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Calculations of a Blowback System

Abstract

The paper deals with the description of the breech movement of free mass-locked weapons. The effects of the individual model elements and the limitations of the simplified computational procedures are presented using the simplest and the more complex concentrated parameter model. The computational results are compared with measurements on real weapons to determine the validity of the model. The applicability of the results of the model calculations to design problems will be evaluated.

Keywords: blowback operation weapons, automatic weapon

Introduction

An automatic or automatic weapon is a device which, by a single actuation of the firing button, can be fired continuously without interruption, i.e. in a series of shots. During a burst firing, all operational processes are automatic, except for the firing of the first round. The actuating energy is either derived directly from the energy of the propellant gases (gas-engine guns) or from the recoil impulse of the shot. One of the simplest realisations of the latter technical solution is the free mass-locking automatic.

Mass-locked weapons belong to the family of unlocked weapons. Although it may be misleading, there is a reason to call them mass-locked weapons. In a mass-locked (in older terminology, weight-locked) automatic weapon, the inertia of the bolt performs the quasi-locking action. If the mass of the bolt is sufficiently large that the gas pressure that triggers the firing, like the excitation acting on the case bottom, moves the case moving with the bolt only a short distance that the properly sized case can still bear and still provide a plug for the powder gases, then the weapon is locked with the bolt mass. So, a free mass lock is a simple mass, uninhibited in its rearward movement, which, because of its inertia, provides reduced rearward movement of the case.[2] This extremely simple technical solution is nowadays only used/applied

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[2] More precisely, only the force of the positioning spring and the friction forces prevented the lock from moving.

to machine guns, and in the past to submachine guns and machine guns with a lower specific power.[3]

Benefits of the system:

- the simplest and therefore most reliable weapon design
- requiring few components, therefore a low-cost technical solution
- the barrel is rigidly mounted, there is no gas engine, therefore the barrel deflections are negligibly small, and the theoretical dispersion of such weapons is thus also exceptionally low compared to other serial firing weapons

Disadvantages of the system:

- the high mass of the bolt
- considerable mass forces for larger calibres
- large practical variation due to the large variation in the centre of gravity of the weapon during firing
- requires a special, short and cylindrical cartridge case; firing a high-capacity (bottle-shaped) cartridge is generally not possible

The HK G3 self-loading rifle, developed from the MP45, is a uniquely designed weapon that fires a 7.62 × 51 NATO calibre, bottle-shaped cartridge. However, this rifle uses a chamber with longitudinal grooves, known as Rewelli channels, to loosen the case, so that the powder gases entering between the case cavity and the chamber partially relieve the case wall, thus reducing the tensile stress on the case cavity. In this weapon, a semi-rigid roller bolt also provides additional delay and thus reduces the load on the case. Figure 1 clearly shows the grooves on the fired cartridge case.

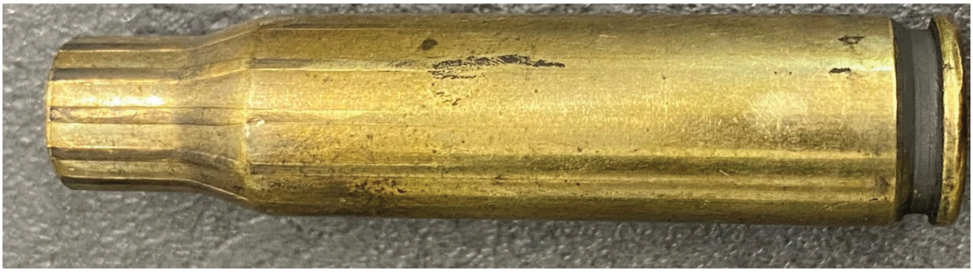

Figure 1: The fired case of the HK G3 automatic rifle
Source: photographed by the author

To examine the change in the state of motion of the bolt during the firing process, consider a schematic sketch of such a design around the chamber (see Figure 2).

[3] There are exceptions of course, see HK G3 automatic rifle.

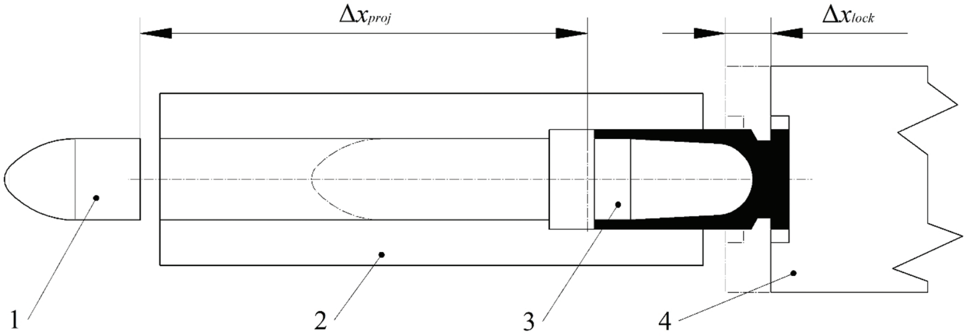

Figure 2: Characteristics of a free mass lock and the limits of exclusion (1) projectile, (2) stationary gun barrel, (3) cartridge case, (4) mass lock
Source: compiled by the author

It is also very important to note that from now on our discussions will be limited to weapons firing from the closed bolt position, i.e. the single degree of freedom models described in the following are not suitable for the discussion of automatic weapons with a firing system and fixed firing pin, which can only be dealt with effectively by means of considerably more complex multi-degree of freedom models.

The four most important components of the simplest five-element model of a free mass lock can be seen in Figure 2. These components are the breech (4), the case (3), the projectile (1) and the stationary case assembly (2), represented in the figure by the rigidly clamped gun barrel. The system element not shown is the positioning spring, which is negligible in the initial, excited phase of the recoil, as will be seen later. Interestingly, for the one more complex model, the number of system components is reduced because, given the gas pressure function, we do not need to know the projectile motion to calculate the motion of the bolt, with a small approximation.

Of course, it is also possible to describe very complicated, multi-degree-of-freedom models of the pendulum system, where the simultaneous volume-increasing effect of the ballistic gas pressure curve and the projectile motion should not be neglected, but we will not go into this in depth here.

