

## SIMULATION MODEL OF TANK COMBAT

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**Abstract:** In this paper, the fire control system for tanks (FCS) is presented, as a complex system, by means of which the target is detected, the necessary elements are occupied and shooting is carried out. The components of the FCS, the way in functions, and the way it is maintained are presented. The essence of FCS is presented in the form of algorithms, which includes all events, from the moment of target detection, to the firing order. The concept of direct fire is explained, as a model, which is characteristic in tank battles, with the problems and errors that may appear. Mathematical models for solving the problem of shooting in the horizontal and vertical planes have been set up. Also, the problem of shooting from a tank, when it is under a certain lateral inclination, in relation to the horizontal plane, where the shoulder of the cannon cradle is tilted, is explained. The mathematical model in this situation, which is presented in the paper, refers to the calculation of corrected angles of direction and elevation. In addition to FCS, in tank combat, one of the main factors for the success of the mission is the training of the crew. Based on all the set mathematical models, an example of a tank battle, consisting of two tanks, is shown. Tank combat is presented in the form of an algorithm, which includes all activities from target detection, through determining the necessary elements, to shooting.

**Keywords:** Tank, Fire control system, Tank combat

## INTRODUCTION

The Fire control system is a complex system, with the help of which the weapons detect the target, take the necessary elements for shooting, and hit it. The creation of the system, made it possible to relieve the crew and increase the probability of hitting. The Fire control system consists of: sensors, computers and executive bodies. The problems of the Fire control system can be presented in the form of an algorithm. [1]



Figure 1. Fire control system procedure

represent the procedure of the Fire control system. [1]

## SHOOTING IN DIRECT TANKS COMBAT

Direct firing from a tank is used in situations where it is necessary to complete the task with at least one direct hit on the target or where it is necessary to complete the task with as little consumption of ammunition as possible, in the shortest possible period of time. This is the basic mode of operation of the tank. Direct shooting can be divided into:

- shooting moving targets,
- shooting at stationary targets.

Hitting moving targets is most effective if shooting is done at distances of 1.5 to 2 swept ranges, because at longer distances the dispersion of hits increases sharply, the speed of the projectile decreases, its penetration of the target's armor decreases and errors occur in determining the elements for shooting. [1]

All members of the algorithm are interconnected and



The total overtaking angle is determined from the following expression, based on the speed of the firing tank:

$$\psi_{V_c V_t} = \frac{6000(6400)}{2\pi} V_t \sin \alpha_c \left( \frac{1}{\dot{X}} - \frac{1}{V_{0M}} \right) + \frac{6000(6400)}{2\pi} \frac{\Delta V'}{X} T \quad (2)$$

$$\psi_{V_c V_t} = \frac{6000(6400)}{2\pi} (\Delta \psi_p + \omega_{cz} T) \quad (3)$$

$$\dot{X} = \frac{X}{T} = const \quad (4)$$

$V_t$  – projectile speed

$\alpha_c$  – the angle between the axis of the barrel of the cannon and the direction of movement of the tank in the horizontal plane

$X$  – range

$V_{0M}$  – the actual initial speed of the projectile

$\Delta V'$  – the relative speed of the target in the direction normal to the axis of the barrel of the cannon

$T$  – the flight time of the projectile

$\psi_p$  – overtaking angle whitout crosswind influence

$\omega_{cz}$  – angular speed of the target

The equation shows that the total overtaking angle, during the movement of both the tank and the target, is reduced to correction. This correction is determined by means of the component of the wind speed in the direction normal to the projection of the axis of the barrel of the cannon in the horizontal plane and the speed of the target, which is determined on the aiming device. [2]

### SHOOTING IN THE VERTICAL PLANE

Here, it is necessary to establish an adequate elevation angle of the barrel. If the target is moving, there must be an elevation angle correction at all times. If overtaking is present in the vertical plane, the elevation angle of the barrel must be determined by the speed of movement of the target and the firing tank. An additional complication is characterized by the fact that both the tank and the target move on terrain with arbitrary irregularities. []

