Autorotation based descend System for Venus Atmospheric Study

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Abstract

This paper discusses the feasibility of using auto rotating rotorcraft UAV for descend in Venus atmosphere. The objective is to attain slow descend speed that can help collect images and other sensor data from its on-board equipment and also make corrections for trajectory or final destination. A platform based on autorotation is more effective than conventional parachute or drag based ones for atmospheric studies or landing on the planet. One of the major advantage being the ability to control the trajectory and also the speed of descend, in a more effective manner than what can be achieved using simple drag based systems. This is a very critical feature for avoiding hazardous regions in atmosphere as well as precise landing in case such an event is planned. Autorotation is a well-studied flight regime for helicopters. Past studies of Venus atmosphere using descend systems through atmosphere has relied on drag based design like that of Venera. Recently there have been feasibility studies using autorotation system [1], [2]. Except for conceptual description, no detailed analysis of the system or modeling is available. However, using rotorcraft for decelerated descend were explored even in 1960s[3].

The mathematical model for auto rotating (unpowered) rotorcraft will be derived. Approximate conditions of Venus atmosphere will be used for designing the vehicle as well as assessing its performance. The rotorcraft will be operated after initial descend phase which will be carried out using aeroshell. This is primarily because very high speeds and its associated high temperature preclude rotorcraft to be used for this regime of flight. In our calculations, we have assumed that the aeroshell design will be able to decelerate to a Mach number of 2 (a typical value) by the time altitude comes down to 80km .A mathematical model for rotorcraft is derived assuming rigid blade models. The dynamics of the body is similar to that of a boomerang. Aerodynamic modeling relies on blade element theory along with inflow dynamics based on Peter-He models. The speeds of rotor blade sections correspond to M = 2 speed of the vehicle and preliminary calculations are done with available aerodynamic data. Preliminary results of rotorcraft descend analysis in Venus atmosphere will be presented. These include:

(1) Variation of rotorcraft descend velocity with altitude for a given rotorcraft configuration

(2) Preliminary sizing of rotorcraft for required descend speed.

References

[1] Smith, B., Venkatapathy, E., Wercinski, P., Yount, B., Prabhu, D., Gage, P., Glaze, L., and Baker, C. (2013). Venus in situ explorer mission design using a mechanically deployed aerodynamic decelerator. In 2013 IEEE Aerospace Conference, 1–18. IEEE.

[2] Young, L.A., Briggs, G., Aiken, E., and Pisanich, G. (2004). Rotary-wing decelerators for probe descent through the atmosphere of venus. Technical report, NASA.

[3] Ham, N.D. (1963). An experimental and theoretical investigation of a supersonic rotating decelerator. Journal of the American Helicopter Society, 8(1), 8–18.