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Specificity of Design and Action of The Weapon's Jump and Recoil Laboratory Test Stand

Łukasz SZMIT, Ryszard WOŹNIAK

Institute of Armament Technology, Faculty of Mechatronics and Aerospace,
Military University of Technology, 2 Gen. Sylwestra Kaliskiego St.,
00-908 Warsaw, Poland

Abstract. This paper presents the specificity of design and action of the weapon's jump and recoil laboratory test stand. This laboratory test stand is able to examine the weapon's jump and recoil of various small arms including technology demonstrators of the new Polish modular rifles (MSBS-5,56) built both in the classic layout and as a bull-pup. Modular rifles and the laboratory test stand were designed and manufactured during a research and development project financially supported by the Polish Ministry of Science and Higher Education from 2007 to 2011.
Keywords: mechanics, recoil, armament weapon's jump, laboratory test stand

1. INTRODUCTION

Military University of Technology from Warsaw in cooperation with the "Archer" – Radom Arms Factory LLC completed the research and development project No O R00 0010 04 (financially supported by the Polish Ministry of Science and Higher Education) in June 2011. The main aim of this project was to build, manufacture and test technology demonstrators of modular rifles cal. 5,56 mm (MSBS-5,56) which may become an armament of the Polish Armed Forces.

One of the main tasks of this project was the versatile studies of these rifles. A need of optimising the rifle's recoil characteristics appeared during the work.

However analyses showed that the ballistic pendulum (the equipment currently used to examine the weapons recoil) does not meet the requirements. Therefore designing a new modern and original laboratory test stand was necessary.

2. REQUIREMENTS FOR LABORATORY TEST STAND

A laboratory test stand is used to measure parameters connected with the recoil of the MSBS-5,56 modular rifles built both in the classical layout and as a bull-pup. The test stand may be also used to examine various types of firearms similar in size to the MSBS-5,56. The requirements for the test stand were made before the construction work started. The final shape of the test stand was determined by both the characteristics of examined weapons and the character of the measured parameters. Due to that, the theoretical description of the examined phenomenon was the first stage of the work.

The weapon's reaction to the shoot was divided into three components – recoil, the weapon's jump and turn. A mathematical model [1,3,4] and a simulation program of each phenomenon were created in the next step. The simulation results were presented in several articles [1,5]. Those results showed that the test stand should be able to measure the parameters of the recoil and the weapon's jump. Measuring the weapon's turn appeared to be unnecessary due to the insignificant values of this parameter. The test stand should be capable to test MSBS-5,56 modular rifles built both in the classical layout and as a bull-pup. The test stand should also allow us to test other firearms similar with the dimensions to the MSBS-5,56. In particular the test stand should be able to measure:

- recoil distance – no less than 100 mm,
- weapon acceleration – in the range of ±3000*g*,
- recoil force – in the range of 3 kN,
- weapon jump angle – in the range of 35°.

3. PROJECT OF THE TEST STAND

The laboratory test stand was designed in accordance with accepted requirements. During the designing process CAD programs like the Solid Works were widely used [2]. 3D models of the test stand's components and an assembly of the complete test stand was made during that process. 3D models of the examined weapon were also made and used.

A weapon mounted on the test stand was placed on its side, this makes operating the weapon easier. This also allows making the construction of the test stand less complicated. According to the design the test stand can be set in three configurations:

- for measuring recoil distance and accelerations of the weapon,
- for measuring weapon's angle and speed,
- for measuring recoil force.

The weapon's recoil and jump parameters are measured separately for several reasons. First of all it is hardly possible to measure them at one time because when the weapon is supported for measuring recoil force there will be no recoil distance at all. Similarly measuring recoil distance and weapon jump at the same time will be very difficult because recoil will reduce the weapon's jump. And last, but not least a weapon mount providing more than one degree of freedom would be very complicated and could affect examined phenomenon.