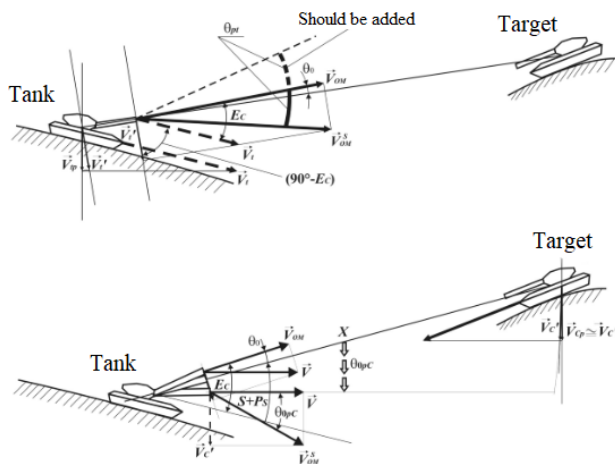


Figure 4. Overtaking during the movement of tanks in the vertical plane [2]

The elevation angle  $E_c$  represents the basic quantity for the dynamic correction of shooting moving target.

It contains the table angle  $\theta_0$  and the target angle  $S$ . Overtaking involves two questions. The first refers to overtaking due to the tank movement of the tank. The overtaking angle is calculated as:

$$\theta_{pt} = \frac{V'_t}{V_0} = \frac{V_t \sin E_c}{V_0} \approx 0 \quad (5)$$

The second refers to overtaking due to target movement. Then the overtaking angle is calculated as:

$$\theta_{0pc} \cong \frac{V'_c T}{X} \left( \frac{6000(6400)}{2\pi} \right) \quad (6)$$

$V_0$  – initial speed of the projectile with the appropriate ballistic correction

$V'_c$  – the speed of the change in the position of the target in the firing plane, in relation to the tank firing in the vertical plane

There is a problem that further complicates the entire shooting preparation, and that is the slope of the shoulder of the tank gun cradle. [2]

### INFLUENCE OF TANK CANNON CRADLE SHOULDER ANGLE

The simplest way to shoot from a tank is when it is standing on a flat surface, that is, when the cradle of its cannon is in a horizontal position. However, in practice, it often happens that the tank is located on the terrain, which is under some slope. One such example can be seen in figure 5. [1]

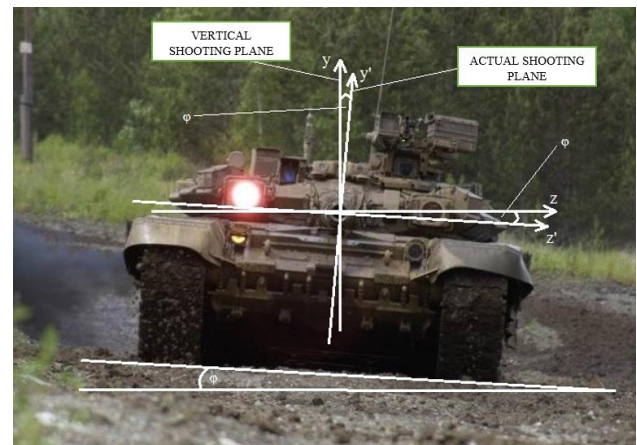


Figure 5. Position of the tank in an inclined plane

The z-y plane represents the horizontal position of the tank

The z'-y' plane represents its actual position

The corrected angle of direction and elevation of the barrel can be calculated as: [1]

$$\theta'_0 = \theta_0 \cos \varphi + \psi_0 \sin \varphi \quad (7)$$

$$\psi'_0 = \psi_0 \cos \varphi - \theta_0 \sin \varphi \quad (8)$$

### ALGORITHM OF TANK COMBAT

The tank battle begins the moment one of the tanks discovers the other, with its observation-aiming device. Then the preparation of elements for shooting begins, with the desire to neutralize the opponent's means as soon as possible. The battle of tanks lasts until that moment, when one tank hits another, and the hit is with a critical outcome for the opposing tank. There is another way to end the battle, and that is when both tanks run out of ammunition. In Figure 6, two tanks can be seen. The sighted tank (target) moves relative to the firing tank, in an oblique trajectory. The figure also show the parameters, which, using mathematical models, are used to calculate the necessary elements for shooting.

