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# Design and Analysis of Aerobatic Unmanned Fixed-wing Aircraft

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***Abstract*—To design a highly aerobatic fixed-wing unmanned aerial vehicle and analyze the performance of it. As the unmanned aerial vehicles serving the combat application must have desired feature of highly aerobatic in order to complete its particular mission during warfare. So, designing such highly maneuverable UAVs would meet the requirements of combat missions during warfare. In this paper, the design and analysis of unmanned aerial vehicle with stepped airfoil to meet the requirement of combat mission.**

***Keywords—KF airfoils; stepped airfoils; fixed-wing UAVs; highly maneuverable; XFLR5.***

## I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are being recognized as cost-effective alternative to manned-aircraft in carrying out both the various civilian and military missions. Where aerobatic flight can be defined as a series of breathtaking manoeuvers which requires an aircraft to operate in abnormal, difficult, and most often dangerous, flight conditions. This type of flight also has military applications in that certain manoeuvers. Most aerobatic manoeuvers involve rotation of the aircraft about its longitudinal (roll) axis or lateral (pitch) axis. Other maneuvers, such as a spin, displace the aircraft about its vertical (yaw) axis. In this paper, let's consider some manoeuvers for designing this aerobatic unmanned fixed-wing aircraft.

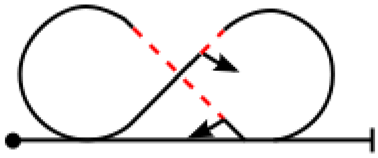

Fig 1: Full Cuban Eight

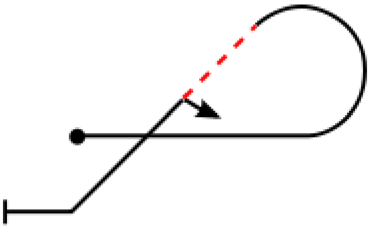

Fig 2: Half Cuban Eight

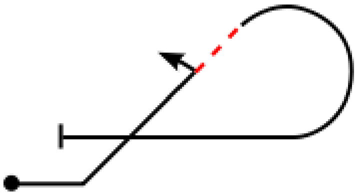

Fig 3: Reverse Half Cuban Eight

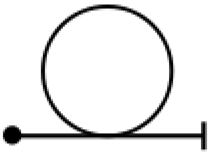

Fig 4:Inside loop

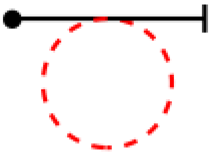

Fig 5:Outside loop

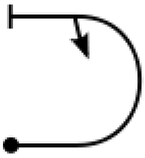

Fig 6: Immelmann; Roll-off-the-top; half loop, half roll.

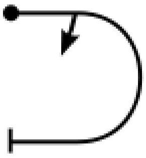

Fig 7: Split-S; half roll, half loop (down)

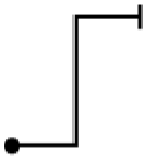

Fig 8: Vertical up line

Fig 9: 45° up line

## II. KF M FAMILY OF AIRFOILS

The KF airfoil was designed by Richard Kline and Floyd Fogleman. In the early 1960s, Richard Kline wanted to make a paper airplane that could handle strong winds, climb high, level off by itself and then enter a long downwards glide. After many experiments he was able to achieve this goal. He presented the paper airplane to Floyd Fogleman who saw it fly and resist stalling. The two men then filed for a patent on the stepped airfoil. Further development resulted in two patents and a family of airfoils known as the KF airfoil and KFm airfoils (for Kline–Fogleman modified). The two patents, US Patent # 3,706,430 and US Patent # 4,046,338, refer to the introduction of a step either on the bottom (KFm1) or on the top of an airfoil (KFm2), or both on top and bottom (KFm4). It can also be used with two steps on the top (KFm3), or two steps on the top and one on the bottom (KFm7).The purpose of the step, it is claimed, is to allow some of the displaced air to fall into a pocket behind the step and become part of the airfoil shape as a trapped vortex or vortex attachment. This purportedly prevents separation and maintains airflow over the surface of the airfoil. Due to poor lift-to-drag ratio, KFm family of airfoils are not fully introduced into the aircraft designs. Recently NACA 4415 airfoil has converted into KFm family of airfoils and results found that it has 37% increase in coefficient of lift and 12% increase in L/D ratio when compared to conventional aircrafts with same airfoil. So, different airfoils has different impact performance when it is converted into KFm family. The different types of KFm airfoils are shown in the Fig 10.

