

## **DECLARATION**

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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## **ABSTRACT**

Airfoils have become a combined aspect of human flight as it has evolved over the last century. As the design of each airfoil determines many aspects of its use in the real world, all significant characteristics must be analyzed prior to implementation. The aerodynamic effects of pressure, drag, lift, and pitching moment were used to evaluate the behavior of the airfoil. In this work, pressure distribution and velocity distribution were recorded over the upper and lower surfaces of the airfoil and compared to theoretical values created by Aerofoil, a computer simulation package.

The airfoil shape is expressed analytically as a function of some design parameters. The NACA 4 digits are used with design parameters that control the camber and the thickness of the airfoil.

The work had been performed using symmetrical and nonsymmetrical airfoils. A NACA 0012 symmetrical airfoil with a 12% thickness to a chord ratio was analyzed to determine the lift, drag forces. A NACA 2412, NACA 4415 and NACA 9608 are nonsymmetrical airfoils. NACA 2412 airfoil have a maximum thickness of 12% with a camber of 2% located 40% back from the airfoil leading edge. NACA 4415 airfoil has a maximum thickness of 15% with a camber of 4% located 40% back from the airfoil leading edge. NACA 9608 airfoil has a maximum thickness of 8% with a camber of 9% located 60% back from the airfoil leading edge. All calculations were taken at a velocity 4 m/s.

The purpose of this work was to determine the velocity distribution, pressure coefficient, lift and drag characteristics of airfoils.

**Keyword:** Airfoils, pressure distribution, velocity distribution, lift, drag

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## LIST OF SYMBOLS USED

### FLOW QUANTITY

$\rho$	density of air
$P_\infty$	pressure in the free stream
$P_L$	Pressure lower airfoil surface
$P_u$	Pressure upper airfoil surface
$U_\infty$	Free stream velocity
$u_\infty$	Free stream velocity in x-direction
$u$	velocity distribution on the plate
$u(x, z)$	the velocity components in the rectangular coordinate in x-axis
$v_\infty$	Free stream velocity in y-direction
$w_\infty$	Free stream velocity in z-direction
$W_\infty$	relative velocity of the airflow
$w(x, z)$	the velocity components in the rectangular coordinate in z-axis
$\Delta W$	velocities on the upper and lower surfaces of the airfoil
$q_\infty$	dynamic pressure of undisturbed flow
$\Gamma$	circulation
$k$	vortex density (vortex strength per unit length) or the circulation distribution

### GEOMETRIC QUANTITY

$A$	area of the airfoil
$A_p$	plan form area
$a$	Radius of circular cylinder
$b$	wingspan or is the distance from one wingtip to the other wingtip of the airplane
$c$	chord length
$h$	Profile chamber
$h/c$	relative camber (camber ratio)

$r_N$	Nose radius
$r_N/c$	relative nose radius
$t$	maximum thickness
$t/c$	relative thickness (thickness ratio)
$x$	position along the chord from 0 to $c$
$x_L$	$x$ coordinate of the lower airfoil surface
$x_h$	Maximum camber position
$x_h/c$	relative camber position
$x_u$	$x$ coordinate of the upper airfoil surface
$x_t$	Maximum thickness position
$x_t/c$	relative thickness position
$z$	Rectangular coordinate: $z$ =vertical axis
$z_L$	$z$ coordinate of the lower airfoil surface
$z_u$	$z$ coordinate of the upper airfoil surface
$Z^s$	Mean camber line coordinate
$Z^t$	Teardrop profile coordinate

#### **AERODYNAMIC QUANTITY**

$\zeta$	Joukowski transformation function
$\alpha$	angle of attack
$2\tau$	trailing edge angle
$F(z)$	complex stream function of the flow
$\bar{w}(z)$	Stream function
$A_0$	Fourier series coefficient
$A_1$	Fourier series coefficient
$A_n$	Fourier series coefficient
$ar$	aspect ratio
$C$	is constant obtained by the integration of mean camber line
$D$	drag force
$h_0$	Fourier series coefficient
$h_1$	Fourier series coefficient

$k_1$	is first standard distribution of the circulation
$k_{11}$	is the first normal distribution of the circulation
$L$	lifting force
$M_a$	pitching moment about a point distance $a$ from the leading edge
$M_{AC}$	pitching moment of the aerodynamic centre
$M_{LE}$	pitching moment about the leading edge
$M_x$	pitching moment about a different point, distance $x$ behind the leading edge
$X$	the location of the vortex element producing the velocity
$X_0$	the location where induced velocity is produced
$x_{AC}$	position of the aerodynamic centre be a distance $x$ behind the leading edge
$x'$	Location of vortex strength at any point on chord
$C_D$	drag Coefficient
$C_{D,0}$	drag coefficient at zero lift
$C_{D,i}$	induced drag
$C_L$	lift Coefficient
$C_{Ma}$	pitching moment coefficient about a point distance $a$ from the leading edge
$C_{MAC}$	pitching moment coefficient of the aerodynamic centre
$C_{MLE}$	pitching moment coefficient about the leading edge
$C_{MX}$	pitching moment coefficient about a different point, distance $x$ behind the leading edge
$C_p$	pressure coefficient
$C_{pl}$	pressure coefficients on the lower surface
$C_{pu}$	pressure coefficients on the upper surface
$C_X$	force coefficients in the $X$ directions
$C_Z$	force coefficients in the $Z$ directions
$K_{CP}$	Fraction of the centre of pressure