INFLUENCE OF INERTIA MOMENT OF INFANTRY FIGHTING VEHICLE TURRET ON ACCURACY OF AIMING AT A TARGET AND TRACKING OF A TARGET

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Abstract

In the paper was tested one of combat vehicles that is highly dynamic military vehicles, combining a high striking and fire power with high mobility and manoeuvrability. Were presented the mechanism of transfer of disturbance from the ground on the angular stabilized turret of the vehicle. Hull vibration caused by bumps in the ground. Angular and axial displacement of vehicle are the input signals acting on the turret and the gun. Two-axis stabilisation system compensates the velocities of the vehicle. Stabilisation system, automatically maintain the position of the turret at a fixed bearing in space. In spate of any motion of the vehicle in roll (hall transversal vibration) or in yaw (hall "snake-like" vibration).

Torques and forces acting on the rigid body of combat vehicle turret are written in equations of motion. To examine the effect of mass inertia moment of the IFV turret on the size of first overshoot (to confirm the theoretical considerations) performed a simple experiment. Was measured the size of the angle of the first overshoot of the turret when braking rotating turret with a maximum angular velocity. Measurements were made on the IFV turret in the previously existing configuration, and when mounted on it extra weight. An experiment confirms the theoretical considerations. The results of measurements show that an increase of approximately 8% of the mass moment of inertia of the turret causes about 16% increase in the amplitude of the first overshoot.

Keywords: *combat vehicle, fire control system, gun stabilizer, amplitude of the first overshoot*

1. Introduction

Combat vehicles are highly dynamic military vehicles, combining a high striking and fire power with high mobility and manoeuvrability, getting stronger armour and susceptibility to structural changes. This represents a great significance among the military vehicles of ground troops. They can perform various tasks, both in offensive operations, as well as defence, conduct the fire from place and motion to the ground and air targets, day and night in difficult terrain and weather. Therefore, for many years combat vehicles such as tanks or infantry fighting vehicles (IFV), are the primary striking force of land forces and they will remain so for years to come. Most of combat vehicles of the armed forces and equipment entering the army are still built in the traditional system design, where the armour is located in the armoured turret rotatable set up on the hull.

The basic characteristics of combat vehicles which determine their usefulness on the battlefield are the firepower, resistance to the enemy (armor), and motility.

Firepower is the ability to destroy the combat vehicle and incapacitate the various objectives in the shortest possible time with minimum consumption of bullets. It is the most important feature and depends on the following factors:

– ability to observe, detect and recognize the targets of which determines the quality of sighting

devices and sights, and the accuracy of the field of view stabilization;
- ability to fire affected by the quality of the guns guidance and stabilization systems, missile firing rate and resonance trajectory;
- probability of hitting and destruction, which depends on the type and quality of weapons, ammunition, stabilizer and fire control system;
- quantity and quality of fire units.

In most of these factors have a significant impact guidance and the stabilization system of the gun. It is therefore important that the factors and to what extent might affect the proper operation of the stabilizer.

2. The mechanism of transfer of disturbance from the ground on the stabilized turret

Vibrations of a moving combat vehicle have a significant impact on the work of all its systems and mechanisms, and a decisive influence on the effectiveness of shooting from moving vechicle, greatly reducing the opportunities to observe and detect targets, guidance, and increasing the errors spread of missiles. As a result of which the probability of hitting for significantly reduced, and the time necessary for the purpose of destruction and rising consumption of ammunition.

Hull vibration caused by bumps in the ground, after which the combat vehicle moves, and depend on the speed of its movement, dynamic properties of the suspension (for tracked vehicles nature of the reactions between track on land) and a whole range of other factors. The hull of the vehicle moves in a complex spatial motion, which can be viewed as a composite of linear displacement and angular displacement of a point.

