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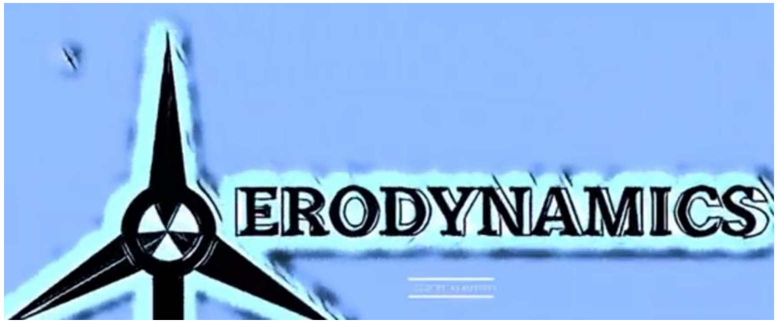


MEE1004-FLUID MECHANICS

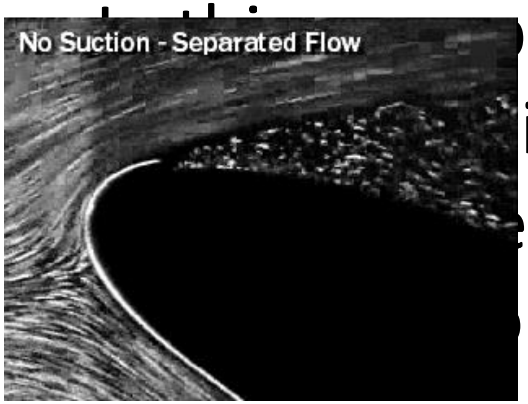
Module 7 - Boundary Layer Flow

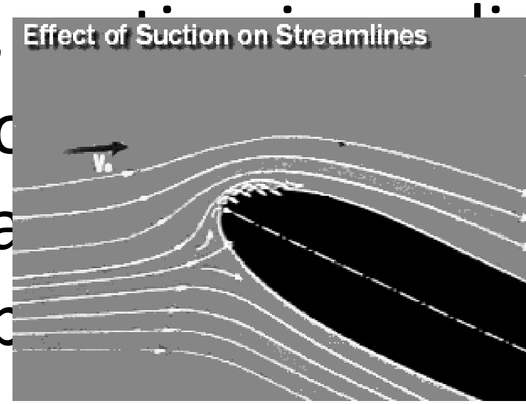
Methods of Flow control/Flow control devices

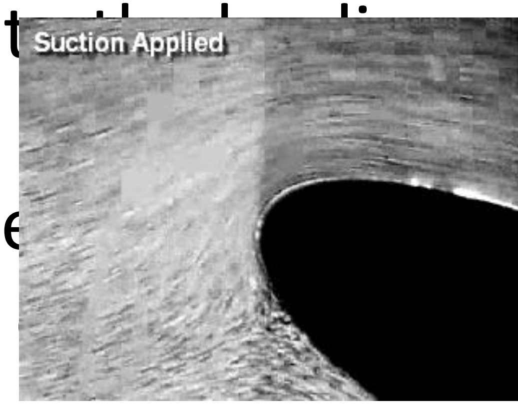
Vinayagamurthy G, Dr. Eng.,
Associate Professor
School of Mechanical and Building Sciences
VIT Chennai

Suction

- Just as flow separation can be understood in terms of the combined effects of viscosity and adverse pressure gradients, separated flows can be reattached by the application of a suitable modification to the boundary conditions.







