iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** VI **Month of publication:** June 2015

DOI:

www.ijraset.com
IC Value: 13.98

Volume 3 Issue VI, June 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Effect of Tubercle Leading Edge Control Surface on the Performance of the Double Delta Wing Fighter Aircraft

P Sharmila[1], S Rajakumar[2]
[1]P.G. Scholar, [2]Assistant Professor, Mechanical Department
Anna University Regional office Tirunelveli-627007

Abstract--To improve the aerodynamic characteristics of the generic fighter aircraft by modifying the leading edge control surface of the tailless double delta wing. Simulations are carried out to determine the lift to drag ratio and pitching moment characteristics of the modified wing (Tubercle LEVCON) and compared with the existing fighter aircraft wing at low Mach numbers and high angles of attack, typically for landing/ takeoff configurations. The computational domain is meshed with unstructured grids and steady state Reynolds Averaged Navier Stokes (RANS) CFD simulations are carried out. Lift coefficient and drag coefficient are considered as the principle performance metrics for a control surface and pitching moment is determined for assessing the performance and longitudinal stability of the aircraft. Results obtained indicate that the tubercle wing increases the lift coefficient due to the vortex formation at each tubercle and the flow remains attached over the entire span of the wing.

Key words: Tubercle LEVCON, Longitudinal stability, Vortex formation.

I. INTRODUCTION

Highly swept delta wings flying at high angles of attack have been studied and are used in combat and supersonic aircraft for several decades. The landing and taking off phase operated at very high angle of attack shows poor aerodynamic performance at low speeds [1]. The lift coefficient decreases as the sweep angle decreases [2]. For highly swept delta wings, the flow is dominated by two large counter-rotating leading-edge vortices (LEV) that are critical to the wing’s performance. In the case of sharp-edged wings, LEV form by the rolling of free-shear layers that separate along the sharp leading edge [3]. As the angle of attack increases the LEV's undergo a flow disruption or breakdown also known as vortex burst that result in sudden flow stagnation in the core and an expansion of the core. Vortex breakdown has negative effects such as a decrease in lift, a resulting pitching moment, and the onset of stalling. Moreover, the position of the vortex breakdown is not stationary but instead indicates unsteady oscillations over some mean position [4].

Tubercles are the leading edge protuberances which delays the stall thus extending the operational envelope of the aircraft. At the zero angles of attack the detrimental effects are negligible [5]. It is found that the airfoil with smaller amplitude improved the performance of the stall angle and maximum lift coefficient. On the other hand, larger amplitude shows the softer stall characteristics [6].

II. METHODOLOGY

A. Numerical Methods

Reynolds averaged Navier-Stokes equations are used for the flow analysis. The 3D parallel Finite Volume Compressible flow solver (VISP 3D) written in FORTRAN language, uses iterative methods such as GS (Gauss-Siedel) and LU method for arriving at a converged steady state solution. The unstructured grid in cobalt format is given as input and the solutions are obtained for in-viscid, viscous laminar and turbulent flows.

B. Model Geometry And Grid

The double delta wing analyzed here has leading-edge sweep angles of 50 and 60.5 degrees. LEVCON is a leading edge deflectable device in a wing apex region for rendering approach speed for carrier landing. The model has three slats which are deflected at different angles of 17, 22 and 24 degrees. The inboard and outboard elevons provide the pitching moment and the lift characteristics.

Sharp and tubercle LEVCON are used for the study (Fig. 1).

