Lab Report

Abstract

The idea for my group project came up from the course title which is "Fluid Mechanics Applications." Since the beginning of the semester, we have learned and do some experiment about pressure factor. On the first day of group discussion, my team pulled out some questions: "what can we do with pressure? How can it be apply in the real world?" We ended up with "Rocket Science." The topic sounds simple, but it has enough complexity for us to apply our skills and concepts learned from the lecture to work. It is simple because we can build a launch pad from a few simple tools and materials around the house. Our group will determinate the high, speed, and the time of the rocket. On this project, we will use the same method as a real rocket. We will use a 2 liters bottle that contained some water and compressed air. The compressed air inside the bottle will force the water flow through the bottle's nozzle. Due to Newton's Third Law of motion: "the action force of the air (and water) as it rushes out the nozzle creates an equal and opposite reaction force propelling the rocket upward". The force come out from the nozzle with create a force to launch the bottle in the air. On this experiment, my team will calculate the high, and the speed of the rocket with the pressurized air from 5-50 psi. At 50 psi, the rocket launched with the speed of 74 ft/s, and the maximum high is 85 ft. The result reveals the concept of a jet engine. With enough amounts of pressure, we can create a powerful jet engine.

Introduction

In this project activity, my team will develop the actual rocket height and compare it to the theoretical results. We are expecting that our result will be close enough to the theoretical. There are some factors would influence our results; those factors are the propulsion mechanism and wind effects. That is why my team decided to launch the rocket straight up, not with an angle. The concept for the bottle rocket has been applying for many serious products. In modern industry, people are using this method to produce a new type of CNC cutting machines. These machines using the jet engine with compressed air at 50,000 psi or more. With that amount of pressure, the jet engine could cut through various type of material. Furthermore, replace the old model of CNC machines with the new model using jet engine, we could save millions. The old model of CNC used cutting tools that made by hard material. When the machine is in use, it gives a lot of heat. With the jet engine, we will no longer worry about heat why cutting material. In military, most of aircraft using this method to launch from USS aircraft carrier.

In the modern world, NASA is using the same procedure for rocket launching. They also provide guild line for student able to hand-on the concept of rocket. We combined some information from NASA website and information we learned from fluid class on this project. The different in pressure lead the different in high. Based on NASA website, and for safety, the pressure inside the bottle will not be excess 60 psi. We will determinate the high of the rocket with the maximum pressure at 50 psi.

Methods and Materials

The bottle rocket consisted of a two liter Coke plastic bottle. The launch pad base material is wood. The assembly of the launching device used in our experiment consisted of four metal L brackets with holes in them secured on to the base by woodscrews. Two pairs of the L brackets set across from each other and used to secure the bottle down. Two holes were drilled in between the two pairs of L brackets. A flat bracket with two holes at each end and one hole in the middles was sat on top of two nuts put on the bolts and secured with two other nuts on top. A rubber stopper with a tire valve stem was inserted through the hole in the middle of the flat bracket. Two long nails were used as the release mechanism of the rocket.

The experiment used the energy of pressure to launch a plastic bottle in to the air. The procedure began by filling the bottle with approximately two cups of water. Once that was done the bottle was secured on to the stopper which prevented the water to leak out. Most plastic bottles have a hard rim on the mouth were the cap sit on. This rim was used to secure the rocket while pressure is being applied. Once the mouth was on the stopper the flat bracket was adjusted so that the two nails where inline with the rim of the mouth. The nails where set through the two pair of L brackets right on top of the hard rim of the bottle mouth. A string was attached to the nails that they could be removed fast and at the same time. A tire pump with a pressure gauge was connected to the tire stem valve. Air was pumped into the bottle until the pressure desired was achieved. Once the pressure was met the nails that held the bottle in place were pulled off by the string and the bottle shot up in the sky. Below are images of the bottle rocket and assembly.

