The design of the operator measuring in fire control system

MARTIN MACKO - TEODOR BALÁŽ
Department of Weapons and Ammunition
University of Defence
Brno, Kounicova 65, 61200
CZECH REPUBLIC
http://www.unob.cz

Abstract: This article deals with the task of human operator during the aiming process and aiming simulation. It is needful to detemine measured gun operator parameters and to choose a method of the measuring. The transfer function of the operator is showed in article. Turret of the combat vehicle with complete electronical equipment is exploited for aiming simulation and this stend is placed on driving simulator.

Key-words: Operator, aiming, transfer function, weapon, simulator

1 Introduction

Equipment for aiming is part of fire control system of the gun. Non - automatic system of the aiming consists of the control (command) part -human operator and regulated part - weapon.
The aiming process of weapon during the ride is the dynamic action. Modeling of this action is very difficult and obviously is it made by theory of automatic proceeding. In the system of aiming, which we can to consider for set of automatic proceeding, human operator is control centre.
The accuracy of sighting is influenced between target and weapon, field of frame, kind of the target, but very important is influence of the operator. Inconsiderable is especially:

- practice,
- experiences,
- individual qualities (eye handicaps ...),
- physical and psychical status.

2 Problem – Determination of the gun operator characteristic for measuring

In the mathematical model calculated quantities are angles, which setting the position of the target, aiming point or gun tubes. There are usual elevation φ and angle of bearing ψ. Control (command) quantities are target angles of the aiming: vertical φ_Z, horizontal ψ_Z , we can label it q_{ZB}. Regulated quantities are gun tube angles (φ, ψ), labeled q_{ZZ}.
Operator is evaluate the control deviation in aiming process, which is difference between control and regulated units. But premise of accurate evaluation of this deviation is adequate sighting of the target (aim point).
Control deviation $e = \Delta q_M$ is

$$e = \Delta q_M = \Delta q_Z + n_{HE}(t), \qquad (1)$$

$$\Delta q_Z = q_{ZB} - q_{ZZ} \qquad (2)$$

where: $n_{HE}(t)$ is operator noice. Through the measuring is possible to detection control signal Δq_{OV} only, which is transfered to actuator of the movement. Hold generally function

$$\Delta q_{OV} = F(\Delta q_M(t)), \qquad (3)$$

$$\Delta q_{OV} = \Delta q_Z \cdot K_{OV} + n_{OV}(t), \qquad (4)$$

where: $n_{OV}(t)$ is operator noice directly on the actuator of the movement (for example: joystick). K_{OV} is constant for calculation angle of the actuator with the assistance Δq_Z .
Linear system for model of the operator according to [2] is in the next text. We can use is transfer function $F_H(p)$, which replaces constant K_{OV}

$$\Delta q_{0V}(p) = F_H(p) \cdot e(p), \qquad (5)$$

$$F_H(p) = F_M(p) \,.\, F_B(p), \qquad (6)$$

where $F_M(p)$ is the basic transfer from eyes to the brain and $F_B(p)$ is the transfer from the brain to the hand(s) of the operator.

Transfer function according to [1] is

$$F_H(p) \cong \frac{k_H \cdot (T_{H1} \cdot p + 1)}{(T_{H2} p + 1) \cdot (T_{H3} p + 1)}, \qquad (7)$$

where: k_H is coefficient of the equipollent gain [m.rad^{-1}] nebo [rad.rad^{-1}] and T_{H1}, T_{H2}, T_{H3} are equipollent time constant [s].

The problem for mathematical modeling of the human operator transfer function is his ability of the adaptation with the regulated system. During experiment was used his transfer function

$$F_{TS}(p) \cong \frac{k_T}{(T_T \cdot p + 1)^n}, \quad n = 0,1,2 \qquad (8)$$

where: k_T is coefficient of the equipollent gain of the regulated system, T_T is time[s].

