# APPLICATION OF PRE-IMPULSE IN THE DESIGN OF AUTOMATIC WEAPONS BASED ON THE FREE BREECH PRINCIPLE

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DOI: http://doi.org/ 10.57001/huih5804.2025.240

**ABSTRACT**

The article develops a dynamic model of a free-breech automatic weapon incorporating a pre-impulse using early ignition based on the law of conservation of energy. The results of the study demonstrate that applying a pre-impulse through early ignition before the breech reaches its uppermost position allows for a reduction in the breech's mass, lessens the impact between the breech and the receiver at both the rearmost and uppermost positions, thereby reducing the force exerted on the mount and increasing the weapon's stability during firing. At the same time, it ensures the weapon's tactical and technical performance remains within acceptable limits. This serves as a basis for the application of pre-impulse in the design calculations and improvement of automatic weapons operating on the free-breech principle.

***Keywords***: *Breechblock, pre-impulse; blowback principle; barrel.*

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Received: 02/4/2025
Revised: 10/6/2025
Accepted: 25/7/2025

## 1. INTRODUCTION

Principle of free breech of automatic weapon barrels (refer to Fig. 1): Upon firing, propelled by gas pressure, the barrel lock retracts, supplying energy for the automated systems to function. Upon the cessation of recoil (perhaps influenced by a dampening effect), the barrel lock, assisted by a spring, advances to chamber a fresh round and discharge. The benefit of this idea is in its straightforward design and production simplicity. Nonetheless, its disadvantages include the increased size and weight of the barrel lock system, as shown by firearms like the K59 handgun and the AGS-17 grenade launcher.

To improve the operational reliability of automatic weapons utilizing free breech and to mitigate issues concerning size and weight, the semi-free breech principle, exemplified by the MP5, or the pre-pulse effect, may be applied. Research papers concerning the pre-pulse effect or early ignition of the breech [1, 7, 8] are comparatively straightforward, encounter substantial constraints, and are not extensively circulated, perhaps owing to military secrecy. This study examines options that use the pre-pulse effect to minimize the dimensions and mass of the barrel lock, streamline the weapon's overall construction, while maintaining the tactical and technical specifications of automatic guns.

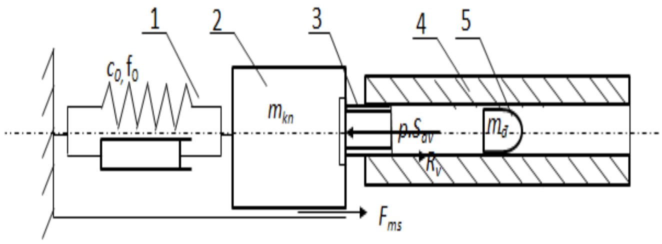


Fig. 1. Breech principle diagram

1. Spring-loaded, hydraulic shock absorber; 2. Barrel lock; 3. Shell; 4. Gun barrel; 5. Bullet head

## 2. THEORETICAL FOUNDATIONS AND SOLUTION METHODS

### 2.1. Features of the breech principle and the pre-pulse effect

The breech concept exhibits two significant motion characteristics [1, 3] as shown below:

Initially, upon firing, the barrel lock, being unconnected to the barrel, will shift when the propellant gas pressure surpasses the counteracting forces, mostly the rearward pull of the spring, frictional forces, and inertial forces.

Secondly, ignition may occur prior to the barrel lock reaching its highest position. The pressure of the propellant gas from the second shot counteracts the barrel lock, inhibiting its movement. This occurrence is referred to as the pre-pulse effect.

The research examines the "*full pre-pulse*" effect, whereby the pressure from the subsequent shot's gases inhibits the lock from ascending to the uppermost position, or allows it to reach that position with zero velocity at that instant.

Consequently, implementing the whole pre-pulse effect in the breech mitigates recoil at both the terminal and beginning positions. This facilitates a decrease in the mass of the barrel lock and removes the hydraulic recoil reduction system seen in Fig. 1, resulting in a more streamlined weapon construction and a reduction in the size and weight of the barrel lock.