The test stand consists of the base with the guides and changeable elements used to mount the examined weapon and the sensors. The test stand prepared for measuring the recoil distance and acceleration of the weapon is equipped with the butt holder, front and rear carts, the barrel holder and the position sensor base. Laboratory test stand set in this configuration is shown at Fig. 1.

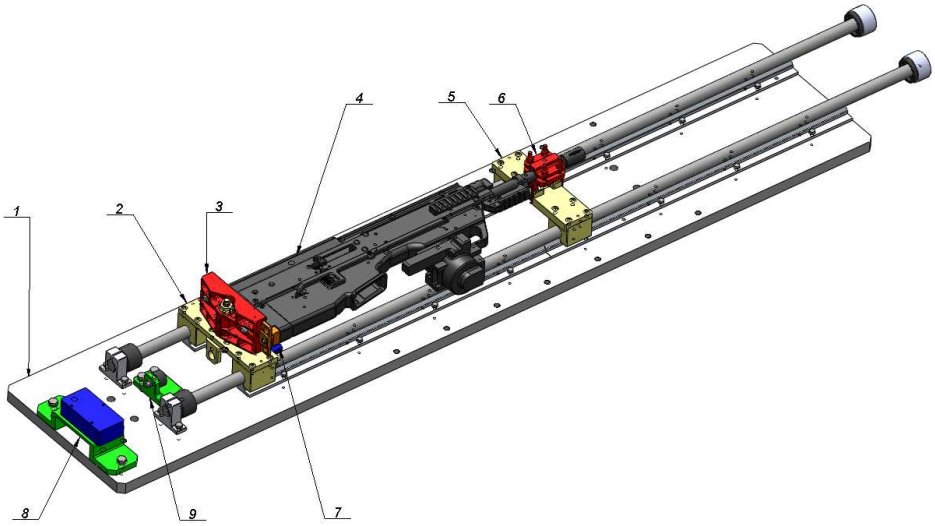

Fig. 1. Test stand set for measuring the recoil distance and the weapon's acceleration:
1 – base, 2 – rear cart, 3 – butt holder, 4 – examined weapon, 5 – front cart,
6 – barrel holder, 7 – acceleration sensor, 8 – position sensor base with the sensor,
9 – force sensor base with the shock-absorber

The base is a massive steel plate with the guides and the force sensor base. The base can be fixed by the screws and special montage elements to the Prototypa STZA 13 gun mount. The base has several sets of threaded holes.

They are used to fix the position sensor base, the turn axis base and the table used to measure the weapon's jump parameters. A set of smooth holes are used to fix the test stand to the ground or STZA 13 gun mount.

The rear cart is equipped with two linear bearings which allow it to move along the guides. Bearings are fixed to the cart's body. The cart's body has sockets for the acceleration and force sensors. The spigot for fixing the butt holder is placed on the top of the cart's body.

The butt holder is adjusted to hold the butt of MSBS-5,56 rifle built in a classical layout. The butt holder is also able to hold (with the help of a special montage element) the receiver of MSBS-5,56 bull-pup rifle. A hole used to fix the butt holder on the rear cart (or on the turn axis) is placed in the rear part of the butt holder. The butt holder placed on the rear cart is fixed with a nut, and a clamp.

The front cart is similar to the rear cart and it is adapted to fix the barrel holder. The fixing height of the barrel holder can be adjusted to the weapon's size and barrel thickness.

Using the proper fixing elements and adjustment capabilities of the test stand allows examining different models of firearms similar with size to the MSBS-5,56 rifles.

A position sensor is placed on the base fixed with screws to the test stand's base. The mirror for the laser beam of the position sensor is at the rear surface of the rear cart.

Discharge is initiated by the electric trigger. The trigger is fixed to the examined weapon instead of the grip and presses the weapon's trigger with a lever.