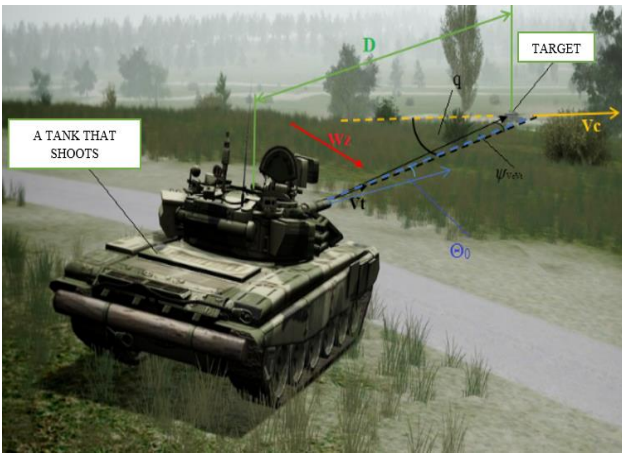
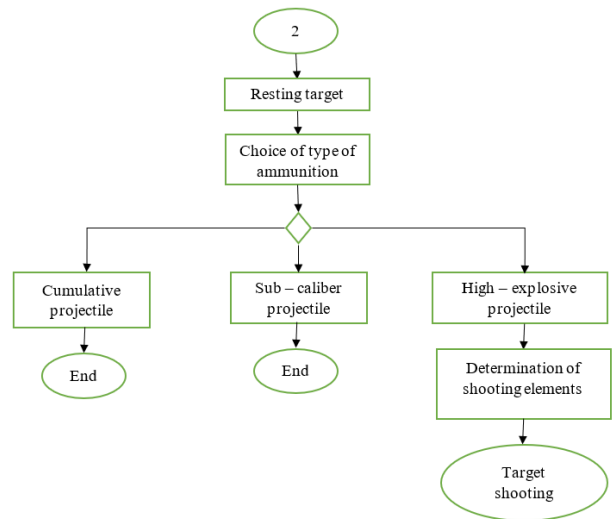
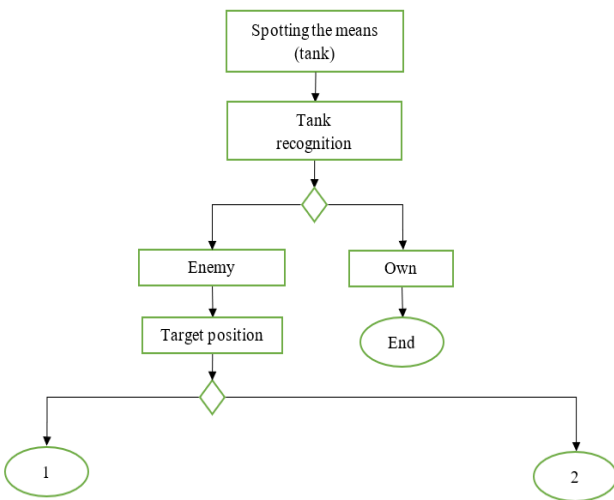
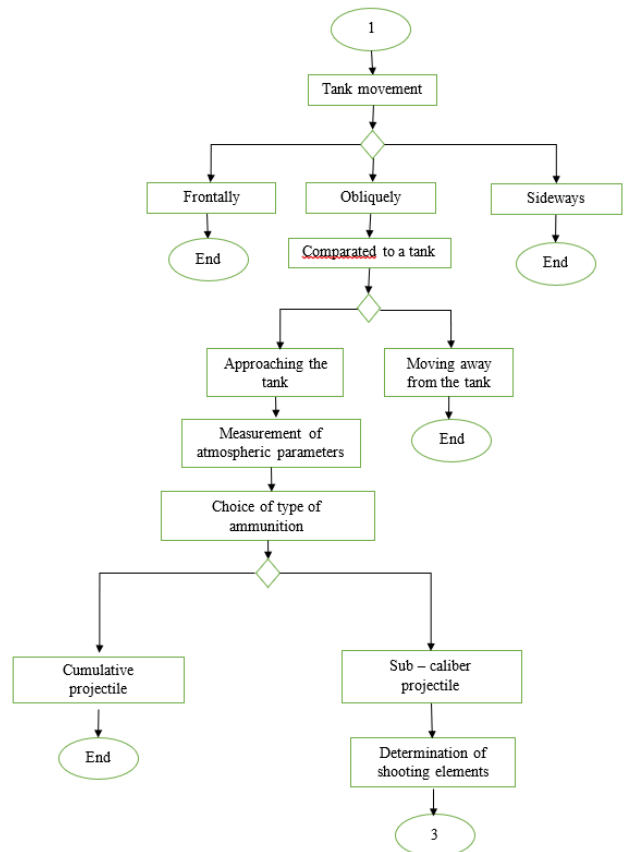