**2.2. Dynamic model of the automatic firearm with a free breech system**

***2.2.1. Assumptions***

To develop a dynamic model of a free breech automatic machine, the paper uses the assumptions of the launching algorithm problem in [1, 4, 5] and of the motion problem of an automatic machine [1, 2, 3]:

- The propellant burns according to the geometric combustion law and the burning speed follows the linear law.

- The combustion temperature of the propellant is considered constant during the combustion process.

- The adiabatic index k is equal to a constant and is equal to the average value over the temperature change range of the gas.

- Secondary works are calculated through the aggravation coefficient. The coefficients $C_v$ and $C_p$ are both average values that do not change over time.

- Other mechanical assumptions [1, 2, 3]: Except for springs which are elastic parts, the links in an automatic machine are absolutely solid, with concentrated mass; the links all move in parallel planes; the connections between the links have no gaps.

***2.2.2. Differential equations of motion of automatic machine***

From the assumptions and models in Fig. 1, we can construct the system of differential equations of motion of the free breech as follows [1, 3, 7, 8]:

$$\begin{cases} \dfrac{dv}{dt} = \xi_1\xi_3\dfrac{p.S}{\varphi.m}, \\ \dfrac{dl}{dt} = \xi_1\xi_3.v\,, \\ \dfrac{dz}{dt} = \xi_2\dfrac{p}{l_k}\,, \\ \dfrac{d\omega_c}{dt} = \xi_2\chi.\omega_t\left(1+2\lambda z\right)\dfrac{p}{l_k} - \left(1-\xi_3\right)G\,, \\ \dfrac{dw}{dt} = \xi_2\dfrac{1-\alpha\delta}{\delta}\chi.\omega_t\left(1+2\lambda z\right)\dfrac{p}{l_k} + \xi_3 Sv + S\dot{x}\xi_x\,, \\ \dfrac{dp}{dt} = \dfrac{1}{w}\begin{Bmatrix} \xi_2\dfrac{p\chi.\omega_t}{l_k}f\left(1+2\lambda z\right) - kp\dot{w} \\ -K_p\left(1-\xi_3\right)G \;\; -K_t p - \sum K_p G_i \xi_i \end{Bmatrix}, \\ \dfrac{dx}{dt} = V_{kn}\,, \\ \dfrac{dV_{kn}}{dt} = \dfrac{pS_{dv} - R_v - {}_{tl} - F_{ms} - \Pi - \sum\limits_{i=1}^{n}\dfrac{k_i}{\eta_i}m_i - \sum\limits_{i=1}^{n}\dfrac{k_i}{\eta_i}F_i}{M_{tg}}. \end{cases} \tag{1}$$

where

x - the displacement of the breech; p - the pressure of the gas acting on the bottom of the bullet;

$S_{dv}$ - base area of the bullet casing;$V_{kn}$ - velocity of the breech; $R_v$ - shell pull force;

$F_{ms}$ - frictional force on the movement path of the breech; Π - spring force pushes back ($\Pi = \Pi_0 + C_x$);

$F_i$ - resistance of link i-th; $m_i$ - mass of link i-th;

$k_i$, $\eta_i$ - gear ratio and secondary efficiency of link i-th;

$\phi_{tl}$ - hydraulic brake force $\phi_{tl} = \dfrac{k\gamma}{2g}.\dfrac{A_t^3}{(a_0 + a_1)^2}V_x^2$ ;

$M_{tg}$ - the collapsed mass of the breech ($M_{tg}$ = $m_{kn}$ + $m_{vd}$+1/3.$m_{lx}$)

$R_v$ - bullet casing resistance $R_v = 2\pi r_2 f(l_{vd} - x)p_r$

**2.3. A dynamic model of an automatic firearm with a free breech system utilizing the full pre-pulse effect**

***2.3.1. Schematic diagram of free breech with full pre-impulse***

To utilize the complete pre-pulse, we refer to the schematic diagram in Fig. 2, which differs from the schematic in Fig. 1 by being engineered to discharge at a distance d from the rear cross-section of the barrel. Subsequently, the gas pressure from the subsequent shot will impede the breech's movement, thereby mitigating the impact force of the breech against the gun in both the elevated and rear positions. This results in a decrease in the bulk of the breech and the substitution of the hydraulic shock absorber with a return spring.

