Design and Fabrication of Pre-Charged Pneumatic Automatic Rifles

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Abstract- *– Power produced by pressurized gases/air has been used in many applications since decades. The power produced by that means is pollution free too. Hence substitution of gunpowder in the firearms, though the firearms has a higher damage and it can cover a high accuracy up to kilometers similar characteristics are not required in indoor shooting ranges hence we can use this for target practice which would be cost effective and pollution free. A high pressure tank is used which is regulated and then channeled through a valve to make an automatic pneumatic rifle which uses Diablo pellets (Lead) fed through a magazine. The design is based on the availability of parts and the Launch valve has been designed on PTC Creo 6.00; manufactured and assembled separately.*

Keywords- Sequence Valve; Pneumatic components; Magazine; Barrel; Stock;Pellet;

I. INTRODUCTION

Pre-charged pneumatic (PCP) airguns represent one of the oldest airgun power plants of all time. They have been around since at least the early 1600s and most likely a bit longer. In the 1780s, the Austrians fielded over 500 riflemen, each armed with a breech loading .47 caliber 21-shot repeating air rifle and the capability to fire at least 42 shots before returning to the rear for more air. This was at a time when repeating firearms were just a glimmer on the technological horizon, and few armies used rifles in any quantity—most used smooth bore muskets.

With air rifles lead soft pellets are used which are less harmful in comparison to the traditional firearms and with that they are less prone to hurt someone in a lethal way unless intended otherwise. [4]...

With black powder, velocity is directly dependent on barrel length. The same is true for compressed air. Both power sources continue to accelerate a projectile as long as the pressure behind the projectile is higher than the pressure in front of it (ambient air pressure, plus the pressure wave in front of the accelerating projectile). Of course, in this example it must be understood that friction is also always a factor to contend with.[4]

What we get from these two facts is a simplistic rule: A longer barrel in a pneumatic gun increases velocity (to a point), and higher air pressure also increases velocity (to a point). As those points are approached, the gains from longer barrels and higher pressures have diminishing returns, so designers must balance that against making a gun too long or using pressures too high for safe and convenient operation [4]…

II. CONCEPT & METHODOLOGY

The concept of the project is to use make a pneumatic rifle based on an air gun by using CO2 gas as a pressurized gas to launch a projectile (Diablo pellets) in the air like a bullet. This is a trial and error method in which multiple designs has been made and tested out to achieve a desired effect/result. Usage of already existing devices has been made which has been altered to our desired form to achieve the desired effects.

This is done to achieve a modern pneumatic weapon which can be used for target practice which acts and works as a modern automatic rifles. Modern air guns has a magazine of about 20-30 bb's in them which are in cylindrical shape and not Diablo. Making a magazine which feeds about 10-25 diablo pellets into the pneumatic rifle so that an air gun would work in consecutive manner without the need for reload (Traditional one by one shot).

Existing devices are being used and modified for the sole reason that they exist in the market and works properly without any problems, the price of the pneumatic rifle is also low because of this reason.

A double acting cylinder is used in this system which works at a maximum pressure of 10 bars now since its double acting cylinder it would have two ports for extraction and retraction. During the retraction period the gas inside the pneumatic cylinder would go back to exhaust port 2 and during extraction it would come out from exhaust port 1. So using the exhaust energy and then combining them together in come junction by a Male Y pneumatic fitting we would be able to launch a projectile at a constant pressure. [11]

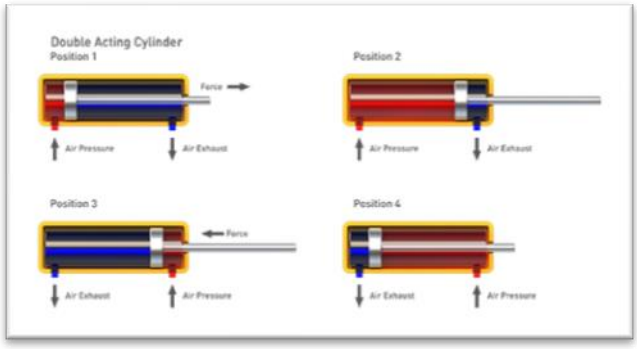

Fig.1: Double Acting Cylinder Concept

Air pressure is applied alternately to the opposite ends of the piston. Application of air pressure produces a thrust in the positive (push) stroke, and thrust in the negative (pull) stroke. [11] Double-acting cylinders are typically used in all applications where the thrusts and stroke lengths required are in excess of those available from single-acting cylinders. [11]