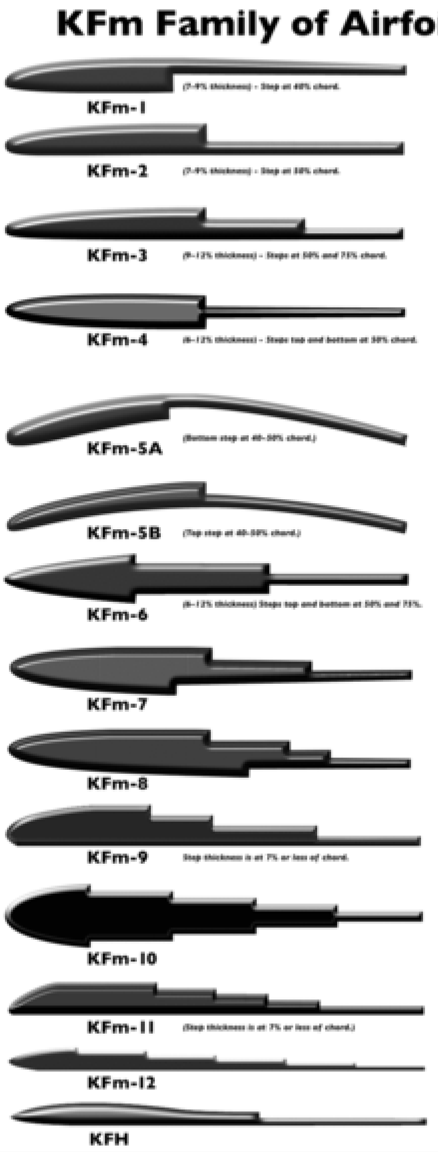

Fig 10: KFm Family of Airfoils

## III. DESIGN OF KFM AIRFOIL

Let's consider the following airfoil in the below Fig 11 which has step at 0.27c of 10.66% thickness at 18.18% and 2.55% camber. The following airfoil is analyzed at 1,00,000 Reynolds number at zero degree of AOA ( Angle of Attack), where the results of it are shown in Fig 11.

