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Research Article

AERODYNAMIC STUDY OF FLAT SURFACES

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ABSTRACT

An aerodynamic study of flat surfaces has been done in the present study. The study related to the application of flat surfaces at low Reynolds number in the field of Aerodynamics and Aeronautics. The most important parameters which decided the aerodynamic behavior of the objects are the angle of attack, Reynolds number and geometry of the object. The study could extend to a flat surface with different geometry at low Reynolds number.

INTRODUCTION

Aerodynamics is a branch of fluid dynamics, or a detailed study of the flow of air past over the objects. Aerodynamics problems mainly depends upon the environmental conditions along with properties of flow like flow speed, compressibility, and viscosity. External Aerodynamics is the study of flow around solid objects of different shapes and size. Evaluating the lift and drag forces on an airplane or the shock waves that form in front of nose of a rocket are some of the examples of external aerodynamics. Internal aerodynamics is the study of flow through passages in solid objects like air flows through conditioning pipe or air flow in jet engine. In 1726, Sir Isaac Newton developed a theory over air resistance and became the first aerodynamicist of the modern world with his famous publication Principia. In the time period18th and 19th centuries, more air resistance experiments were performed by investigators. In 1871, first wind tunnel was constructed by Francis Herbert Wenham. In 1738, Daniel Bernoulli described a fundamental relationship between pressure, velocity and density in his publication, today it is better known as Bernoulli's principle, which provides one of the methods to calculating lift force. Bernoulli described the relationship which was found to be valid only for incompressible, inviscid flow, but later on, Leonhard Euler extended Bernoulli's equation to the compressible flow regime and publish Euler equations. In the early 19th century the Navier - Stokes equations extended the Euler equations taking viscous effects. In 1799, George Cayley became the first person to identify the four fundamental forces of flight which are - lift, thrust, drag and weight as well as the relationship between them. On 17 December 1903, Wilbur and Orville Wright flew the first successful powered aircraft. By this achievement and publicity received, led to more organized collaboration between aviators and aerodynamicists, leading the way to modern aerodynamics. Investigators also made specific additions to study cambered airfoil like those on World War I aircraft and published a simplified thin airfoil theory for these designs. Aerodynamic force is commonly resolved into two components Drag and Lift.

Terminology of Flat Plate

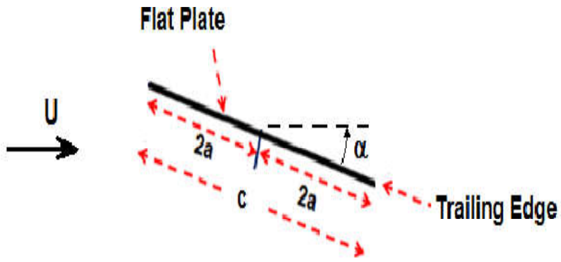

Fig Terminology of flat plate

Leading edge – It is the starting point of the flat plate, where flowing fluid firstly touches the flat plate.

Trailing edge – It is the point at the rear side of flat plate.
Chord line – It is the straight line which joining the front and rear points of flat plate.

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Chord length – It is the length of straight line which joins front and rear points of flat plate. It is denoted by 'c'.

Angle of attack- It is the angle between the chord line of flat plate and the direction of the free stream of air.

LITERATURE SURVEY

Chauhan and Singh -have done their experimental investigation on a flat plate. The experiment was done under different flow condition and the plate is changed from horizontal to inclined positions to 20°, 40° and 60° with the horizontal. In the experiment they evaluate the drag and lift coefficients at different positions. In his experiment, it investigates that the position of flat plate has large effect on Drag and Lift forces. In experiment it was concluded that the static pressure changes entire with his length of plate which is not constant over its entire length and the drag force changes apparently as increases its angle from horizontal whereas velocity increases from leading edge to trailing edge of the plate.