III. DESIGN AND IMPLEMENTATION

1. Pressure release valve

A high pressure tank which is capable of 2500 PSI pressure or a higher tank can be used for this modeling. We have used a 1.3kg clear line 140 bar pressure tank in our modeling that is having poppet type valve. To bring out the pressure from the tank a soda machine (Co2)is used which is then cut and modified to make the system compact and made the soda machine valve accordingly.

Fig.2: Soda machine

Fig.3: Modified Soda Machine Valve

2. Support Structure & Arm Rest

A structure is required to support the weight of pressurized tank which is when full (1.6 KG), and along with a support structure it also requires to look as a pneumatic gun and give an aesthetic feel as well. A stainless steel plate has been used for the support of the tank which has been brazed onto the soda machine valve firmly. Below the plate an aluminum channel has been installed which works and act like a channel (guide) for the Stock which is used to give a firm position on our shoulder blade.

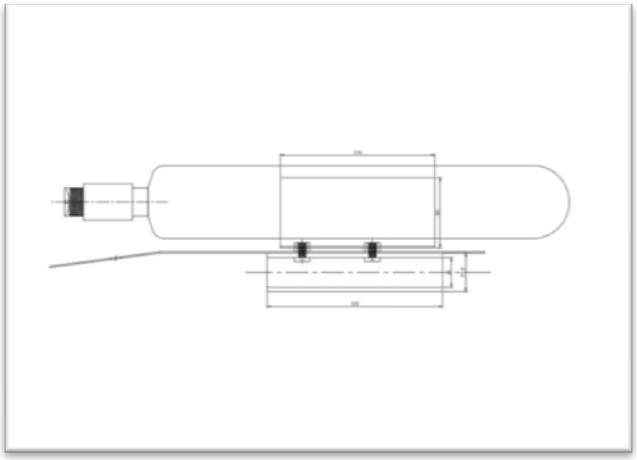

Fig.4: Support plate with the channel

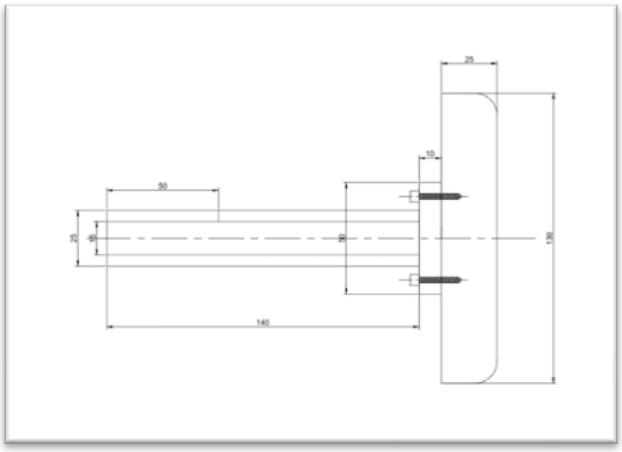

Fig.5: Arm rest

3. Pressure Regulator

The pressure coming out of the tank is unregulated at this stage, and to bring it to a controllable level (10bar pressure) a pressure regulator has to be installed but as in the market there were no such device available to drop the pressure from 140 bars to 10 bars and that also which are compact in size. So a space was created and utilized around the PCV pipe and trigger [shown in Fig. 2]. A hole was created and using a 6mm bolt and some springs a pressure regulator was made around the space which used a winged nut as a knob [as shown in Fig 3].

