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FUZZY CONTROL OF THE OBSERVATION AND TRACKING HEAD PLACED ON A MOVEABLE BASE

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Abstract: *The Observation and Tracking Head is a significant element of equipment of self-propelled anti-aircraft missile systems. It is used for detecting, identifying and tracking air and ground targets in different lighting conditions. The paper contains the analysis of fuzzy control of the head. The impact of kinematic excitations caused by the movement of the base on which the head is mounted on the operation of head has been taken into account. Selected results of numerical research are presented in a graphical form.*

Keywords: Observation and Tracking Head, Control, Fuzzy logic.

1. Introduction

The Observation and Tracking Head (OTH) is a significant element of equipment of remotely controlled modules of weaponry, mounted on combat vehicles. The head is used for detecting, identifying and tracking air and ground targets during the day and at night, also in the conditions of dense smoke and fog (Krzysztofik & Koruba, 2012; Krzysztofik, 2012).

OTH is a modern optoelectronic system which integrates many sensors (M. Blasiak & Kotowski, 2009). First of all, it is equipped with a thermographic camera, daylight camera and an eye-safe laser range finder. Moreover, it can be equipped with a weak light camera which increases the possibility of head operation to dawn and dusk. Manufacturers frequently equip their observation systems with an indicator or a laser illuminator as well as an internal GPS/IMU navigation system. Thanks to that it is possible to determine the geographical location of a target. The mentioned sensors are placed on a controlled and gyroscope-stabilized platform which ensures stability of image regardless of manoeuvres made by the vehicle (Koruba et al., 2010a).

The head performs movements in two planes: a vertical one, in an angular scope usually up to 90 degrees, and a horizontal one, in the full angular scope. During the search of the air space, the head performs the programmed movement. After detecting a target, it automatically passes into the tracking mode. Simultaneously, strong disruptions coming from the deck of the self-propelled missile system on which the head is located affect the head (Koruba et al., 2010b). Hence, a careful selection of parameters of the automatic control system is important so that, independently of the said disruptions, the process of searching and tracking a detected target went stably.

2. Formulation of problem

It is necessary to determine a suitable physical model and then to formulate a mathematical model for conducting simulation research on the dynamics of the Observation and Tracking Head, as shown in papers (Baranowski, 2013; S. Blasiak et al., 2013; S. Blasiak et al., 2014; S. Blasiak, 2015a, 2015b).

In this paper, the spatial model of the Observation and Tracking Head placed on the deck of a movable object shown in Fig. 1 was adopted for the research. The head consists of an outer frame of mass m_{ex} and moments of inertia $J_{x_{h1}}, J_{y_{h1}}, J_{z_{h1}}$ as well as an inner frame, including an observation and tracking device of mass m_{in} and moments of inertia $J_{x_h}, J_{y_h}, J_{z_h}$. We determine head movement with the

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use of two functions: $\psi_h(t)$ – the angle of rotation of the head around axis y_h and $\vartheta_h(t)$ – the angle of rotation of the head around axis z_h .

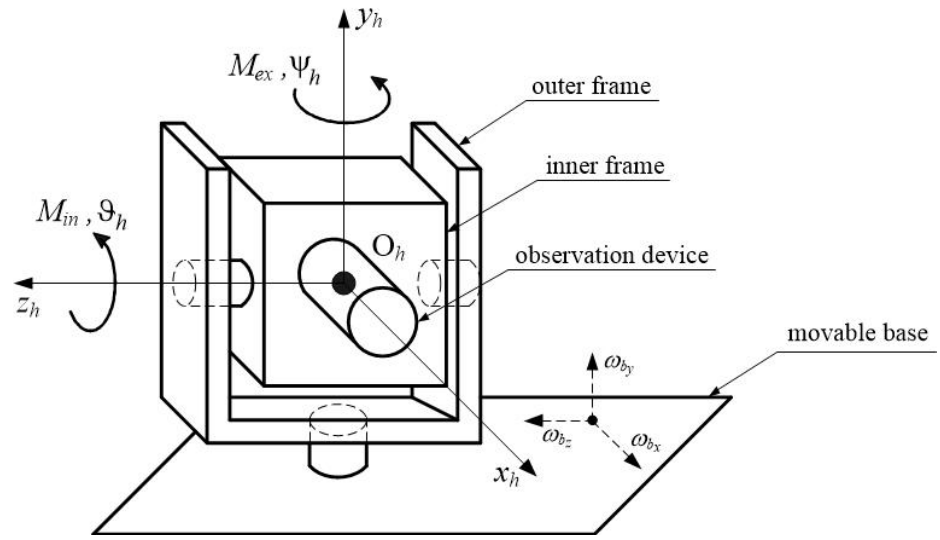

Fig. 1: The view of the Observation and Tracking Head.