The weapon fixed to the test stand is able to move along the guides. Activation of the electric trigger causes discharge. Recoil force that is generated during the discharge gives the velocity of the examined weapon. The position and acceleration sensors are measuring the weapon's recoil parameters (recoil distance and acceleration of the weapon) when the weapon moves. The weapon is stopped by the shock absorbers on the end of the guides and the force sensor base.

Measuring the recoil force is possible with use of a force sensor. The force sensor is mounted on the force sensor base in the place of the removed shock absorber. Fig. 2 shows the test stand set for measuring the recoil force. The examined weapon doesn't move when the recoil force is measured. The rear cart is fixed to the base by the force sensor.

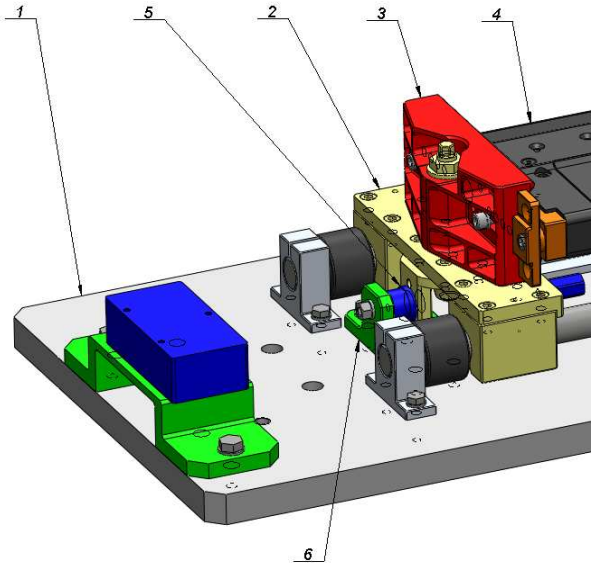

Fig. 2. Test stand set for measuring the recoil force:
1 – base, 2 – rear cart, 3 – butt holder, 4 – examined weapon, 5 – force sensor,
6 – force sensor base

A major modification of the test stand is needed to set the test stand for measuring the weapon's jump. The table supporting the weapon's barrel during the weapon's jump must be fixed to the base of the test stand. The table is placed in a position proper to the length of examined weapon. The test stand set for measuring the weapon's jump parameters is shown on Fig. 3.

The barrel of the tested weapon is placed in the barrel holder and fixed to the transverse cart. The connection between the transverse cart and the barrel holder allows the adjustment of the stand to the different width of the tested weapons. The transverse cart has two rolls rolling on the table.

The position sensor base must be removed to set the test stand for measuring weapon's jump parameters. The turn axis base with the encoder is mounted in its place. The turn axis base is equipped with an axis designed to support the butt holder. The encoder connected with the turn axis is mounted inside the turn axis base.

A weapon placed on the test stand is able to turn around the turn axis. The possible weapon jump angle measurements range depends on the weapon's length. The test stand allows to measure the weapon's jump angle in a range of 36° for the MSBS-5,56 rifle built in the classical layout and in a range of 48° for MSBS-5,56 bull-pup.

The electric trigger causes a discharge. The turning momentum (weapon's jump) occurs when the direction of reaction forces do not cross the turn axis. The encoder mounted in the turn axis base measures the weapon's jump angle.

The butt holder allows the adjustment of the weapon's fulcrum. This makes it possible to study and rate the influence of the fulcrum position on the weapon's jump.

