# The Buffer Mechanism Optimization Design of 30mm Gun

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***Abstract*—In the process of fire of rapid firing rate 30 mm guns, it was not only difficult to guarantee firing accuracy and mobility but also had high requirements on the carriage strength because of large recoil force, therefore this design provided a scheme about hydraulic spring buffer mechanism to reduce recoil force. In view of the determined buffer mechanism scheme, the dynamics model of gun was established with the effect of buffer mechanism. Parameters of buffer mechanism were obtained by calculation. Then analysis of the recoil mechanism was carried out. The results indicated that the recoil force during fire was greatly reduced by using the determined buffer mechanism scheme and the design parameters. It showed that the design of buffer mechanism could meet the requirements.**

***Keywords-dynamical model, recoil force, buffer mechanism, high rate of fire***

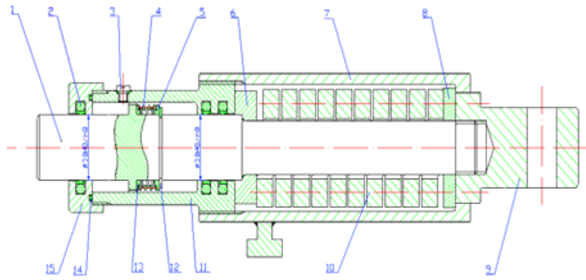
## I. INTRODUCTION

In modern wars, minor-caliber rapid firing rate guns can effectively make up the intercept dead area of missiles and other air defenses. And shells are low-cost, in large quantities, can work for long. So minor-caliber rapid firing rate guns have become an important part of a short-range air and missile defense system. As technology advances, the performance of small-caliber rapid firing rate guns advances rapidly, which allows them to fire tens of thousands to hundreds of thousands bullets per minute. The gun's frame is subjected to a heavy impact load when it fires. The more quickly the gun fires, the heavier the force acted on the gun's frame is. To solve the problem, the recoil mechanism must be properly designed.

## II. THE OVERALL DESIGN

A spring-loaded hydraulic recoil mechanism is simple, compact, efficient, reliable, and has good maintainability and adaptability of temperature and other environmental conditions.

The overall design of the recoil mechanism is shown by the Fig.1.



1-piston rod；2- Sitefeng seal；3-oil fill plug；4- a shutter torsion spring
5- oil baffle；6-stop piece；7-sleeve；8- buffer spring retainer ring；
9-connector；10-buffer spring；11- hydraulic cylinder；12- circlip；
13-valve；14-o-ring；15-end cap

Figure 1 The Overall Design of the Recoil Mechanism

When the gun fires, the piston rod is driven to backlash to the right, the piston squeezes the hydraulic oil in the cylinder on the right, so that the hydraulic oil flows into the left cylinder through a fixed hole between the piston and the cylinder wall. Since the area of the hole is small, the pressure of the hydraulic oil in the right cylinder builds up, so the piston provides a greater resisting force to the gun. During the recoil phase, the buffer spring releases energy to make the gun recoil to the left, the pressure of the hydraulic oil in the left cylinder builds up, which opens the one-way valve and the throttle, the hydraulic oil flows into the right cylinder through the fixed hole and the throttle. Because the total area of the hole and the throttle is larger, the pressure of the hydraulic oil is lower, so that the gun can recoil easier.

## III. DYNAMICAL MODEL

### A. Basic Assumptions

To design the recoil mechanism, some reasonable assumptions are made for theoretical analysis and simplify calculation:

(1)The moment that the projectile acts on the rifling is ignored.

(2)Every part (except the buffer spring) is treated as a rigid body.

(3)The motion of the recoil part is treated as a plane motion.

(4)The hydraulic oil is incompressible.

(5)The motion of the hydraulic oil in the cylinder is one-dimensional steady flow. The earth is an inertial reference frame.

(6)The internal friction of the buffer spring is ignored.

*B. The Dynamical Model*

To build the dynamical model of the gun, the recoil mechanism is simplified as a buffer spring connected with a damper in parallel, coordinate system is established with the static equilibrium position of the gun as the origin and the recoil direction as the positive direction, then forces on the gun in the process of fire can be simplified as in-plane forces.