Fig 11 : New KFm generated in XFLR5 FOIL Design Environment

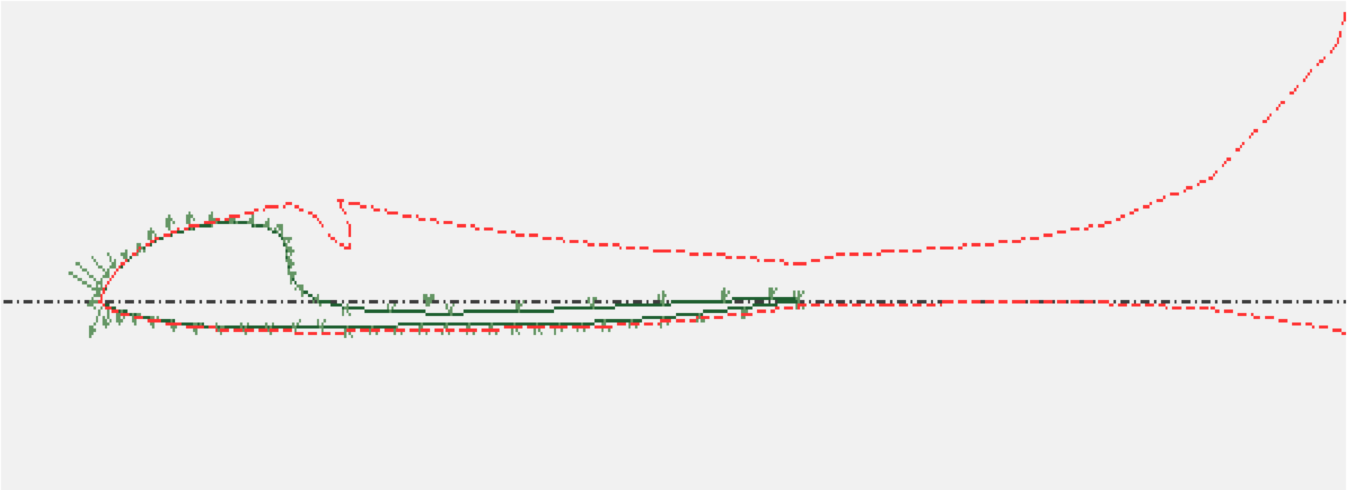

Fig 12 : Boundary Layer and Pressure Distribution of New KFm Airfoil at zero degrees of AOA

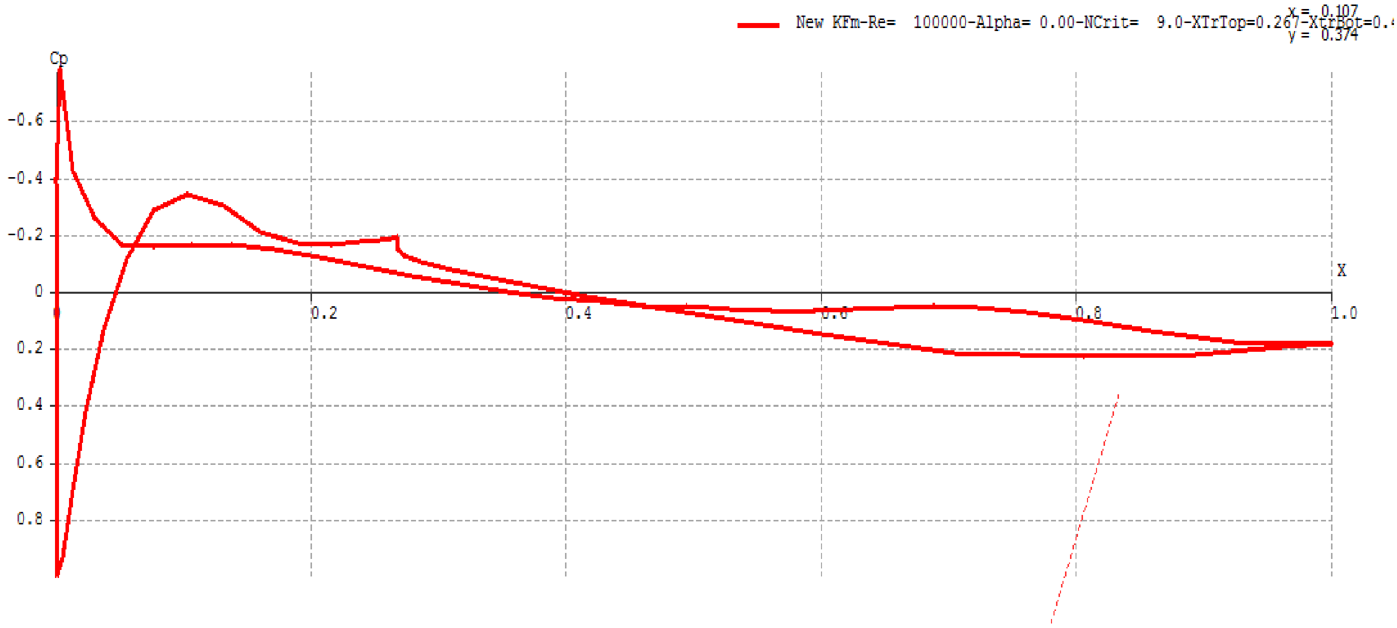

Fig 13 :Cp Distribution of New KFm Airfoil at zero degree of AOA

The boundary layer separation is reduced at step in the following airfoil which is shown in Fig 12. Even the Cp distribution has high performance which is shown in Fig 13. The results of the following airfoil at various AOA as follows;