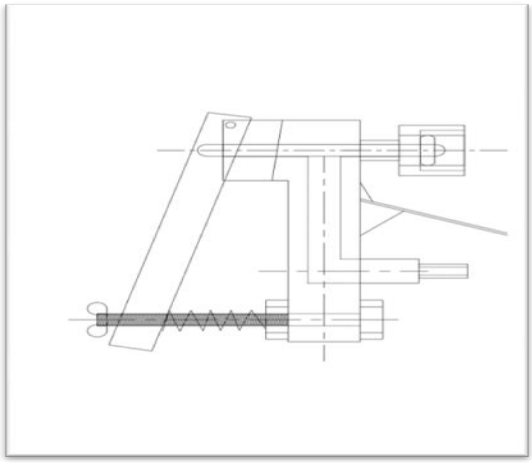

Fig.6: Pressure Regulator

A limit switch is also installed which can be seen in Fig 3. That is a bolt, now the length of the bolt can be adjusted to the degree of high pressure we require but since almost all pneumatic components' works on 10 bar pressure, the bolt was set accordingly so that the regulator cannot be pressed more than that.

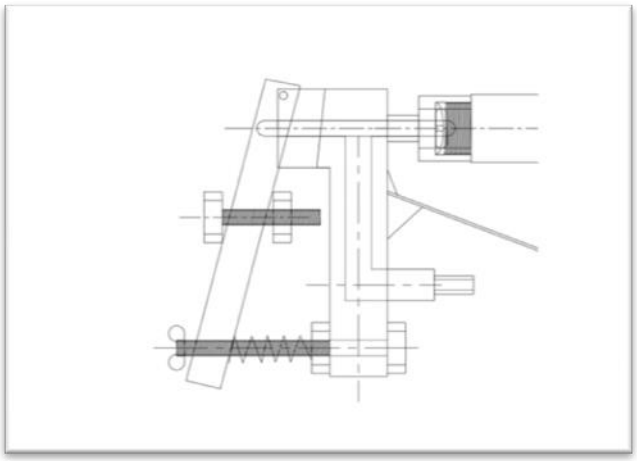

Fig.7: Pressure Regulator

4. Pressure gauge

To achieve an accurate flow of the pneumatic fluid (CO2) a required pressure was installed near the spacing of the soda machine valve, the reason behind using a CO2 tank was that with compactness it also cools the system further to sub temperature as it works more. Like a pneumatic system longer it works, cooler it runs [8] in a CO2 operated tank the temperature decreases to sub cool temperatures.

Fig.8: Pressure Regulator & Pressure Gauge

5. Sequence Valve

Sequence valves can improve the operation, efficiency, performance, and safety of fluid power circuits in which they are used. Sequence valves are normally closed and usually allow bidirectional flow when equipped with a bypass check valve. Sequence valves always have an external drain connected directly to tank. [9]

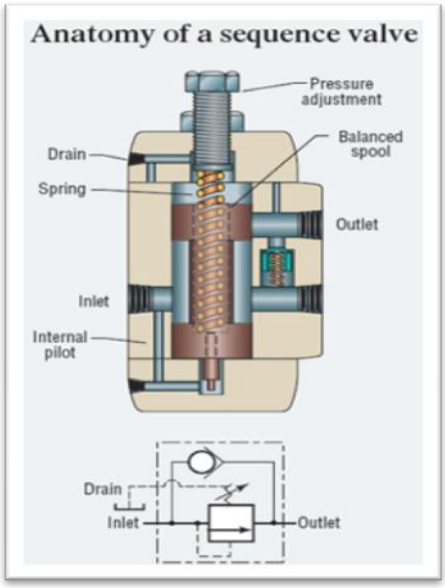

Fig.9: Anatomy of a sequence valve

When two or more cylinders operating in a parallel circuit must move in sequence, the only positive way to do this is with separate directional control valves and limits switches or limit valves. This setup ensures the first cylinder reaches a positive location before the second one begins to move. When safety or product quality will not be compromised if the first cylinder does not complete its cycle before the second one starts, a sequence valve can be a simple way of controlling cylinder actuation. [9]

A sequence valve is the best choice for a pneumatic system but due to lack of availability of it in compact size, a double acting cylinder and a 5/2 mechanical push pull valve was used in the system instead of a sequence valve. A sequence valve opens up the port 2 (in figure) when a set pressure has been achieved and when the pressure exceeds that amount a sitting valve opens and pressure is directed towards the port 2 hence in our system when the single acting spring return cylinder extension rod would move forward due to port 1 being normally open after the desired pressure is set the port 2 would open and the pressurized air would flush out of the port 2 which is connected to the barrel. But due to lack of availability of it in size two more components has been used.

