AiMT Advances in Military Technology
Vol. 4, No. 1, June 2009

Influence of the Breech Locking Clearance on the Automatic Weapon Function

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The manuscript was received on 11 December 2008 and was accepted after revision for publication on 3 February 2009.

Abstract:

The paper deals with the influence of breech locking clearance in the automatic weapon on its function. Small clearance is necessary for the correct function of the weapon. But in case of its increase this clearance may decrease the service life of the breech mechanism and negatively influence the function of the weapon automatics. The theoretical solution and the influence of the increase of the clearance are shown.

Keywords:

Breech mechanism, breech locking clearance, gas operated drive

1. Introduction

If the breech mechanism of the automatic weapon is locked, then in standard conditions there must be some minimum clearance x_{CL} between the locking lugs of the breech block and the locking surfaces in the barrel casing to ensure continuous smooth locking and unlocking. The principal scheme of such a breech mechanism is shown in Fig. 1. The breech mechanism consists of the breech block (which ensures the rigid connection with the barrel when firing) and the breech block carrier (which controls the unlocking and locking of the breech block by means of the transmission between both components at the relative motion of the carrier with respect to the breech block). This relative motion is ensured by the drive of the automatic weapon. In this paper the gas operated drive is considered.

If the mentioned locking clearance is small, then its influence on the weapon function is relatively negligible and it is not necessary to take it into consideration at the theoretical solution. But sometimes this clearance might be increased. It can be caused either by a mistake in the production or by the wear of the locking surfaces. The theoretical solution of the influence of this increased clearance x_{CL} and its results

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can be utilised in the weapon design and in the judgement of the locking surfaces wear. The situation shown in Fig. 1 – i.e. the breech block carrier is pressed to the breech block by the return spring - is supposed in the following solution.

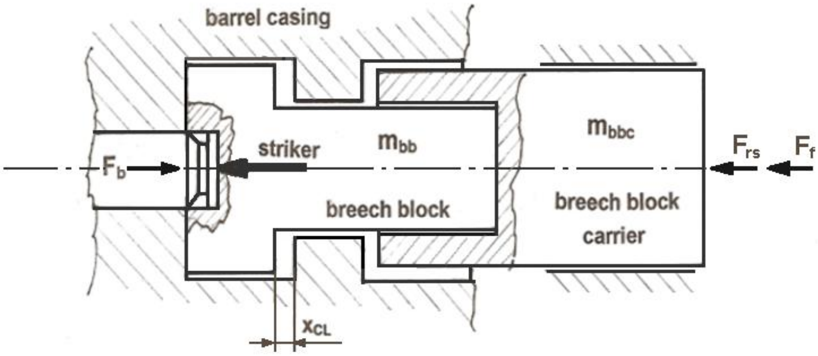

Fig. 1 Simplified principal scheme of rotating breech mechanism

2. Theoretical Solution

Let us suppose the mechanism shown in Fig. 1 completed with the gas operated drive of the breech block carrier. The shot begins by the cartridge primer (capsule) initiation by means of the striker. The motion of the mechanism begins at the instant in which the projectile starts to move. At first the breech mechanism (the breech block with the cartridge case and the breech block carrier) moves in similar way, as it is in blow-back weapons, i.e. it is accelerated by the force of propellant gases F_b acting from the barrel bore on the bottom of the cartridge case. The forces F_{rs} (the return spring) and the friction force F_f act against it. This period continues till the instant in which the locking surfaces of the breech block come into the contact with the locking surfaces in the barrel casing, i.e. the displacement of the breech mechanism equals the locking clearance x_{CL}. After this impact the breech block is stopped and the breech block carrier continues in the backward motion decelerated by the forces F_{rs} and F_f. If forces acting against the backward motion of the breech block are not able to stop this motion, then this way of motion continues till the opening of the gas vent of the gas arrangement (till the instant in which the projectile bottom in the barrel bore passes beside the gas vent Fig. 2). Beginning this situation the propellant gases start to flow through this gas vent into the gas cylinder, where they accelerate the gas piston connected with the breech block carrier. The motion of the breech mechanism is controlled by the gas operated drive of the automatic weapon.

Thus the function of the weapon can be divided into the following three periods:

A the period of the blow back drive of the complete breech mechanism,

B the motion of the beech block carrier on the return spring, and

C the period of the gas operated drive function.

The way of the theoretical solution of all three mentioned periods is shown in the following parts of this paper.