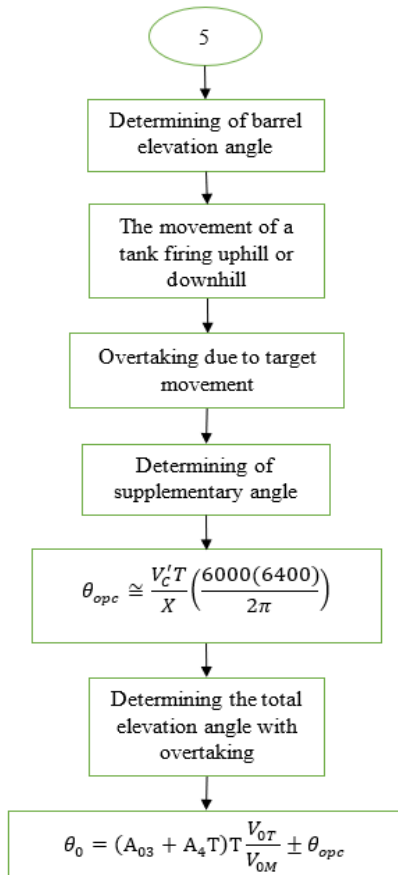
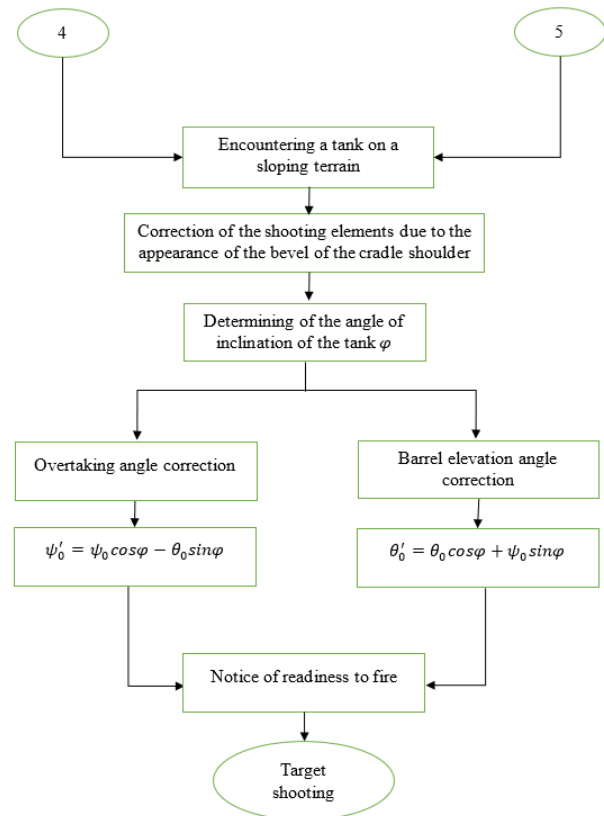
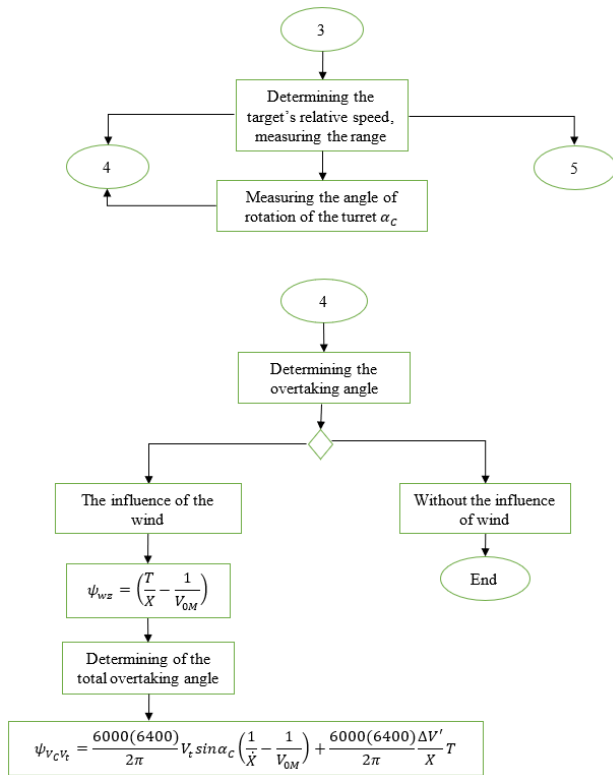
Figure 6. Tank battle with parameters for determining firing elements

