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EFFECT OF TRAILING EDGE ROUNDNESS ON FX 63-137 AND SELIG S1223 AIRFOIL

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ABSTRACT

Wortmann FX 63-137 and Selig S1223 are high lift low Reynolds Number Airfoils which have widespread applications in heavy lift cargo planes and student projects like FSAE. The trailing edge is often given a radius for the ease of manufacturing and safety. This paper studies the variation in lift coefficients, drag coefficients and aerodynamic efficiency because of the amendments in the trailing edge radii of these two airfoils, ranging from 0.25% to 1.5% of the chord length.

Keywords: airfoil, trailing edge radius, high Lift, Selig S1223, wortmann FX 63-137, chord, computational fluid dynamics.

1. INTRODUCTION

High lift airfoils like Wortmann FX 63-137 and Selig S1223 [1] are two of the very popular airfoils for the low Reynolds number regime in which high lift cargo planes, unmanned aerial vehicles (UAVs) and vehicles of student projects like FSAE operate. The airfoils have a sharp trailing edge which is a concern of safety when used in ground vehicles. Also, manufacturing of a wing which has a sharp trailing edge complicates the process of manufacturing. Since the generation of lift by an airfoil is a property of its shape, an alteration in trailing edge will affect the forces generated by it and thereby affecting the force coefficients and aerodynamic efficiency. Considering the student projects like FSAE, incorporation of aerodynamic devices like wings on the vehicle is desirable for generation of maximum downforce with lesser increase in drag.

2. AIRFOIL PERFORMANCE PARAMETERS

2.1 Coefficient of lift

The Coefficient of Lift is a dimensionless coefficient which relates the lift generated by a body to the fluid density, velocity and an associated reference area.

$$C_l = \frac{L \times 2}{\rho \times v^2 \times S}$$

Where,

C_l = Coefficient of Lift
ρ = Density of fluid
v = Velocity of fluid
S = Reference area
L = Lift generated

2.2 Coefficient of drag

The Coefficient of Drag is a dimensionless coefficient which relates the drag generated by a body to the fluid density, velocity and an associated reference area.

$$C_d = \frac{L \times 2}{\rho \times v^2 \times S}$$

Where,

C_d = Coefficient of Lift
ρ = Density of fluid
v = Velocity of fluid
S = Reference area
D = Drag

2.3 Aerodynamic efficiency

Aerodynamic efficiency is a measure that assesses a design to generate aerodynamic forces for efficient flight parameters; this can also be applied to the ground vehicles where it describes the relationship between the dowbforce a car generates and the drag associated with it. The most common measure of aerodynamic efficiency is the lift/drag ratio.

$$Aerodynamic\ efficiency\ (E) = \frac{C_l}{C_d}$$

3. FLOW MODEL

Since one cannot 'perfectly' represent the effects of turbulence in Computational Fluid Dynamics simulations, we need a turbulence model for the same. The model used for the simulation is standard K-Epsilon Model (k-ε). The SKE model is the most widely used turbulence model for such applications. The k-epsilon model solves for two variables: k, the turbulent kinetic energy, and epsilon (ε), the rate of dissipation of kinetic energy.

$$k_t = \alpha\left(\frac{k^2}{\varepsilon}k_x\right)_x - \varepsilon$$

$$\varepsilon_t = \beta\left(\frac{k^2}{\varepsilon}\varepsilon_x\right)_x - \gamma\frac{\varepsilon^2}{k}$$

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Here, α, β and γ are positive constants.

Wall functions are used in this model, so the flow in the buffer region is not simulated. The k-epsilon model is very popular for industrial applications due to its good convergence rate and relatively low memory requirements. It does not very accurately compute flow fields that exhibit adverse pressure gradients, strong curvature to the flow, or jet flow. It does perform well for external flow problems around complex geometries like the airfoils presented in this paper. The SKE is robust and reasonably accurate for wide range of applications.

