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Experimental Investigations of Motion of Slide of Selected Pistol Types

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Abstract. In the presented paper, kinematic characteristics of movable parts of investigated pistols have been experimentally determined with application of high speed camera and appropriate software TEMA motion. Results of measurements can be useful in validation of various theoretical models and can reveal the influence of some technical solutions on parameters of motion of selected parts. Obtained curves presenting dependence of slide velocity versus time, allowed for rough estimation of average value of interaction force between slide and frame of the investigated construction. The results of study highlights advantage of HK USP pistol design. The achieved results are from reduction of the value of the mentioned interaction force (approximately 50%) due to elongation of the most intensive phase of slide motion damping process.

Keywords: mechanics, pistol slide motion, fast camera measurements, experimental investigations

1. INTRODUCTION

Modern battle field imposes development tendency in area of weapon evolution. Due to this reason, it is important to apply modern computational techniques during design and optimization of construction of weapon systems in order to shorten and improve the efficiency of the whole process. Unfortunately, before application of the mentioned techniques in the design process, the proposed approach should be sufficiently validated in order to estimate the physical accordance of the investigated model with a real object [1]. To conduct correct validation of a numerical model, reliable experimental results should be provided. In modelling of weapon system elements, one of the most useful validation data, seems to be kinematic characteristics of movable elements of gun. These parameters are relatively easy to measure and provide important parameters describing kinematic state of parts, which can be easily compared with numerical results. Obviously, after sufficient mathematical operations, these parameters can also ensure information about the dynamic state of a system, which can be useful during validation of models of interior ballistics phenomena or interaction between gun and user, which has crucial meaning during the design stage of weapon devices [2, 3].

There is lack of mentioned data in available papers, so the main aim of the presented work is to provide kinematic characteristic of movable parts (in the investigated case – slide) for several popular types of pistols available in various armed formations in the World and on civilian market.

2. EXPERIMENTAL SET – UP

Measurements of the investigated values have been conducted at the Ballistics Laboratory of Faculty of Mechatronics and Aerospace of the Military University of Technology in Warsaw.

The experimental set – up consisted of the following devices:

- investigated gun;
- high speed camera Phantom v12;
- ballistic mount;
- precision light screen B-470 for velocity measurement;
- personal computer with appropriate software – TEMA motion.

In order to implement high speed camera in a process of estimation of kinematic characteristics of parts, appropriate markers have been applied to the movable surfaces.

Used software allows for determination of displacement of selected point (in our investigations – applied markers) as a function of time [4]. The view of crucial elements of a measurement set – up is presented in Fig. 1. In order to obtain mass properties of parts, RADWAG PS 6000/X weight was used.

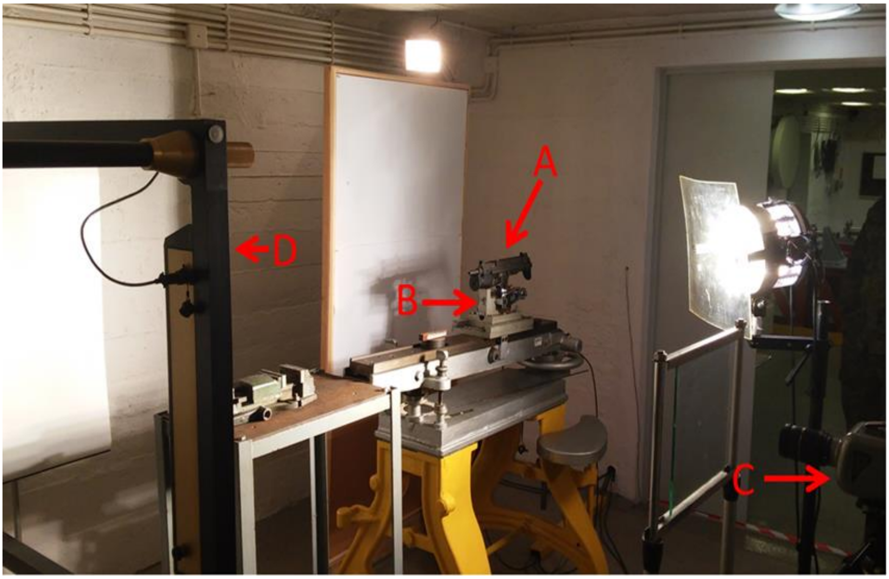

Fig. 1. Measurement set – up (A – investigated pistol, B – ballistic mount, C – high speed camera, D – precision light screen B-470)

3. SHORT DESCRIPTION OF INVESTIGATED HANDGUN TYPES

As a part of the study, the following types of pistols have been investigated:

- Austrian Glock 17;
- German Walther P – 99;
- Swiss SIG Sauer P226;
- German Heckler & Koch USP;
- Croatian HS9;
- Czech CZ – 75;
- Belgian FN Five – seveN.

