EXPERIMENTAL MECHANICAL DEVICE FOR RECOIL SIMUALTION

Tomáš LUKÁČ, Roman VÍTEK, Linh DO DUC, Vladimír HORÁK

Faculty of Military Technology, University of Defence, Brno, Czech Republic
(tomas.lukac@unob.cz, roman.vitek@unob.cz, duclinh.do@unob.cz, vladimir.horak@unob.cz)

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Abstract: *The paper deals with the development and testing of the experimental, spring powered mechanical device for the simulation of the gun's recoil and further for the obtaining the experimental data for the purpose of research and development of the device for gun's recoil simulation. Several kinds of the present firearm recoil simulation systems and principles of their function are closely described and explained. Measured force diagrams for the experimental mechanical device and for the real assault rifle are presented.*

Keywords: *recoil simulation, assault rifle, SA vz.58, force diagram*

1. INTRODUCTION

Presented experimental mechanical setup was designed to provide an experimental data for the purpose of the research and development of the device for the gun's recoil simulation. The main idea for the design and development is to simulate gun's recoil and behavior as realistically as possible and therein make the training shooting more faithful. Mechanical setup was designed for the purpose of acquisition of the force diagrams provided by the present pneumatic and electromagnetic recoil simulation devices, which use the mechanical impact for the recoil force generation. Obtained force diagrams provide the image of the behavior and dimension of the generated force from the mechanical impact. These force diagrams were used further for the comparison with the real assault rifle force diagrams, obtained from the measurement on a real assault rifle. Czechoslovakian assault rifle SA vz.58 was chosen as a reference firearm.

2. PRESENT RECOIL SIMULATION SYSTEMS

Gun recoil simulation becomes a part of the shooting training firearms and devices, which raises the authenticity of so called "dry shooting". Purpose is to simulate the behavior of the firearm during the shooting more faithful and to train the shooters for the usage of the real gun with the lower costs and higher safety. At present, pneumatic and electromagnetic systems for gun's recoil simulation are used for the professional training.

2.1 Pneumatic recoil simulation systems. The most widespread recoil simulation systems are nowadays the pneumatic systems powered by the compressed air, carbon dioxide or in some cases by compressed nitrogen.

Common design of this systems is in the shape of the additional recoil simulation kit for the real semiautomatic and automatic firearms. With this kit, it is possible to convert real firearm temporarily to the training device, which provides recoil simulation and sound effect. After a training session, the entire assembly can be quickly removed from the handgun or rifle, making the weapon available again for use with live ammunition [1].

Depending on the type of the reservoir, this kits are made as tethered, where the converted gun is connected to the external reservoir or compressor by the pressure hose, or as tetherless, where the reservoir with the power medium is stored in the firearm, mostly as the replacement of the real magazine. VirTra company provides a small belt clips with compressed air or carbon dioxide for the tethered systems. This allows more mobility than other tethered systems due to the fact that the trainee can have a small and lightweight tank on their belt or back [2].

Some producers use a liquid carbon dioxide reservoirs, located in the weapons magazine instead of pressurized gas tubes. It gives to the user freedom of movement, thus significantly widening the area of its use compared to conventional systems [3].

In the tethered systems, magazine imitation serves as a transition component between the external actuating medium source and the operating cylinder. In this systems, the actuating medium is delivered from the reservoir, or supplied by the compressor, to the cylinder with the movable piston, which replaces a barrel. When the pressure in the cylinder rises, the piston begins to move backwards and shunt the bolt, which is thrown to its rear position, where the bolt impacts to the receiver. Consequential pulse is transferred via the stock to the arm of the shooter as the recoil pulse. Quantization of the actuating medium is provided by the impact valve located in the piston head and activated by the hammer strike via the firing pin. Figure 1 shows the TRS (Tetherless Recoil System) for the pistol, provided by the company Dvorak Instruments[1].

FIG. 1 TRS recoil simulation kit [1]

2.2 Electromagnetic recoil simulation systems. The electromagnetic recoil simulation systems use an electromagnetic field, generated by the coil, to speed up the piston, which is made as the movable coil core, and throw it to the rear position to impact the receiver. In comparison with the pneumatic system, electromagnetic system provides more possibilities in the recoil simulation. The control of the electromagnetic field allows to modify the position and movements monitoring of the piston in the coil and course and size programming of the recoil force, which makes this recoil simulation system very adaptable to the various firearm types, such a pistols, assault rifles or machineguns. Whole system requires less maintenance as the pneumatic system and provides longer service life due to smaller amount of movable parts. [4]

Disadvantage of this system is in the impossibility to design it as the upgrade or a drop-in kit for real firearms. Due to this impossibility, electromagnetic recoil simulation systems are designed as an imitations of a real firearm types. Another disadvantage is in the mobility of whole simulation system due to relatively high power consumption. Accumulator capacity depends on its dimensions and therefore it's hard to get a suitable battery pack for a longer supplying of whole system.

