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Feasibility Study on Developing Hydrophobic Skin Material for Aircraft Structures

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ABSTRACT

Making an aircraft's outer skin as hydrophobic is the proposed idea of this paper. Hydrophobic skin or surface is a surface which repels the water droplets deposited on it. As soon as the water deposit is eliminated, the ice formation can be controlled easily. To assure safe flight operation, the ice formation needs to be removed for preventing the increase in vehicle weight and for visibility. Poly-tetra- fluro-ethylene is identified from literatures as hydrophobic agent and it is used in this research to coat it over a sample aircraft aluminium alloy (2014) specimen. Both analytical and experimental studies are conducted for performance evaluation of the test material. ANSYS software is used for analytical examination of wall shear stress, volume fraction and drag force. Around 33% of wall shear stress reduction has been estimated in this analytical testing and coefficient of drag force Cd has been found decreased from 0.09656 to 0.04231. In the real time experimental studies, the coated specimen is tested for hydrophobic nature in testing laboratory. Since the coating process involves heating of the metal, the hardness of the specimen is subjected to investigation during this research. The testing results have been found that the tensile strength of the specimen reduced from 96.5 N/mm^2 to 91.2 N/mm^2; and hardness found decreased from 18.4 HR15T to 17.4 HR15T. During the hydrophobic testing, the rate of water absorption has been found reduced from 0.255% to 0.083%. Though the mechanical properties of the specimen has been found decreased, the hydrophobic has been achieved as the water absorption found decreased.

KEY WORDS: Aircraft, Aluminium, Alloy, Hydrophobic, Poly-tetra-fluro-ethylene, ANSYS.

1. INTRODUCTION

The materials used in aircraft have changed significantly from the construction of the first aircraft. With its objective of flying using air support while resisting gravitational forces, the materials used for construction of aircraft must have a small weight, high specific strength, heat resistant, fatigue load resistant, crack resistant, and corrosion resistant. Back in the days, aircraft were constructed using wood and fabric. But aircrafts that are made up of wood and fabric were subject to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminum, steel, titanium and composite materials are preferred in the construction of aerospace structures. Most of the air planes today are made out of aluminum, a strong, yet light weight metal. Other metals, such as steel and titanium, are sometimes used to build aircraft. Since then, aircraft of all kinds and sizes have relied on aluminum to achieve take off. Aluminum's combination of lightness, strength and workability makes it the ideal material for mass-produced commercial aircraft. Strong aluminum alloys take the extraordinary pressures and stresses involved in high altitude flying; wafer-thin aluminum panels keep the cold out and the air in. Today, there are over 27,000 commercial aircraft flying in the world, and many thousands of light aircraft and helicopters. Demand from 15,000 today to more than 31,500 by 2030. Aluminum is the primary aircraft material, comprising about 80% of an aircraft's unlade weight. Because the metal resists corrosion, some airlines don't paint their planes, saving several hundred of Kilograms in weight.

Aircraft flying at high altitude the temperature is very less. Hence, the ice formed in aircraft outer surface such as wings leading edge, horizontal vertical stabilizer, and control surfaces. This ice formation reduces the aerodynamic efficiency, increases drag, reduces lift and higher stall speed, greater fuel consumption, and reduces maneuverability. Anti-ice systems are used to prevent ice from forming. High performance turbine aircraft often direct hot air from the compressor section of the engine to the leading edge surfaces. The hot air heats the leading edge surfaces sufficiently to prevent the formation of ice. A newer type of thermal anti-ice system referred to as thermo wring uses electrically heated graphite foil laminate applied to the leading edge of the wing and horizontal stabilizer. The weeping-wing design uses small holes located in the leading edge of the wing to prevent the formation and build-up of ice. An antifreeze solution is pumped to the leading edge and weeps out through the holes. By the design and construction of such anti-icing systems, the aircraft weight increases and achieves in low efficiency. Under this light this paper has introducing hydrophobic surface on aircraft skin surface for preventing ice formation. Aluminium alloy material has been taken for research in the paper and coated with Teflon to achieve hydrophobic surface. Further the mechanical and nature water absorption test are conducted on the specimen coated material. The further subsections of the paper describe the proposed methodology and the results achieved.