4. COMPUTATIONAL METHODOLOGY

The free stream temperature (T), viscosity (μ) and density (ρ) considered for the computation are 300K, (1.7894 X 10^{-5}) kg/ms and 1.225 kg/m^3 respectively. The free stream velocity is taken as 17 m/s. At this velocity, it is purely evident that the flow is incompressible. The average velocity on FSAE tracks generally range from 55-60 kmph and hence, this velocity was selected. The energy equation was turned on for all the computations. 2-D simulations were carried out for both Wortmann FX 63-137 and Selig S1223, providing the trailing edge radii in steps of 0.25% in the range 0% - 1.5% of the initial original chord of 1m. A proper C-Domain was used for the simulations in Ansys Fluent Module. Unstructured mesh around the airfoils was generated along with inflation on the airfoil surface.

5. RESULTS

5.1 WORTMANN FX 63-137

Table-1. Aerodynamic characteristics of Wortmann FX 63 - 137 airfoil at different trailing edge radii.

Trailing Edge Radius (% chord)	Coefficient of Lift (Cl)	Coefficient of Drag (Cd)	Aerodynamic Efficiency (E)
0.00	0.6991	0.01533	45.5823
0.25	0.5951	0.01560	38.1288
0.50	0.4739	0.01580	29.9766
0.75	0.3944	0.01591	24.7853
1.00	0.3296	0.01622	20.3067
1.25	0.2768	0.01673	16.5358
1.50	0.2307	0.01715	13.4525

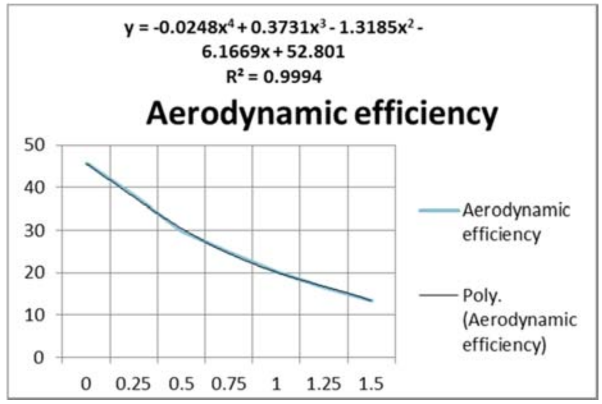

Figure-1. Plot of aerodynamic efficiency versus TE radius (% chord).

The aerodynamic efficiency of an airfoil is the ratio of its coefficient of lift to coefficient of drag. Firstly, taking Wortmann FX 63-137 airfoil into consideration. From the Figure-1. and Figure-2, it can be clearly perceived that the

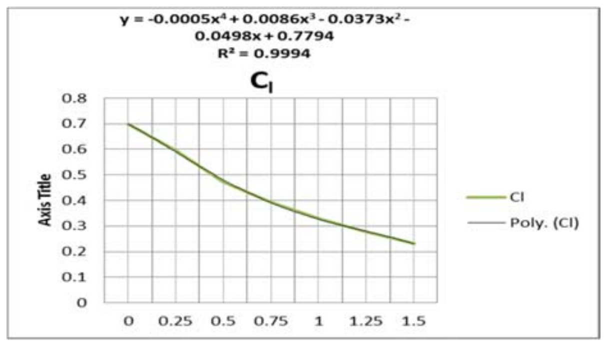

Figure-2. Plot of C_l versus TE radius (% chord).

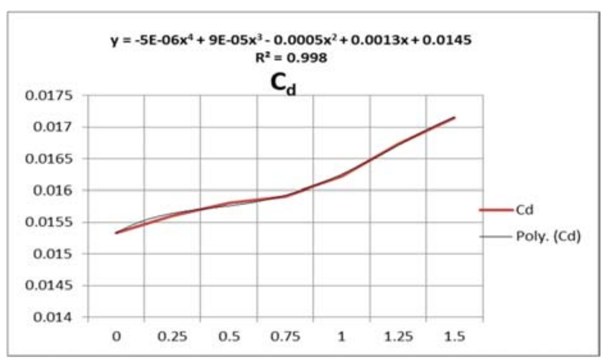

Figure-3. Plot of C_d versus TE radius (% chord).

