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ANALYSIS OF PARTICULAR STRUCTURES AND MECHANISMS INVOLVED IN A HANDGUN SEMIAUTOMATIC FUNCTIONING

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ABSTRACT
The semiautomatic cycle of a handgun is a complex phenomenon which implyes many moving parts at high velocities, due to burnt gases action.
The goal of this paper is to relieve some aspects in part modeling and analysis for the major assamblies components. In order to write up the achievements of this work, there are briefly presented the mathematical background used in theoretical study of a semiautomatic operating cycle.
Keywords: handgun, CAD modeling, simulation

1. AUTOMATIC AND SEMIAUTOMATIC PRICIPLE
There are a large variety of modern weapons called 'automatic weapons', mostly used as individual fire systems. To operate a weapon, a sequence of events must be fulfiled. First, the cartridge must be inserted into the loading chamber and the breech block closed behind it to support the cartridge case. The primer is initiated. After the shot has been fired, the breech must be opened and the empty cartridge case removed from the chamber and ejected from the weapon. The next cartridge must be loaded into the weapon by removing a round from the magazine and feeding it into the chamber.
In automatic weapons, the continuous transfer from one event to the next is controlled by the operating system of the weapon. Automatic functioning can be achieved for part of the functional cycle to give semiautomatic operation or for all of the cycle to give fully automatic operation.
In this paper we present a semiautomatic handgun case, which is a blow-back system. That means the propellant gases act on the breech block through the cartridge case, in order to complete the cycle. In the same time, the gases act on the bullet, giving it's necessary energy. [1]

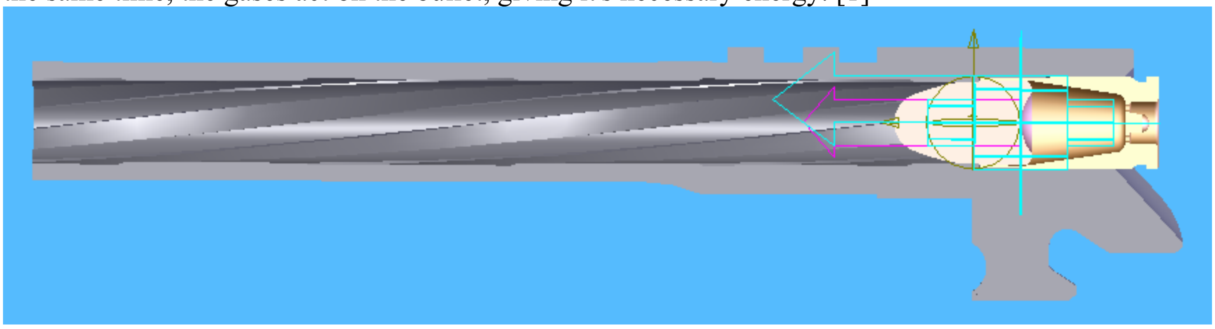

Figure 1. Barrel-bullet assembly. Initial position of the bullet inside the loading chamber

2. THEORETICAL BACKGROUND
The dynamic theoretical study of semiautomatic operation is made in the hypothesis that the gun is rigid fixed on a fixed support, stationary

The general form of the motion equation is [2]:

$$M_{red}\frac{dv}{dt}+v^2\left(\sum_i\frac{\nu_i}{\eta_i}m_i\frac{\partial\nu_i}{\partial x}+\sum_j\frac{\chi_j}{\eta_j}J_j\frac{\partial\chi_j}{\partial x}\right)=F_{red} \qquad (1)$$

M_{red} – reduced mass of recoiling system;

v - velocity of the leading part;

ν_i - transmission ratio between the motion of the leading part and driven parts which have

m_i - masses and which executes a translational motion;

m_r - recoiling mass;

η_i - kinematic couple efficiency;

χ_j - transmission ratio between the leading part and driven parts which executes a rotation;

J_j - moments of inertia for the parts which have motion of rotation;

F_{red} - the force which react on the recoiling system, focused on the leading element.

The reduced mass is calculating as bellow [2]:

$$M_{red}=m_r+\sum_i\frac{\nu_i^2}{n_j}m_i+\sum_j\frac{\chi_j^2}{n_j}J_j \qquad (2)$$

The friction forces between the lock and the gun's body are ignored, as well as the frictions in the fire cock axis and the friction between the barrel and the lock during the unlock motion;
The mechanical energy loss of the mechanical work from the internal forces inside the springs material are ignored (retrieval spring and the fire cock spring).