Basic technical data of the above – presented types of gun are summarized in Table 1.

Table 1. Basic technical parameters of the investigated pistols [5]

Parameter	Glock 17	P – 99	P226	USP	HS – 9	CZ – 75	Five – seveN
Cartridge	9 x 19 mm Parabellum						5.7 x 28 mm
Muzzle velocity [m/s]	375*	408*	350*	340*	340*	360*	650*
Total length [mm]	186	180	196	196	180.5	206	208
Barrel length [mm]	114	102	112	112	102.5	120	122.5
Weight (unloade) [kg]	0.625	0.630	0.750	0.720	0.705	0.900	0.610
Slide weight [kg]	0.363**	0.339**	0.349**	0.334**	0.330**	0.315**	0.256
Barrel weight [kg]	0.114	0.093	0.138	0.106	0.097	0.098	0.109****
Movable parts weight*** [kg]	0.477	0.432	0.487	0.44	0.427	0.413	0.365****

* Value of muzzle velocity depends on applied bullet
** Author's measurements
*** For locked, short recoil systems, it is a sum of the barrel weight and the slide weight. For blow – back system – it is only the slide mass
**** In the case of Five – Seven, the barrel is connected with the recoil spring system, which introduces an overstated value of mass)

4. RESULTS

Available software allows for determination of the movable parts velocity and the displacement relatively to frame of a gun. Seven tests with application of 9 mm MESKO and 5.7 mm ammunition (Table 2), for each 9 mm and 5.7 mm handgun type were conducted.

Additional uncertainty to results of measurement is introduced due to elastic deformations of frames and gun's jump. This is the effect of imposing of reference system coincided with characteristic points of a gun frame, which was intended to ensure parallelism of selected axis with slide motion direction.
In Table 3, the results of bullet velocity measurements were presented.

Table 2. Technical characteristics of 9 mm MESKO and 5.7 mm pistol ammunition [5, 6]

Parameter	**Value for 9 mm MESKO ammunition**	**Value for 5.7 mm ammunition**
Caliber	9 mm Parabellum Luger	5.7 x 28 mm
Bullet type	Full Metal Jacket (FMJ)	Full Metal Jacket (FMJ) SS190
Bullet weight [g]	8	2.1
Propellant mark / weight [g]	N340 / 0.34	N/A
V_{10} velocity [m/s]	350	650
E_{10} kinetic energy [J]	490	444
Barrel length [mm]	200	122
Maximum pressure [MPa]	260	345

Table 3. Measured values of the bullet's velocity in the distance of 3 m from the muzzle

Test No	**Velocity V_3 [m/s]**						
	Glock 17	**P – 99**	**P226**	**USP**	**HS – 9**	**CZ – 75**	**Five – seveN**
1	353.9	337.0	335.3	349.8	341.8	341.6	614.1
2	334.1	345.7	333.9	340.9	341.4	332.9	605.3
3	338.6	345.1	339.8	348.0	339.5	333.2	602.2
4	341.3	340.8	342.7	340.8	331.2	334.1	612.9
5	332.4	343.9	347.2	346.4	342.1	331.3	612.7
6	344.3	341.6	337.7	343.3	341.2	326.4	608.3
7	349.0	351.8	347.7	341.9	345.1	332.2	613.9
Average	341.9	343.7	340.6	344.4	340.3	333.1	609.9
Min	332.4	337.0	333.9	340.8	331.2	326.4	602.2
Max	353.9	351.8	347.7	349.8	345.1	341.6	614.1

In order to investigate a level of repeatability of the recorded values for the investigated pistol types, the results of the slide velocity measurements were presented in Figs. 2-8.

