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Study of Friction Between Breech Block Carrier and Receiver Assembly in Amphibious Rifle

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***Abstract*—The paper deals with the analysis of the friction force between the breech block carrier and receiver assembly in the amphibious rifle when firing in air and firing underwater by experimental method. Besides, the coefficient of friction between the breech block carrier and receiver assembly in two environments is determined. The influence of material composition, normal force and firing environment on the friction force between them is carried out. The results of this research can be applied to dynamic analysis of automatic weapons mechanism and design the underwater rifle and amphibious rifle.**

Keywords-coefficient of friction; breech block carrier; receiver assembly; amphibious rifle

I. INTRODUCTION

Amphibious rifles are designed for using in two environments water and air. They are being utilized in armed forces of various nations. However, the research about these rifles is poor, especially the problem of the friction between the breech block carrier and receiver assembly to dynamic analysis of automatic mechanism and design the underwater rifle and amphibious rifle, see [1].

Compared to friction research between the breech block carrier materials and the receiver assembly in the amphibious rifle, we encounter many difficulties connected with the material properties of weapon parts with conventional materials, [2], [3]. In addition, there exists a thin water layer between breech block carrier and receiver assembly when firing under water. It inhibits direct contact between breech block carrier and receiver assembly, thereby, replaces dry friction with liquid friction. Moreover, in this water layer has impurities in solid. So, it is difficult to determine this friction by calculating way. A better way is to use an experimental procedure.

To solve this problem, the content of the paper presents an experimental method to investigate the friction between the breech block carrier and receiver assembly in the amphibious rifle when firing in air and under water. The purpose of the article to solve two problems as follows:

- Determine the coefficient of friction between the breech block carrier and receiver assembly in the amphibious rifle when firing underwater and in air;

- Investigation of the influence of material, normal force and firing environment on the friction between the breech block carrier and receiver assembly in the amphibious rifles.

II. FRICTION MODEL FOR SLIDING CONTACTS BETWEEN BREECH BLOCK CARRIER AND RECEIVER ASSEMBLY TO EXPERIMENT

A. *Features of friction between breech block carrier and receiver assembly*

In the operation of automatic machine in amphibious rifle, the breech block carrier slide on the receiver assembly causes friction force, see Fig. 1. This friction force impedes the motion of breech block carrier assembly and it is a very important parameter to investigate the dynamics of mechanisms automatic weapons, see [4].

The problem is more comlicated from calculation point of view because forces exerted by the gas pressure, springs, case extraction, ejection, and others do not always act on the centre of gravity of the moving components. The dynamic couple that this causes increases the passive resistances to movement of the components and affects the movement of the weapon mechanisms during firing, see [5], [6].

According to the general theory of friction, see [7], [8], the friction force has the following characteristics:

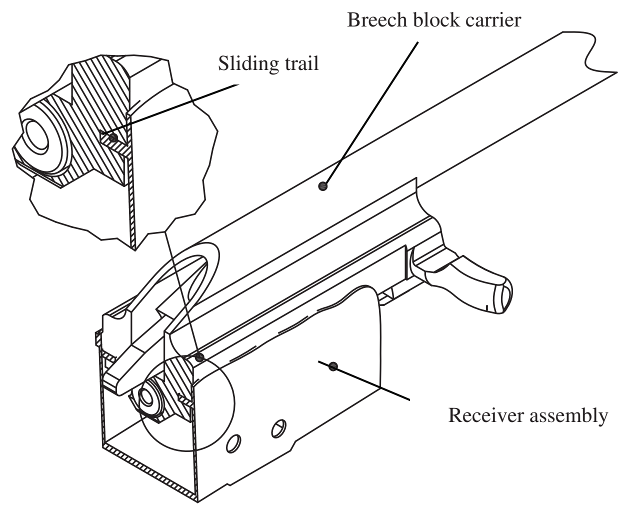

Figure 1. The drawing of amphibious rifle and schematic diagram of the contact between breech block carrier and receiver assembly.

- The friction force is proportional to the normal contact force:

$$\left|\overrightarrow{F_R}\right| = \mu \cdot \left|\overrightarrow{N}\right| \quad (1)$$

The coefficient μ is called the coefficient of friction. Often two values of μ are quote: the coefficient of static friction μ_s, which applies to the onset of sliding and the coefficient of kinetic friction μ_k, which applies during sliding motion. In Fig. 2 there is the F_{R_S} static friction and the F_{R_K} kinetic friction.

