Manta Ray Inspired Drone for Venus Exploration: Biological-Solution for Extreme Conditions.

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Introduction

Manta rays are extremely graceful and efficient swimmers. Their pectoral fins are large and attached to their head forming a broad, flat disc that can be manipulated into a variety of shapes. Primarily, manta rays use oscillatory motion similar to that of a bird flapping its wings but an undulatory component of motion is also present. When mantas use a flapping wing, they can generate a great deal of power. Because of the large surface area of their pectoral fins, mantas can swim at incredible speeds. Manta rays offer a good solution to UAVs in that their body is rigid and they are efficient swimmers. The stiffness of their body would allow for easy integration of electronics for the design of a bioinspired manta ray UAV. Manta rays have a small turning radius of 0.27 of its body length, which also allows them to maneuver easily[1]. While manta rays are fast and efficient, they are also able to withstand high pressures while hunting, diving over 1 km below the ocean's surface[2]. This study analyzes a bioinspired manta ray wing shape for use on an exploratory UAV on Venus. The flapping-wing and fixed-wing drone proposed in this paper was analyzed for flight on Venus at an altitude between 30 and 70 km above Venus's surface. The density of the atmosphere in this region is similar to Earth. The drone would soar to the surface of Venus, take measurements for a period of time, and fly back to a safer altitude.

Flapping-Wing Model

The flapping wing drone was designed in FlapSim with a wingspan of 2m, an elevation amplitude of 75 degrees, a pronation amplitude of 20 degrees, a stroke plane of -10 degrees, and a velocity of 10m/s. Using these parameters, the lift, drag and mechanical power for a flapping wing drone of the defined wing shape was calculated.