The height that the bottle rocket reached could not be directly measured so it had to be calculated using the time it took the bottle to reach its max height. The height $h = h_t + v_o\, t - ½\, gt^2$ formula the derivative of the equation is $v = v_o - gt$. The velocity at the max height equal zero therefore the velocity formula can be rearranged to $v_o = gt$. This initial velocity is plugged into another height formula. Since the rocket is shot from the ground hi is zero. Therefore the new formula is $h = gt^2 - ½\, g^2 t$ or $h = ½\, gt^2$.

A few assumptions had to be made to use the formula previously mentioned. First: the bottle is assumed to go up and down in a strait line with no interference from cross winds (or movement in the x direction). Second: that the bottle travels with the fat end front in both up and down directions. Third and final: that the bottle takes on the same drag forces on the way up and on the way down. The theoretical height was obtained using the general energy equation $Z_1 + P_1/\rho g + v_1{}^2/2g + E_A/FW - E_L/FW = Z_2 + P_2/\rho g + v_2{}^2/2g$ where ρ is the density of water and g is the acceleration due to gravity. Only two cups of water was used so the difference in Z's is negligible. P_2 is atmospheric pressure so it equals zero. There is no energy added to the flow of the water out of the bottle. The energy losses are low therefore they were ignored. Because v_2 ›››› v_1 , v_1 is ignored.

The GE equation now takes the following form $P_1/\rho g = v_2{}^2/2g$. Rearranging the terms the velocity of the water coming out of the mouth can be calculated using the formula $v = \sqrt{P_{1\cdot 2}/\rho}$. This velocity was used as the v_o edin the original height equation to get the theoretical height. This was done by calculating the time it would take the rocket to reach the max height or velocity equaling zero by using the formula $t = v_o/g$. The time is inserted in to the original height equation to get the theoretical height. Some assumption had to be made. First: the drag coefficient of the bottle is not known therefore the drag force was not taken into account in the theoretical height calculation. Second: since there was only two cups used for the experiment and the water came out so fast it can be considered instantaneously therefore the weight of the water was not considered.

The weight of the bottle was also not considered (very low). Third: since air has a very low density and it escapes the bottle almost instantaneously the mass of the air is not considered. Basically, the rocket was treated as a mass-less frictionless object. Fourth and last: the bottle is assumed to go up in a straight line. Nine trials were done at incremental pressure values and the time to reach the max height was recorded. The values for both the theoretical and experimental heights were plotted. The calculated initial velocity was also plotted. The results can be found in the results section of this report.

Results

Experimental				
Trial	t	P	Vo (ft/s)	H(ft)
1	1.55	5	49.8697	39
2	1.9	10	61.1306	58
3	2.1	15	67.5654	71
4	2.25	20	72.3915	81
5	2.1	25	67.5654	71
6	2.35	30	75.6089	89
7	2.6	35	83.6524	109
8	2.2	40	70.7828	78
9	2.3	50	74.0002	85

Theoretical			
Trial	Vo (ft/s)	H(ft)	t (theoretical)
1	27.245	11.536	0.847
2	38.530	23.072	1.198
3	47.189	34.608	1.467
4	54.489	46.144	1.694
5	60.921	57.680	1.893
6	66.735	69.216	2.074
7	72.082	80.752	2.240
8	77.059	92.287	2.395
9	86.155	115.359	2.678

