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Implementing Micropatterned Surface for Drag Reduction in UAV

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Abstract*: The Aerodynamics of the Unmanned Aerial Vehicle plays a vital role in determining its performance. The reduction in drag helps the UAV to augment its flight time in terms of range as well as endurance. In our work an attempt was made to reduce the drag by means of changing its surface morphology in micro level without changing the entire shape and size of the UAV. The patterned surface morphology in the form of grooves and pillars were introduced on the surface of UAV. The wettability and aerodynamic parameters were quantitatively measured on the target micro patterned surface and the relation between them was explored in this work. The optimized size and shape of the micro patterns which supports to reduce drag in UAV was found experimentally in this work.

Keywords: Micro patterned surface, Hydrophobicity, Drag Reduction, UAV and Fluid Structure Interaction

I. INTRODUCTION

The aerodynamics of Unmanned Aerial Vehicle (UAV) plays a major role during its long endurance flights and at extreme low temperature operating environment. Through systematic review of literatures and patents in the area pertinent to improve the endurance at cruise and to overcome the icing problem, it is possible by making the surface hydrophobic either by coating or preferably implementing the textured surfaces over the drone [1-3]. While going through the behavior of super hydrophobic surfaces used in the literatures, even though the surfaces exhibits high contact angle, their contact angle hysteresis exhibits high value [4-6]. Because of the high contact angle hysteresis, the three phase contact line of the liquid drop gets pinned in the roughness asperities helps to reduce drag and acts as ice particle adhesion and growth location on the surface [7-9]. Textured surface modifies the surface roughness and enhances the non-wetting condition thereby inducing the phenomenon of "Lotus Effect". The lotus effect (similar to the effect of water on lotus leaf) can handle the icing and drag reduction by achieving the contact angle of liquid drop with solid surfaces close to 180° and contact angle hysteresis ($\Delta\theta=\theta\_adv-\theta\_rec$) as low as possible [10&11]. The same effect can be observed in rose pedals also, the image of the water droplet sitting on the rose pedal was shown in Figure.1.

Figure 1: Morphology of the water droplet sitting on the rose pedals

The phenomenon "Lotus effect" can be achieved by suitable modifications of surface structure with or without physical as well as chemical treatments. Because of higher contact angle of the liquid drop with superhydrophobic solid surfaces, the surface ice aggregation can be controlled so effectively in the drones operating at the ice cold environment. Hence wetting study plays a major role in determining the aerodynamic characteristics like drag of the RPAS [12].

II. EXPERIMENTAL WORK

A. Fabrication of Microgroove Patterned Samples

Micropatterns in the form of grooves and pillars were preferred in this work because of its better durability when compared to coatings [13&14]. The micropatterns were formed on the carbon plate using vacuum bag method with autoclave mould. The schematic sketch of the fabrication method was shown in Figure 2.

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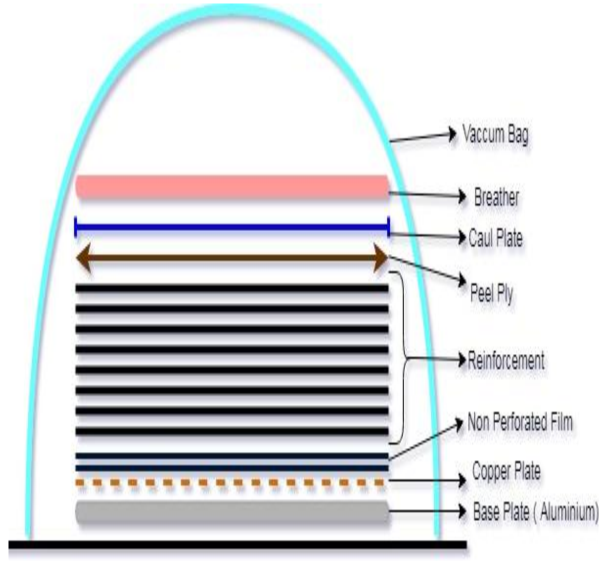

Figure 2: Fabrication method of micropatterns on carbon plate

Copper plate engraved with pattern of interest is placed over the base plate. A non perforated film is used in conjunction with the release fabric. This film helps to hold the resin in the laminate when high vacuum pressure is applied [15]. Release film is applied on the copper plate to release the reinforcement layers after curing [16 & 17]. Unidirectional carbon fiber layers are placed in the orientation 00 and 900. Carbon fiber along the grooves of copper plate is taken as 00 and perpendicular as 900. The whole setup is placed in a bag made of flexible film and all the edges are sealed.. The bag is then evacuated, so that the pressure eliminates voids in the laminate. The curing was done in autoclave at a temperature of 1200C for 180 minutes.

