A Study of Reduction of Flow Separation in Aero foil Using Dimples

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Abstract- **The present work describes change in aerodynamic characteristics of an airfoil by applying certain surface modifications in form of dimples The main objective of aircraft aerodynamics is to enhance the aerodynamic characteristics and maneuverability of the aircraft. This enhancement includes the reduction in drag and stall phenomenon. The airfoil which contains dimples will have comparatively less drag than the plain airfoil. Introducing dimples on the aircraft wing will create turbulence by creating vortices which delays the boundary layer separation resulting in decrease of pressure drag and also increase in the angle of stall. In addition, wake reduction leads to reduction in acoustic emission. In the present work, a car model with different dimple geometry is simulated using k-ε turbulence modeling to determine its effect to the aerodynamics performance. Overall, the results show that the application of dimples manages to reduce the drag coefficient of the car model.**

Index terms- **Airfoil, Angle of attack, Drag and Lift**

INTRODUCTION

A short takeoff and landing (STOL) aircraft is an aircraft with short runway requirements for takeoff and landing. Many STOL-designed aircraft also feature various arrangements for use on runways with harsh conditions (such as high altitude or ice). STOL aircraft, including those used in scheduled passenger airline operations, have also been operated from STOL port airfields which feature short runways.

Runway length requirement is a function of the square of the minimum flying speed (stall speed), and most design effort is spent on reducing this number. For takeoff, large power/weight ratios and low drag help the plane to accelerate for flight. The landing run is minimized by strong brakes, low landing speed, thrust reversers or spoilers (less common). Overall STOL performance is set by the length of runway needed to land or takeoff, whichever is longer of equal importance to short ground run is the ability to clear obstacles, such as trees, on both take-off and landing. For takeoff, large power/weight ratios and low drag result in a high rate of climb required to clear obstacles. For landing, high drag allows the aeroplane to descend steeply to the runway without building excess speed resulting in a longer ground run. Drag is increased by use of flaps (devices on the wings) and by a forward slip (causing the aeroplane to fly somewhat sideways through the air to increase drag).

At present, different kinds of surface modifications are being studied to improve the maneuverability of the aircraft. Vortex generators are the most frequently used modifications to an aircraft surface. Vortex generators create turbulence by creating vortices which delays the boundary layer separation resulting in decrease of pressure drag and also increase in the angle of stall. It helps to reduce the pressure drag at high angle of attack and also increases the overall lift of the aircraft. Riblets are another type of modification that is being considered these days. The surface modifications which are being considered in the given study are dimples of types and shapes. Till now these have been ignored because dimples help in reduction of pressure drag. In case of aerodynamic bodies pressure drag is very little compared to bluff bodies. An airfoil is an aerodynamic body so dimples do not affect to its drag much at zero angle of attack, but as soon as airfoil attains some angle of attack, wake formation starts due to boundary layer separation. Application dimples on aircraft wing model works in same manner as vortex generators. They create 2012 International Conference on Fluid Dynamics and Thermodynamics Technologies (FDTT 2012) IPCSIT vol.33(2012)©(2012) IACSIT Press, Singapore 92 turbulence which delays the boundary layer separation and reduces the wake and thereby reducing the pressure drag. This also assists in Lift of the aircraft. Most importantly this can be quite effective at different the angle of attacks and also can change angle of stall to a great extent. A stall is a condition in aerodynamics and aviation where the angle of attack increases beyond a certain point such that the lift begins to decrease. The angle at which it occurs is called the critical angle of attack or angle of stall. Flow separation begins to occur at small angles of attack while attached flow over the wing is still dominant. As angle of attack increases, the separated regions on the top of the wing increase in size and hinder the wing's ability to create lift. At the critical angle of attack, separated flow is so dominant that further increases in angle of attack produce less lift and vastly more drag.

