Experimental study of Bias Acoustic Liner on nacelle lip-skin

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ABSTRACT

The paper demonstrates the effect of Bias Acoustic Liner for nacelle lip-skin for civil aircraft. The effect of drag on nacelle lip-skin porous surface profile with liner. Additionally, the absorption of noise that reduced by using of Bias acoustic liner has been discussed. An acoustically absorbent material is employed with honeycomb liner for the required acoustic attenuation features for the aircraft engines. The BAL system behaves differently at different positions, around the rotor fan to absorb the fan noise; however, at the nacelle position along with anti-icing system, it shows dual nature i.e., noise reduction as well as drag reduction by using of bias flow through the micro-channels of the liner. The experiment runs between 0^0-5^0 (degree) angle of attack and Reynolds no. 2.2×10^5 to 5.8×10^5 to achieve drag reduction by 22%. At 2^0 angles of attack found the effective inclination for drag reduction. Backplate using at the large area over where the acoustic reducing material is used from the close source. In this paper, we will also discuss briefly Bias Acoustic Liner applications in aircraft engines.

Keywords: *drag reduction, nacelle lip-skin, Reynolds number, anti-icing, Acoustic Liner.*

Introduction

The discussion started with the globalization of increasing traffic in aircraft for huge demand result to increase in travel frequency where people use aircraft in different modes. Almost all people prefer airplane to meet loved ones or other purposes. The awareness on improvement and modifications as result of these frequent traveling or using aircraft for various necessities. But the negative consequences come along as noise and air pollution issues come

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first to tackle in aviation research, and continuously enhancement has been made it more efficient. Efficiency is always an interesting but challenging job in aviation research. An aircraft performance comes under scale by consumption of a huge amount of fuel, on different means like turbulence, vibration, noise lift/drag for the different geometrical structures [1]. Even the scale result goes low for any specific kind of structures by lift/drag consideration around 20% [2].

In this paper, we will discuss nacelle lip-skin drag effect by using the acoustic liner. The improvement is continuously going on in aviation industries for progress, efficient, safe and effective on behalf of performance. Mostly the progress has been concentrated on aerodynamic related properties to enhance the overall aspects of aircraft. These related work focused on aerodynamics advance technologies for the input of atmospheric state like as ice accumulation [3]. Ice accumulation is always a serious problem for civil transportation on nacelle surface [4]. Especially for those aircraft those using higher altitude for a flight like Boeing and Airbus. In history, we have several severe accidents happen due to ice accretion on nacelle lip-skin but the anti-icing system made it safer. For anti-icing, Swirl Anti-icing system (SAI) has developed and tested as a most efficient system [5]. Further, some more devices developed to solve these problems that related to nacelle lip-skin. Figure 1 shows the nacelle lip-skin along with the aircraft engine.

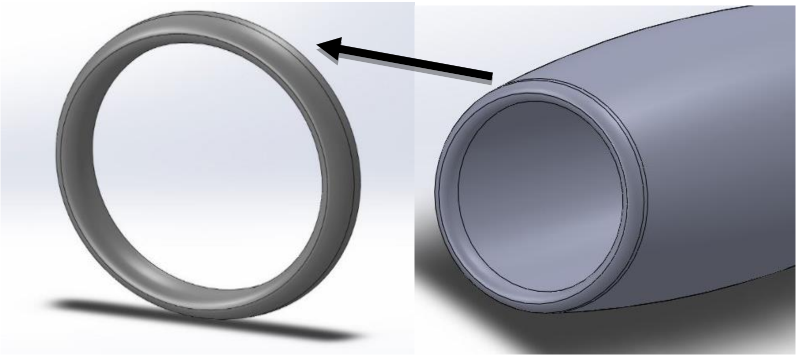

Figure 1: Nacelle lip-skin along with the engine.

Noise is another serious challenge for aviation as a pollution that affects the living creatures along with the human society. The research has been still under progress to overcome for various sources of noise generation from aircraft. In recent years' immense effort by the scientist has been working on different type of acoustically absorbing techniques that has significance acceptability for the aircraft engine applications [6]. The related research for engine generated noise has focused on different aspects of noise abatement like turbomachinery and some other aspect of noise including airframe

generated noise [7]. The noise which propagates in an aircraft turbofan inlet duct is just because of the fan tone that relies on the power of engine [8].
A successful technology has been introduced, the acoustic liner is the most efficient passive method for radiated noise energy as well as far field noise [9]. In this article, we will discuss the effect on nacelle lip-skin with respect to flow mixing featured with boundary layer effect by using the Acoustic liner through the liner channels with a perforated sheet.