The technical problem

The system has five components, of which up to four can be neglected, depending on the complexity of the model, but one can never be neglected, and that is the lock.

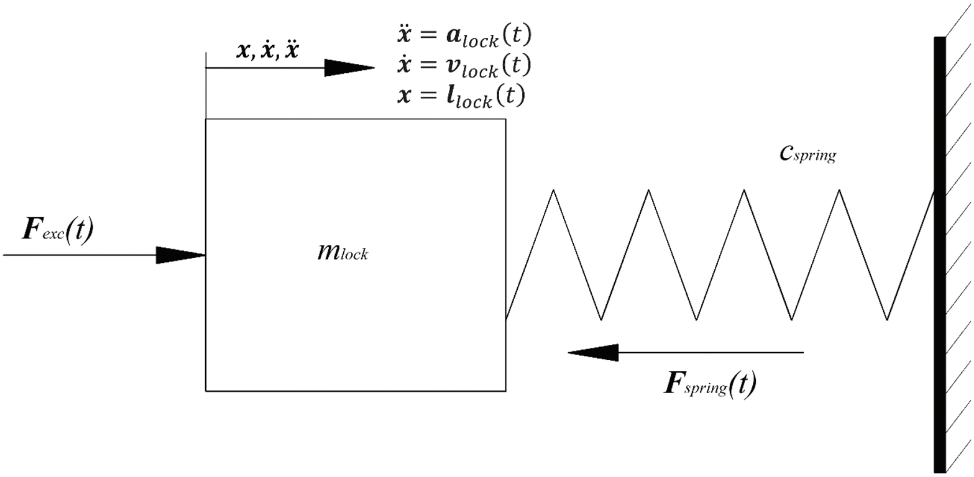

Figure 3: Dynamical model of a free mass lock as a single degree of freedom, undamped oscillating system
Source: compiled by the author

Figure 3 shows one simple model, where the free mass lock is assumed to be a single degree of freedom, undamped rocking system. If we mentally remove the spring and wall on the right side of the mass from the figure, we obtain the simplest possible model with only one system element, the lock. The equation of motion of this system is the basic equation of dynamics, which with these simplifications is a scalar equation:

$$F_{exc}(t) = \frac{d}{dt} I(t) = m_{lock} \frac{d}{dt} v_{lock}(t) = m_{lock} \frac{d^2}{dt^2} x_{lock}(t) \qquad (1)$$

where $I(t)$ is a function of the amount of lock movement.

Depending on the nature of the excitation function, this equation can be solved either analytically or numerically. The excitation function is given by the gas pressure

$$F_{exc}(t) = p(t) A_{barr} \qquad (2)$$

where A_{barr} is the cross-sectional area of the gun barrel and $p(t)$ is the time dependence of the gas pressure.

The instantaneous velocity of the lock can be determined using the force theorem:

$$A_{barr} \int_0^t p(\tau) d\tau = m_{lock} v_{lock}(t) \qquad (3)$$

at the moment when the gas pressure in the gun barrel equals the atmospheric pressure (t_5):

$$A_{barr}\int_0^{t_5} p(\tau)d\tau = m_{lock}v_{lock}(t_5) \tag{4}$$

Since the system, consisting of the projectile, the propellant gas and the bolt, is closed, its overall momentum is unchanged throughout the firing process. If the mass of the powder charge is neglected, and the equalisation of the muzzle pressure after the projectile is ejected (time t_4) is considered instantaneous, the absolute value of the projectile's momentum will be equal to the absolute value of the breech's momentum:

$$A_{barr}\int_0^{t_4} p(\tau)d\tau = m_{proj}v_{proj}(t_4) = m_{lock}v_{lock}(t_4) \tag{5}$$

We also know (because we have measured or calculated) that the projectile left the barrel at velocity v_0, and that our muzzle velocity[4] reaches its maximum at this point, so equation (5) takes the simple form:

$$m_{proj}v_0 = m_{lock}v_{lock\_max} \tag{6}$$

The maximum shutter speed can be a design parameter or a quantity to be calculated for an existing weapon, so equation (5) has to be ordered in two ways:

$$m_{lock} = m_{proj}\frac{v_0}{v_{lock\_max}} \tag{7}$$

$$v_{lock\_max} = \frac{m_{proj}}{m_{lock}}v_0 \tag{8}$$

From this simplest model (7) it is possible to determine the required lock weight, or to calculate the maximum lock speed for a given design (8). For a given calibre, the lock weight calculated in this way is approximately the same as the weight of locks in existing guns, but the lock speed obtained differs from the measured values, so after this brief analysis we will turn our investigations to an explanation of this empirical fact.

4 In our current study, we neglect the gas path effects.

Objective and tasks

When designing a blowback weapon, we need to be able to determine from the calibre data the locking weight at which neither a case rupture nor a case break will occur. Knowing the lock weight, the breech speed, the recoil length and the expected rate of fire, we also need to calculate the recoil spring.

In order to provide an efficient method for determining the required closing mass and the equations of motion with as little simplification as possible, we need to build a model with sufficient depth but not too much complexity.

Our goal is to construct a dynamical model that is tractable at the engineering level for the most common blowback weapons firing from a closed bolt position. The calculations of the model should not require knowledge of internal ballistic processes and systems of equations, but should be able to calculate the response functions of the model using only digital data from internal ballistic gas pressure measurements.

Furthermore, our aim is to verify and validate the established model by means of a rapid-filming procedure for two different friction coefficients of the case-fill-space pairing, in the metal-clean and thinly silicon grease-coated states of the case-fill-space pairing.

The tasks to be carried out can be sequenced, as they are chronologically sequential:

1. identify the model elements to be used and assemble them in the correct order
2. write down the dynamic equation system of the model and solve it
3. take measurements and then determine the values of the free model parameters fitted to the measurement results

Literature used

Solutions to free mass-locked systems are (also) discussed by Peter Dannecker, whose schematic diagrams were a great help in preparing our own diagrams.

A more detailed discussion of the subject can be found in the work of V. M. Kirillov, where sample computational procedures supported by sample problems are available, but from the pre-digital computing era, based on models optimised for analogue computers.