The head is affected by base vibrations $\omega_{b_x}, \omega_{b_y}, \omega_{b_z}$ which were adopted in the harmonic form:

$$\omega_{b_x} = \omega_{xo} \cdot \sin(\nu_b t + \phi_x) \tag{1}$$

$$\omega_{b_z} = \omega_{zo} \cdot \sin(\nu_b t + \phi_z) \tag{2}$$

where: $\omega_{b_y} = 0$, $\omega_{xo} = 1.5$ rad , $\omega_{zo} = 1.5$ rad , $\nu_b = 10$ rad/s , $\phi_x = 0.314$ rad , $\phi_z = -0.314$ rad .

The equations of dynamics of the head were introduced with the use of Lagrange II-nd kind of equations with the assumption that the centre of mass of the head overlaps with the centre of movement. The following system of equations was obtained:

$$\begin{aligned} &\left[J_{y_{h1}} + J_{y_h} + \left(J_{x_h} - J_{y_h}\right)\sin^2\vartheta_h\right]\left(\ddot{\psi}_h + \dot{\omega}_{b_y}\right) + \frac{1}{2}\left(J_{x_h} - J_{y_h}\right)\left(\dot{\omega}_{x_{h1}} + \omega_{y_{h1}}\dot{\vartheta}_h\right)\sin 2\vartheta_h \\ &- \left[J_{y_h} + \left(J_{x_h} - J_{y_h}\right)\sin^2\vartheta_h\right]\omega_{x_{h1}}\dot{\vartheta}_h + J_{x_h}\omega_{x_h}\omega_{z_h}\cos\vartheta_h - J_{y_h}\omega_{y_h}\omega_{z_h}\sin\vartheta_h \\ &+ \left(J_{x_{h1}} - J_{z_{h1}}\right)\omega_{x_{h1}}\omega_{z_{h1}} - J_{z_h}\omega_{z_h}\omega_{x_{h1}} + \eta_{ex}\psi_h = M_{ex} \end{aligned} \tag{3}$$

$$J_{z_h}\left(\ddot{\vartheta}_h + \dot{\omega}_{z_{h1}}\right) - \left(J_{x_h} - J_{y_h}\right)\omega_{x_h}\omega_{y_h} + \eta_{in}\vartheta_h = M_{in} \tag{4}$$

where:

$\omega_{x_{h1}} = \omega_{b_x}\cos\psi_h - \omega_{b_z}\sin\psi_h$, $\omega_{y_{h1}} = \omega_{b_y} + \dot{\psi}_h$, $\omega_{z_{h1}} = \omega_{b_x}\sin\psi_h + \omega_{b_z}\cos\psi_h$;

$\omega_{x_h} = \omega_{x_{h1}}\cos\vartheta_h + \omega_{y_{h1}}\sin\vartheta_h$, $\omega_{y_h} = -\omega_{x_{h1}}\sin\vartheta_h + \omega_{y_{h1}}\cos\vartheta_h$, $\omega_{z_h} = \omega_{z_{h1}} + \dot{\vartheta}_h$;

η_{ex}, η_{in} – friction coefficient in suspension bearings of the outer and inner frame, respectively;

M_{ex}, M_{in} – moment of forces interacting on outer and inner frame, respectively.

3. Fuzzy control

In order to achieve precision when searching and tracking a detected target it is necessary to isolate the observation and tracking device completely from angular movements of the base. It can be done by properly formulated controls M_{ex} and M_{in}, applied to two mutually perpendicular axes of the head (Gapiński & Stefański, 2013; Krzysztofik & Koruba, 2012, 2014; Osiecki & Stefański, 2008). In the

Matlab/Simulink software fuzzy controllers Mamdani's PD type were designed (Driankov et al., 1996; Sivanandam et al., 2007). Input signals to head deflection controller are error $e_1 = \psi_{hr} - \psi_h$ and error change Δe_1, whereas the output signal is the control M_{ex}. Analogously, input signals to head inclination controller are error $e_2 = \vartheta_{hr} - \vartheta_h$ and error change Δe_2, whereas the control M_{in} is the output signal. Angles $\psi_{hr}, \vartheta_{hr}$ mark a set angle of head deflection and inclination, respectively. The inference was conducted based on 25 fuzzy rules. Trapezium and triangular functions were adopted as membership functions (Takosoglu et al., 2009; Takosoglu et al., 2012).

In order to assess the proposed fuzzy control of the Observation and Tracking Head mounted on a movable base, numerical simulations were conducted with the Matlab/Simulink software, with the use of *ode3* procedure, with a fixed constant of integration amounting to $dt = 0.0001$, for the following parameters: $I_{x_{h1}} = 0.22$ kgm^2, $I_{y_{h1}} = 0.114$ kgm^2, $I_{z_{h1}} = 0.117$ kgm^2, $I_{x_h} = 0.061$ kgm^2, $I_{y_h} = 0.035$ kgm^2, $I_{z_h} = 0.029$ kgm^2, $\eta_{ex} = 0.05$ Nms, $\eta_{in} = 0.05$ Nms.

Figs. 2-3 show the set and real head trajectory as well as control errors for the programmed movement on the surface of a circular cone.