B. Geometrical Characterization and Wettability Measurement

The image of the micro groove patterns on carbon plate was captured using 3D optical profilometer (WYKO NT 1100) [18]. The geometrical parameters like ridge width, channel width and ridge height were extracted qualitatively from the captured image with the help of Veeco software. The geometrical parameters of the microgroove patterns were listed in Table 1. The wettability parameters contact angle and contact diameter are measured with the help of Image J software from the image using high speed camera [17].

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Table: I Geometrical Parameters of Micro patterns on Carbon Plate

S.No	*Surface*	*Ridge Width (RW) (μm)*	*Channel Width (CW) (μm)*	*Channel Depth (CD) (μm)*
1.	Carbon Plate	124.57	179.04	41

C. Aerodynamic Study

Open circuit subsonic wind tunnel with test section size of 600mm X 600mm X 1000mm is used to analyze the aerodynamic flow over the flat and micropatterned surface (200mm X 200mm). The wind tunnel used in this study was shown in Figure 3.

Figure 3: Wind Tunnel Used in Aerodynamic Study

Calibration is done to measure the actual velocity. Display instrument shows pre-set approximate velocity in accordance to the frequency of the axial fan, which is operated by the user. This frequency fluctuates based on the input voltage fluctuation. Therefore, it is required to find out the actual velocity through the Pitot tube placed inside the test section for every respective RPM

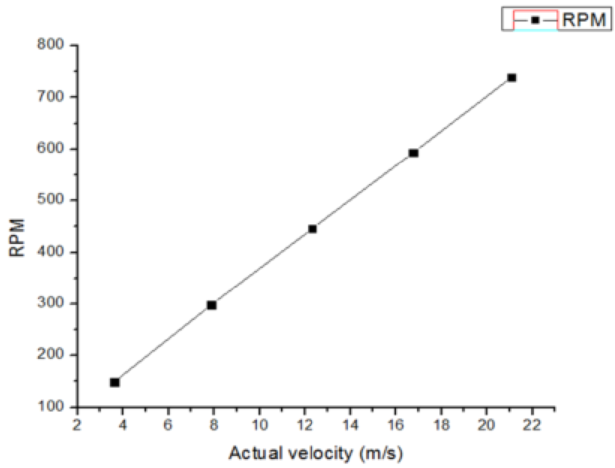

Figure 4: RPM Variation as a function of Actual Velocity

III. RESULTS AND DISCUSSION

The wind tunnel test was performed in all the cases of carbon plates design (smooth, groove, pillars) for three velocities 7m/s, 10 m/s and 15m/s. The wind speed of the tunnel is set at 7m/s and the corresponding Cl and Cd values are noted down. The graphs are drawn for L/D ratio, Cl and Cd value with respect to different angle of attack.

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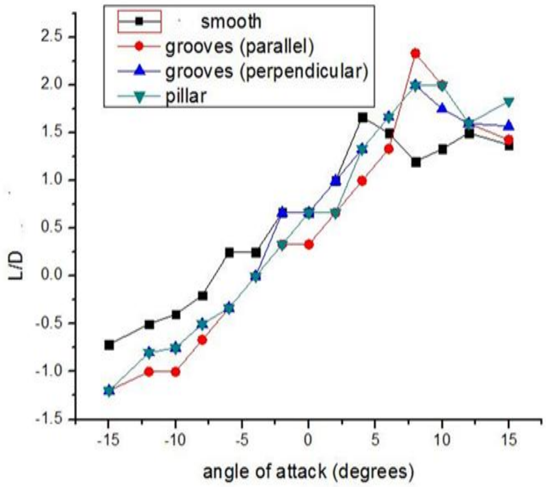

Figure.5. L/D Variation as a function of AOA at 7m/s

From the above graph, at the speed of 7 m/s linear increment in L\D occurred due to the angle of attack from -15 to -6. The increment of L/D noted at angle of attack 5 and further increment occurs at the angle of attack from 6 to 13.