LITERATURE REVIEW

By Michael B. Patacsil Test results show that dimpled wings stall at a slightly steeper, yet consistent, angle of attack. Research following my experimentation indicate that dimples may create friction on a wing's surface hindering its performance. If this problem is solved this concept can theoretically shorten take-offs and landings (STOL) and allow aircraft to be more maneuverable; furthermore, I believe that my experiment has supported my hypothesis that dimpled wings stall at a steeper angle of attack than a traditional smooth wing.

The aerodynamics of wings in ground effect has been studied using experimental and computational methods. Wind tunnel tests were used to quantify the effect of the ground on the aerodynamic performance of a wing, with the suction surface nearest to the ground. Features of the flow field around the wing were investigated using Laser Doppler Anemometry and Particle Image Velocimetry to map the wake at the centre of the wing, and the state of the tip vortex. Initially, a single element configuration was used, both under transition free and transition fixed conditions. The application of Gurney flaps was then examined. The experimental study was completed using a double element configuration. The performance is discussed together with the flow field results. Wind Tunnel testing was performed at a Reynolds number of approximately 0.75x10(6) based on the chord of the double element wing. The application of a computational technique has been examined using a Reynolds averaged Navier Stokes solver. Trends in the aerodynamic performance of a single element aerofoil in ground effect were predicted well using a Spalart-Allmaras turbulence model.

The main objective of aircraft aerodynamics is to enhance the aerodynamic characteristics and maneuverability of the aircraft. This enhancement includes the reduction in drag and stall phenomenon. The airfoil which contains dimples will have comparatively less drag than the plain airfoil. Introducing dimples on the aircraft wing will create turbulence by creating vortices which delays the boundary layer separation resulting in decrease of pressure drag and also increase in the angle of stall. In addition, wake reduction leads to reduction in acoustic emission. The overall objective of this paper is to improve the aircraft maneuverability by delaying the flow separation point at stall and thereby reducing the drag by applying the dimple effect over the aircraft wing. This project includes both computational and experimental analysis of dimple effect on aircraft wing, using NACA 0018 airfoil. Dimple shapes of Semi-sphere, hexagon, cylinder, square are selected for the analysis; airfoil is tested under the inlet velocity of 30m/s and 60m/s at different angle of attack (5˚, 10˚, 15˚, 20˚, and 25˚). This analysis favors the dimple effect by increasing L/D ratio and thereby providing the maximum aerodynamic efficiency, which provides the enhanced performance for the aircraft. This is given in International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:9, No:2, 2015 by E. Livya, G. Anitha, P. Valli

Addition of dimples has proven to be effective in altering various aspects of the flow structure. With such significant flow structure the resultant lift and drag forces are also altered. Primarily the outward dimples are proved to be most suitable as proved by the results of this study. Based on these results a new Smart dimple matrix is suggested over airfoils which will sense boundary layer separation and arrange dimple in the least drag and high lift configuration. Downright, the total aerodynamic efficiency of the airfoil is improved by this complete idea. But for complete verification of its effect an experimental study is required. Also full scale testing focusing on aerodynamic force measurement is essential to determine the sustainability of the outward dimples to act as highly efficient vortex generators. The concept is very new and with the implementation of dimple matrix, it could be extremely beneficial in making an aircraft more maneuverable by changing flow characteristics. Also it increases the aerodynamic efficiency and therefore helps in improving the performance also. The idea will also assist in shorter take-offs at low speed.

DESIGN AND DOMAIN SETUP

The design was done by using CATIA, in this design NACA 64212 series aerofoil was chosen for analysis; because it is used in real time purpose, so by analyzing this would to applicable for practical application.

