15th International Symposium on Flow Visualization
June 25-28, 2012, Minsk, Belarus

THE EFFECT OF LEADING EDGE PROTUBERANCES ON THE PERFORMANCE OF SMALL ASPECT RATIO FOILS

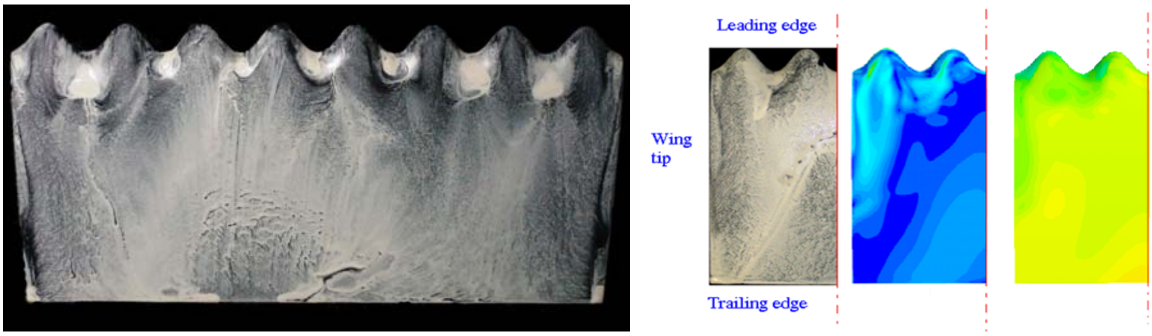
J.-H. CHEN[1,c], S.-S. Li[1], V.T. NGUYEN[1,2]

[1] Department of Systems & Naval Mechatronic Engineering, National Cheng Kung University, Tainan, 70101, Taiwan
[2] Department of Naval Architecture, University of Da Nang, Da Nang, Vietnam

[c]Corresponding author: Tel.: +886-62747018#210; Fax: +886-62747019; Email: chenjh@mail.ncku.edu.tw

KEYWORDS:
Main subjects: leading edge, protuberances
Visualization method(s): oil film
Other keywords: turbulence, aspect ratio

ABSTRACT: Inspired by humpback whale's flippers [1,2], this study investigated the effect of aspect ratio and shape of protuberances on the performance of airfoil with protuberances on leading edge. NACA0012 foil is used for modifying the leading edge with three different forms and three aspect ratios (1, 2, 3). The experiment of the airfoils was carried out in a low-speed wind tunnel, including airfoil performance measurements and visualization of airfoil surface flow field by oil film. The results of performance experiments show that when the aspect ratio equal to 1, the stall-delay phenomenon is very clear. It means that it is more useful than the high AR foil at high attack angle. The airfoil performance with protuberances on leading edge has no significant increase in lift, but the drag was reduced. The most significant effect for performance took place for the foil with longest amplitude of the protuberances. The flow visualization results show that the airfoil's flow field becomes very turbulent on the wing surface after stall angle. But the protuberance foil's flow field distribution was regular. From the difference between these two results, one could conclude the reason why the leading edge protuberance delayed stall and reduce the drag. The results of CFD simulation by Star-CCM+ was also accordant to experiments. The results will provide some base for the application of small aspect ratio wing with leading edge protuberances to the situations with a wide range of attacking angle.



(a) (b)

Fig. 1 (a) Flow visualization of a modified NACA 0012 airfoil with protuberances (aspect ratio of 2) at angle of attack 14 degree. Vortices between protuberances, separation behind protuberances, and tip vortices are clearly seen. (b) For NACA 0012 airfoil with protuberances (aspect ratio of 1) at angle of attack 30 degree, the separation bubble pattern shown by visualization (left) is consistent with vorticity (center) and pressure (right) distribution.

References

1.Fish F. E. & Battle J. M., *Hydrodynamic Design of the Humpback Whale Flipper*, J. Morphology, 1995, **225**, pp. 51-60.

2. Miklosovic, D. S. et al., *Leading-Edge Tubercles Delay Stall on Humpback Whale (Megaptera novaeangliae) Flippers*, Physics of Fluids, 2004, **16**, p. L39.