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PARAMETERS CHARACTERISTIC FOR THE STABILISATION SYSTEMS FOR WEAPON MODULES

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Abstract

The theoretical analyses of requirements for the weapon stabilisation systems, being important element of remotely controlled weapon modules, make it necessary to conduct the analyses as far as the possibilities to measure and assess the weapon stabilisation system operating parameters. In order to properly approach this issue the article presents the requirements for the weapon stabilisation systems and theoretical analyses of the operating parameters of the automated control systems (ACS). The requirements for weapon stabilisation systems, defined in the literature, make it necessary to conduct ACS technical parameter analyses from the point of view of experimental testing of stabilisation system. The article presents also the 3rd generation stabilisation scheme. The analysis of the parameters (theoretical parameters) of the automated control systems was made from the viewpoint of the control quality assessment. The few years of experience in the weapon stabilisation system and the analysis of the theoretical parameters, presented in the second chapter, conducted for the needs of the article's third chapter, enable to conduct theoretical analyses and to propose parameters which should be determined during experimental testing of the weapon stabilisation system.

***Keywords**: weapon stabilisation systems, automated control system, stabilisation parameters*

1. Introduction

Each real automated control system (ACS) usually operates under heavy, constantly changing conditions. The set value as well as type and character together with the interference signal amplitude are subject to changes. The lower the difference between the set value and the real value, the better quality of system operation. However so far it was impossible to develop a single, universal quality factor, the numerical value of which would allow for assessment and comparison of different systems [1].

Generally, the weapon stabilisation system is an automated control system for aiming line. Its tasks consist in maintaining the set aiming line determined by the aimer while the ballistic information is entered at the regulator input at the same time.

Figure 1 presents the general 3rd generation stabilisation system. From the view point of experimental testing the values of angles α and β as well as deratives directly related with them (angular speeds, maximum values, average square values, etc.) are interesting values that determine the stabilisation system operation.

The requirements for the weapon stabilisation systems are as follows [2]:

- Precision of set position stabilisation (small angular vibrations of the turret at known requirements determined by the surface),
- Short control time,
- Fast start,
- Fast braking,

- Wide range of guidance speed (small speed for precise and high speed for rapid fire manoeuvre),
- Simple and easy operation,
- Operation reliability,
- Safety during use,
- Small dimensions and weight.

