Computational Race Car Aerodynamics

Description of Specific Steps

(Design of experiment) SolidWorks, a three dimensional computational fluid diagram simulation software tool, will be used to understand drag and lift forces on a race car through geometric modelling of an air foil by importing coordinates.

(Factors likely to influence results) Drag and lift can vary significantly based on the angle of attack, boundary layer and whether the subject airfoil is symmetric or cambered. Thickness, surface roughness, Reynolds number, occurrence on stall and impact of camber line geometry frequently exert a notable influence on outcomes as well.

(Precision in measurements, materials used, procedure) To first import a basic airfoil structure in SolidWorks, coordinates were pasted into Microsoft Excel and formatted through use of ‘Text to Columns’ feature. As a result, the first 3 columns in the spreadsheet represented the x, y and z axis respectively. The z-axis column was populated with zeros. This dataset included coordinates for the trailing edge point, upper and lower portions of the airfoil profile, and the leading edge saved in a ‘text tab-delimited’ file format. To progress forward, a new part in solid works was opened and through the insert tab’s ‘Curve Through XYZ Points’ option, the saved file was imported. A chord line was drawn along the shape for future reference. ‘Extrude surface’ was used by selecting the front plane and applying ‘Convert Entities’. ‘Smart Dimensions’ was utilized from the point on chord line near the leading edge to the trailing edge and depth was defined.

Previously mentioned factors were used as independent variables to draw conclusions for the study.

For a high lift application, highly cambered airfoils were be used

For a low drag application, less cambered and possibly thinner airfoils were selected

(Way the data is analyzed). When discussing the lift of an airfoil, it was essential to analyze effect of angle of attack due to its significant impact on measurement accuracy. Larger angles of attack could cause flow separation, leading to stall and no further lift increase. Furthermore, changing the geometry of the camber line will affect lift of the airfoil, with the trailing edge exerting the most influence. This alteration can occur independently of adjustments of the angle of attack. (Katz, 1995). Slightly increasing thickness was used to see the enhancing of the lift slope. Drag analysis required precision, especially regarding the viscous boundary layer. Thickening of the boundary fluid was used to check for increased drag. The flow was let advance over the surface and velocities escalated (yielding higher Reynolds numbers), to see the transition to a turbulent boundary layer and its effect on viscous drag. Surface roughness and increased thickness/camber was used to check for drag too. Higher angles of attack were used to induce thicker boundary layers and increased drag. Higher Reynolds numbers were checked so see if they improved airfoil performance by reducing boundary layer thickness and drag coefficient.

NOTES CH4

Design of Experiment:

To understand drag and lift forces on a race car a study was conducted using SolidWorks through which a geometric modelling of an air foil was done using a three dimensional computational fluid dynamic simulation software tool.

Shape of an airfoil’s pressure distribution can be altered by varying the angle of attack and the camberline shape (the shape of the thickness distribution is important too)

Symmetric airfoil and cambered airfoil

Factors influencing results:

Lift is directly proportional to the angle of incidence and the multiplier is 2pi

Airfoil’s camber doesn’t change the lift slope and can be viewed as an additional angle-of-attack a

Cl= lift coefficient per unit width

Symmetric airfoil will have zero lift at a=0

Cambered airfoil will have life of Cl=2pi.angle of attack effect at zero angle of effect

Trailing edge of a camberline has largest effect on airfoil’s lift, hence lift can be changed by changing camberline geometry without changing a

Larger angles of attack, flow separation, wing stalls and no additional lift is gained

When airfoil is very thin or leading edge is too sharp, stall is abrupt: leading edge separation

For thicker airfoils with large camber, it is gradual and develops at trailing edge: trailing edge separation

Increasing thickness slightly increases lift slope

For larger angles of attack, thicker airfoils can have a larger maximum lift coefficient and a delayed stall

Drag is caused by viscous boundary layer

Thicker the boundary layer, the more fluid is slowed down and larger the drag

Undisturbed flow will initiate a laminar boundary layer at the airfoil’s leading edge but with increasing distance on surface or due to higher speeds (higher Reynolds number), a transition to turbulent boundary layer will take place

Earlier transition from laminar to turbulent causes larger turbulent friction regions, resulting in more viscous drag

Surface roughness will increase friction coefficient and promote boundary layer transition

On smooth surface friction drag is smaller and transition is delayed

Increase in thickness and camber increases boundary layer thickness on upper side hence increase in drag

At larger angles of attack, sharp turns of streamlines near the leading edge cause a thicker boundary layer resulting in more drag remains

If flow of airfoil is partially separated due to large camber or high angles of attack then form drag will result

Separated flow drag is usually much larger than friction drag and is accompanied by loss of lift

At lower angles of attack the boundary layer is thinnest and drag lowest

With increased angle of attack boundary layer becomes thicker and drag increases

Near max lift usually trailing edge separation exists and this form drag sharply increases section drag

With higher reynold’s numbers airfoil performance improves and boundary layer thickness and friction coefficient and drag coefficient usually decrease

For a high lift application, highly cambered airfoils will be used

For a low drag application, less cambered and possibly thinner airfoils will be selected