STOPPED-ROTOR CYCLOCOPTER FOR VENUS EXPLORATION

National Aeronautics and Space Administration

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INTRODUCTION

Venus is believed to hold the key to understanding the evolution of the Earth's environment. On the surface of Venus the temperature is 740K and the pressure is 93bar. The winds of Venus blow up to 100m/s, which is 60 times the speed of rotation of the planet, causing the entire atmosphere to circulate in only four Earth days. This wind speed decreases closer to the surface reaching only 2.8 m/s.

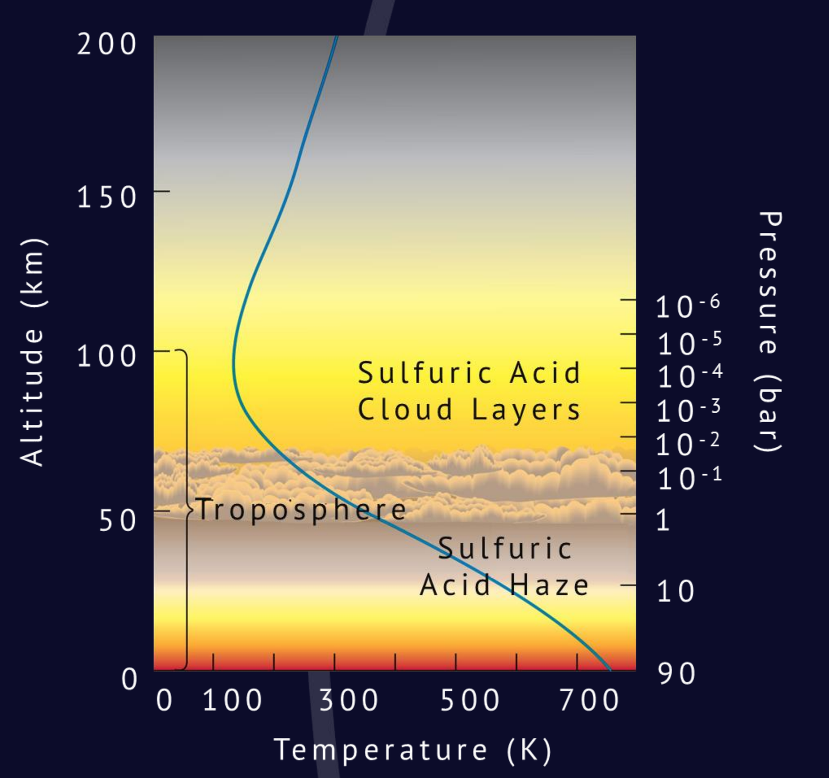

Figure 1: Structure of Venus's atmosphere (Pearson Education, 2011)

The chemical composition consists of mostly carbon dioxide and nitrogen where the clouds are sulphuric acid. Because of these clouds it is nearly impossible to penetrate observationally from Earth. The use of U.S. and Soviet probes have determined the composition and surface structure we know today.

The atmosphere is split into sections depending on the altitude. The densest part of the atmosphere starts at the surface and extends 65km upwards, this is known as the troposphere. At the top of the troposphere the pressure and temperature are increasingly Earth like but winds move at high speeds.

Since the Vega 2 balloon and lander in 1984 no other missions have entered and landed on Venus. Due to the harsh temperature and pressure of the planets surface this lander only lasted for 53 mins but was able to find rock samples similar to that on Earth. The balloon of this mission was able to float at a steady height of 53km above the surface taking samples. Proposals have been made for landing rovers and flying other aircrafts in the lower atmosphere of Venus.

THE MISSION

Thproject focuses on a proposed mission to Venus, which would gather further information of all layers of the Venus atmosphere as well as the surface by using a capable novel design.

The main purposes of this mission would be to:

- Interchange from high to low altitudes on Venus which will allow for deep radar penetration of the surface as well as atmospheric sampling.
- Find appropriate surface sampling areas via vertical take-off and landing.
- Mission capable of lasting days on the surface of Venus, not hours.

Atmospheric and surface measurements are the main scientific goals of this mission, which are important to learn more about the environment of Venus. This new found knowledge will also assist in categorizing thousands of newly found exo-planets as either being like Earth, Mars or Venus.

The design considerations of the novel aircraft will include:

- The temperature and pressure difference between the surface of Venus and the entry altitudes.
- The vast wind speeds in higher altitudes.
- Lower wind speeds in lower altitudes.