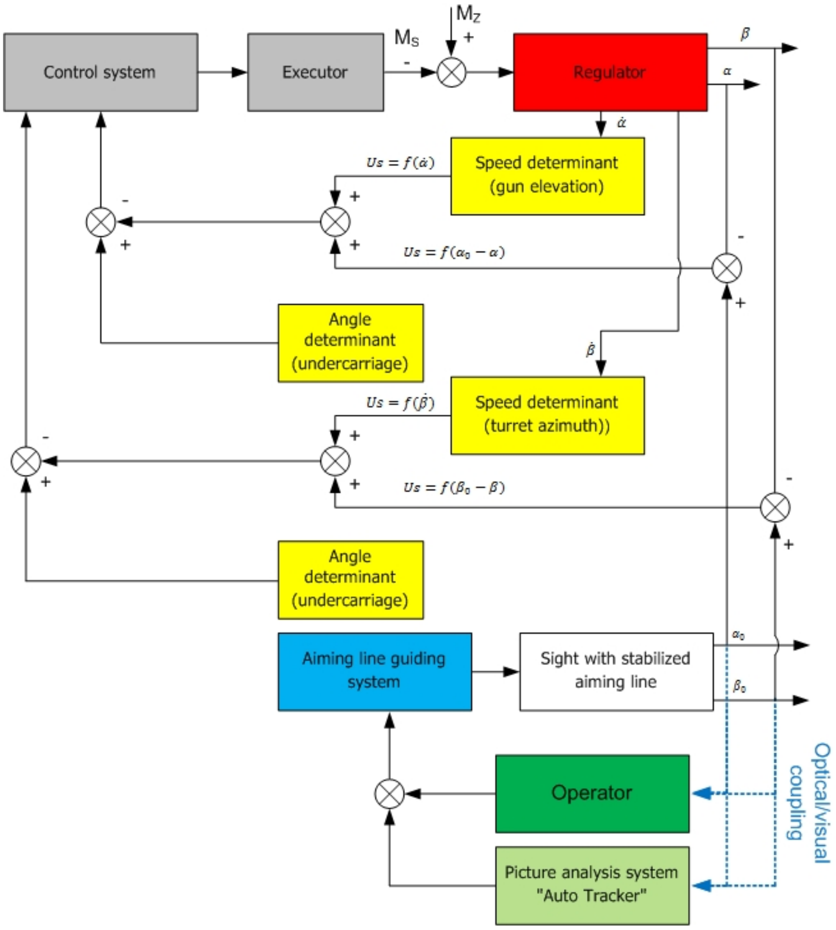

Fig. 1. Scheme of 3rd generation stabilisation system

Due to the fact that the barrel (gun) is the adjustment object for the surface in elevation and the turret for surface in azimuth and they are the components of the automated control system whereas the parameter measurement, being characteristic for ACS, requires intervention into the system, what is not advisable during the experimental testing for the complete and integrated turret system as this may introduce additional errors to the operation of the weapon stabilisation system. The second chapter deals with theoretical approach to the problem, whereas the third chapter discusses the problem from the view point of experimental testing performance.

2. Theoretical analysis of ACS technical parameters

When theoretically considering ACS, the control quality testing involves the control of regulation deviation e(t) triggered by standard determination or standard interference both during set and transitions states. The quality control measurement is here so called quality factor which should be defined in such a way as to measure the features of the regulation deviation e(t) process with sufficient precision.

The response of the automated control system, in form of output value change which follows the set value, can have different shapes, e.g. Fig. 2.

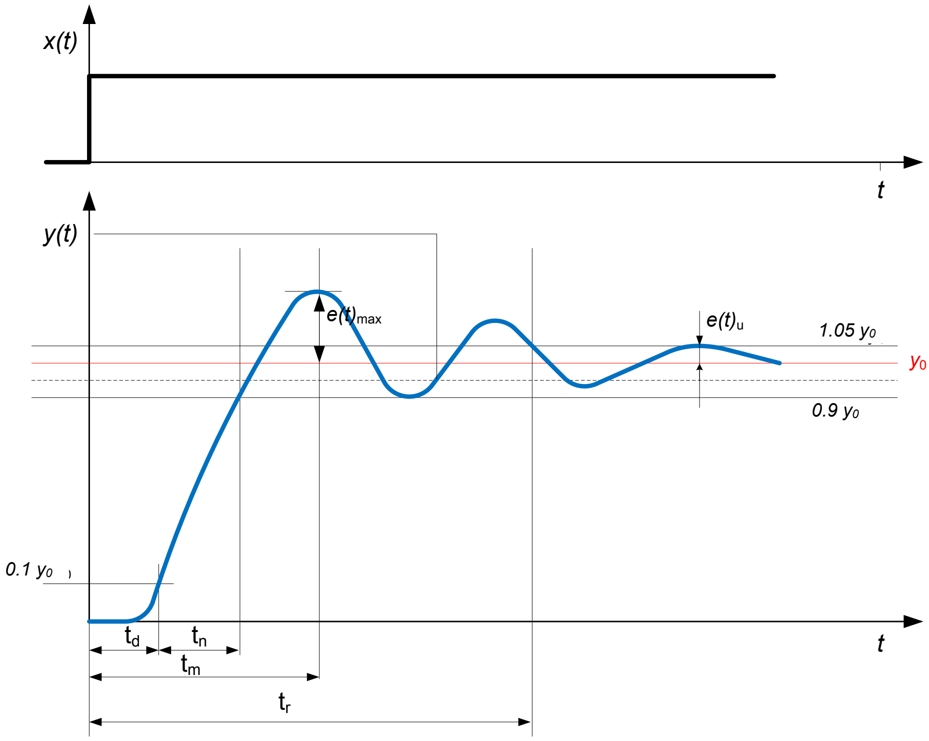

Fig. 2. The response of the automated control system to single stroke impulse

The following theoretical factors apply to the assessment of system dynamic values based on the response to the signal stroke at control input:

- t_d – delay time from the stroke development at input to the appearance of response at the output,
- t_n – increment time, time during which the signal changes from 0.1 to 0.9 of set value,
- t_m – time to the appearance of the maximum first re-control,
- t_r – control (setting) time, upon the lapse of which the value of system output signal will not deviate from the value of this signal in the set state by no more than Δ (Δ = 1, 2, 5%), control time which is the quality measurement for the dynamic stroke response of the automation system,
- $e(t)_u$ – set deviation in the control system is the difference between the signal set value and output signal value in the set state,
- $e(t)_{max}$ – maximum deviation is the highest deviation value e(t), i.e. the difference between y(t) and w(t), present during transition flow (for $0 \leq t \leq \infty$) [3],
- χ – re-adjustment, allows to assess the difference between the maximum value of transition flow e_{max} and set e_o, expressed in percentage [1],

$$\chi = \frac{e_{\max} - e_0}{e_0} 100\%. \tag{1}$$

Stab Acc – the stabilisation precision expressed in *mrad* is calculated as a standard deviation from integral of the regulator error. The *Cmd* parameter is the speed value from the user, whereas *Fbk* is the feedback value from the gyroscope speed of the responding axis [6]. To make it simple, the stabilisation precision parameter described with the formula below, defines how broad the values of the angular deflection of the tested axis are spread from its average.

$$Stab\ Acc = std\left(\int_0^t (\mathrm{Cmd} - \mathrm{Fbk})\,dt\right). \tag{2}$$

3. The ACS technical parameter analysis from the point of view of experimental testing based on the testing of weapon stabilisation systems

Therefore when considering the weapon stabilisation system and the turret of the turret system from the view point of experimental testing as well as considering theoretical factors to provide comprehensive assessment the following parameters need to be determined within experimental testing:

3.1. The change of value of barrel angular inclination in the elevation in time $\alpha_l(t)$ and inclination on azimuth $\beta_l(t)$ – *temporary position*

This characteristics allows to analytically determine the necessary parameters, used to assess, verify or compare the turret and weapon stabilisation system, remotely or manually controlled turret module. The charts 1 and 2 present the examples of registered characteristics of value changes.