Blowing

- Separation in external flows, such as the flow past a sudden expansion can be controlled not only by suction but also by blowing.
- In this video, the region of separated flow is eliminated by the introduction of high momentum fluid at a point near the separation point.
- This acts to eliminate the adv gradient by accelerating the f boundary, leading to re-attac

EXAMPLE 11–5 Lift and Drag of a Commercial Airplane

A commercial airplane has a total mass of 70,000 kg and a wing planform area of 150 m^2 (Fig. 11–54). The plane has a cruising speed of 558 km/h and a cruising altitude of 12,000 m, where the air density is 0.312 kg/m^3. The plane has double-slotted flaps for use during takeoff and landing, but it cruises with all flaps retracted. Assuming the lift and the drag characteristics of the wings can be approximated by NACA 23012 (Fig. 11–45), determine (*a*) the minimum safe speed for takeoff and landing with and without extending the flaps, (*b*) the angle of attack to cruise steadily at the cruising altitude, and (*c*) the power that needs to be supplied to provide enough thrust to overcome wing drag.

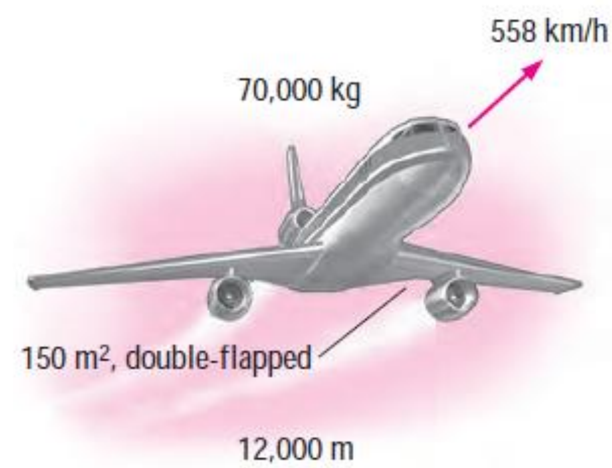


FIGURE 11–54
Schematic for Example 11–5.