a b

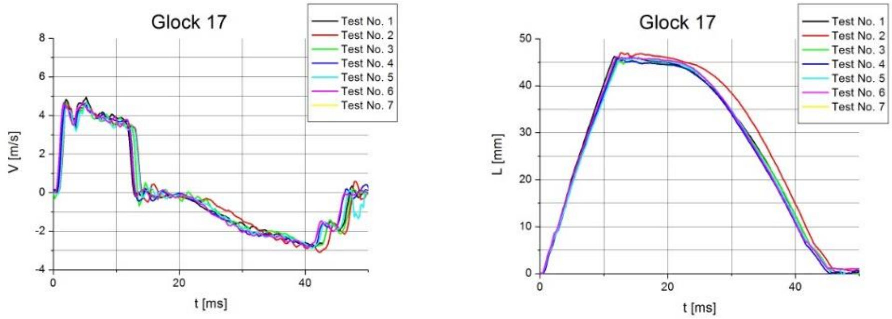

Fig. 2.Experimentally obtained kinematic characteristics of Glock 17 pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

a b

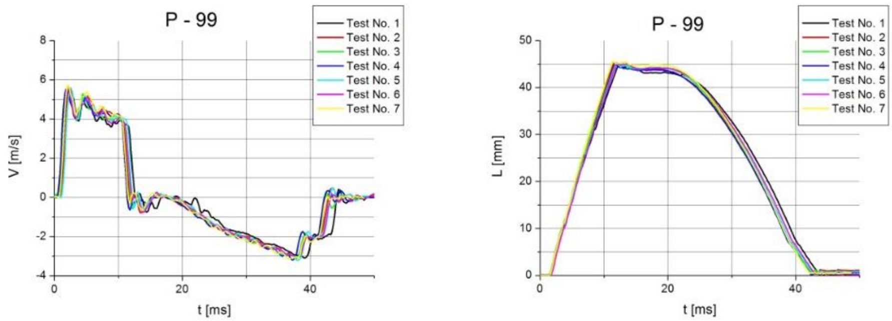

Fig. 3. Experimentally obtained kinematic characteristics of Walther P – 99 pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

a b

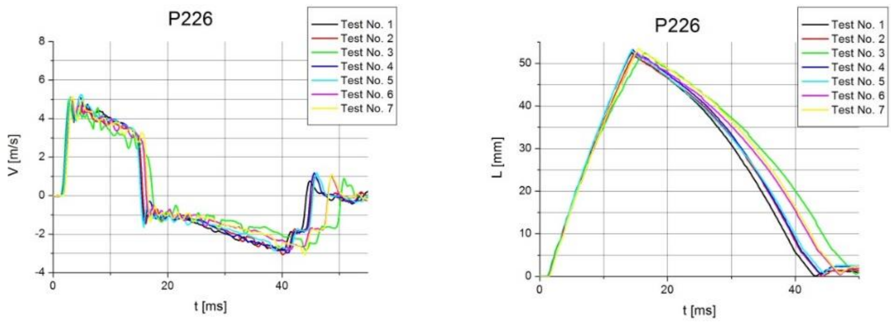

Fig. 4. Experimentally obtained kinematic characteristics of Sig Sauer P226 pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

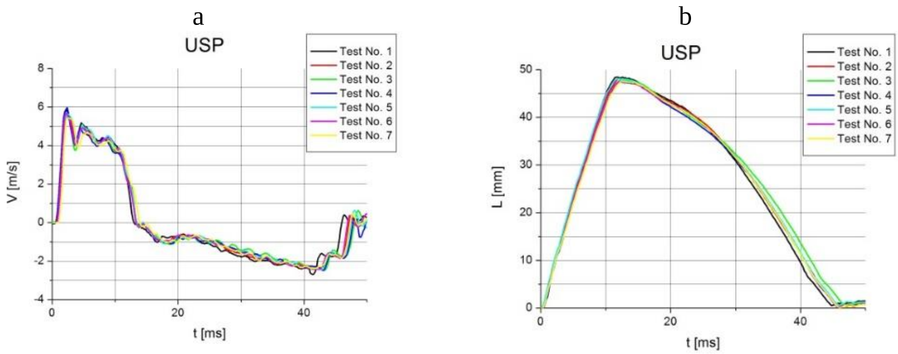

Fig. 5. Experimentally obtained kinematic characteristics of HK USP pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