Corresponded frequency transmission is

$$F_{TS}(\omega) = \frac{k_T}{\left[1 + \left(\frac{\omega}{\Omega_0}\right)^2\right]^{\frac{n}{2}}}, \qquad (9)$$

where:

$$\Omega_0 = \frac{1}{T_T} \, [\text{s}^{-1}] \qquad (10)$$

The transfer function (8) can be calculated like this

$$F_H(p) \cong \frac{k_H \cdot \Omega_{0H}^2 \cdot (T_{H1} \cdot p + 1)}{p^2 + 2\xi_H \cdot \Omega_{0H} \cdot p + \Omega_{0H}^2}, \qquad (11)$$

where: $$\Omega_{0H} = \frac{1}{\sqrt{T_{H2} \cdot T_{H3}}} \qquad (12)$$

is eigenfrequency of the operator and

$$\xi_H = \frac{1}{2} \cdot \frac{T_{H2} + T_{H3}}{\sqrt{T_{H2} \cdot T_{H3}}} \qquad (13)$$

is relative damping of the operator.

The operator adapts to regulated system. The expert operator is able keep of the aiming equipment (weapon) stability during aiming process. He modifies eigenfrequency, relative damping, gain k_H and time constant T_{H1}.

According to [3] similar to gun operator problem is linear model of the driver dynamical properties. Known is so called Crossover model:

(3.26)

$$G(p) = \frac{K \cdot (T_L p + 1)}{(T_N p + 1)} . e^{-p(T_D + T_N)} \qquad (14)$$

where:

$G(p)$ - transfer function of the operator

K - gain of the operator (12 dB až -35 dB)

T_L - predictive time constant (0 - 2) s (3.29a)

T_I - neuron-muscular time constant (0 - 0,67) s

T_D - delay of the operator (0,12 - 0,3) s

T_N - delay of the neuron-muscular system

According to [5] drivers were measured to be determine values of the constants in (14). (3.29b)

3 Solution of the problem – Aiming Simulator

There are two possibilities: measuring of the operator directly in weapon or simulator measuring. Measuring of the operator in terrain is expensive and number of the measured solutions is insufficient. For find out of influence of operator to quality of aiming was developed (Fig. 3) the simulator of the aiming process of BVP-1 (combat vehicle). It is equipment for education of students, for demonstration of the aiming process too.

(3.35)

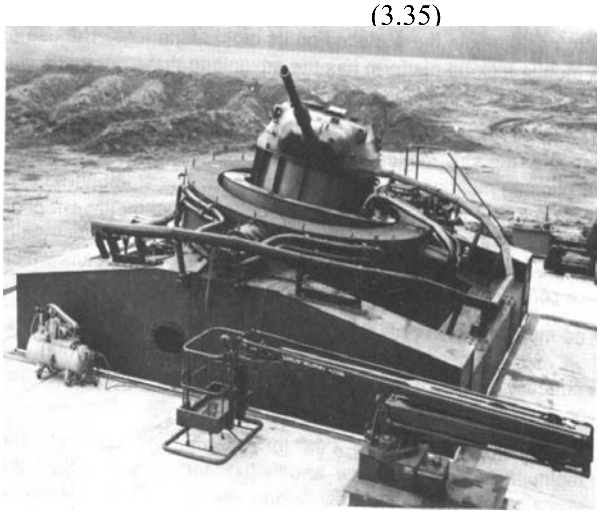

Fig. 1 Aiming simulator - firm Rheinmetall, 1920.