Period A:

The propellant gases pressure-time dependence $p = f(t)$ obtained from the internal ballistics or from ballistic measurement is utilised (p is the pressure of propellant gases in the barrel bore). All the action in this period is characterised by the following equations:

- the force of propellant gases acting from the barrel bore

$$F_b = 0.82 d^2 p \,, \tag{1}$$

- the force of the return spring

$$F_{rs} = F_{rs0} + c_{rs} x \,, \tag{2}$$

- the friction force

$$F_f = (m_{bb} + m_{bbc}) g f \,, \tag{3}$$

- the acceleration of the breech mechanism (from the equation of motion) is

$$a = \frac{F_b - F_{rs} - F_f}{j\left(m_{bb} + m_{bbc} + \dfrac{m_{rs}}{3}\right)} \,. \tag{4}$$

Period B:

This period - in which no force of gases F_b is acting - is characterized by the following equations:

- the formula for the force of the return spring (2) is the same as in the previous period A;
- the friction force

$$F_f = m_{bbc} g f \,, \tag{5}$$

- the acceleration of the breech block carrier

$$a = \frac{-F_{rs} - F_f}{m_{bbc} + \dfrac{m_{rs}}{3}} \,. \tag{6}$$

Symbols in the equations (1) to (5) are:

d - calibre of the barrel,
F_{rs0} - initial force of the return spring,
c_{rs} - rigidity of the return spring,
x - displacement of the breech mechanism – period A – or the breech block carrier,
m_{bb} - mass of the breech block (see Fig. 1),
m_{bbc} - mass of the breech block carrier,
m_{rs} - mass of the return spring,
g - gravity acceleration (9.80665 m/s^2),
f - friction coefficient,
φ - coefficient replacing the extraction friction of the cartridge case.

Period C:

The theoretical solution of the gas-operated drive of the automatic weapon mechanism needs to determine mainly the pressure of gases in the gas cylinder. The scheme of the gas system is shown in Fig. 2. The whole process can be examined as gas flowing through the channel (the gas vent) connecting two vessels of varying volume. In the first vessel, the barrel, the pressure p_b rises steeply to the value about 300-400 MPa, which then falls due to the movement of the projectile. In the second vessel, the gas cylinder, the piston moves due to the gas pressure p_{cy} acting on it. Additionally, there is a loss of pressure caused by gas leaking between the piston and the cylinder wall. The piston is connected with the breech block carrier and thus it controls its motion.

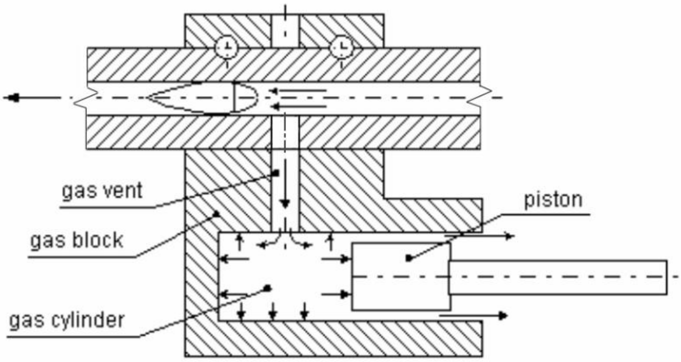

Fig. 2 Scheme of the gas operated drive arrangement

Following equations are used for the solution of this action:
- equation of motion of the piston and components connected with it,
- equation of the instantaneous volume of the cylinder,
- equation of the instantaneous force of the return spring,
- equations of state for the gas in the barrel and in the cylinder,
- equation of the piston velocity,
- equation of the gas energy change in the gas cylinder,
- equation of the gas mass change in the gas cylinder,
- formulae for the sub-critical and critical flow of gases.

All the action is solved for two periods of gases flow through the gas vent, i.e. for case $p_b > p_{cy}$ and for case $p_b < p_{cy}$.

The basic features of this theory are mentioned in [1] and [2], the procedure of complete solution is explained in [3] and [4]. The procedure of the solution of the periods A and B is shown in the flow diagram in Fig. 3.

3. Calculation of the Influence of the Clearance x_{CL}

The influence of the clearance x_{CL} on the mechanism function has been calculated for the following entrance data of the mechanism chosen on the base of the universal machine gun Mod. 59:

d = 7.62 mm,	g = 9.80665 m/s^2
F_{rs} = 12.36 N	f = 0.1
c_{rs} = 508.9 N/m	φ = 1.35.
m_{bb} = 0.083 kg	
m_{bbc} = 0.352 kg	
m_{rs} = 0.0114 kg	

The pressure of propellant gases $p = f(t)$ in the period A is characterised by values in Table 1.