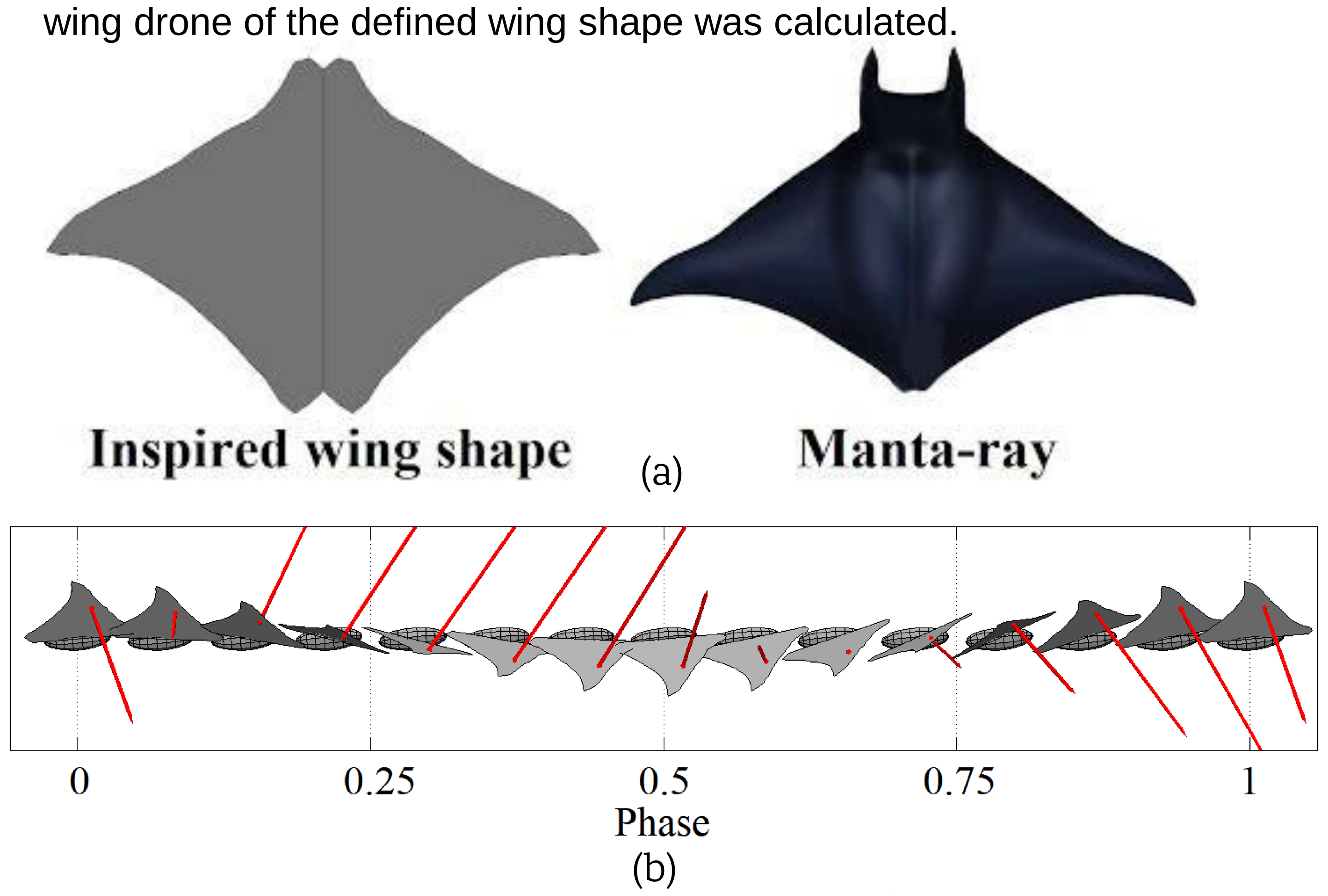

Figure 1. (a) Wing shape used for aerodynamic analysis of a manta ray bio-inspired drone and (b) visualization of one cycle of flapping wing drone's flight progression.

Results

Analysis of Flapping-Wing Model:

From the generated figures for a flapping-wing drone, it can be seen that the lift force, drag force, and mechanical power are all maximized closer to the surface of Venus. This is due to the increased density closer to Venus's surface. Also to be seen from Figure 4 is the large amount of mechanical power that is generated by the large surface area of the manta ray wing shape.

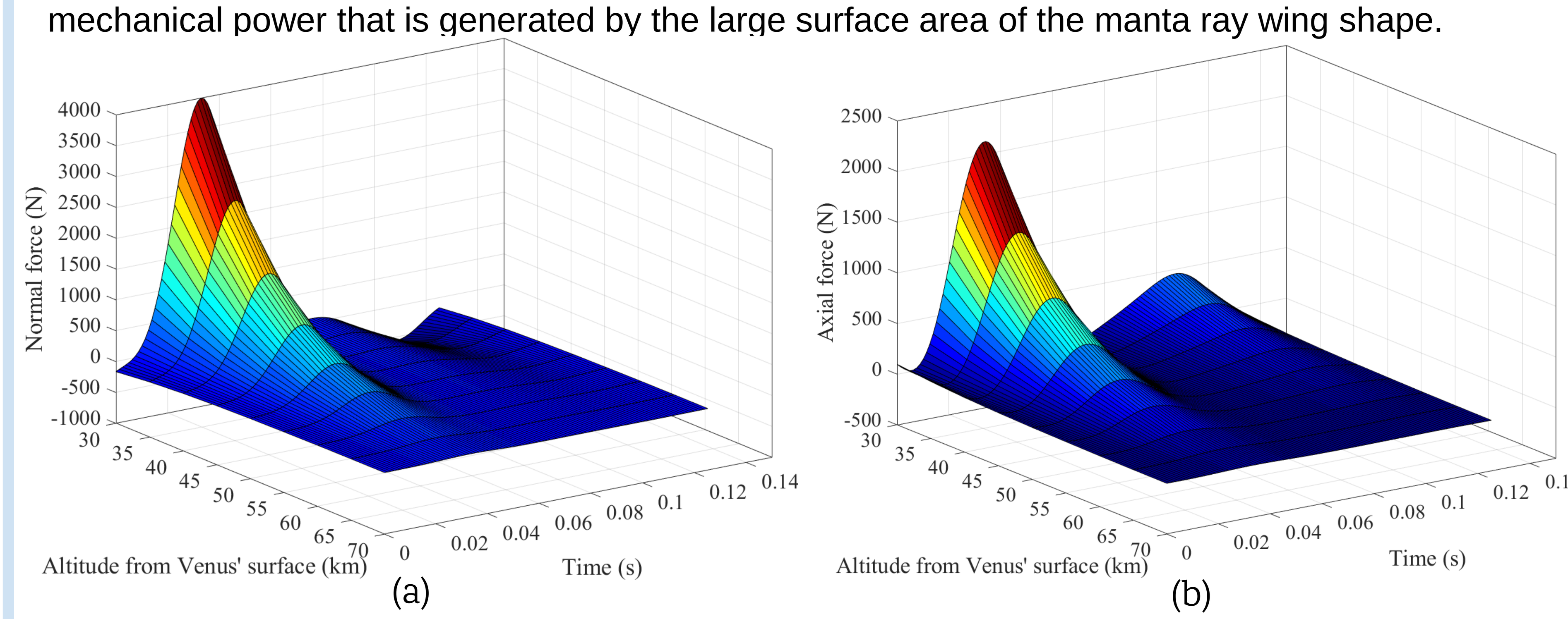

Figure 3. (a) Lift force and (b) drag force of flapping wing drone on Venus from 30 km to 70 km.