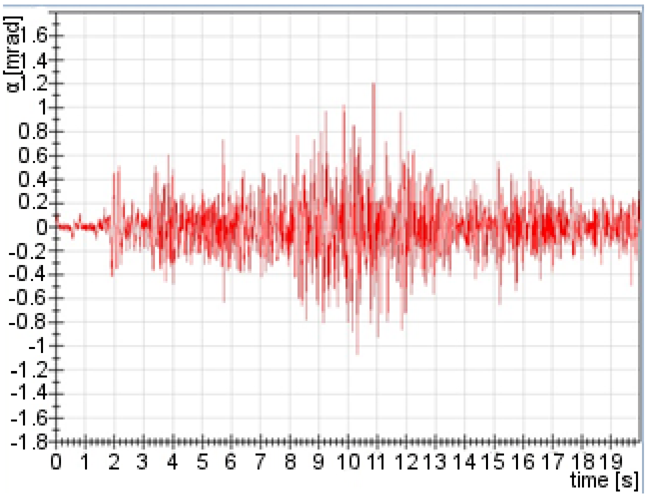

Chart 1. Angular changes in elevation

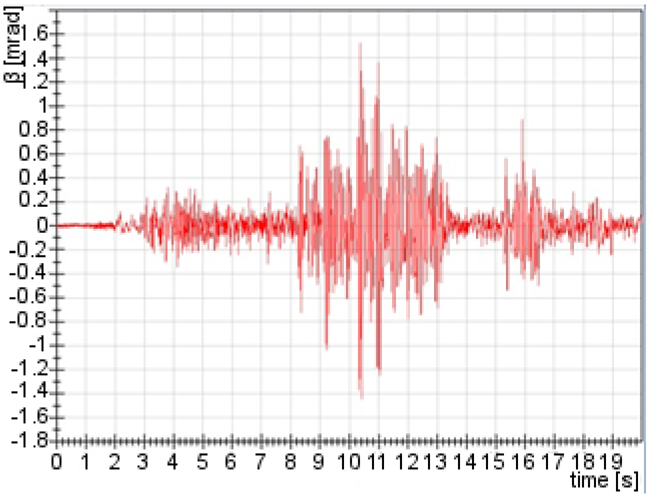

Chart 2. Angular changes in azimuth

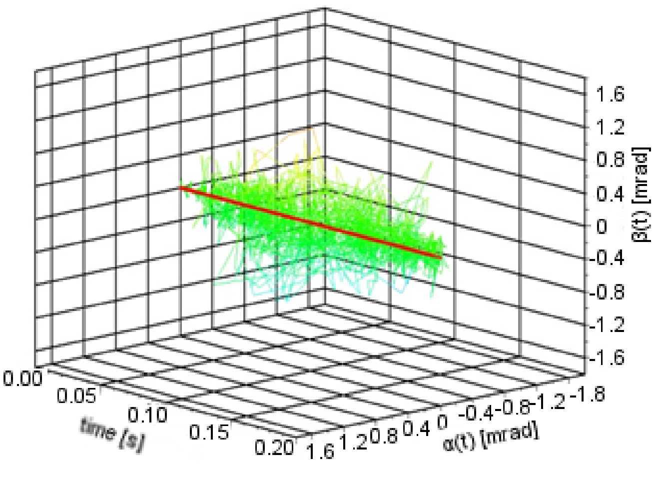

*Chart 3. 3D characteristics of angular changes of barrel position**

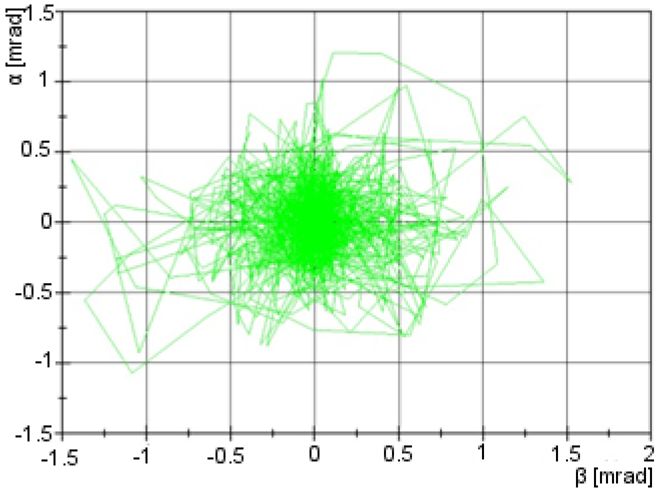

Chart 4. 2D characteristics of angular changes of barrel position

*The view of weapon deflection towards the remote aiming line, can be also called the view of the target perspective [4], will present in a graphic manner the barrel operation in 3D.

3.2. The maximum barrel angular inclination in elevation α_{max} and deflection in azimuth β_{max} from the set aiming line

Maximum parameters of barrel angular inclination in elevation and deflection in azimuth inform about the greatest weapon deflection value from the set aiming line, present during the process *(for* $0 \le t \le t_k$*)*.

The examples for presented processes are as follows:

$$\alpha_{max} = -1.07 \text{ and } + 1.21, \qquad \beta_{max} = -1.45 \text{ and } + 1.53. \tag{3}$$

3.3. Average square value of barrel angular inclination in elevation $RMS_{\alpha l}(t)$ in azimuth $RMS_{\beta l}(t)$

The parameter of average square values for the stabilisation system operation from the formula (4) set as example from the processes in charts 1 and 2 can be used as comparative factors of stabilisation system integrated on the same platform. We can also determine these as variable characteristics in time as well as averages from all the processes.

$$RMS_{\alpha l}(t) = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \alpha(t)^2 dt \quad \text{and} \quad RMS_{\beta l}(t) = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \beta(t)^2 dt, \tag{4}$$

