667. Design and research of a laser trainer with all the functions of the G-36

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(Received 12 July 2011; accepted 5 September 2011)

Abstract. Riflemen trainers are effectively applied for the training of armed forces, police and shooting athletes. However, the training quality directly depends on the perfection of trainers as well as their functional features. Trainers should qualitatively develop the skills of correct leveling of the G-36 to the target, represent probable combat situations and reproduce the process of single shots and shot series. This research work presents the theoretical and experimental investigation of the pneumatic drive for recoil imitation of the automatic gun G-36 and its employment in the laser riflemen trainers.

Keywords: trainer, shot, recoil, imitation, pneumatic, mechanisms, dynamics.

Introduction

Lately laser trainers have been effectively used in the training process of riflemen and sportsmen. However, the majority of trainers have neither real recoil nor sound imitation systems. The simulation trainers are used first for the formation of the new conscripts and then to train soldiers to the more experienced one (Fig. 1).

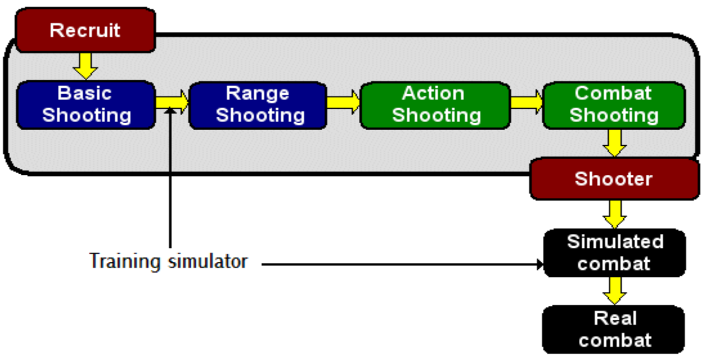

Fig. 1. Place of shooting laser trainer G-36

For this reason the objective of this work is to investigate the recoil of the automatic rifle under single and serial shooting regimes and their interaction with a shot so that training G-36 could be developed with a complete recoil imitation.

Recoil is a backward movement of a rifle when it is fired up. It seems to as that there is quite a difference between “recoil” and “kick”. The gun recoiled, and we got a kick on the shoulder. The recoil is mechanical, while the kick, or at least the effect of it, is mostly physical and psychological. The amount of kick resulting from the recoil force applied by G-36 is largely dependent on the weight and conformation of the shooter, whether he holds the gun tightly or loosely. The location and shape of the shooter’s bones and the texture of his flesh seems to have a big effect in some cases. The recoil consists of three parts [1]. The first is the reaction, which accompanies the acceleration of the bullet from a state of rest to the velocity it possesses when it leaves G-36, that is, to its muzzle velocity. The second is the reaction, which accompanies the acceleration of the powder charge in the form of gas to a velocity in the order of half the muzzle velocity of the bullet. The third is reaction due to the muzzle blast, which occurs when the bullet leaves and releases the gas, which rushes out and gives the same kind of reaction or push that propels a rocket or a jet plane. The effect of the secondary recoil is minimized by making grooves at the end of the G-36 barrel. Outgoing gas dispersed and it has no great impact on the gun motion when it is fired. Therefore, G-36 recoil will be further analyzed without taking into account the impact of gas.

Several pneumatic drives for recoil imitation developed by the authors we successfully applied in laser trainers [2,3]. In this paper the dynamics research of one way operation pneumatic drive for the training G-36 is presented.

One way operation pneumatic drive for the G-36 recoil imitation

Pneumatic drive of one way operation can be used very effectively for all shooting regimes recoil imitation in laser training G-36 for riflemen (Fig. 2). In this case pneumatic drive of one way operation consists of a lock mechanism, which operation is ensured by pressure pulses of compressed air supplied though the main pipeline. As it is illustrated in Fig. 2, the compressed air from the main pipeline flows to the chamber of pneumatic cylinder 2. Under the action of compressed air on piston 3 the latter moves to the right thus compressing spring 4. After switching the valve the cylinder chamber is connected to the atmosphere and pressure it starts dropping and the piston under the spring action is shifted to the other side position.