Horizontal angular vibration of the hull are caused by periodic changes in direction of motion (low frequency component), and soil quality along the route (high frequency component) and the tracked vehicles also irregularity of track tension. In winter, when moveing on the hard frozen ground horizontal angular vibration intensity increases from a half to two times. The nature of horizontal angular vibration of the hull to a large extent depends on the experience and skill of the driver. These vibrations, like longitudinal vibration, worsening conditions for detection of targets and firing on the move, being the primary cause of dispersion of shells in azimuth (sideways). The intensity of horizontal angular vibration of the hull to a large extent determines the accuracy of the weapon stabilization systems work in azimuth (the turret with a gun - Figure 1).

The transverse angular vibrations of the hull (Figure 2) as the longitudinal profile are dependent on the substrate, the speed and fluidity of movement and dynamic properties of the suspension. Typically, the amplitude and angular velocity of transverse vibration of the hull is about two times smaller than the amplitude and angular velocity of longitudinal. When shooting in front the transverse angular vibrations acting on the unbalanced turret, have a decisive impact on the spread of bullets in azimuth which leads to less accurate stabilization and reduce the effectiveness of shooting on the move. With high-speed moving in the heavily pleated ground, transverse vibration intensity increases.

Linear vibration of the hull are of relatively low amplitude (approximately 100-150 mm), but quite a large acceleration (an average of 0.4-1.5 m/sek^2). While the turret and gun are not balancing these speeds cause additional disrupting torqe, lowering the accuracy of the gun stabilization. In addition, the high frequency components of linear vibration cause vibration of sights, which leads to a reduction of detection distance (corresponding to high frequency vibration influence of the hull, caused by engine operation.)

Angular and axial displacement of vehicle are the input signals acting on the turret and the gun. Two-axis stabilisation system compensates the velocities of the vehicle. Stabilisation system, automatically maintain the position of the turret at a fixed bearing in space. In spate of any motion of the vehicle in roll (hall transversal vibration - γ_H) or in yaw (hall “snake-like” vibration - ψ_H).

The turret stabiliser, minimise the effects of vehicle motion on the main armament, under typical conditions of combat vehicle operation over rough ground. In other words, a two-axis stabilisation system compensates for the angular velocities of the vehicle so that, the turret is almost unaffected by them.

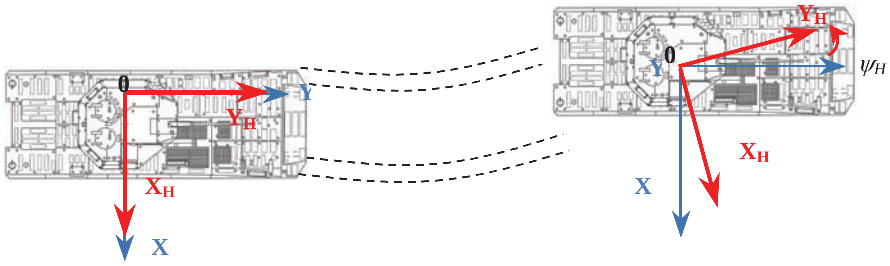

Fig. 1. Horizontal angular vibration of the hull

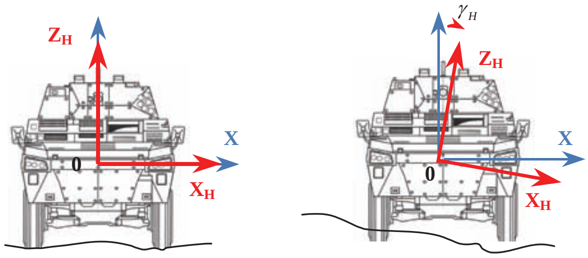

Fig. 2. Transverse angular vibration of the hull

3. Torques acting on the turret

When the vehicle is in motion the forces from the ground by tires, suspension and hall moves to the turret. As a result of friction in the bearing and seal and through the inertia of the turret and the turret not balance the inertia and resistance of the DC motor torque is created mechanical torque precipitated the gun turret from a fixed position.
Torques and forces acting on the rigid body of combat vehicle turret are illustrated in Fig. 3 and may be written in equations of motion form as follows:

$$M_{JT} + M_{ORT} + M_{NT} + M_{ST} = 0\,, \tag{1}$$

where:
M_{JT} - the total torqe acting on the turret due to moment of inertia,
M_{ORT} - the total damping torqe between the hull and the turret,
M_{NT} - the total torqe acting on the turret due to non-balance,
M_{ST} - the torqe produced by an azimuth drive motor.