Acoustic liner

After the development of the ultra-high bypass ratio engines added a new chapter on noise reduction in aircraft engine on a remarkable scale [10]. The liners absorbed generated noise as well as radiated acoustic energy with far-field noise intensity [11]. Liners mostly installed internally at the place of inlet and outlet with the engine profile. Acoustic liners equipped with the perforated absorbent material sheet with honeycomb channel of the specific material. The complete setup of single layer liner creates one degree of freedom. The channels pass the hot air through the hole to prevent the accretion of ice by using of anti-icing system [12]. Aviation industries used the liners on different aspects of aircraft with various purpose here Figure 2 shows types of liner.

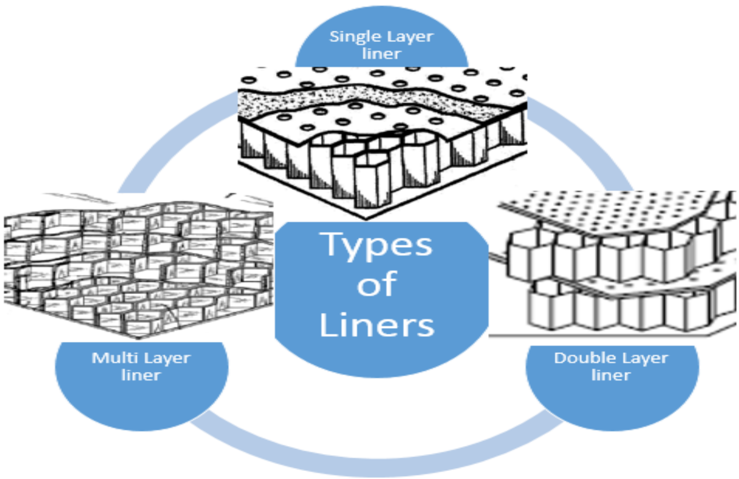

Figure 2: Types of the acoustic liner.

The skin drag reduces with the help of bias acoustic liner by flow control techniques for both types of the flow like turbulent or laminar flow [13]. They already set the tremendous concepts for reduction of drag with different types of experiment over passive or active flow control [14]. In addition, the

experiment also shows the skin friction more on the porous surface with bias flow. But the flow controlled experiment lead by bias flow techniques through a microporous wall or the homogeneous holes on the surface which participate in the mixing of the flow so that the boundary layer thickness has increased [15]. Due to increment in boundary layer thickness, the drag reduced on the nacelle surface.
Hwang, NASA Glenn research institute researcher had investigated on a specific idea to reduce the surface drag with passive flow control through the porous surface and found the drag reduction about 40-65% in comparison of solid surface with the subsonic flow [16]. The simulation based study on the same techniques also verifies the significant drag reduction on similar porous ratio and nature of the hole [17]. So, this article also motivated from the same techniques but without using any flow through the porous surface.

Experimental setup

The equipment used in the experimental investigation for drag on nacelle lip-skin was balancing unit which was attached to the experimental section of a wind tunnel. Wind tunnel configuration was open circuit type with cylindrical inlet and honeycomb attached rectangular shape outlet. One of the digital displays showed the pressure difference between the outlet vent to the testing box, other display used for lift and drag. The displays connected with the computer to monitoring the experimental data. Air flow used at the test section to measure the exact flow rate before the nacelle profile. Before the experiment balancing unit calibrated with high precision, nacelle lip-skin (fig. 4) model attached with the balancing unit as well as placed in the test section of a wind tunnel. The angle of attack controlled from the balancing unit manually, for this experiment test run between 0 to 5 degree of the angle of attack. Every experiment runs till five iterations to achieve the precise result. Figure 3 shows the setup of the experiment.