Flow over an airfoil

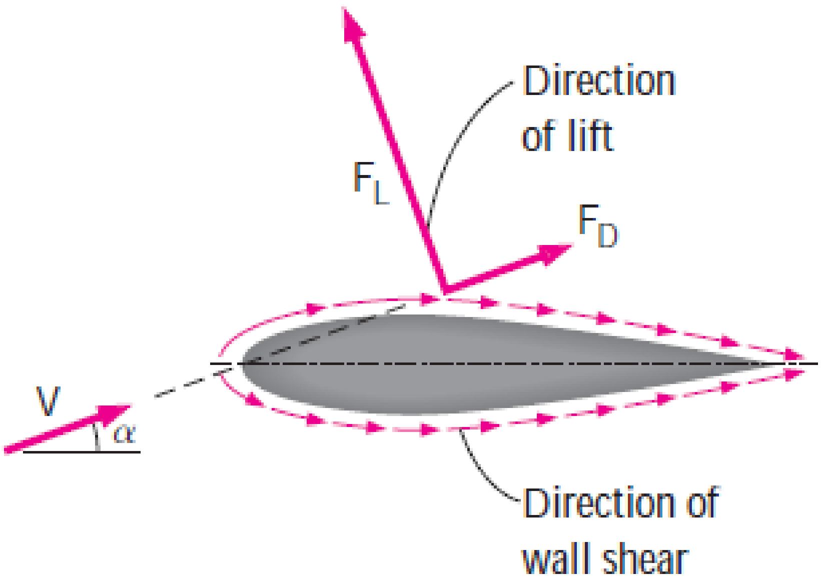
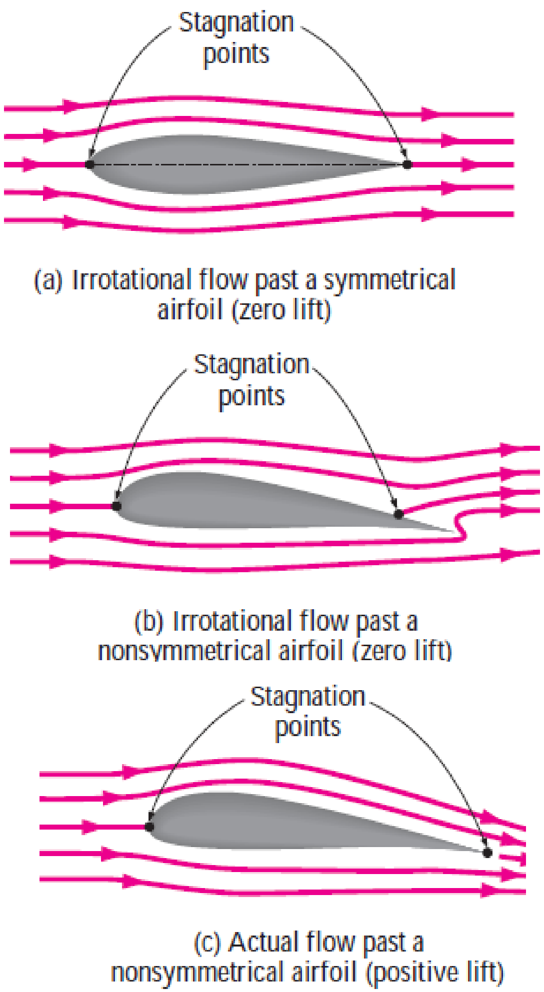
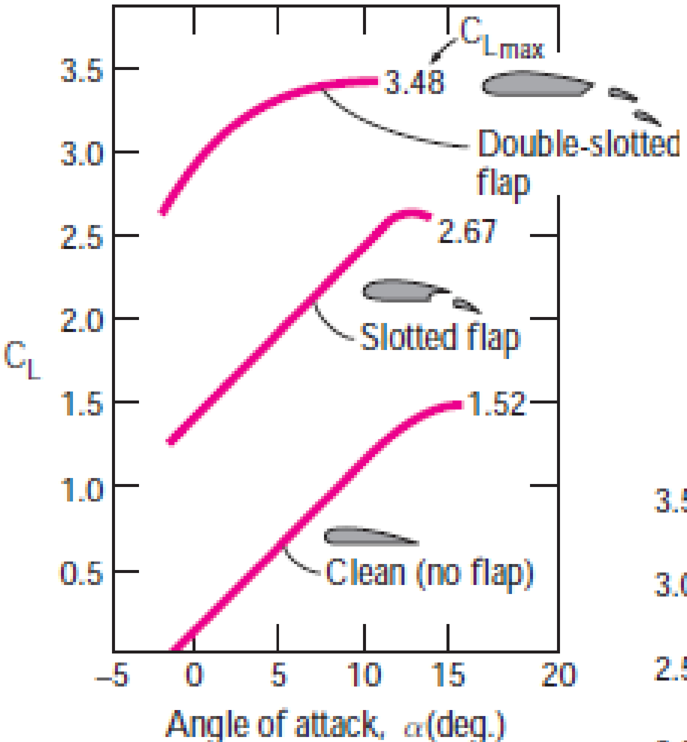


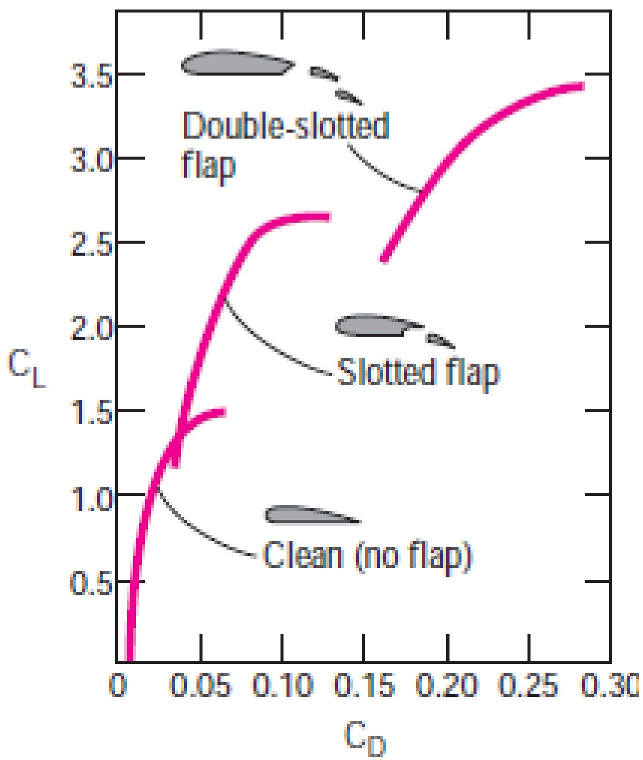
FIGURE 11–40
For airfoils, the contribution of viscous effects to lift is usually negligible since wall shear is parallel to the surfaces and thus nearly normal to the direction of lift.