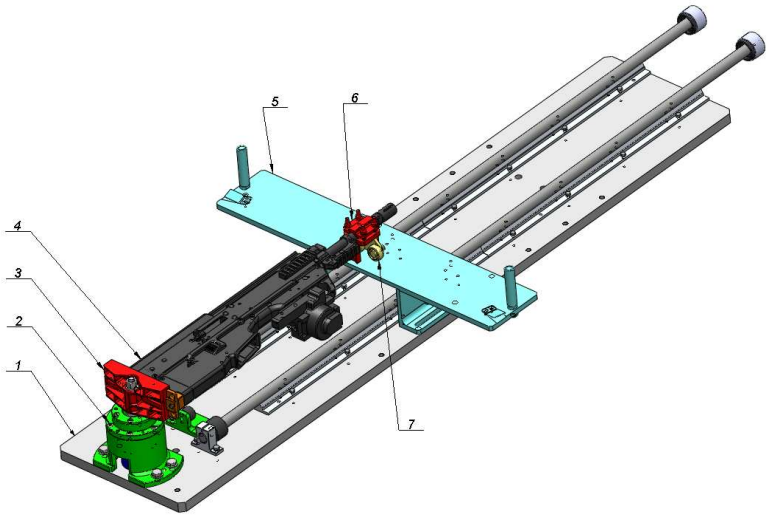

Fig. 3. Test stand set for measuring the weapon's jump angle:
1 – base, 2 – turn axis base with the encoder, 3 – butt holder, 4 – tested weapon,
5 – table, 6 – barrel holder, 7 – transverse cart

4. TEST OF THE STAND

The laboratory test stand was made by the „Archer" – Radom Arms Factory LLC with the use of blueprints made by the Department of Special Design from the Military University of Technology. Fitting of the main parts and mobility of carts and the turn axis was checked during the stand assembly.

The checked test stand was placed on the STZA 13 base. Then the sensors were mounted in their sockets. After that the possibility of the movable components collision with the sensors was checked. Finally the test stand was set for measuring recoil distance and the weapon's acceleration.

The tested weapon was placed on the prepared test stand. The live fire tests started after assurance that the weapon was properly fixed to the test stand. The ready to fire test stand is shown on Fig. 4. The next stage of the tests was setting the test stand for measuring the recoil force and checking the test stand in this configuration. The test stand set for measuring the recoil force is shown in Fig. 5.

After finishing the tests with a rifle built in the classical layout the test stand was checked and prepared to mount a rifle built as a bull-pup.

Then the test procedure was repeated. The test stand action was recorded by a video camera and a fast camera.

Live firing tests showed that the test stand works correctly and the sensors were recording proper parameters.

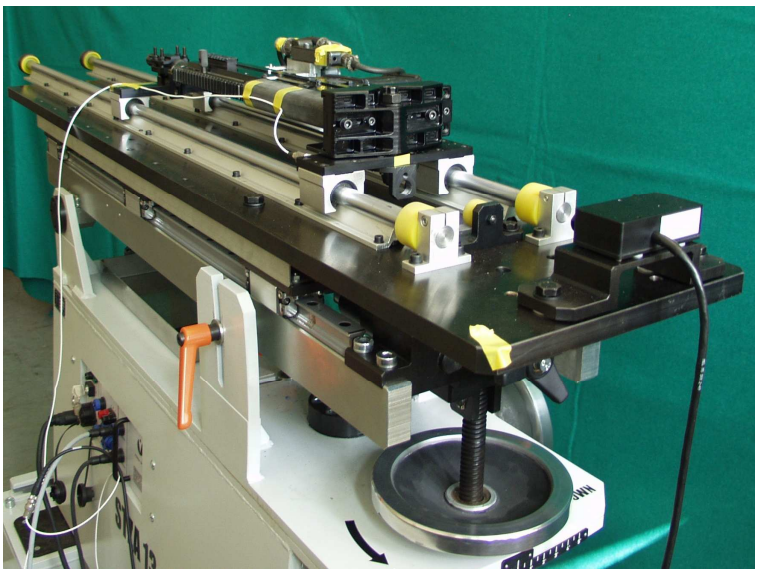

Fig. 4. Test stand placed on the STZA 13 gun mount and ready for measuring recoil distance and weapon's acceleration

