GENERAL
Home
Laboratories
Contact Info

COURSES
Overview
MEAM 101
MEAM 150
MEAM 247
MEAM 410
MEAM 420
IPD 501
Senior Design

GUIDES
Materials
Laser Cutting
3-d Printing
Machining
PUMA 260
MaEvArM

SOFTWARE
SolidWorks
Adobe Illustrator
Matlab
NX
Nastran
Fluent, Gambit
SolidCAM
Eagle
ProtoTRAK

OTHER
Design Links

Editing Tips

MEAM.Design - MEAM 247 - P1: Launch - Fundamental Rocket Relationships

---

(Note - we're using embedded LaTeX typesetting on this page. You may need to download the jsMath fonts from here to properly view the equations.)

Air Expansion

We will begin with the rocket motor, filled with a certain volume of water, $V_w(0)$, and air, $V_a(0)$, at an initial pressure, $P_a(0)$. Upon launch, we will assume adiabatic expansion of the air as water is quickly ejected through the nozzle. The pressure and volume of the air are thus related by:

$$\frac{P_a(t)}{P_a(0)} = \left(\frac{V_a(t)}{V_a(0)}\right)^{-\gamma}$$

where $\gamma = 1.4$ is the adiabatic index for air.

Water Nozzle Exit Velocity

Recognizing that the water is essentially incompressible, we can use Bernoulli's equation to find the velocity of the water through the nozzle. Bernoulli's equation states that at any point in a streamline

$$\frac{v^2}{2} + \frac{p}{\rho} + gh = \text{constant}$$

where v is the velocity, p is the pressure, ρ is the density, g is gravity, and h is the height above a reference plane. Given that the motor is relatively short, we can ignore gravitational effects. We can therefore apply Bernoulli's equation to compare the nozzle exit to the air/water interface:

$$\frac{v_e(t)^2}{2} + \frac{P_{atm}}{\rho} = \frac{v_a(t)^2}{2} + \frac{P_a(t)}{\rho}$$

where v_e is the nozzle exit velocity, P_{atm} is the atmospheric pressure, and v_a is the velocity of the air/water boundary.. Now, solving for v_e:

$$v_e(t) = \sqrt{v_a(t)^2 + \frac{2(P_a(t) - P_{atm})}{\rho}}$$

Thrust

The linear momentum of a water particle of mass Δm expelled from the nozzle at velocity of $v_e(t)$ can be expressed as

$$\Delta L = \Delta m \; v_e(t)$$

dividing by Δt and taking the limit as t goes to zero results in edit SideBar

SEARCH

Go

$$\dot{L} = \dot{m}\; v_e(t)$$

which is equal to the sum of external forces acting on the water particle, and therefore equal to the thrust acting on the rocket

$$F(t) = \dot{m}\; v_e(t)$$