The following is a presentation of the tank battle algorithm.



Note: The second case will be presented first, because it is much shorter than the first. Also, it is displayed informatively, so there won't be much lingering on it. For the selected projectile type, shooting elements are determined. After that, target shooting was done.





The algorithm starts with detecting the asset (tank). Immediately after sighting, it should be established whether it is one's own tank or an enemy tank. If it is its own, the tank continues its movement according to its predefined plan. In case the tank is enemy, the emergency mode of tank activity follows. By observing the target, the tank first collects information about whether the target is moving or stationary. The simplest way to fight is to shoot at a target at rest (case 2). A much more difficult situation is when both assets are in motion (case 1). When moving the target, the tank must see how the target is moving towards it (frontally, obliquely or sideways). The tank realizes that the target is moving obliquely, moving away from him. After that, the atmospheric parameters are measured. The combat kit of the tank consists of three types of projectiles: sub-caliber, high-explosive and cumulative. With the choice of ammunition, it was decided that the tank shoots sub-caliber projectile, because this ammunition is most often used to shoot moving targets, due to the high initial speed of the projectile. In the algorithm, the determination of the shooting elements was approached only for the selected type of projectile. Furthermore, the speed of movement of the target and the range are determined, which are necessary for determining the elements for shooting. After determining these parameters, the azimuth angle is determined. The influence of side wind, which further complicates the whole situation, is taken into account. Since the target is moving, it is necessary to determine the overtaking angle. The following is the determination of the elevation angle of the cannon barrel. Depending on the terrain, the firing tank can move uphill or downhill.

This type of movement requires a constant correction of the elevation angle, by supplementing it with a certain value of the supplemental angle.

After determining the requires angles, a new situation occurs, which further complicates the shooting process. A tank that is shooting encounters a steep plane, which forces it to move at a certain side slope, which results in the slope of the cradle shoulder by a certain angle. It is necessary to determine the angle at which the tank is now in relation to the horizontal plane, and then, using it, perform the correction of the azimuth and elevation angle. After determining the elements, there is a notification about readiness for shooting, and then the execution of the same. The tank must hit the target the first time, otherwise it becomes a target.

## CONCLUSION

The problem of shooting from a tank during a sudden tank battle, where both the tank and the target are moving in certain directions, is, by all accounts, a very complex and extremely inexhaustible topic for research and analysis. No two tank battles are the same, because each brings with it a different situation: the position of the target, the position of the firing tank, the range, the climatic conditions, the terrain on which it takes place and everything that goes with it. The role of the Fire control system is reflected in the fact that it solves all the

questions that the crew faces during the fight and reduces its solutions to successful shooting from the tank. The training of the crew plays a big role in all of this, because it means nothing if the Fire control system is functional and ready to use, and the crew is not prepared to apply it in the best away.

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