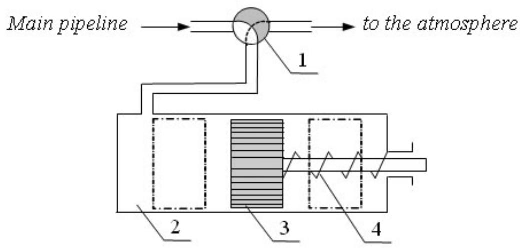

Fig. 2. One way operation pneumatic drive scheme: 1) – valve, 2) – pneumatic cylinder, 3) – piston, 4) – spring

The operation of one way drive is expressed by the following equation [6]:

$$m\ddot{x} = (p - p_a)F - c_1 x - c_2 \dot{x} - P \tag{1}$$

here c_1, c_2 - coefficients of proportionality. The resultant of all acting forces with the exception of air pressure force is as follows:

$$P = \pm P_0 + P_1 \pm P_2 \tag{2}$$

here P_0 - the force due to initial compression of the spring, P_1 - friction force, P_2 - the force of resistance to motion. The methodical calculation of one way operation pneumatic drive is presented in [5, 6].

In the case under investigation the dynamics of training G-36 when its lock is affected by the pulses of compressed air was analyzed. Dynamical model of the investigation case is shown in Fig. 3.

The plane motion of the training weapon G-36 at the moment of a shot imitation is described by the mathematical model where the influence of the movement of the gunlock imitation mechanism during firing is evaluated. The force $F(t)$ (air pressure) initiating recoil in a training G-36 first of all makes the lock move when the influence of recoil is transferred to the gun body. The gunlock imitation mechanism moving inside the G-36 influences the movement of the gun during firing. In order to adjust the mathematical model in question the forces acting on the gunlock imitation mechanism and the training weapon have to be determined.

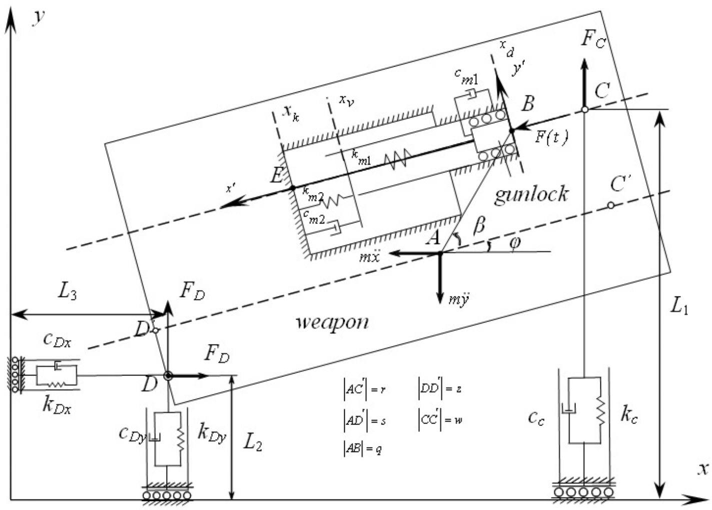

Fig. 3. Dynamical model of the training G-36

The plane motion of the training weapon G-36 at the moment of a shot imitation is described by the mathematical model where the influence of the movement of the gunlock imitation mechanism during firing is evaluated. The force $F(t)$ (air pressure) initiating recoil in a training G-36 first of all makes the lock move when the influence of recoil is transferred to the gun body. The gunlock imitation mechanism moving inside the G-36 influences the movement of the gun during firing. In order to adjust the mathematical model in question the forces acting on the gunlock imitation mechanism and the training weapon have to be determined.

The piston of the gunlock imitation mechanism moves along axis *x'*. The equation describing piston movement will depend on its position in this axis. The coordinates of the piston are $(x',0)$. The following four cases will be considered:

1) when $x_v < x_{m1} < x_d$, then the equation describing movement of the piston:
2)

$$m\ddot{x}_{m1} + c_{m1}sign(\dot{x}_{m1}) + k_{m1}x_{m1} = F(t) \tag{3}$$

here $sign(\dot{x}_{m1}) = \begin{cases} 1, & kai\ \dot{x}_{m1} > 0 \\ -1, & kai\ \dot{x}_{m1} < 0 \\ 0, & kai\ \dot{x}_{m1} = 0 \end{cases}$

