Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #
Preferred Topics: FDGNCAV / AEROFLIPHY
Corresponding author: Chang-Hun LEE
e-mail of corresponding author: lckdgns@kaist.ac.kr
Type: Oral
Status of corresponding author: Regular

Title

Mid-Course Trajectory Optimization of VFDR Missiles via Pseudospectral Sequential Convex Programming

Authors

Boseok KIM [1], Chang-Hun LEE [2], Min-Jea TAHK [3], Yongkun LEE [4], Hong-Gye SUNG[5]*

** Corresponding author*
[1] Aerospace Engineering, KAIST, 34141 Daejeon, Korea, kbobo6@kaist.ac.kr
[2] Aerospace Engineering, KAIST, 34141 Daejeon, Korea, lckdgns@kaist.ac.kr
[3] Aerospace Engineering, KAIST, 34141 Daejeon, Korea, mjtahk@kaist.ac.kr
[4] Aerospace & Mechanical Engineering, Korea Aerospace University, 10540 Goyang, Korea, yongkun0116@kau.kr
[5] Aerospace & Mechanical Engineering, Korea Aerospace University, 10540 Goyang, Korea, hgsung@kau.ac.kr

Abstract

Modern long-range air-to-air missiles (AAMs) adopt an air-breathing type rocket motor to improve their performance. Especially the variable-flow duct rocket (VFDR) motor has been recognized as a promising one for long-range AAMs since it can adjust the thrust magnitude by controlling the fuel consumption rate. This feature provides the VFDR missiles to accomplish efficient energy management, resulting in superior interception performance.

The mid-course guidance phase plays a crucial role for AAMs since it determines the operating conditions of AAMs at the beginning of the terminal guidance phase. The mid-course flight trajectory of VFDR missiles depends on the load factor and fuel consumption rate, so we need to properly design their profiles during the mid-course flight phase. Furthermore, several flight constraints on the Mach number, air-to-fuel ratio, and fuel consumption rate makes the problem more complicated. In this case, the trajectory optimization approach can be a good candidate for solving the problem [1-2]. After solving the trajectory optimization problem, the trajectory solution can be leveraged to establish a guidance logic mimicking the optimal trajectory pattern or directly utilized to guide the missiles.

This paper elaborates on obtaining the optimal mid-course trajectory of the VFDR missiles in the vertical plane. The minimum-final time problem is defined for the VFDR missiles to reach the predicted intercept point (PIP) while satisfying the flight constraints. In establishing the system equation, we propose to select the air-to-fuel ratio as a control variable instead of the fuel mass flow rate, as done in previous works. This choice is advantageous in two aspects, as shown in numerical results; the first is that the air-to-fuel ratio constraints are frequently active during the flight, so it is preferable to address them as an input bound instead of nonlinear path constraints. The second is that providing the initial guess to start the solution procedure is straightforward. Based on the resulting system equation, pseudospectral sequential convex programming is utilized to solve the trajectory optimization problem. The successive linearization technique is employed with a variable trust-region structure to avoid artificial infeasibility. Numerical experiments have been conducted for some representative engagement scenarios. The results reveal that the optimal trajectory pattern of the VFDR missiles is slightly different from the traditional missiles due to the characteristics of the VFDR motors.

References

[1] T. Kuroda, S. Mihara, H. Matsuda, R. Hiroakwa, and F. Imado, "Optimal Mid-course Guidance of Variable Flow Ducted Rocket Missiles," *Guidance, Navigation, and Control Conference and Exhibit.* 1998, p. 4213.
[2] W. Halswijk, "Online Dynamic Flight Optimisation Applied to Guidance of a Variable-Flow Ducted Rocket," *Guidance, Navigation, and Control Conference*. 2009, p. 6090.