Measuring a Rifle's Recoil Using Wireless Dynamics Sensor System

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Abstract

As a member of the Morehead State University rifle team for the last four years, many hours have been spent at the Button Rifle Range. In this project, we are investigating the physics of the rifle. Using the Vernier wireless dynamics sensor system (WDSS), we were able to examine the rifle's recoil by integrating our knowledge of riflery and physics. In addition to the WDSS, we also conducted the experiments using a chronograph that measured the muzzle velocity of the bullet as it was coming straight out of the barrel. In this presentation, we were able to look at the conservation of momentum of the system and apply Newton's Second Law. Using the WDSS and the values provided by the manufacturer, we can compare the actual values of the velocity and acceleration of the rifle to the theoretical values of velocity and acceleration and compare the results.

Introduction

From the conservation of momentum, we know that the initial momentum of the system and the final momentum of the system are equal. That is, the product of the initial mass and velocity of the rifle and bullet is equal to the product of the final mass and velocity of the rifle and bullet. Since the initial velocity of the system is zero, the initial momentum of the system goes to zero and we can derive a formula for the final velocity of the rifle. Observe:

$$0 = m_g v_g - m_b v_b$$
$$m_g v_g = m_b v_b$$
$$v_g = \frac{m_b v_b}{m_g}$$

The Apparatus

The first apparatus consisted of the rifle hanging from a fixed support in which a chain connected to the support was attached to the buttstock of the rifle and another chain connected to the support was attached to the barrel. The lengths of the chains were not identical due to the fact that the rifle had to be level in order for all of the recoil to be in one direction. The WDSS was attached to the cheek piece of the rifle using tape and multiple rubber bands and the firing pin was released using a camera trigger attached to the trigger guard of the rifle.

The second apparatus was identical to the first, except instead of using chains, lengths of rope were used and the WDSS was bolted to the side of the rifle. In each apparatus, a chronograph was positioned near the muzzle of the rifle to record the velocity of the bullet.

The Experiment

In order to obtain accurate statistics, there were a total of 120 data samples collected over multiple days and the experiments were conducted indoors to avoid any outside interferences such as temperature, humidity, wind and other hindrances. In all of the experiments, there were six different types of ammunition used which include:

- SK Standard Plus
- CCI Minimag
- Winchester Super-X
- Remington Golden Bullets
- CCI Stinger
- Lapua Center-X

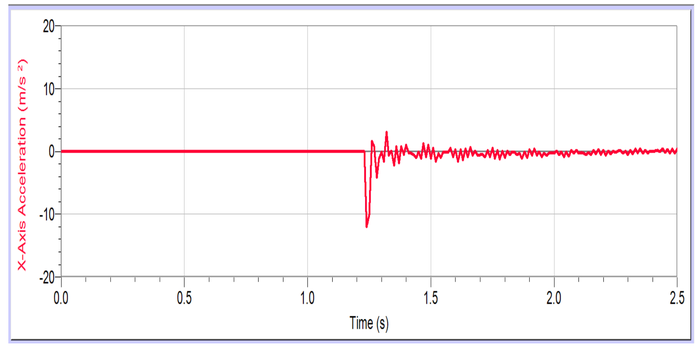
Each ammunition was tested five times for when the rifle was less massive (3.9 kg) and five times again for when the rifle was more massive (5.3 kg) for each apparatus. The WDSS measured acceleration in the negative X-direction and was recorded wirelessly using Logger Pro software. All of the data was converted to metric for all of the calculations.

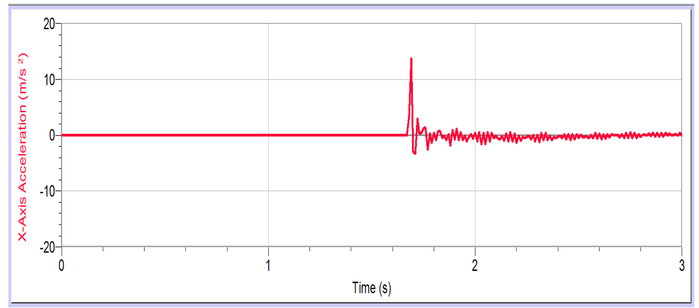
Data Collection

After conducting the experiment and collecting over 100 data points, it immediately became clear that the acceleration of the rifle was inconsistent and inaccurate. The graph below is a sample from each type of ammo in the order mentioned above.

AMMO	Bullet Mass (kg)	Bullet Velocity (m/s)	Rifle Mass (kg)	Rifle Acceleration (m/s^2)
Type 1	0.00259196	322.78	3.9	10.4
Type 2	0.00259196	397.76	3.9	39.0
Type 3	0.00207357	416.97	3.9	26.5
Type 4	0.00259196	357.84	3.9	30.9
Type 5	0.00233276	484.94	3.9	11.9
Type 6	0.00259196	324.61	3.9	26.2

The Results





Examining the first graph above, one will notice that there is an almost instantaneous spike in the acceleration of the rifle. This is the rifle's recoil. One will notice that the spike is in the negative direction. This is due to the fact that the WDSS was set to record the acceleration of the rifle in the negative direction. However, in the second graph, the acceleration is in the positive direction. The oscillations after represent the rifle swinging back and forth until coming to a stop.

Conclusion

After collecting the data points, calculating the momentum and comparing the results, the momentum of the system was not conserved. Of the six ammunitions tested, no consistency was found. There is no clear reason why the tests proved to be inconclusive, but we believe this to be the result of the WDSS being insensitive and unable to record the initial acceleration of the rifle.

References

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