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FUEL EFFICIENCY ANALYSIS OF THE JET ENGINE AND SOLID-PROPELLANT BASED SMALL REUSABLE SUB-ORBITAL LAUNCH VEHICLE CANDIDATES

Abstract

Sub-orbital launch vehicles have been utilized for specialized purposes such as micro-gravity environment testing, and mesosphere climate research. Also, it can be used to deploy small unmanned aerial vehicles (UAVs) with foldable wings into sub-orbital trajectories to increase the performance of missions.

From a commercial perspective, it is more economical to use reusable launch vehicles than expendable launch vehicles. Furthermore, compared to large vehicles, small sub-orbital vehicles have a different duration of rocket propulsion, a vehicle's mass ratio, and aerodynamic parameters. To exploit these differences, this paper proposes a concept of a small reusable sub-orbital launch vehicle equipped with a heterogeneous propulsion system that combines a rocket engine with air-breathing jet engines for auxiliary propulsion.

The proposed system utilizes the jet engine thrust along with a solid-propellant rocket for extended flight time in the atmosphere. Also, the proposed system is capable of retro-propulsive vertical landing using jet engines. Together with rocket engines, the jet engines provide thrust to overcome gravity and drag it until reaches the supersonic phase. After payload separation and initial mission completion, the sub-orbital rocket returns to the launch point with retractable auxiliary wings and jet engines to achieve vertical landing.

The jet propulsion system deactivates at a certain subsonic speed until it reaches supersonic speeds. If excessive thrust is set, performance degradation can occur due to increased empty mass and drag factors. We set specific mission conditions for the UAV payload deployment into a sub-orbital trajectory to compare four cases including symmetrically arranged jet propulsion modules (two, three, and four jet engines) against non-jet propulsion. In particular, the effect of jet propulsion on rocket recovery performance was compared by analyzing the remaining quantity of the jet engine fuel.

The jet engine thrust was adjusted to control the velocity and location to be consistent at the payload separation point for all four cases. The specific impulse of the solid-propellant rocket and jet engines was analyzed with varying pressure changes along with changing flight altitude. Also, weather conditions were taken into consideration as an additional parameter by assuming a specific launch site location and

date. The same jet fuel mass was added to each comparison group for analysis. The remaining fuel mass of the jet engine, which can be excluded from the initial weight, was added to the payload performance for accurate comparison, making it a key performance indicator.