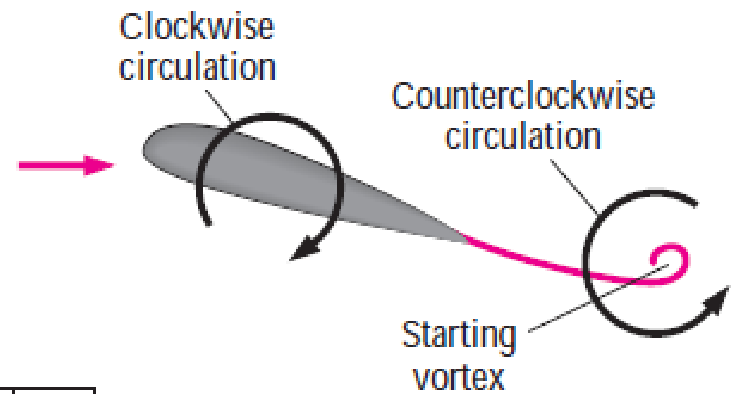


Recall the lecture taught in the lecture !

Methods to control - boundary layer separation







Shortly after a sudden increase in angle of attack, a counterclockwise starting vortex is shed from the airfoil, while clockwise circulation appears around the airfoil, causing lift to be generated.

Methods to control - boundary layer separation

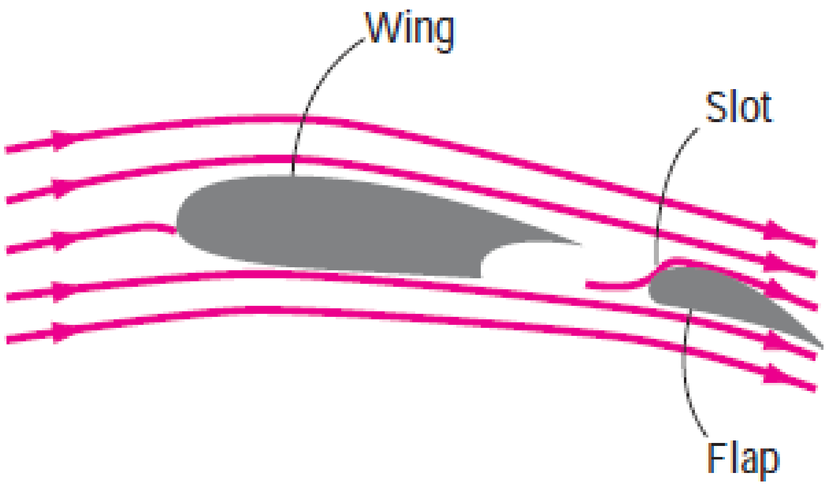


FIGURE 11–46
A flapped airfoil with a slot to prevent the separation of the boundary layer from the upper surface and to increase the lift coefficient.

The total drag on a body is attributed to form drag and skin friction drag. In some flow configurations, the contribution of form drag becomes significant.

In order **to reduce the form drag, the boundary layer separation** should be **prevented or delayed** so that **better pressure recovery takes place** and the form drag is reduced considerably. There are some popular methods for this purpose which are stated as follows.