Aerodynamic efficiency and the coefficient of lift decreases with increase in the roundness of the trailing edge of the airfoil. The empirical formula to relate the trailing edge radius with the aerodynamic efficiency and the coefficient of lift is shown in the respective figures above.

In case of coefficient of drag, from Figure-3, it can be seen that the coefficient of drag increases with the

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increase in the roundness of the trailing edge. The empirical formula of 4^{th} degree is found by fitting the curve along the graph line to relate the same is also mentioned.

Analysis was carried out on the airfoil using Ansys Fluent module with trailing edge radii of 0%, 0.25%, 0.50%, 0.75%, 1.00%, 1.25% and 1.50% of the intial chord length, i.e. say if the analysis was carried out with 0.50% of chord length (1000mm), the trailing edge was given a radius of 5mm and so on.

The velocity contours at different trailing edge radius is shown in the Figures 4 to 10.

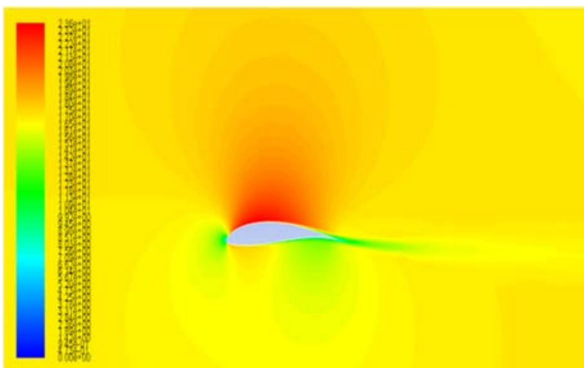

Figure-4. Velocity contours at radius of 0.00% of chord length.

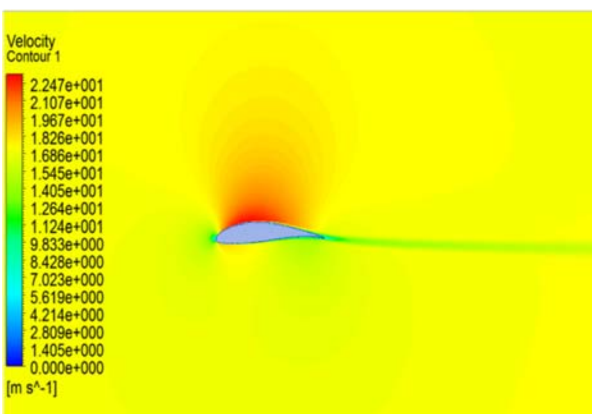

Figure-5. Velocity contours at radius of 0.25% of chord length.

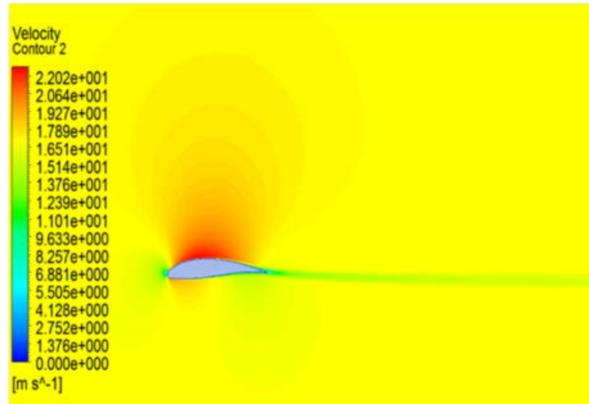

Figure-6. Velocity contours at radius of 0.50% of chord length.

