Session XXXX

Fixed-wing drones for Venus exploration: Design and challenges

Gabriel Acosta, Mostafa Hassanalian
Mechanical Engineering Department
New Mexico Institute of Mining and Technology

Abstract
An atmospheric analysis was done to model Venus' characteristics at lower altitudes between 0 km and 55 km. Functions were made to model the atmospheric properties of Venus, temperature, pressure, density, and viscosity. It should be noted that a set of functions for density, pressure, viscosity, and temperature are derived from a set of data presented by Petropoulus in 1987 [1] . This was then used to investigate the wing and thrust loading of a fixed-wing UAV in Venus. The results from this wing and thrust loading investigation where that wing loading and thrust loading increase with altitude. This study gives outlines for future steps of designing fixed-wing UAVs for Venus exploration.

Introduction
Venus has a harsh environment that makes its exploration especially difficult. Standard rovers like on Mars would not work as the intense temperature and pressure would cause them to have a short operating time. At an altitude of about 55 km Venus has an Earth-like atmosphere where a robotic system could survey for different features. At 55 km the pressure and temperature of Venus is about 50 kPa and 297 K [1]. A fixed-wing drone that can fly at this altitude would be practical. To obtain more information on Venus, the UAV can fly at lower altitudes, until pressure and temperature operational limits are met. Then the drone can come back to an altitude of 55 km and alleviate until it is ready to go back into the lower altitudes. A promising lower altitude to reach is 30 km as the pressure and temperature of 892 kPa and 474 K are maximums that are still within practical design consideration [1]. Investigating the effects of different wing loadings and atmospheric properties at different altitudes on thrust loading can provide a sense as to how much thrust loading a UAV will need to maintain flight. From the observations of a plot showing wing loading vs altitude vs thrust loading the best altitudes to maintain flight at are recognized as they require the least amount of energy.

Wing and Thrust Loading of a Fixed-Wing UAV in Venus' Atmosphere
Different flight modes can be considered for a UAV flying in Venus; constant altitude and cruise speed flight, constant climb speed flight, constant altitude loitering flight, horizontal acceleration flight, and accelerated climb flight. To obtain a general understanding of thrust performance on Venus, the best flight mode to consider is flight at constant altitude and cruise speed, as this is the flight mode that requires the minimum number of variables to keep into consideration. As a general approach, calculations of thrust loading were performed for different altitudes and wing loadings on a fixed-wing UAV with a rectangular wing shape that has an aspect ratio of 4, Oswald number of 0.85, a cruise speed of 10 m/s, and chord length of 1 m. The equation used to calculate thrust loading as a function of wing loading and the changing variables based on changing altitude is Equation 1

[2,3]. From the plot on Figure 8, thrust loading decreases the closer the UAV gets to the surface of Venus, 0 km. Also, the decreasing wing loading causes thrust loading to decrease. Altitude, wing loading, and thrust loading seem to increase together.

$$\frac{T_{SL}}{W_{TO}} = \frac{1}{\alpha}\left[\left(\frac{1}{\pi e AR}\right)\frac{1}{q}\left(\frac{W}{S}\right) + \frac{q C_{D0}}{\left(\frac{W}{S}\right)}\right] \quad (1)$$

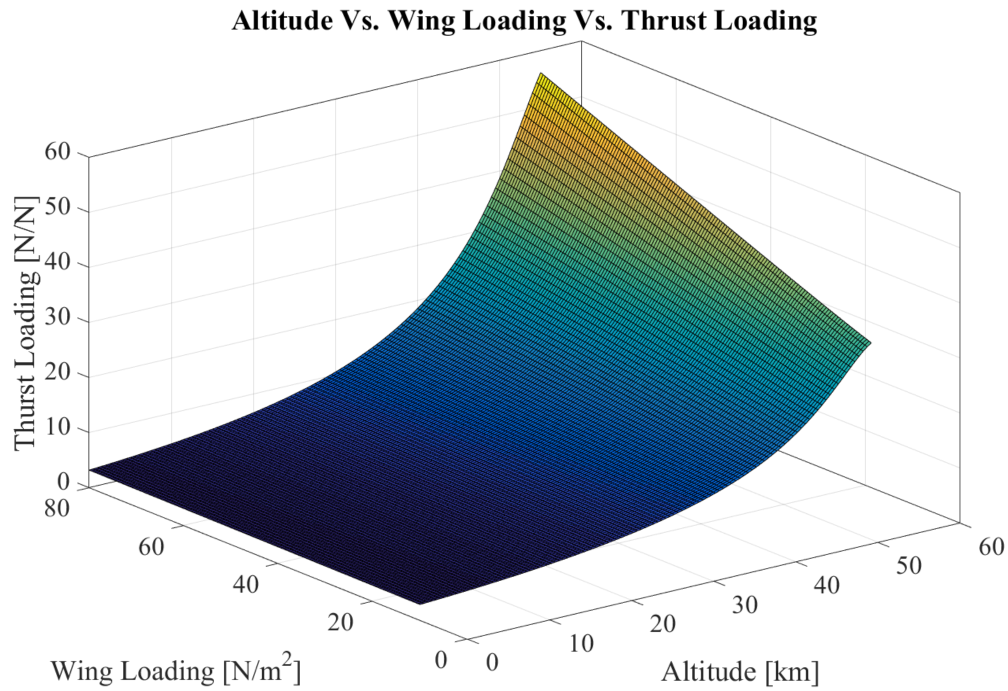

Figure 1. Altitude Vs Wing Loading and Thrust Loading for Flight at Constant Cruise Speed and Altitude

Summary and Conclusions

The 3D plot of Figure 1 gives adequate information to understand how thrust loading changes depending on wing loading and altitude, but some details are lost, especially for altitudes less than 40 km. From the Figure 1 plot, we observe that an increase in wing loading causes an increase in thrust loading, which is sensible. To better observe what is happening at lower altitudes, we can look at the thrust vs wing loading plane, and the altitude vs thrust loading plane. Changing slope patterns can be interpreted better by looking at 2-D graphs.

References

1. Petropoulos, B., "Physical parameters of the atmosphere of Venus. Earth, Moon, and Planets", Vol. 42, No. 1, pp.29-40, 1988.
2. Hassanalian, M. and Abdelkefi, A., "Design, manufacturing, and flight testing of a fixed wing micro air vehicle with Zimmerman planform", Meccanica, Vol. 52, No. 6, pp.1265-1282, 2017.
3. Hassanalian, M., Rice, D. and Abdelkefi, A., "Evolution of space drones for planetary exploration: A review", *Progress in Aerospace Sciences*, Vol. 97, pp.61-105, 2018.