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Effect of Inertia Forces on Function of Automatic Weapon

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Abstract:

Inertia forces affect on the automatic weapon during firing. Inertia forces can cause a malfunction of the automatic weapon or can help important moving parts of the automatic weapon. Article deals with a new mathematical model describing a resistive force of the human body during working forces of the automatic weapon. Mathematical results are verified by an experiment.

Keywords:

Automatic weapons, inertia forces, main function element, nonlinear biomechanics models.

1. Introduction

The main function of the automatic weapon is, impart a motion, a direction and stabilization to the bullet. The bullet has only one main task – to hit the target.

Automatic weapons (AW) can fire many bullets for a better probability of hitting a target. In the AW there operate many forces which affect accuracy of the AW during firing. One special of them are inertia forces [1, 2]. Inertia forces cause some errors during function of the AW. The main influence of inertia forces is on the main function element (MFE). It is a part of the AW which controls other mechanisms in AW. MFE is a breech carrier on the gun which is described in this text and its functional principle is based on the gas operated system [3, 4].

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Inertia forces come up during several synchronous motions. It happens to a gun which is shoulder fired. Firer causes gun to move during firing. Firer’s body is very weak to resist a big impulse of the shot and impulse of the shock is among the mechanisms of the AW. The motion of the weapon is called a drift motion. In this example it is supposed that the AW is the receiver, barrel, stock and other parts of the AW which are fixed to the receiver and it makes one solid body of the AW. Some parts of the AW can be moving in face of the body of the gun. The other parts are called moving parts. The moving parts do relative motion in face to body of the AW. In the next part of this article will be solid body of the AW called only AW.

Main element of the moving parts is the MFE. The main motion part of the AW (MFE) is one of some reasons for describing the effect of the inertia forces on the MFE of the AW. The second reason can be that the MFE is one of the most important parts of the AW which supports the reliable function of the automatic system of the AW. An effect of the inertia forces on the MFE can cause failure of the automatic system. Wrong inertia forces can be made by a very weak human body.

Describing this situation is drawn in the Fig 1. The stationary system *Oxy* is fixed to the ground. The AW can move in face of a system *Oxy*. A motion of the AW is a drift motion. MFE can move in face of the AW ($O_u x_u y_u$ system). O_u is situated to centre of gravity T_u of the gun and axis x_u is parallel with axis of the barrel.

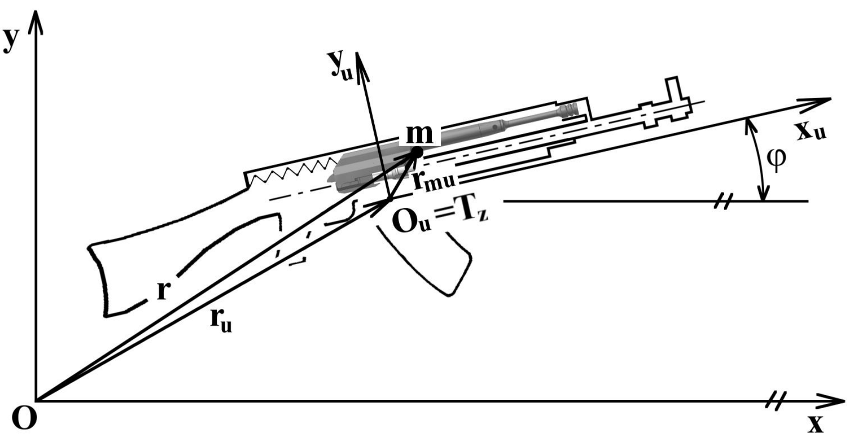

Fig. 1 Scheme of two systems – Oxy is connected with ground and $O_u x_u y_u$ is connected with gun.

A motion of the MFE is a relative motion in face of AW. Finally, MFE can move in face of *Oxy* system. This motion is called an absolute motion. Both kinds of the motions are influenced between them. Drift motion causes to birth the inertia forces affect on the moving parts of the AW for example MFE. Inertia forces affect the centre of gravity of the MFE.

Inertia forces depend on drift motion and drift motion depends on holding an automatic gun during firing. AW is the most widely used by firers. Firers bring a lot of variable things that we have to describe for good result of inertia forces.

