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Impulse Control of Anti-Tank Mortar Missile

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Introduction

Report explains problem of control dynamics of flying object with discontinuous impulse control inputs. Control is realised by the rocket correction motors locate around the centre of gravity of flying object. Start up the motor causes formation the force impulse direct perpendicular to main symmetry axis of object and direct along axis crossing object gravity centre. We tested possibilities of more effective influence on speed vector by impulse correction motors.

1. Problem description.

Goal of the paper is explain of guidance problem of anti-tank mortar missile. Missile is guiding from upper hemisphere. Flying trajectory is correcting by one time use, impulse, rocket correction motors. Projectile is firing from mortar and 80% of flight time is ballistic phase. To provide the missile aerodynamic stability and spin, the aft section is fitted with fins. The fins are immediately unfolded when the projectile left the barrel and their fixed cant angle impart slow spin to the projectile. Missile is guided at the last phase of flight. There is “fire and forget” projectile. Missile is launch over the targets activity area and at the last steep phase of the flight is automatically guided to the target. Missile mast be accurate launch over the targets activity area. We found that seeker has observation angel under 20^0 and find objects from distance under 1500m.

Paper presented at the RTO AVT Symposium on “Active Control Technology for Enhanced Performance Operational Capabilities of Military Aircraft, Land Vehicles and Sea Vehicles”, held in Braunschweig, Germany, 8-11 May 2000, and published in RTO MP-051.

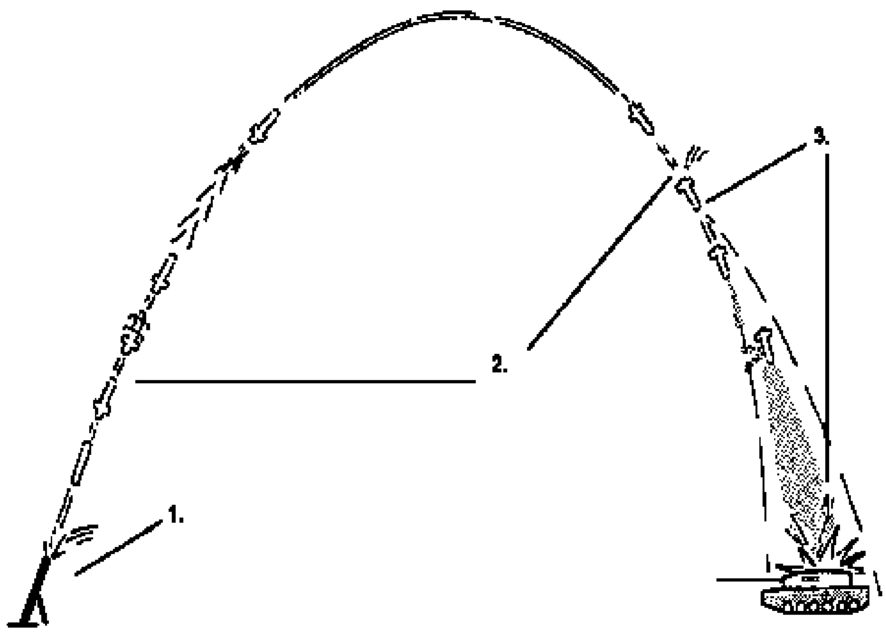

figure 1. Phases of flight:
1. launch
2. ballistic phase
3. guidance phase

These conditions give us an observation area with diameter around 300m. To launch projectile to that area is first and necessary condition of target intercept and successful missile attack. Phases of flight show the figure number 1.

