ME EN 2450 | Ryan Dalby u0848407 | AI001

Analyzing Error

• where is largest source of error? Is it worth time to invest in better sensors?

$P_o = 26.02$ in Hg → every hundredth $P_{1gauge} = 50psi$ → every 2 psi $P_1 = P_{1gauge} + P_{atm}$ $P_{gauge\,error} = 13789.5\,Pa$ (2psi)

$r = 4.5\,in$ $h = 0.55m$ → Ruler, every 1/16 in $P_{1gauge} = 50psi = 344738$

$P_0 = 26.02\,inHg = 88113.833\,Pa$ $P_1 = 432851.833\,Pa$

$P_{0\,error} = .01\,inHg = 33.8639\,Pa$ $P_{1error} = P_{0error} + P_{gauge\,error} = 33.8639\,Pa + 13789.5\,Pa$

$P_{1error} = 13823.3639\,Pa$

$V = \pi r^2 h$

$r = 4.5in = 0.1143m$ $h = 0.55m$

$r_{error} = 1/16\,in = .0015875m$ $h_{error} = 1/16\,in = .0015875m$

$$X = P_1 V\left(\ln\frac{P_1}{P_0} + \frac{P_0}{P_1} - 1\right)$$

$$X_{calculated} = (432851.833)(\pi(.1143)^2(0.55))\left[\ln\left(\frac{432851.833}{88113.833}\right) + \frac{88113.833}{432851.833} - 1\right]$$

$$\boxed{X_{calculated} = 7771.28\,J}$$

$V = \pi r^2 h$

$$\left|\frac{\partial X}{\partial P_0}\right| = P_1 V\ln\left(\frac{P_1}{x}\right) + \frac{x}{P_1} - 1) = P_1V \cdot -P_1P_0^{-2}\cdot\frac{1}{\left(\frac{P_1}{P_0}\right)} = P_1V\left[-\frac{P_1}{P_0^2}\cdot\frac{P_0}{P_1} + \frac{1}{P_1}\right)$$

$$= -\frac{P_1V}{P_0} + V\Big|_{P_0,P_1,r,h} = -.08831 = 0.0883\,\frac{J}{Pa}$$

$$\left|\frac{\partial X}{\partial P_0}\right| \delta P_0^{\,P_0\,error} = 2.99\,J$$

$$\left|\frac{\partial X}{\partial P_1}\right| = \frac{1}{P_0}\,\frac{1}{\frac{P_1}{P_0}} - \frac{P_0}{P_1^2}\,P_1V + V\left(\ln\left(\frac{P_1}{P_0}\right) + \frac{P_0}{P_1} - 1\right) = .0359\,J/Pa$$

$$\left|\frac{\partial X}{\partial P_1}\right| P_{1error}\ (\delta P_1) = 496.7\,J$$

$V = \pi r^2 h$, $2\pi r h$

$$\left|\frac{\partial X}{\partial r}\right| = P_1(2\pi r h)\left(\ln\left(\frac{P_1}{P_0}\right) + \frac{P_0}{P_1} - 1\right)\Big|_{P_0,P_1,r,h} = 135950.418\,J/m$$

$$\left|\frac{\partial X}{\partial r}\right| \delta r^{\,r_{error}} = 215.87\,J$$

$$\left|\frac{\partial X}{\partial h}\right| = P_1\pi r^2\left(\ln\left(\frac{P_1}{P_0}\right) + \frac{P_0}{P_1} - 1\right)\Big|_{P_0,P_1,r,h} = 14129.6\,J/m$$

$$\left|\frac{\partial V}{\partial h}\right| \Delta h^{\,h_{error}} = 22.43\,J$$

The error is 9.50% of the calculated value so yes it's worth it to invest in new sensors

Total error = 738.0 J

The pressure gage is the largest source of error since it contributes 496.7J to the total error