A 5/2 Solenoid valve can also be used in this but it is not that feasible because of the solenoid being 24V DC, the system would require 2 car batteries to operate it as it needs to be compact and portable. Weight of 1 car battery is around 1.8KG which would only increase the system weight and make it more heavier nothing else. Hence solenoid valve is not feasible for this system.

6. Pneumatic Components

Since it's a Pneumatic rifle is it only understandable that Pneumatic components would be involved, the pneumatic components used in this system are mentioned as below [10];

- Techno 16*100 Double Acting miniature Cylinder
- Male Studs Mini Fitting
- Techno 5/2 Mechanical Push Pull Valve
- Male Stud - Parallel Thread
- Male Stud Taper Thread
- Push Male Y
- Push Elbow Union
- Push Union Tee
- Swivel Elbow – Taper Thread
- Male Push Connectors
- Miniature Dial Gauge
- Blanking Plug
- 4 mm Polyurethane Tubing
- 6 mm Polyurethane Tubing

These above pneumatic system were purchased and assembled together and infused in the pneumatic system.

Steps to assemble the pneumatic components in a sequence are given as below.

1) In the Techno 16*100 double acting miniature cylinder insert the Male studs after applying some Teflon to it for a firm grip. Use spanner to tight the fittings to prevent air leaks.
2) In the Techno 5/2 Mechanical push pull valve insert the Male Stud in them using Teflon tape and use the spanner to tight the fittings.
3) Cut the Polyurethane tubing (6mm, 4mm) according to the size and length required.

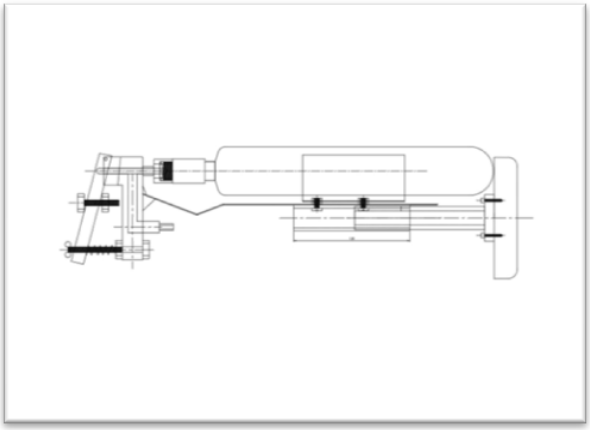

Fig.10: Pressure Regulator

Fig. 11: Pneumatic Fittings

4) Assemble the pneumatic fittings according to the image shown in Fig. 7
   - Fit the Swivel Elbow fittings in the Port A and Port B of the 5/2 mechanical valve.
   - And in the E1 port & E2 port connect the Male studs and in the Input port (I) also connect the Male stud.
   - In the Input port (I) connect the 6mm Polyurethane tube and in E1, E2 use the 4mm Polyurethane tube which in turn is connected to the Push Male Y.
   - On port A & port B use the 4mm Polyurethane tube to connect the males stud mini fittings.

5) Use the spanner to tight the pneumatic fitting in their place as any gaps or untighten fitting would lead to leakages and pressure lose.

Fig. 12: Pneumatic Assembly

7. Launch valve (Junction)

Launch valve is designed in AutoCAD (2D) and PTC Creo wildfire 6.00 (3D). It is a component in which the pellet falls in a slot and then taken ahead towards the chamber of the barrel and inserted at the entrance of the barrel. Where the Male Y fitting is also attached to the junction from whom the compressed gas comes out and flushes the pellet out of the barrel with velocity.

On Junction valve the Pneumatic cylinder, Male Y fitting, the barrel and the slot for the magazine is connected to it altogether making it a critical component. Below is the design of the launch valve.