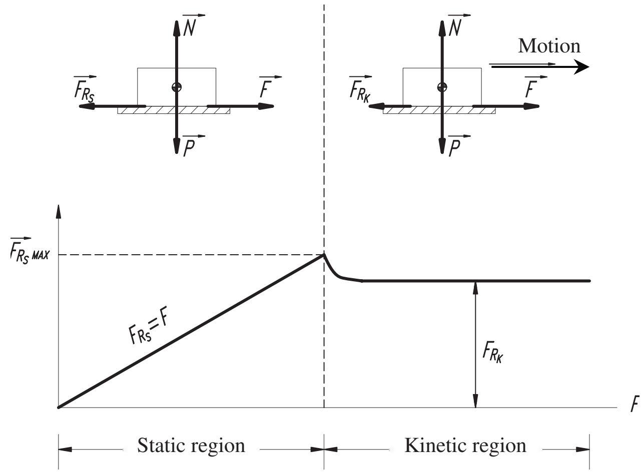

Figure 2. Schematic diagram of the friction force.

- The coefficient of friction is independent of the apparent area of contact.

- The static coefficient is greater than the kinetic coefficient.

- The coefficient of kinetic friction is independent of the sliding velocity.

B. *Composition and mechanical properties of material for breech block carrier and receiver assembly*

The composition and the mechanical properties of this material are presented as Tab. I.

TABLE I. COMPOSITION AND MECHANICAL PROPERTIES OF MATERIAL FOR BREECH BLOCK CARRIER

Chemical composition			
Number	***Metal***	***Percentage (%)***	
1	Fe	94.3 ÷ 95.56	
2	C	0.27 ÷ 0.33	
3	Mn	0.3 ÷ 0.6	
4	Si	0.17 ÷ 0.37	
5	P	≤ 0.025	
6	S	≤ 0.025	
7	Ni	2.75 ÷ 3.15	
8	Cr	0.6 ÷ 0.9	
9	Cu	≤ 0.3	
Mechanical Properties			
1	Elongation (%)		≥10
2	Reduction in area (%)		≥50
3	Tensile strength (MPa)		≥980
4	Yield strength (MPa)		≥785
5	Impact, AK (J/cm2)		78
6	Hardness (HRC)		42 ÷ 48
7	Roughness at contact area with receiver assembly (Ra)		2,5

Composition and mechanical properties of material influence greatly to the friction of two bodies in contact. Material of breech block carrier is 30XH3A alloy steel according to the standard ГОСТ4543-71.

The receiver assembly is produced by 40 steel plate or 45 steel according to the standard ГОСТ10720-78 and ГОСТ1050 respectively. The composition and the mechanical properties of 40 steel plate and 45 steel are presented as Tab. II.

TABLE II. COMPOSITION AND MECHANICAL PROPERTIES OF MATERIAL RECEIVER ASSEMBLY

Chemical composition				
Number	***Metal***	***Percentage (%)***		
1	Fe	40 Steel	97.93 ÷ 98.01	
		45 Steel	97.51 ÷ 98.09	
2	C	40 Steel	0.37 ÷ 0.45	
		45 Steel	0.42 ÷ 0.5	
3	Mn	40 Steel	≤ 0.6	
		45 Steel	0.5 ÷ 0.8	
4	Si	40 Steel	≤ 0.2	
		45 Steel	0.17 ÷ 0.37	
5	P	40 Steel	≤ 0.035	
		45 Steel	≤ 0.035	
6	S	40 Steel	≤ 0.04	
		45 Steel	≤ 0.04	
7	Ni	40 Steel	≤ 0.25	
		45 Steel	≤ 0.25	
8	Cr	40 Steel	≤ 0.25	
		45 Steel	≤ 0.25	
9	Cu	40 Steel	≤ 0.25	
		45 Steel	≤ 0.25	
Mechanical Properties				
1	Hardness (HRC)			35 ÷ 40
2	Roughness at contact area with receiver assembly (Rz)			40

C. *Friction model for sliding contacts between the breech block carrier and receiver assembly to experiment*

To build the friction model between the breech block carrier and receiver assembly, there are two assumptions supposed as follows:

- Water can be soundly approximated as incompressible;

- Amphibious rifle is fully under water when firing;

- Ignore the external forces acting on the breech block carrier, just interest in friction force and the forces related to friction.