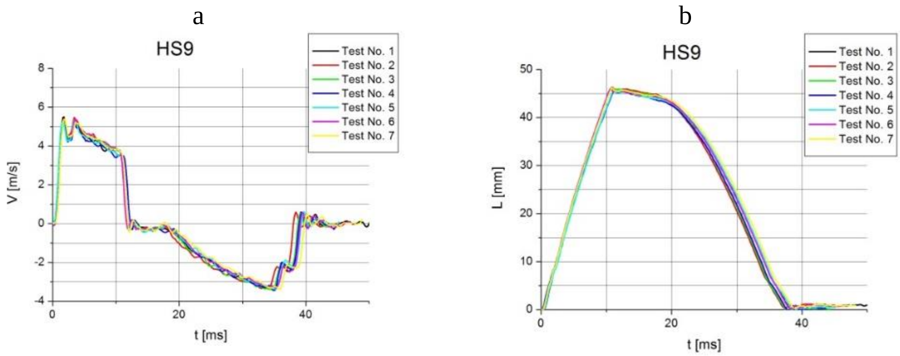

Fig. 6. Experimentally obtained kinematic characteristics of HS9 pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

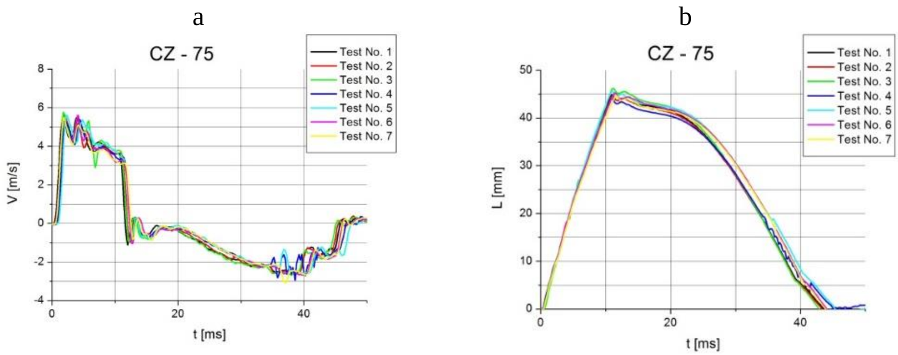

Fig. 7. Experimentally obtained kinematic characteristics of CZ – 75 pistol
(a – slide velocity vs. time; b – slide displacement vs. time)

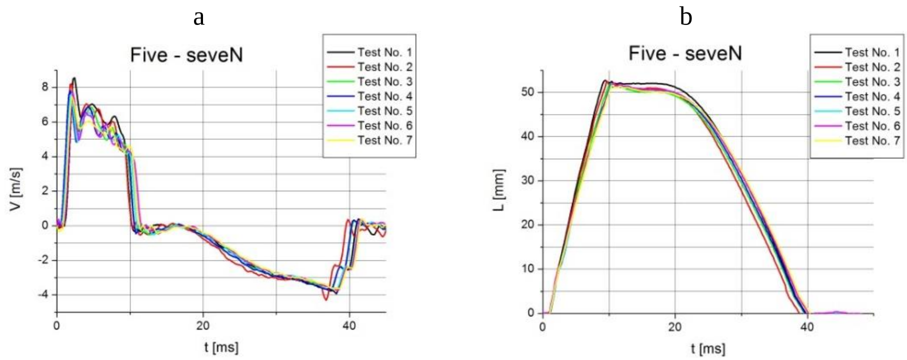

Fig. 8. Experimentally obtained kinematic characteristics of FN Five – seven pistol (a – slide velocity vs. time; b – slide displacement vs. time)

Taking into account acceptable level of the results' repeatability, it is reasonable to select representative dependence of slide velocity on time for each studied model and compare selected curves in one figure (Fig. 9). This comparison is aimed to show the divergence between work cycles of the investigated models.