At point *B* the gun will be impacted by force $c_{m1}sign(\dot{x}_{m1})$, and at point *E* the gun will be impacted by force $k_{m1}x_{m1}$. When making the equation describing the movement of training weapon, the Coriolis and centrifugal forces are not evaluated because the training G-36 angular velocity in the previously researched model is < 2 *rad/s* (when 3 shots in a row are simulated). The equations describing the movement of training weapon are as follows:

$$\begin{cases} m_1\ddot{x}_{m1} + c_{m1} sign(\dot{x}_{m1}) + k_{m1}x_{m1} = F(t) \\ m\ddot{x} = F_{Dx} + c_{m1} sign(\dot{x}_{m1}) cos\,\varphi + k_{m1}x_{m1}\, cos\,\varphi \\ m\ddot{y} = F_{Dy} + F_C + c_{m1} sign(\dot{x}_{m1}) sin\,\varphi + k_{m1}x_{m1}\, sin\,\varphi \\ I\,\ddot{\varphi} = F_{Dx}\,(s\, sin\,\varphi + z\, cos\,\varphi) - F_{Dy}\,(s\, cos\,\varphi - z\, sin\,\varphi) + \\ \qquad + F_C\; r(\,cos\,\varphi - w\, sin\,\varphi) - c_{m1} sign(\dot{x}_{m1}) w - k_{m1}x_{m1}w \end{cases} \tag{4}$$

3) when $x_k < x_{m1} < x_v$

$$m\ddot{x}_{m1} + (c_{m1} + c_{m2}) sign(\dot{x}_{m1}) + (k_{m1} + k_{m2})x_{m1} = F(t) \tag{5}$$

At point *B* the gun will be impacted by force $(c_{m1} + c_{m2}) sign(\dot{x}_{m1})$, and at point *E* the weapon will be impacted by force $(k_{m1} + k_{m2})x_{m1}$. Now it is possible to write the differential equations of weapon movement:

$$\begin{cases} m_1\ddot{x}_{m1} + (c_{m1} + c_{m2}) sign(\dot{x}_{m1}) + (k_{m1} + k_{m2})x_{m1} = F(t) \\ m\ddot{x} = F_{Dx} + (c_{m1} + c_{m2}) sign(\dot{x}_{m1}) cos\,\varphi + (k_{m1} + k_{m2})x_{m1}\, cos\,\varphi \\ m\ddot{y} = F_{Dy} + F_C + (c_{m1} + c_{m2}) sign(\dot{x}_{m1}) sin\,\varphi + (k_{m1} + k_{m2})x_{m1}\, sin\,\varphi \\ I\,\ddot{\varphi} = F_{Dx}\,(s\, sin\,\varphi + z\, cos\,\varphi) - F_{Dy}\,(s\, cos\,\varphi - z\, sin\,\varphi) + \\ + F_C\,(r\, cos\,\varphi - w\, sin\,\varphi) - (c_{m1} + c_{m2}) sign(\dot{x}_{m1}) w - (k_{m1} + k_{m2})x_{m1}w \end{cases} \tag{6}$$

4) when the piston hits the left edge at point *E*, the gunlock imitation mechanism velocity before the impact is $\dot{x}_{m1}$, after the impact – $R_{sm}(-\dot{x}_{m1})$, here R_{sm} – coefficient of restoration, $0<R_{sm}<1$.

It is assumed that the coefficient of restoration equals 0.56 (steel-to-steel impact). The projections of change of the G-36 velocity will be as follows:

$$\begin{aligned} \Delta\dot{x} &= -\frac{m_1(1+R_a)\dot{x}_{m1}}{m} cos(\varphi) \\ \Delta\dot{y} &= -\frac{m_1(1+R_a)\dot{x}_{m1}}{m} sin(\varphi) \end{aligned} \tag{7}$$

Now, the forces impacting the weapon at points *C* and *D* are evaluated:

$$\begin{cases} F_C = -\,k_C\,(y + r\, sin\,\varphi + w\, cos\,\varphi - L_1) - c_C\,(\dot{y} + \Delta\dot{y} + r\, cos\,\varphi\,\dot{\varphi} - w\, sin\,\varphi\,\dot{\varphi}) \\ F_{Dx} = -\,k_{Dx}\,(x - s\, cos\,\varphi + z\, sin\,\varphi - L_3) - c_{Dx}\,(\dot{x} + \Delta\dot{x} + s\, sin\,\varphi\,\dot{\varphi} + z\, cos\,\varphi\,\dot{\varphi}) \\ F_{Dy} = -\,k_{Dy}\,(y - s\, sin\,\varphi - z\, cos\,\varphi - L_2) - c_{Dy}\,(\dot{y} + \Delta\dot{y} - s\, cos\,\varphi\,\dot{\varphi} + z\, sin\,\varphi\,\dot{\varphi}) \end{cases} \tag{8}$$

In this case the differential equations of G-36 movement will be the same as in Eq. (6). When the piston hits the right edge at point *B*, the change in training G-36 velocity, the forces acting on the weapon at points *C*, *D* and the differential equations of training weapon movement are represented by Equations (4), (7) and (8). Due to structural qualities of the weapon, it is assumed that the restoration coefficient R_s equals 0. Comparative analysis of theoretical and experimental research results of the developed training G-36 was performed. As it is observed from dynamical characteristics of the G-36, the results of theoretical and experimental research are in good agreement (Fig. 4).