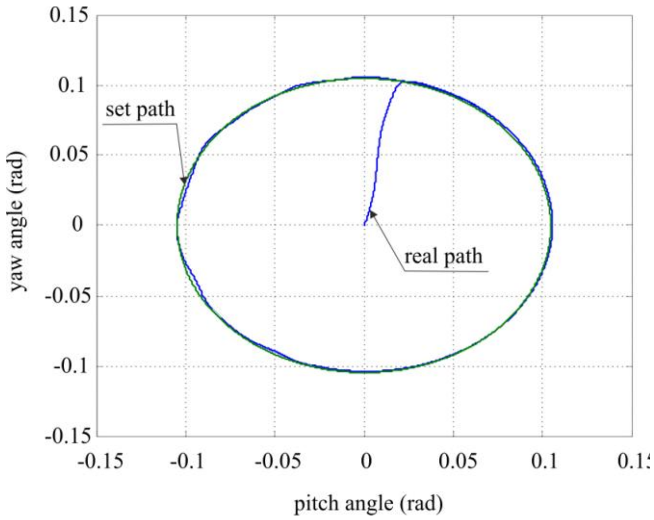

Fig. 2: The set and real head trajectory.

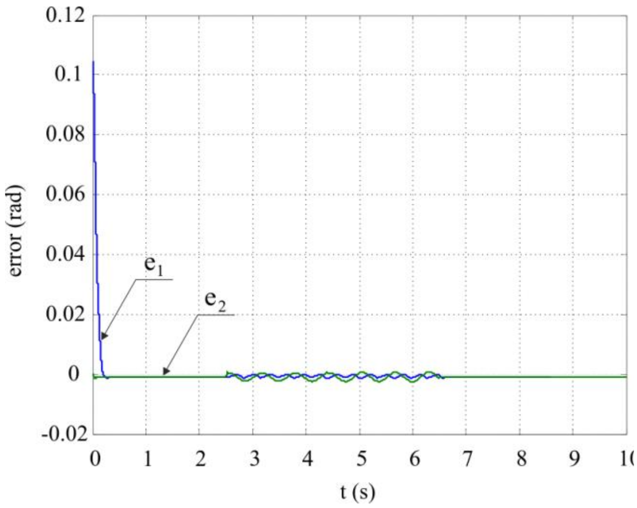

Fig. 3: Control errors.

Figs. 4-5 show the set and real head trajectory as well as control errors for the programmed movement on the unwinding spiral.

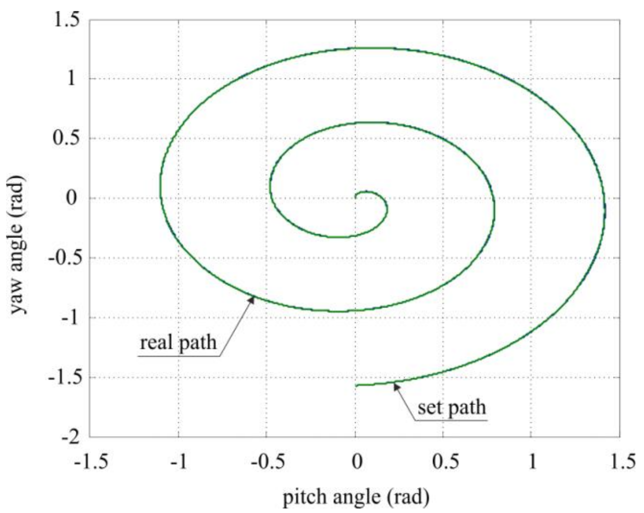

Fig. 4: The set and real head trajectory.

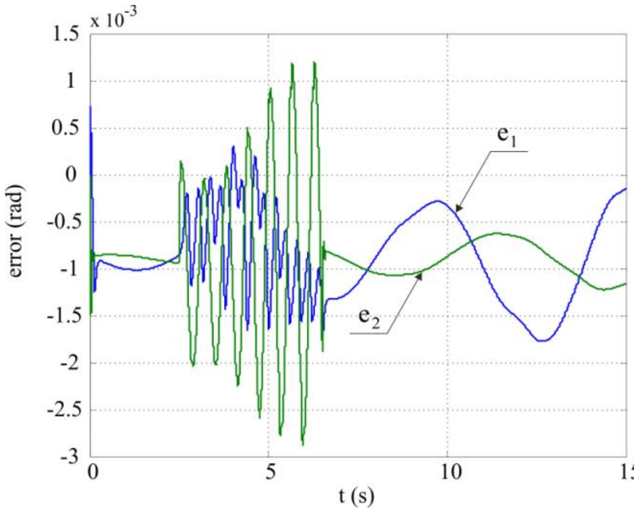

Fig. 5: Control errors.

4. Conclusions

The task of Observation and Tracking Head consists in effective identification and subsequent tracking of targets which are to be destroyed. Therefore, the reliability and precision of operation of the head are important.

The presented research results confirm the correct operation of the designed fuzzy controllers for controlling OTH in deflection and inclination movement. The programmed movement is fulfilled with high precision. Base vibrations affecting the head are simply imperceptible. Slight deviations from the set location occur. It is particularly visible in Fig. 2.

In the next stage of research, tests of effectiveness of operation of the proposed control system at the moment of the head passing from searching to tracking a detected target should be conducted.

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