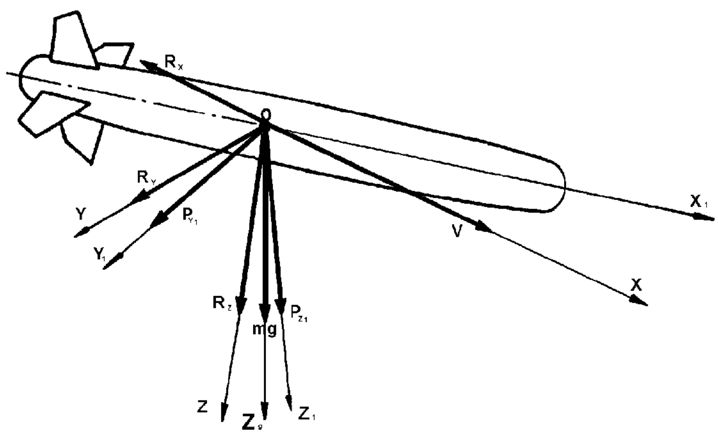

figure 2. Forces interacted to the missile at the control flight.

At this kind of projectile, where flight is controlling only at the last phase, we need not very big but quick influence on projectile's speed vector. This task we can do well by use control system made on the base rocket correction motors. Small rocket motors will have more successful influence on speed vector than classic aerodynamic control. This control conception will have to give better results of missile guidance.

2. Effect's dynamic.

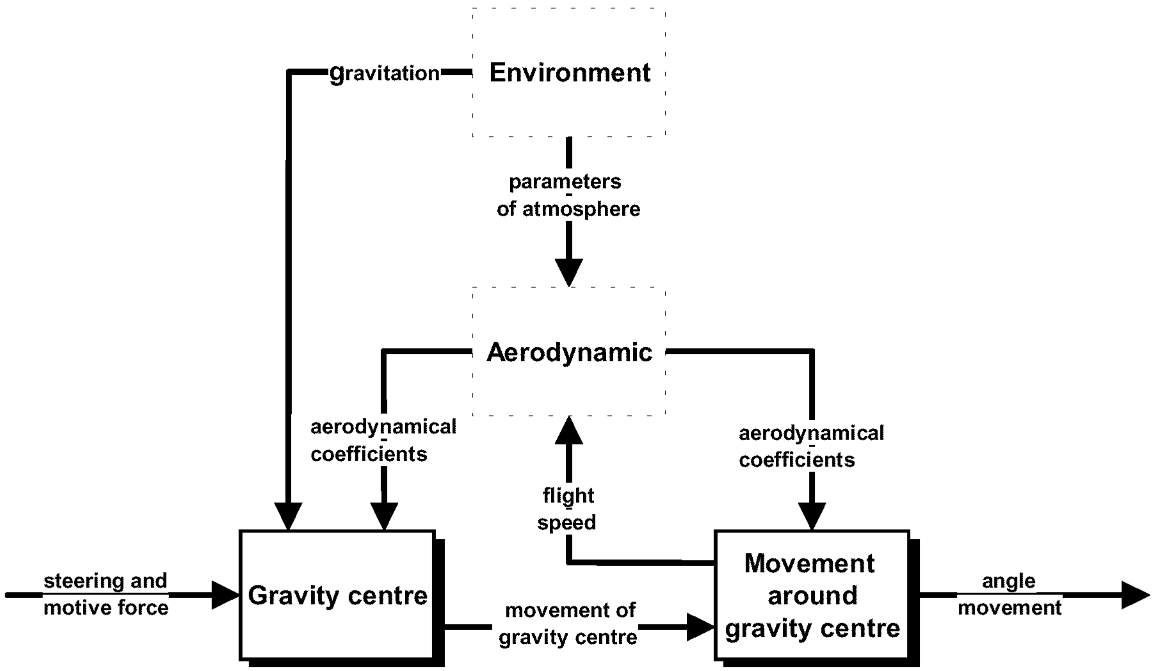

figure 3. Block scheme of object dynamic.

Classic methods of flying object control make assumption that the way of control system interaction on object is:

- steering forces first make change of force moment influence on object, it makes object rotation around gravity centre;
- supporting surfaces get necessary angels of attack and make steering forces.