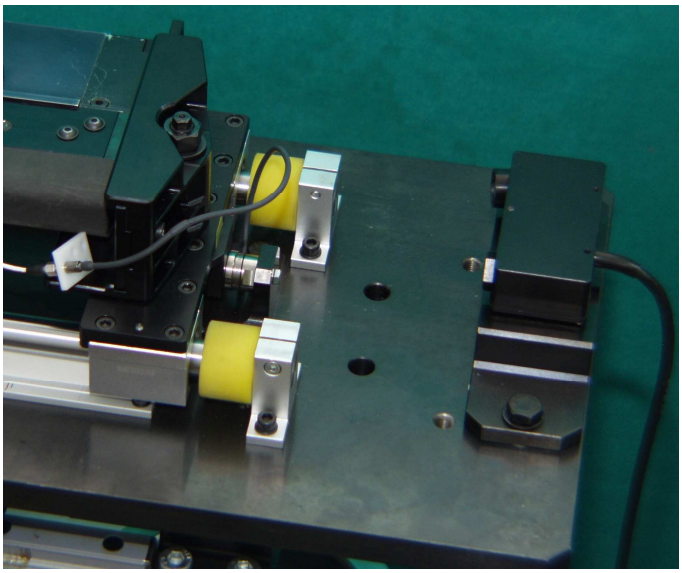

Fig. 5. Rear part of the test stand set for measuring the recoil force

After the tests of the stand set for measuring recoil parameters, the test stand was rebuilt for measuring the weapon's jump parameters. The test stand set for measuring the weapon's jump parameters is shown on Fig. 6. Live firing test in this configuration included shooting in chosen positions of the weapon fulcrum. Life firing tests in this configuration were made both with the rifles built in the classical layout and with a bull-pup. This allowed the examination of the test stand in all conditions.

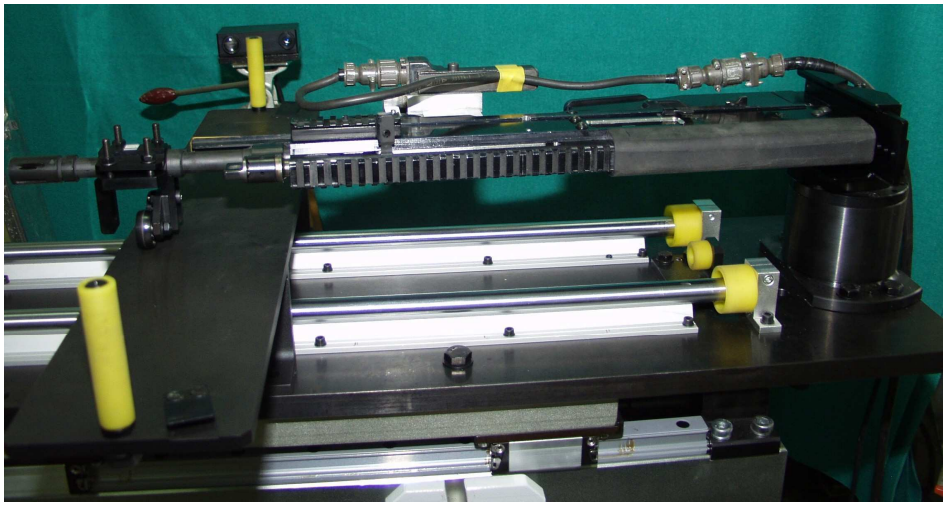

Fig. 6. Test stand placed on the STZA 13 gun mount and ready for measuring weapon's jump parameters

Data gained by the test stand sensors can be used to create the weapon's jump and recoil characteristics. Fig. 7, 8 and 9 presents example recoil and weapon's jump characteristics created with data from the test stand sensors.

Characteristics shown in Fig. 7 (recoil distance and weapon's acceleration versus time) proved that the moving parts of the weapon were affecting the recoil. Two characteristic points can be seen on the recoil distance characteristics. The first one refers to the slide's hit into the receiver at the rear position, the second refers to the slide's hit into the receiver at the return.