2. Voight's Viscoelastic Model of the Human Body

At the present time viscoelastic models of human body are used [5-14]. Biomechanics use three different viscoelastic models (Fig. 2). Base of all viscoelastic models are springs and dampers with linear characteristics.

These models are used for describing the force response of human body during stress. A parallel model called Voight's model that is used in a lot of cases for describing a firer's body during shooting. Generally, the human body has a nonlinear characteristic.

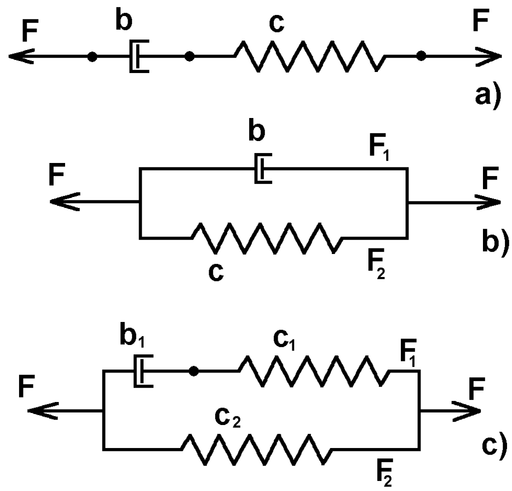

Fig. 2 Three different biomechanics models [6]; a) serial model, b) parallel model, c) combination of parallel and serial models; ***b – damper, c – spring, F – force.***

Here is the first conflict between reality and bio-mechanic models. Because there does not exist anything better than present bio-mechanic models so these models are used for mathematical simulation of a human body. For simulation displacement of the human body and some others physical value's in time over 1 s or 2 s it is a good way. But for describing inertia forces it is not a good way because there is a big distortion in result of the mathematical simulation of an inertia forces effect on the MFE. The big distortion of inertia forces is made by a wrong simulation of the gun motion by use of a viscoelastic models.

At first, the motion of the gun was simulated with use the Voight's viscoelastic simulation model of the human body. Important forces affecting the gun are shown in the Fig. 3. Results of the simulation at first sight look very good. However it was only guess. The mathematical model of the absolute motion of the breech carrier is described by this three dimensional matrix's equation

$$\boldsymbol{M}\ddot{\boldsymbol{x}} = \boldsymbol{F_U} + \boldsymbol{F_R} + \boldsymbol{F_S} - \boldsymbol{C}\boldsymbol{x_c} - \boldsymbol{B}\dot{\boldsymbol{x}}, \tag{1}$$

where is:

$\boldsymbol{M}$ – matrix of the inertia (mass and moment of inertia),

$\ddot{\boldsymbol{x}}$ – vector of the acceleration,

$\boldsymbol{F_U}$ – vector of the drift load,

$\boldsymbol{F_R}$ – vector of the relative load,
$\boldsymbol{F_S}$ – vector of the inertia forces,
$\boldsymbol{C}$ – matrix of the spring rate,
$\boldsymbol{B}$ – matrix of the damping,
$\boldsymbol{x_c}$ – vector of the displacement of the spring and damper,
$\dot{\boldsymbol{x}}$ – vector of the velocity AR.

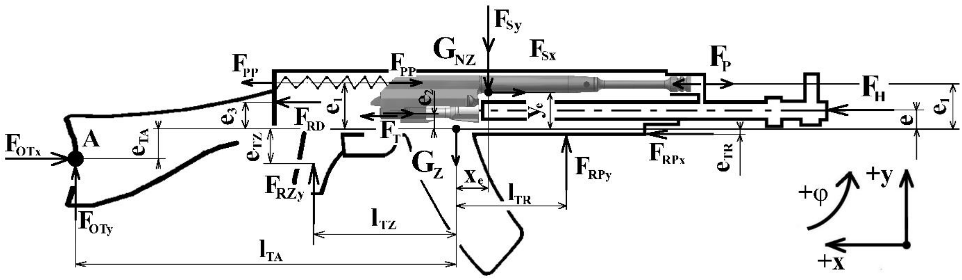

Fig. 3 Diagram of affecting the most important forces to the AR [2]

After this simulation was made an experiment with gas operation automatic rifle (AR) LADA calibre 5.56×45 NATO (lock by rotating breech) and result of the experiment with result of the mathematical simulation of a drift motion were different. From whence it follows that mathematical inertia forces are different from real inertia forces in important places of the motion of the MFE (Fig. 4). It was made out that it was not a good way for the correct result of the simulation of inertia forces.