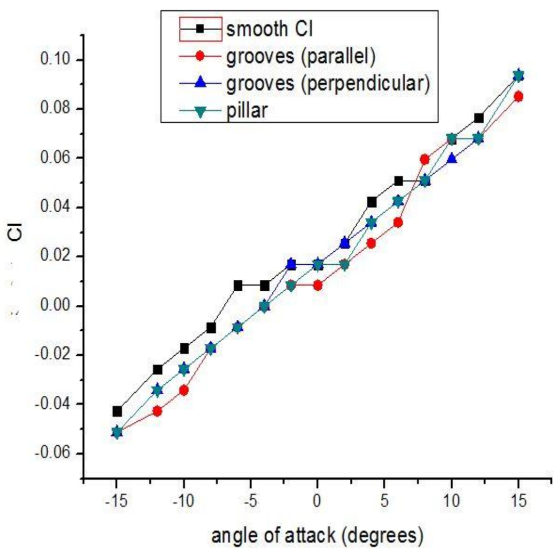

Figure.6(a). Cl and AOA

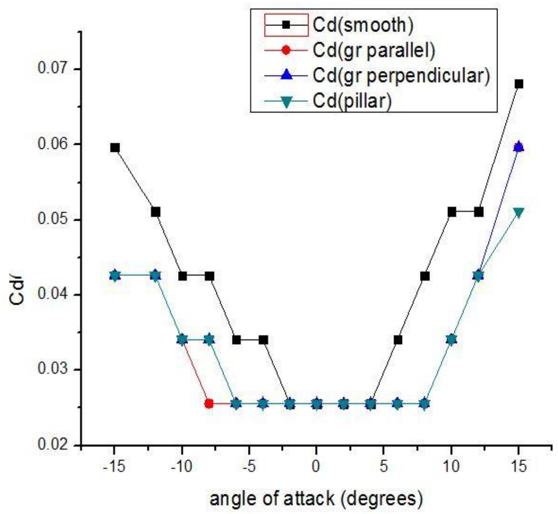

Figure.6(a). Cd Variation as a function of AOA

From figure 6 (a) smooth plate provides better Cl value for the negative angle of attack whereas Cl value is comparatively lesser than other cases for positive angle of attack and in figure 6 (b) at 7 m/s the smooth plate has high Cd of 0.06 at the negative angle of attack of -15 degree and also has high Cd in the positive angle of attack. From figure 7, at 10m/s smooth line of L\D is formed from -15 to -3 angle of attack. The maximum of L\D occurs at the angle of attack at 3. The same trend was observed in variation of Cl with respect to angle of attack and it was shown in figure. 8(a). The above statement was proven in the figure 8 (b) by the plot between Cd and angle of attack.