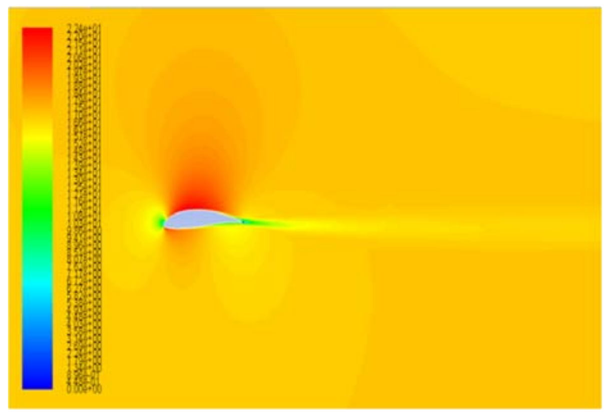

Figure-7. Velocity contours at radius of 0.75% of chord length.

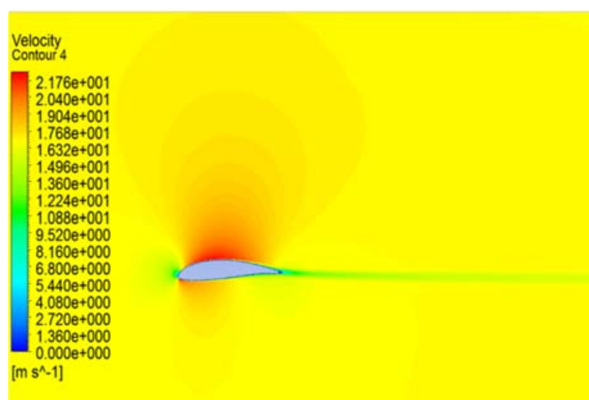

Figure-8. Velocity contours at radius of 1.00% of chord length.

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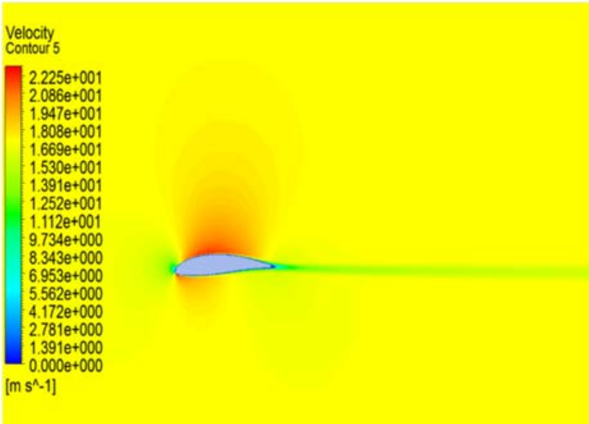

Figure-9. Velocity contours at radius of 1.25% of chord length.

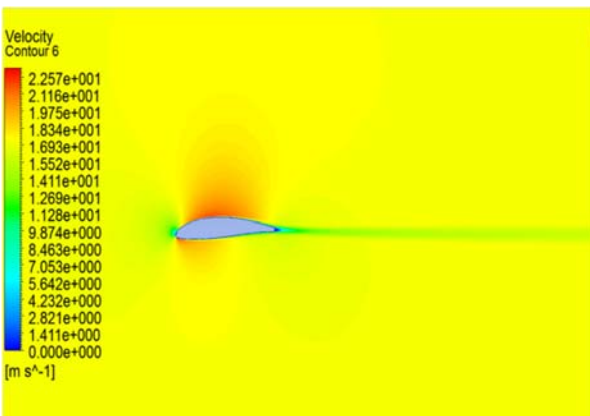

Figure-10. Velocity contours at radius of 1.50% of chord length.

5.1 SELIG S1223

Table-2. Aerodynamic characteristics of Selig S1223 airfoil at different trailing edge radii.