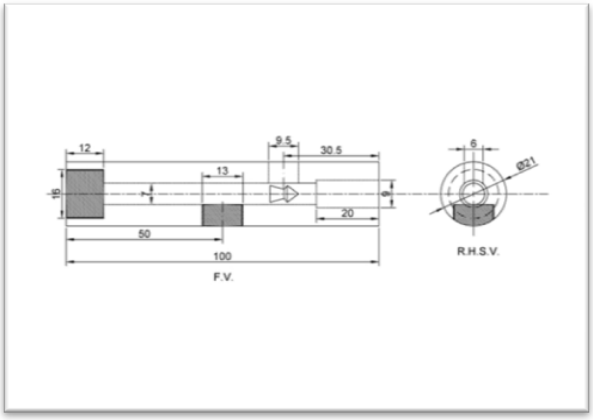

Fig. 13: Launch Valve 2D (AutoCAD)

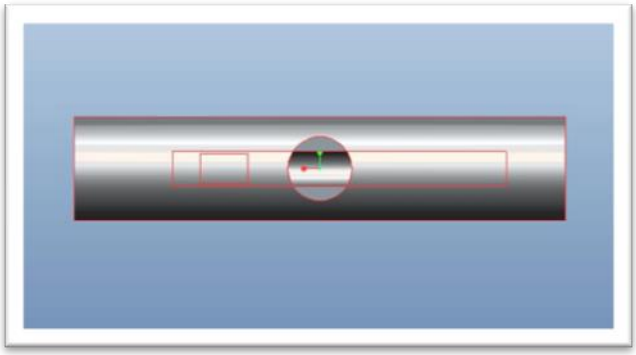

Fig. 14: Launch Valve 3D (PTC Creo)

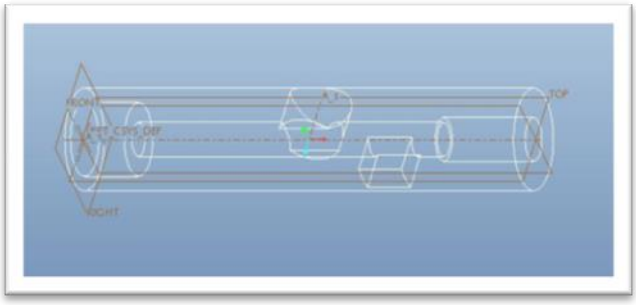

Fig. 15: Launch Valve 3D Wireframe (PTC Creo)

Fig. 16: Launch Valve Assembled

Above image represents how the Launch Valve (Junction) being all assembled and how it would take shape after assembly. The component is designed in such a way that the stroke length of 100mm from the pneumatic cylinder would end exactly on the entrance of the barrel delivering the pellet from the slot into the barrel for launch. Due to this very integration this component is named Launch Valve.

8. Pellet Magazine

The magazine is also another crucial part of the Pneumatic Rifle, to give it a continuous and consecutive pellet delivery into the slot of the Launch valve below designs were make;