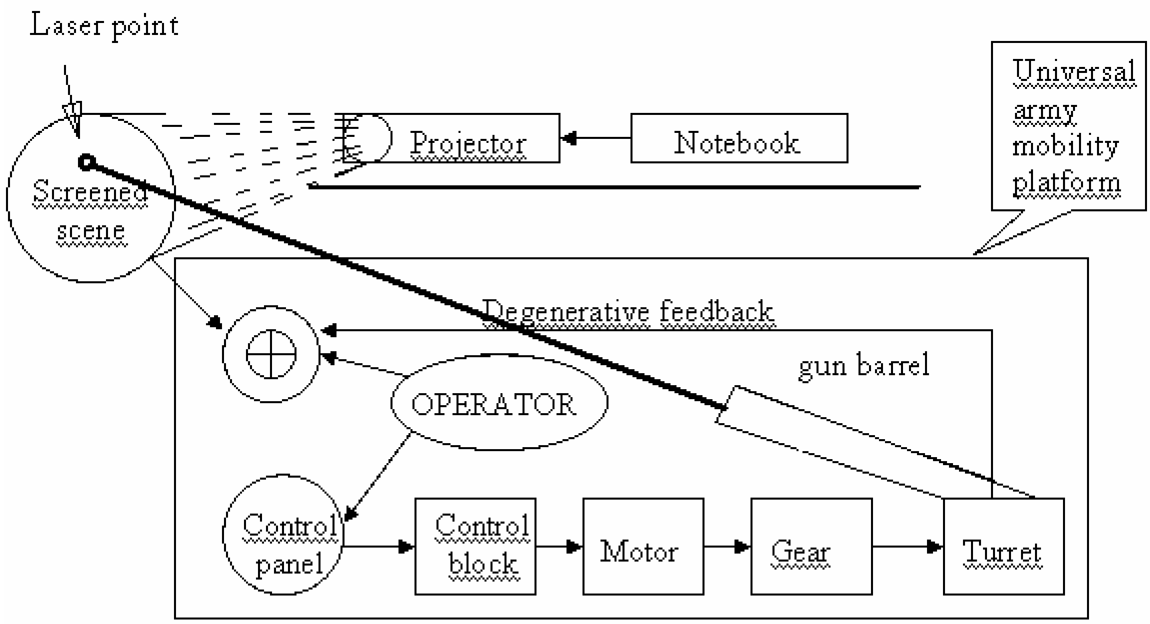

Fig. 2 Block chart of the aiming simulator

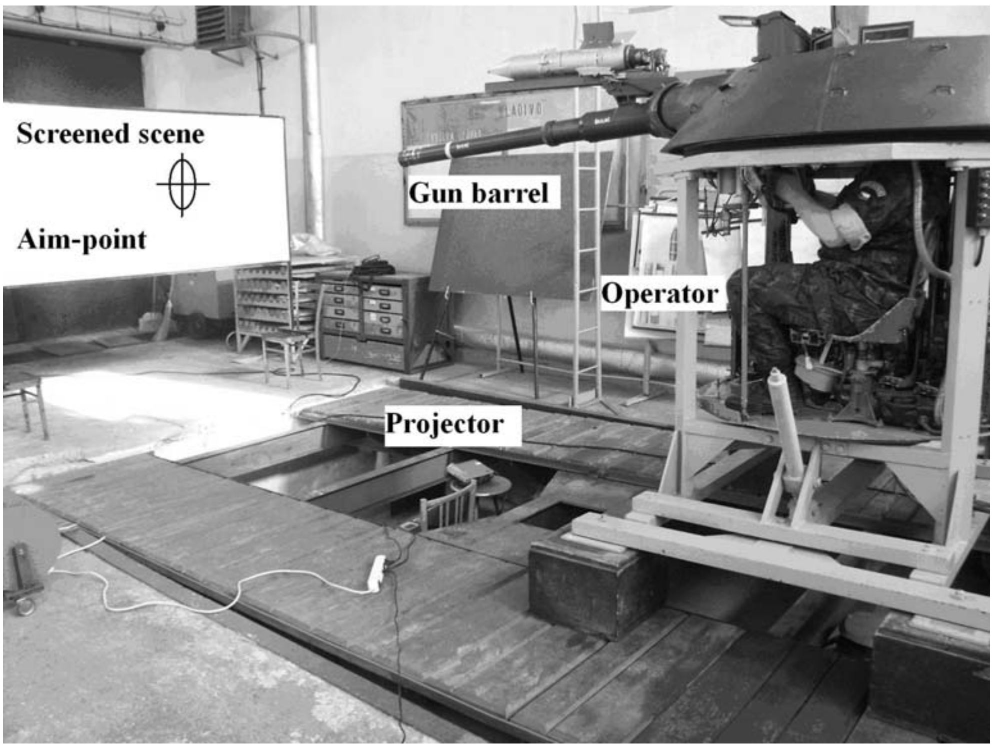