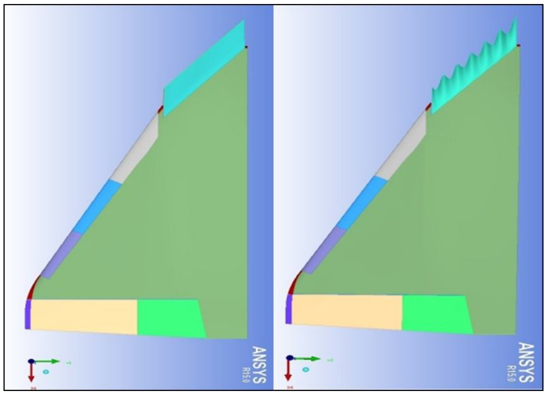


Fig.1 Sharp and Tubercle leading edge

The wing thickness ratio is 3.7 based on each chord length. The flow fields are assumed to be symmetric on center line of the wing. Therefore, the computational domain covers only half of the wing. The computational grid is elliptical with major and minor axes of 120 m and 80 m respectively. The amplitude and the wavelength are modeled as 0.20 c_{LEVCON} (chord length of LEVCON) and 0.25 c_{LEVCON} for the low aspect ratio wing AR= 1.75 [7]. The unstructured grid containing the tri and tetra elements covers about 22 million elements (Fig. 2).

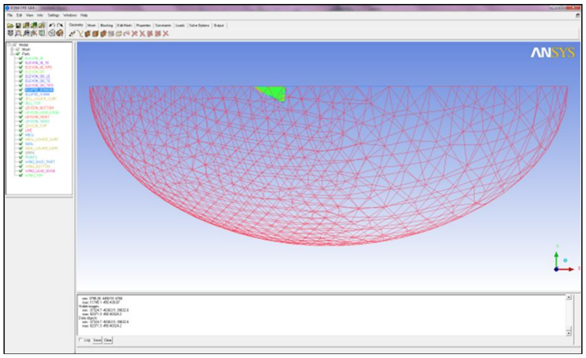


Fig. 2 Wing and domain

C. Flow Conditions

The flow conditions are chosen for the landing/ takeoff and maneuvering configurations (Table 1). The deflection of the LEVCON is analyzed from zero degree to 30º deflection upwards. Reynolds number (Re) is calculated for the corresponding velocity based on Sutherland's viscosity with the aerodynamic chord length of 5.6 meters.

S.NO.	M	α°	β°	Re
Zero LEVCON, Zero Slats and Zero Elevon deflections				
1	0.3	15	0	3.9e7
2	0.3	25	0	3.9e7
LEVCON 30 up, Zero Slats and Zero Elevon deflections				
3	0.3	15	0	3.9e7

Table 1 Flow field classification

III. RESULTS AND DISCUSSIONS

A. Validation Of The Present Computational Approach

To validate present computational approach, obtained computational data are compared with the wind tunnel results of the aircraft 1 and the wing 1. The present approach is adequate to qualitative discussion of the aerodynamic characteristics of the present double delta wing 2 containing the coefficients of pitching moment (C_{pm}) and lift (C_L) characteristics with respect to angle of attack (α°) (Fig. 3)**.**

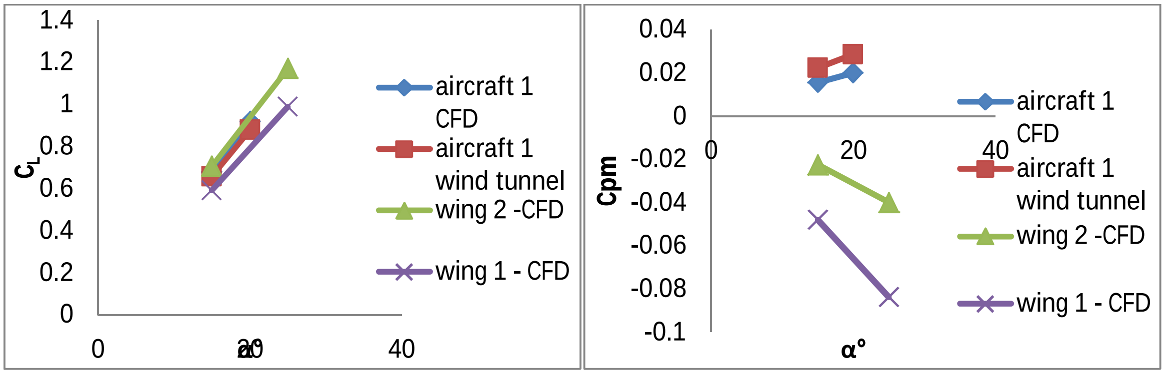
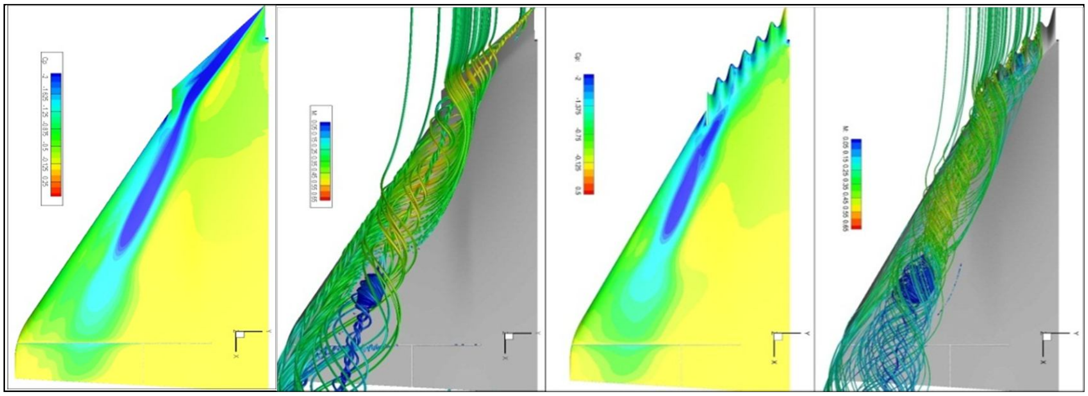