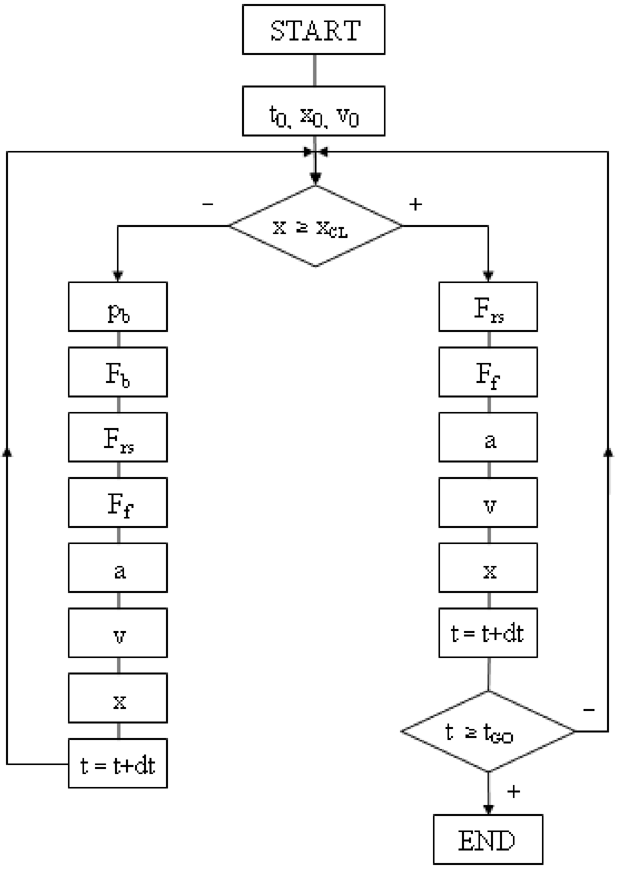

Fig.3 Flow diagram of the solution of periods A – left column - and B - right column

Tab. 1 Dependence of the barrel pressure p on the time t for the 7.62mm cartridge Mod. 59

t [ms]	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
p [MPa]	37.5	92.5	212.5	325.5	357.5	306.3	235.0	172.5	130.0

Note: At the time 0.1 ms the projectile starts to move and at the time 0.9 ms the projectile opens the gas vent

3.1 Calculation of the Period A

The task of the calculation of the breech mechanism movement in this period is to determine the characteristics of this movement at the end of the breech mechanism at its displacement $x = x_{CL}$. First of all it is the impact velocity v_{CL} of the breech block locking lugs on the locking surfaces in the barrel casing. This velocity influences the service life (the wear) of the locking surfaces of the breech block and the barrel casing.

The second important characteristic is the time of the period A t_{CL}, which is the initial condition – together with the velocity v_{CL} – for the solution of the period B. Results of this calculation - the dependencies of the velocity v_{CL} and the time t_{CL}, on the magnitude of the breech clearance x_{CL} – are shown in Fig. 4.

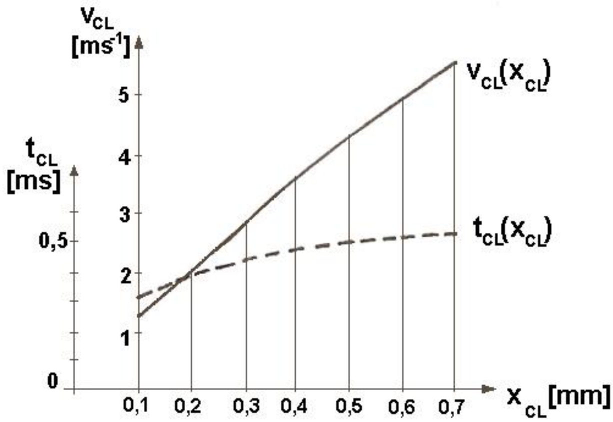

Fig. 4 Dependencies $v_{CL} = f(x_{CL})$ and $t_{CL} = f(x_{CL})$

3.2 Calculation of the Period B

After the stopping of the breech block, the breech block carrier continues in the backward motion. According to the results of the period A calculation the initial conditions for the calculation of the period B are:

$x_{B0} = x_{CL}$ and the initial time and velocity are t_{CL} , v_{CL} from the Fig. 4 (according to the magnitude of the breech clearance).