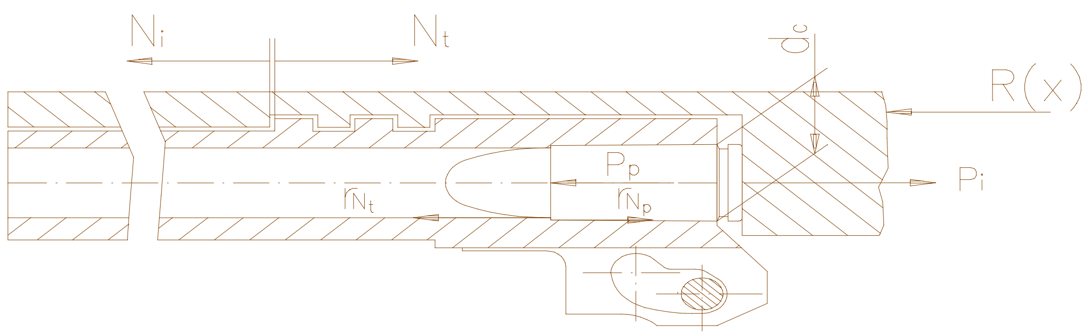

Figure 2. The forces which act over the lock mechanism during the fire time, in longitudinal plan

P_i – pressure force which acts over the breech;
P_p – pressure force which acts over the projectile;
N_t – the force which the breech acts over the barrel during the high pressure in loading chamber;
N_i – the reaction force of the barrel over the breech;
r_{Np} – the resistant force between the projectile and the rifling;
r_{Nt} – the act of the projectile over the barrel;
R(x) – the resultant of the elastic forces that acts over the lock during the recoil;
d_c – the diameter of the loading chamber from the considered section.
From the above considerations, we have a mechanical system defined by gun barrel, bullet and the breech. Taking apart each element of this system, is possible to write the motion equations.
The breech block movement equation is as follow:

$$m_{bb}\frac{d^2x}{dt^2} = P_i - N_i - R(x) \qquad (3)$$

3. PART & ASSEMBLY MODELING

The whole parts of the handgun were designed with Solidworks, based on dimensions measured on a real handgun. Several main parts are shown bellow:

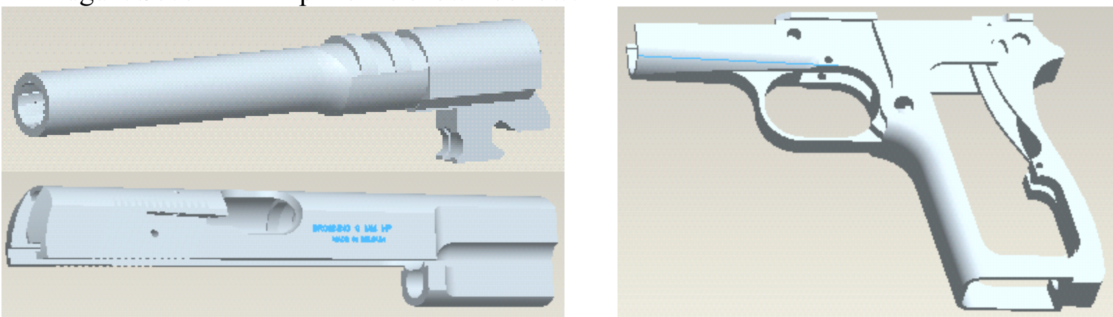

Figure 3. The barrel, slide (breech block) and the body of handgun

For the assembly structure, the kinematic constraints must be known. These help us to guarantee the model will fulfil the functional cycle of the handgun, with respect to slide displacement. The slide succesive positions during the cycle is known as cycle diagram. Using an experimental device and an inductive displacement transducer, the cycle diagram has been measured. Also the recoil force, with a force transducer.

The gun is rigid fixed to the device through an arm jointed with the base of the device. The barrel axis is orthogonal on the arm-support joint axis, having the barrel in horizontal position. The movement of the arm is blocked by the force transducer. The stiffing device gives a constant pressing force, F_0. It's value is chosen high enough to eliminte oscillations. Between base support and the slide a displacement transducer is placed. The force transducer and displacement transducer are coupled through adequate amplifiers to a data aqcuisition system which affords simultaneously recording of the measured units, for an operational cycle of the gun. The measured values with displacement transducer represents the slide position as a time function, x(t). The gathered values by the force transducer serve to the determination of the recoiling force of the gun. Knowing the recoiling force of the gun is necessary because it affects the value of the prancing angle of the gun, and this affects the gun precision.

The mean values for a series of 20 measurements are given in Figure 4, as time [s] function.