For the solution of the vibration problems, we consulted the book of Gábor Csernák and Gábor Stépán, written with the mathematical formalism of the present day.[5] The model and its calculations describing the man-weapon system as a multi-freedom degree of freedom system can be found in Dziopa et al.,[6] where the authors do not discuss the internal oscillation system built from the components of the weapon in detail, but we aimed at describing it.

5 Csernák–Stépán 2019.
6 Dziopa et al. 2023.

The solutions of the systems of equations and the diagrams of the problem were obtained with the Maple symbolic mathematical editor, for the programming of which we used the work of André Heck.[7]

Model making

When building our model, we need to decide the very important question of how we want to generate our internal ballistic excitation function – the gas pressure function $p(t)$ – and we have two options. Either we generate it ourselves by solving the internal ballistics equations or we obtain it from measured data. At the design level, the former is not usually expected, but measurement data or simulation results from commercial ballistics software are always available to those who are more concerned with this. We will use the latter, in line with our objective.

When using an external data source, the gas pressure curve is given, so any system element that only affects it can be neglected or ignored. These are the gun barrel, the powder charge and the projectile. Our model is from now on purely mechanical, more precisely a concentrated parameter damped single degree of freedom swing system. This system needs to be further subdivided, because the backward and forward movement of the bolt are treated separately to account for the different conditions of forward and backward movement, but in this paper, we will only deal in detail with the backward movement of the bolt under the effect of firing. The vibration model of the backward motion oscillation system is shown in Figure 4.

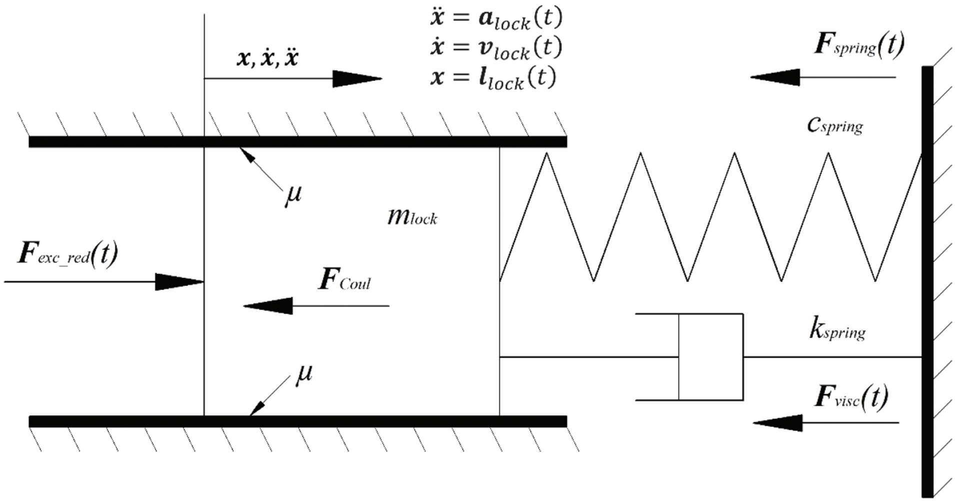

Figure 4: Dynamic model of the mass lock when the lock is moved backwards
Source: compiled by the author

[7] Heck 1999.

The main constraints and neglect of our swinging system:

- The positioning spring has linear characteristics and zero mass
- The friction force is constant (the external Coulomb friction coefficient is constant)
- The effect of the gravity field is neglected
- The viscous damping coefficient is constant
- The masonry is ideal, no displacement
- The lock is rigid

The forces acting on the mass lock and the equation of motion

The equation of motion of a constrained pendulum system with the notations in Figure 4:

$$F_{exc\_red}(t) = m_{lock}\ddot{x}(t) + \left(c_{spring}x(t) + F_1 + F_{Coul}\right) + m_{lock}k_{spring}\dot{x}(t) \tag{9}$$

which, after naming the time derivatives and transforming them into first order equations, takes the following forms in our example:

$$\frac{d}{dt}v_{lock}(t) = \frac{F_{exc\_red}(t) - c_{spring}l_{lock}(t) - F_1 - F_{Coul}}{m_{lock}} - k_{spring}\frac{d}{dt}l_{lock}(t) \tag{10}$$

$$\frac{d}{dt}l_{lock}(t) = v_{lock}(t) \tag{11}$$

where:

$F_{exc\_red}(t)$ is the function of the reduced excitation force, unit N,
$v_{lock}(t)$ is the velocity function of the lock, unit $\frac{\mathrm{m}}{\mathrm{s}}$,
$l_{lock}(t)$ is the displacement function of the lock, unit m,
m_{lock} is the mass of the lock, unit: kg,
c_{spring} is the spring stiffness of the positioning spring, unit $\frac{\mathrm{N}}{\mathrm{n}}$,
F_1 is the preload of the positioning spring, unit N,
F_{Coul} is the Coulomb friction force, unit N ,
k_{spring} is the viscous damping coefficient of the positioning spring, unit $\frac{1}{\mathrm{s}}$.

It can be seen that after a reasonable choice of parameters and the determination of the reduced excitation force function, the problem can be solved both analytically and numerically. Without going into the specification of the parameters, let us define the reduced excitation force function, for which see Figure 5.