Fig. 3 Simulator of the aiming process

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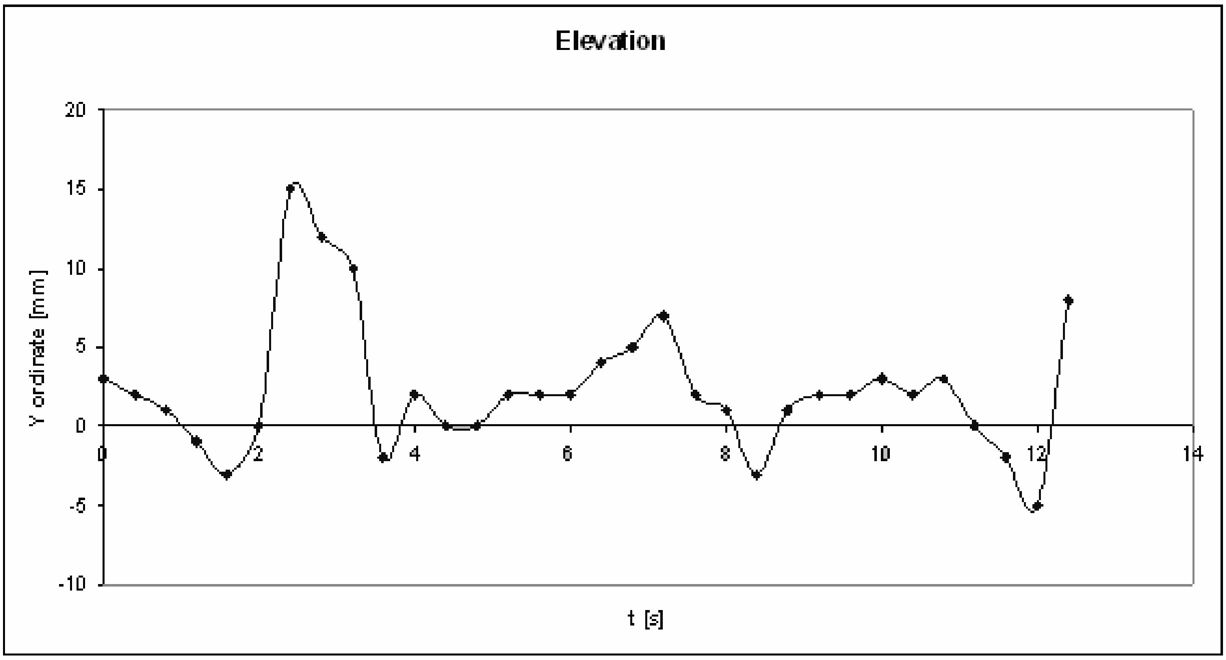

