Design of Automatic Shooting & Sensing Mechanism Bot using Unmanned Vehicle

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Abstract- ***The objective of this analysis is to develop new defense techniques to reduce human casualties during war attacks, which is a major goal for developed countries these days. A small prototype was developed to accomplish the desired goal. The mechanism is made up of two modules: sensing and firing. The sensing unit includes a micro-controller as well as sensors to detect the presence of humans in the targeted area and processes the firing unit, which is made of electro-mechanical components. This article describes a small prototype of an unmanned automation bot control model that supports an ultrasonic sensor and an automatic shooting mechanism.***

Keywords – Shooting & Sensing, Unmanned Vehicle, Automation bot, Arduino kit

I. INTRODUCTION

Automation is an ocean of opportunities for the development of new technologies and mechanisms. The transformation from manual handling to automatic handling has led to easy manufacturing and controlling in various fields. With new researches and technologies surfacing quickly, there is a need for building a strong foundation of automation. It makes a vital contribution to the industry in several ways such as integration, installation, maintenance, and design. Automation involves robotics, electro-optics, control systems with the help of sensors, actuators, valves, etc. The Indian army has been using various ammunitions which include sniper rifles, light machine guns, pistols, combat shotguns, etc. The paper proposes a design to assist these semi-automatic guns in sensing automatically with a short response in the form of firing the bullet. It was found that the bullet is propelled using a spring but its operation significantly relies on the use of gunpowder so we aimed to construct an effective and efficient model for sensing an object automatically and shooting the same purely by mechanical means. A basic concept in an automatic gun targeting system is to detect the presence of a living object and target its position. The targeting mechanism is automated as it uses an ultrasonic sensor to detect the living object, its range and Ultrasonic sensors emit short, high-frequency sound pulses at regular intervals. The echo signals have reflected the sensor, when the object is hit, which itself computes the distance to the target based on the time-span between emitting the signal and receiving the echo.

II. SYSTEM DESIGN

The basic assumptions that we are considering for the prototyped model as follows. The bullet model has charge-free that means for experimentation purposes no person should be harmed.
Let us consider,

e Represents the Coefficient of restitution

$$e = \frac{v_2 - u_2}{v_1 - u_1}$$

Assuming $e = 0.75$ and $u_1 = 24$ m/sec , Mass of the bullet is M_2 = Density of the material * Volume

$$= 7800 * \left[\frac{\pi}{4} * 14^2\right] * 40 = 0.702 \text{ kg}$$

Substitute the above value in the Momentum equation
Therefore, M1 = 1.540 kg.

As per IS Catalogue, Selecting suitable material as 40Ni2Cr1Mo28 having $\sigma_c = 1100\,N/mm^2$ and $\sigma_c = 400N/mm^2$.
Also, as per IS standard selecting the Number of teeth on gear as 14

Step [1]: Motor Design from design data book:

Based on Lewis Form factor equation mentioned PSG 8.50 for pressure angle of 200 Full depth Involute tooth profile system
Y = 0.315 Since, We have considered the minimum number of the tooth to avoid interference is 14
Let's assume, the ratio of b/m = 10
Then using a correlation of module based on strength criteria as

$$m = 1.26 * \sqrt[3]{\frac{[M_T]}{Y[\sigma_b]*b/m*Z}} \quad [1]$$

$[M_T]$ = 2891.156 N-mm

Referring, PSG 8.15 we can write

$$[M_T] = M_T * K * K_d \quad [2]$$

The system is assumed to be designed with a service factor of 1.3, since considering 10 hours of duty hours

Therefore, $K * K_d$ = 13

Putting all the design value in equation [2] we get,

M_T = 2223.96 N-mm

Using standard relation of design motor power as

$$M_T = 97420\frac{KW}{N}$$

As N = 100 rpm therefore KW rating for the design system found to be 2.28
Step [2]: Calculation of Gear tooth profile under strength and wear criteria:
The condition for gear to be safe under strength and wear criteria is,

$F_s \le F_d$ i.e Dynamic force must be higher value than the strength force [3]

$F_w \le F_d$ i.e Dynamic force must be higher value than the wearing force [4]

From the research study, it was found that The gear tooth was subjected to either pitting or scoring failure. Depending upon the material used for design. For example, if the gears are made up of the same material then maybe chance that gear set subjected to scoring failure whereas if the gears are designed with heterogeneous materials then lead to pitting failure if the above condition was not satisfied.