After some research into Unmanned Air Vehicles (UAV) for the Venus mission it was decided to examine the possibilities of using cyclocopter configurations as stopped rotor systems to meet these design requirements. This combination is novel in itself is novel and is likely easier to implement than a stopped rotor using a conventional helicopter-type rotors.
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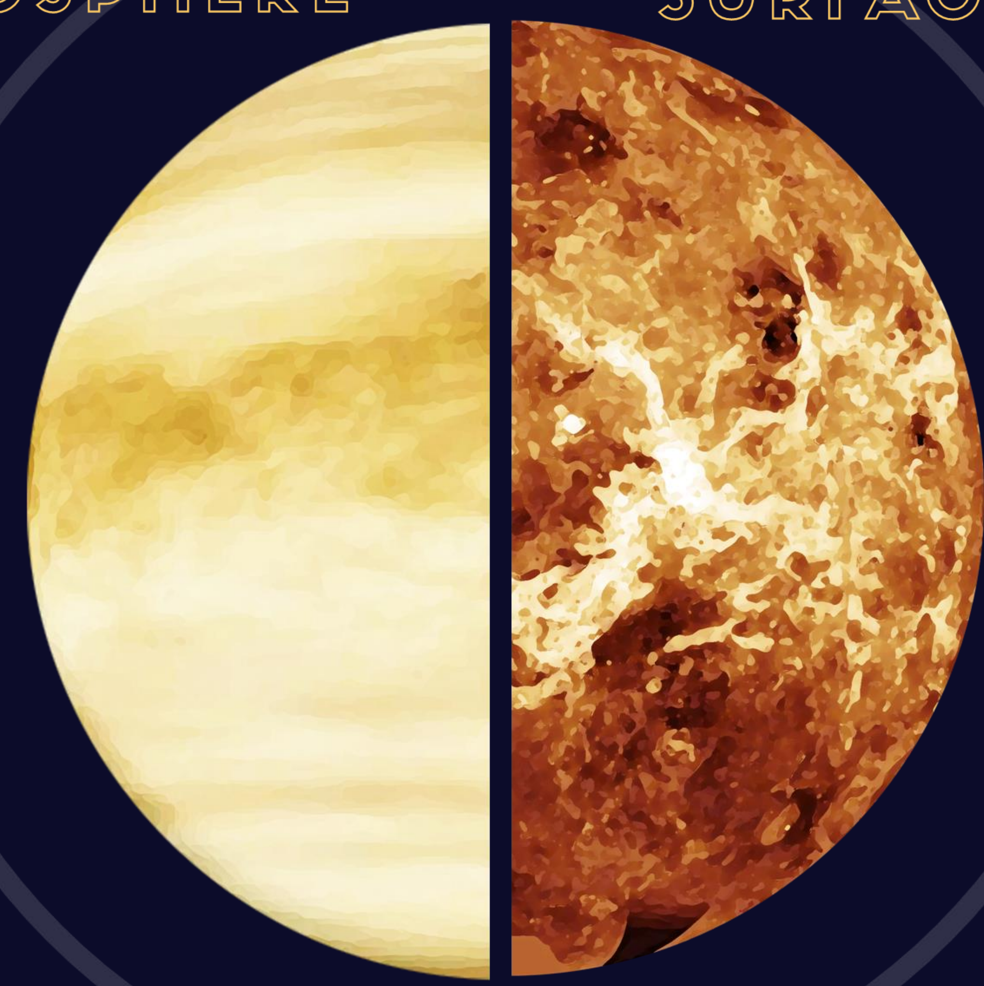
ATMOSPHERE[4] SURFACE[5]



DESIGN HERITAGE

STOPPED ROTOR

Stopped rotors are designed to act as a fixed wing during forward flight. When stopped, they provide some, if not all, of the lift. This system can be used for vertical flight and hovering. When in forward flight it can be stopped to act as a fixed wing. Other rotors and propellers can be added to stabilize the aircraft. Much research has been done on stop rotors including the research done by the US Naval Research Laboratory (NRL) and StopRotor Technology Pty Ltd, Australia, who have created a prototype which has been tested in transition flight. A stopped rotor concept will be implemented in the design for this mission to Venus. It will allow for stable travel through the harsh winds and save power during the mission.

CYCLOCOPTER

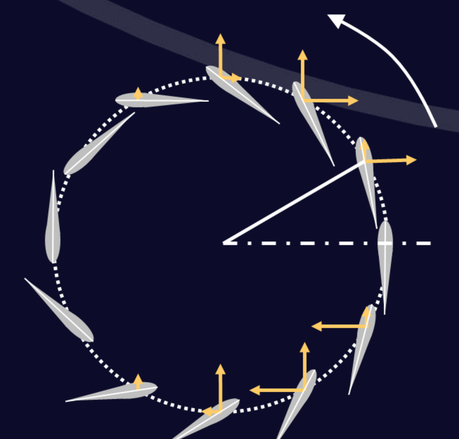


Figure 2: Blade pitch angle variation during a revolution

The cyclocopter, also known as the cyclogyro, is the main type of UAV rotary system to be explored for this mission to Venus. This system can use two or more rotating blades, rotating about the axis parallel to the blades to create lift, propulsion and control of the aircraft.

The difference between the cyclocopter and a normal helicopter rotor system is that they are not limited to the same disadvantages such as speed and altitude. They can also provide 360 degrees of vector thrusting which is favourable for good manoeuvrability.