Using the full pre-pulse effect after eliminating hydraulic recoil reduction and reducing the mass of the barrel lock must satisfy the energy conservation requirement, in which the total kinetic energy of the moving barrel lock and the elastic potential energy due to the compression of the spring are generated by the energy exerted by the propellant gases on the barrel lock through the cartridge case bottom during the interval from firing until the barrel lock reaches the top position, at which point the velocity of the barrel lock is zero. Specifically, this can be expressed as follows:

$$\frac{1}{2}M_{knct}V^2 + \frac{1}{2}K\Delta x^2 = \int_{td}^{t\lambda} pSddt \quad (2)$$

Where: $M_{knct}$: Mass of breech after change; V: Muzzle velocity at the moment of firing; K: Spring stiffnes; $\Delta x$: Spring compression; p: Gas pressure in the barrel; S: Area of the bottom of the shell; $t_\lambda$: Full stroke lock time; $t_d$: Time to lock the barrel up to the firing position.

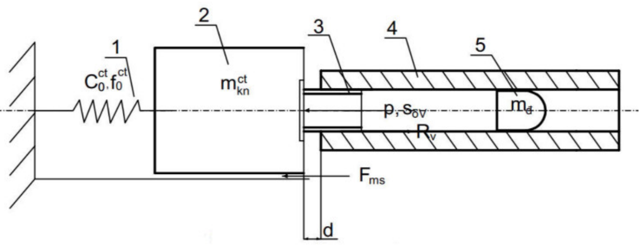


Fig. 2. Schematic diagram of a free-loading breech block using full pre-pulse: 1. Return spring; 2. Lock; 3. Shell; 4. Barrel; 5. Bullet

***2.3.2. Differential equations of motion of automatic machine***

$$\begin{cases} \dfrac{dv}{dt} = \xi_1\xi_3\dfrac{p.S}{\varphi.m}, \\ \dfrac{dl}{dt} = \xi_1\xi_3.v, \\ \dfrac{dz}{dt} = \xi_2\dfrac{p}{I_k}, \\ \dfrac{d\omega_c}{dt} = \xi_2\chi.\omega_t(1+2\lambda z)\dfrac{p}{I_k} - (1-\xi_3)G, \\ \dfrac{dw}{dt} = \xi_2\dfrac{1-\alpha\delta}{\delta}\chi.\omega_t(1+2\lambda z)\dfrac{p}{I_k} + \xi_3 Sv + S\dot{x}\xi_x, \\ \dfrac{dp}{dt} = \dfrac{1}{w}\begin{Bmatrix} \xi_2\dfrac{p\chi.\omega_t}{I_k}f(1+2\lambda z) - kp\dot{w} \\ -K_p(1-\xi_3)G - K_t p - \sum K_p G_i \xi_i \end{Bmatrix}, \\ \dfrac{dx}{dt} = V_{knct}, \\ \dfrac{dV_{knct}}{dt} = \dfrac{pS_{dv} - R_v - F_{ms} - \Pi_{ct} - \sum_{i=1}^{n}\dfrac{k_i}{\eta_i}m_i - \sum_{i=1}^{n}\dfrac{k_i}{\eta_i}F_i}{M_{tgct}} \end{cases} \quad (3)$$

Based on the above assumptions and dynamic models, we can build the system of differential equations of motion (4) of a free breech using a completely pre-pulse (Ignoring the hydraulic shock absorber, changing the return spring, reducing the mass of the lock and firing at a distance d from the same position).

**2.4. Methods for solving automatic machine learning dynamics problems**

Addressing the dynamic challenge of an automatic machine necessitates the concurrent resolution of the internal launch procedure's equation system and the motion's differential equation system integrated in system (1) for an automatic machine employing the principle of free breech locking, as well as systems (2) and (3) for an automatic machine utilizing the principle of free breech locking with complete pre-pulse. Initially, it is essential to ascertain the input parameters, which encompass the launch procedure parameters of the propellant, the structural parameters of the firearm and projectile; establish the transmission ratio, the efficiency of the transmission mechanisms in the automatic system, and concurrently determine the collision times of the components to facilitate the formulation of the equations. Subsequently, employ the fourth-order Runge-Kutta method to approximate the solution of the differential equations (1), (2), and (3) to ascertain the pressure law, the bullet's velocity within the barrel, and the motion law of the primary component, which is the breech locking mechanism in the automatic firearm, for both the free breech locking principle and the pre-pulse free breech locking. Compare and assess the outcomes.