Therefore a lot of this systems uses an external power source, connected to the imitation firearm through a cable. Trained shooter is in this case limited in movement and the range by the length of the cable. Prospect image of the electromagnetic recoil simulation system for the assault rifle, provided by the Haptech company is shown in the Fig. 2.

FIG. 2 Haptech electromagnetic recoil simulation system [4]

3. ASSAULT RIFLE TESTING

Data for the real firearm force diagram were obtained by the measuring on the Czechoslovakian assault rifle SA vz.58. As a sensor for the force measuring, Kistler, type 9051A, piezoelectric annular force-sensor with the measure range from 0 to 120 kN was used. Whole measurement was realized on the STZA 12 mobile firing rest and data were collected with a ballistic computer, see Fig. 3.

FIG. 3 SA vz.58 assault rifle on the firing rest

Five shots before the measurement were fired due to the rifle stabilization in the firing rest. Next five captured shots shows very similar courses after the rifle stabilization and only small deviations are present, which are caused by the ammunition properties. From this sight, this measurement can be considered as very trustworthy. Figure 4 shows the obtained force diagrams for this five shots.

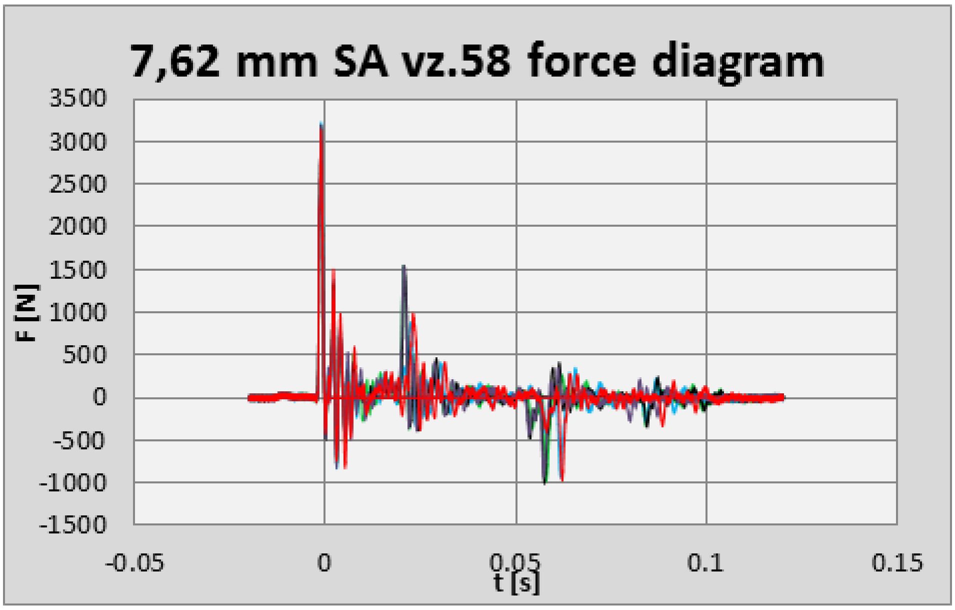

FIG. 4 Measured assault rifle force diagram

Zero time and data recording on the ballistic computer were triggered automatically by the pulse from the optical gate, generated in the point of the projectile crossing through the optical gate. The optical gate was situated 2 m from the barrel muzzle.

The first spike shows the force from the gun-shot itself, caused by the burning of a propellant. After the shot, the bolt carrier is forced to move backwards, unlock the chamber, and in its rear position impacts the receiver, which is represented by the second, smaller spike in the diagram. It's evident that the component of the gun's recoil force, caused by the impact of the bolt carrier in the rear position is comparatively smaller in the comparison with the effect of gun-shot itself.

After the impact, the bolt carrier is forced by the recoil spring to move forwards and in its front position locks the chamber and impacts on the front side of the receiver, which shows the third spike in the opposite direction. This impact is followed by the smaller impact, which shows the fourth spike and it is caused by the repeated impact of the bolt carrier in the front position.