Table 1. Average lift force, drag force, and mechanical power for a drone on Venus from 35 km to 70 km.

Altitude (km)	30	35	40	45	50	55	60	65	70
Normal force (N)	659	422	264	164	97	58	25	11	4
Axial force (N)	586	376	235	146	86	51	23	10	4
Mechanical power (W)	28122	18027	11260	6995	4151	2468	1083	458	186

Analysis of Fixed-Wing Model:

Similar to the flapping-wing drone, the lift and drag are maximized closer to Venus's surface. Additionally, a higher angle of attack generates a higher lift and drag force.

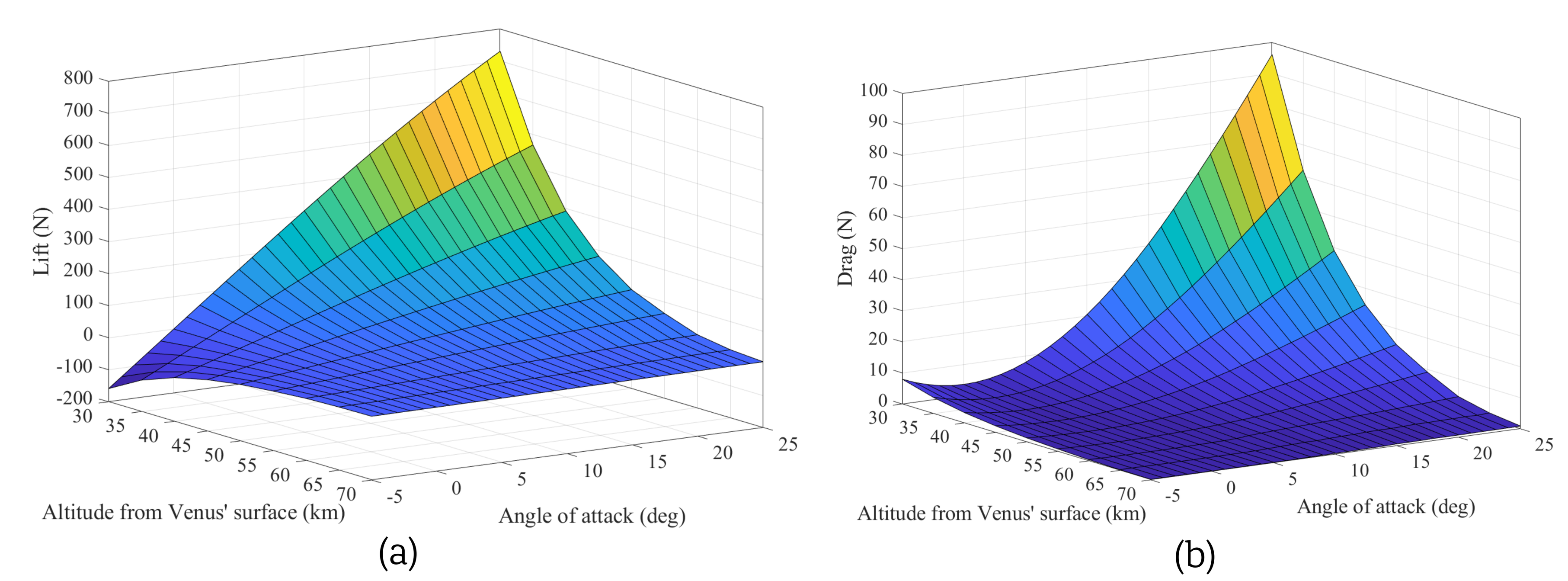

Figure 4. (a) Lift force and (b) drag force of fixed-wing drone on Venus vs. angle of attack from 30 km to 70 km.

Conclusion

The aerodynamic analysis of a fixed- and flapping- wing drone was performed for a wing shape using bioinspiration of a manta ray, since manta rays are powerful swimmers that can withstand large amounts of pressure. It was found that the largest lift and drag force for each wing was obtained at lower altitudes. The largest mechanical power value was also obtained at lower altitudes. This analysis can be used to find the optimal altitude for flight of a manta ray inspired UAV on Venus. However, other factors such as temperature, pressure, and acidity of the atmosphere will need to be taken into account before the most ideal atmosphere can be obtained.