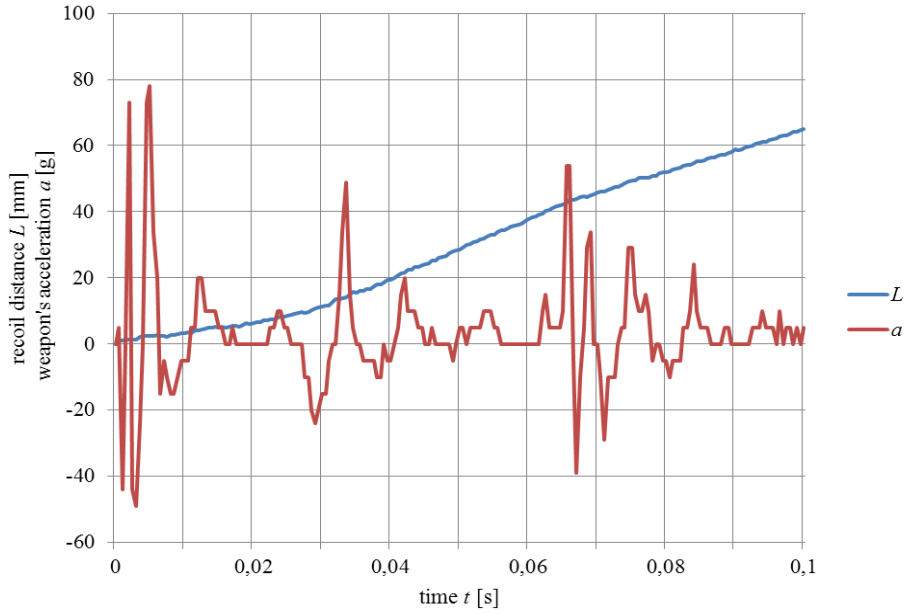

Fig. 7. Recoil distance *L* and weapon's acceleration *a* vs. time *t*

The weapon's acceleration characteristics also shows slide's hit with the receiver – peaks at the same time as characteristic points on the recoil distance characteristic. High values of the acceleration in the beginning of the recoil are referred to the period when the weapon's bolt is closed and the pressure inside the barrel powers the weapon.

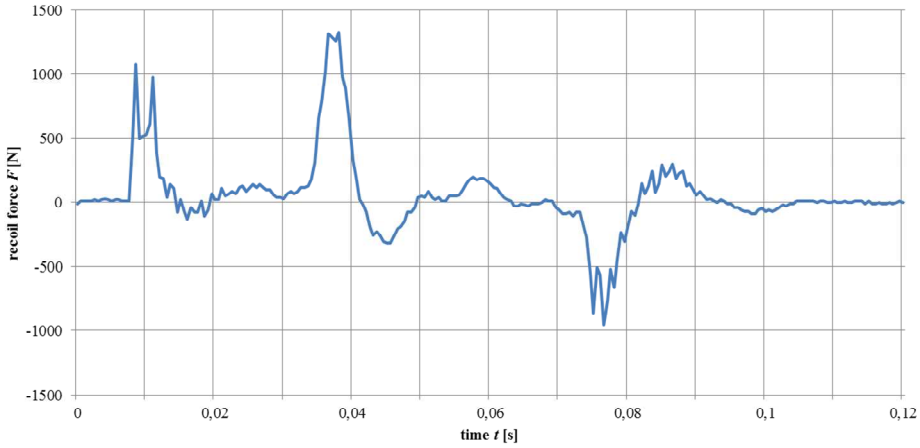

Fig. 8. Recoil force *F* vs. time *t*

Recoil force characteristics (Fig. 8) show three peaks. The first refers to the period when the bolt is closed and the pressure inside the barrel powers the weapon. The second peak refers to the slide's hit into the receiver at the rear position. The third peak refers to the slide's hit into the receiver at the return. The third peak has minus values because the slide hitting the receiver is trying to move the weapon forward.