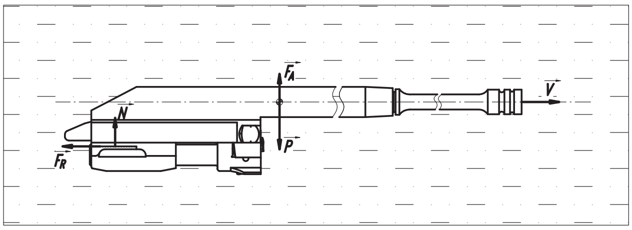

Figure 3. Friction model for sliding contacts between the breech block carrier and receiver assembly.

According to the third assumption, the forces related to the friction force acting on the breech block carrier include (Fig. 3): Gravity force $\vec{P}$ and Buoyant force acting on the breech block carrier $\vec{F_A}$. These two forces affecting on the friction force $\vec{F_R}$ through normal force $\vec{N}$ as follows:

$$\begin{cases} \left|\vec{N}\right| = \left|\vec{F_A}\right| - \left|\vec{P}\right| \\ \left|\vec{F_R}\right| = \mu\left|\vec{N}\right| \end{cases} \tag{2}$$

According to Archimedes, the buoyant force is determined, [9]:

$$F_A = V \cdot \rho \cdot g \tag{3}$$

Here, F_A is the buoyant force, V is the volume of the body below the surface of the water (m^3); ρ is the density of the water and with the sea water $\rho = 1030$ kg/m^3; g is the acceleration of gravity and $g = 9.81$ m/s^2. The volume of the breech block carrier assembly was calculated by Autodesk Inventor software and, where $V \approx 74\times10^{-6}$ m^3 (Fig. 4).

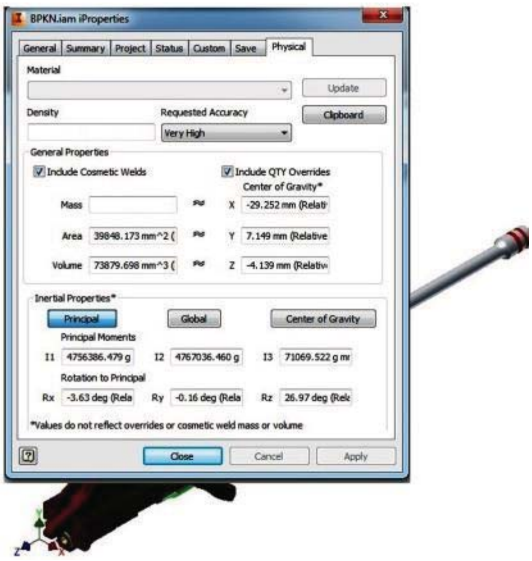

Figure 4. Volume calculation of breech breech block carrier assembly by Autodesk Inventor software.

So $F_A = 74\times10^{-6}\times1030\times9.81 = 0.748$ (N).

In addition, the gravity force is defined as: $P = m\cdot g$

Where $m = \sum_{1}^{9} m_i$ is the mass of breech block carrier assembly and it is determined in Tab. III [1].

Therefore, the normal fore is $N = \sum_{1}^{9} m_i \cdot g - V\cdot\rho\cdot g = 4.424$ (N).

According to the model was analyzed as above, if we determined forces horizontal and versa direction acting on breech block carrier assembly by experiment, we can be calculated the coefficient of friction between the breech block carrier and receiver assembly. This is also the principle of the experiment which the paper mentioned.

TABLE III. *COMPOSITION OF BREECH BLOCK CARRIER ASSEMBLY*

Number	Name of part	Mass (kg)
1	Breech block carrier	0.354
2	Piston	0.0835
3	Pin of piston	0.001
4	Breech block	0.079
5	Firing pin	0.0055
6	Extractor	0.0023
7	Spring of extractor	0.0001
8	Pin of firing pin	0.0008
9	Pin of extractor	0.001
Total mass		***0.5272***

III. TECHNICAL EXPERIMENT

A. *Samples*

Fig. 5 illustrates the shape of the breech block carrier and the receiver assembly samples. The breech block carrier is made by original breech block carrier of amphibious rifle. The pin is added on it to assemble on tribological instrument. The receiver assembly sample is produced by 40 steel plate and 45 steel according to the standard ГОСТ10720-78 and ГОСТ1050 respectively. The hardness of it is 37 HRC and the roughness's face is Rz40. Breech block carrier and receiver assembly samples are produced and certified by Z111 factory in Vietnam. In addition, the water tank is produced to contain water and receiver assembly sample, see Fig. 5.