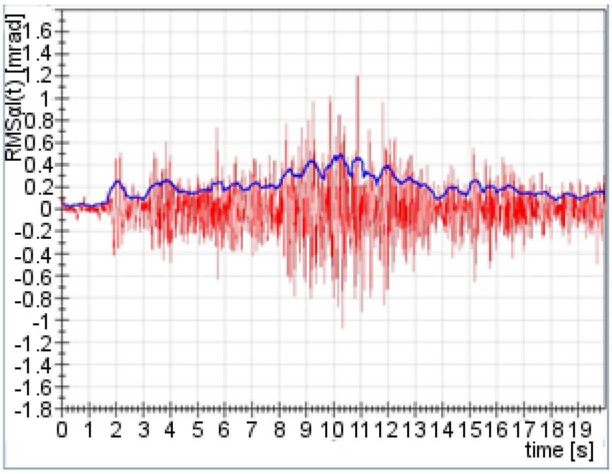

Chart 5. Changes of average square value in elevation $RMS_{\alpha l}(t)$

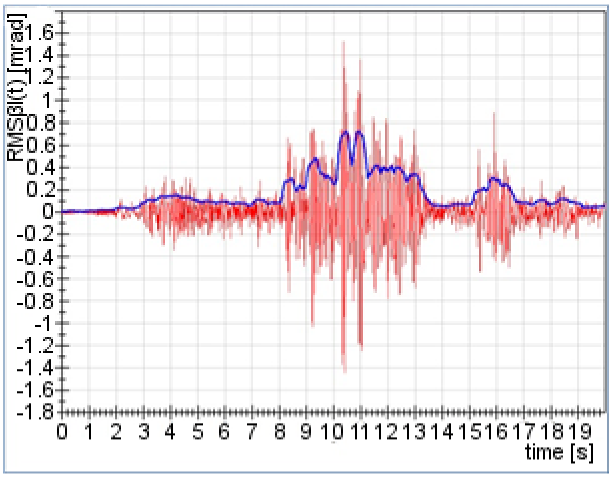

Chart 6. Changes of average square value in azimuth $RMS_{\beta l}(t)$

$$\overline{RMS}_{\alpha l} = 0.23\,mrad \quad \text{and} \quad \overline{RMS}_{\beta l} = 0.23\,mrad. \tag{5}$$

3.4. Maximum weapon guiding angular speed in elevation $\omega_{\alpha max}$ and in azimuth $\omega_{\beta max}$

The maximum weapon guiding speed values are very important parameter from the point of view of action at the contemporary combat field for the systems equipped with the Hunter Killer mode (in this mode the commander observes the combat field using his independent aiming system, and when he detects the target it can subordinate the turret to his sight, automatically aiming the weapon at the target), in which the commander can transfer the fire is also a very important parameter from the view point of requirements determined for the turret system. For small and medium calibre systems.