$$\%\,Error = \frac{738.0J}{7771.28J} = 9.50\%$$

```python
# -*- coding: utf-8 -*-
"""
Created on Tue Jan 29 17:45:50 2019
AID01
@author: Ryan Dalby
"""
import numpy as np

diameters = np.array([2.0, 2.0, 2.0, 8.0, 8.0, 8.0, 8.0])#inches
radii = diameters/2 #inches
lengths = np.array([10.0, 10.0, 10.0, 20.0, 20.0, 20.0, 24.0]) # inches
startingPressures = np.array([10.0, 100.0, 150.0, 10.0, 100.0, 150.0, 150.0])# psi
P0 = 88113.833 #Pa (26.02 inHg)

def energyEq(r, h, P0, P1):
    """Takes in an ndarray of radii(of tank), heights/lengths(of tank), surrounding atmospheric pre
    and pressure inside the tank and gives the max energy we could get by bringing the gas inside t
    to the same state as the environment"""
    V = np.pi * r**2 * h
    ans = (P1 * V * (np.log(P1/P0) + P0/P1 - 1))
    return ans

def inToMeters(inch):
    """Converts inches to meters"""
    return inch * (.0254)

def psiToPa(psi):
    """Converts psi to pascals"""
    return psi * (6894.76)

def averageForce(energy, distanceForceApplied):
    """Converts from total energy(J) and the distance a force was applied(m) to average force(N)"""
    return energy/distanceForceApplied



energyVals = energyEq(inToMeters(radii), inToMeters(lengths), P0, psiToPa(startingPressures))
forceVals = averageForce(energyVals, 10.0) #force is over 10m

table = np.array((diameters,lengths,startingPressures, energyVals, forceVals)).transpose()

np.set_printoptions(suppress = True)
print(table)
```

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System Modeling:

Results Summary(Energy and average driving force):

d(in)	h(in)	P1(psi)	Energy(J)	Average Force(N)
2.	10.	10.	1.161	0.116
2.	10.	100.	420.654	42.065
2.	10.	150.	824.182	82.418
8.	20.	10.	37.142	3.714
8.	20.	100.	13460.94	1346.094
8.	20.	150.	26373.813	2637.381
8.	24.	150.	31648.575	3164.858

Implications: From applying different diameters(d), heights(h), and starting pressures(P1) the theoretical energy output and average force were recorded above. We notice with a higher starting pressure and a larger volume(related to d and h) we get a higher energy output and average driving force. We notice that we get a lower energy output and lower average driving force with a lower starting pressure and lower volume We can modify these parameters in order to get the correct amount of energy output to go the correct distance and not over or undershoot.

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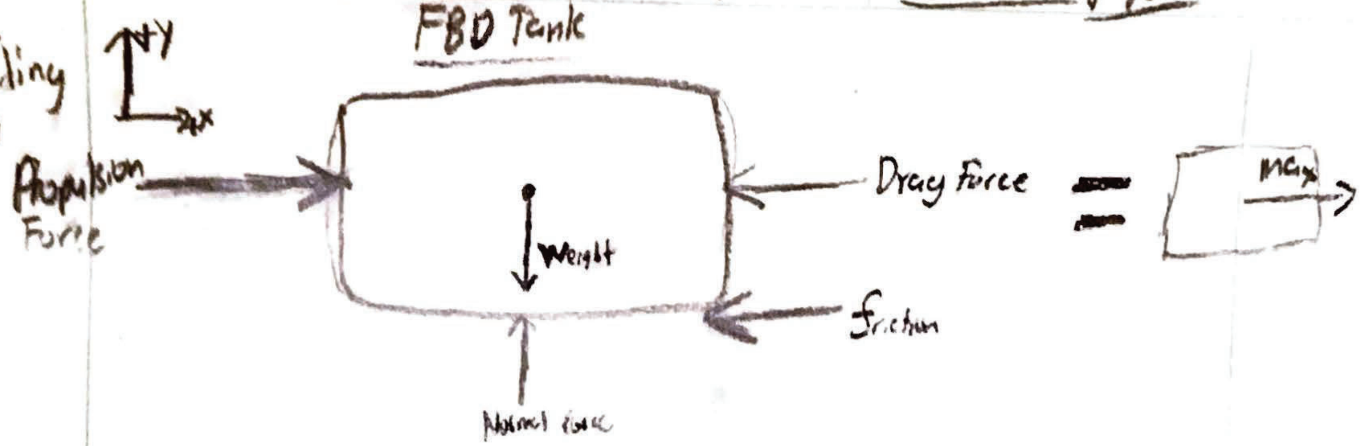
System Modeling

FBD Tank



$$\sum F_x = F_{propulsion} - F_{drag} - f = m_{tank} a_{x_{tank}}$$

$$\sum F_y = -Weight + N_{force} = 0$$

The main assumption for the model described above is that no other forces act on the body, (that is idealized as a rectangle and in 2D above), other than the ones described in the free body diagram. For now I am also assuming that the propulsion force acts uniformly against the body, not at an angle or at a point that would cause a moment.