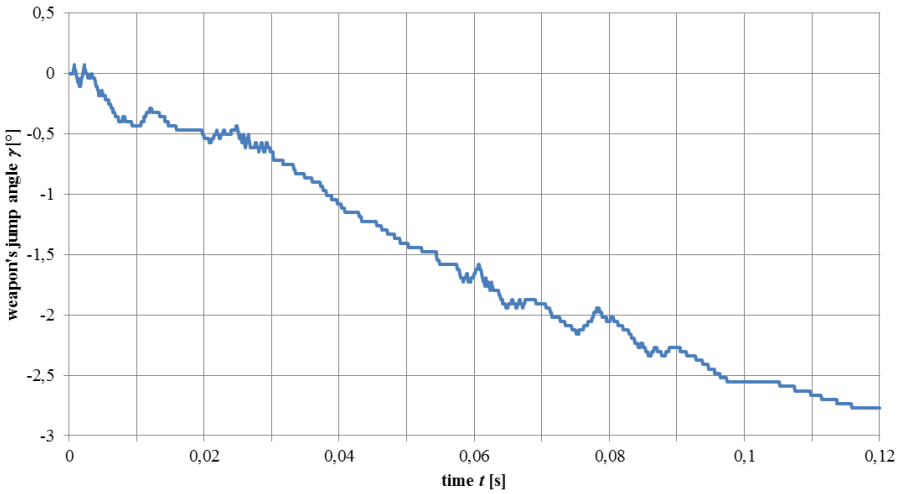

Fig. 9. Weapon's jump angle γ vs. time t

Weapon's jump angle characteristics (Fig. 9) show two characteristic points. The first one refers to the slide's hit into the receiver at the rear position. The second refers to the slide's hit into the receiver and the return.

5. SUMMARY

1. Able to measure parameters of the recoil and the weapon's jump laboratory test stand was made as part of the research and development program no O R00 0010 04. Preliminary test showed that the test stand meets the requirements and is able to examine the phenomenon connected with recoil.
2. Due to the unique design of the test stand it is patent protected by the Polish Patent Office (Patent nr P396750).
3. Further works will concentrate on examining recoil and weapon jump parameters of different weapons and verifying mathematical models of the recoil and weapon's jump.

REFERENCES

[1] Surma Z., Szmit Ł., Torecki S., Woźniak R., Simulations of weapon turn by example 5,56 mm automatic carbine, *Proceedings of the VIth International Symposium On Defence Technology*, 5-6 May 2010, Budapest, p. 921-932, BJMTF, Budapest, 2010.

[2] Szmit Ł., Woźniak R., Usage of CAD/CAM software in the firearms test stand design process *(in Polish)*, *Proceedings of the XVth International School of CAD/CAM/CAE*, 9-13 May 2011, Jurata, vol. 2, p. 341-348, Warsaw, 2011.

[3] Szmit Ł., Torecki S., Mathematical model of the gas operated carbine recoil (*in Polish*), *Proceedings of the VIIIth International Armament Conference on Scientific Aspects of Armament & Safety Technology*, 6-8 October 2010, Pułtusk, p. 921-932, Warsaw, 2010.

[4] Surma Z., Szmit Ł., Torecki S., Woźniak R., Mathematical model of gas operated weapon jump (*in Polish*). *Problems of Mechatronics. Armament, Aviation, Safety Engineering*, no 2(2) 2010, p. 51-63, Warsaw, 2010.

[5] Surma Z., Szmit Ł., Torecki S., Woźniak R., Chosen results of the simulations of gas operated carbine constructional parameters influence on the recoil and the jump of the weapon (*in Polish*), *Problems of Mechatronics. Armament, Aviation, Safety Engineering*, no 2(4) 2011, p. 73-84, Warsaw, 2011.

[6] A Jęczmyk, Ł. Szmit, R. Woźniak, Polish patent no P.396750 – Weapon's Jump and Recoil Laboratory Test Stand.