Pressure forcearea research paper

Engineering, Aviation

ASSIGN BUSTER

Fundamentals

When a fluid flows over the surface of a body, pressure is exerted on the body. This pressure multiplied by the surface area results into a force, since pressure is defined as this resultant force is a vector quantity with both magnitude and direction. The component of this total force that is perpendicular to the direction of flow of the fluid is called the lift. The other component of this force that is parallel to the direction of flow of the fluid is called the drag. If the lift force is positive, the object is able to fly but if negative, the object cannot fly.

How Lift force is generated in an aerofoil

An aerofoil produces a lift much easier with less drag. To explain how this lift is produced, let us start with the Newton’s 2nd and 3rd laws of motion which respectively state that the rate of change of momentum of an object is equal to the force causing the change, and action and reaction are equal and opposite. Consider an aerofoil with airstreams around it in a wind tunnel, as shown below.

Observe the downward deflection and the curved airstreams

As the air passes the aerofoil, it is deflected downwards. According to the second law of motion, this downward deflection of air results from a downward force exerted by the aerofoil. The air also exerts an equal force in magnitude but in opposite direction to that of the aerofoil according to the third law. The result is the upward force or the lift force.

Considering pressure; it is obvious that the upper side of the aerofoil experiences less pressure as compared to the lower side. This is because; the air moves at much higher velocities on the upper aerofoil surface as compared to the lower surface. The pressure difference results into the lift force. The greater the pressure difference, the greater the lift force.

Mathematically, the lift force can be obtained by the integration of pressure. This lift force is given as the integral of the vertical pressure forces over the whole wetted surface area of the aerofoil.

The lift L is given by where:

p is the pressure,

n is the normal unit vector pointing into the aerofoil

k is the vertical unit vector, normal to the direction of the airstream

a is the surface area of the aerofoil

Effects of temperature, pressure and density on the generation of lift and drag as an aircraft gains altitude

From the above explanations and the equation, it is clear that both the lift force and the drag are directly proportional to the pressure difference. The greater the pressure difference, the greater the lift and the drag. The pressure exerted by a fluid depends on the temperature and the fluid density. Considering a fixed mass of a fluid, increase in temperature increases the volume and lowers the fluid density. This in turn lowers the pressure exerted by the fluid on the aircraft and results into lower lift and drag.

As the aircraft gains altitude, the air temperature falls. This leads to a fall in the pressure difference and both the lift and drag fall.

The density of air also falls with an increase in the altitude. Since pressure is directly proportional to the density, there is a fall in the pressure difference resulting into a decrease in both the lift and the drag.

Further Research

a) Below are the aircraft power curve and the drag polar.

At constant speed, Thrust (T) is equivalent to drag (D) in a level flight. The drag polar (lower chart) reveals the thrust needed to overcome the drag so as to maintain a given velocity.

Power is the product of thrust and velocity (TV). The power required curve (upper chart), is derived by multiplying each point on the thrust required chart by the corresponding velocity. This reveals the power required so as to maintain a given velocity.

b) The curve below summarises the variation of drag and the airspeed

Parasite drag will always be present on a moving body. It results from form drag and the resistance of skin friction. Form drag is as a result of the interference with the streamline flow.

Shape highly affects the Parasite drag. When an object is more streamlined, the parasite drag reduces. The reverse is also true.

c) Induced drag is a drag force that results when an object in motion redirects the flow of air coming towards it. It is as a result of the lift. Considering a level flight, the wing properties produce the required lift.

However, this can only be obtained at some penalty. This penalty is the induced drag. Whenever a lift is produced, the induced drag must also be present.

When the aeroplane in the above figure is viewed from the tail, the vortices circulate in a CCW about the right wingtip and in CW about the other. An upward air flow is induced beyond the wingtip and a downwash one behind the trailing edge, which is the source of the induced drag. The induced drag has an effect that is similar to bending the lift vector backwards.

d) A supersonic wind tunnel derives its name from the speed it produces. It is described as a wind tunnel which produces supersonic speeds in the range of 1. 2

In its operation, the Reynolds number is varied. This in turn changes the density level (the settling chamber pressure). As a result of this, a high pressure ratio must be availed. Other than that, liquefaction or condensation can occur. This necessitates a pre-heating or a drying facility. Due to its high power demand, it has intermittent operation. Its working area is so small so as to maximise the pressure.

As the technology advances, designers aim at making aircrafts with perfectly smooth surfaces. This however, is not possible. The aim of this is to reduce the wave drag. Also, the aerodynamic shape of the planes is required to change as smoothly as possible in cross-sectional area.

The area rule stipulates that an aeroplane must be carefully designed such that the larger volumes like the wings get positioned at the widest area of the equivalent Sears-Haack body. It also requires that the bumps which include tailplane, cockpit and the intakes be spread along the fuselage. There is also a requirement that the fuselage be thinned.

References

1. Anderson, John D. Jr., Introduction to Flight, 3rd edition, McGraw-Hill Book Company, New York, 1989.

2. Carson, B. H., " Fuel Efficiency of Small Aircraft," AIAA Paper AIAA-80-1847.