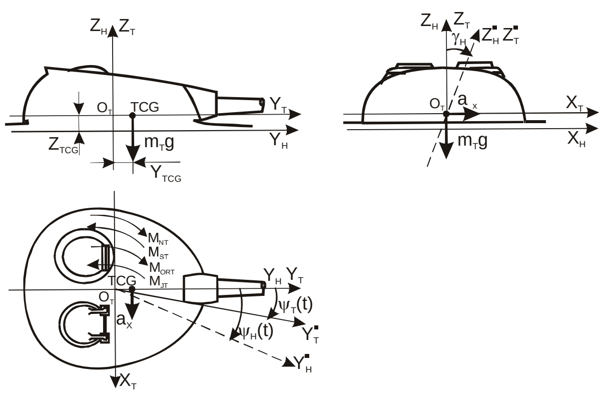

Fig. 3. Torqes acting on the turret of combat vechicle

– Torqe acting on the turret due to moment of inertia may be written in the form as follows:

$$M_{JT} = J_T \ddot{\psi}_T \,, \tag{2}$$

where:

J_T - the turret moment of inertia with respect to vertical axis of rotation Z_T,

$\ddot{\psi}_T$ - The turret angular acceleration in yaw (plane $X_T O_T Y_T$),

– Total damping torqe between the hull and the turret may be written in the form as follows:

$$M_{JRT} = M_{TT} + M_{JR} + M_{OS} \,, \tag{3}$$

where:

M_{TT} - torqe acting on the turret due to coulomb damping between the turret and the hull (mainly in the turret ball bearing),

M_{JR} - torqe acting on the turret due to moment of inertia of azimuth drive system (motor's rotor and gear box's inter-mating gears),

M_{OS} - torqe acting on the turret due to azimuth drive system (depends on the type of drive).

The components of total damping torqe between the hull and the turret can be defined as follows:

$$M_{TT} = M_{STT}\, sign(\dot{\psi}_H - \dot{\psi}_T) = M_{STT}\, sign\, \dot{\psi}_{TH} \,, \tag{4}$$

$$M_{JR} = J_{SR} i^2 \ddot{\psi}_{TH} \,, \tag{5}$$

$$M_{OS} = F \dot{\psi}_{TH} \,, \tag{6}$$

where:

M_{STT} - static torqe of friction,

$\dot{\phi}_{\mathrm{H}}, \dot{\phi}_{\mathrm{T}}$ - the hull and the turret angular velocity in yaw,

$\dot{\phi}_{\mathrm{TH}}$ - the velocity of the turret relative to the hull,

J_{SR} - the azimuth drive motor's rotor and gear box's moment of inertia with respect to the axis of rotation,

i_r - azimuth drive transmission ratio,

F - damping coefficient of azimuth drive.

– The TCG is displaced to fore-part of turret due to thick front armour and heavy main gun. In consequence the total torqe due to non-balance of the turret may be written in the form as follows:

$$M_{NT} = M_{ax} + M_{\gamma} \,. \tag{7}$$

The components of the total torqe due to non-balance of the turret (angular displacement of turret while stabilising the position of the gun are very small) can be defined as follows:

$$M_{ax} = a_x m_T y_{TCG} \,, \tag{8}$$

$$M_{\gamma} = m_T y_{TCG} z_{TCG} \ddot{\gamma}_H + m_T g y_{TCG} \gamma_H \,, \tag{9}$$

where:

M_{ax} - torqe due to non-balance of the turret caused by a_x (acceleration of the TCG in X_T direction), M_{γ} - torqe due to non-balance of the turret caused by angular displacement γ_{H} of the TCG in roll (plane $Z_T O_T X_T$), a_x - accelerations of the TCG in X_T direction, m_T - total mass of turret, g - accelerations of gravity, y_{TCG} - the distance of the TCG from Z_T

(turret axle of rotation), z_{TCG} - the distance of the TCG from Y_H (hull axle of rotation), γ_H - angular displacement in roll.

