Does Vibration on Flexible Wing Affect Its Stall Characteristic?

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Introduction

This project explores if flow characteristic of the wing cause by small vibrations will affect its stall characteristics. The project will mainly focus on one class of Unmanned Aerial Vehicle (UAV) called the Micro Aerial Vehicle (MAV). These vehicles operate at a low Reynolds number. Flying at a low Reynolds number produces a laminar flow, however, there will be a laminar-turbulent flow transition as the airplane speed and its angle of attack increase. According to research papers [1, 2] that examine the effect of flexible airfoils on the flow separation at the boundary layer of the wing, the membrane skin of flexible airfoils can deform and adapt with the incoming flow stream. The flexible membrane skin has the ability to balance the pressure differences on the upper and lower surfaces of the airfoils which results in a spontaneous change of its camber. The effects of this situation are; the flow remains attached at the laminar-turbulent transition longer and will deflect the airfoil trailing edge upward from its original position thus reduces its effective angles of attack. Therefore, this will delay the onset of stall

Apparatus and Methods

A wind tunnel experiment was performed using a closed-return tunnel at the University of Minnesota. Two sets of Mini Ultra Stick wings – one with eight mini speakers attached to the spar of the wing and another is filled with cottons. The Mini Ultra Stick wing has a symmetric airfoil with a wing span of $b = 0.985$m and a chord length of $c = 0.18$m thus yield an aspect ratio of $AR = 5.47$. The mini speakers were connected in series and functioned to excite small vibrations in the wing while the cotton functioned to make the wing slightly solid and absorb the vibrations that the skin produces. The test bodies were mounted on a six degree of freedom strain gage called a sting that was designed to measure the forces and moments that acted on the test bodies caused by the incoming free-stream velocity. These measured forces and moments from the sting were interfaced with the lab's computer in order to obtain the data points of the specific experiment. The experiment was done at an incoming free-stream velocity of 5m/s which yields a Reynolds number of $Re = 535.2$ and at 2º angle of attack. The wing with the mini speakers was tested by ranging the speakers' frequency of sine wave function by using a function generator. The frequency was varied from 300Hz to 1000Hz.

Figure 1. The Mini Ultra Stick wing filled with cotton is shown on the right. The cotton functioned to make the wing slightly solid and absorb vibrations caused by the skin. Meanwhile, the wing with mini speakers is shown on the left. The speakers are attached to the spar and being connected in series. The speakers functioned to excited small vibrations in the wing.

Results and Discussion

The results in Figure 2 show a comparison of the lift coefficient between the wing with mini speakers and the wing filled with cotton. The wing with the speakers was tested by ranging the speakers' frequency of sine wave function by using a function generator. The frequency was varied from 300Hz to 1000Hz. Based on the plots for the wing with the speakers, it shows that the lift coefficient increases as the frequency increases. However, when comparing these data points with the data point of the wing filled with cotton, it shows that only the frequencies from 700Hz to 1000Hz have effective results of higher lift coefficient values than the one filled with cotton. The wing with speakers yields the highest lift coefficient value of $C_L = -0.090$ at a frequency of 900Hz while the wing filled with cotton yields the lift coefficient value of $C_L = -0.098$. The negative lift coefficient values affected by the airspeed condition that the experiment was tested and the shape of the airfoil being symmetric thus caused a slightly higher force hence a slightly higher pressure on the upper surface of the wing.