Fig. 3 Comparison of the Aerodynamics data

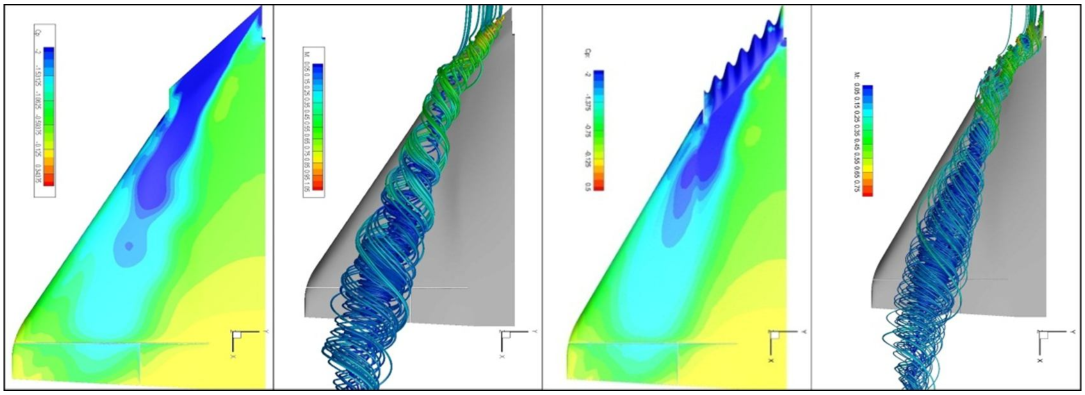
B. Flow Field Classification

The simulations are conducted on the double delta wing with tubercle leading edge to understand the effects of protuberances on the control surface (LEVCON). Pressure distributions and streamline patterns (Fig. 4, 5 & 6) shows that the sharp LEVCON produces the strong primary vortex and the tubercle LEVCON produces vortices at each tubercle and hence joins the primary vortex which is weak resulting in the reduction of pitching moment characteristics (Fig.8).



