INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date: , FN/AN, Time: 2 hrs, Full Marks 30 , Department: Aerospace Engineering
Number of students: 48, Mid Spring Semester Examination 2012-2013
Subject No. AE31008, Sub Name: Theory of Jet Propulsion
3rd year B.Tech/DD, Instruction: Assume any missing data with suitable justification

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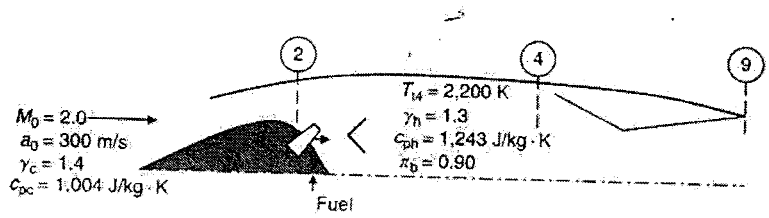
1. Obtain an expression for polytropic efficiency of a compressor in terms of its isentropic efficiency. A compressor has an isentropic efficiency of 0.85 at a pressure ratio of 4.0. Calculate the corresponding polytropic efficiency, and then plot the variation of isentropic efficiency over a range of pressure ratio from 2.0 to 12.0. Would you expect the same nature of the plot in case of a turbine? Explain with justification. [4]

2.

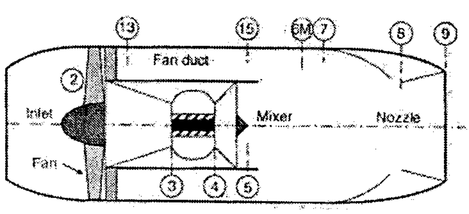


Note that suffix 'c' stands for cold and suffix 'h' stands for hot in the diagram above. π stands for stagnation pressure ratio across an engine component.

A ramjet is cruising at supersonic speed at an altitude where $p_0 = 10\text{kPa}, T_0 = -40°\text{C}$ with intake air mass flow rate of 100kg/s. Note that suffix '$_0$' stands for freestream static value. The inlet pressure recovery is given by $\eta_d = 0.91$. The engine uses hydrogen as fuel with Q_R=117,000 kJ/kg which is burnt at a combustion efficiency of $\eta_b = 0.96$. Fuel injector is located at station 2 and the flameholder is located downstream of the injector. The combustion products are ideally expanded in the nozzle but with a stagnation pressure loss given by $\pi_n = 0.93$. Calculate the following for the ramjet engine:

(a) Inlet capture area
(b) Gross and net thrust
(c) Nozzle exit Mach number
(d) Fuel-to-air ratio
(e) Engine efficiencies: η_t, η_p, η_o [8]

3.



For a mixed exhaust turbofan engine the design parameters are as follows:

$M_0 = 0.8, p_0 = 15\text{kPa}, T_0 = -20°\text{C}, \dot{m}_0 = 120\text{kg/s}$

The other operating parameters of the engine are given as follows

(i) $\pi_d = 0.92, \pi_f = 2.0, \pi_{fd} = 0.99, \pi_c = 20, \pi_b = 0.98, \pi_n = 0.95$, where π stands for stagnation pressure ratio across a particular engine component. (Subscripts 'd', 'f', 'fd', 'c', 'b', and 'n' stand for diffuser, fan, fan duct, compressor, burner (combustor), and nozzle respectively.)

(ii) Polytropic efficiency of fan and compressor=90% and polytropic efficiency of turbine=84%

(iii) Mechanical efficiency of spool connecting compressor, fan and turbine=99%

(iv) Combustor exit temperature is 1600K

(v) Fuel heating value= 42,000 kJ/kg, burner efficiency $\eta_b = 0.98$

(vi) $M_5 = 0.55$

(vii) The stagnation pressure loss parameter in constant area mixer=0.98

(viii) $p_9 = 17\text{kPa}$

The gas properties in inlet, fan and compressor section: $\gamma = 1.4, c_p = 1004 J/kg.K$

The gas properties in turbine section: $\gamma = 1.33, c_p = 1152 J/kg.K$

Calculate the following:

(a) Static and stagnation pressure and temperature distribution throughout the engine

(b) Fuel to air ratio

(c) Bypass ratio

(d) Area ratio A_{15} / A_5

(e) Flow and thermodynamic properties in the mixer M_{6M}, p_{6M}, h_{t6M}

(f) TSFC

(g) Engine efficiencies: η_t, η_p, η_o [14]

4. Explain the concept of 'power split' in a turboprop engine. Obtain an expression for optimum power split. [4]