Fig. 3 Elevation deviation by operator

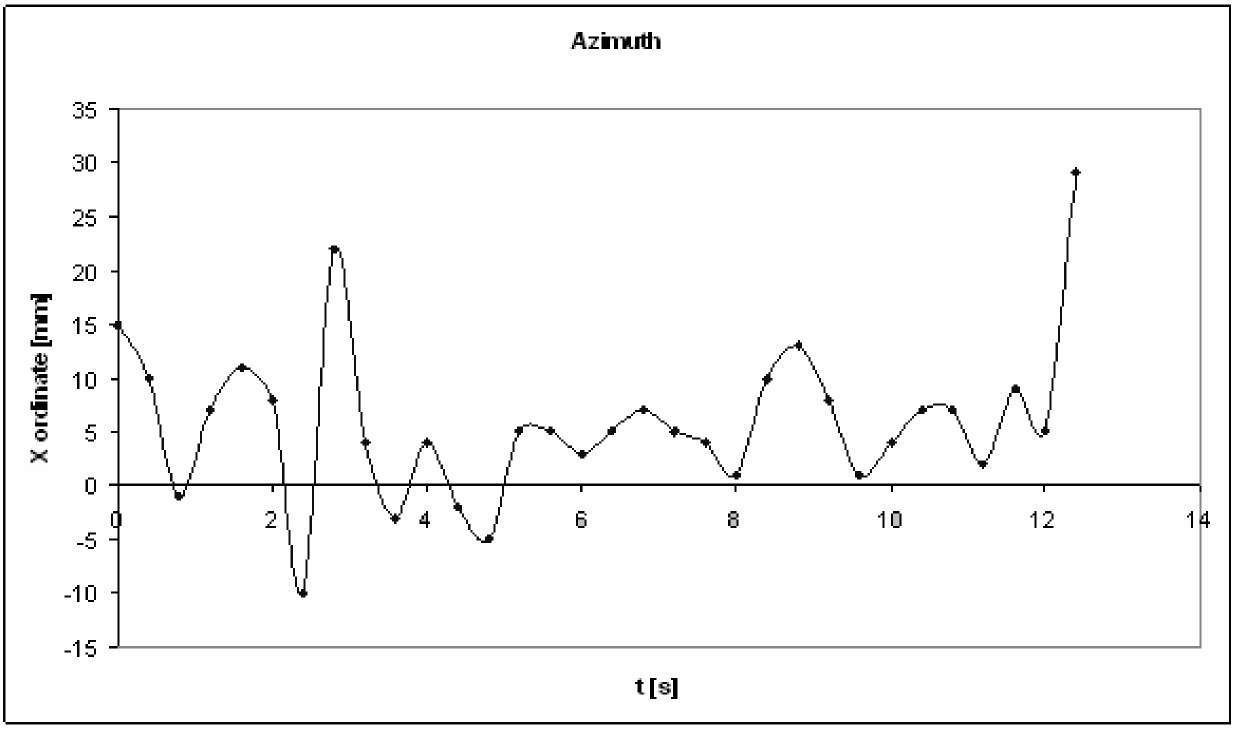

Fig. 4 Azimuth deviation by operator

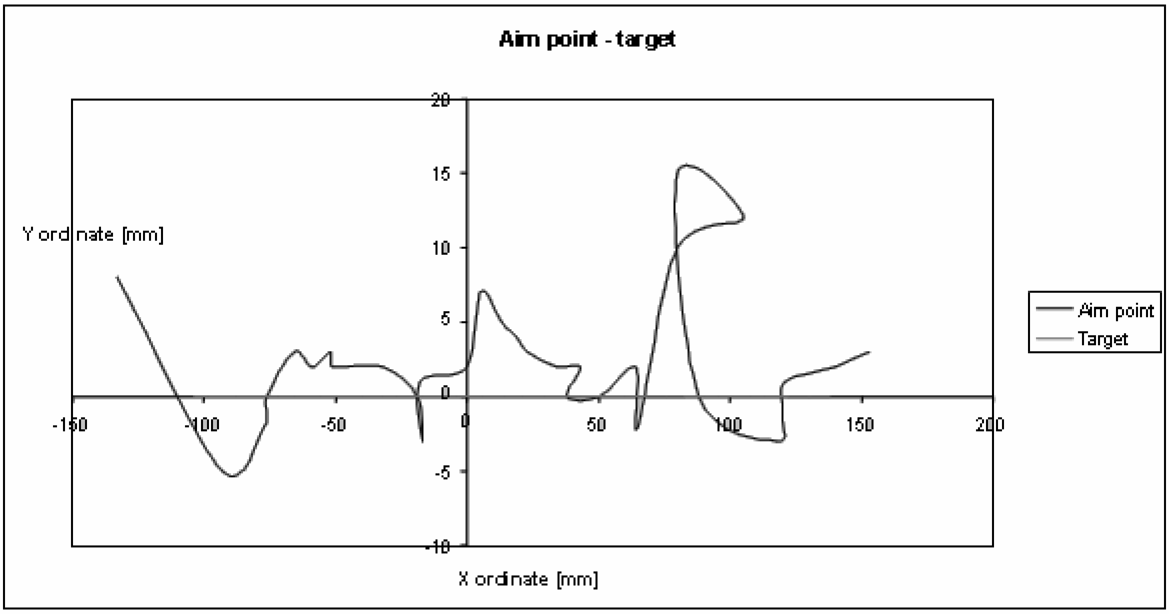

Fig. 5 Movement of the aimpoint

4 CONCLUSION

On the following time will be prepared procedure of measuring and will be initialized the realizing of experiments. It will be necessary to measure angles of the actuator (joystick) and time constants to get eigenfrequency, relative damping, gain and time constants. The simulator will be used primarily for research a human factors in fighter situation. It is combined with simulator of the gun chassis movement.

References:

[1] V. Čech, *Research report „Cilepas“* , Oprox a.s., Brno, 2003.

[2] I.Je. Cibulevskij, *Čelověk kak zveno sledjaščej sistěmi*, Nauka, Moskva, 1981.

[3] M. Havlíková, *Modely chování řidiče*, VUT, Brno, 2004.

[4] P. Vysoký, *Dynamické vlastnosti lidského operátora jako řidiče*, Automatizace 12/46, 2003

[5] P. Vysoký, *Central fatigue identification of human operator*, Neutral network world, 2001 11(5) p. 525-535.

[6] P. Fischer and J. Bucholcer, *Tank fire control systems*, Vol. 2, Military academy, Brno, 2002.