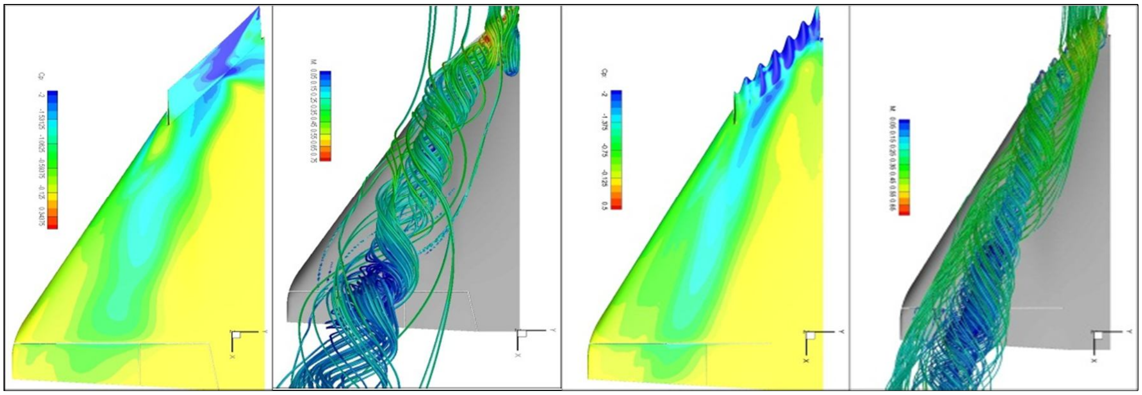
(a) Coefficient of pressure (b) Mach lines (c) Coefficient of pressure (d) Mach lines

Fig. 4 Pressure distributions and the stream lines at $M_\infty = 0.3$ $\alpha = 15^\circ$ $\beta = 0^\circ$, Zero LEVCON



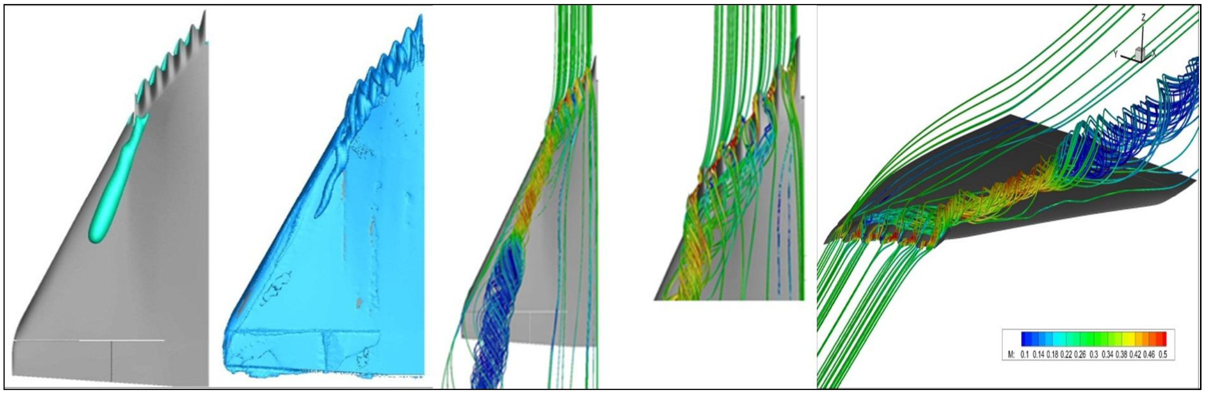
(a) Coefficient of pressure (b) Mach lines (c) Coefficient of pressure (d) Mach lines

Fig. 5 Pressure distributions and the stream lines at M∞= 0.3 α= 25º β=0º, Zero LEVCON



(a) Coefficient of pressure (b) Mach lines (c) Coefficient of pressure (d) Mach lines

Fig. 6 Pressure distributions and the stream lines at M∞= 0.3 α= 15º β=0º, LEVCON 30º up



