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Aerodynamics Drag Curtailment Using Phlegmatic Contraption

Rengasamy.K, Irish Angelin S, Raja S, Kabilan Siranjivi

Abstract— **Drag reduction on the surfaces directly or indirectly increase the efficiency of the overall system. Reducing the drag consists of reducing viscous skin friction, delaying flow separation and boundary layer formation by external means. In this paper Passive technique is used for reducing the drag formation thereby delaying flow separation and boundary layer growth. This paper deals with a passive structure that results in a drag reduction greater than 5% reduction observed for riblets on aerodynamic wall structures by modifying the surface of the wall structure with micro-fibres that modify the coherent structures in the inner flow. A fibre kind of structure is developed to achieve the result. The modelling of the fibre structure is done and then analysed using with the standard atmospheric parameters.**

***Index Terms*— Drag Reduction, Passive Devices.**

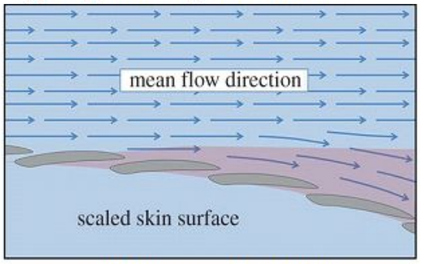
I. INTRODUCTION

From the advent of aviation, drag has been one of the most dangerous threats for flying an aircraft efficiently. Since then various developments have taken place in order to reduce the drag for more smoother and efficient flying. Drag is the force pulling the plane backwards which is the resistance created by the air molecules struck by the aircraft, being spread apart and flowing around the plane as it flies through them. The drag force is due to the pressure and shear forces acting on the surface of the object. The tangential shear stresses acting on the object produce friction drag (or viscous drag). A field of pressure gradient and surface shear stress should be predicted properly in turn boundary layer and flow separation.

Passive techniques, such as applying surface roughness, riblets, and/or additives, are simple and easy to apply without additional requirement of external power and complicated control schemes. Riblets, a shark-skin inspired technology, have been used extensively to reduce drag particularly for airfoils applications. The small riblets that cover the skin of fast-swimming sharks work by impeding the cross-stream translation of the stream wise vortices in the viscous sub layer. In practical, impeding the translation of vortices reduces the occurrence of vortex ejection into the outer boundary layers as well as the momentum transfer caused by tangling and twisting of vortices in the outer boundary layers. [1]

In this paper the surface is designed to give a more streamlined airflow by introducing a passive technique, where a fibrillar structure is placed on the surface in a form of micro-fiber structures as shown in Fig.1. This structure reduces/delays the growth and formation of boundary layer and flow separation.

(a)Magnified image of shark skin



(b) Flow over the shark skin

Fig.1 Shark skin and flow over the surface

II. DELAYING BOUNDARY LAYER

By using passive technique, shark-skin technology is adapted and the surface modified into a fibrillar structures that can be twisted and placed on a surface. The fibrillar structure is kept on top of the surface of the wing section. It is found that the intensity of the boundary layer growth is minimised and flow separation is reduced. By keeping the fibrillar structures on the surface as twisted one after another at regular intervals, a stream of pattern is created. So when the air flows through the pattern before the formation of the vortices due to boundary layer separation the second structure comes in contact with the flow field hereby forming a laminar linearized smooth flow with a minimal region of flow separation thereby reducing the drag over the surface.

III. LITERATURE SURVEY

From the primitive analysis reported by Brian Dean and Bharat Bhushan, “Shark-Skin surfaces for fluid-drag reduction in turbulent flow”,[1] the skin of fast-swimming sharks exhibit riblet structures aligned in the direction of flow that are known to reduce skin friction drag in the turbulent-flow regime providing a maximum drag reduction of nearly 10 percent. Luciano Castillo (US), Burak Aksak (US) and Metin Sitti (US), “Fibrillar structures to reduce viscous drag on aerodynamic & hydrodynamic wall surfaces” [4] stated that drag reduction on aerodynamic and hydrodynamic surfaces consists of reducing viscous skin

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Rengasamy.K, Assistant Professor, Parisutham Institute of Technology & Science, Thanjavur, India
Irish Angelin S, Assistant Professor, Parisutham Institute of Technology & Science, Thanjavur, India
Raja S, Assistant Professor, Parisutham Institute of Technology & Science, Thanjavur, India
Kabilan Siranjivi, Independent Researcher, Thanjavur, India

friction, delaying flow separation and boundary layer relaminarization by using passive devices. From the study by M. J. Walsh, W. L. Sellers, "Riblet drag reduction at flight condition", [5] the sinusoidal riblets due to an oscillatory span wise component added to the mean flow is found that drag reduction depend strongly on the a/λ ratio.

