AA103 Homework 7

Cantwell Spring 2020-21

Due May 18, 2021

Suggested Reading

AA283 Course reader Chapters 10 and 11.

Problem 1

It is a beautiful summer day at the Cape and a space shuttle astronaut on her second mission finds that the g-forces during launch are noticeably larger than during her first mission that previous December. Can you offer a plausible explanation for this?

Problem 2

A solid propellant rocket operates in a vacuum with a $10cm$ diameter nozzle throat and a nozzle area ratio of 100. The motor has a cylindrical port $300cm$ long. After the ignition transient, at the beginning of the burn, the port is $20cm$ in diameter and the propellant recession velocity is $1.0cm/sec$. The port diameter at the end of the burn is $80cm$. The regression rate law is

$$\dot{r} = a\left(P_{t2}\right)^{1/2} \tag{1}$$

The solid propellant density is $2.0grams/cm^3$. The combustion gas has $\gamma = 1.2$ and molecular weight, $M_w = 20$. The combustion chamber temperature is $T_{t2} = 2500K$. Determine the thrust versus time history of the motor during the burn.

Problem 3

One of the simplest types of solid rocket designs utilizes an end burning propellant grain as shown in Figure 1 The motor diameter is $100cm$ and the grain length at the beginning of the burn is $200cm$. The

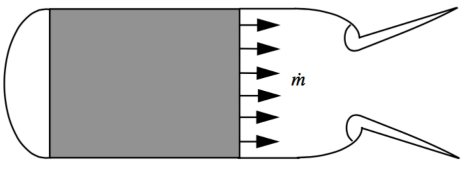

Figure 1: Solid rocket with end burning grain.

solid propellant density is $2grams/cm^3$. The combustion gas has $\gamma = 1.2$ and molecular weight, $M_w = 20$. The combustion chamber temperature is $T_{t2} = 2500K$ and at the beginning of the burn, the pressure is $P_{t2} = 5 \times 10^5 N/m^2$. The motor exhausts to vacuum through a $30cm$ diameter nozzle throat with a nozzle area ratio of 10. Sketch the thrust-time history of the motor and determine the total impulse

$$I = \int_0^{t_b} (Thrust)dt \tag{2}$$

in units of $kg - m/sec$. Assume specific heats are constant.

Problem 4

A hybrid rocket with an initial mass of $m_{initial} = 900kg$ operates in space. The fuel is paraffin with a density $0.93gm/cm^3$ and the oxidizer is nitrous oxide. The oxidizer mass flow rate is held fixed at $2.4 \times 10^4 gm/sec$. The motor has a $10cm$ diameter nozzle throat, $30cm$ diameter nozzle exit, and a cylindrical port $143cm$ long. The initial port radius is $8.75cm$. At the end of the burn, the port radius is $15.5cm$. The regression rate law is $\dot{r} = 0.035{G_o}^{0.6} cm/sec$. A calculation using CEA shows that $C^* = 1.64 \times 10^5 cm/sec$ where C^* is defined by $\dot{m} = P_{t2}A^*/C^*$. The effective nozzle exit velocity is $C = 2.8 \times 10^5 cm/sec$. Neglect nozzle erosion during the burn.

1) When the fuel is all burned the oxidizer flow is turned off. Determine the time when this occurs.
2) Determine the total mass flow rate and motor thrust at the beginning and end of the burn.
3) Determine the chamber pressure at the beginning and end of the burn.
4) Determine the velocity change of the vehicle.