(a)Vortex burst (b)Vorticity (c)Stream lines (d) Mach lines

Fig. 7 M∞= 0.3 α= 15º β=0º, Zero LEVCON, Zero slats and Zero Elevon deflections

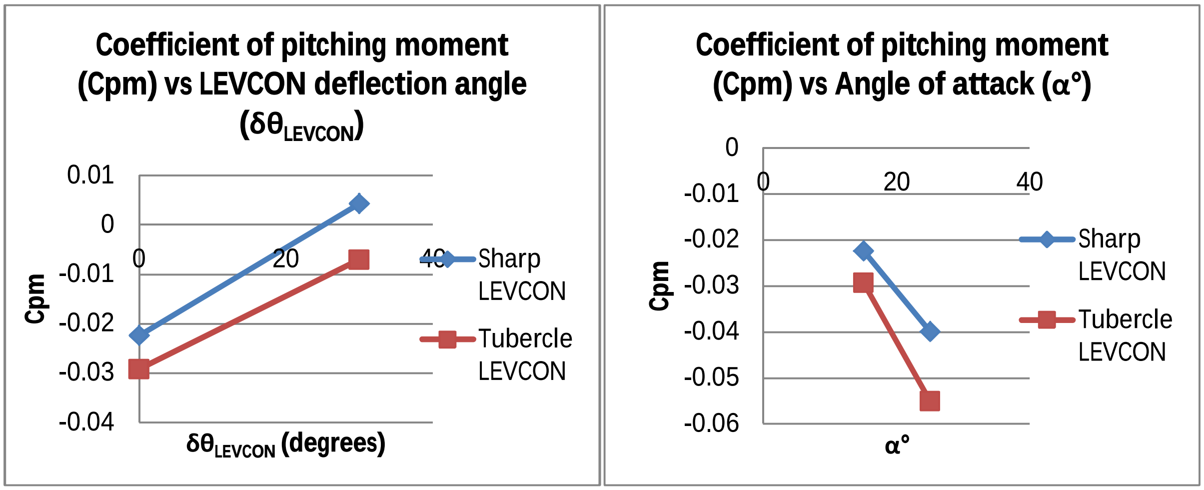


Fig. 8 Pitching moment characteristics at M=0.3 α=15° β=0°

The pressure distributions are obtained over the large model for a Reynolds number of 3.9 e7 at angles of attack of 15°and 25°. The vortex burst is calculated for the value of $U/U\infty = 0$ (Fig.7).The vortices are energized while climbing the protuberance and are de-energized while descending. This leads to the weak core of the primary vortex. However the flow remains attached over the entire span of the wing.

IV. CONCLUSION

In the present study, subsonic flows over a delta wing at high angles of attack and corresponding aerodynamic characteristics of the tubercle delta wing have been computationally investigated.

The flow over the protuberance remains attached significantly increases the aerodynamic characteristics of the delta wing such as the coefficient of lift.
The amplitude and the wavelength of the tubercle wing are important parameter for better performance on the wing optimization.
The flow separation at the leading edge is prevented by the longitudinal vortices around the protuberances.
The longitudinal vortices are generated in the troughs between tubercles and that vorticity and circulation are highly dependent on streamwise location and angle of attacks.
The low pressure regions resides between tubercles increases the lift coefficient, thus reducing the stalling speed while landing the aircraft with the LEVCON deflected up and shows the better performance in the longitudinal stability.

REFERENCES

[1] Akira Oyama, Genta Imai, Akira Ogawa, Kozo Fujii, “Aerodynamic Characteristics of a Delta Wing at High Angles of Attack”, AIAA 2008-2563, 28 April - 1 May 2008, Dayton, Ohio
[2] Earnshaw, P.B., Lawford, J.A., “Low-speed wind tunnel experiments on a series of sharp edged delta wings” ARC Reports and Memoranda No. 3424, March 1964
[3] Andrej Furman, Christian Breitsamter, “Turbulent and unsteady flow characteristics of delta wing vortex systems”, Aerospace Science and Technology 24 (2013) 32–44
[4] Menke, M., Yang, H., Gursul, I., “Experiments on the steady nature of vortex breakdown over delta wings”, Experiments of Fluids, 1999, 27, 262-272
[5] P. Watts, F. E. Fish, “The Influence of Passive, Leading Edge Tubercles on Wing Performance”, Applied Fluids Engineering, Inc. , office of Naval research under contract N00014-00-C-0341
[6] Kristy L. Hansen, Richard M. Kelso and Bassam B. Dally “Performance Variations of Leading-Edge Tubercles for Distinct Airfoil Profiles”, AIAA JOURNAL Vol. 49, No. 1, January 2011
[7] J.-H. CHEN, S.-S. LI, V.T. NGUYEN, “The Effect of Leading Edge Protuberances on the Performance of Small Aspect Ratio Foils”, 15th International Symposium on Flow Visualization June 25-28, 2012, Minsk Belaru