At this way first we turn object around mass centre and the effect of this will be change of mass centre speed vector. This solution is characterised by big inercion between the control system's decisions and theirs commands execution. This effect makes inercion in control results. This is an important fault in situation when we need precision guidance of object to the goal in short time, or when control process need very quick reactions on the informations coming to the missile seeker. This fault we can limited by the direct interaction to the gravity centre. In presented method servo control system's (correction rocket motors set) interacted to the gravity centre of object (figure 2).

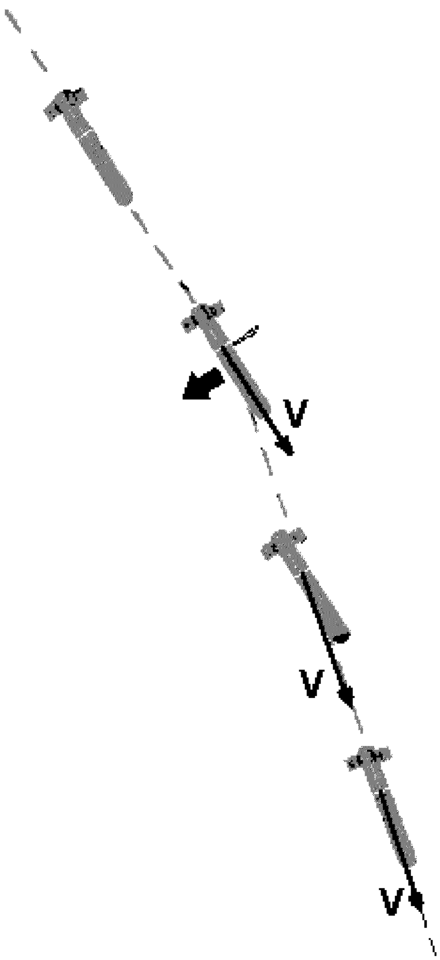

figure 4. Way to course change.

This method of flying object control make assumption that the way of control system interaction on object is:

- steering forces first make influence on object gravity;
- movement around gravity centre is an effect of gravity centre movement and aerodynamic interaction (figure 4).

Solution like this giving us more effectively interaction on speed vector. Block scheme of object dynamic show figure number 3.

At spinning object one channel is used to control in horizontal plane and vertical plane. These assumptions can be realised by gasodynamic impulse interaction to the object gravity centre. This solution give us not only quicker object reaction on seeker information and follow it possibility more precision object guiding to the attack target, but also make easier servo control system. We don't need complicated mechanics of aerodynamic servo.

3. Method of realising.

In that solution control is realised by one time used correction motors locate around the flying object centre of gravity. When the target has been selected, it is tracked during the rest of the flight of projectile. The error vector between the centre of the target and projected impact point of missile continuously monitored. As soon as this error vector or error vector time derivative exceeds a pressed value, one or several rocket correction motors are fired in a direction to bring the value of the error close to zero. The impulse of the rocket correction motors passes through the centre of gravity of projectile, which gives instantaneous course correction when the rocket is fired.

By continuous calculation of the predicted impact point relative to predicted target position at impact, it is possible to use proportional navigation, which avoids any influence of target movement, wind effects etc. Missile can be used against both stationary and moving targets.

The tracking technique also makes it possible to make several course corrections in rapid succession. If necessary all rocket correction motors can be used with control in the last few seconds of flight.

The task of the rocket motors is to correct the course of the projectile in the last phase of the trajectory, making it home in on the target, achieving a direct hit. Correcting rocket motors are located in a cylindrical unit, arranged radial around the periphery. Each one of the correction rocket motors can be fired individually in a selected radial direction.

The correction motors set is placed close to the centre of gravity of the projectile. When the rocket motor is fired the course of the missile is changed instantaneously. Way to course change shows figure 4. By successive firing of several rocket motors, the projectile is steered with high precision on to the target. The chosen steering system gives a very fast response to the guidance signals.