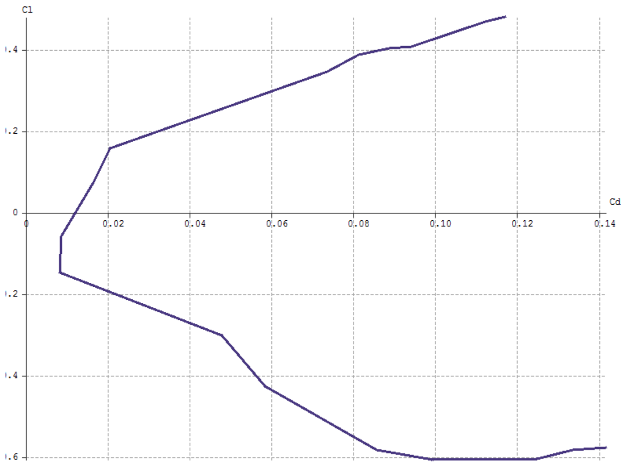

Fig 14: Cl vs. Cd of new KFm Airfoil

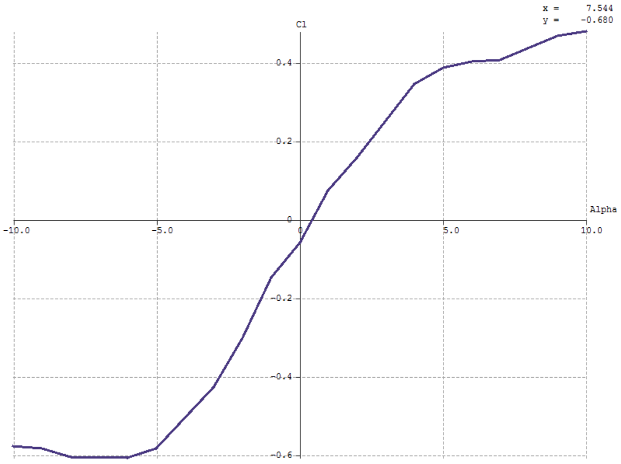

Fig 15: Cl vs. Alpha of new KFm Airfoil

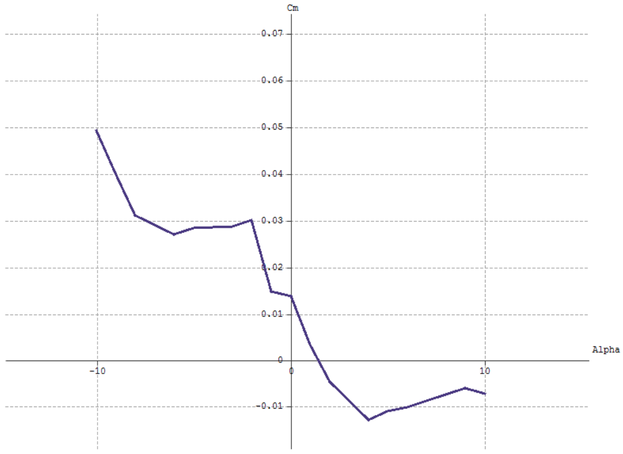

Fig 16: Cm vs. Alpha of new KFm Airfoil

## IV. DESIGN OF AEROBATIC WING PLATFORM

Consider the design of the wing in XFLR5 wing design environment with the cross-section of the previous designed airfoil. Since literature survey of the aerobatic wing ranks the trapezoidal wing having highly maneuverability performance. The following figure visualizes the wing platform.

