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Guidance Philosophy for Impact Angle Maximization for Anti-Tank Flight Vehicle

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Abstract- **In general, anti tank weapons are designed to attack the tank on the top of the tank, where the armour is relatively weak compared to the front and sides of the tank. In this paper, a generalized guidance philosophy for top attack mode is described. This paper presents a novel guidance philosophy which enhances the impact angle for top attack mode by using seeker measurements. This proposed method also reduces the weight and cost of the weapon system by eliminating the need for Laser Range Finder, which is primarily used for target range measurement. Sensitivity analysis of the algorithm is carried out with different parameter perturbations. Lastly, the performance of the algorithm is evaluated through nonlinear Six Degrees of Freedom simulation in time domain.**

I. Introduction

An anti-tank weapon (ATW), is primarily designed to hit and destroy heavily armored military vehicles. ATW's vary in sizes from a) shoulder-launched weapons transported by a single soldier, b) tripod-mounted weapons requiring a squad or team to transport and fire c) vehicle and aircraft mounted weapon systems. A shoulder-fired weapon or man-portable Flight vehicle is one type of ATW. It is small enough to be carried by a single person, and fired while held on one's shoulder to a target. Therefore, having a minimum weight of the weapon is desirable.

A Laser Range Finder (LRF) in a Flight vehicle (FV) system is used to get the target range information for the guidance. This range information can be used to shape the trajectory and obtain maximum impact angle for the specified target range. But the disadvantages associated are the extra weight of the LRF system and vulnerability. A man portable vehicle, should be as light as possible. Apart from that, to make LRF's and laser-guided weapons less useful against military targets, various military arms might have developed laser-absorbing paint for their vehicles. Adding to these, the logistics involved in pointing the beam towards the target also increases the time cycle between the launch of successive Flight vehicles. Also, for Top attack mode the impact angle needs to be maximum for maximum destruction to the tank.

This paper aims at reducing the weight as well as cost of the system by eliminating LRF range measurement. At the other end, algorithms have been designed to estimate the target range information without compromising on the impact angle for top attack mode. In Section II, the design objectives and constraints for the top attack mode are presented. Section III describes a generalized guidance philosophy for top attack mode. Section IV presents online algorithm to improve the impact angle for top attack mode along with sensitivity studies. Time domain 6 DOF simulation results for few case studies are demonstrated in Section V. Section VI concludes the work.

II. Problem Statement

A. *Problem Definition*

With the technological advances in armour, it is becoming increasingly difficult to defeat futuristic armour including those fitted with explosive reactive armour in front attack, where the tank enjoys maximum armour protection or even in side attacks depending on the azimuthal representation of the target area. However, the top of the tank is relatively weak compared to the front and sides of the tank. The impact angle in top attack needs to be maximum for inflicting maximum damage to the tank. Thus, maximizing the impact angle in the presence of practical constraints is one of the design objectives.

A variety of guidance laws have been proposed in the literature to cater for terminal impact angle constraint. These guidance strategies can be classified as Proportional Navigation (PN) guidance laws and optimal guidance laws. The optimal guidance law proposed in [5], is based on time-to go calculation methods where the range measurement is required. In the paper [6], PN guidance along with an orientation guidance strategy is proposed to obtain a wide range of impact angles. In these papers, several practical considerations like realistic homing head constraints which has limitations on gimbal freedom, body rate for providing seeker inertial environment, trajectory height to avoid cloud coverage, aerodynamic limitations in terms of turning radius and sufficient homing distance requirement for acceptable hit to kill miss distance in the presence of several subsystem lags (except autopilot lag) are not addressed. Most of the Imaging Infrared (IIR) seekers used for these applications do not give range measurement.

The top attack capability in which the Flight Vehicle dives on to the top of the tank needs to be built into the vehicle by suitable shaping of the trajectory keeping in mind the above mentioned constraints. Here, the various constraints are seeker gimbal limit, trajectory height limit, angle of attack limit and fin deflection limit. In the presence of all the constraints, the impact angle has to be maximum from the view of warhead kill effectiveness.

In this paper, considering all the above said constraints a Generalized guidance Philosophy with an impact angle

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optimized trajectory and PN guidance with nonlinear gain is presented. In the Generalized guidance philosophy, simulation has been carried out assuming that target range information is not available to the guidance. In the proposed modified guidance philosophy, the target range information is estimated online using seeker measurements and the improvement in impact angle for both the philosophies (without range input vs with range input) is presented.