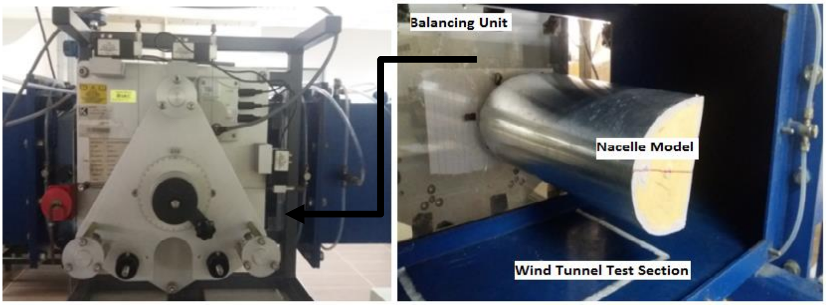

Figure 3: Balancing Unit along with Nacelle lip-skin model in wind tunnel.

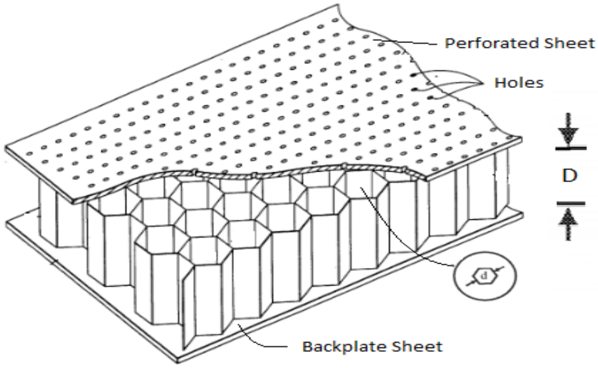

Figure 4: Single layer liner along with the perforated plate.

In this experiment, single layer liner used at the lower profile of the nacelle lip-skin at the critical position of the liner. The single layer liner shows in figure 4 with a perforated plate and back face solid surface plate. Diameter and thickness of the honeycomb with specific dimension are also considered.

Result and Discussion

The calculation based graphical figure presenting drag coefficient result along with the different Reynolds numbers. Drag coefficient continuously increases with respect to Reynolds number cause of drag force appeared on the surface of the nacelle for the turbulent flow, drag force proportionally existed which has been varying between 2.2×10^5 to 5.8×10^5. The drag force on nacelle with BAL shows to enhance the result. Lower drag force with respect to the inclined Reynold number depicts the effect of BAL, that cause of boundary layer separation. The generated bump shape appeared at the porous surface of the liner that is established at the lower profile of the nacelle. The bump shape enlarges the boundary layer length where the boundary layer separated from the surface.

The effect of the hole over the surface stands for the pressure reduction loss to increase the length of the boundary layer. These holes regulate the intermittent of shock waves with boundary layer for the total pressure loss by the compression effect. Over the holes the effect of compression having equal entropy. Although isentropically pressure increases the downstream suction because shockwave induced across the surface over the holes. The suction of the generated shockwave on the surface increases the boundary layer thickness along with the consecutive compression waves. The length of the boundary layer interaction with the porous surface increases as long as

the length of the porous surface that followed as the result of homogeneous pressure distribution for drag reduction.
The fluid dynamics for boundary layer shows the different medium of resistance in fluid. Interaction with the fluid and solid surface explain the noticeable resistance by the context of viscosity without slipping condition with the shear stresses at the surface. The shear stresses on the surface can be explained with the help of Newtons Friction law that basic theory showing by equation 1,

$$\tau = \tau(y = 0) = \mu \frac{du}{dy}|_{y=0} \quad (1)$$

And the sress valid upto the experiment targeted area as resistance force by equation 2,

$$\mathrm{F}_x = \int \tau_w ds = \mu \frac{du}{dy}|_{y=0} ds \quad (2)$$

A another research on blowing techniques by Eckert and rake [18] used and found the effective mass and conservation integral for the boundary layer with the cross velocity and define as following equation 3 for shear stress like,

$$\tau_w = (\tau_w)_0 - \rho_w \vartheta_w U_\infty \quad (3)$$

where w shows the wall condition, and *w υ* is for blowing external velocity. As per the equation the blowing techniques explained shear reduction hence the surface resistance decreases that resulted as drag reduction. Over the maximum range of Reynold number micro blowing shows its effect on skin friction. The process of drag reduction is very simple even though its can reach till minimum value [19].At 0^o drag coefficient decrease about 16% by using of BAL with nacelle lip-skin. The Same as 2^o angle of attack has approached about 18% but the minimum drag reduction on 4^o according to the results. The best result found at 2^o angle of attack as per the graphical presentation due to change of the effective incident relocation of the boundary layer of the fluid. If we consider the gap and steepness according to the graphs, came on conclusion the difference by using BAL and without BAL. This effective difference of drag at the exact location of the critical position stop following the surface through the surface at the moment of the flight stalled maneuver.