NACA 64212 coordinate file:

Z	X	Y
0	0	0
0	0.00336	0.01071
0	0.00567	0.0132
0	0.01041	0.01719
0	0.02257	0.0246
0	0.04727	0.03544
0	0.07218	0.04379
0	0.09718	0.05063
0	0.14735	0.06138
0	0.19765	0.06929
0	0.248	0.07499
0	0.2984	0.07872
0	0.34882	0.08059
0	0.39924	0.08062
0	0.44964	0.07894
0	0.5	0.07567
0	0.55031	0.07125
0	0.60057	0.06562
0	0.65076	0.05899
0	0.70087	0.05153
0	0.75089	0.04344
0	0.80084	0.03492
0	0.8507	0.02618
0	0.90049	0.01739
0	0.95023	0.00881
0	1	0
0	0	0
0	0.00664	-0.00871
0	0.00933	-0.0104
0	0.01459	-0.01291
0	0.02743	-0.01716
0	0.05273	-0.0228
0	0.07782	-0.02685
0	0.10282	-0.02995
0	0.15265	-0.03446
0	0.20235	-0.03745
0	0.252	-0.03919
0	0.3016	-0.03984
0	0.351118	-0.03939
0	0.40076	-0.03778
0	0.45035	-0.03514
0	0.5	-0.03164
0	0.54969	-0.02745
0	0.59943	-0.02278
0	0.64924	-0.01799
0	0.69913	-0.01265
0	0.74911	-0.00764
0	0.79916	-0.00308
0	0.8493	0.00074
0	0.89951	0.00329
0	0.94977	0.0033
0	1	0

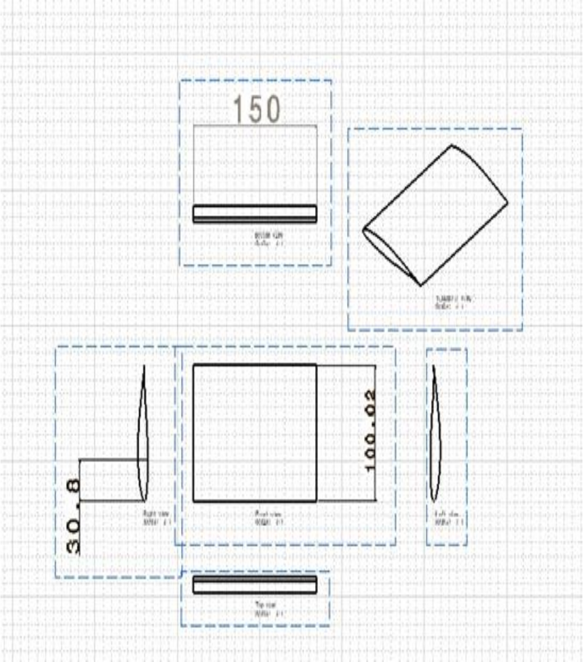


Fig.-1 Draft of NACA 64212 from CATA

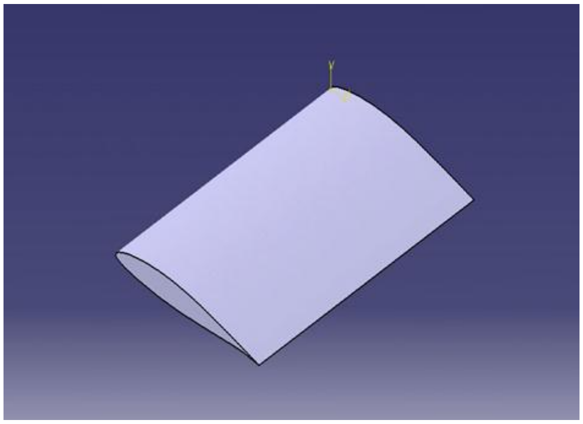
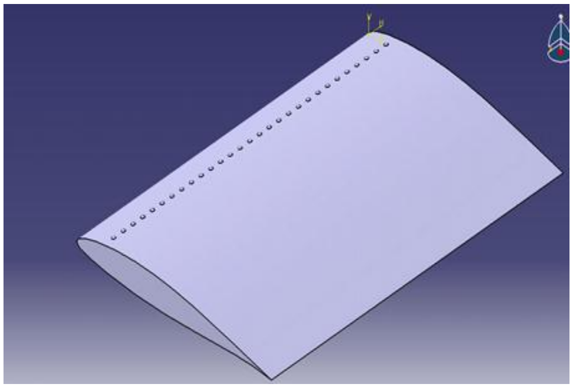