4. MECHANICAL RECOIL SETUP TESTING

The schematics of the experimental, spring powered setup is shown in Fig. 5.

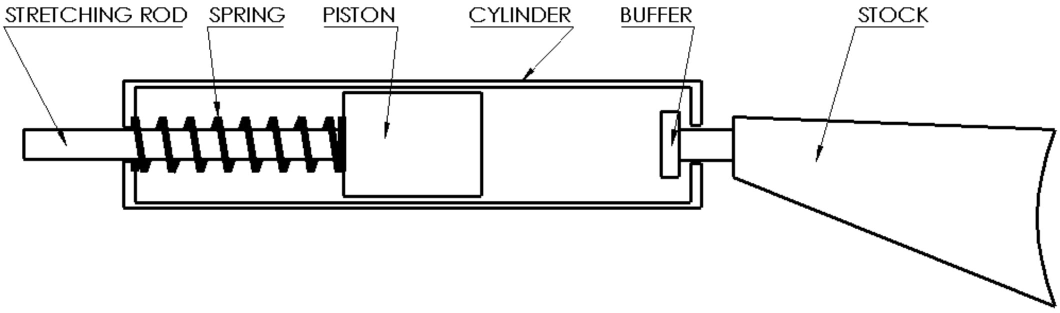

FIG. 5 Mechanical recoil setup schematics

Device consists from the movable piston of a diameter 45 mm with a spring within the closed cylinder. The function stroke of the piston in the cylinder is about 130 mm. The spring stiffness is 4.01 $N.mm^{-1}$ and mass is 142.5 g. In the back side of the cylinder a small movable buffer is inserted, directly connected to a firearm stock. There is a locking mechanism in the front side of the cylinder, which fixes the piston in the front position. The stretching mechanism is provided by the threaded stretch rod, connected with the piston. Four pistons of a different mass are available. The resulting mass of the moving parts in the simulator is given by the formula:

$$m_{mp} = m_p + m_{sr} + \frac{1}{3} m_s \qquad (1)$$

where m_p is the mass of piston,
m_{sr} is the mass of stretching rod and
m_s is the mass of the spring.

The individual masses of the movable parts in this configuration are 1321.5 g, 1383.5 g, 1444 g and 1501.5 g. A bronze was chosen as a material for the slip edges, due its better slip properties.

The final view of the experimental setup on the firing rest is shown in Fig. 6.

FIG. 6 Mechanical recoil setup on the firing rest

The measurement was realized with two different pistons with the weight 1321.5 and 1501.5 grams and the same firing rest STZA 12 with the Kistler 9051A force-sensor was used. Several free runs were realized before the measurement due to the device stabilization in the firing rest. Obtained force diagrams for the five runs with heavier piston are shown in Fig. 7.

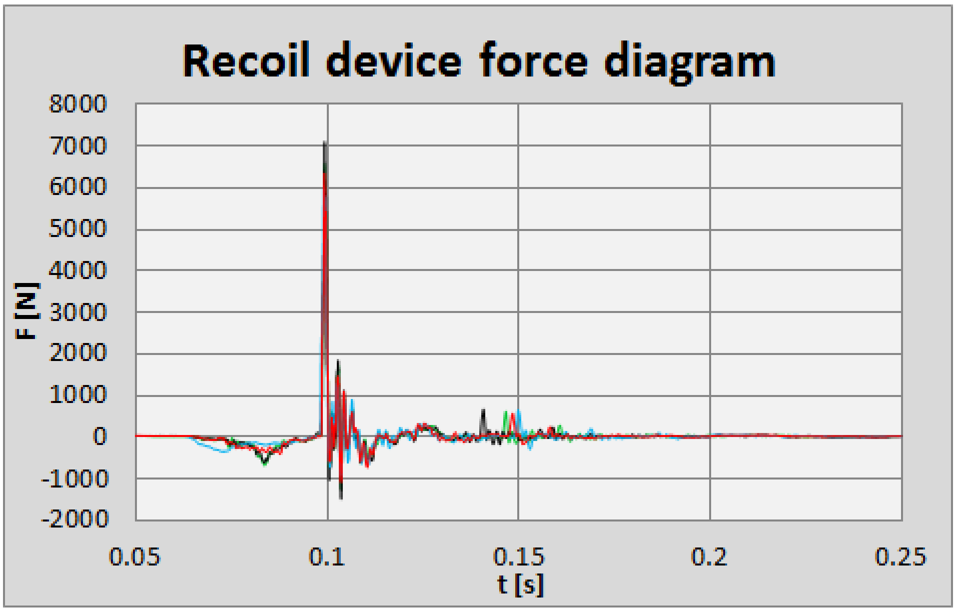

FIG. 7 Mechanical recoil device force diagram(heavier piston)

All captured force diagrams after the initial stabilization shows again almost identical courses, what makes this measurement representative and repeatable. Data capturing was started manually on the ballistic computer.

