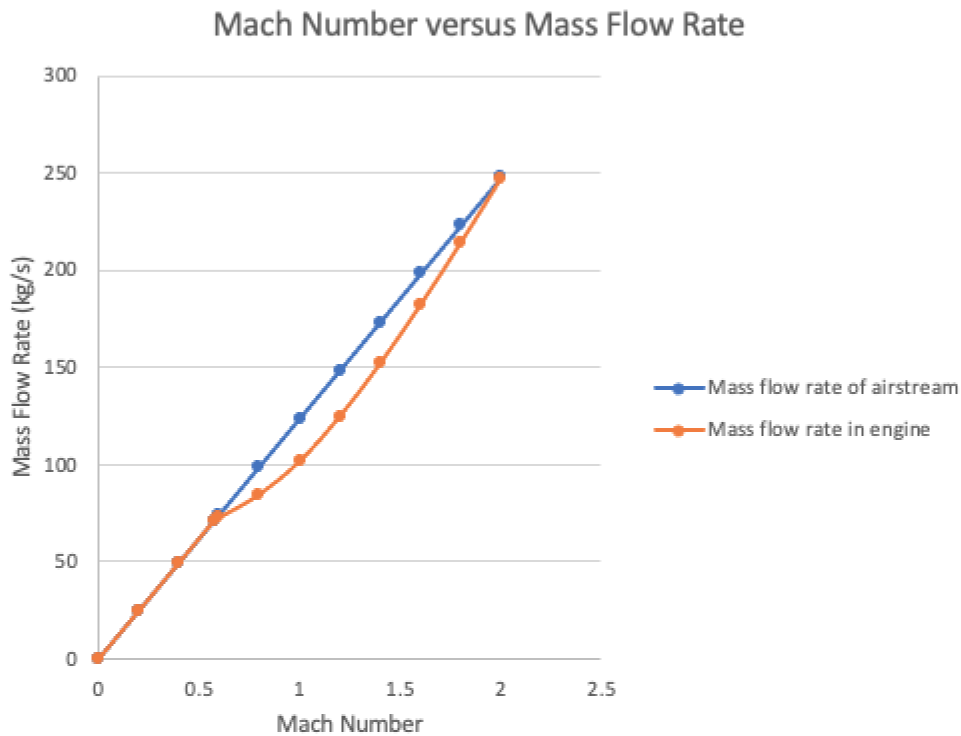

Figure 1: Mass flow rate vs. cruising speed at the throat and at infinity

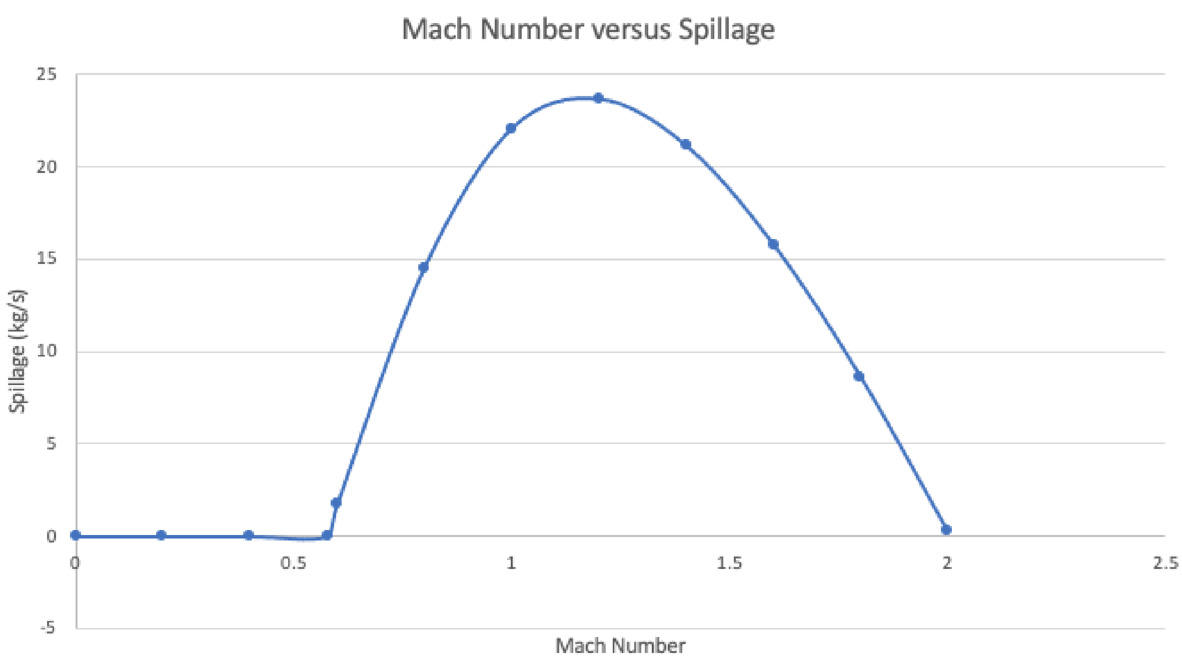

Figure 2: Spillage vs. cruising speed

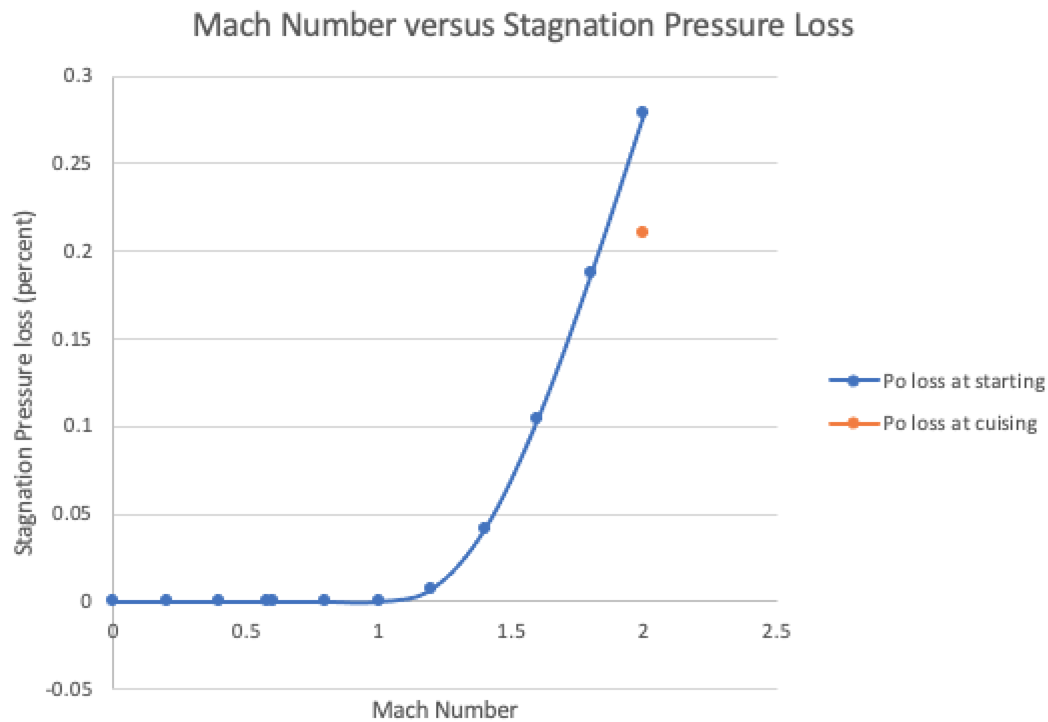

Figure 3: Stagnation pressure loss vs. cruising speed with the stagnation pressure loss for a swallowed shock

Conclusion:

There were several notable trends in the graph. The point of maximum spillage occurred at M=1. This means that flying at mach 1 is very inefficient. The P_0 loss increased exponentially after mach 1. At mach 2 with the shock at the inlet, the P_0 loss was 27.9%, which is fairly large. By swallowing the shock and moving it to the throat, the P_0 loss can be decreased to 21.1%.