1. By giving the profile of the body a streamlined shape (as shown in *Fig. 31.2*). This has an elongated shape in the rear part to reduce the magnitude of the pressure gradient. The optimum contour for a streamlined body is the one for which the wake zone is very narrow and the form drag is minimum.

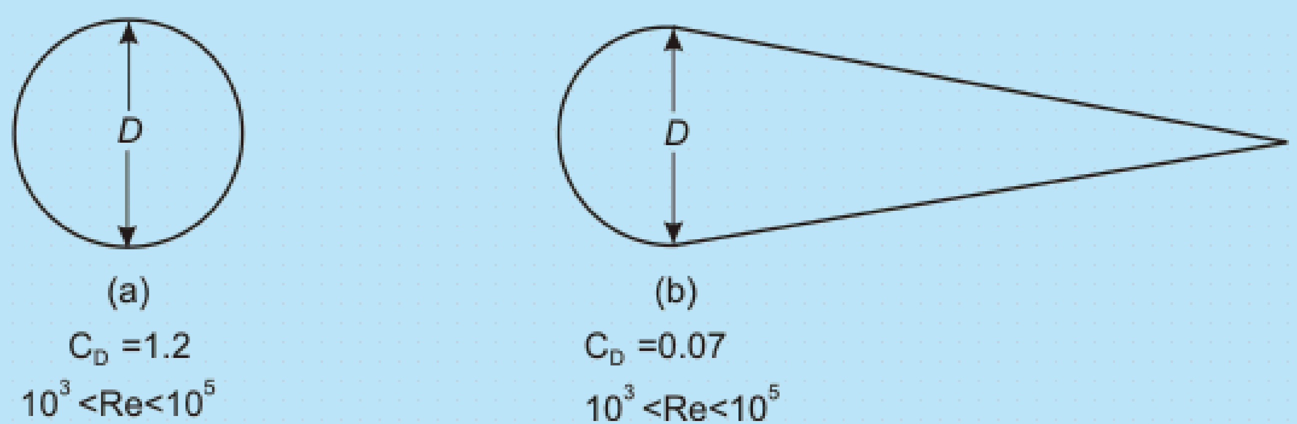
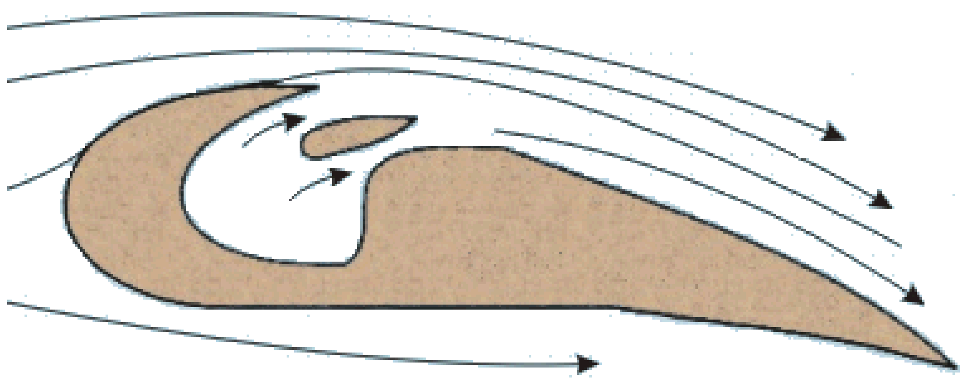


Fig. 31.2 Reduction of drag coefficient (C_D) by giving the profile a streamlined shape

2. The injection of fluid through porous wall can also control the boundary layer separation. This is generally accomplished by blowing high energy fluid particles tangentially from the location where separation would have taken place otherwise.