Trailing Edge Radius (% chord)	Coefficient of Lift (Cl)	Coefficient of Drag (Cd)	Aerodynamic Efficiency (E)
0	1.1882	0.01895	62.6946
0.25	0.9484	0.01932	49.0825
0.5	0.6015	0.01926	31.1973
0.75	0.4014	0.02137	18.7646
1	0.2692	0.02241	12.0228
1.25	0.1684	0.02425	6.9304
1.5	0.0834	0.0279	2.9784

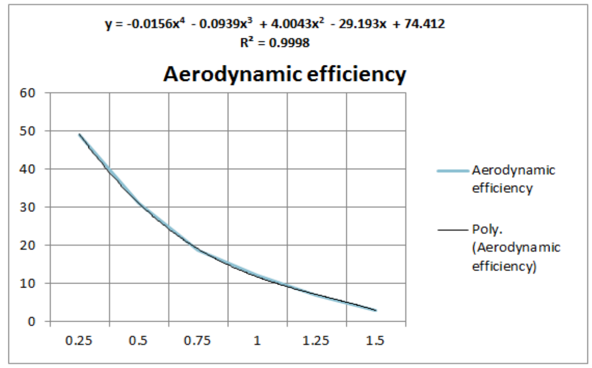

Figure-11. Plot of Aerodynamic Efficiency versus TE radius (% chord).

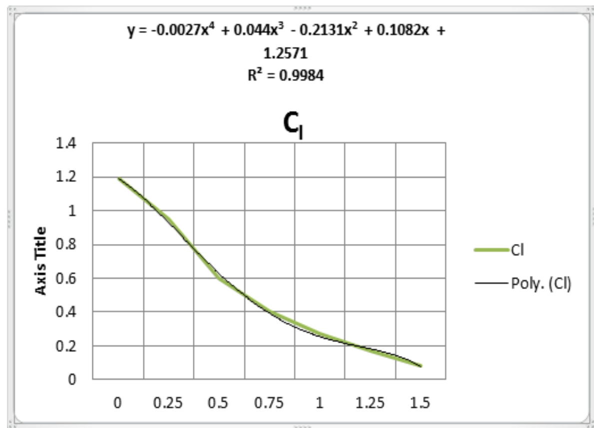

Figure-12. Plot of C_l versus TE radius (% chord).

Now, considering Selig S1223 airfoil, from the Figure-11 and Figure-12, it can clearly be seen that the Aerodynamic efficiency and the coefficient of lift decreases with the increase in the roundness of the trailing edge of the airfoil. The 4th degree empirical formula to relate the aerodynamic efficiency and the coefficient of lift was found by fitting a curve along the graph obtained.

In case of coefficient of drag, from Figure-13, it can be seen that the coefficient of drag increases with the increase in the roundness of the trailing edge. The empirical for this is also obtained by fitting the curve along the graph.

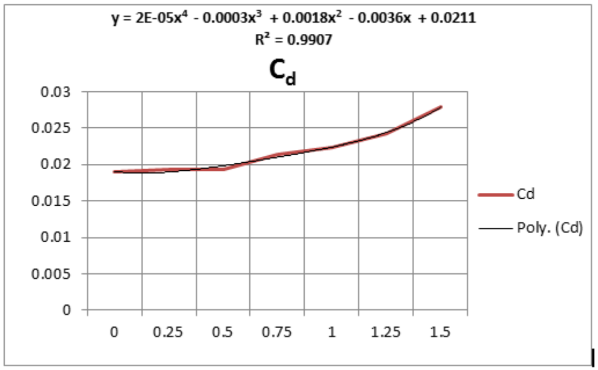

Figure-13. Plot of C_d versus TE radius (% chord).

Like the former airfoil, the analysis was carried out on this airfoil as well using Ansys Fluent module with trailing edge radii of 0%, 0.25%, 0.50%, 0.75%, 1.00%, 1.25% and 1.50% of chord length.

The velocity contours at different TE radius is shown in the Figures 14 to 20 below.