IV. DESIGN CONFIGURATION

The cross section of the wing is considered on which a fibrillar structure which is designed separately is incorporated. The design is generated using CATIA V5. The aerofoil is selected from the NACA 5 series and "NACA 22112" is generated for analysis (most suited for the commercial aircrafts). The fibrillar structure designed is shown in Fig.2 is assembled on the upper surface of the wing section at a twisted angle.

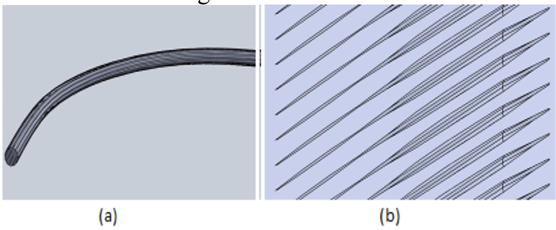

(a) (b)

Fig.2 (a) Fibrillar Structure (b) Fibrillar structures twisted

A numerous similar fibrillars are placed at regular intervals on the surface as shown in the Fig.3 which is the optimized design.

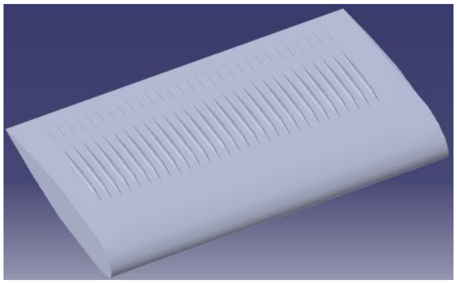


Fig.3 Surface on which fibrillars are incorporated

V. MATERIAL AND MANUFACTUING

The smaller dimensions of the sheet fabricated in a composite material reduce aerodynamic drag and minimize the inaccuracies caused by cross-winds. Usage of composite materials reduces approximately 15 to 20 % of the total drag by offering increased flight performance. The selected material is called as the, "MICRO FIBRILLAR REINFORCED COMPOSITES" which may be a carbon fibre based or cellulose based polymer blends.

VI. RESULT AND ANALYSIS

As stated in the previous sections, reducing the boundary layer growth, flow separation thereby, reducing the drag is studied over the surface incorporated with fibrillar structure is analysed using ANSYS ICEM CFD.

Basically analysis is done on two different designs, one with fibrillar and another without fibrillar structures. And they are subjected to the following boundary conditions. The analysis is done at three different angles which are 0, 5 and 10 degrees respectively. All these are done on the basis of the pressure variation, velocity difference and vorticity effect. At last, according to the results graphs are plotted for C_L and C_D.

VII. CONDITIONS GIVEN

For the geometry created, the initial conditions are given according to the study required which are given in Table.1

Inlet Velocity	**100 m/s**
Pressure (Po\P)	**1.035 Pa**
Type of Mesh	**Tetra Hedral Mesh**

Table.1 Initial conditions

Tetrahedral mesh is carried out all over the domain. The Mesh generated is shown in Fig.4

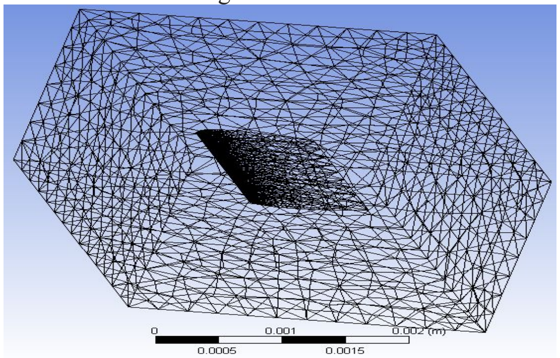
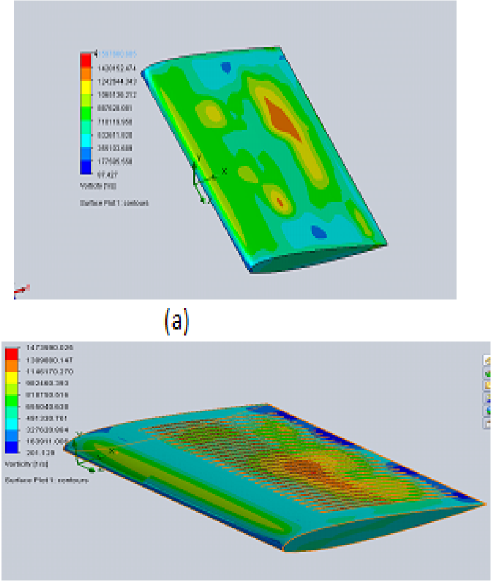


Fig.4 Mesh generated

VIII. ANALYSIS RESULT

Analysis were carried out separately over the cross section of the wing surface for with and without fibrillar structure at various angles and the pressure distribution, vorticity formation over the surface were studied. From the analysis it was found that the effect of vorticity over the surface was deceased for a surface with a fibrillar structure. This reduction in the vorticity indicates the delay in boundary layer formation and its growth and also reduced in flow separation on the surface of the structure.