For this project the use of cyclogyros as stopped rotor systems is explored to meet the design requirements for the Venus mission. It is believed that the cyclogyro will allow the aircraft to operate through the different layers of atmosphere and implementing the stopped rotor system at higher atmospheric densities. The use of the cyclogyro will allow for vertical take-off and landing from the surface of Venus.

DESIGN SPACE

The design considerations for this Venus mission aircraft will include a cycloidal rotor and a stopped rotor system. There are multiple ways of implementing a cycloidal rotor onto an aircraft and the most popular are deemed to be twin rotor systems and quad rotor systems. Even though the idea of cyclorotors has been around since 1927, successful flights only began from 2007 after the concept was introduced to UAV. The University of Maryland has successfully built and tested a cyclocopter[6].

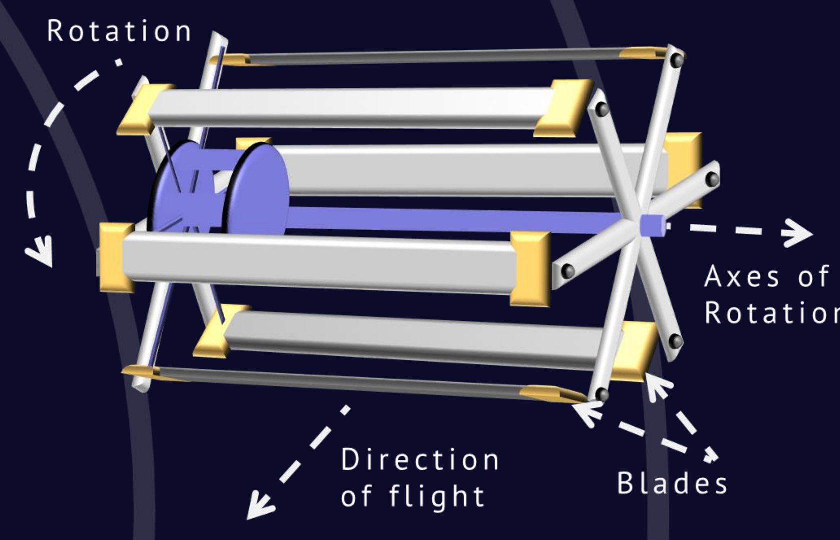


Figure 2: Cycloidal Rotor

Cyclorotors can also be used in multiple orientations. When applying the stopped rotor system the ideal is to create the least amount of drag possible. By orientating the rotors inline with the air vehicle body and the freestream this will reduce drag but impact forward motion capabilities. An additional tail rotor may need to be added for stability.

Cyclorotor blades normal to air freestream are another option and enable forward propulsion capabilities. In order to prevent these rotors creating excessive drag once stopped, a fixed surface area can be designed around the rotors, diverting airflow over the top of the rotors rather than through.

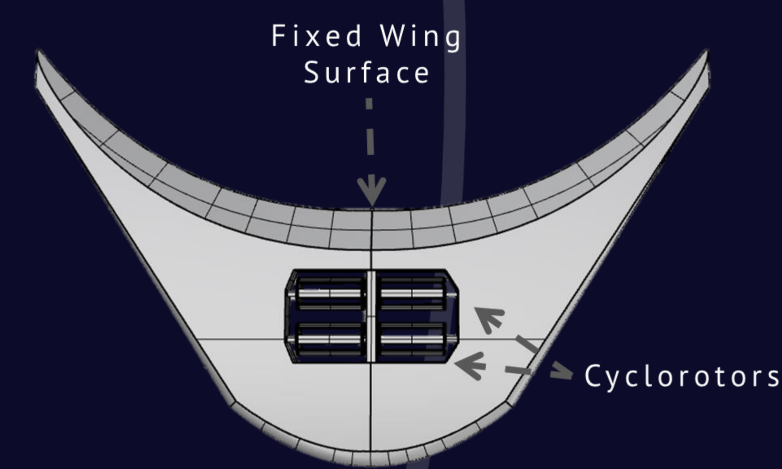


Figure 3: Rhino design of Cyclorotors surrounded by fixed wing.

Other design considerations can include hybrid and parasite flyers where the fixed-wing vehicle is separated from the cyclocopter when no longer in use. This is dependent on the need for vertical landing and take-off. The mission requires this for surface measurements but in the case of a one time landing it maybe beneficial to save power and implement a gliding system for the remaining mission time.

A way of analyzing these two systems is a two parameter design characterization can be implemented when considering the fixed wing and cyclorotor combination where the relative sweep of the cycloidal rotors can be varied with respect to the fixed wing sweep.

CONCLUSION

This project discusses the design considerations for a stopped rotor cyclocopter for a mission to Venus. A design space is created where all aspects of cyclorotor design can be explored and employed for the use in a stopped rotor system. The atmosphere of Venus is a harsh one and there are many design factors to consider such as wind speed, atmospheric density and surface temperature.

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