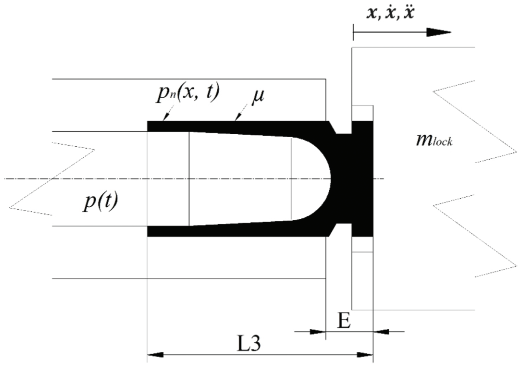

Figure 5: Bivariate surface pressure on the vaginal surface
Source: compiled by the author

The time-varying gas pressure generates a spatially varying surface pressure along the sleeve casing, from which the Coulomb friction force function on the casing can be calculated. The resulting surface pressure decreases steadily towards the bottom of the sleeve, i.e. the wall thickness of the sleeve increases steadily in this direction. The resulting bivariate surface pressure function can be calculated in principle (under equilibrium conditions), but for simplicity, let us use the approximation that in the deformable section $L_3 - E$ of the sleeve, both the thickness of the sleeve wall and the gap between the shell space and the sleeve casing are assumed to be zero. However, this latter simplification causes a problem. The model cannot take into account the fact that in reality the gunpowder gases can penetrate between the casing and the chamber, counteracting the effect of the gas pressure on the casing. This can be taken into account by varying the value of the friction coefficient and/or the length of the freely deformable casing section (as free model parameters) by fitting the simulation results to the measurement results. The pressure compressing the surfaces will then be independent of the location and equal to the gas pressure (Figure 6).

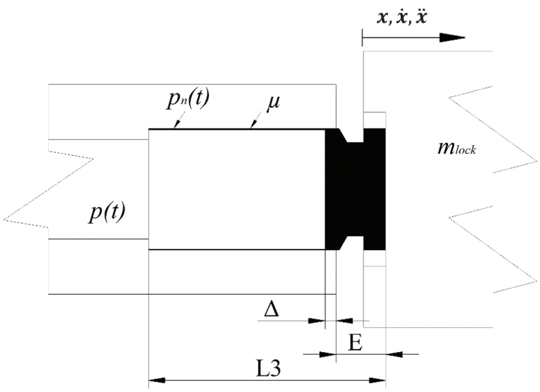

Figure 6: Univariate surface pressure on the vaginal surface
Source: compiled by the author

We know that the freely backward moving shutter is accelerated by the gas pressure through the bottom of the sleeve, so it is necessary that the function of the shutter travel is the same as the function of the displacement of the sleeve as long as the sleeve is directly exposed to the gas pressure. From this consideration, the current contact casing surface can be defined.

At the start of the shot, the contact surface area of the casing:

$$A_{surf\_0} = (L_3 - E - \Delta)d_{case}\pi \tag{12}$$

where d_{case} is the outer diameter of the sleeve, measured in m.

This is the current contact surface area of the casing:

$$A_{surf}(t) = \begin{cases} A_{surf\_0} & t < t_\Delta \\ A_{surf\_0} - l_{lock}(t)d_{case}\pi & t \geq t_\Delta \; and \; t \leq t_{L3} \\ 0 & otherwise \end{cases} \tag{13}$$

where t_Δ is the time instant associated with the condition $l_{lock}(t) = \Delta$ and t_{L3} is the time instant associated with the condition $l_{lock}(t) = L_3 - E$, unit s.

Knowing the contact slab surface function, we can write the friction force function on the slab:

$$F_{Coul\_surf}(t) = p(t)A_{surf}(t)\mu \tag{14}$$

where μ is the coefficient of sliding friction between the case and the chamber, measured in units.

From these, the complex force function that excites our vibration system:

$$F_{exc\_red}(t) = p(t)A_{case\_int} - F_{Coul\_surf}(t) \tag{15}$$

where A_{case_int} is the area of the cross-section defined by the projectile diameter in m^2 .

Now that we have all the necessary parameters and functions, our problem is solvable.

Measurement results for 9 × 19 mm NATO calibre

The measurements were carried out in the ballistics laboratory of the Civilian Small Arms and Ammunition Testing Ltd. Our measurements can be divided into two parts, an internal ballistic gas pressure measurement combined with an initial velocity measurement and a rapid filming of the breech movement of a CZ EVO submachine gun. Both the recorded gas pressure data and the rapid film recordings were processed using proprietary software. The gas pressure and projectile velocity measurements provided the basic characteristics of the ammunition used, as well as the exact value of the excitation function for the swing system. The gas pressure measurement of the ammunition used and the initial velocity measurement, carried out simultaneously with the gas pressure measurement, were performed using a NATO AEP-97 standard measuring tube, which is essentially identical to the CZ EVO tube from a ballistic point of view.

We were not able to prepare the weapon in the usual way for the production of the short films, so we only made reversible modifications to the weapon. As the breech mechanism of the gun is only visible in the opening of the ejector window, the full range of breech movement cannot be recorded, only the approximate first 35 mm of the movement. This can be filmed during both forward and backward movement, but for our task the forward movement is irrelevant and the first 12 mm of movement is sufficient to simulate the excitation that occurs. The right thumb release port of the gun and the observed edge are shown in Figure 7.

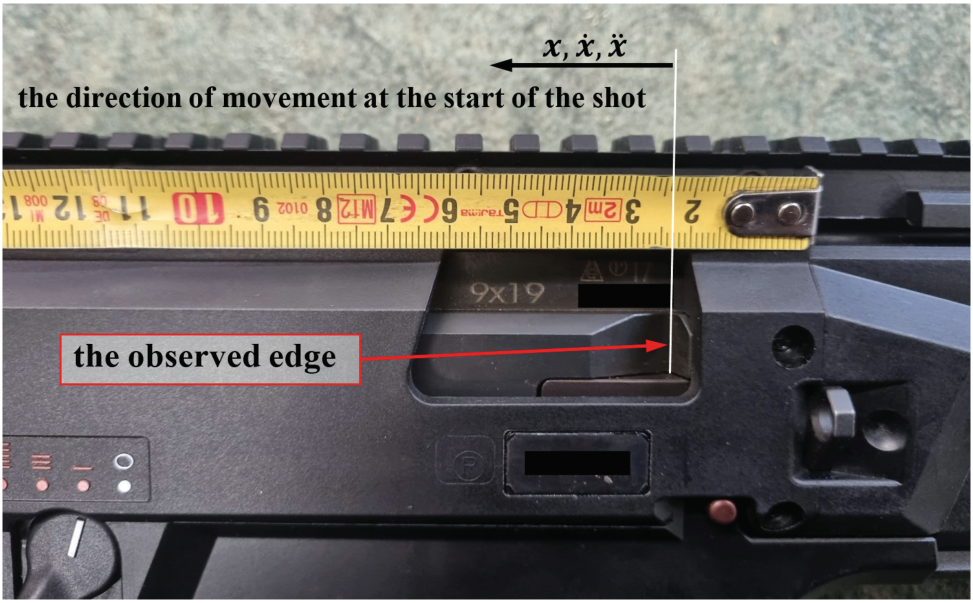

Figure 7: Right side view of the unprepared CZ EVO submachine gun included in the study, with the ejection port in focus
Source: photographed by the author

From digitally recorded short film files, digital frames of video can also be extracted as image files. The image files were processed using a proprietary analysis algorithm written in the symbolic math program Maple. Figure 8 shows the 45th control frame generated by the program for a shot taken with a degreased (dry) shell casing and shell casing pair.