1.1. Aircraft Materials-Aluminium alloy: The typical aircraft aluminium alloying elements are copper, magnesium, manganese, silicon, tin and zinc. The different type of aluminium alloys series which are widely used in engineering structures and components where light weight and corrosion resistance is required are given in Table

1. Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. In this research work, aluminium 2014 is taken for analysis because of its wide usage and acceptability in many applications.

Table.1.Aluminium alloy series

1000 series	2000 series	3000 series	4000 series	5000 series		6000 series			7000 series		8000 series
1050	2014	3003	4041	5005	5154	6005	6070	6262	7005	7075	8000
1060	2024	3004	4043	5052	5356	(6005A)	6082	6351	7022	7079	8090
1100	2219	3102		5059	5456	6061	6105	6463	7046	7116	
1199				5083	5754	6063	6111		7068	7129	
				5086		6066	6162		7072	7178	

1.2. Aluminium 2014: Aluminium 2014 grade material whose chemical composition is given is Table 2, is often used in the aerospace industry. It is easily machined in certain tempers, and among the strongest available aluminium alloys, as well as having high hardness. Forging can be done at the temperature range of 750 to 850 F. However, it is difficult to weld, as it is subject to cracking. It is commonly extruded and forged. The corrosion resistance of this alloy is particularly poor. To combat this, it is often clad with pure aluminum.

Table.2.Chemical Composition and properties of aluminium 2014

Chemical composition		Properties
Aluminum: Remainder	Remainder: Total 0.15% max	Density: 2.80 g/cm^3
Chromium: 0.1% max	Silicon: 0.5% - 1.2%	Young's modulus: 73 GPa
Copper: 3.9% - 5%	Titanium: 0.15% max	Electrical conductivity: 34 to 50% IACS.
Iron: 0.7% max	Titanium + Zinc: 0.2% max	Ultimate tensile strength: 190 to 480 MPa
Magnesium: 0.2% - 0.8%	Zinc: 0.25% max	Thermal Conductivity: 130 to 190 W/m-K.
Manganese: 0.4 - 1.2%	Remainder: Each 0.05% max	Thermal Expansion: 23 μm/m-K.

2. PROPOSED METHODOLOGY

Hydrophobic materials are used for oil removal from water, the management of oil spills, and chemical separation processes to remove non-polar substances from polar compounds. Hydrophobic molecules tend to be non-polar and thus prefer other neutral molecules and non-polar solvents. Hydrophobic molecules in water often cluster together. Water on hydrophobic surfaces will exhibit a high contact angle. Physical property of a molecule is repelled from a mass of water as shown in figure 1. Examples of hydrophobic molecules include the alkanes, oils, fats, and greasy substances in general. In this research work Teflon coating is preferred among other coating materials for developing hydrophobic surface. The contact angle of water on a surface is the angle of the leading edge of a water droplet on the surface as measured from the center of the droplet. A surface with a contact angle of 180 degrees would mean that water sits on it as a perfect sphere. Hydrophobic surface are measured between 90 degrees and 180 degrees as referred in figure 2. Polytetrafuluroethylene (TEFLON) is a thermoplastic polymer as shown in refer figure 3.