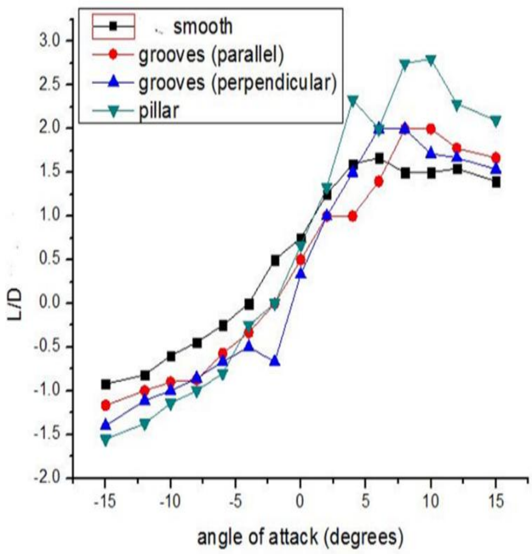

Figure 7: L/D Variation as a function of AOA at 10 m/s

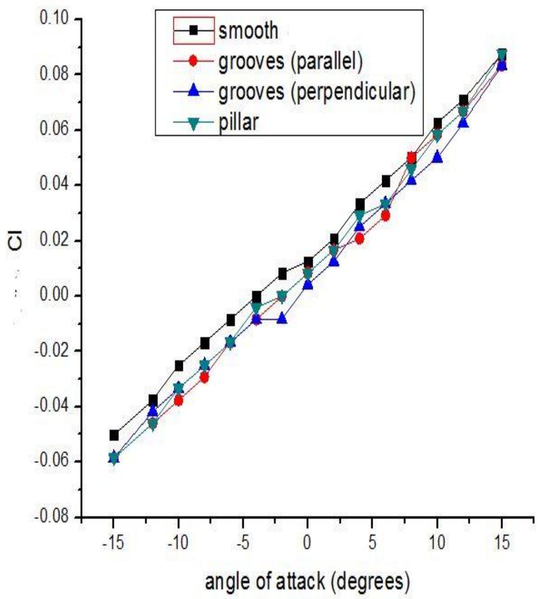

Figure 8: (a) Cl and AOA at 10 m/s

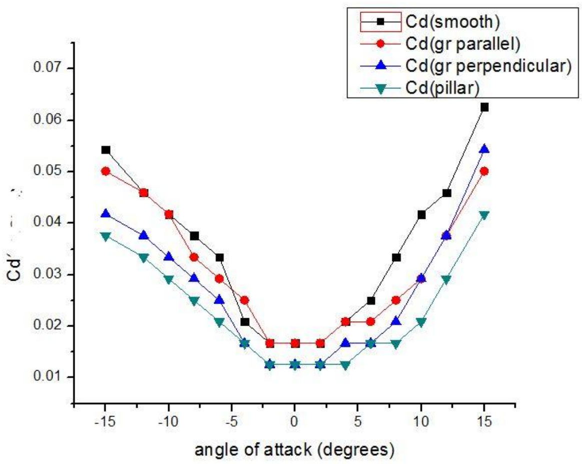

Figure 8: (b) Cd Variation as a function of AOA at 10 m/s

The same trend was observed at 15 m/s. According to the analysis, the optimum velocity for better aerodynamic performance of flat plate is ranges from 7 m/s (25km/hr) to 15m/s (54hm/hr). The graphs are obtained at lower velocities, variations of respective lift and drag forces with respect to the corresponding angle of attack is less. The results shows that the coefficient of drag (Cd) is significantly less for the micropillar surface when compared to other cases. The microgrooves when placed perpendicular to the air flow performs similarly to the micropillar surface. If the microgroove surface is placed parallel to the air flow shows higher coefficient of drag (Cd) similar to the smooth surface. The quantitative values of the aerodynamic parameters from our research for different velocities are listed in Table 2 Therefore, in our work it is proved that hydrophobic surface can stand as a chance to reduce drag.

Table- II: Percentage of Variation in L/D, Cl and Cd in Micro patterned Surface with respect to Velocities

Velocity	*Aerodynamic Parameters*	*Minimum*		*Maximum*	
		% change	*AOA*	*%change*	*AOA*
7 m/s	L/D	25	+15°	6.25	+12°
	Cl	24	-8°	0	0°
	Cd	13	+15°	0	0°
10 m/s	L/D	33	+15°	12	0°
	Cl	20	-15°	7	0°
	Cd	18	+15°	5	0°
15 m/s	L/D	48	-10°	6	+4°
	Cl	15	-8°	4	0°
	Cd	13	+15°	5	0°

IV. CONCLUSION

Wettability of carbon plate surface was investigated and found the relation between surface morphology, wetting and aerodynamic characteristics. The micropatterns were impinged on the surface of carbon plates using dies while fabrication itself. Micropatterned surface shows lesser wetting property and better aerodynamic characteristics when compare to smooth surface and acts as hydrophobic surface. Geometrical surface asperities were found to be interlinked with wettability and aerodynamics characteristics of the surface. From this work, it is proved that proper selection of surface morpology is necessary to optimize the wetting and aerodynamic characteristics of micropattern surface. Micropattern surface may stand as a possible solution to reduce the drag in UAV without altering its shape..

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