The end of this period is at the instant of the gas vent opening. In the calculated case, this instant is given by the time t = 0.9 ms measured from the initiation of the cartridge capsule by means of the striker. The results of both periods A and B are represented by the curves in the Fig. 5 for three different magnitudes of the breech clearance x_{CL} . The nearly horizontal lines in Fig. 5a show the fact, that the velocity of the breech block carrier is changed only slightly in this period. It is the result of low values of forces acting against the breech block carrier motion. During the period A this velocity increases progressively.

3.3 Calculation of the period C

As it was mentioned, the calculation of the period C begins at the instant of the opening of the gas vent. This gas vent connects two vessels of the changeable volume:

- the barrel bore (its volume is changed by the projectile motion) and
- the gas cylinder (its volume is changed by the motion of a piston connected with the breech block carrier).

In addition to the flow of propellant gases through the gas vent, a part of gases flows from the gas cylinder into the atmosphere through the clearance between the piston and the cylinder wall.

This principle of the drive of the weapon mechanism is often used in automatic weapons. The theoretical solution of this function is slightly complicated. The substance of the theory and the way of the calculation of the gas operated drive of the weapon mechanism has been mentioned Chapter 2. The results of calculations made are represented by the Fig. 6.

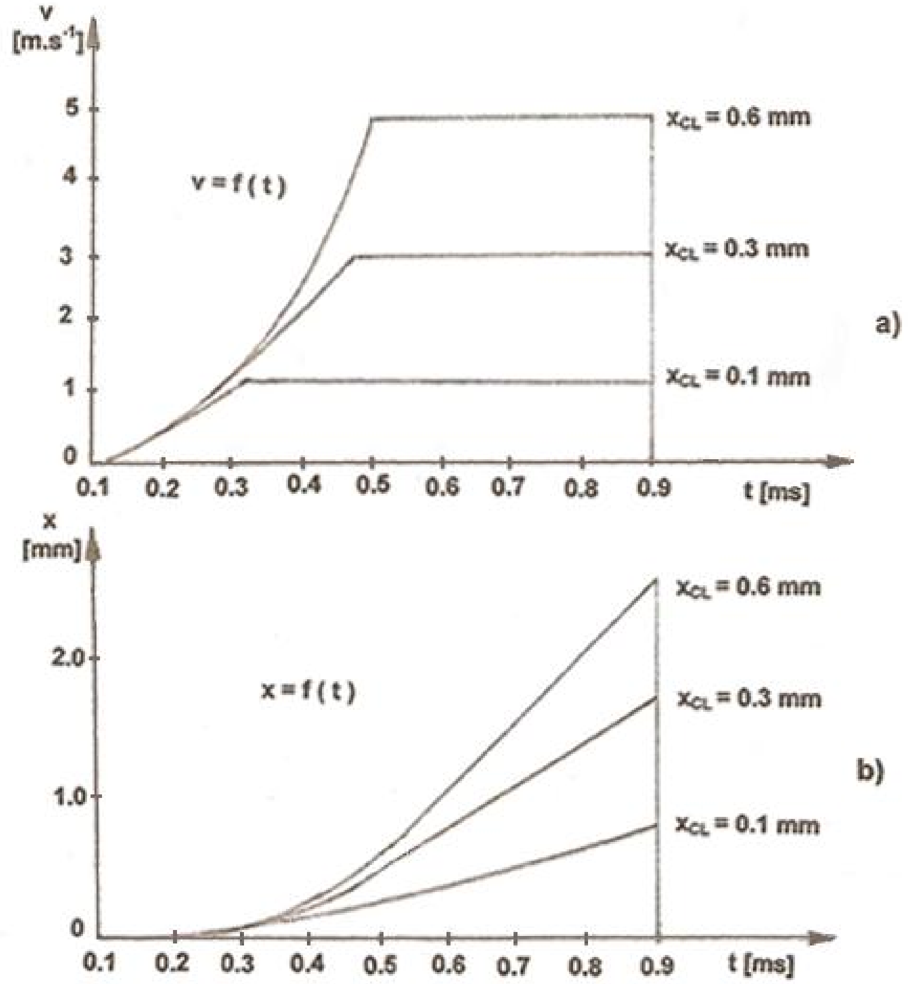

Fig. 5 Results of the calculation of periods A and B shown in diagrams a) $v=f(t)$ and b) $x = f(t)$

The function represented by this figure begins at the instant of the gas vent opening $t = 0.9$ ms and it is limited by the end of the under-slide which is the relative displacement of the breech block carrier with respect to the standing breech block till the beginning of the unlocking $x = 9$ mm. The lower curves show the change of the displacement $x = f(t)$ and the velocity $v = f(t)$ for the case without the clearance ($x_{CL} = 0$). The other two couples of curves belong to the increased breech clearance x_{CL} – either 0.3 mm or 0.6 mm. They show a significant influence of the increased breech clearance on the final displacement and velocity of the breech block carrier and thus on the time of the breech block carrier under-slide passing.