Fig-2 to 6. NACA 64212 wing isometric view

Design data for profile with different shaped dimples:



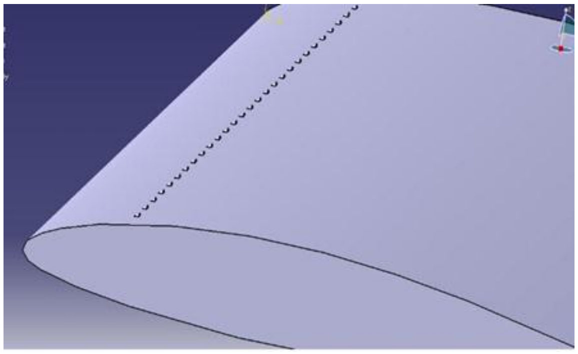


Fig-3

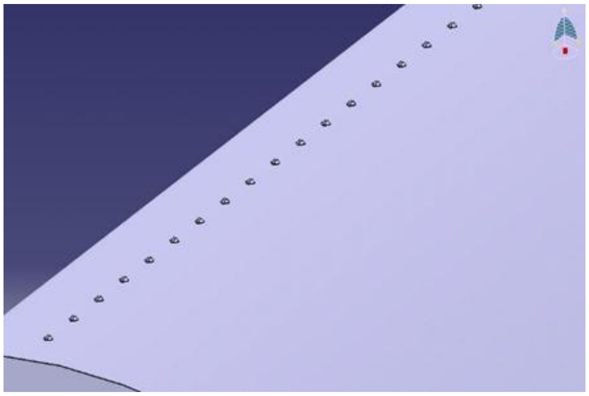


Fig-4

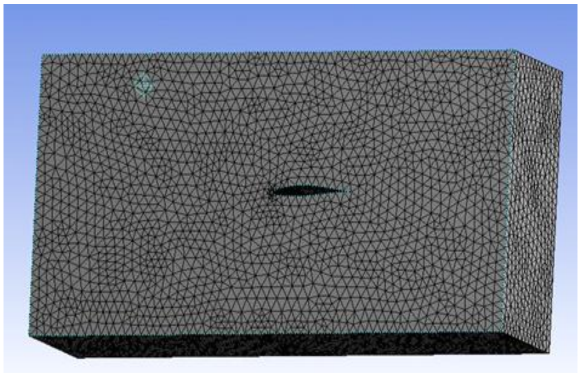


Fig-5

After the design the pre posting works are to be done. They are meshing or discretizing and setting up initial value and boundary values for the fluid domain to be analyzed.

Fig. Mesh created in the cfx solver for the domain has to be set before starting to post processing. The physical properties of the fluid and the analyzing domain are seen in the tabl.

The picture shown above is the meshing or discretization of the normal wing profile. Their corresponding data's are tabulated in the table.

Then the domain initial and boundary values are defined and the physical values

Mesh Report

Table. 1 Mesh Information for CFX

Domain	Nodes	Elements
Default Domain	32433	150075

Physics Report

Table.2 Domain Physics for CFX

Domain - Default Domain	
Type	Fluid
Location	B81
Materials	
Air at 25 C	
Fluid Definition	Material Library
Morphology	Continuous Fluid
Settings	
Buoyancy Model	Non Buoyant
Domain Motion	Stationary
Reference Pressure	1.0000e+00 [atm]
Heat Transfer Model	Isothermal
Fluid Temperature	2.5000e+01 [C]
Turbulence Model	k epsilon
Turbulent Wall Functions	Scalable

RESULT

From the CFD analysis using cfx solver the result has been taken out for different analysis. Those results were plotted with different parameters of the fluid flow interactions. The parameter which are taken into analysis are pressure, velocity and temperature, but for some cases turbulence eddy dissipation and turbulence kinetic energy are calculated. The pressure plot shows the variation of pressure around the body in which the fluid get interacted, as the same way velocity too. These various parameter are plotted with contour and streamline plot, in addition vector plots are also used to see the direction of the flow. The results are taken and plotted with different parametric plots they are as follow.