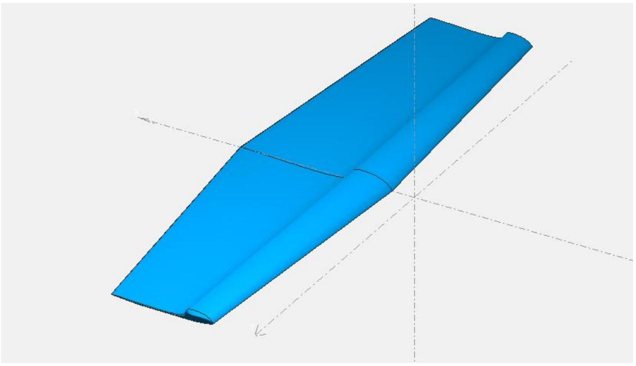

Fig 17: Wing Platform

The analysis results of the following wing platform at 1,00,000 Reynolds number as follows;

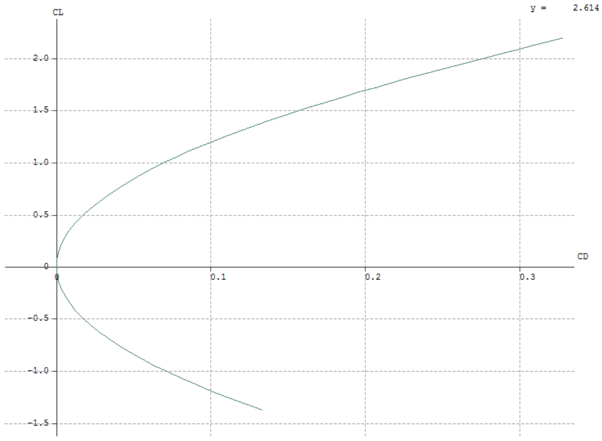

Fig 18 :Cl vs. Cd of Wing Platform

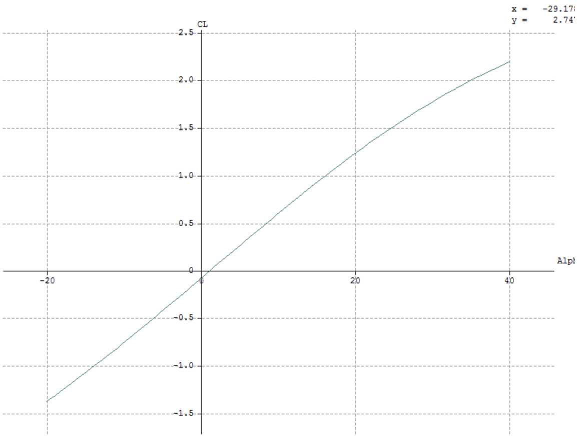

Fig 19 :Cl vs. Alpha of Wing Platform

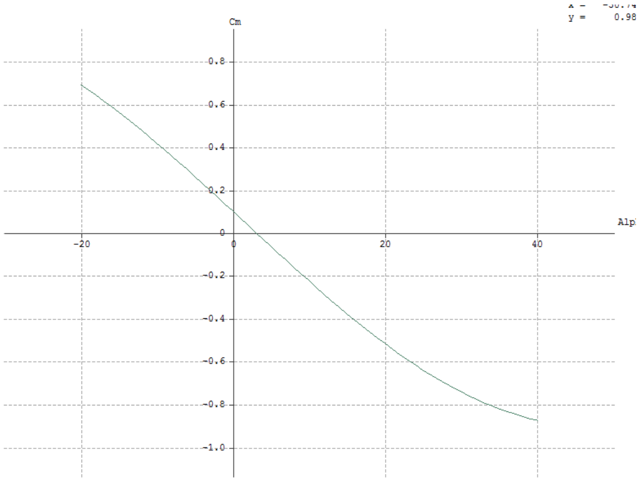

Fig 20 : Cm vs. Alpha of Wing Platform

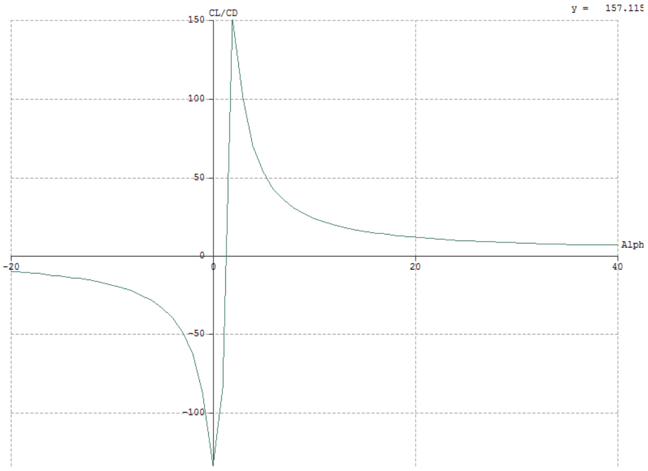

Fig 21 :Cl/Cd vs. Alpha of Wing Platform