Chougule et al. - was investigated the multi air jet impingement on a flat plate both experimentally and numerically. They use shear stress transport (SST) k-w turbulence model, taking various parameters like effects of jet Reynolds number (R_e), target spacing to jet diameter ratio (Z/d) on average nusselt number (N_{ua}) of target plate. Jet impingement is one of the best cooling methods to cool hot objects. In his experiment they found Nusselt number increases from 40 to 50.1 by increasing Reynolds number from 7000 to 11000 at Z/d = 6. By increasing Z/d ratio from 6 to10, N_A decreases from 50.1 to36.41 at R_e 11000. It is also observed that in multi-jet impingement, the spacing between the air jets play an important role.

Prater and Lian. - has been examined flight characteristics of a flat plate in low Reynolds number flow with gusting conditions. The aerodynamic forces are calculated by solving the incompressible Navier-Stokes equation on an overlapping grid using pressure- Poisson method. The impact of reduced frequency on the phase between oscillating free stream and lift, time averaged lift and lift oscillation amplitude are discussed in detail. In this experiment they conclude that the time averaged lift increases with reduced frequency but at high frequencies, lift does not follow the free stream velocity variation. They also analyzed that there is reduced frequency dependence for the average lift force and the amplitude.

Cao et al. - have investigated the wind loads on solar panels on flat roofs, focusing on their area-averaged characteristics such as mean and negative peak force coefficients and peak factors. Some parameters are considered in his experiment including panel position, tilt angle and distance between arrays. Mean and peak force coefficient and peak factors were investigating through wind tunnel experiments. In his experiment they conclude that effective area decreases mean and peak force coefficient while it does not affect peak factors. Panel wind loads increase with increase in tilt angle and array distance increase wind loads on panels located in the inner region, but not for those at the array boundary.

Ortiz et al. - has investigate wind loads on photovoltaic structures and to study, starting flow on low aspect ratio wind turbine blades, a series of wind tunnel were undertaken. They use thin flat plates of aspect ratios between 0.4 and 9. The Reynolds number varied 6×10^4 to 2×10^5. The measurements were taken at 0° to 90° of angle of attacks both in free stream and in wall proximity with increase turbulence and mean shear. In his experiment they conclude that, the ratio of drag to lift is approximately equal to the tangent of incidence angle, showing that these forces result from the pressure, rather than the shear stress acting on thin plates.

Ortiz et al. -has carried out an investigation to determine extreme wind loads on photovoltaic structures mounted on flat roofs at the high angles required in high altitudes. His experiment was carried out in an environmental wind tunnel at university of Calgary. His measurements are taken at eleven different angles of attack, α (0°,25°,35°,40°,45°,50°,55°,60°,70°,80°,90°) and five different clearances between the model and the wind tunnel floor. His experiment investigates the forces on thin rectangular plate over a wide range of aspect ratios, angle of attack and distance from the wind tunnel floor. In experiment it conclude that at free stream an increase in aspect ratio increased the low frequency contribution to the instantaneous drag and simplified the spectra and as the wind tunnel floor is approached, the high frequency fluctuation reduce significantly.

Sun and Boyd has investigated air flows over a flat plate at zero incidences a function of the Reynolds number Re and the Mach number M under subsonic, low-Reynolds-number conditions. Good agreement is obtained between the DSMC and IP results and between the IP results and available experimental data because the flows are simulated using the direct simulation Monte Carlo (DSMC) method and the information preservation (IP) method that is a modified DSMC method developed for low-speed rarefied gas flows. The simulations predict that the drag coefficient on the flat plate depends on the Reynolds number and the Mach number, and both the rarefied and compressible effects on the drag coefficient increase when the flow Reynolds number decreases. It is found that the normalized drag$CD \cdot M$ depends on $\sqrt{(Re)}/M0.8$ when this parameter varies between 1 and 100, which suggests a scaling law for engineering analysis.

CONCLUSION

After study and analysis of these research papers it is concluded that the application of flat surfaces at low Reynolds number are commonly used in our practical life and these studies still wants the investigation to enhance the aerodynamic performance of the objects. Nowadays both software and experimental methods are used for the analysis of objects.

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