Fig.1.Hydrophobic surface

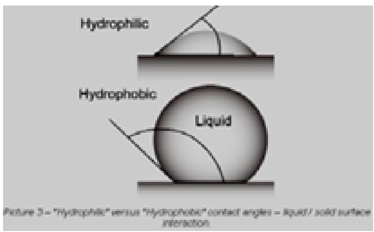

Fig.2.high contact angle of water

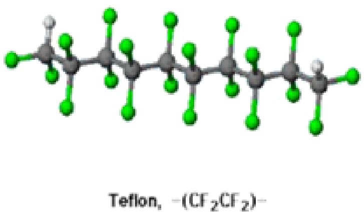

Fig.3.Polytetrafluoroethylene

Teflon coating s provideanti-corrosive properties and en sure metal components have the longest possible life span. the high dielectric strength, low dissipation factor and very high surface resistivity and good Chemical resistance, Corrosion resistance, Abrasion resistance, Durability, Lubricating proerties, Easier clean-up . In this rese arch a 10 x 10 cm aluminium 201 4 specimen has been taken for coating and analysis. Methods of testing the adhesion strength of ice to coating s vary widely, and many of the different test method results are not com parable, in addition, standardized tests have not been applied to testing the longevity, application characteristics, and resistance to contamination of coatings. Therefore, only relative crude and incomplete guidelines are presently available regarding their performance. We have conducted both real time analysis and simultaneous analysis using ANSYS-FLUENT. Also we have tested the specimen in universal testing machine and Rockwell Hardness tester.

3. RESULTS AND DISCUSSIONS

Base wing model has been developed with suitable NACA airfoil as shown in figure 4. The testing of the model wing is simulated in wind tunnel as shown in figure 5 for which the model has been meshed suitably with selected meshing element as given in figure 6. Besides basing model, a coated wing is also modeled a meshed for analysis and comparison as shown in figure 7.

Fig.4.Base wing model

Fig.5.Wing inside the wind tunnel

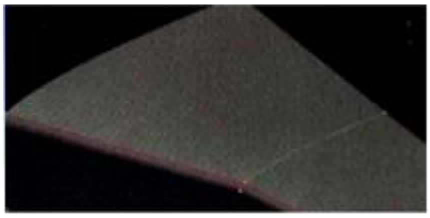

Fig.6.Wing meshing

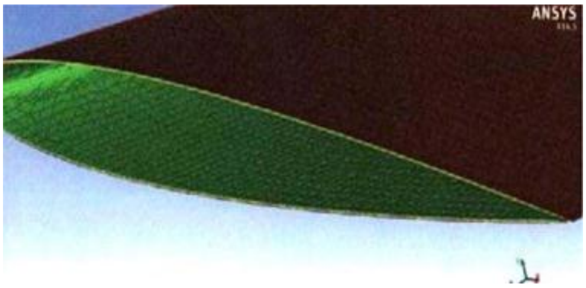

Fig.7.Meshing of luminium wing with Teflon coating

Figure.8.Wall shear stress in base wing

Figure.9.Wall shear stress in base wing with mixture

Figure.10.Wall shear stress with Teflon coating

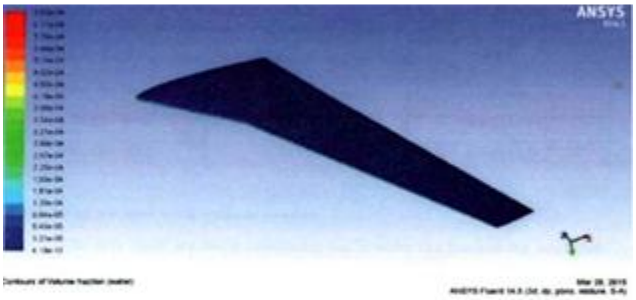

Figure.11.Volume fraction test n base wing

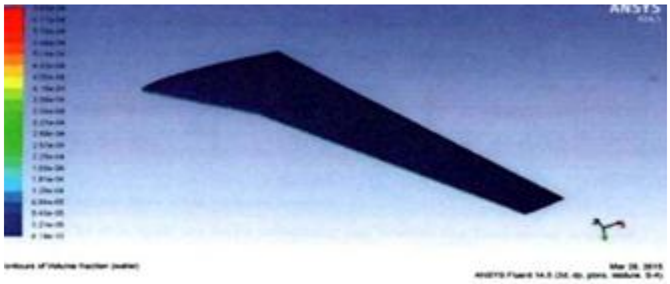

Figure.12.Volume fraction test n coated wing

In base wing case the droplets have found deposited on the trailing edge and leading edge of the wing. In coated wing t e droplets have been found deposited on the trailing edge only and here is no deposition in leading edge. Analytical the drag force on base wing and coated wing model are estimated and tabulated in table 3.