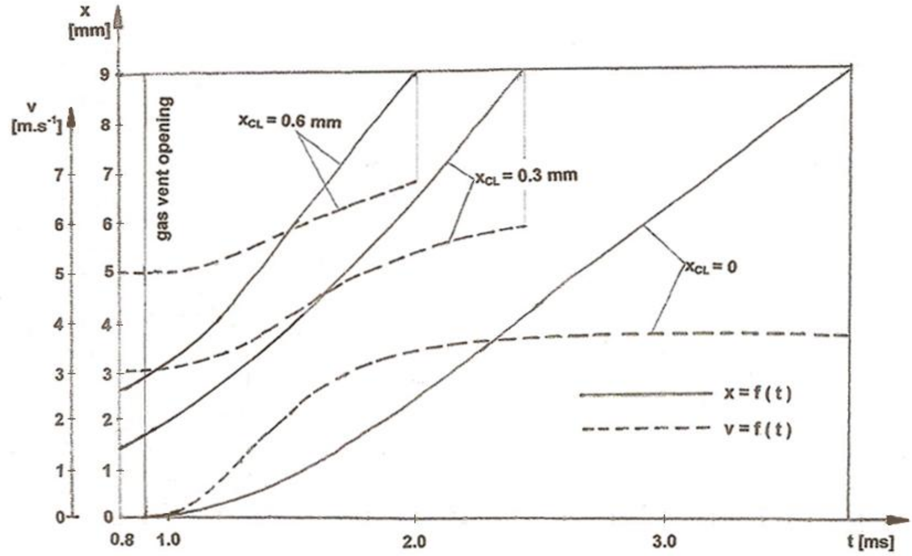

Fig. 6 Curves representing results of the solution of the period C (gas-operated drive of the weapon)

4. Conclusions

From the previous discussions it is possible to make the following conclusions:

a) The aim of this paper was to show the possibility of the theoretical solution of the problem discussed. The calculations made have proved this possibility with positive results.

b) The solution of the period A resulted in the determination of the impact velocity v_{CL} at the end of the breech clearance x_{CL} . Fig. 4 shows the intensive increase of this impact velocity in dependence on the breech clearance magnitude. The intensity of this impact is dangerous for the service life of the locking surfaces on the breech block and in the barrel casing. The wear of these surfaces depends on the impact kinetic energy of the breech block. For the case used in this paper – i.e. for the mass of the breech block m_{bb} = 0.083 kg the energy calculated for several values of x_{CL} is demonstrated in Tab. 2. Although the impact energy mentioned in the Tab. 2 has been calculated for the relatively light breech block (0.083 kg), the increase of the energy with the increase of the clearance x_{CL} is very great. It is necessary to mention that for automatic weapon of greater calibre (with heavier breech block) this energy can be increased which will cause greater danger for locking surfaces.

Tab. 2 Influence of x_{CL} on the magnitude of the breech block impact energy

x_{CL}	[mm]	0.1	0.3	0.6
E_{CL}	[J]	0.0598	0.3253	0.9964

c) The solution of the period B (in the dependence on the results of the previous period) shows the following part of the calculation of the weapon functional diagram i.e. the breech block carrier deceleration by the return spring and by the friction [4]. The obtained dependences $x = f(t)$ and $v = f(t)$ are limited by the instant of the gas vent opening.

d) The end of the last period C of the solution of the functional diagram is limited by the end of the under-slide x_{un} of the breech block carrier. – i.e. the beginning of the breech block unlocking. The results show the possibility of the utilization of the published theory for $x_{CL} > 0$. The initial conditions for the solution of the gas operated drive of the automatic weapon are the time, the velocity and the displacement of the carrier at the end of the period B. The results of the period C are utilised for the following period – the unlocking of the breech block. The graphs in Fig. 6 show great influence of the increase of the velocity and the shortening of the time for the beginning of the unlocking – at reaching the end of the under-slide, in this case $x_{un} = 9$ mm.

All these conclusions show that the discussed method of the solution can be accepted as an improvement of the automatic weapon theoretical solution.

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