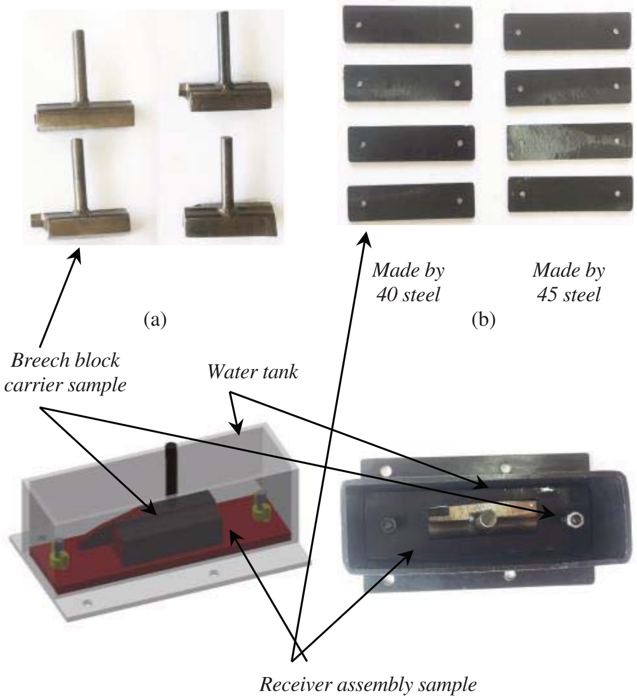

Figure 5. Breech block carrier samples (a), receiver assembly samples (b) in water tank.

B. Tribological instrument

The experimental is carried out by UMT system. The UMT multi-specimen test system can be used effectively for the tribological testing of ferrous and non-ferrous metals, plastics, ceramics, paper, composites, thin and thick coatings, as well as of solid lubricants, lubricating fluids, oils and greases. Various common tribology test modes are available, including: pin on disc, ball on disc, ball on one, two or three balls, pin on V-block, block on ring, disc on disc (flat on flat), and screw in nut [10], [11]. Installation diagram of the system and the photograph of the experiment setup are shown in Fig. 6, and Fig. 7.

C. Experimental procedure

The experiment was worked out in two cases:

Case 1: study of friction when there is no water. This case is when firing in the air.

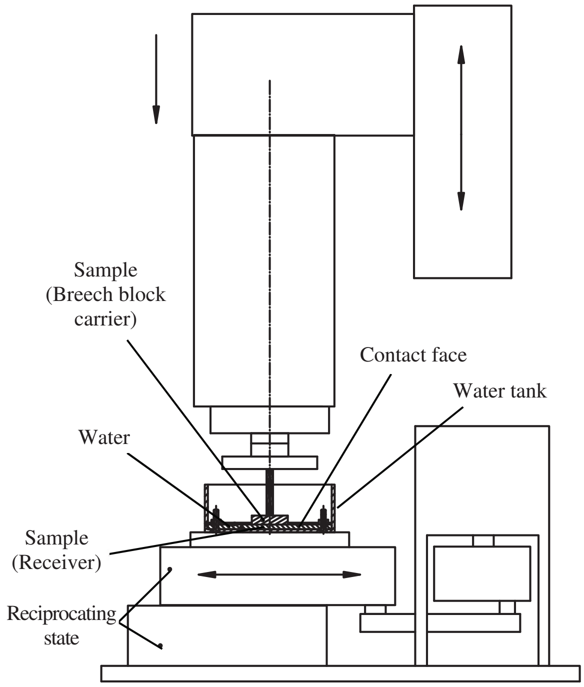

Figure 6. Installation scheme of experiment system.