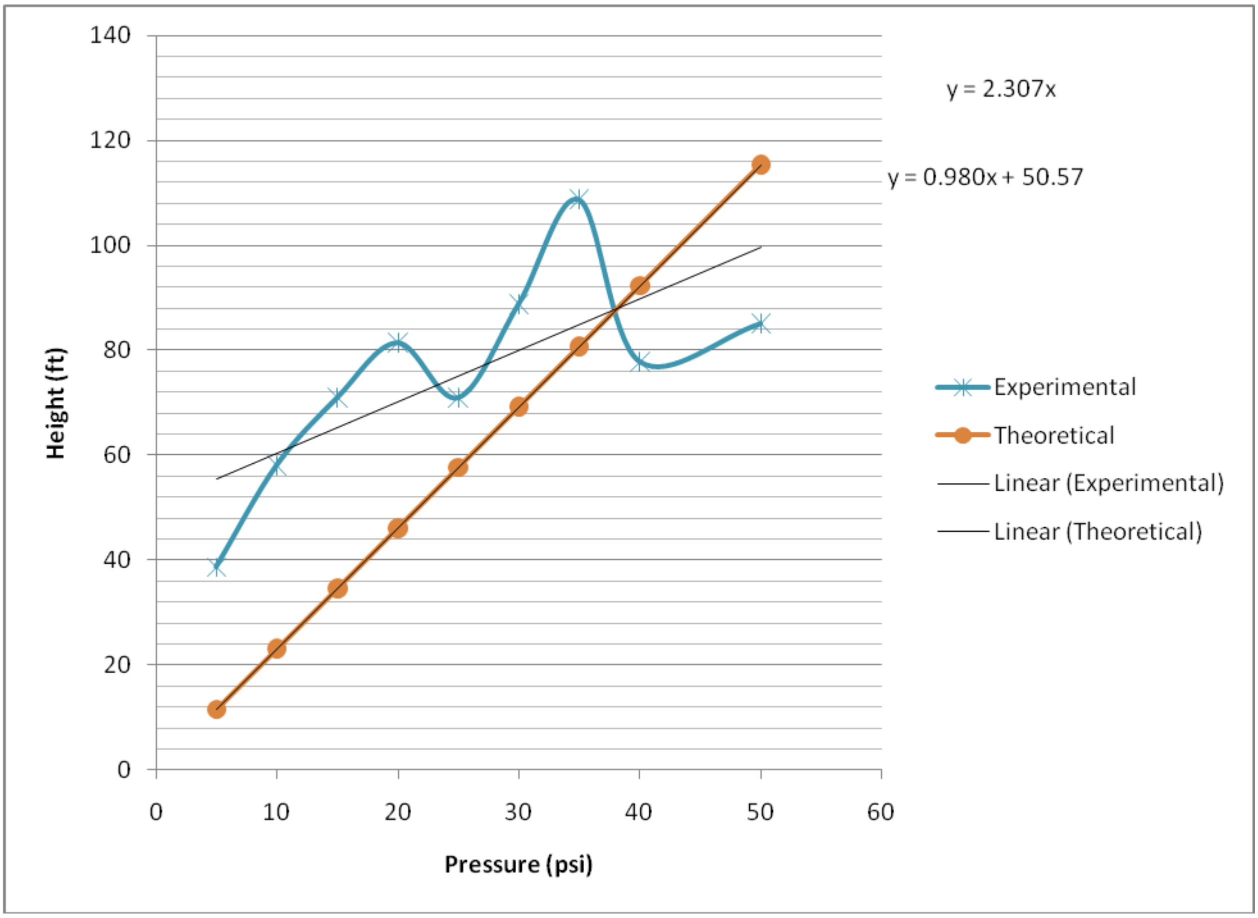

Figure 1: Graph of height vs Pressure

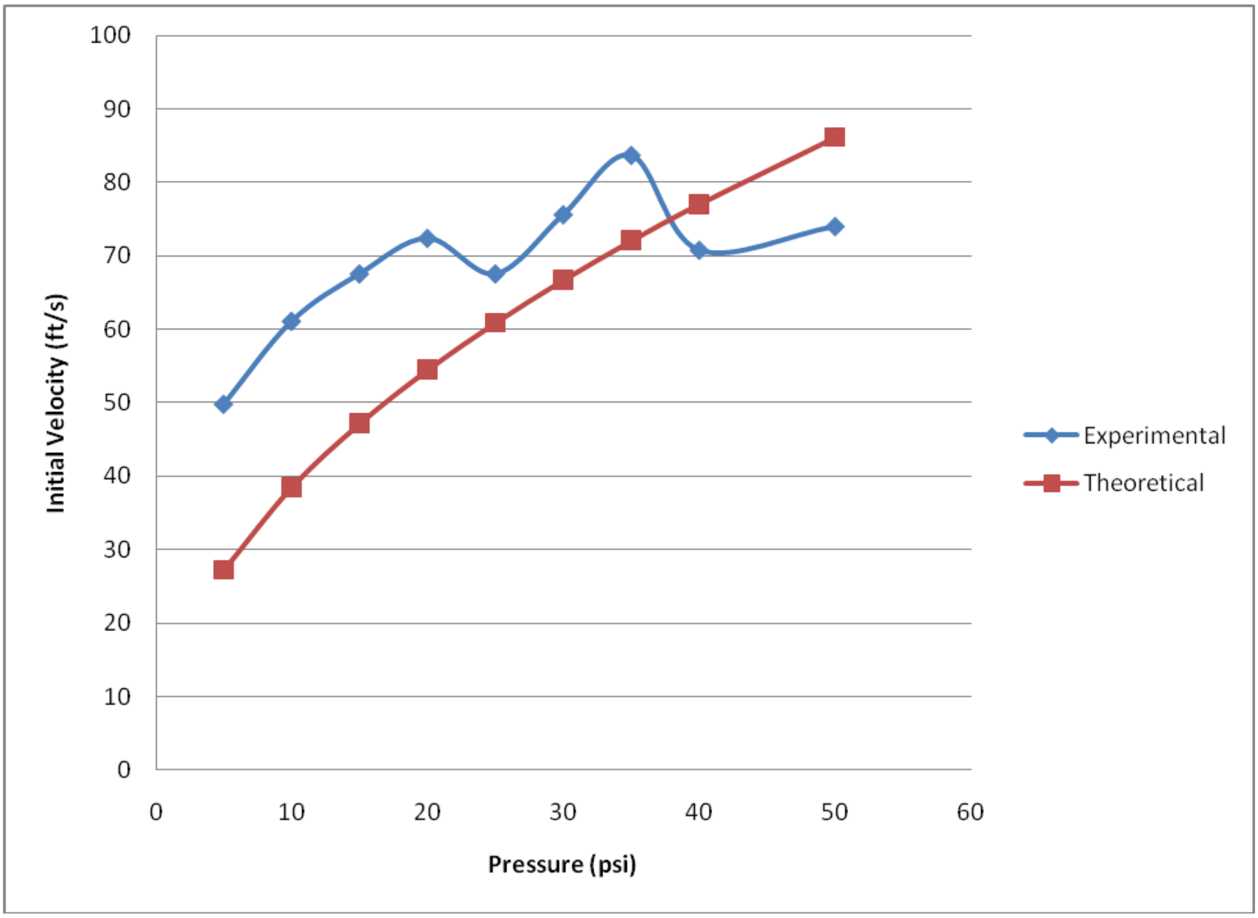

Figure 2: Graph of Initial Velocity Vs Pressure

Discussion:

From the results it is clear that experimental and theoretical results are different. The variation in the obtained results can be attributed to the errors that may arise during the experiment. The variance in the experiment and the theoretical value can be due to the approximation that used in the calculation of the heights and the time taken. The assumption that the bottle goes up in a straight line may not have hold since there exist other externalities that the environmental set up of the experiment could not control. The argument that the fat end top of the bottle will travel up and down in the lead may not hold since the external forces may tilt the bottle and thus changing the path taken by the bottle in its movement. The effects of the gravitational pull may also contribute in the variance. We also assumed that the drag force is the same but that may not be the case since the shape of the bottle is not uniform and the experiment is not being done in a vacuum. There is definite energy loss as the bottle gains height and thus this may also contribute to the changes in the velocity.

Looking at the relationship between the height and pressure, we see the linear relationship between the height and pressure. As the bottle gains height the pressure increases. When looking at the velocity and pressure, we also observe the linear relationship and thus as the velocity increases the pressure also increases. The principle can be employed where both height and velocity increase will result in the rise in the pressure. This application can enable the deployment of the technology in many uses as suggested in our initial arguments.