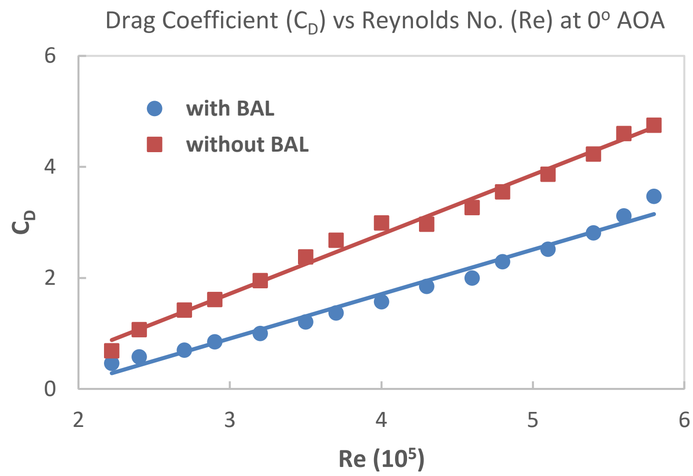

Figure 5: Drag coefficient at 0º AOA.

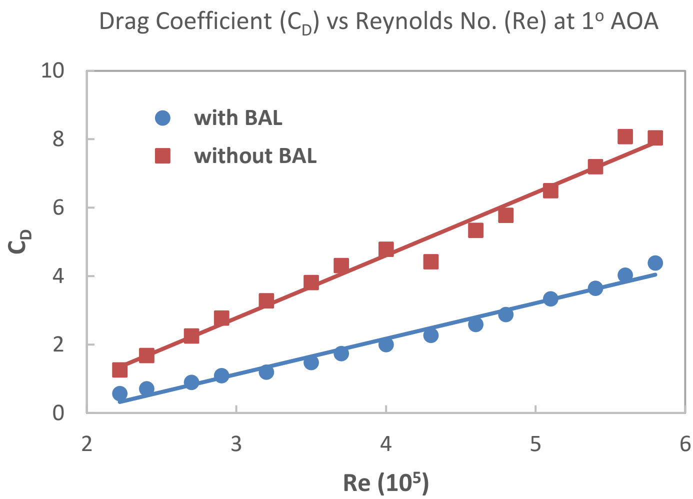

Figure 6: Drag coefficient at 1º AOA.

BAL properly effective with the fluid boundary thickness to control as an increment of the Reynolds number [20]. The effect of BAL shows the effective result also at 4º and 5º angle of attack as expected on the same pattern from fig. 5 to fig 10. This noticeable trend has been developed the affected of BAL for drag reduction on nacelle lip-skin.

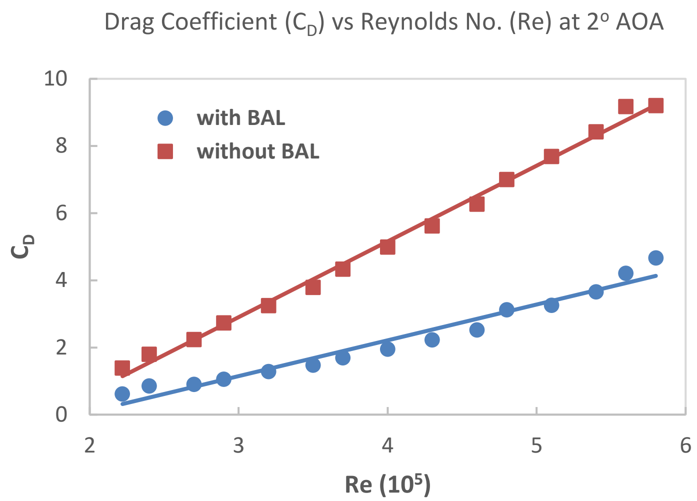

Figure 7: Drag coefficient at 2º AOA.