   I. The **injection of fluid promotes turbulence**
   II. This **increases skin friction.** But the **form drag is reduced** considerably due to suppression of flow separation.
   III. The reduction in form drag is quite significant and **increase in skin friction drag can be ignored.**



Boundary Layer Separation methods

Aerodynamic Flow Control :

Shifts flow separation regime by delaying separation point.
Improved lift and power characteristics.
Classified into Active and Passive flow control

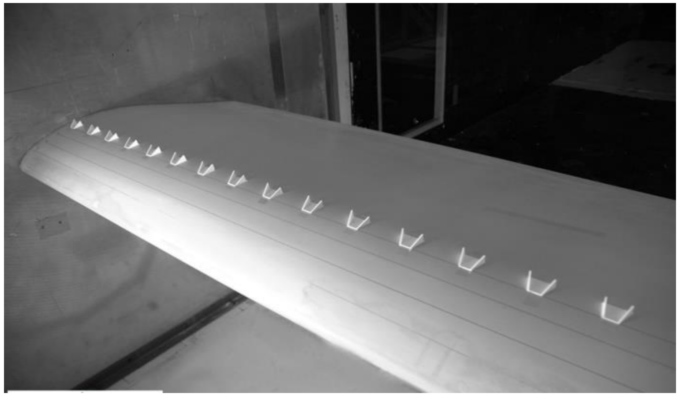


Fig:01 Vortex Generator in Car (Sedan) Fig:02 Vortex Generators in Wing section

Source: Karthik & Vinayagamurthy (NCWE 2016)