Mean velocity, $V_m = \frac{\pi DN}{60}$ = 0.266 m/sec

$$F_T = hp * \frac{75}{V_m} \quad [5]$$

F_T = 8599.6 N

For, Commercial cut gears $C_v = \frac{3+V_m}{V_m}$ = 10.88

Dynamic force based on barth velocity factor, $F_d = F_T C_v$ = 9356.36 N

Lets us consider, Spring material is made up of HCS with Resilience R= 4.82e-^{2} , Based on the selected material the ultimate strength of the material is 750 N/mm^2, G = 81370 N/mm^2, τ = 375 N/mm^2 [Material Propoerties selected from PSG Design Databook]

Wahl stress factor , $K_s = \left[\frac{4C-1}{4C-4} + \frac{0.615}{C}\right]$ = 1.1810 [6]

Since, $C = 8$

$$\tau = K_s \frac{8PC}{\pi d^2} = 1.18\left[\frac{8*58.43*8}{\pi d^2}\right] \quad [7]$$

$d = 1.99$ mm = 2 mm

$D = c*d$ = [8*2] = 16 mm

The ends of the spring are considered squared and ground

Number of active coils in spring: Spring constant for HCS, $K = 1$ N/mm

$$K = \left[\frac{Gd^4}{8D^3N}\right] \quad [8]$$

Substitute, all the values in equation [8],

$N = 12$

Deflection of spring:

$$\partial = \left[\frac{8PD^3N}{Gd^4}\right] = 59.56 \text{ mm} \quad [9]$$

Total coils = $N + 2 = 24$

Total gap $(N_t - 1) * \text{Gap between two coils}$

III. ALGORITHM STRUCTURE

The sector gear will be in an engaged position with the rack and rotated using a servo motor. The sector gear has teeth only on the fixed region of its total circumference for disengagement. A motor will rotate the sector gear which in turn pushes the rack against the spring; the restoring force and resilience of the spring will be used to launch the bullet. The number of teeth on sector gear is designed in such a way that after launching the bullet when the rack comes to its mean position the sector gear will engage again. The prototype is capable of shooting a target within 1 meter. To reduce the frictional loss between the casing and upper surface of the rack we are using roller bearings. a sensor is an electronic component, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. Shooting is the act or process of discharging projectiles from a ranged weapon such as guns, bows or crossbows, and slingshots. Shooting machines are normally hand-loaded with targets in automatic throwing machines used or are loaded with the use of some quick feed mechanism. In guns, the bullet is shot with the help of gunpowder and the hammering of a spring mechanism. By combining the above two we aimed to develop a mechanism to shoot bullet size targets without the use of gunpowder and are inspired by ball throwing machines.