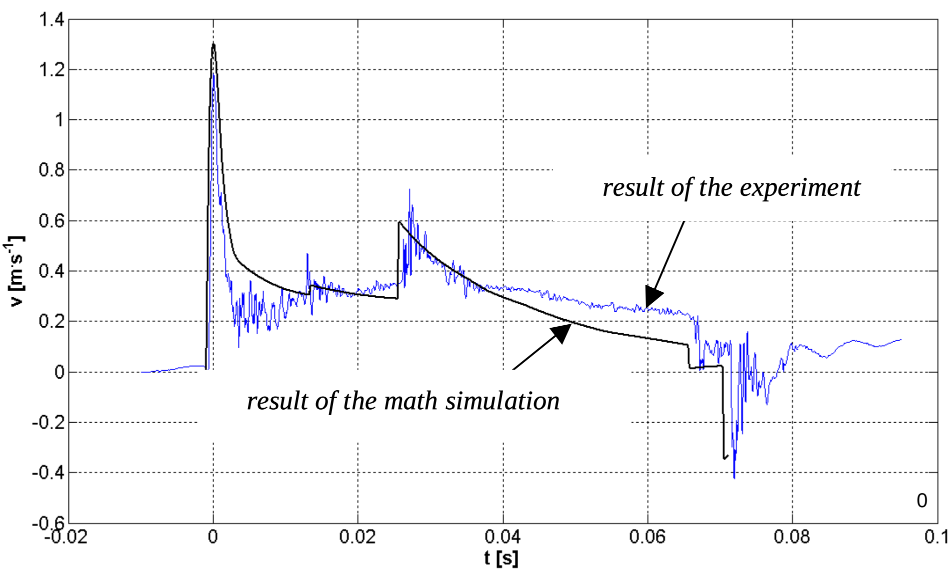

Fig. 4 Comparing results of the calculation and experiment of the velocity of the MFE. Voight’s viscoelastic model of the human body.

3. Nonlinear Model of the Human Body – Dynamic Mass of Continuum

On the basis of these findings a new mathematical model was looked for, for more accurate describing of the interaction between human body and the gun. A lot of practical experience and earlier experiments [10, 11, 13, 15, 16] showed one different way and different experience.

The human body behaves like a stiff ”dead“ body without response during the effect of plenty of force impulses made by function cycle (FC) of the AW. One FC is too short for any response of the human body. Usually one FC takes about 0.1 s (600 rounds per minute). Response of the human body takes the least 0.2 s and it can even be more then 0.5 s. It depends on physical and mental condition of a firer and also the situation affect to the firer.

Shooter can use several firing positions. For this case is used the standing position with a gun held in the shoulder. Firer takes an aimed shot at the target. Firer must concentrate for an accurate shooting. Firer and his rifle stay still before the shot. System firer-gun is an equilibrium system because forces of the automatic rifle (AR) acting on the human body and forces of the human body acting on the AR are the same. After pulling the trigger the motion of the bullet is starting to make forces on a firer and equilibrium is disturbed but firer does not act consciously to the rifle. Forces acting on the rifle are made by physical properties of structure of the human body that are not affected by nervous system and brain. On the basis of these findings was created a new nonlinear mathematical model of the resistive force of human body that is described by this equation [2]

$$F_{OT} = d_m \left(\frac{\mathrm{d}x}{\mathrm{d}t} \right)^2 [N] \tag{2}$$

Where: d_m - incremental characteristic of mass [kg/m] [8],

$\left(\frac{\mathrm{d}x}{\mathrm{d}t} \right)$ - velocity of the AR [m/s].

New mathematical model is created with a new bio-mechanic model describing resistive force of the human body during impacting forces of the AR. New mathematical model is

$$\boldsymbol{M}\ddot{\boldsymbol{x}} = \boldsymbol{F_U} + \boldsymbol{F_R} + \boldsymbol{F_S} - \boldsymbol{D}\dot{\boldsymbol{x}} \ , \tag{3}$$

where is: $\boldsymbol{D}$ – matrix of the nonlinear damping (dynamic mass of continuum).