Table.3.Drag for Base Wing & Base Wing without Coating & with coating

Model	Pressure drag	Viscous drag	Total drag
Base wing	0.015 807692	0.0173392 8	0. 02215752
Base wing in mixture without coating	0.071 191838	0.0254024	0.096594238
Teflon coat wing	0.020 177473	0.0221365 89	0.042313922

Another important aerodynamic force, drag coefficient and shear stress were estimated as depicted in table 4.

Table.4.The comparison of Drag & shear stress without coating wing &with coating wing

Model	C_d	Shear stress
Base wing	0.0331	1.07*e^2
Base wing in mixture without coating	0.09 659	3.05*e^1
Teflon coated wing	0.04 231	2.05*e^1

Experimental analysis of the test specimen for strength and water absorption has been done with outsource laboratory situated in south Tamilnadu. The lab oratory results have been summarized in table 5.

Table.5.Tensile, hardness & water absorption experimental test results

Parameter	Without coating	With coating	Types of test	Before coating	After coating
Initial weight	71.163	71.164	Tensile	96.5N/mm^2	91.2N/mm^2
Final weight	71.321	71.221	Hardness	18.4 HR15T	17.4 HR15T
Observed water	0.158	0.059			
Percentage of water absorption	0.225%	0.083%			

4. CONCLUSION

This proposal has been developed based on a comprehensive literature review. Making the aircraft's outer skin as hydrophobic was the proposed idea. Polytetrafluroethylene was identified from literatures as hydrophobic agent and used in this research to coat it over a sample aircraft aluminum 2014 specimen. Both analytical and experimental studies were conducted for performance evaluation of the test material. ANSYS software was used for analytical examination of wall shear stress, volume fraction and drag force. Around 33% of wall shear stress reduction has been estimated in this analytical testing and coefficient of drag force Cd has been found decreased from 0.09656 to 0.04231.The coated specimen was then tested for hydrophobic nature in testing laboratory. Since the coating process involved heating of the metal, the hardness of the specimen was also subjected to investigation during this research. The testing results have been found that the tensile strength of the specimen reduced from 96.5 N/mm^2 to 91.2 N/mm^2; and hardness found decreased from 18.4 HR15T to 17.4 HR15T. During the hydrophobic testing, the rate of water absorption has been found reduced from 0.255% to 0.083%. Though the mechanical properties of the specimen has been found decreased, the hydrophobic has been achieved to certain extend as the water absorption found decreased.

REFERENCES

Ackley SF, Itagaki K, Frank M, An evalution of passive of passive deicing, mechanical deicing and ice detection, U.S. Army cold Regions Research and Engineering Laboratory: CRREL Report, No:IR 351, 1997.

Anderson D.N, Reich A.D, Tests of the performance of coatings for low ice adhesion, Proceedings of NASA Tech. Mem. 107399, AIAA 35th Aerospace Sciences Meeting & Exhibit, Jan. Reno, Nv, 1997.

Antonini C, Innocenti M, Horn T, Marengo M, Amirfazli A, The energy reducing for anti-icing system by implementing hydrophobic surface as well as modifying some coatings, University of Aiberta, Edmonton, AB, Canada, T6G2G8, 2010.

Boluk Y, Adhesion of freezing precipitation to aircraft surfaces, Transport Canada publication No. TP 12860E, 1996.

Datasheets – Aluminium Alloy – BS-L – L168T6511 – 2014A Bar, Wilsons Ltd, www.wilsonsmetal.com

Jones AK, Sikka VK, Wu J, Gao D, Anti-icing Super hydrophobic coatings, Langmuir., 25 (21), 2009, 12444-12448, 2009.

Zhenlong Wu, Yihua Cao, and M. Ismail, Numerical Simulation of Airfoil Aerodynamic Penalties and Mechanisms in Heavy Rain, International Journal of Aerospace Engineering, 2013.