The experience of armed conflict is clear that the turret is the most vulnerable to shocks to the enemy element in the combat vehicle, which will be struck in 70 ÷ 80% of the projectiles. Therefore, to ensure the protection shall be amended in the construction of armor and increases in thickness especially in front of the turret. This causes a significant increase in weight of the turret and its mass moment of inertia.

Another factor causing the same effect is the continuous increase of the caliber cannons caused a desire to achieve greater firepower. The improvement in the caliber cannon ammunition accompanied by increased weight, a large proportion (depending on the type of vehicle) are deployed in the turret. This results in an additional increase in weight of the turret, its mass moment of inertia and the balance can not increase or decrease depending on the location of the containers of ammunition in the turret.

4. Experimental studies

Drive in azimuth provides the ability to rotate the turret when moving fire from one to the other target and to stabilize the given angular position of the turret when the forces acting on the road. Turret drive is operating under a wide range of vibration amplitudes and frequencies. In order to obtain a high probability of hitting the system should have a little adjustment time, short delay time in activation, a small overshoot and oscillations. They run faster transient processes in the drive, the more accurately and faster, you can guide the weapons to the target.
The drive should provide a quick run down, a quick moveing from one to another selected speed and fast braking. Particularly important is the rapid braking of the rotating turret with a maximum angular velocity. Turret because of the large inertia "passes" the correct position missing the target from view. This requires additional time to locate and accurate pointing. Hence, the key is the size of the first overshoot angle.

To examine the effect of mass inertia moment of the IFV turret on the size of first overshoot (to confirm the theoretical considerations made above) performed a simple experiment consisting of:

- measurement of the mass inertia moment of the turret of some IFV,
- measure the size of the angle of the first overshoot of the turret when braking rotating turret with a maximum angular velocity (as is happening during an indication target to the gunner by the commander) and after moving of the turret with a specified angular position (which occurs when the forces are transferred from the road at the stabilized turret),
- measurements were made on the IFV turret in the previously existing configuration, and when mounted on it extra weight (which can imitate the increase of turret armor, instol additional external and internal turret equipment or increasing the fire unit placed in the turret),
- measurements were done on the turret is installed on a special test stand that is used to test the final turret in the manufacturing process or after the renovation,
- tests were conducted on the same stand, on the same turret, with equal conditions of supply and the same measurement methods.

Figure 4 shows the test stand with equipment to measure mass inertia moment of the turret. With a known used spring stiffness was measured the arm of force and the period of gun vibration.

The value of inertia moment, we define the formula:

$$I - \frac{k \cdot l_w^2}{4 \cdot \pi^2} \cdot T_w^2, \qquad (10)$$

where:
k - stiffness of springs, l_w - the arm of force from springs, T_w - period of gun oscillation.

The period of gun oscillation was calculated by analyzing the filmed turret vibration. Use the same method were measured value of the first overshoot under braking before rushing the turret.

Fig. 4. Measurement stand with equipment to measure inertia moment of the turret

5. Concluding remarks

An experiment confirms the above theoretical considerations. Simulated increase in armour of the turret will not substantially increase its resistance to motion of the bearing. The measured increase in resistance torque is within the measurement error. Visible is a significant increase in the angle of the first overshoot. The results of simple measurements show that an increase of approximately 8% of the mass moment of inertia of the turret causes about 16% increase in the amplitude of the first overshoot. This represents a deviation in azimuth of about 0.6 m, bullets shot from guns, when shooting objects at a distance of 2 km.

This case demonstrates that any change in the parameters of the controlled mass, which is the turret, should result in appropriate changes to the FCS. Such deviations should be compensated by proper selection of feedbacks in the system turret stability.

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