Results of the new mathematical model go together with results of the experiment much better than the previous model. One of the all results is shown in the Fig. 5. It means that inertia forces are simulated much better then before. Results of the simulation are very close to the experiment results and it is a very important for the next accurate scientific work.

It was found that inertia forces help the motion of the breech carrier at the time of the FC where breech carrier loses the majority of its energy. The time is during unlocking and the starting movement of the breech. After this time inertia forces accelerate breech carrier enough to finish the first important part of the FC. It was also found that the right support to the AR is necessary to correctly carry out the FC. If support to the AR is very weak or very hard then it is not good conditions for motion of the breech carrier and other moving parts of the AR. Very hard support to the AR does not allow the motion of the AR and there is not any inertia forces affect to the breech carrier. Affection of the forces left can affect the malfunction of the breech carrier in a majority cases. The breech carrier does not have enough energy to finish its work (full functional cycle).

In the opposite case it is a different situation, because there are inertia forces that do not help the breech carrier. Inertia forces cause negative affect to the breech carrier because motion of the AR is not decelerated during the first part of the FC. In both cases it is possible that mistakes happen during FC and that causes a malfunction of the breech carrier of the AR.

For LADA 5.56×45 NATO it has the best support for human body that has d_m equal close to around 950 kg/m [2]. On the basis of the new mathematical model of the resistive force the human body it is possible to say that it is more important to know how to use your muscles, in a large weighing body.

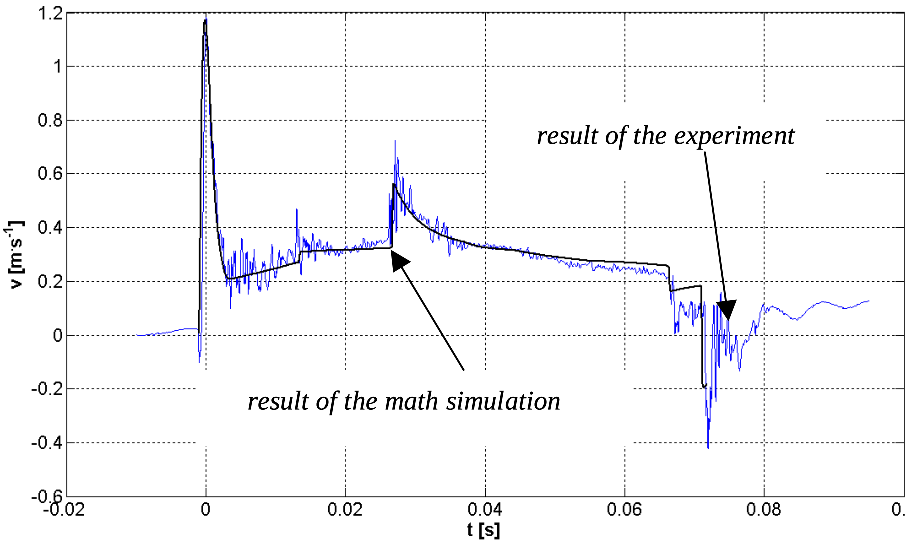

Fig. 5 Comparing results of the calculation and measurement of the velocity of the MFE. Nonlinear model of the human body – dynamic mass of continuum.

The new mathematical model of the resistive force of the human body started new research in interaction of the human body and the gun. It was shown that the result of the new model's better fit with results of the experiment than the viscoelastic models with linear characteristics. In the near future research will carry on about the human's body behaviour.

4. Conclusions

New mathematical model is new and better way for describing inertia forces and resistive force of the human body that was difficult to express before it. The complete mathematical models are published in [2] and there are described all forces acting in the system gun and firer. Experiment was made only for one position of the firer. But model is likely possible to use for other firer's positions that were not verified.

For another work we recommend to consider these points:

- § to verify mathematical model of the resistive force for another firer's positions,
- § to analyze slip between gun and firer's hands,
- § to find theory about shocks in the gun during firing,
- § to create three dimensional model of the system gun and firer.

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