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Complex experimental analysis of rifle-shooter interaction

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ABSTRACT

In this study, a complex analysis of a man-weapon interaction based on experimental effort is presented. The attention is focused on how a shooter can influence on a rifle, opposite to generally considered in literature rifle's impact on a shooter. It is shown, based on the kbk AKM weapon, that each support point of the rifle has an substantial impact on the system. It is said that identifying human reactions on weapon may let to describe gun movement and thus may be applied to weapon accuracy determination.

1. Introduction

Working on a new weapon model it is necessary to solve many technical problems, for instance interior ballistic, endurance, variety of mechanisms etc. One of the most important aspect is to design a gun with as high as possible accuracy. Analyzing a problem of rifle movement during a discharge requires free body diagram determination, especially forces between shooter and given weapon model. Up to date man-weapon interaction efforts, including experiments, focus on measurement and assessment of rifle influence on shooter's shoulder. Force and energy of recoil were measured at contact point between rifle's butt and a shoulder. Results were analyzed with respect to shooter subjective feeling under applied recoil energy. Ranges of recommended recoil energy vs. weapon model were introduced. Designers focused on shooter and neglected mutual interaction between shooter and rifle. Particularly, weapon accuracy phenomenon was not considered. To date, no published effort has been made to indicate correlation between rifle-shooter interaction and weapon accuracy. Rifle's impact on a shooter was solely highlighted.

This paper is focused on the kbk AKM (AKM rifle) – shooter interaction. It is proposed to disjoin nodes of rifle-shooter system, which may be treated as a new approach of the analysis. Moreover, a following hypothesis is stated: human reactions on rifle are crucial to weapon accuracy. Those forces will be introduced to the nodes (points of rifle-shooter contact) together with forces generated due to propellant burn. Above approach will let to determine and solve system of motion equations (Fig. 1).

Mathematical model of the analyzing system is derived by utilizing the formalism of Lagrange equations of the second kind [9]

$$\frac{d}{dt}\frac{\partial E}{\partial \dot{q}_j} - \frac{\partial E}{\partial q_j} + \frac{\partial D}{\partial \dot{q}_j} + \frac{\partial V}{\partial q_j} = Q_j, \quad j = 1, 2, \ldots\ldots, s$$

Trying to obtain an analytical description of shoulder-fired rifle motion during both the shot and interaction with the user, it is necessary to determine wide spectrum of input data. One of them are reactions between rifle and shooter in the mutual contact points, namely: rifle butt and user shoulder, hand and pistol grip, hand and hand grip/forend.

Thinking of complex analysis, it was decided to measure reactions in all three directions of orthonormal basis in Euclidean vector space [7], where coordinate system (CSYS) is attached to contact point between rifle butt and shooter shoulder (Fig. 2).

Introduced approach rids entirely of human modeling and focuses how forces of mutual reaction impact on gun motion. Shooter is represented as reactions of specified characteristics. Such approach allows to new weapon design optimization or already

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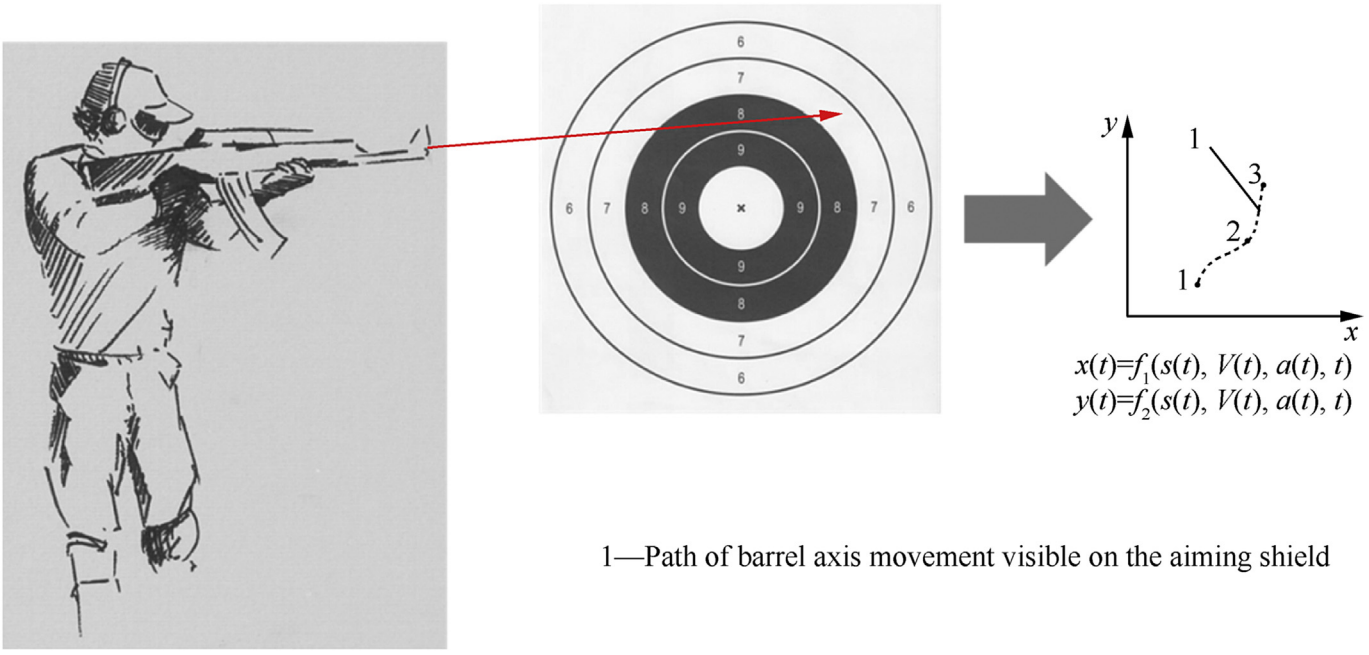