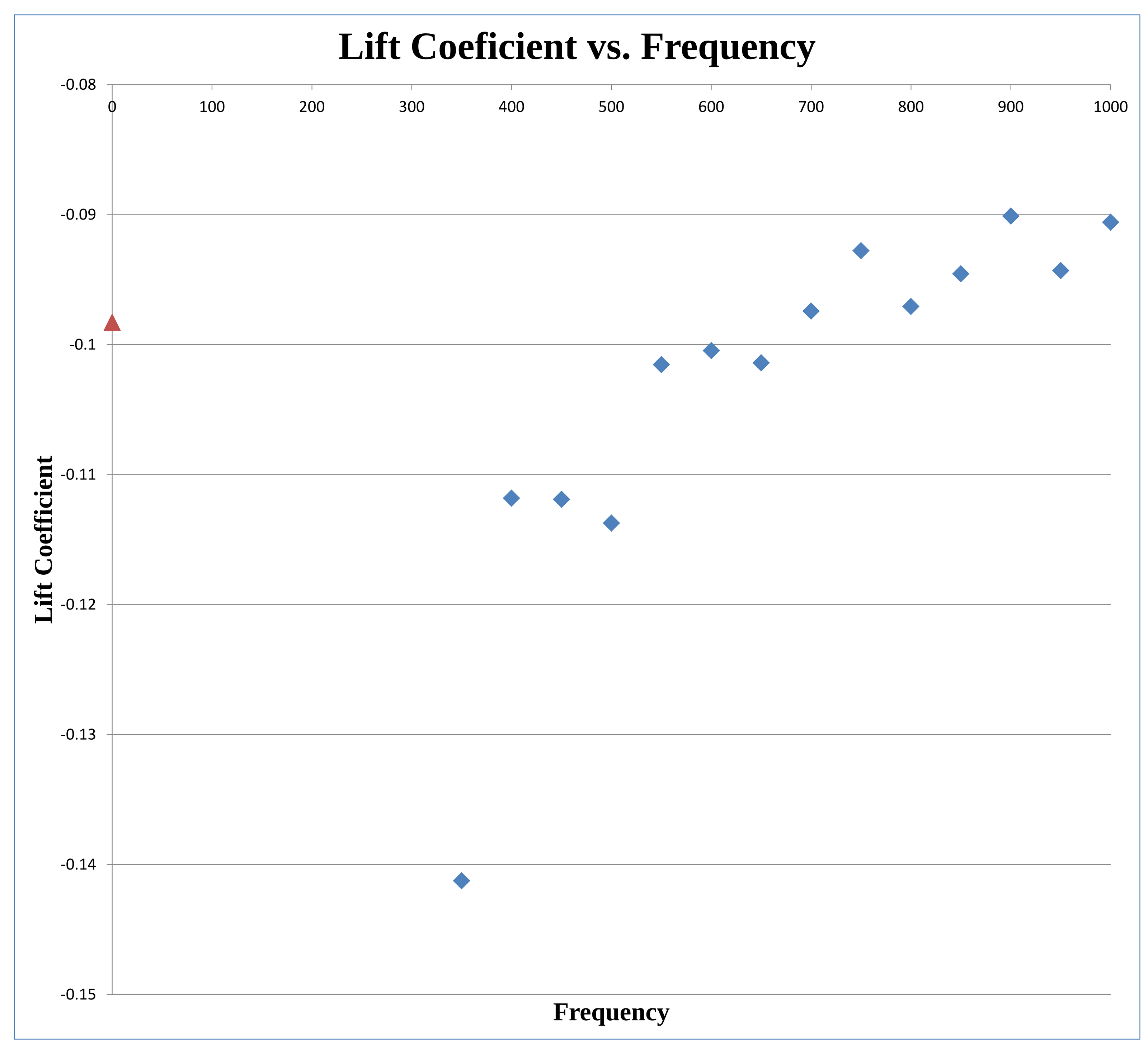

Figure 2. A comparison of the lift coefficient at different frequencies. The blue data points represent the lift coefficient values for the wing with speakers while the red data point represents the lift coefficient for the wing filled with cotton.

Conclusion

This experiment only represents the first finding of the project in examines if flow characteristic of the wing cause by small vibrations will affect its stall characteristics. Therefore, the results in this experiment are not significant enough to make a conclusion about the effect of small vibrations in wing on the wing stall characteristics since the experiment was only conducted at a single airspeed and at one position of the angle of attack. However, it still meets the expectation that the small vibrations in the wing changes the measurements of the forces thus affect the lift coefficient of the wing. Therefore, this experiment should be carried out further by ranging the incoming free-stream velocity, the angle of attack, and the speakers' frequency in order to perform further investigations on this phenomenon.

References

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2. Lian, Yongsheng., and Shyy, Wei. July 2007. "Laminar-Turbulent Transition of a Low Reynolds Number Rigid or Flexible Airfoil". AIAA Journal, Vol. 45, No. 7.

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