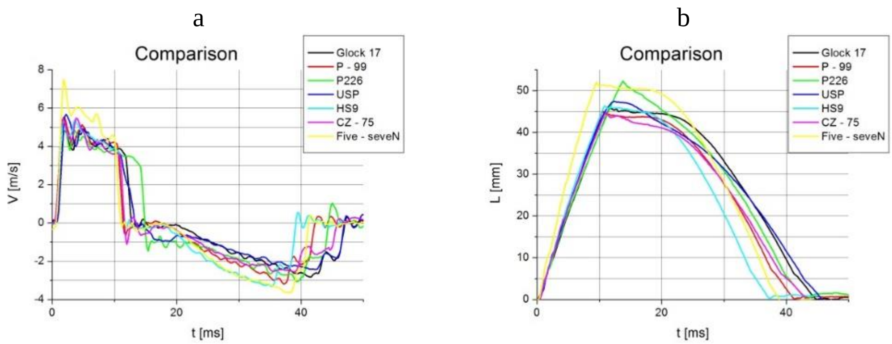

Fig. 9. Comparison of experimentally obtained kinematic characteristics of investigated pistol models (a – slide velocity vs. time; b – slide displacement vs. time)

As it can be seen, the measured values of slide velocity, for all studied 9 mm models, are on a similar level. The same parameter for investigated 5.7 mm pistol amounted approximately 35% more.

The above – presented values of the velocity and the slide mass allow for determination of the momentum transferred to the gun's frame and user. As shown in the above – presented Figures, slide damping process can be divided into two phases.

Second one (final phase) is much more intensive and it seems to have crucial influence on shooting stability and a level of comfort during shooting.

Calculated values of momentum change for pistols slides during impact into shock absorbing element (mentioned second phase of damping) have been summarized in Table 4.

Table 4. Estimated values of dynamic parameters of recoiled system

Pistol model		**Change of velocity [m/s]**	**Change of momentum [kg·m/s]**	**Process time [ms]**	**Average force [N]**
Glock 17		3.60	1.31	1.2	1089
P – 99		4.62	1.57	1.2	1305
P226		4.37	1.53	1.6	953
USP		3.92	1.31	3.4	385
HS9		4.08	1.35	1.6	842
CZ – 75		4.46	1.40	1.6	878
Five – seveN		4.51	1.15	1.6	720

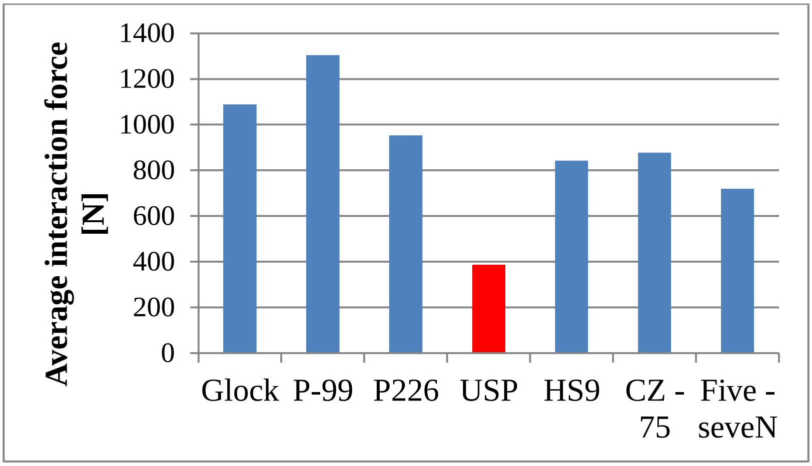

Fig. 10. Comparison of estimated interaction force for investigated pistols.

The above – presented values show noticeably reduced value of force acting on a user in case of HK USP pistol (Fig. 10), which is the result of significantly longer time of slide motion damping stage (over two times longer). The reason of the described effect is the fact of application of specific recoil damping system.

5. CONCLUSIONS

The conducted measurements of the slide displacement characteristics of the selected pistols models provide data for numerical models validation. Moreover, as a result of measurements and calculations, a rough estimation of the force acting between slide and gun's frame was obtained. Glock 17, Walther P – 99 and Sig Sauer P226 were characterized by damping force on the level of 1000 N. It should be noted, that in the considered group, the greatest value of momentum is transferred in the case of P – 99 and P226 (over 16% more than in the case of Glock).

Other studied constructions, except HK USP, are characterized by similar values of interaction force on the level of 800 N. USP, due to its unique technical solution, ensures the low level of the force, which results in a "smooth" interaction between a gun and a user. Main reason for so significantly reduced recoil force is that HK USP uses a captive dual spring recoil assembly. The larger outer spring serves as the primary recoil spring. Nearly at the end of recoil, the inner spring is engaged as a recoil buffer.

Taking into account different external designs of the investigated models and the divergence in the level of ergonomics, the obtained results should not be the main argument in a process of choosing a pistol predestined to the individual usage.

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