III. GUIDANCE PHILOSOPHY

Many guided ATW employ some version of PN as the guidance law during the terminal homing phase due to its robustness and relative simplicity of mechanization [1] [3]. FV target closing velocity and sight line rate (SLR) information is required to mechanize PN guidance command. Derivation of Sight Line Rate (SLR) information depends on type of the sensor and how it is mounted on the ATW.

A. Mid Course Guidance

Fire and forget capability for ATW requires autonomous homing guidance implemented based on SLR obtained in this case from the IIR seeker in FV. However, during initial phase, to optimize the impact angle, FV trajectory is made to pitch up sharply through gimbal hold phase.

B. Terminal Phase Guidance

Fig 1 shows an impact angle optimized trajectory which provides maximum impact angle in the presence of seeker gimbal angle limit, airframe turning capability and subsystem lags. The required Switching Sight Line Range (R_{SW}) is derived from the known value of maximum gimbal angle freedom θ_g, minimum radius of turn of the configuration R and the required homing distance dH as per the relation in (1).

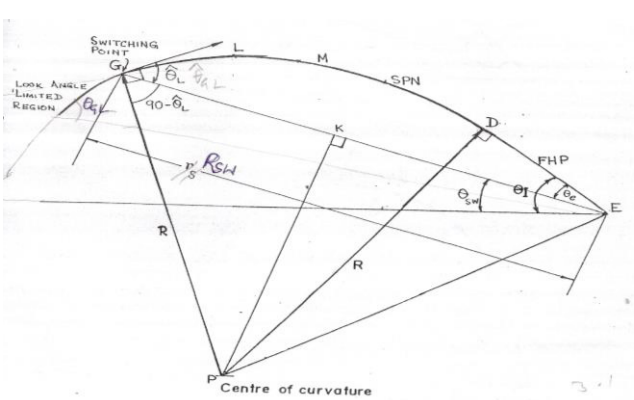

Fig-1. Impact Angle Optimized Trajectory

$$R_{SW} = R\sin\theta_g\left[1+\sqrt{1+\left(\frac{dH}{R\sin\theta_g}\right)^2}\right] \qquad (1)$$

As range measurement is not available from the seeker, Switching Sight Line Rate (SLR_SW) for switching to PN phase is computed based on R_{SW} requirements for each range as given in (2).

$$SLR\_SW = \frac{V_m Sin\theta_g}{R_{SW}} \qquad (2)$$

Switching from gimbal angle hold phase to PN guidance phase is done as soon as the required R_{SW} or SLR_SW is reached for each of the target range. This R_{SW} is obtained so that after correcting the heading error between line of sight and flight path with minimum radius of turn capability of the configuration, required homing distance is available for settling the transients in the final homing phase. Minimum requirement of homing distance is established with normalized simulation of seeker based homing guidance loop for achieving the required miss distance [2] [8].

In Fig.1. θ_I is the Impact angle which is the angle between the missile body to the horizontal. Here, PN guidance with a nonlinear navigation constant law is evolved to ensure that large heading error at switching to PN guidance is corrected with the minimum radius of turn of the configuration. This navigation constant is chosen such that required impact angle and homing distance is obtained to achieve hit to kill miss distance.

Guidance law based on PN tends to keep the rate of rotation of line of sight as low as possible. The latax demand during this phase $F_{zd} = N^{'} V_c \dot{\lambda}$ where $N^{'}$ is the navigation constant, V_c is the closing velocity (estimated missile velocity:10% error on the actual missile velocity) , $\dot{\lambda}$ is the line of sight rate (SLR) measured by seeker. The complete guidance philosophy depicting guidance phases for various target ranges is shown in Fig 2.

In the generalized guidance philosophy, a fixed value of SLR is chosen as it is assumed that range information from LRF is not provided as the guidance input.

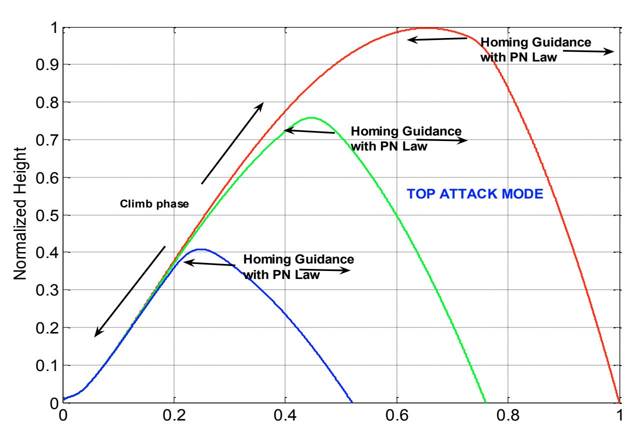

Fig. 2 . Generalized Guidance Philosophy for different range