For circular dimples

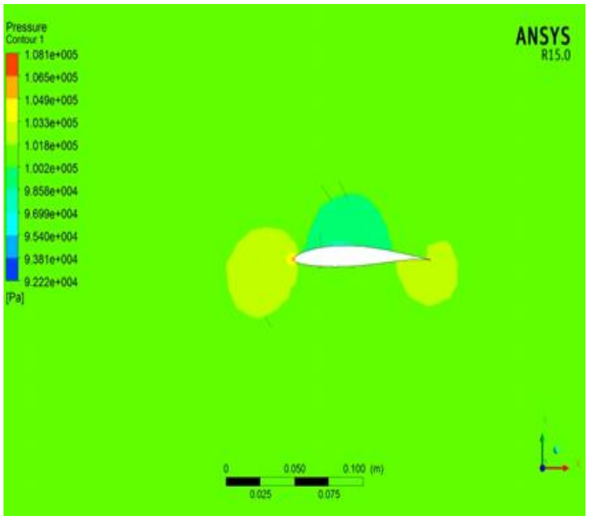


Fig. pressure contour for circular outward dimples

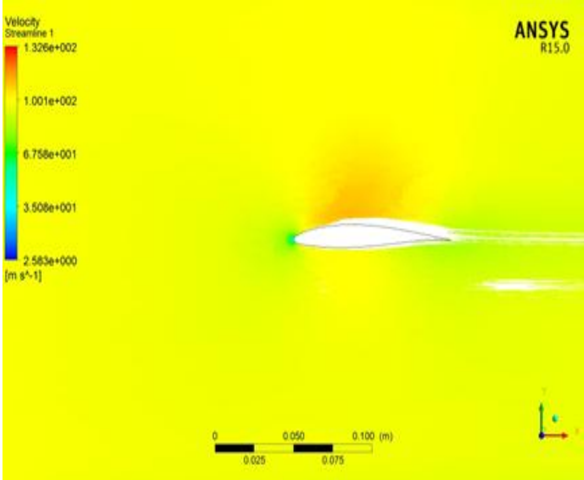


Fig. streamline plot for circular outward dimples

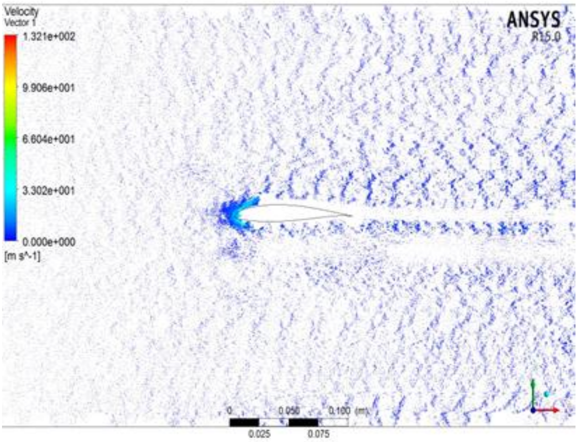


Fig. vector plot for circular outward dimples

For diamond shaped dimples:

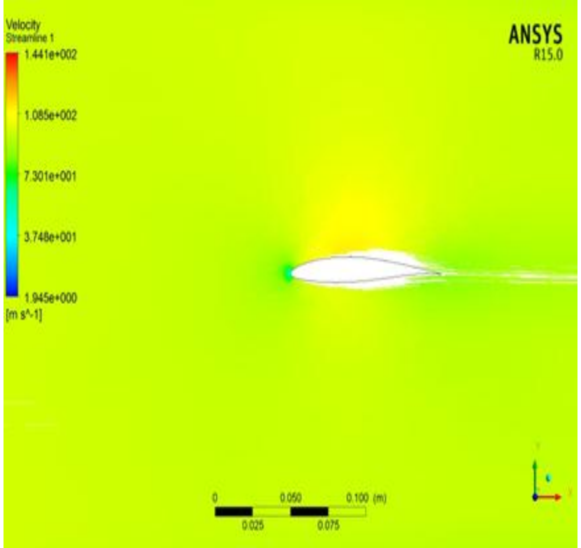


Fig streamline plot for diamond outward dimples

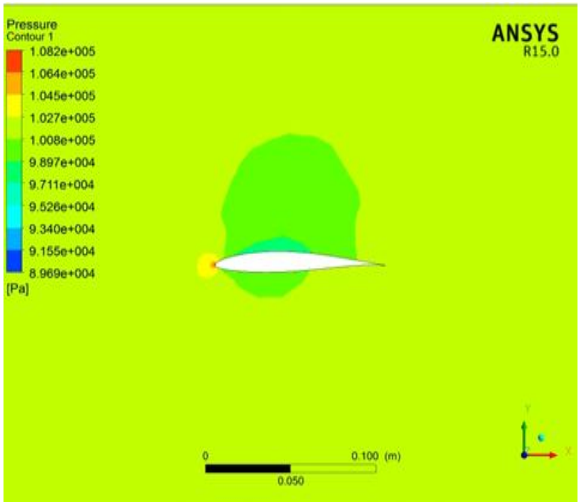


Fig pressure contour for diamond outward dimples

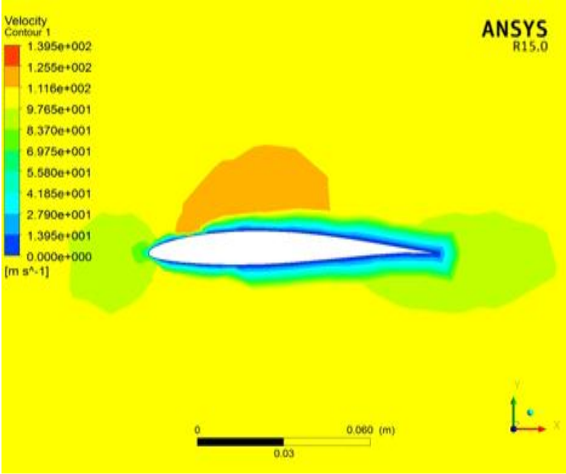


Fig velocity contour for diamond outward dimples

For triangular dimples:

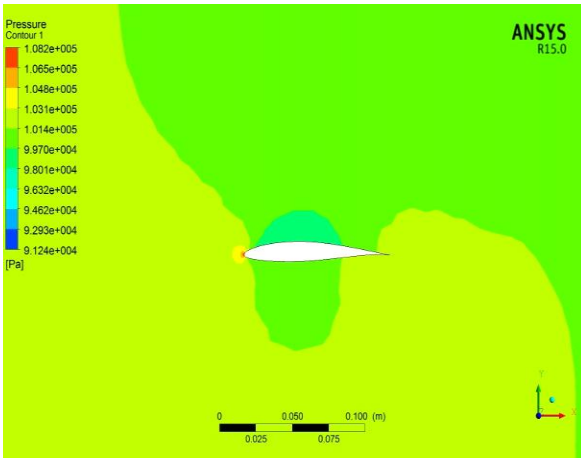


Fig pressure contour plot for triangular outward dimples

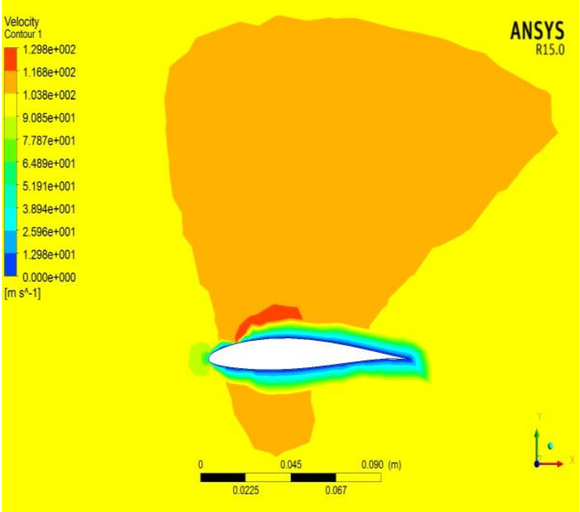


Fig velocity contour for triangular outward dimples

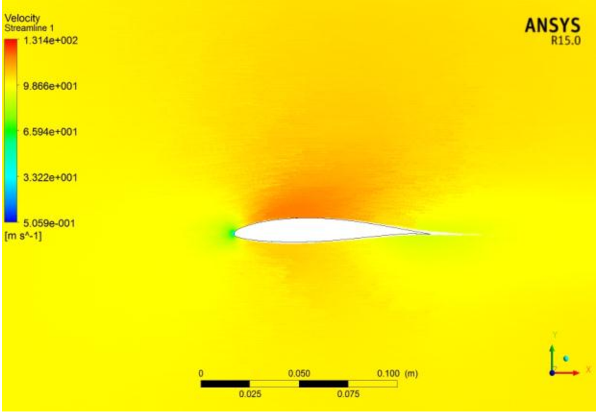


Fig streamline plot for triangular outward dimples

For normal wing profile:

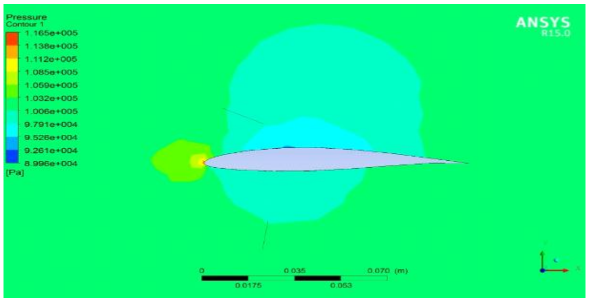


Fig pressure contour plot for normal wing

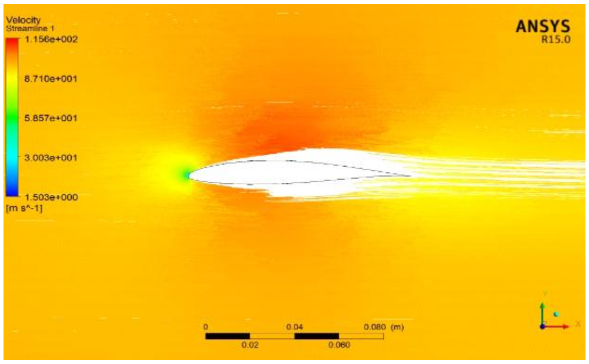


Fig streamline plot for normal profile

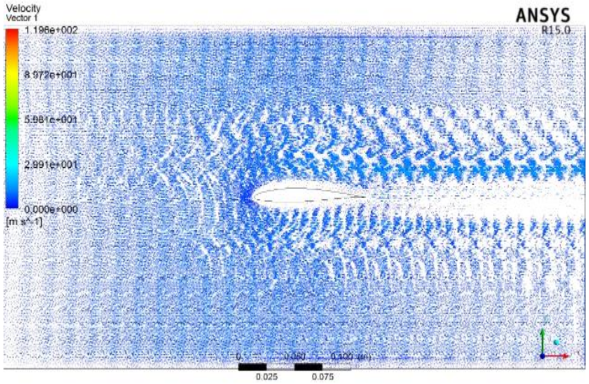


Fig. vector plot for normal profile

Tabulation from the analyzed results

Table. Outward dimple comparison of lift vs. velocity

Velocity	Diamond	Circular	Triangular
25	1.2929	1.29936	1.29172
50	5.15483	5.1485	5.17762
75	11.9558	11.576	11.5156
100	21.2587	21.1001	21.237
125	33.327	32.1069	32.1807
150	47.6759	46.1298	46.3541
175	65.5249	62.9133	63.2451
200	85.6715	82.1965	82.6495
225	108.515	104.011	104.667
250	133.972	128.333	129.34

Fig. comparison of lift vs. Velocity in outward dimples

Table. Outward dimple comparison of drag vs. velocity

Velocity	Diamond	Circular	Triangular
25	0.181601	0.185994	0.184494
50	0.663343	0.659584	0.668293
75	1.42169	1.41031	1.43014
100	2.44661	2.64132	2.47099
125	3.75594	3.69021	3.75216
150	5.31442	5.21159	5.29969
175	7.09565	6.97891	7.09623
200	9.17424	8.9775	9.15974
225	11.5053	11.1999	11.45
250	14.072	13.9866	14.337

Velocity	Normal	Di (in)	Cd (in)	Tri (in)	Di(out)	Cd(out)	Tri(out)
25	1.27189	1.2815	1.29033	1.30806	1.2929	1.29936	1.29172
50	4.93583	5.14417	5.14133	5.31224	5.15483	5.1485	5.17762
75	11.1061	11.6139	11.6128	12.0025	11.9558	11.576	11.5156
100	19.5524	20.5671	20.6805	21.4484	21.2587	21.1001	21.237
125	31.0971	31.8984	32.4816	33.5443	33.327	32.1069	32.1807
150	44.5735	45.9686	46.8644	48.3922	47.6759	46.1298	46.3541
175	60.9711	62.8072	63.8995	65.9696	65.5249	62.9133	63.2451
200	79.607	81.9319	83.6448	86.122	85.6715	82.1965	82.6495
225	101.214	103.654	106.339	109.199	108.515	104.011	104.667
250	123.028	127.895	128.59	133.525	133.972	128.333	129.34

Table3. Overall comparison of lift vs. velocity of all profile

Velocity	Normal	Di (in)	Cd (in)	Tri (in)	Di (out)	Cd (out)	Tri (out)
25	0.18123	0.182802	0.182824	0.181246	0.181601	0.185994	0.184494
50	0.468305	0.664273	0.659368	0.656806	0.663343	0.659584	0.668293
75	1.00744	1.40885	1.41648	1.41899	1.42169	1.41031	1.43014
100	1.69623	2.4328	2.45733	2.44273	2.44661	2.64132	2.47099
125	2.62688	3.68952	3.72308	3.71135	3.75594	3.69021	3.75216
150	3.6123	5.2478	5.28495	5.24881	5.31442	5.21159	5.29969
175	4.80877	6.97381	7.07641	7.02361	7.09565	6.97891	7.09623
200	6.20377	8.98672	9.134	9.05849	9.17424	8.9775	9.15974
225	7.71731	11.2453	11.4423	11.3478	11.5053	11.1999	11.45
250	9.7205	13.7516	14.0184	13.8592	14.072	13.9866	14.337

CONCLUSION

By analyzing different wing profiles, the calculation and the tabulation for different velocities for the different profile were taken out and plotted. From the overall plot it seems that the triangular inward dimples shows much more lift and less drag when compared with other design. So, the triangular inward dimple is the best shape to increase the lift in an aircraft wing. Therefore it require less runway for take-off an aircraft. That give approximately 12% of higher efficiency when compared with all designs.

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