Fig. 1. Effect of shooter – rifle interaction.

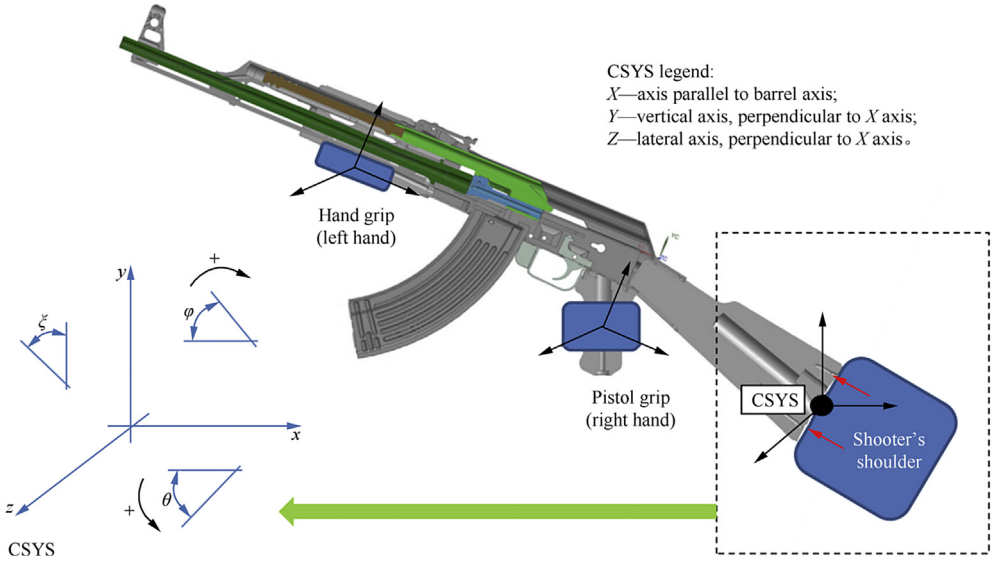

Fig. 2. Definition of vector space and coordinate system.

existed ones by variations of individual parameters.

Experimental results of reaction forces in defined contact points (nodes) and theirs initial analysis are subject of this paper. Analysis of kinematic and dynamic of motion (both linear and angular) will be topics of subsequent papers.

2. To date methods of rifle-shooter interaction analysis – overview

Considering existing methods of rifle-shooter interaction analysis is worth to mention Piotr Wilniewczyc, an ingenious polish weapon designer who one of the first begun working of this phenomenon. In monograph [8] he has formulated requirements for allowable level of recoil energy based on weapon model and subjective shooter feeling.

Another polish scientist who worked on that subject was S. Kochański, who in monograph [5] shown the kbk AKM rifle reactions on shooter and named existing impact as *pushing/breech force*. Unfortunately, entire analysis was restricted only to a period where gases from propellant burn were active in the barrel. That is essential disadvantage of the approach.

More accurate analysis was conducted by J. Ewertowski in Ref. [2]. He managed a complex analysis of the kbk AKM rifle's impact on shooter and proved that this interaction has two related stages. First one named – *impulsive weapon effect*, second (which starts right after 1st ends) – *elongated weapon effect*. Simultaneously claimed that recoil energy is higher in the 2nd period than in the 1st.