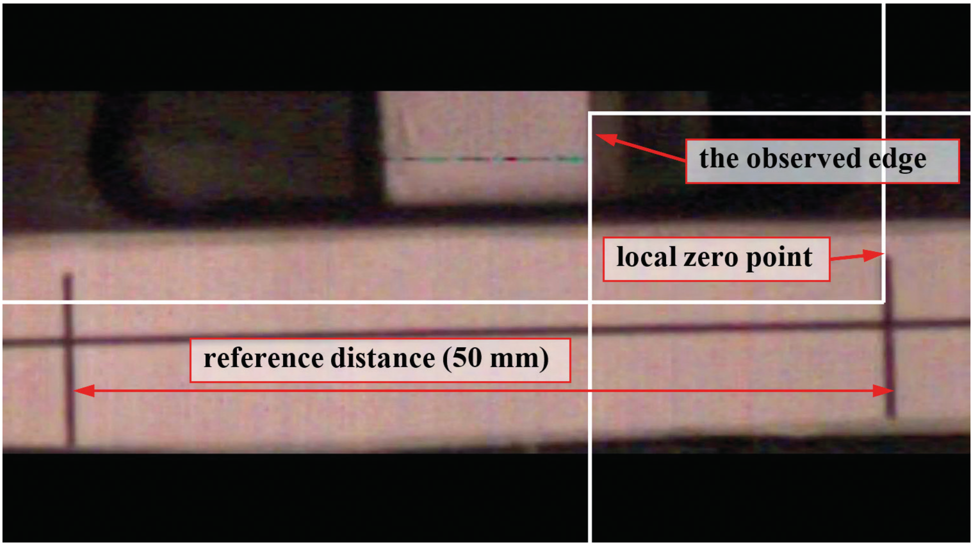

Figure 8: Control frame 45 of the dry firing on the prepared gun
Source: compiled by the author

The result of the gas pressure measurement and the fitted function are illustrated in Figure 9. (The left side of Figure 9 shows the gas pressure measurement report diagram, the right side shows the fitted spline function.)

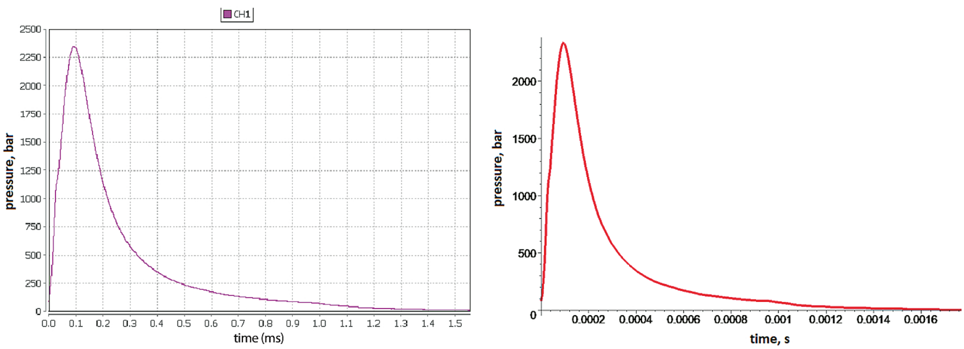

Figure 9: Univariate surface pressure on the vaginal surface
Source: compiled by the author

High-speed filming was performed at 32,667 fps or 320 × 120 resolution, which was already relatively usable and provided a sufficient number of frames for motion analysis.[8] However, although a telephoto lens was used to film the motion, the horizontal resolution for observing the initial (1-2 mm) phase of the motion is only acceptable with compromises, as the excessive pixel sizes result in a relatively high uncertainty of the readout compared to the relative displacement at that time instant. For more accurate studies of the excitation phase, a camera with a minimum vertical resolution of 1,280 pixels at 50,000 fps is required.[9]

These fluctuations due to increased reading uncertainty had to be filtered out, since with high-speed filming we are recording the instantaneous position of the shutter, which is significantly burdened by reading uncertainty. The numerical derivation of noisy displacement-time value pairs without filtering can already render the velocity-time values almost unusable, but this is even more true for the second derivative acceleration, since the derivation operator amplifies errors due to the fluctuations.

The displacement-time point pairs recorded by filming were filtered twice, taking care to minimise data loss. The best results were obtained using the moving average filter (first filter) and the logarithmic filter (second filter). The maximum velocity value was obtained from the analytical function obtained by regressing the filtered measurement points, which were loaded by the longitudinal oscillation of the spring-lock system. The unsmoothed discrete velocity function is shown in Figure 11 by the black diagram similar to the black sawtooth signal, and the filtered measurement points by the blue diagram, which was approximated by a similar analytical function, now detached from its actual physical content.

It is useful to plot the regression objective function on the shutter speed because it is easier to visually judge the "goodness" of the regression than for directly measured displacement-time pairs.[10] The nature of the graph given by the velocity-time point pairs is similar to that of an exponential function describing a single-loop system.[11] This function still needs to be corrected by the method of least squares to change the strict monotonic increase in the function to a strict monotonic decrease after the maximum shutter speed is reached. A polynomial of degree one is the most appropriate for this purpose, based on the runs, and this gives the best fit. This gives a parametric function approximating the shutter speed-time value pairs:[12]

[8] The video recordings were made with a CHRONOS colour high-speed camera, type CH14-1.0-C.