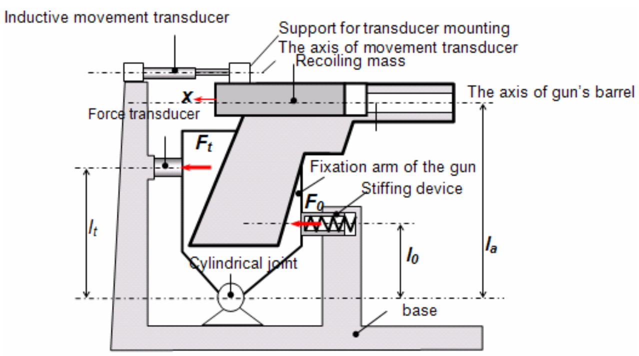

Figure. 4 Experimental device

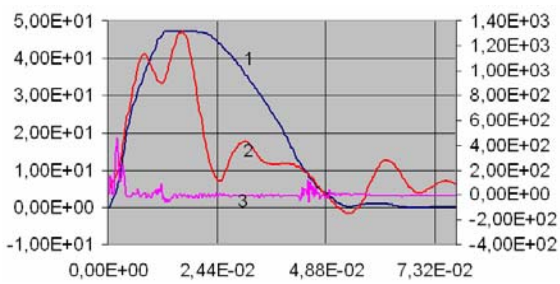

Figure 5. Curve1 – slide displacement, left values [mm], Curve 2 – recoil force, right values[N]

4. SIMULATION RESULTS

This part represent the model validation. The simulation result must be close to the real result. If not, the model is succesively refined by changing the constraints, the contact properties or parts geometry.

Here are presented an intermediar model with the simulation results close to the real data. The markers on the graphic results correspond to the events in Figure 6.

EVENTS	
Initial position of the breech block; Firing cap percussion	A
The displacement until unlocking moment	B
Firing cock arming	C
Cartridge tube ejection	D
End of the recoil	E
Displacement until new cartridge touch	F
Charging a new cartridge in the barrel	G
Locking and the end of the return	H

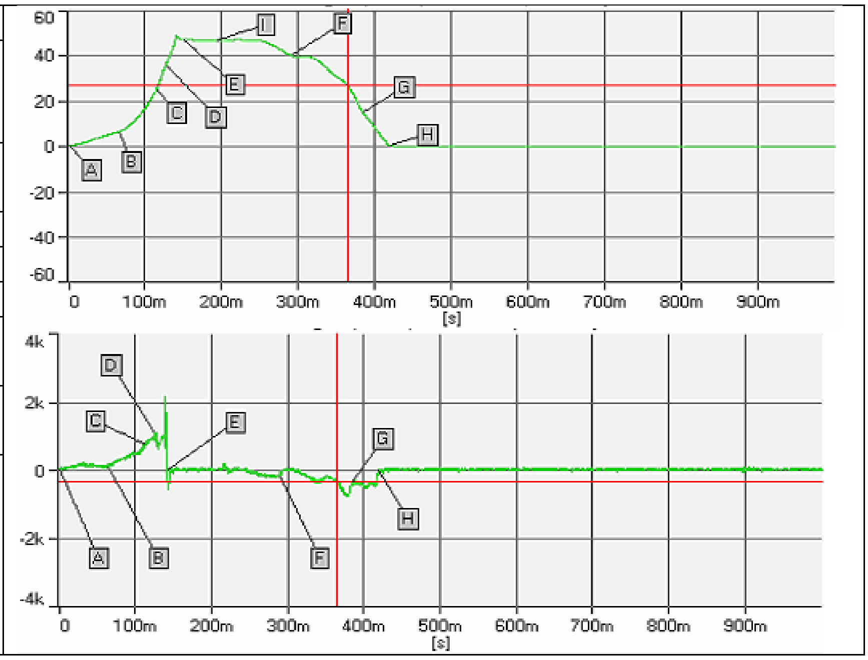

Figure 6. Events in cycle diagram of the model

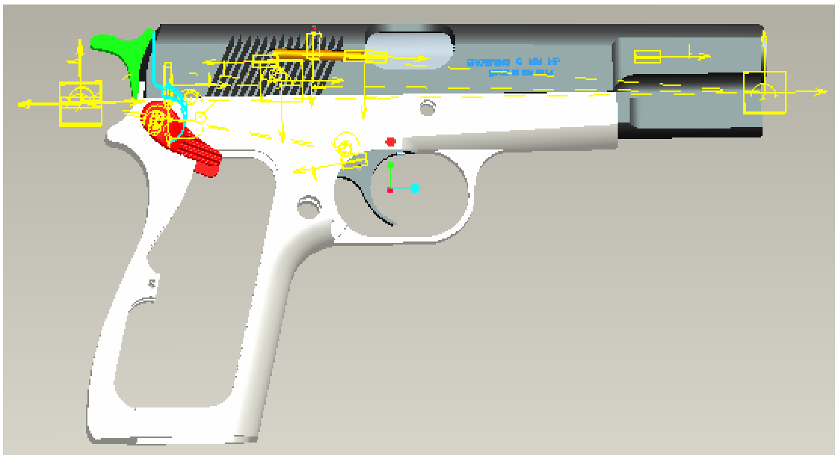

Figure 7. The model of real handgun. Main assembly with kinematic constraints

5. REFERENCES

[1] Allsop, D.: Military Small Arms, Brassey's Essential Guide, 1997,
[2] Marinescu I., Verboncu S.: Mecanisme de armament automat, Editura Militară, Bucureşti, 1973