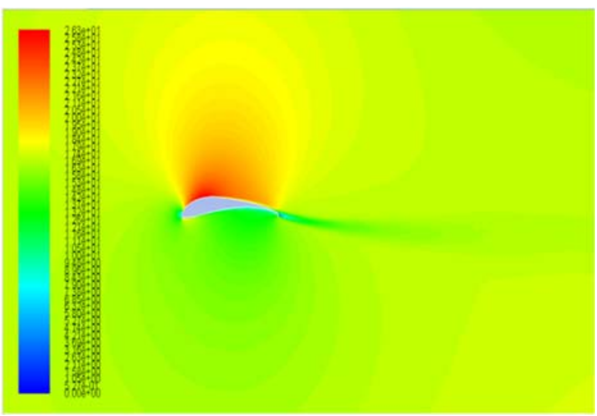

Figure-14. Velocity contours at radius of 0.00% of chord length.

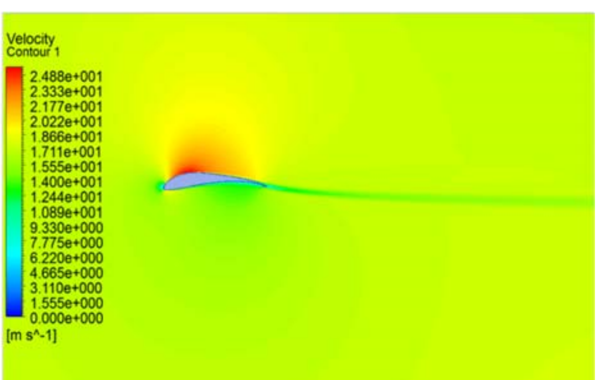

Figure-15. Velocity contours at radius of 0.20% of chord length.

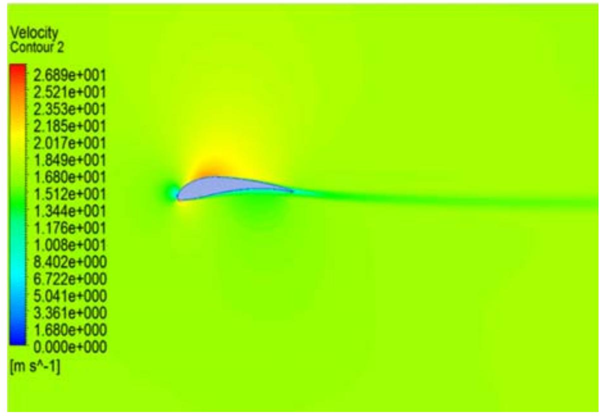

Figure-16. Velocity contours at radius of 0.50% of chord length.

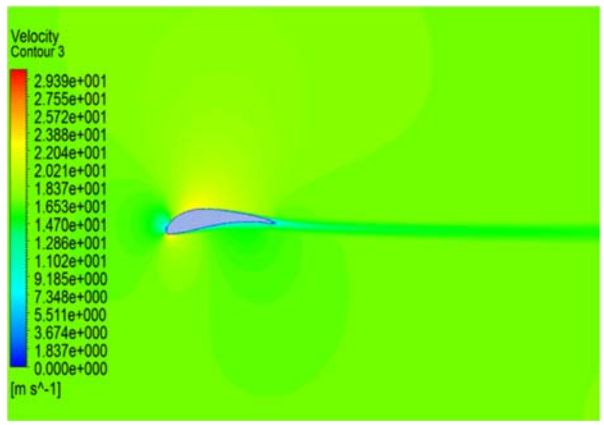

Figure-17. Velocity contours at radius of 0.75% of chord length.