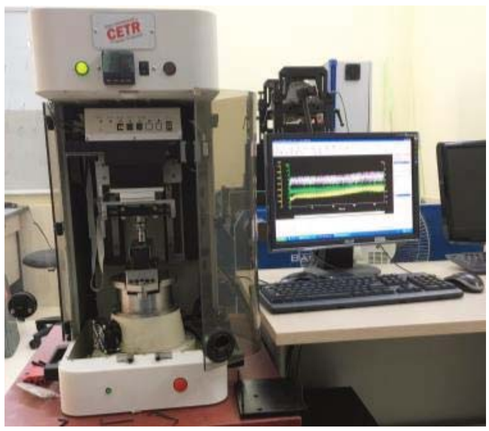

Figure 7. Photo of experiment setup.

Case 2: This case is firing under water. The sea water characteristics are sea in Vietnam, see [12].

The experimental conditions of this experiment are shown in Tab. IV.

TABLE IV. *THE EXPERIMENTAL CONDITION*

Parameter	Value
Normal load	
Case 1	5.172 N
Case 2	4.424 N
Time (Duration)	3 minutes
Temperature	25^0C
Average salinity of water	3.5%

IV. RESULTS AND DISCUSSION

Experiment results are shown in Tab. V and Fig. 8, Fig. 9, Fig.11, and Fig. 12.

TABLE V. *THE EXPERIMENT RESULTS*

Environment firing	Material of receiver assembly	Coefficient of friction
Air	40 Steel	0.492
	45 Steel	0.337
Sea water	40 Steel	0.290
	45 Steel	0.273

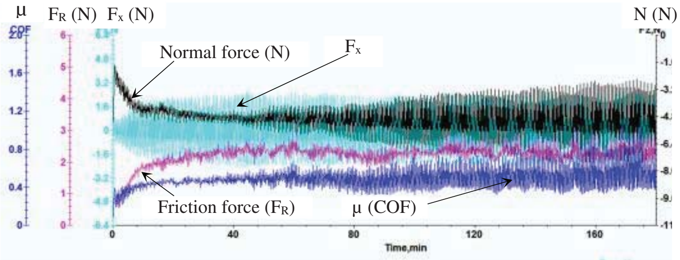

Figure 8. Friction between breech block carrier and receiver assembly when firing in air and the material of receiver assembly is 40 steel.

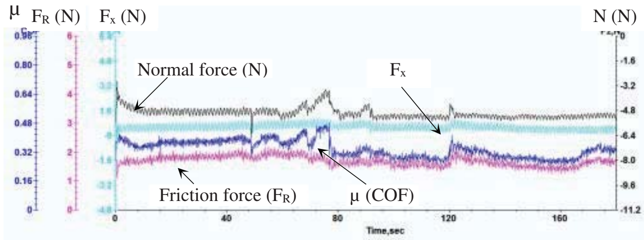

Figure 9. Friction between breech block carrier and receiver assembly when firing in air and the material of receiver assembly is 45 steel.

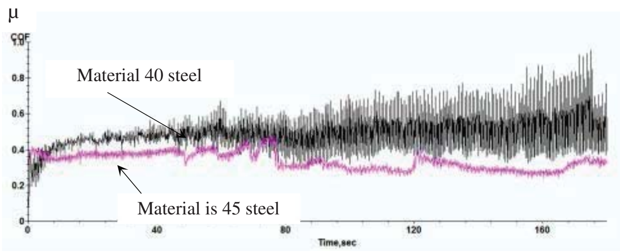

Figure 10. Coefficient of friction between breech block carrier and receiver assembly when firing in air.

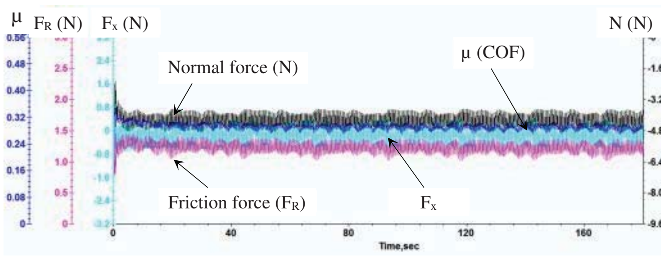

Figure 11. Friction between breech block carrier and receiver assembly when firing under water and the material of receiver assembly is 40 steel.

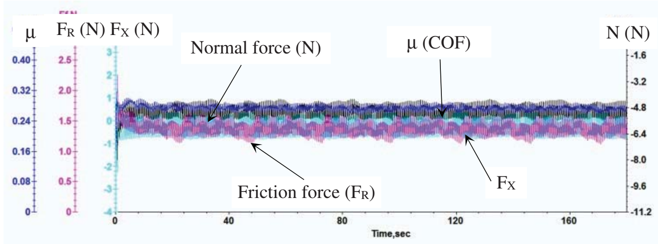

Figure 12. Friction between breech block carrier and receiver assembly when firing under water and the material of receiver assembly is 45 steel.