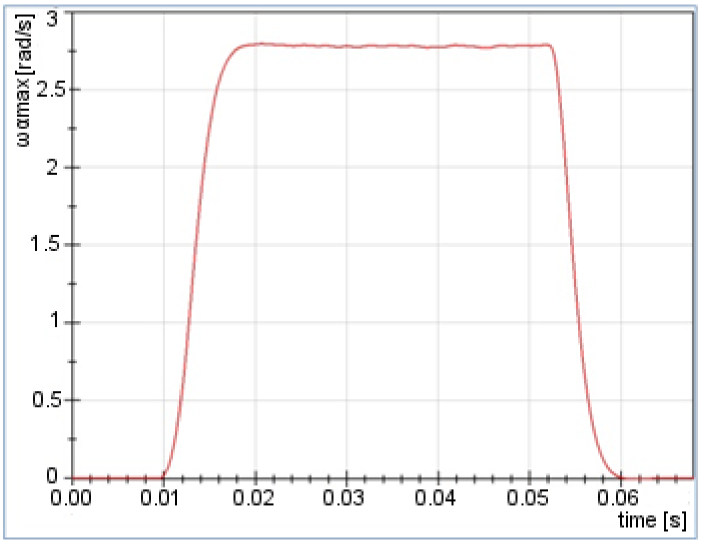

Chart 7. The example of changes of maximum angular speed in time

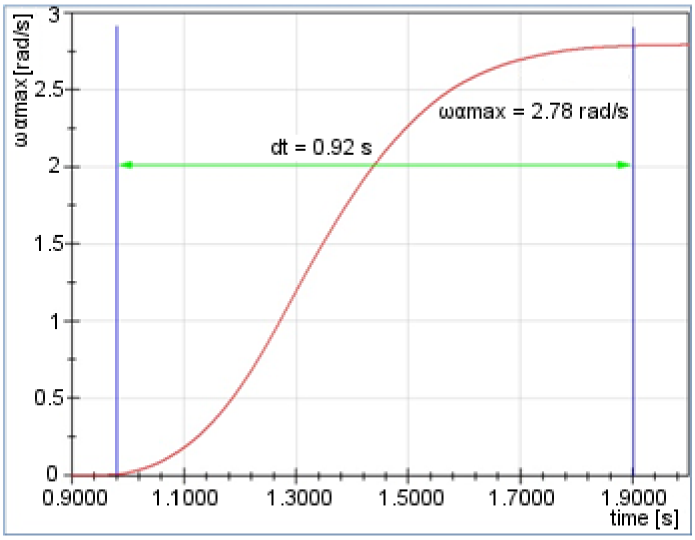

Chart 8. The analysis of the angular speed changes

3.5. Minimum weapon guiding angular speed in elevation $\omega_{\alpha max}$ and in azimuth $\omega_{\beta max}$

Minimum weapon angular speed is of importance for the accuracy of the fire and the capacity to track the target. In terms of the object angular speed, with angular speed lower than the possible to achieve by the system there will be problem with stable maintaining of the target in the "sight" [5].

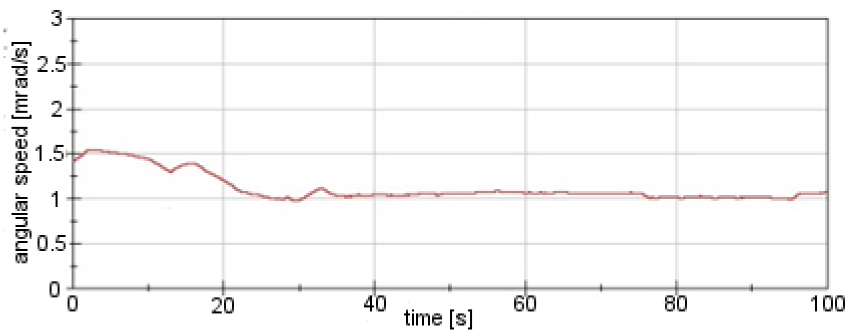

Chart 9. The example of changes of minimum angular speed in time

3.6. Maximum weapon angular guiding acceleration (gaining speed) in elevation $\varepsilon_{\alpha max}$ and in azimuth $\varepsilon_{\beta max}$

The weapon angular accelerations are also important technical parameter due to the requirement such as weapon acceleration speed (fast take-off), what is among other related to the possibility to transfer fire to the systems equipped with the Hunter Killer operation mode.