4. Simulation researches.

Goal of researches was to find algorithms and dynamic properties of impulse control of flying object by ourselves methods. Researches were made on numerical model of dynamic of control missile. Model was a system of differential equations. Model was non-linear and discontinuous. It described space movement of projectile at all phases of flight. From launch till the hit to target or to ground. Description of movement is enough overall to research the control process with differential guided methods.

Two experiment results show figure 6. Error angle between seeker-target line and main symmetry axis of object oscillated in short range. Control system shows good results of control process. The huge errors at the last milliseconds of flight is the effect of assumption the target as a point.

5. Summary.

Numerical experiment shows large possibilities of control objects by interaction to their gravity centre. We can use impulse correction rockets to control falling objects. Like for example mortar control missiles and bombs. Attainable, at the phase of computer simulation, accuracy and control quality gives good prognostics to possibilities of practice use. This way of control more complicated control algorithms but make easier servo control. Servo has only correction rocket motors set and electrical system of initiation.

Researches show that for successful control missile must have proper charge of energy in correction rocket motors potential. Charge of energy depends from mass of missile. Their divide for the number of rocket motors and their time of work are constructor's decision.

Results of numerical researches are used in program RAD. It is polish government military program currently at the field test.

Construction based on the similar effect was made in Sweden by SAAB Missiles and BOFORS Weapon Systems. Their product has named STRIX and is used by Swedish army.

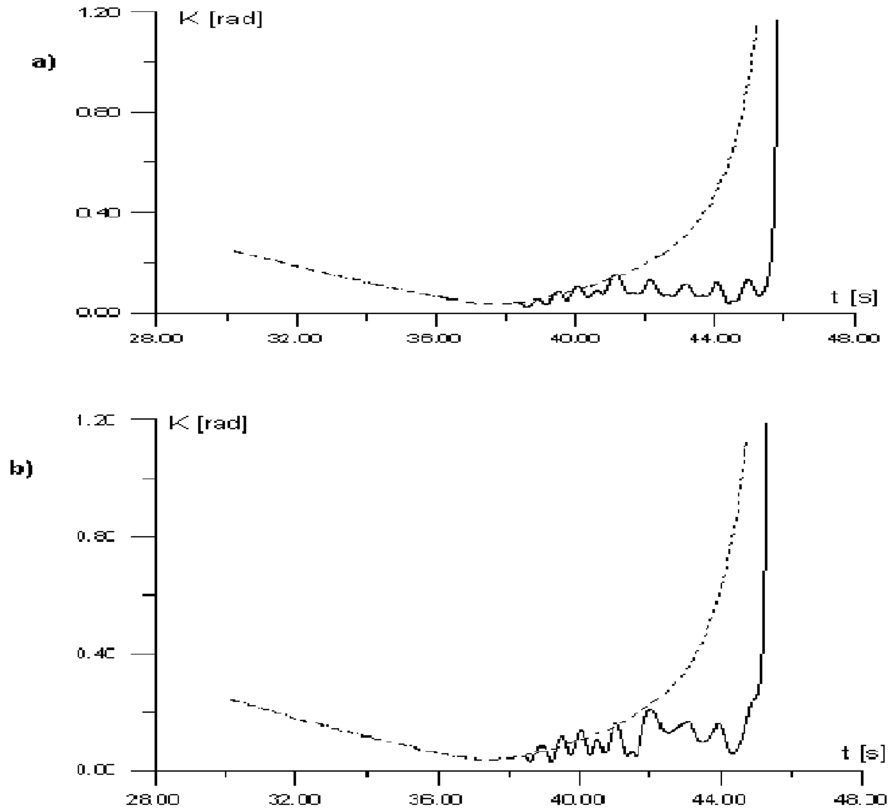

figure 5. Error angle between seeker-target line and main symmetry axis of object for two different numerical experiments. Solid line - controlling missile, dash line ballistic flight.

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