## V. DESIGN OF AEROBATIC UAV

Based on the empirical relations between wingspan, fuselage dimensions and tail dimensions, their parameters have be determined. The design views of aerobatic UAV are shown below.

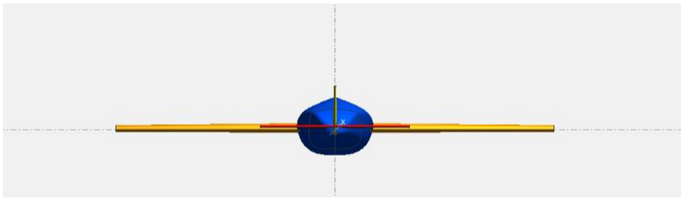

Fig 22: Back View of Aerobatic UAV

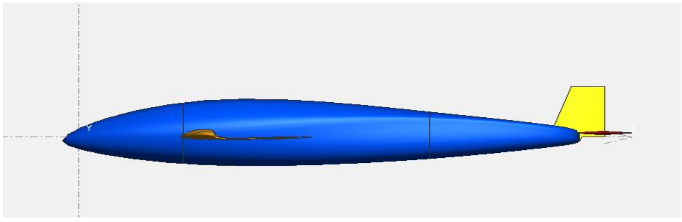

Fig 23: Side view of Aerobatic UAV

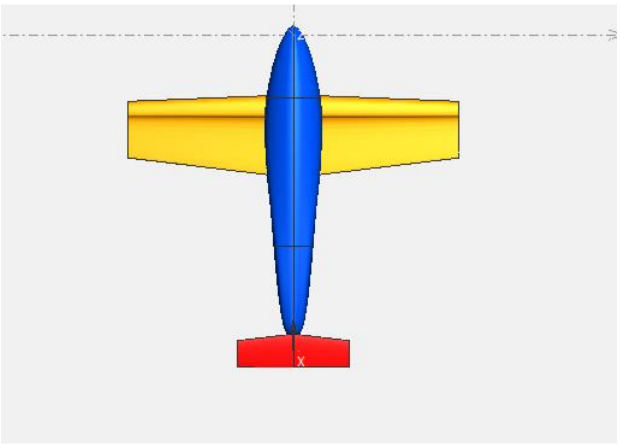

Fig 24: Top View of the Aerobatic UAV

## VI. RESULTS & DISCUSSIONS

The Cp Distribution of the aerobatic UAV at 10 and 20 degrees of Angle of Attack (AOA) as show in the following contour plot.