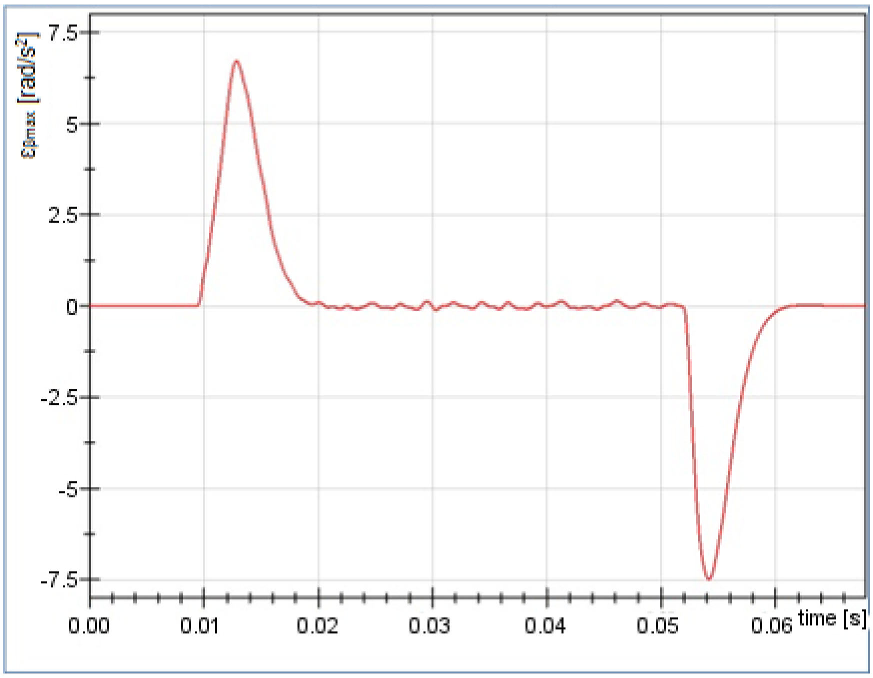

Chart 10. The examples of changes of angular accelerations and delays

3.7. Weapon guiding angular delay (braking) in elevation $-\varepsilon_{\alpha max}$ and in azimuth $-\varepsilon_{\beta max}$

The parameter of the values for the weapon guiding angular delays determined from the angular acceleration characteristics shows the possibilities of weapon braking, what is important in case of medium and large calibre systems since they have high inertia due to their weight. In practice this parameter describes also indirectly the possibility of the proper use of the Hunter Killer mode.

3.8. The response time for the stabilisation system for single input function in elevation t_{odpe} and in azimuth t_{odpa}

In order to determine these parameters it is necessary to determine, in the synchronized time preserving repeatable measurement conditions (known hindrance dimensions and constant journey speed):

- the changes of value of barrel angular inclination in the elevation in time $\alpha_l(t)$,
- changes of turret deflation (barrel) values in azimuth $\beta_l(t)$,
- the changes of value of body angular inclination in the elevation in time $\alpha_l(t)$,
- the changes of value of body angular deflation in the elevation in azimuth $\beta_k(t)$,
- maximum vales of barrel inclination in elevation $\alpha_{maxl}(t)$,
- maximum values of turret deflation (barrel) values in azimuth $\beta_{maxl}(t)$,
- maximum vales of body inclination in elevation $\alpha_{maxl}(t)$,

– maximum vales of body deflection in azimuth $\beta_{maxk}(t)$.

The response time for the stabilisation system for single input function (single obstacle) describes the system reaction speed and the response time characteristics in the vehicle speed function will allow to provide answers on the optimal selection of vehicle speed during dynamic shooting.

4. Conclusions

The parameters determined experimentally in the laboratory conditions (lack of the need to have shooting in military training area conditions) described above decide on the stabilisation system quality which is directly related to the effectiveness of the fire during dynamic shooting.

The determination of these parameters is not an easy process, there occur problems mainly related to maintaining repeatable measurement conditions. Moreover in order to have these checks made it is necessary to have specialised measurement equipment which has been purchased by the Military Institute of the Armoured and Automotive Technology as part of the programme "The programme for the support of the research infrastructure as part of Polish Science and Technology Fund".

References

[1] Chłędowski, M., *Wykłady z automatyki dla mechaników*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2003.
[2] Papliński, K., *Badania możliwości polepszenia układu stabilizacji wieży czołgowej,* Rozprawa doktorska, Warszawa 1994.
[3] Żelazny, M., *Podstawy automatyki,* PWN, Warszawa 1976.
[4] Dorczuk M., Świętek T., *Możliwości podwyższenia walorów taktycznych zdalnie sterowanego wieżowego modułu uzbrojenia KOBUZ*, Pułtusk 2013.
[5] Dorczuk, M., *Analiza porównawcza bezzałogowych systemów wieżowych do kołowych i gąsienicowych pojazdów wojskowych*, Sprawozdanie WITPiS nr 64/ZCiPG/2012.
[6] Gümüsay, O. R., *In partial fulfillment of the requirements for the degree of master of science in electrical and electronics engineering*, November 2006.