Fixed-Wing Model

The analysis for a fixed-wing drone was done in XFLR5 using the same wing shape and wingspan mentioned above. NACA 0012, 0015, and 0020 airfoils were used to create a wing shape that tapers, similar to that of a manta ray. This model is shown in Figure 6. Using the described model, the lift and drag for a fixed-wing drone on Venus was calculated at an altitude between 30 km and 70 km. This is shown in Figures 6 and 7.

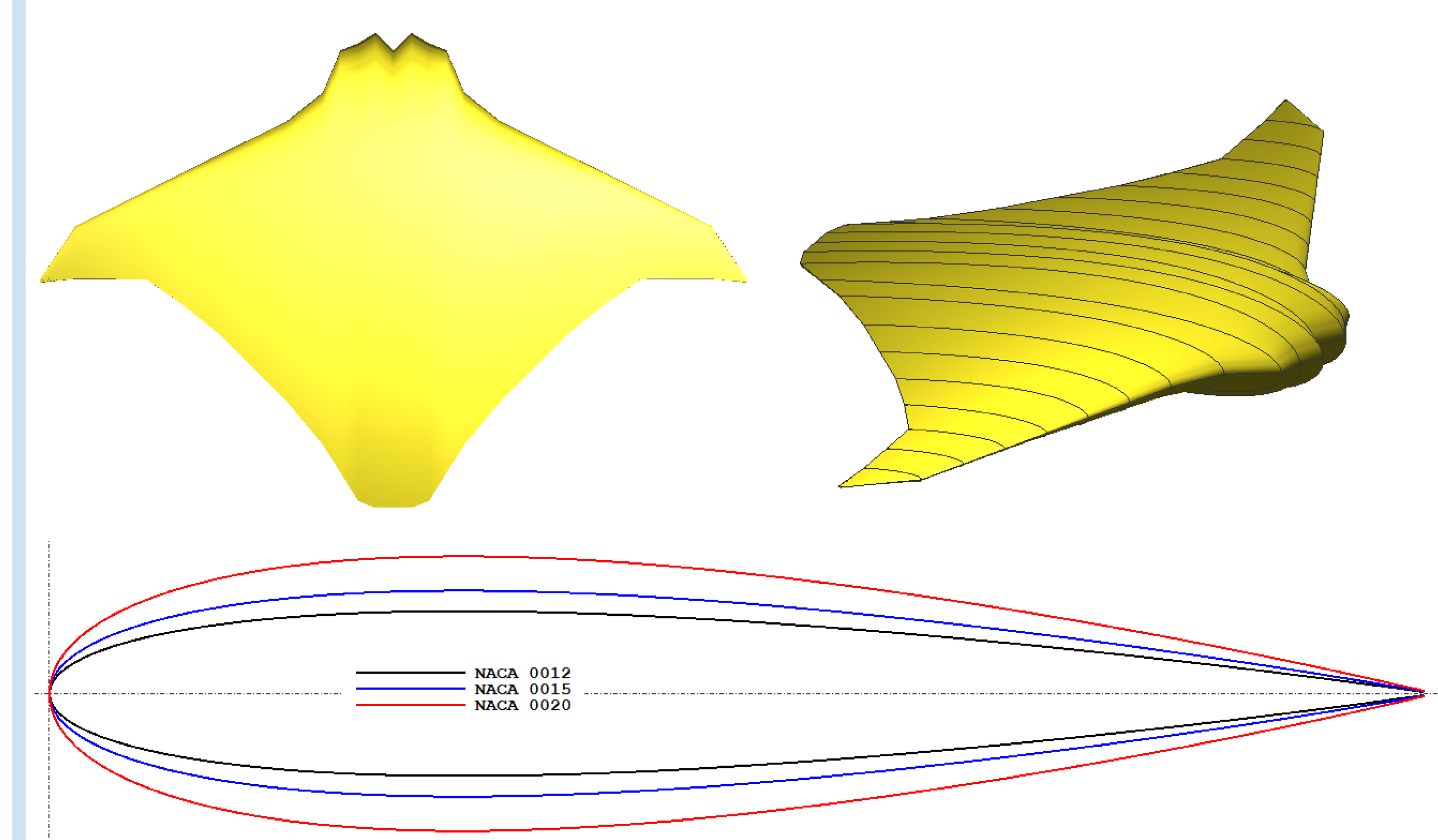

Figure 2. Model of fixed-wing drone in XFLR5.

References

[1] Fish, F. E. (2018). *The Journal of Experimental Biology,* [2] Pennisi, E. (2011) *Science*