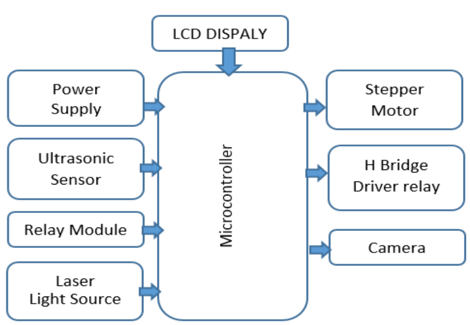

Figure 1: A schematic layout of controller element

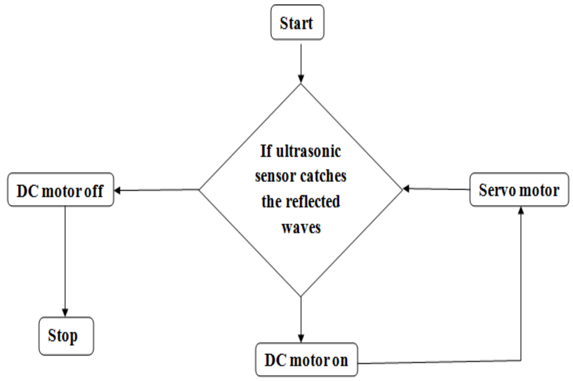

Figure 2: Simplified algorithm

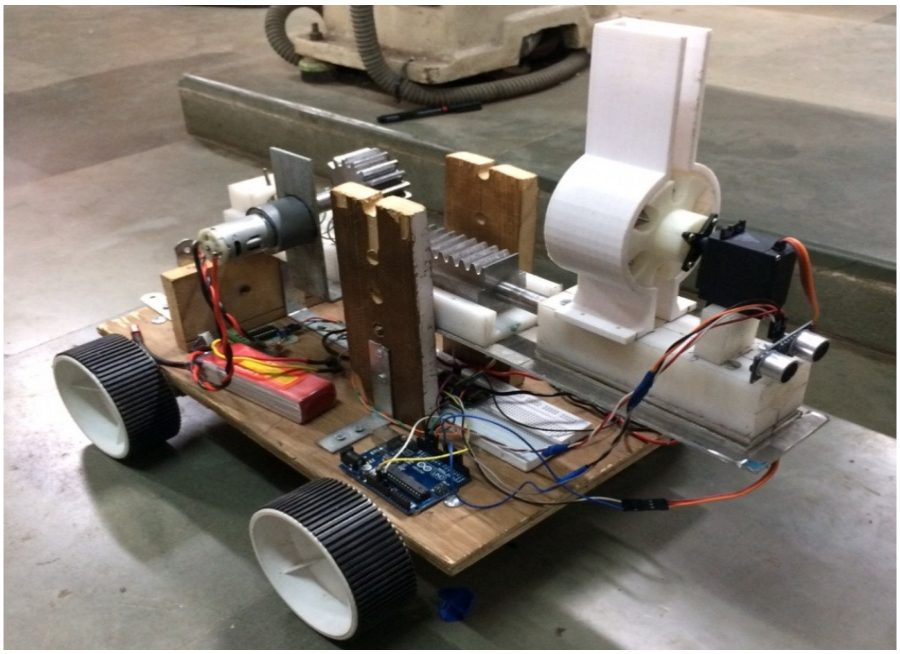

Figure 3: Unmanned Model Unit

IV. RESULT AND DISCUSSION

Testing was done by keeping the prototype in an open space. The stated range of the ultrasonic sensor is 4 meters, however, for our prototype, we modified it up to 1 meter as a sensing range set as per the control program. Within that 1 meter range, any obstacle was able to be recognized by an ultrasonic sensor which as anticipated sent the signals to Aurdino. As programmed Aurdino could actuate servomotor and feed prototype bullets in exact position optimum for firing through the slot provided in the casing, but the Motor Driver (L293d) used to drive High Torque DC motor (coupled with Sector Gear) was unable to provide constant 12 volts supply to the motor. Due to this unforeseeable occurrence of the problem the motor could not compress the spring as desired. So for testing of Firing Range motor was directly supplied with a 12 Volts Battery.

The kinetic energy of the spring was transferred to the rack with minimum losses. The impact of the rack was not completely imparted to the bullet because of its geometrical discontinuity; stress concentration is also a factor to be considered in long-term effect. The energy was getting imparted partially on the casing provided for the guideway of the bullet which was undesired.

The formula of range for the projectile motion was used to calculate the range at different angles

$$R = \left[\frac{u^2 \sin 2\theta}{g} \right] \quad [10]$$

The testing results for the spring with a wire diameter of 1.5 mm are as shown below:

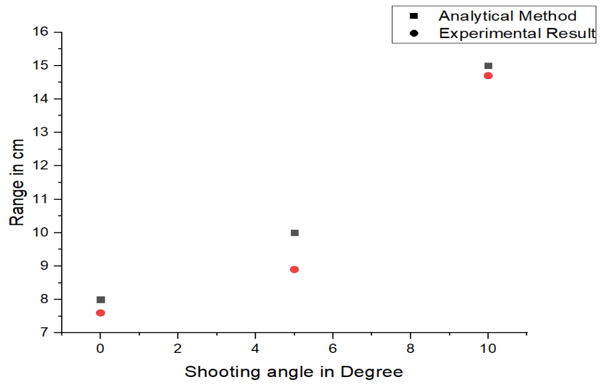

Figure 4: Rangein cm vs Shooting angle in degree

Also, the prototype bullet being heavy compared to the mechanism followed a projectile motion rule when we tested it from 2m above the ground. The gravitational force and the impact caused the bullet to move further in the projectile trajectory. The same principle of projectile motion pushed the bullet to land forward with more distance on 10 degrees. Testing with the spring of wire diameter 2mm was also done but the firing results could not be persuaded due to the hindrance in disengaging of the rack and sector and the spring being more rigid than the previous so the compression requires more power. For adjusting the disengagement more teeth will have to be removed from the sector but doing so will not refine the efficiency, since the removal of more teeth will lead to less engagement resulting in less compression of rigid spring. Also, the spring is attached to a rack and on its forward launch, the spring's wire diameter being more provides the spring with faster recovery after releasing the load, so ultimately making the springless efficient under the circumstances of the shooting mechanism even though the design of the spring should ideally provide more effective results.

V. CONCLUSION

The prototype was programmed to achieve the shooting of the target within 1 meter purely by mechanical impact. Despite the proper working of sensing and shooting mechanism individually, when assembled couldn't give anticipated results. Problems being the over designing of rack and pinion, motor unable to provide desired torque to the sector through sensed signals from Arduino, resulting in the prototype being able to shoot only up to 0.5 meters. The velocity of the bullet was high but did not achieve the maximum desired velocity. If these limitations are overcome, the prototype will be able to shoot the target within a range of 4 meters by increasing the range of the ultrasonic sensor. The mechanism and control system with certain modifications can be implemented for defense purposes. The ideal outcome and the expected outcome have differences but can be overcome to transform the prototype into an accurately working autonomous bot.

VI. SCOPE AND IMPROVEMENT

1. Rack and sector gear were over-designed resulting in increased overall weight of the system. By the proper design optimization, we can reduce the weight of the mechanism & overall system as well.

2. The position of the bullet casing was previously near the Rack but then it differed because it resulted in a major loss in the impact force, as we varied the position and brought it a little further from the rack the operation got better but still the optimum impact position was not achieved because when rack hits the casing only partial impact force acts on Bullet. So finding the right position can enhance the shooting up to a certain level.

3. Initially feeding unit was designed for a firing angle of 0 degrees (from horizontal). Testing was also carried out on 10, 20, and 30 degrees respectively. It was found that for 10 degrees the firing is working smoothly but if the firing angle is kept more than 10 degrees the bullet slides backward in the casing because of the tilt and falls out of the

casing due to gravitational force. By setting proper bullet feed timing prototype can defeat the gravitational force and will be able to shoot at firing angles more than 10 degrees. There are no changes in the feeding unit required to achieve the shooting at angles.

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