AA103 Homework 8

Cantwell Spring 2020-21

Due May 25, 2021

Suggested Reading

AA283 Course reader Chapters 2 and 3.

Problem 1

It is late August and a female Bar-tailed Godwit with a mass of $0.6kg$ takes off from the west coast of Alaska beginning her fall migration south. Estimate her mass when she arrives eight days later after a nonstop flight of $11,680km$ to the Piako river on the North Island of New Zealand. Assume the overall efficiency is $\eta_{overall} = 0.45$ and the change in weight is mainly loss of fat. You will need to do some internet research to supply whatever additional information you need to make the estimate.

Problem 2

A ramjet operates at a free-stream Mach number, $M_0 = 3$. The area ratio across the engine is $A_1/A_8 = 1.75$. Supersonic flow is established at the entrance of the inlet and a normal shock is stabilized in the diverg-

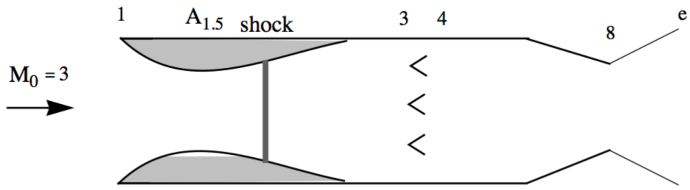

Figure 1: Ramjet with fully expanded nozzle.

ing part of the inlet. The stagnation temperature exiting the burner is $T_{t4} = 1512K$. The nozzle is fully expanded, $P_e = P_0$. The fuel enthalpy is $h_f = 4.28 \times 10^7 J/kg$. The ambient temperature and pressure are $T_0 = 216K$ and $P_0 = 2 \times 10^4 N/m^2$.
1) Determine the fuel/air mass flow ratio, f.
2) Determine the stagnation pressure ratio, P_{t8}/P_{t0}.
3) Determine the nozzle exit Mach number, M_e.
4) Determine the dimensionless thrust, $T/(P_0A_0)$.

Problem 3

Shown below is a unique concept for a hypersonic scramjet. It operates on principles similar to a hybrid rocket except that the oxidizer is air entering the motor at $M_0 = 5$. The ambient temperature and pressure are $227K$ and $0.01bar$ corresponding to flight at about 100, 000 feet. The air is decelerated through a loss-free inlet to $M_3 = 2$. The stagnation temperature of the incoming air is so high that auto-ignition occurs at the leading edge of the solid fuel grain and a diffusion flame is established over the length of the fuel surface producing hot gases for thrust. In a sense the solid fuel acts like a distributed spray injector of fuel into the supersonic stream. The solid fuel protects the motor case from the high combustion temperatures meaning the ramjet can operate at the stoichiometric fuel/air ratio, $\dot{m}_f/\dot{m}_a = 0.07$ at station 4. The gas

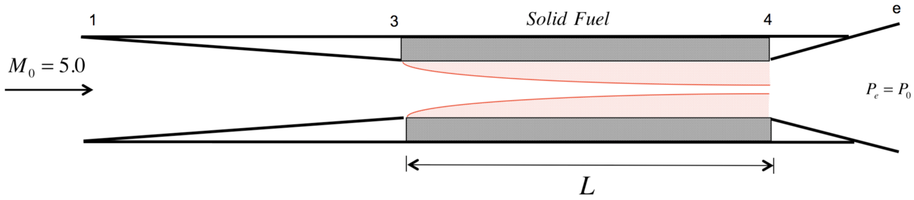

Figure 2: Solid fuel scramjet.

then expands to ambient pressure in a diverging nozzle. The exit velocity is $U_e = 2337m/sec$. Assume that the regression rate of the fuel is given by the simplified form $\dot{r} = a(G_{air})^{1/2}$ where $G_{air} = \dot{m}_{air}/\pi r^2$ is the mass flux of air along the port and $r(t)$ is the instantaneous radius of the port. The regression rate constant is $a = 1.54 \times 10^{-4} m^2/kg^{1/2} sec^{1/2}$. The air mass flow rate is $\dot{m}_{air} = 1000kg/sec$. The fuel density is $\rho = 800kg/m^3$.
1) Show that the fuel mass flow rate is independent of the radius of the port.
2) Determine the port length L needed to generate the required fuel mass flow rate.
3) Determine the capture area, A_0.
4) Determine the thrust coefficient, $C_{thrust} = T/(\gamma {M_0}^2 P_0 A_0/2)$.