[9] The vertical resolution (perpendicular to the direction of motion) was measured to be 320-pixel columns, resulting in a scaling factor of 0,179 $\frac{\mathrm{mm}}{\mathrm{pixel}}$ for a reference distance of 50 mm. This discretisation imposed a measurement uncertainty of ± 0,0895 mm on all displacement values of our measurements (analogous to the measurement uncertainty component due to the finite resolution of digital instruments).

[10] When evaluating the measurements, the moving average filter window size was 20 measurement points, and the logarithmic filtering parameter was 0.2.

[11] This can be observed in the blue graph in Figure 11 as a periodic variation in velocity.

[12] Although our function $v_{reg}(t)$ is difficult to integrate analytically, the differential equations are solved numerically, so analytical integrability is not a consideration here.
You can also choose a higher order polynomial as the regression function, in which case integrability is ensured, but pure regression algorithms cannot be used because of the bias in the initial and final values. In this case, the initial and final values are either bound as interpolation points, or the set of regression point pairs is extended by extrapolation to define virtual measurement points.

$$v_{reg}(t) = b_0 v_{max} \cdot \mathrm{e}^{-\frac{1}{c_0 + c_1 t}} \cdot (a_0 + a_1 t) \tag{16}$$

where:

b_0 is the multiplier for the asymptotic shutter speed, there is no unit of measurement,

v_{max} is the maximum closing velocity averaged over the maximum velocity values, unit $\frac{\mathrm{m}}{\mathrm{s}}$,

c_0, c_1 are the parameters of the single storage system fitted to the measurement points, units: none, $\frac{1}{\mathrm{s}}$,

a_0, a_1 are the parameters of the first degree polynomial determined by the method of least squares, units: none, $\frac{1}{\mathrm{s}}$.

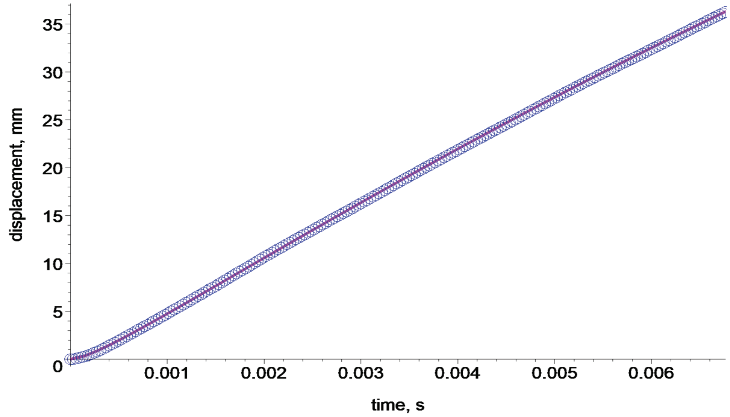

Figure 10: Shutter positions obtained by processing frames from a shot fired in the dry state (circles on the diagram), using the integral function of the regression function
Source: compiled by the author

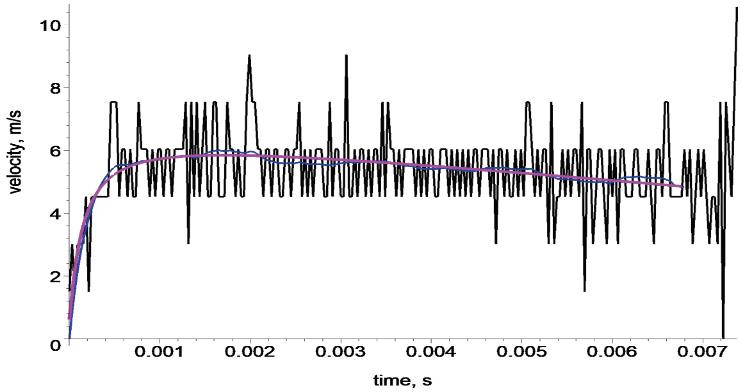

Figure 11: Shutter speed calculated numerically from the frames, from a shot fired in dry conditions
Note: The black noisy velocity is the unfiltered velocity, the blue smoother is the velocity produced from the filtered data, the purple is a regression analytical approximation.
Source: compiled by the author

Calculation results for 9 × 19 mm NATO calibre

Let's look at the results of running the above model for a machine gun firing 9 × 19 mm NATO ammunition, where the main model parameters are as follows:

Table 1: Main parameters of the simulation with projectile data

Name	Value	Unit of measurement
lock road	75	mm
the mass of the lock	600	g
spring force, lock in forward position	25	N
spring force, lock in rear position	60	N
viscous damping factor	2	1/s
friction force of the lock	5	N
dome-steel coefficient of friction (literature value)	0.120	unit
dome-steel coefficient of friction in dry condition (fitted parameter)	0.049	unit
dome-steel coefficient of friction in the greased condition (fitted parameter)	0.010	unit
length of the deformable sheath of the case	10	mm
outer diameter of the case	10	mm

Source: compiled by the author

The excitation gas pressure curve was obtained by interpolation of the measured data, the first order interpolation spline curve is illustrated in Figure 9, Figure 12, Figure 13 and Figure 14 show the response function plots obtained. In the figures, the excitation phase – when the gas pressure in front of the sleeve is not zero – is uniformly marked in red, the greenish yellow is the sleeve still in the charge space but not under gas pressure, the blue is the damped backward displacement and the black is the forward displacement of the lock.

