Experiment Evaluation of Skin Friction Drag by Surface Tailoring

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Abstract. Reduction of drag is an important role of aerodynamic specialist in real time world. The performance of forward moving object improved when the drag is reduced. Skin friction drag caused when the fluid tending to shear along the surface of the body and it is dependent on energy expenditure. Initial research concluded that nearly 20 to 40% of total drag is skin friction drag, based on flight forward velocity. This means a lot of fuel burned. In this paper we investigate a methodology to reduce the skin friction drag by implementing different kinds of exterior treatments. The ideology inspired from the world fastest moving oceanic creature. Structures are fabricated based on the replica of scales of the oceanic creature. The outer skin of the aerofoil NACA0012 is modified like shark scales. Then it is tested using open type sub sonic wind tunnel. In addition to that, the leading edge thickness effect also studied. The turbulent flow phenomenon is validated at different velocities and compared with numerical results using STAR CCM+. From the plots and graphical results, it is found that the skin friction drag is generated less due to reduction of transverse shear stress present in turbulent flow and skin friction drag depends on boundary layer thickness and on the percentage of chord of flow separation. In addition to this, the result delivers that the ordinary polished surface produces more drag than the modified scales. The outlook of this technology is exerescence for different applications. This open section wind tunnel testing produces 10-15% reduction in drag and can be turn to high values when the experiment is conducted in closed section wind tunnel with real time atmospheric conditions, which can be done as a future work.

1. Introduction

Skin friction drag is a constituent of parasite drag. It is the main contributor to the total drag, due to the strong bond between turbulence and friction drag and energy consumption. It occurs due to flow over the lifting body; laminar or turbulent body. Reynolds number plays a key role in laminar and turbulent flows. This paper deals about the reduction of the skin friction drag by applying the surface tailoring approach, which is inspired from the previous research papers.

Elias Aljallis[1] carried out the experiment on super hydrophobic flat plates in high Reynolds number boundary layer towards the reduction of skin friction drag [16]. He found that drag is dependent on contact angle and the hydrophobicity. He also found that the surface air layer are also reduces the drag at high Reynolds number flow regions.

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Kang Active[2] conducted experiments on wall motions for skin-friction drag reduction and he proved that 13 to 17% of the drag is reduce when the active wall motions are controlled due to the reduction of stream wise vortices reduction. Sagong [3] did experiments on the sailfish skin to reduce the skin friction like the shark skin. In his study he discussed the possibility of reducing the skin friction using its shape is investigated in a turbulent boundary layer. He concluded the skin friction is reduced but the total drag is larger than that of a smooth surface. Bushnell deals with the drag reduction by natural things he concluded scales reduces the drag larger than that of riblets. This paper divided into 3 basic sections based on the profile of the body and the surface treatments to reduce skin friction drag. The section 1 deals with the ordinary airfoil and the section 2 deals with the shark scales throughout the outer layer of the airfoil skin. And finally the section 3 deals about the leading edge thickness.

2. Experimental setup

The specimen is tested at the Aerodynamic laboratory, Sathyabama University, Chennai, India. The experiments are conducted in open type wind tunnel at the free stream velocity of 25m/s. The specimen is designed as four cases
- Shark scales
- Single step leading edge thickness
- Multi step leading edge thickness
- Conventional Airfoil

We have fabricated five types of the specimen made of Kevlar fibre[12, 13, 14] which is fabricated by hand layup process and it is tested for the calculation of total drag. The total drag is not measured directly, they are evaluated by measuring the pitot pressure at each port and they plotted for pressure distribution. The pressure values are taken from the manometers having ethanol as the fluid and the velocity of air is measured using digital pitot indicator. For calculating pressure values at each port these manometer tubes are used which is mounted on the adjustable bottom. All investigations are carried at constant velocity of 25 m/s at 1200rpm of the motor.

Figure 1. Fabrication of the Shark scales over the symmetrical airfoil (case 2)
Figure 1 shows the structure of the shark scales placed at the outer cover of the airfoil and the scales are distributed throughout the section. Figure 2 presents the airfoil with differential leading edge thickness. Two and single step leading edge are used for this study. The turbulence tapes are used to increase the thickness of the airfoil.

