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Analysis of Thermal ICE Protection Using Piccolo Tube

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Abstract- In-flight icing is a major concern in aircraft safety and a non-negligible source of incidents and accidents, and is still a serious hazard today. It remains consequently a design and certification challenge for aircraft manufacturers. The aerodynamic performance of an aircraft can indeed degrade rapidly when flying in icing conditions, leading to accidents. In-flight icing occurs when an aircraft passes through clouds containing super cooled water droplets at or below freezing temperature. Droplets impinge on its exposed surfaces and freeze, causing roughness and shape changes that increase drag, decrease lift and reduce the stall angle of attack, eventually inducing flow separation and stall. This hazardous ice accretion is prevented by the use of dedicated anti-icing systems, among which hot- air-types are the most common for aircraft. A widely used method in aviation Industry to overcome this problem is to employ a Hot-Air Anti-icing system owing to its simplicity, efficiency and reliability. High temperature, hig pressure air from the engine compressor is extracted and passed through a piccolo tube, and the distance between piccolo tube and wing inner surface have strong influence on keeping the external surface of the wing leading edge sufficiently hot to avoid ice formation. In the present work, anti-icing scheme for a typical aircraft wing of an airfoil shape, involving effect of hot air jets from a piccolo tube, is investigated numerically. The CAD model of the wing-piccolo tube assembly is generated using CATIA software and discretisation of the flow domain is being done using ANSYS software.

I. INTRODUCTION

Design of the aircraft bleed-air ice protection systems involves optimization of multiple geometric and flow of parameters under constraints such as a system weight and bleed air availability from the power plant at various flight regimes. Geometric design parameters that have sufficient impact on the bleed air ice protection system performance include airfoil section, diffused shape, number of piccolo tube hole diameter, hole pitch, hole circumferential parameter and hole pattern. Ice formation on an aircraft structure occurs over the leading edge of aircraft wings, lip of the intake duct and also on the aircraft nose and fuselage. Even a small ice formation on the wing leading edge would cause decrease in lift and decrease in drag force .The various systems to avoid ice formations are based on mechanical, chemical and thermal techniques. The bleed air technique is the most popular in the aircraft industry. A piccolo tube with a series of in line staggered holes is placed inside the leading end near to its inner surface. The hot bleed air from the engine compressor is passed through the piccolo tube and it ejects from the piccolo tube holes in the form of high velocity jets that impinge on the inner surface to outer surface maintaining the wing leading edge hot enough to avoid accretion of ice.

On the other hand Icing wing tunnel testing is costly and limiting. Both these cases are suitable for analyzing a system but can hardly be used for design platform. Therefore, it is logical to benefit from CFD model to optimize anti icing systems before they are tested. Nevertheless fully coupled 3D stimulations are quite demanding in terms of computing resources.

II. EXPERIMENTAL METHODOLOGY

NACA 2412 airfoil was used for wing section. The profile was decline with maximum camber of 2%chord length, maximum camber position at 40% chord length and maximum thickness of 12% chord length a chord length of 1.5 m was selected. The wing leading edge was equipped with a bleed air system consisting of a piccolo tube. The heated region extended to 12% of chord on both upper surfaces. The piccolo tube had an outer diameter of 22mm. The diameter jet hole was 9mm and the spacing between adjacent holes was 7mm.

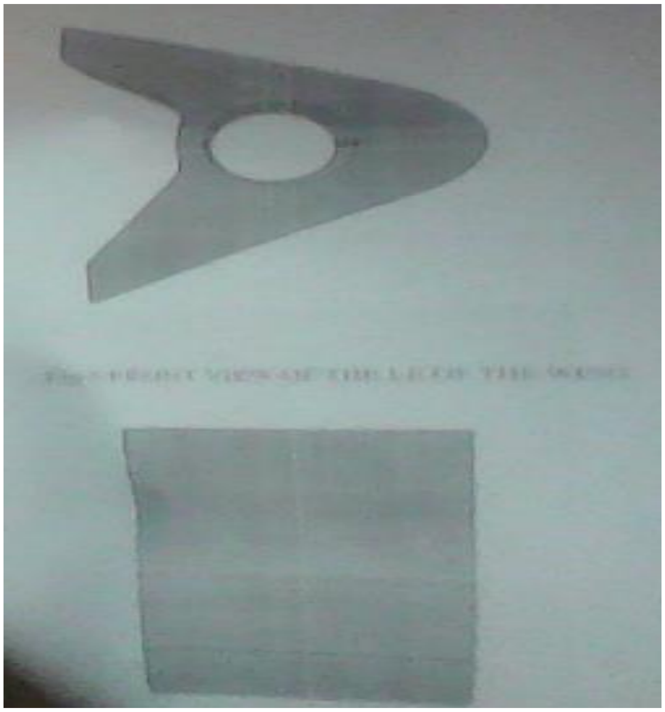

Fig. 1.