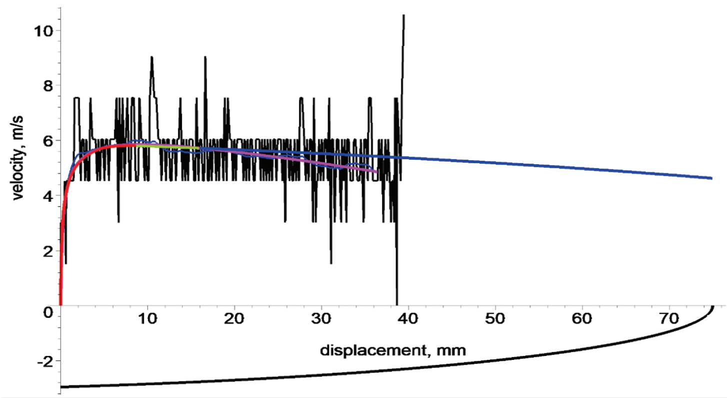

Figure 12: Closing velocity – closing displacement function from dry fired shots, with values from Table 1 and calculated closing velocity from measurement, and regressed closing velocity

Source: compiled by the author

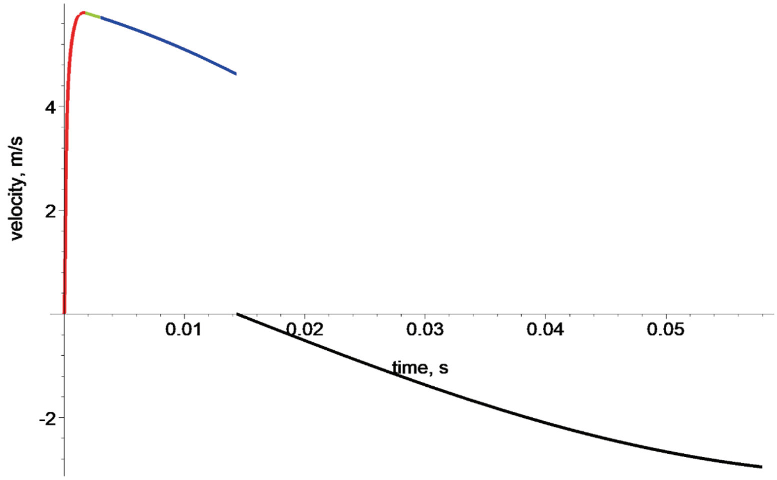

Figure 13: Closing velocity-time function from a shot fired in the dry state, with the values shown in Table 1
Source: compiled by the author

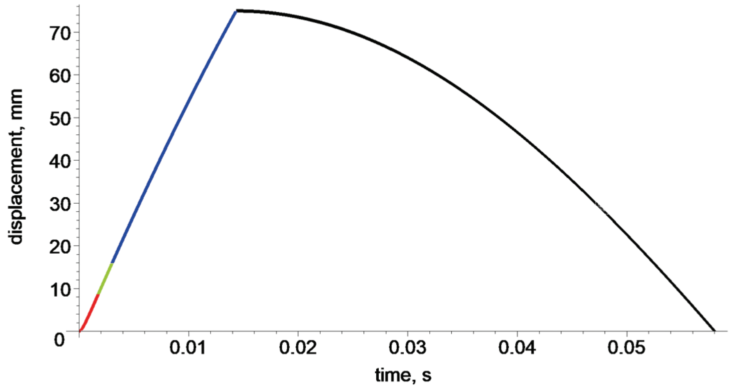

Figure 14: Closing displacement-time function from a shot fired in the dry state, with the values shown in Table 1
Source: compiled by the author

It can be seen that with the given parameters, the simulation is a good approximation of reality, the automatics work, there is locking energy for the impact.

Let's now look at the case where friction is strongly reduced by thin lubrication of the case and chamber. Now the calculated shutter speeds and regression from the measurement are illustrated in Figure 15.

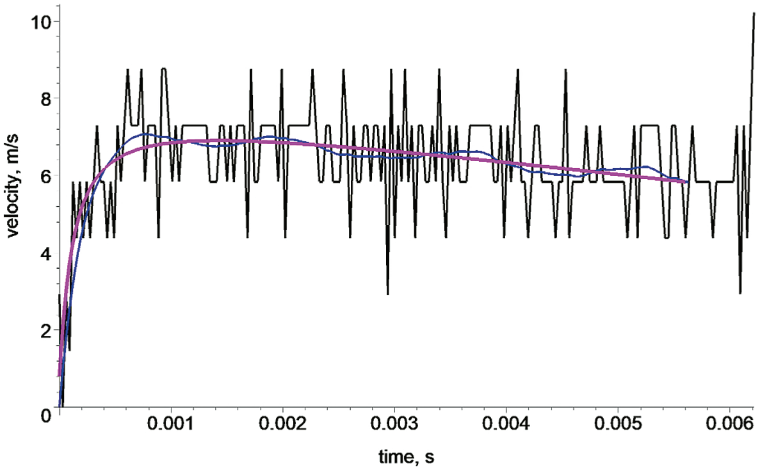

Figure 15: Numerically calculated shutter speed from frames, fired in a greased condition

Note: The black noisy velocity is the unfiltered velocity, the blue smoother is the velocity produced from the filtered data, the purple is a regression analytical approximation.

