Problem Set #6: EP and Engine Component Analysis (No Credit)

1. Electric Propulsion

A gridded ion thruster for an in-space satellite uses gaseous Ar \((c_p/R = 2.5, \text{ MW} = 39.95)\) as a propellant. It is operating with a power supply that can produce a maximum voltage of 675 V, and a maximum power of 0.330 kW. The ion production system requires a voltage of 155 V, while the neutralization system requires 18 V. What is the maximum specific impulse that can be delivered by this device? For this specific impulse, what is the maximum thrust it can deliver? For this thrust, estimate the number of individual accelerator grids required.

Answers: 5020 s, 9.97 mN, 6400

2. Aircraft Engine Inlet Design

You have been tasked to do the preliminary design of the engine inlet for a turbofan engine. Based on the engine requirements and preliminary cycle design for the turbofan, the following parameters are known:

<table>
<thead>
<tr>
<th>Bypass Ratio</th>
<th>Takeoff (0 ft; 288.15K, 1 atm)</th>
<th>Cruise (30kft; 229K, 30.15kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flight Speed (m/s)</td>
<td>Specific Thrust (kN s/kg)</td>
</tr>
<tr>
<td>5.50</td>
<td>0</td>
<td>2.40</td>
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</tbody>
</table>

Determine the corrected mass flow rate at each of these flight conditions, and provide a reasonable estimate of the proper diameter for the inlet’s entrance assuming a maximum allowable Mach number of 0.75 at the front face of the inlet.

Answers: 393 kg/s, 370. kg/s, 1.48 m

3. Compressor Stage Performance

Consider the 1st stage of the axial LPC for an aircraft engine. At an operating condition where the stagnation temperature and pressure entering the compressor are 278 K and 32.5 kPa, and the inlet axial air velocity is 133 m/s, the air enters the stage with a swirl angle of 34°. At this condition, the stage’s flow coefficient is 0.480 and its loading coefficient is 0.430. Furthermore, the mean radius of the rotor is 0.341 m.

What are the rotational speed (in rpm) of the stage’s rotor and the rotor’s blade Mach number at the mean radius?

For a stage efficiency of 0.93, what are the stagnation pressure and stagnation temperature exiting the stage?

Answers: 7760 rpm, 0.829, 370. kg/s, 46.8 kPa, 311 K