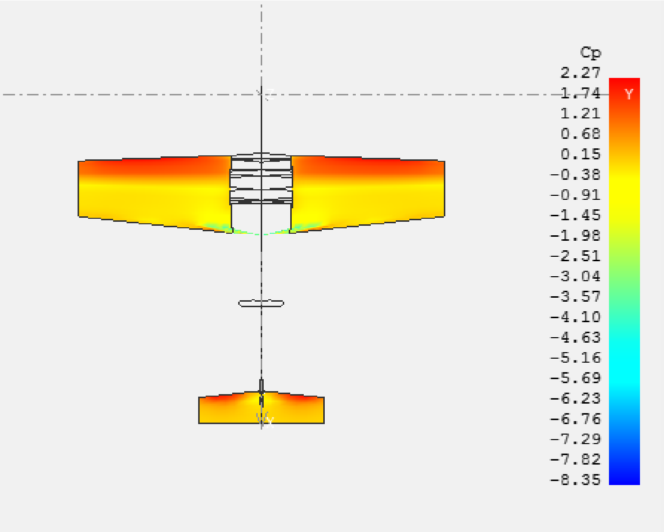

Fig 25 :Cp Distribution at 10 Degrees of AOA

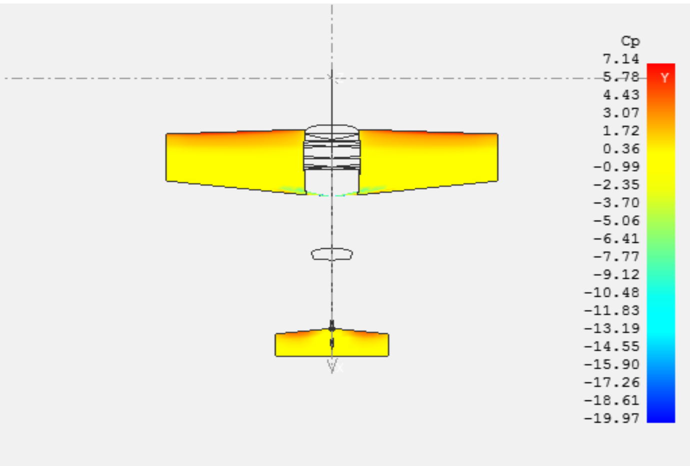

Fig 26 :Cp Distribution at 20 Degrees of AOA

Then following the results of aerodynamic performance varying with other parameter for the aerobatic UAV.