Source: compiled by the author

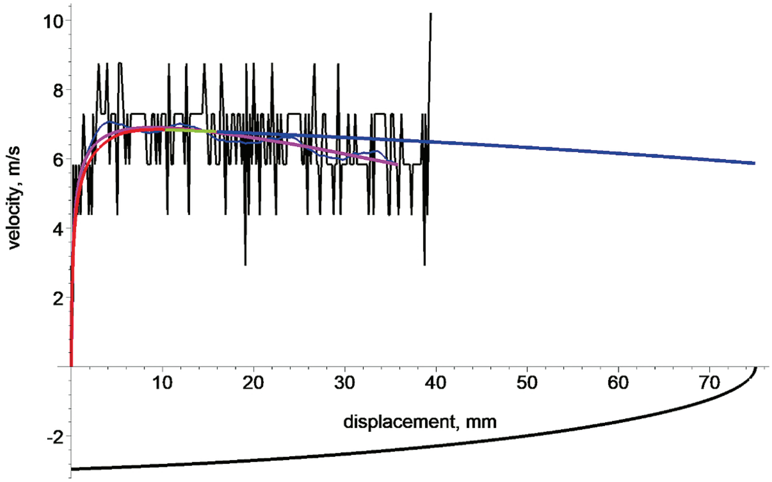

Figure 16: Closing velocity-closure displacement function in the greased state

Source: compiled by the author

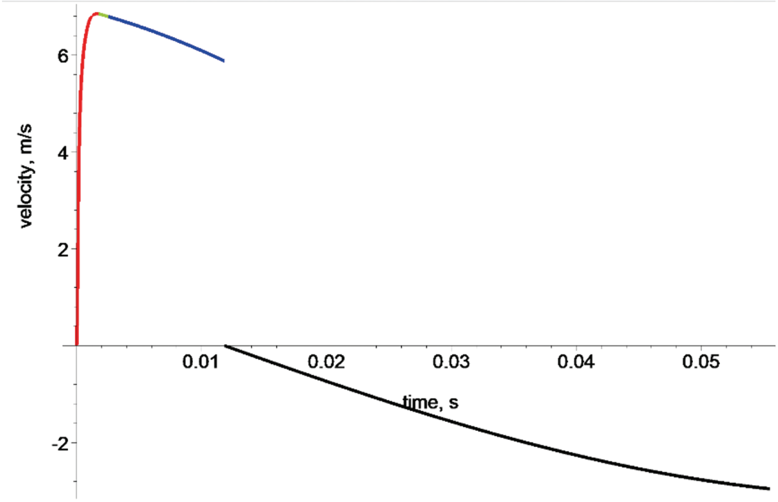

Figure 17: Closing speed-time function in the greased state
Source: compiled by the author

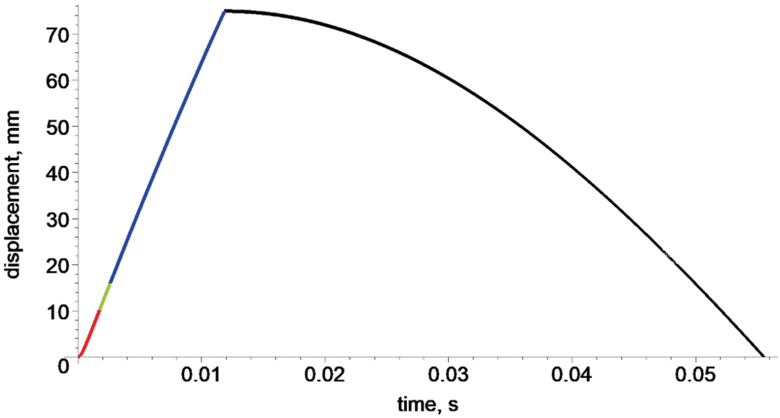

Figure 18: Closed-motion-time function in the greased state
Source: compiled by the author

Now we can also conclude that the simulation is a good approximation of reality with the given parameters, and the simulated shutter speed can be exactly matched to the one calculated from the measurement results.

Let us consider the case where we do not take into account the sleeve-loosening effect of the gases flowing between the casing and the chamber. In this case the friction coefficient can be determined from the literature. Figure 16 illustrates the simulation of the closure displacement-closure velocity function. It can be clearly seen that the results obtained are far from reality.

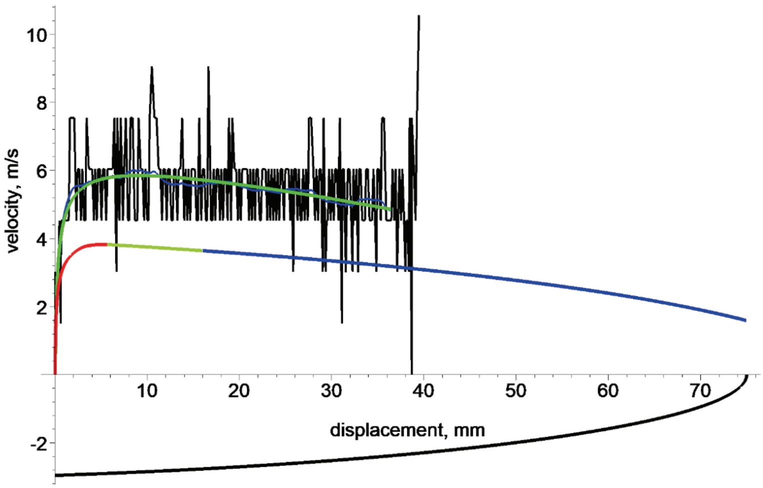

Figure 19: Closing velocity-closing displacement function with the literature friction coefficient values according to Table 1 and the closing velocity calculated from the measurement, as well as the regressed closing velocity
Source: compiled by the author

Remarkably, this seemingly insignificant neglect[13] means that our calculations will have little to do with the movements that occur in reality. It should be seen that by treating the walls of the sheath as a membrane of zero thickness and by excluding the inflow of gases between the surfaces, we have made a significant simplification which, although it would save costly and time-consuming measurements, is not allowed by the validity of the model. Although the membrane approximation of the sleeve wall can be solved, the excitation function in our equation (9) is now bivariate and our equation is transformed into an integro-differential equation, but we still cannot deal with the relaxing effect of the inflowing gases with this model. It is also important to see that, for free mass-locked systems, the design, quality and sliding characteristics of the sleeve and the friction surfaces are very sensitive, which cannot be taken into account at all by the simpler models.

Summary

- The mass locks (by design) are not capable of arbitrarily high backward velocities,[14] which limits their rate of fire and makes them susceptible to filling-discharge problems.

13 With which we can “save” on measurements.
14 In the case of machine guns, even 1,000 rpm a rate of fire can be achieved that is considered high, but note that this is only due to the short recoil distance resulting from the relatively short case length.

- The design of weapons with this system should always be based on models that can at least take into account the effects of friction. Their free model parameters should be fitted to the results of measurements carried out at least on an existing weapon, but preferably on a technological demonstrator, in order to achieve the lowest possible simulation error.
- The quality of the cartridge case used is of paramount importance, both in terms of the raw material and the surface quality.
- The ammunition and cartridge cases of free-floating weapons must not be altered from their factory condition, i.e. neither oiled, nor polished, nor “tuned” by any efficiency-enhancing process, because the case-cartridge pair is the most critical point of this system.
- The manufacturers minimise the sealing weight, therefore any gun barrel that does not have a factory silencer connection is an accident hazard to retrofit a silencer to that gun due to its gas retention effect. The consequence of such retrofitting is a drastic increase in gas backflow.
- In particular, the use of reloaded ammunition (once or more than once reshaped cartridge case) for this type of weapon is contraindicated because it increases the risk of case rupture, which is an increased risk of accident.

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