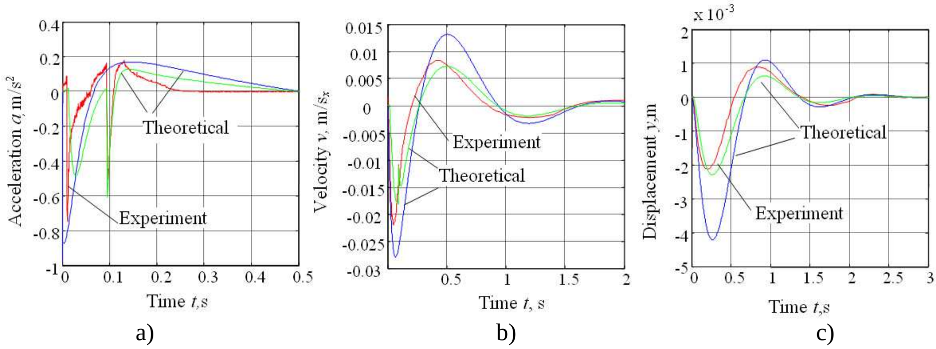

Fig. 4. Temporal characteristics of training G-36: a) - acceleration, b) - velocity, c) – displacement

Laser trainer with all the functions of the G-36

The scheme of the laser trainer with all the functions of the G-36 is presented in Fig. 5. The laser trainer consist from: training rifle G-36, 2 – IR laser, 3 – recoil imitation mechanism, 4 – the shots sound imitation systems, 6 – compressed air supply system, 7 – computer projector, 8 – video camera, 9 – target screen, 10 – laser beam tracking system, 11 – computer, 12 – monitor, 13 – printer.

During the teaching process, the training rifle 1 with a mounted IR laser 2 and recoil imitation mechanism 3 imitates single shots and shot series. The control block 5 synchronically controls the shot sound imitation 4 and the compressed air supply systems and transmits the information about the shooting regime to the personal computer 11. The projector 7 projects the targets on the careen 9 and the information about the shooting process (the trajectory of weapon movement, sight situation at the moment of shooting, target hits, etc.) is received by the video camera 8 and is transmitted to the laser beam tracking system 10, which is connected to the personal computer 11. The shooting process, hitting results and the statistical data are visualized on the computer monitor 11 in real time.

With a rifleman laser trainer designed in this way it is possible to conduct the whole training cycle of the rifleman – from initial instruction to full preparation and to maintain already acquired shooting skills.

It has been proven in practice that it is a very effective training tool which allows not only to economize valuable recourses but also to improve the quality of training as well as reduce its duration.

Laser trainer G-36 in a practice room is shown in Fig. 6.

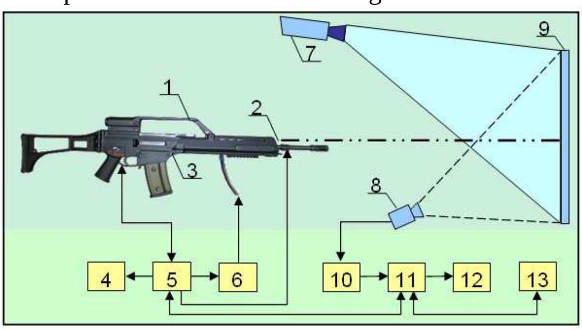

Fig. 5. Functional scheme

Fig. 6. Training G-36 in a practice room

Conclusions

- The article presents a theoretical and experimental investigation of planar motion of recoil of the training G-36 when it is fired in single shots and shot series. The dynamical model and differential equations of the training G-36 were constructed.
- Differential equations for planar motion of trainer G-36 were composed and solved by using *Runge – Kutta* algorithm [5] in conjunction with *MATLAB* software. The dependencies were obtained that describe the motion of training G-36 in time (acceleration, velocity, displacement).
- The results of experimental investigation fully validated the data obtained during the solution of the mathematical model.
- It was determined that pneumatic pulse drives with forced control of operating conditions are the best choice for imitating recoil of small arms.
- The structural synthesis of the training G-36 with full simulation of single shots and series of shots was accomplished and successfully used for the defense and sport institutions.

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