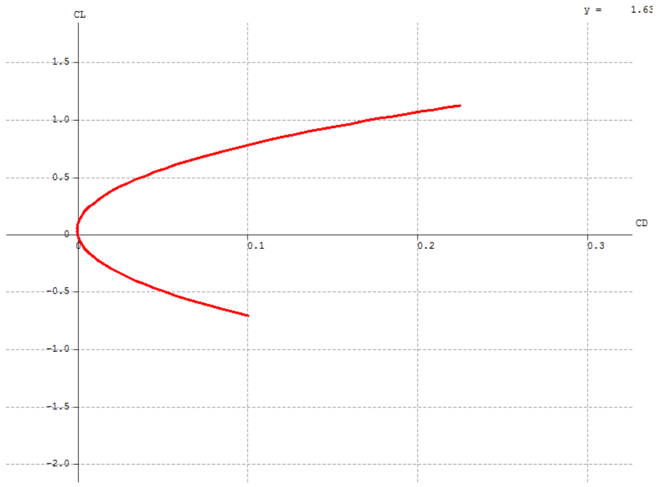

Fig 27 :Cl vs. Cd plot

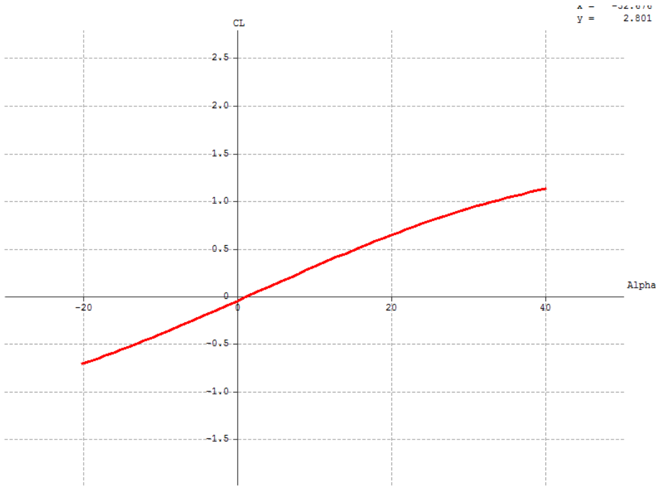

Fig 28 :Cl vs. Alpha plot

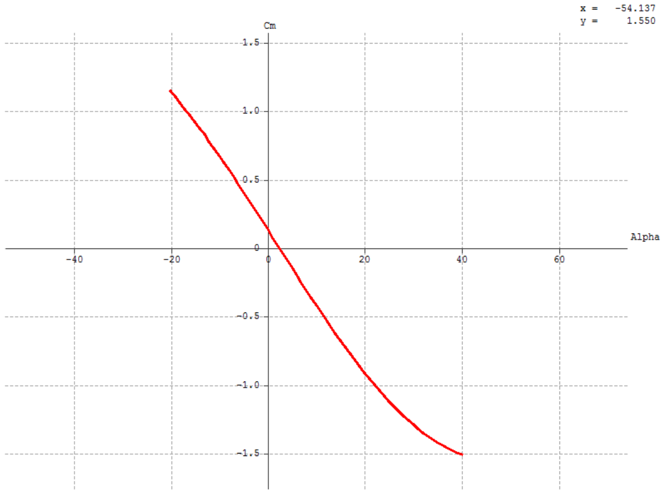

Fig 30 :Cl/Cd vs. Alpha plot

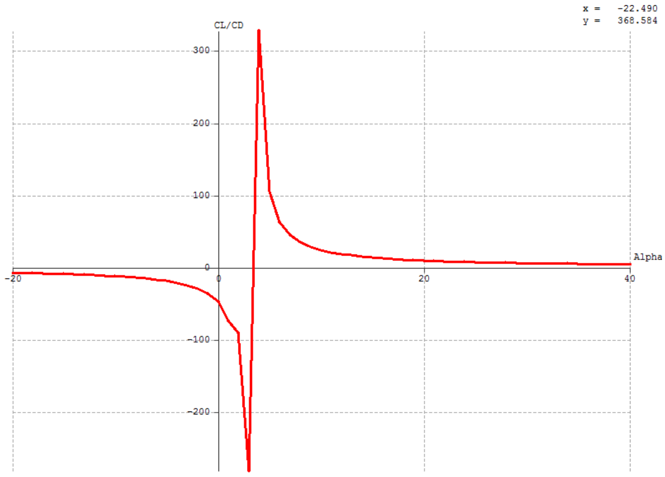

Fig 29 : Cm vs. Alpha plot

The above results discussed that the UAV has high aerodynamic performance with highly controllability and stability. This design results justify that the requirement of aerobatic performance has been met. It has a stall angle at 40 degrees of AOA where it implies that design can perform all above discussed maneuvers at 1,00,000 Reynolds number.

# REFERENCES

[1] Ali Doosttalab, Mohammad Mohammadi, Mehdi Doosttalab, Ali Ashrafizadeh, 2012, "Numerical Investigation of Aerodynamical Performance of Damaged Low-Reynolds Airfoils for UAV Application", TFAWS 2012.

[2] UIUC website:https://m-selig.ae.illinois.edu/

[3] URL: https://en.wikipedia.org/wiki/Aerobatic_maneuver

[4] Anderson JD (1999) Aircraft performance and Design. WCB/McGraw-Hill, Boston, UK.

[5] Deperrois A (2009) XFLR5 analysis of foils and wings operating at low Reynolds numbers. Guidelines for XFLR5..

[6] Mostafa Hassanalian, Hamed Khaki and Mehrdad Khosrawi, 2014, "A new method for design of fixed wing micro air vehicle" Journal of Aerospace Engineering 2014.

[7] Somashekar V, 2014, "A Computational Study of Unsteady Aerodynamics of a Smaller Fixed Wing Micro Aerial Vehicle (MAV)", International Journal of Research in Aeronautical and Mechanical Engineering, Volume 2, Issue 5, 2014

[8] Loth J (2007) Engineering approach to aerodynamics and aircraft performance, McGraw-Hill. New York, USA.

[9] URL: https://en.wikipedia.org/wiki/Kline%E2%80%93Fogleman_airfoil