*C. Dynamics Equations*

Taking the recoil part as the study subject, the dynamics equations are obtained.

$$\begin{cases} \dfrac{dx}{dt} = v \\ \dfrac{dv}{dt} = \dfrac{F_{p_t} - F_R}{M} \end{cases} \tag{1}$$

In equations above: x is the recoil displacement, v is the recoil speed, t is the time, M is the mass of the recoil part, $F_{P_t}$ is the bore resultant force, $F_R$ is the recoil force.

*1) Determination of $F_{P_t}$*

When the gun is designed, the force backward that the gunpowder fuel gas pressure acts on the barrel bore is he bore resultant force, which makes the gun backlashes. To simplify the analysis, the gunpowder fuel gas work process is divided into two phases: passage of the projectile within the gun barrel and after-effect period.

The computational formula of the bore resultant force is given:

$$F_{P_t} = \begin{cases} \dfrac{1}{\varphi}\left(1+\dfrac{1}{2}\dfrac{\omega}{m}\right)Ap & 0 \le t < t_g \\ \dfrac{1}{\varphi}\left(\varphi_1+\dfrac{1}{2}\dfrac{\omega}{m}\right)Ap_g & t = t_g \\ Fge^{-(t-t_g)/b} & t_g < t \le t_k \\ 0 & t > t_k \end{cases} \tag{2}$$

The bore resultant force $F_{P_t}$ is obtained by interior ballistic calculation.

The firing rate is 2000 bullets per minute, it is to say, a bullets every 30 milliseconds. The total time from firing to the end of the after-effect period is 24.157 milliseconds. When the after-effect period is over, the bore pressure is nearly zero, only the recoil force is acting until the next bullet is fired, then the bore resultant force works again. Fig. 2 shows the relationship between the bore resultant force and time.

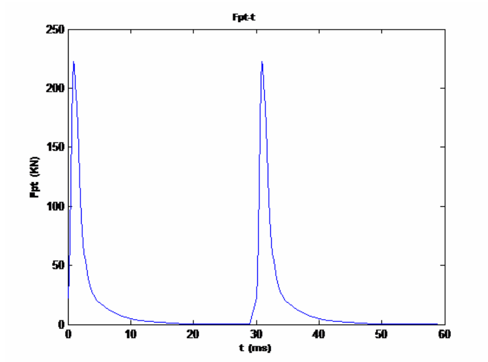



Figure 2 The Relationship between Bore Resultant Force and Time

*2) Determination of $F_R$*

The recoil force is determined by the recoil displacement x and the recoil speed v, including four parts:

$$\begin{cases} F_R = F_m + F_0 + Kx + F_{\Phi h} - Mg\sin\theta & x \ge 0, v \ge 0 \\ F_R = -F_m + F_0 + Kx - F_{\Phi h} - Mg\sin\theta & x \ge 0, v < 0 \\ F_R = -F_m - F_0 + Kx - F_{\Phi h} - Mg\sin\theta & x < 0, v < 0 \\ F_R = F_m - F_0 + Kx + F_{\Phi h} - Mg\sin\theta & x < 0, v \ge 0 \end{cases} \tag{3}$$

In equations above: $F_m$ is the frictional resistance, $F_0$ is the preload of the buffer spring, K is the spring stiffness, $F_{\Phi h}$ is the

hydraulic resistance, M is the mass of the recoil part, g is the gravitational acceleration, $\theta$ is the angel of fire, whose value is 85° .

*3) Determination of $F_m$*

The frictional resistance $F_m$ includes the resistance of sealing device F and the resistance of cradle guide $F_T$. In design, they are treated as constants. In general,

$$\begin{cases} F = vMg \\ F_T = fMg\cos\theta \end{cases} \tag{4}$$

In equations above, v is the equivalent friction coefficient of sealing device, whose value is 0.4; f is the friction coefficient of cradle guide, whose value is 0.16. Therefore the frictional resistance is obtained by:

$$F_m = 0.42Mg \tag{5}$$

*4) Determination of $F_{\Phi h}$*

Based on principles of fluid mechanics, the hydraulic resistance of the recoil mechanism is obtained.

$$\begin{cases} F_{\Phi h} = \dfrac{K\rho}{2} A_0 \left(\dfrac{A_0 - \alpha x_1}{\alpha x_1}\right)^2 v^2 & v \ge 0 \\ F_{\Phi h} = -\dfrac{K\rho}{2} A_0 \left(\dfrac{A_0 - \alpha x_1 - \alpha x_2}{\alpha x_1 + \alpha x_2}\right)^2 v^2 & v < 0 \end{cases} \tag{6}$$

In equations above, K is the hydraulic friction coefficient; $\rho$ is the density of the recoil fluid; $A_0$ is the piston area; $\alpha x_1$

is the area of the fixed hole; $\alpha x_2$ is the area of the throttle; v is the recoil speed.