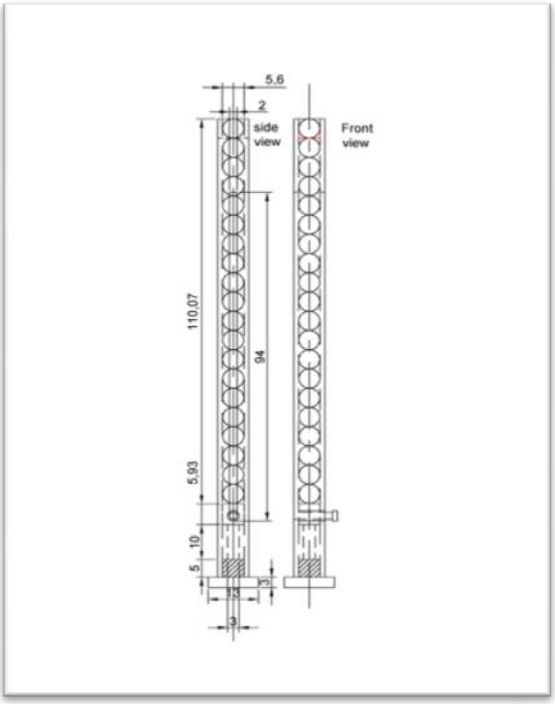

Fig. 17: Magazine Design

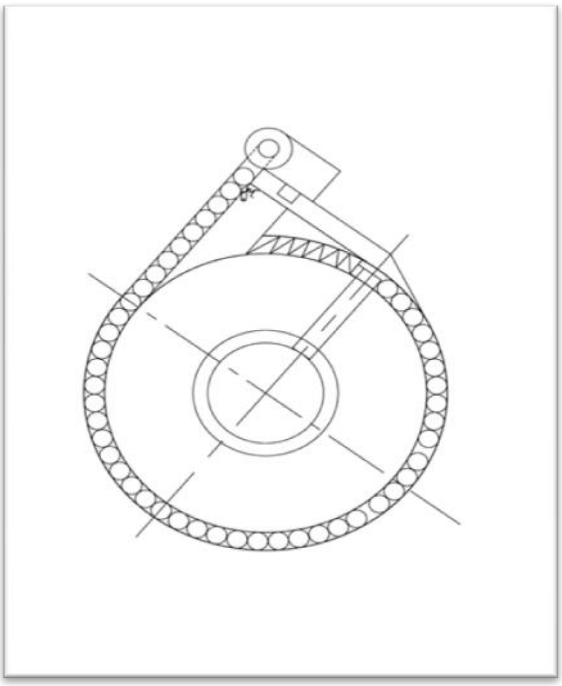

Fig. 18: Drum Magazine Design

Since the pellet size was small to manufacture, aluminum channels are used as magazine. The outer casing and the inner case makes it a perfect select for the 5.5 Diablo double head pellets.

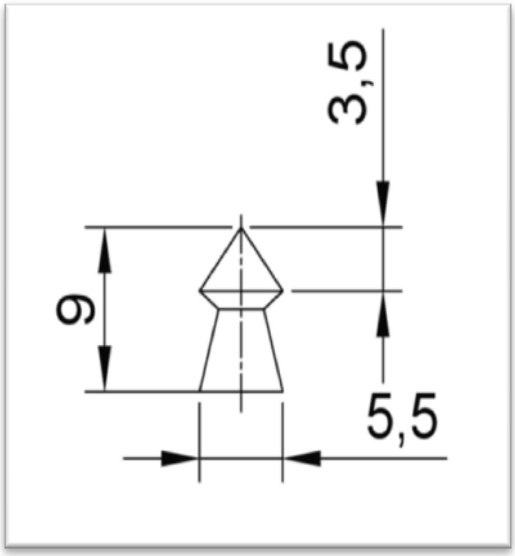

Fig. 19: Pellet

The springs used in this were manufactures and the specification for it is below;

Spring Material – Stainless Steel
Spring Thickness – 0.5 MM, 0.6 MM
Spring OD – 5.5 MM
Spring Length – 14 MM (Cut it if required)

Fig. 20: Channel Magazine

9. Trigger System and Barrel

The trigger system is attached on the 5/2 Mechanical push and pull valve, the idea is to utilize the push pull mechanism and adding a spring in the system would make it a spring return system. Short springs are used to give enough force to push back the connecting rod out again like a spring return system which in turn would act like a trigger mechanism.

A Stainless steel plate is used to make an attachment on the 5/2 mechanical valve as it has three holes in that it makes it easier to attach it on the plate horizontally by nut and bolts.

A hinge like mechanism is used to provide an extension to the aluminum rod which is the trigger handle attached to the hinge by a nut and bolt.

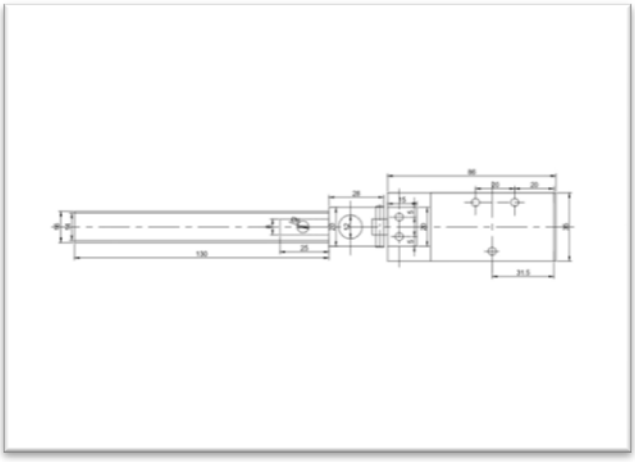

Fig. 21: Trigger Mechanism

The Barrel for the pneumatic rifle is an aluminum pipe of OD 9mm and ID 5.5mm which is highly suitable for this pneumatic as for two primary reasons.