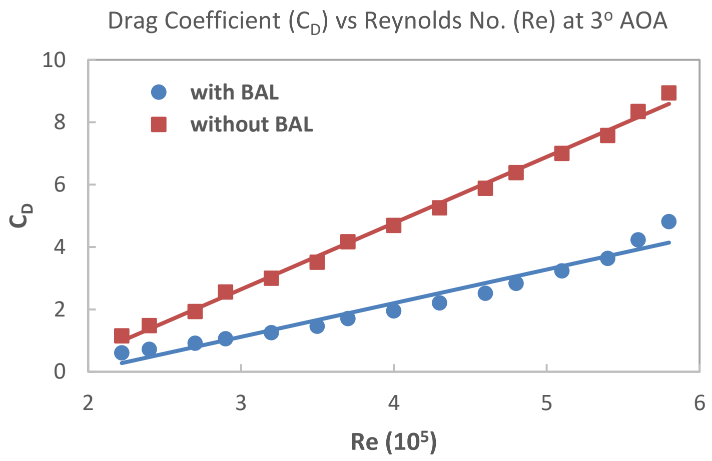

Figure 8: Drag coefficient at 3º AOA.

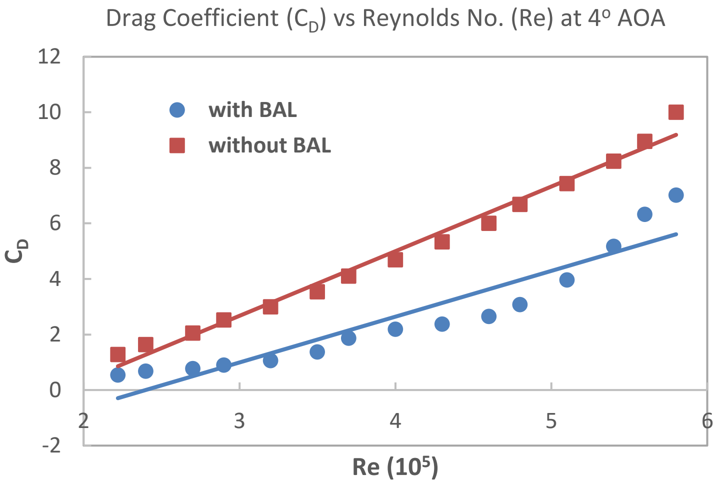

Figure 9: Drag coefficient at 4° AOA.

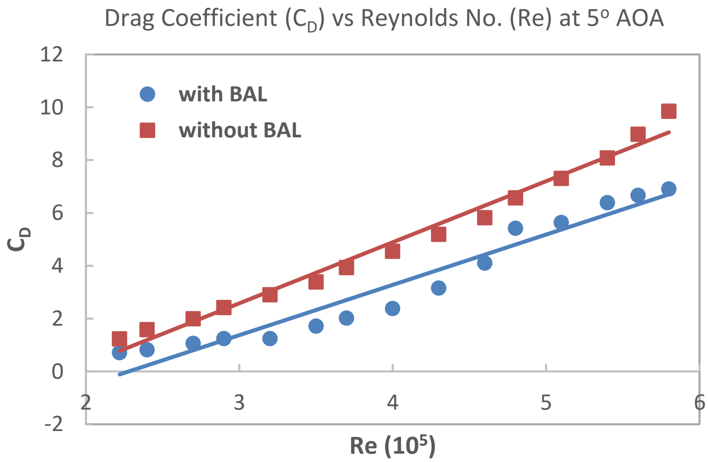

Figure 10: Drag coefficient at 5° AOA.

Conclusion

The drag coefficient calculation shows their relevant variation for the Reynolds number with increasing angle of attacks. These investigated data showed the slope of drag enhance the effect for the better performance of aircraft. According to the experimental values drag coefficient reduced by 22%. The effective performance by reducing drag happens at increasing angle of attacks by differences between using of BAL and without BAL system. The maximum drag reduction reached 2º angle of attack with the free stream velocity. In conclusion, BAL helps to enhance aerodynamic performance with the conventional design of the nacelle lip-skin.

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