### *D. Solve the Dynamical Model.*

By adjusting parameters, the design of the recoil mechanism could meet the requirements when $F_0$=10500N, K=3.55 × $10^5$N/m, A0=1.085 × $10^{-3}$m$^2$, αx1=1.45 × $10^{-5}$m$^2$, $\alpha x_2$=2×$10^{-5}$m$^2$, the maximum recoil displacement is 17.37 mm, the maximum recoil force is 40.737 N. The relationships between recoil displacement, recoil speed, hydraulic resistance, spring force and time is showed in Fig. 3,4,5,6 and 7.

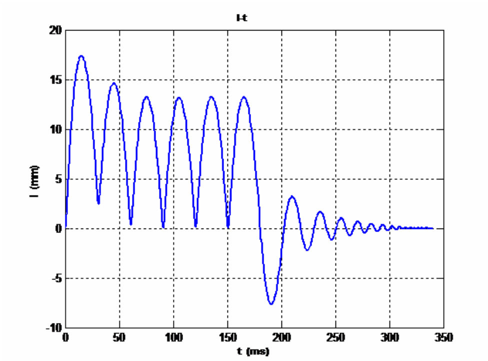



Figure 3 Recoil Displacement and Time

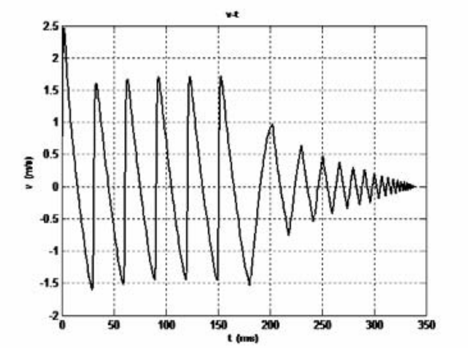



Figure 4 Recoil Speed and Time

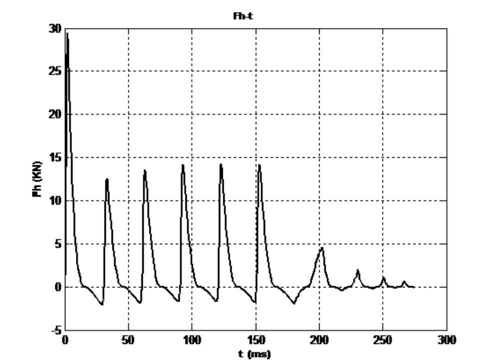



Figure 5 Hydraulic Resistance and Time

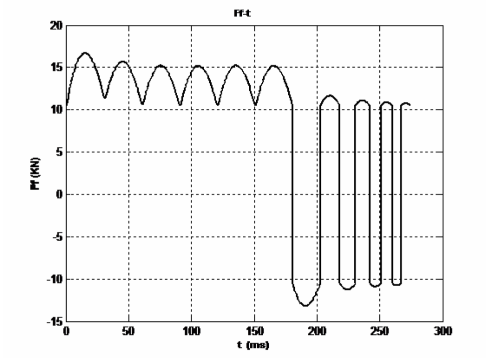



Figure 6 Spring Force and Time

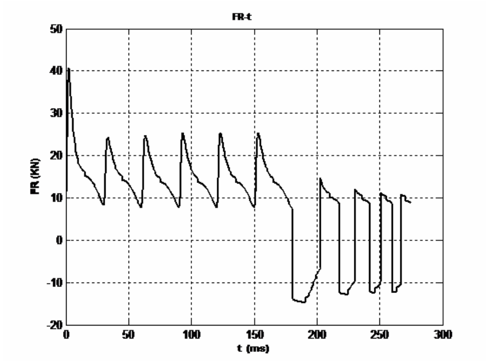



Figure 7 Recoil force and time

### *E. Conclusions*

The theoretical analysis shows that the design of the recoil mechanism is feasible in principle, reasonable in structure, reliable and efficient, could meet the requirements.

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