The straight line in the beginning of the diagram represents the reaction time of the experimental setup operator between the data recording activation and the point of the piston release in the experimental setup after its activation.

The next negative spike is caused by the acceleration of the the piston after its release, due to the closed, spring powered system. During the forced motion of the piston to its rear position, whole setup is forced by the spring to move in opposite direction. This effect is present in every pneumatic and electromagnetic recoil simulation system which uses a movable piston. Duration and the size of this pulse depends on the dynamics of the system and on the length of the piston stroke. Influence of this pulse on the shooter depends on the strength with which is the gun held and it can be very different between the different trained shooters.

The second spike in the diagram is caused by the impact of the piston on the buffer head in its rear position and via the stock is transferred on the arm of a shooter as a recoil pulse. Following small spike in the time about 150 ms is caused by the repeated impact after the reflection of the piston from the buffer head.

Figure 8 shows the five captured force diagrams for the device with the lighter piston installed. The measurement conditions were the same as in the previous measurement with the lighter piston.

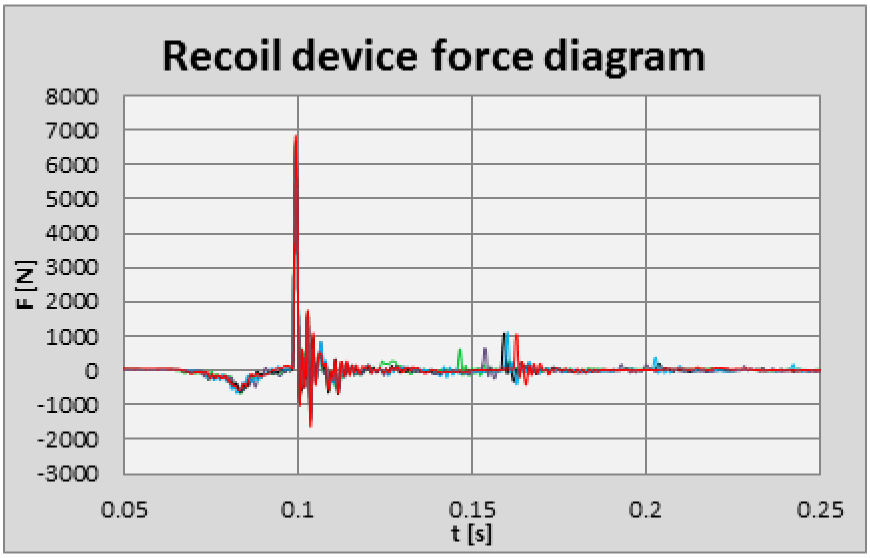

FIG. 8 Mechanical recoil device force diagram(lighter piston)

The course of the force is almost identical in this configuration and proves that the mass of the piston is not critical as expected in this conditions.

CONCLUSIONS

The presented mechanical experimental device represents a first phase in the research and development of the device for gun's recoil simulation, which should simulate the gun's recoil as close as possible. The measurement provided a refreshing results and shows that the mechanical impact of a relatively small piston can provide even bigger force effect than an ordinary assault rifle. In the future work, the spring powered mechanism will be replaced with the carbon dioxide used as a actuating medium. Interaction between the shooter and the firearm will also be studied.

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REFERENCES

[1]Dvorak Product listing and descriptions, *TRS Firearms training systems*, http://www.stressvest.com/pdfs/dvorak_tetherless.pdf [online, retreieved 9.3.2016];

[2] VirTra, *Standard recoil kits – Weapons Simulator*, http://www.virtra.com/tethered-recoil-kits/ [online, retrieved 28.2.2016];

[3] *Recoil simulation equipment*, http://eli.ee/products/1/recoil-simulation-equipment.html [online, retrieved 28.2.2016];.

[4] *Haptech product descriptions*, http://www.haptech.co/products [online, retrieved 2.3.2016].

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