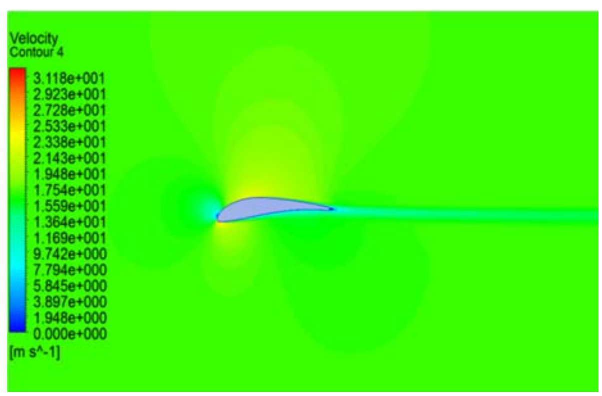

Figure-18. Velocity contours at radius of 1.00% of chord length.

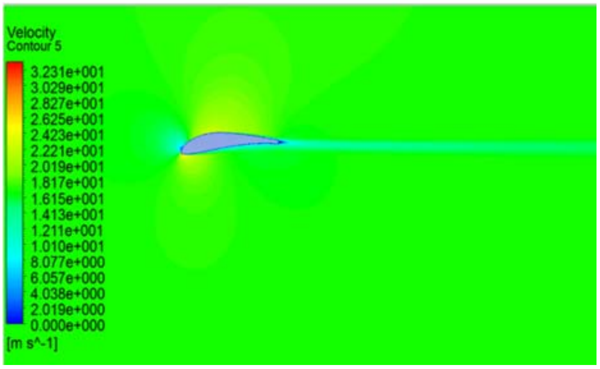

Figure-19. Velocity contours at radius of 1.25% of chord length.

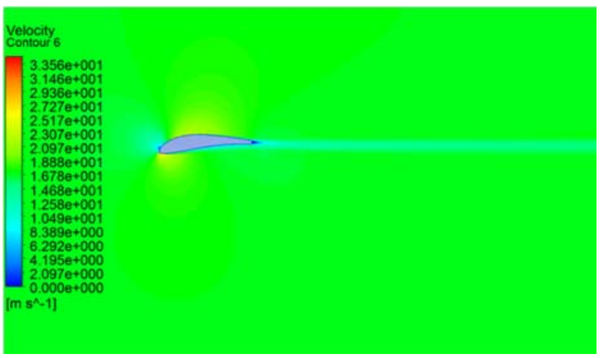

Figure-20. Velocity contours at radius of 1.50% of chord length.

6. CONCLUSIONS

From the above derived results, it can be concluded that the coefficient of lift and aerodynamic efficiency of Wortmann FX 63-137 and Selig S1223 airfoil decreases with the increase in the roundness of the trailing edge radius. The maximum coefficient of lift and aerodynamic efficiency of Wortmann FX 63-137 airfoil is 0.6991 and 45.5823 respectively (at radius of 0.00% of chord) and minimum coefficient of lift and aerodynamic efficiency of Wortmann FX 63-137 airfoil is 0.2307 and 13.4523 respectively (at radius of 1.50% of chord). The maximum coefficient of drag is 0.01715 (at radius of 1.50% of chord) and minimum coefficient of drag is 0.01533 (at radius of 0.00% of chord).

The maximum coefficient of lift and aerodynamic efficiency of Selig S1223 airfoil is 1.1882 and 62.6946 respectively (at radius of 0.00% of chord) and minimum coefficient of lift and aerodynamic efficiency of Selig S1223 airfoil is 0.0279 and 2.97 respectively (at radius of 1.50% of chord). The maximum coefficient of drag is 0.02790 (at radius of 1.50% of chord) and minimum coefficient of drag is 0.01895 (at radius of 0.00% of chord).

In case of multi-element wings (like the ones used in Formula Cars), its desirable that the enormous amount of downforce is produced along with the ease of manufacturing. To achieve this, high lift and low Reynolds number airfoils like Wortmann FX 63-137 and Selig S1223 airfoils are widely used. It can be concluded that, till the roundness of the trailing edge of 0.50% of chord (starting from 0.00%), Selig S1223 airfoil would be efficient whereas at higher trailing edge radius (more roundness), that is, above 0.50% (till 1.50% of chord), Wortmann FX 63-137 airfoil would be efficient.

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