Fig.5 shows the vorticity variation for 5 degree angle of attack when the surface is incorporated with fibrillar structure and without fibrillar structure. It is clear from the Figure that the vorticity is reduced when fibrillar structure is placed over the surface.

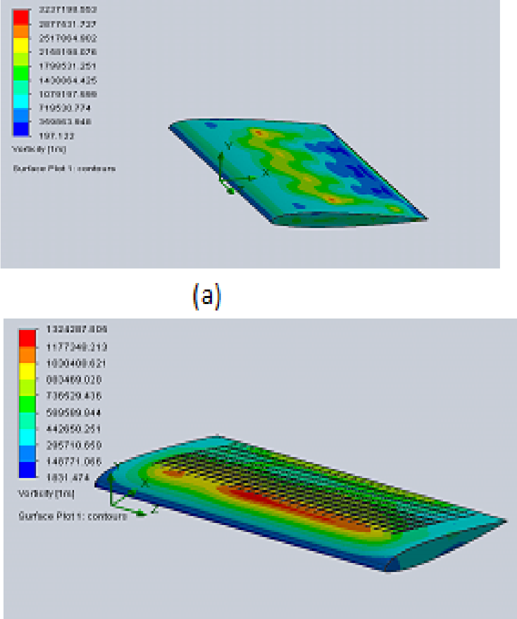


(b)

Fig.5 Vorticity distributions (5 deg) (a) without fibrillar (b) with fibrillar structure

Similarly, Fig.6 shows the vorticity variation for 10 degree angle of attack when the surface is incorporated with fibrillar structure and without fibrillar structure. It is clear from the Fig.6 (b) that the vorticity is reduced when fibrillar structure is placed over the surface.

From Fig.6 (a) and (b) it is observed that the turbulent boundary layer is more at the mid-section for the structure without fibrillars and the turbulent boundary layer intensity is decreased and brought to the rear section and not occurring in the mid-section of the structure with fibrillars.

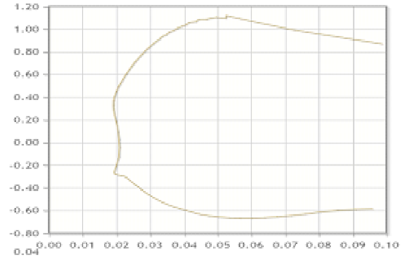


(a)

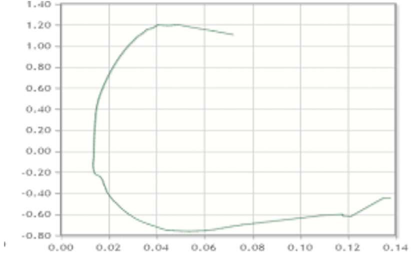
(b)

Fig. 6 Vorticity distributions (10 deg) (a) without fibrillar (b) with fibrillar structure

A graph between co-efficient of lift and co-efficient of drag is plotted to study how shows the relation between drag is reduced for with and without fibrillar structures. Fig.7 shows the relation between C_L/C_D for 5 degree angle of attack.



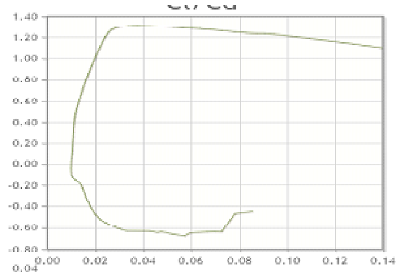
(a) without fibrillars



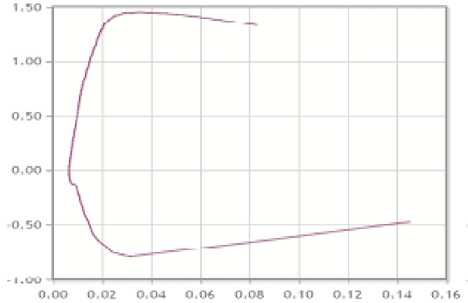
(b) with fibrillars

Fig.7 C_L/C_D for 5 degree angle of attack

Fig.8 shows the C_L/C_D ratio for 10 degree angle of attack.



(a) without fibrillars



(b) with fibrillars

Fig.8 C_L/C_D for 10 degree angle of attack

From the C_L/C_D graph, the drag percentage has been calculated for each case. It is clear from the graphs of with and without fibrillars; drag has been reduced for with fibrillar structure. It was found that the average drag reduction on the aircraft wing section is approximately 8.5 %.

CONCLUSION

From the analysis studied, by the use of the passive devices on the aircraft wing structure the drag can be easily reduced. The intensity of the turbulent boundary layer has been successfully delayed and its effects are reduced. The comparative results demonstrate that the performance of the aircraft will improve considerably with this technique. Research has taken place for the fibrillar structures in hydrodynamics but it was not proved in aerodynamics. Hence, this design and the basic analysis give the successful concept of usage of fibrillars in the aerodynamic designs.

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