1) The weight of the pipe is low as the material is aluminum.
2) The ID of the pipe is 5.5MM which of the same size of the pellet diameter making it a good choice of the barrel for this system.

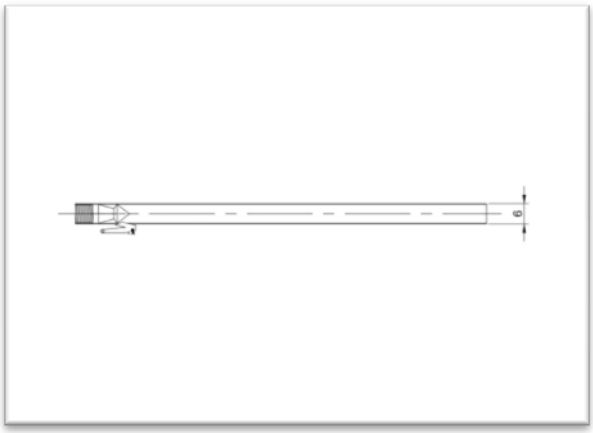

Fig. 22: Trigger Mechanism

IV. TESTING

The testing was carried out and it was determined that the system does work as intended but it also exhibits few troubles such as the slot for the magazine from which the pellet is dropped has become a source for leakage since the inner rod can't be an exact fit hence there has to be given a tolerance for it to move properly without being jammed in the system. Now because of this tolerance the air tried to escape from that slot instead of the barrel which results in pressure lose. One of the remedies to tackle this is to put a plug on the above magazine slot which will not allow the pressure to escape from that.

Fig. 23: Testing the Rifle

Once the slot is covered up, it launches the pellet at an estimated pressure of 60PSI which can be noticed from the pressure gauge attached on the Support plate which is connected to the valve itself. Below is an image shown few shots fired from the pneumatic rifle, at different PSI different effects can be seen on the pellet.

Fig. 24: Effects of Pressure on the Pellet

V. CONCLUSION

To conclude; following things were observed and mention as below;

The careful design and Manufacturing of the Launch valve is required as the pellet requires a smooth transition from the launch valve to the barrel. If there is any debris left in the holes of the launch valve it jams the system. In the magazine the spring material and thickness can be changed if the forced generated by it is more and because of which the pellets are getting deformed.

It has been noticed that the high pressure tank only has about 140 bar pressure which comprises about 300 gram of CO2. With every shot the pneumatic cylinder exhaust about 60-70 PSI pressure of discharge to the barrel so that would make the rifle capable of shooting each shots at 60 PSI on average. The velocity of the pellet couldn't be measured due to the absence of the chronograph in our location.

The tank gas holding capacity is less and runs out of gas much faster as it has a low capacity, if given a high pressure holding capacity tanks up to 3500PSI or 4500 PSI the performance of the system would increase. PCP tanks of the paintball guns can also be used in this system.

It has been noticed that the Diablo double head pellets works much better with the current magazine design, as it provides a guide way to the inner case which only works better with the double head and no single head or BB's.

The barrel is made up for aluminum and even thought working with aluminum is easier comparatively to other metals but it is also true that aluminum threads may get damage easier and faster wearing is also possible. Hence we can use the barrel without the threading too just need to firmly place it.

As the pressure tank hold a max of 140 bar to 150 bar and the required pressure for pneumatics is 10 bars max the issue faced here is the wait for the compress gas to come out (regulated by air regulator) slowly and fill the pneumatic component which slows the system and if excess air regulated per say 10 bars which is the maximum limit allowed it may damage the pneumatic component itself, hence this is one of the issue if sorted it would increase the fire rate of the pneumatic rifle.

The weight of the system is kept around 3-4 KG and it can be made even more lightweight by using materials like Aluminum and wood in many places instead of Stainless steel and bulky metals like brass. Alone the tank comprises about 1.6KG hence if aluminum pressure tanks are used which are also of high pressure capacity the system weight would decrease further.

The escape of the pressure from the magazine slot is also one of the trouble which would require a fix, currently we can plug the slot to make it an airtight chamber, but that would mean it won't have a magazine anymore. A new design to this component might provide a proper solution for the pressure lose in the component from the slot.

VI. ACKNOWLEDGEMENT

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