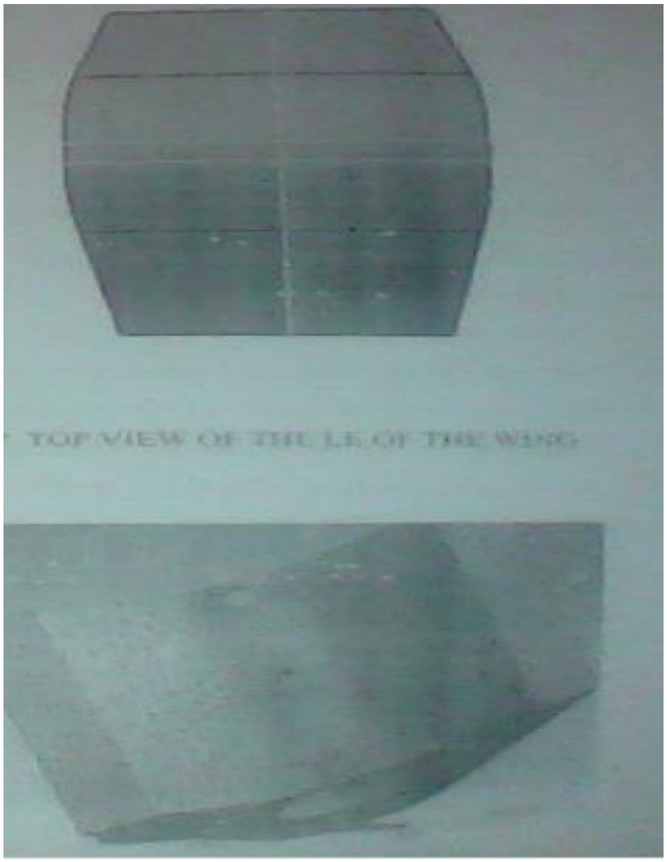

Fig. 2.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Case1-Hot air jets coming out of the piccolo tube arrangement at -45 D to 45 Degree. The accelerated flow subsequently lowered the static temperature and increased the cooling effect on the upper surface. The hot ir from piccolo tube impinged on the wing skin and circulated inside the diffuser region before leaving through the upper and lower diffuser passages formed between the inner liner and the wing skin.

Case 2-Hot air jets coming out of piccolo tube arrangement at centre 0 degree. The temperature distribution along either side of the chord line is more inform and the results appear to be better and efficient when compared to case 1. Analysis results it is evident that case 2 piccolo tube and wing inner surface gives favorable temperature distribution on the outer surface of the wing and the surface is sufficiently high to avoid ice formation under flight condition.

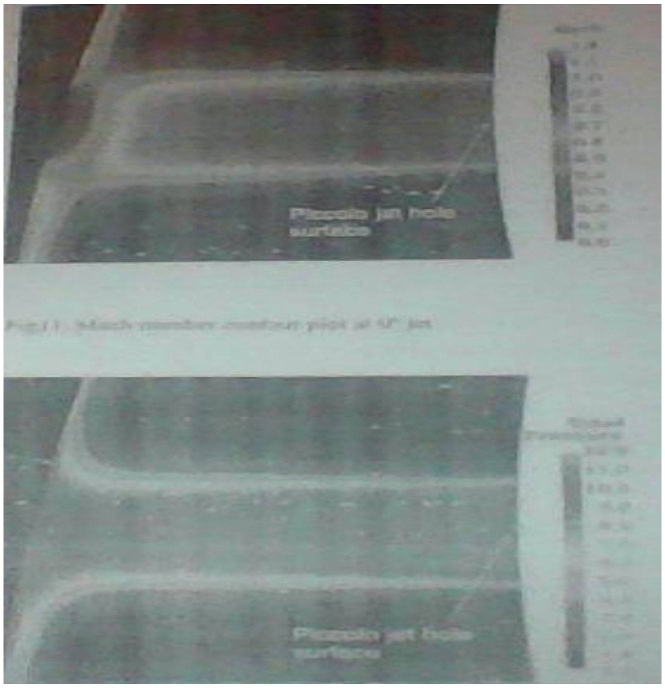

Fig. 3.

IV. CONCLUSION

In case 1 temperature distribution was not that sufficient and effective for removal of ice. From analysis it is found that in case 1 maximum temperature distribution was 225k but overall temperature around the span was found to be 175k and minimum temperature was 35k. But in case 2 maximum temperature was 375k and minimum temperature was 25k and this temperature is sufficient for ice removal.

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