A. *Efficiency of material of receiver assembly*

In case firing in air and the material of receiver assembly is 40 steel, see Fig. 8, the value of coefficient of friction between breech block carrier and receiver assembly is 0.492. However, if the material of receiver assembly is 45 steel, this value is 0.337, see Fig. 9. So, material of receiver assembly significantly influence to the coefficient of friction. It increased to 31.5% when replacing the material of receiver assembly from 40 steel by 50 steel.

The comparison of coefficient of friction when changing the material of receiver assembly and firing in air is shown in Fig. 10.

Fig. 11, and Fig. 12 illustrate the friction between breech block carrier and receiver assembly in case firing underwater and the material of receiver assembly is 40 and 50 steel. Similar to the case of firing in the air, coefficient of friction is greater if receiver assembly was made by 40 steel. However, the difference is not as big as in the air. The ratio of this friction coefficient is 1.04 times, while firing in air is 1.46 times. The comparison of coefficient of friction when changing the material of receiver assembly and firing underwater is shown in Fig. 13.

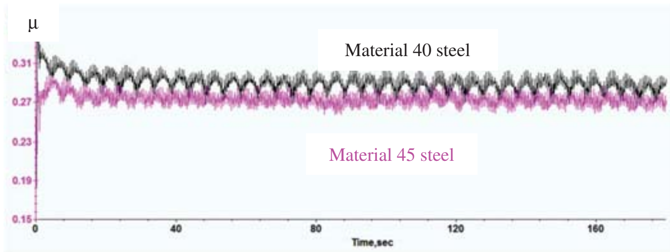

Figure 13. Coefficient of friction between breech block carrier and receiver assembly when firing under water.

B. *Efficiency of environment firing*

The effect of firing environment on the friction between breech block carrier and receiver assembly are shown in Fig. 14, and Fig. 15.

The coefficient of friction reduces 0.59 times when firing in air if the material of receiver assembly is 40 steel, see Fig. 14. If the material of receiver assembly is 40 steel, the value of the coefficient of friction reduces 0.8 times as it is depicted in Fig. 15.

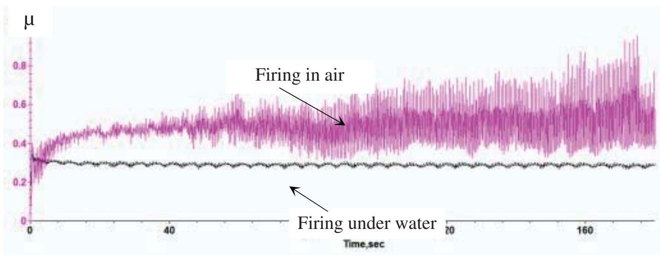

Figure 14. Coefficient of friction between breech block carrier and receiver assembly when the material of receiver assembly is 40 steel.

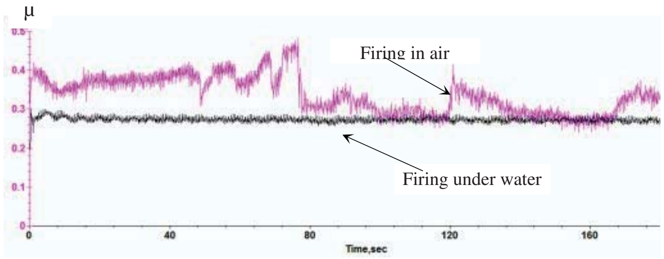

Figure 15. Coefficient of friction between breech block carrier and receiver assembly when the material of receiver assembly is 45 steel.

V. CONCLUSION

Based on an experimental analysis of the material properties of the breech carrier and gun housing, paper presents a method for determining the friction coefficient not only in the amphibious rifle but for conventional automatic weapons.

Tab. V shows that the coefficient of friction may not be constant and its mean value is greater than is generally recommended in publications dealing with this issue, for example [2], [3], [4], [8], and [11]. The results of this research can be used as important inputs for the analysis and design of dynamics of automatic weapons mechanisms and especially of amphibious rifles.

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