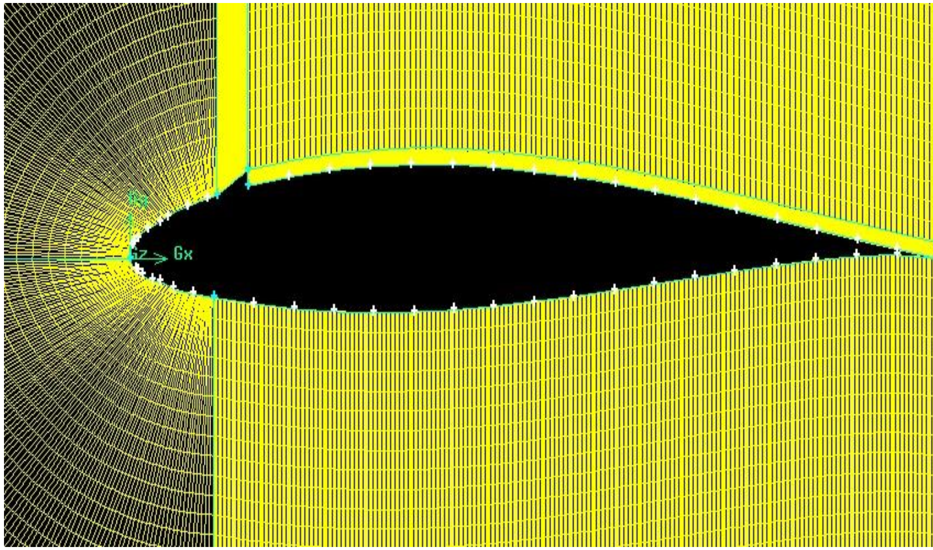


Fig: Meshing of Airfoil with Vortex generator

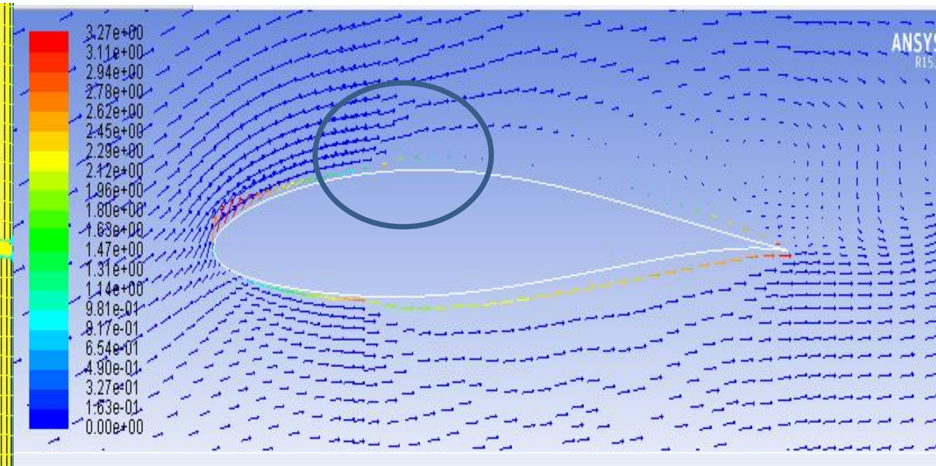
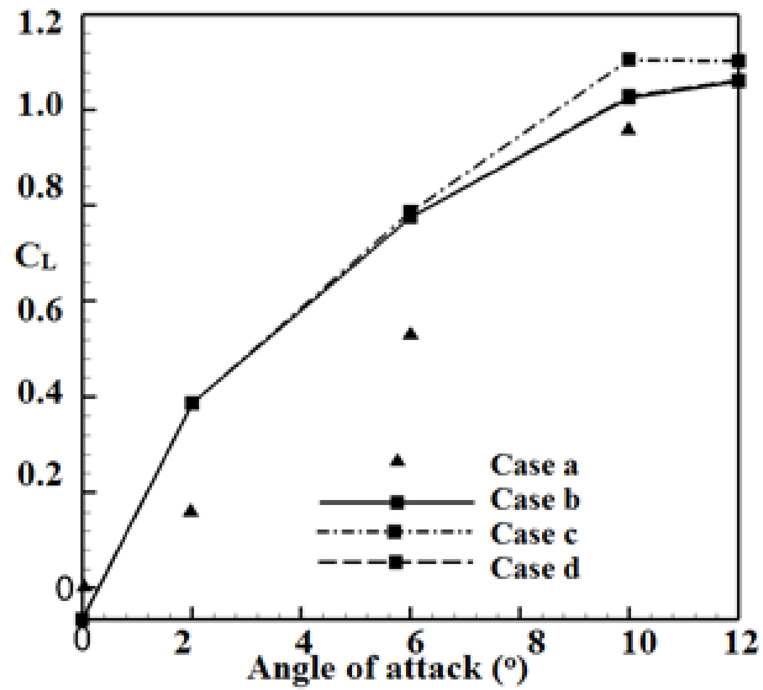