**2.5. Practical application**

Table 1. Different input parameters

| Order | Name | Symbol | Unit | Value in the free-lock model | Value in free-breech model using full pre-impulse |
|---|---|---|---|---|---|
| 1 | Barrel weight | $m_{kn}$ | kg | 4.3 | 3.45 |
| 2 | Spring stiffness push back | Flxo | N/m | 76.4 | 104 |
| 3 | Mass of shock absorber | Mgv | Kg | 1.8 | No shock absorber |

Utilizing the aforementioned model and solution methodology, proceed to resolve the basic input parameter set for the AGS-17 automatic grenade launcher, which operates on the free locking principle [6-9]. Implement enhancements in accordance with the free locking principle utilizing pre-pulse, as illustrated in Fig. 2, while maintaining identical structural parameters and launching techniques between the two fundamental models, differing solely in specific structural parameters as detailed in Table 1.

Utilizing the outcomes of automatic machine dynamics based on the principle of free locking, we determine the firing position, which is 3mm from the top position relative to the initial AGS-17 gun, by solving the energy conservation equation (2) with the application of the full pre-pulse. At this position, the locking velocity attains 37.82dm/s, serving as the input parameter for resolving the differential equation system (3). Consequently, we derive the pressure law and velocity in relation to the bullet's distance within the barrel (Fig. 3), as well as the velocity law and displacement of the locking barrel over time.

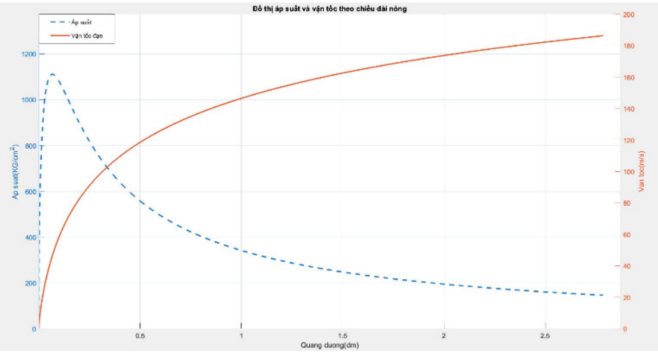

Fig. 3. The law of gunpowder gas pressure and bullet velocity according to barrel length

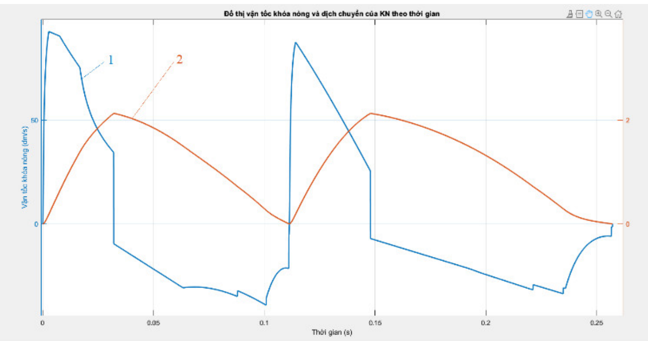

Fig. 4. Velocity and displacement of the breech block over time

1. Law of velocity; 2. Law of displacement

***Comments:***

- From the calculation results shown in Fig. 3, it can be observed that the initial velocity of the projectile at the muzzle when using the full pre-pulse is 186.3m/s, compared to 184.4m/s when not utilizing the pre-pulse, and close to the manufacturer's documented value of 185 m/s. The measured experimental value is 187.56m/s. The maximum pressure inside the barrel with the pre-pulse is 1110kg/cm$^2$; without the pre-pulse, it is 1090kg/cm$^2$; and the experimental measurement is 1129kg/cm$^2$. The calculation errors for the velocity are less than 1%, and for the pressure, less than 2%, confirming the accuracy of the model and indicating that the use of the pre-pulse nearly does not affect the maximum pressure and the velocity of the projectile as it exits the barrel.

