Numerical Simulation and Experiment of a Lifting Body with Leading-Edge Rotating Cylinder


Abstract—An experimental and simulation flight test has been carried out to evaluate the longitudinal gliding characteristics of a lifting body with blunted half-cone geometry. The novelty here is the lifting body's pitch control mechanism, which consists of a pair of leading-edge rotating cylinders. Flight simulation uses aerodynamic data from computational fluid dynamics supported by wind-tunnel test. Flight test consists of releasing an aluminum lifting body model from a moving vehicle at the appropriate wind speed while measuring the lifting body's variation of altitude against time of flight. Results show that leading-edge rotating cylinder is able to give small amount of improvement to the longitudinal stability and pitch control to the lifting body.

Keywords—Lifting body, pitch control, aerodynamic, rotating cylinder.

I. INTRODUCTION

A lifting body is a wingless vehicle that flies due to the lift generated by the shape of its fuselage [1]. The lifting body program at National Aeronautics and Space Administration (NASA) started as an attempt to design an aircraft that could fly back from space in a smooth landing rather than a dangerous plunge to Earth in a ballistic entry. According to Monti et al. [2], high-risk and uncomfortable re-entry in a capsule will be unfeasible in the future as space transportation becomes more widespread; hence, safe, glider-like vehicles will become the choice for re-entry vehicle.

Lifting body is considered promising for such re-entry due to its favorable aerodynamic characteristics at high angle of attack. The lifting body studied here adopts the design of a blunt-nosed, half-cone vehicle without the main wing structure seen on most conventional aircrachts which will cause excessive friction and heating. The flat part of the half-cone body surface can produce lift force while enhancing aerodynamic stability [3].

This study investigates the longitudinal gliding characteristics of a lifting body based on blunted half-cone geometry. The lifting body model used in this study has a novel feature in the form of a pair of leading-edge rotating cylinders. In terms of aircraft flight control systems, an aircraft is conventionally controlled by ailerons, elevators and rudders. Direct-lift control, which generates lift force directly without a change of aircraft incidence angle is also widely used, such as helicopters and VTOL (vertical take-off and landing) aircrafts [4]. More recent advancements include thrust vectoring and use of forebody strakes [5, 6]. There is also active research in hinge-less flight control such as using Piezo-fluidic actuators and plasma actuators [7, 8]. Hence, the novelty here is the application of rotating cylinders as a form of flight control, namely, to control the lifting body in pitch mode.

This study aims to evaluate the effectiveness of such leading-edge rotating cylinders in terms of pitch control by combining aerodynamic data, obtained from validated computational fluid dynamics (CFD) studies, with a flight simulator capable of calculating data such as airspeed, angle of attack, pitch angle, pitch rate and aircraft altitude. The flight characteristics of the lifting body with and without rotating cylinders are compared.

II. METHODOLOGY

Aerodynamic data of the lifting body with rotating cylinders was obtained by CFD and validated by wind-tunnel testing. For CFD, Unsteady calculation using PISO algorithm (Pressure Implicit with Splitting Operators) by Issa was used [9]. A steady state solver was not preferred as it was known to yield inaccurate results for unsteady flow. This paper concludes...