Figure 3. Testing section of open tunnel
3. Results and Discussions

The specimen is kept on the test section figure 4 and it is tested for aerodynamic efficiency at the velocity of 25m/s and the flow is laminar. The pressure ports are connected to the manometers and digital indicator to calibrate the pressure values. The pressure values are derived for all the cases and the plot is drawn to find the coefficient of lift and coefficient of drag at various angle of attack

![Figure 4. Angle of attack vs drag coefficient](image)

![Figure 5. Pressure ratio to the change in velocity](image)
Figure 5 to figure 7 gives various results and plots for all four different cases. The figures and plots depict that, the level of coefficient of pressure is minimum for the shark scales when compared to the leading edge thickness. However, the leading boundary layer separation is very short than the shark scales structure. Since the flow is subsonic the pitot oscillation is neglected. The plots reveals the shark scales and the two layer leading thickness provide less amount of drag than the conventional and single step airfoil.

| S.No | Conventional | Shark scales skin | Single layer leading edge | Multi layered leading edge |
|------|--------------|-------------------|---------------------------|----------------------------|
| Pressure (Bar) | 1.350 | 1.101 | 1.281 | 1.200 |
| Velocity (m/s) | 33 | 32 | 31.8 | 31 |
| Coefficient of drag | 0.07 | 0.008 | 0.02 | 0.01 |
| Reduction in Drag % | - | 22% | 8% | 13% |

4. Conclusion

The evaluation of drag at various types of surface treatments is presented in this paper both experimentally and computationally. The plots and the graphical representation are derived from numerical and experimental to understand the variation of drag force post tailoring of the surface of the body. The results reveals that the shark scale structure generates less amount of drag than the other types of structures, this is happening since the vortices generated on the model are embedded with it. From the plots and graphical results, it is found that the skin friction drag is generated less due to reduction of transverse shear stress present in laminar flow and skin friction drag depends on boundary
layer thickness and on the percentage of chord of flow separation. In addition to this, the result delivers that the ordinary polished surface produces more drag than the modified scales. This testing produces near 10-15% reduction in total drag of the body.

References

1. Aljallis, Elias, et al. "Experimental study of skin friction drag reduction on superhydrophobic flat plates in high Reynolds number boundary layer flow." Physics of fluids 25.2 (2013): 025103.
2. Kang, Sangmo, and Haecheon Choi. "Active wall motions for skin-friction drag reduction." Physics of Fluids 12.12 (2000): 3301-3304.
3. Sagong, Woong, et al. "Does the sailfish skin reduce the skin friction like the shark skin?" Physics of Fluids 20.10 (2008): 101510.
4. Bushnell, Dennis M., and K. J. Moore. "Drag reduction in nature." Annual Review of Fluid Mechanics 23.1 (1991): 65-79.
5. Raayai, Shabnam, and Gareth McKinley. "Optimizing Geometry Mediated Skin Friction Drag on Riblet-Textured Surfaces." APS Division of Fluid Dynamics Meeting Abstracts. 2016.
6. Gunasekar, P., Manigandan, S., Anderson, D., & Devipriya, J 2017 Evaluation of Fe-Epoxy metal nanocomposite in glass fiber and Kevlar. International Journal of Ambient Energy.
7. S. Manigandan 2015 Computational Investigation of High Velocity Ballistic Impact Test on Kevlar 149, Applied Mechanics and Materials.
8. S. Manigandan 2015 Determination of Fracture Behavior under Biaxial Loading of Kevlar 149, Applied Mechanics and Materials.
9. Manigandan, S., Gunasekar, P., Devipriya, J., Anderson, A. and Nithya, S., 2017. Energy-saving potential by changing window position and size in an isolated building. International Journal of Ambient Energy, pp.1-5.
10. Manigandan, S., Gunasekar, P., Devipriya, J., Anderson, A. and Nithya, S., 2016. Determination of heat flux on dual bell nozzle by Monte carlo method. Journal of chemical and pharmaceuticals sciences.
11. Gunasekar, P., Manigandan, S., Devipriya, J. and Saravanan, W.S.R., Investigation of Dual Mode RJ Nozzle by Discrete transfer method.
12. Nithya, S., Manigandan, S., Devipriya, J. and Gunasekar, P., Finite Element Analysis of Droplet Impact on Kevlar Flat Plate. Journal of Chemical and Pharmaceutical Sciences ISSN, 974, p.2115.
13. Devipriya, J., Manigandan, S., Gunasekar, P. and Nithya, S., Experimental Evaluation of Metal Nanocomposite Al-Epoxy in Kevlar. Journal of Chemical and Pharmaceutical Sciences ISSN, 974, p.2115.
14. Nithya, S., Manigandan, S., Gunasekar, P., Devipriya, J. and Saravanan, W.S.R., Investigation of Stacking Sequence on Glass and Kevlar Fiber. Journal of Chemical and Pharmaceutical Sciences ISSN, 974, p.2115.
15. S.Manigandan, P. Gunasekar, J. Devipriya, and W. S. R. Saravanan. "Reduction of greenhouse gases by the effect of window position and its size in isolated building." Journal of chemical and pharmaceuticals sciences, (2016).
16. J.Devipriya, S. Manigandan, S. Nithya, and P. Gunasekar, Computational Investigation of Flow over Rough Flat Plate, Journal of Chemical and Pharmaceutical Sciences, ISSN 974: 2115,2017.