The reasons for the discrepancies between the calculations and the design/test documents are due to the assumptions made in the firing simulation, the mechanical assumptions, and the fact that, when utilizing the pre-pulse, the ignition position is approximately 3 mm ahead of the original free barrel lock position without the pre-pulse.

- From the calculation results of the displacement and velocity change laws of the breech in Fig. 4, we see that:

+ The firing cycle with the barrel lock using the entire pre-pulse is $T_{ck}$ = 0.156 seconds, equating to a potential firing rate of 385 rounds per minute. In comparison to the original cannon without the pre-pulse, which had a theoretical firing rate of 425 rounds per minute, it is evident that the theoretical firing rate is diminished. Nevertheless, since the theoretical fire rate falls within the design requirements of 375 to 425 rounds per minute, the weapon continues to satisfy the necessary tactical and technical performance standards.

+ The maximum velocity of the breech using the pre-pulse is $V_{max}$ = 87.6dm/s and the velocity of the breech when colliding with the rear gun case is 25.54dm/s, and when there is no pre-pulse (initial gun), $V_{max}$ = 92.66dm/s and the velocity of the breech when colliding with the rear gun case is 34.44dm/s.

+ When the barrel lock is pushed upward using the full pre-pulse, the velocity of the lock at the ignition point, which is 3mm below the top position, is reduced from 37.82m/s to zero due to the effect of the pre-pulse (caused by the pressure of the propellant gases acting on the lock through the cartridge case) before reaching the top position. In contrast, when the pre-pulse is not utilized, the barrel lock impacts the front of the gun chamber with a velocity of 7.09m/s.

Thus, during firing, the breech uses a pre-impulse to impact the gun barrel at the rear with a velocity reduction of 25% and when colliding with the gun barrel at the front, it is reduced by 100% due to the effect of the pre-impulse, helping the gun to be more stable during firing.

## 3. CONCLUSION

The paper has developed a dynamic model of an automatic firearm with a free barrel lock utilizing the full pre-pulse effect. After solving, comparing, and evaluating the results against the free breech dynamic model and some experimental data, the findings demonstrate that applying the pre-pulse through early ignition before the barrel lock reaches the top position allows for a reduction in the mass of the barrel lock, minimizes the impact between the lock and the gun chamber at the final position and at the top position, thereby reducing the force exerted on the slide and enhancing the weapon's stability during firing. This also results in a decrease in firing speed while still ensuring the weapon's tactical and technical performance within permissible limits. These outcomes provide a basis for applying the pre-pulse concept in design calculations and in the improved development of automatic weapons operating on the free barrel lock principle.

**REFERENCES**

[1]. Pham Huy Chuong, *Structural basis and calculation of automatic machine design*. Military Technical Academy, Hanoi, 340p, 1998.

[2]. A.K. Golombovsky, *Theory and calculation of automatic weapons*. Penza, 492p, 1973.

[3]. Alferov V.V., *Design and calculation of automatic weapons*. Mechanical Engineering, Moscow, 248p, 1977.

[4]. Nghiem Xuan Trinh, Nguyen Quang Luong, Nguyen Trung Hieu, Ngo Van Quang, *The art of internal reporting*. Military Technical Academy Publishing House, 2005.

[5]. Serebryakov M.E., *Internal ballistics of barrel systems and missiles*. Oboronogizd, 345p, 1960.

[6]. *Dynamics of automatic weapons*, People's Army Publishing House, 2002, p. 500.

[7]. Dao Manh Hung, *Simulation of structure and operation of M79 and AGS-17 grenade launchers*. Military Technical School, 2007.

[8]. Dao Van Doan, Vo Thi Hong Thang, *Dynamics of free-locking automatic machine*. Vietnam Journal of Mechanics, 14-19, 2015.

[9]. Dao Manh Hung, *Dynamic study of 30mm AGS-17 grenade launcher and the influence of some structural elements on the stability of the gun when firing*. PhD thesis, Military Technical Academy, Hanoi, 2016.