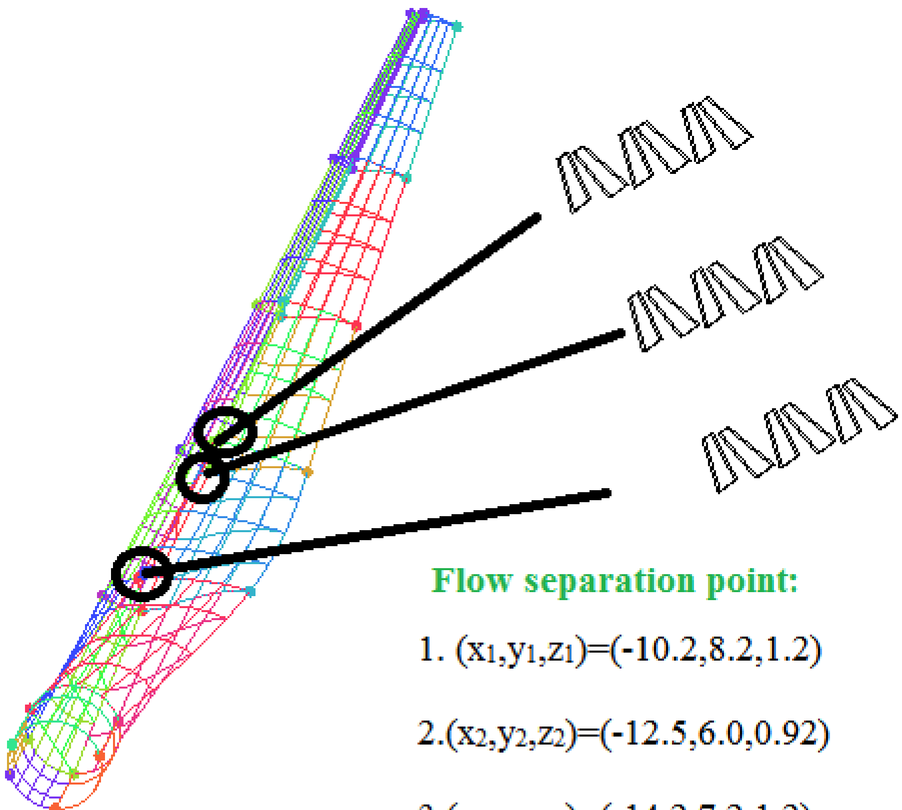
Fig: Wall shear contour of airfoil

Case	x/c	l/c	h/δ	C_L
A	**10%**	**1%**	**1**	**0.9**
B	**20%**	**2%**	**2**	**1.0**
C	**Separation Point**	**2%**	**1**	**1.1**
D	**30%**	**3%**	**3**	**1.0**



Source: Karthik & Vinayagamurthy (NCWE 2016)

VG DESIGN AND POSTION

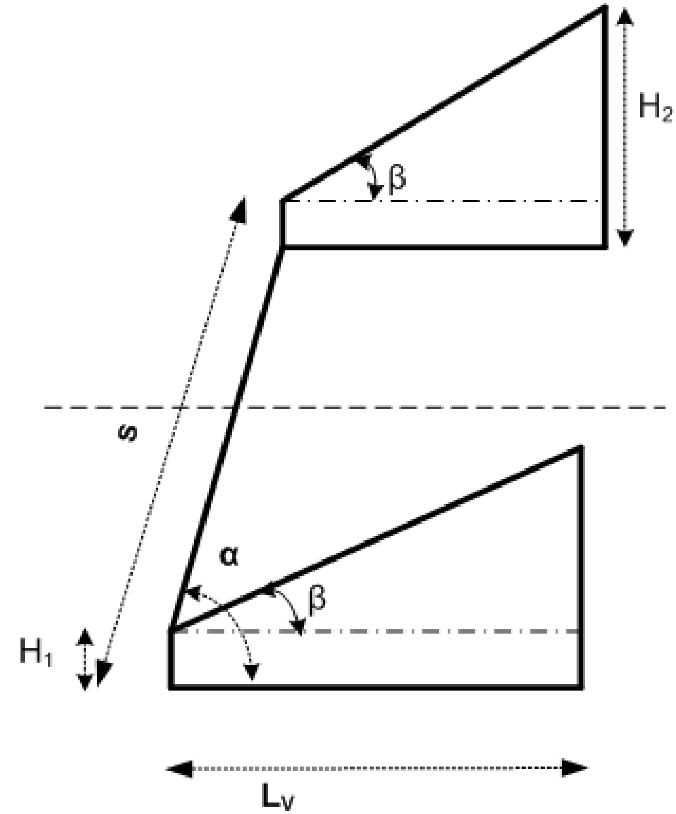


Flow separation point:

1. $(x_1,y_1,z_1)=(-10.2,8.2,1.2)$

2. $(x_2,y_2,z_2)=(-12.5,6.0,0.92)$

3. $(x_3,y_3,z_3)=(-14.2,7.2,1.2)$



1. H_{VG} = Boundary Layer thickness
2. L_{VG} = 1-2% of total length
3. S_{VG} = 50% L_{VG} = 5 mm

Source: Karthik & Vinayagamurthy (NCWE 2016)