INTERNATIONAL RESEARCH JOURNAL ON ADVANCED SCIENCE HUB
e-ISSN : 2582 - 4376
Open Access
RSP SCIENCE HUB
(The Hub of Research Ideas)
Available online at www.rspsciencehub.com

Special Issue of Second International Conference on Advancements in Research and Development (ICARD 2021)

Performance Improvement of Subsonic aircraft wing by Dimple Effect

Sivaraman S[1], Dr Ganesh M[2], Saravanan R[3], Saravanakumar[4]
[1,2,3,4]Assistant Professor, Dept. of Aeronautical Engineering, Hindusthan College of engineering and technology, Coimbatore, Tamilnadu, India.
sivaraman.aero@hicet.ac.in[1]

Abstract

Improving lift and drag ratio is the most important parameter that helps to improving the aerodynamic efficiency of the wing Vortex generators are used to delay flow separators for higher angle of attacks. Simple on surface of body tend provide vortex to delay flow separators and make boundary layer attached with the surface. NACA 0018 symmetrical aerofoil is considered for analysis of dimple in various position on the wing like leading edge, middle of the wing and end of the wing to predict optimum position. In that dimple in middle of the wing shows good improvement in delaying the flow separation this improves the lift to drag ratio compared to other position of the wing.

Keywords: Aerofoil, Effect of Dimple, Separation of Flow, Reduction in Stall, the Boundary layer.

1. Introduction

Aerodynamics is the important phenomenon for understanding the flow physics around the aerofoil or aircraft in the atmosphere. Lift to drag ratio is the important parameter that discuss about aerodynamic efficiency of wing and also measure the performance of the airplane. Improving lift to drag ratio is prominent airplane performance characteristics, whether it may be commercial or military aircraft. Reducing the fuel consumptions are a major factor always under consideration for the aerodynamic efficiency. Angle of attack is also an important parameter that helps to increase the lift to drag ratio. But When angle of attack is increased to certain level it will lead to stall of airplane wing. Because flow separation develops once the angle of attack increases beyond the stalling angle of the attack of airplane. For the improvement of lift to drag ratios, many devices are used. Slots are used in the leading edge of airfoils, for short take-off and landing of aircraft. Slots helps the flow in the suction side of airfoil to engine and airflow remain attack with surface of airfoil at higher angle of attacks. Dimples help remain attack with the surface of the airfoil. Dimples works a vortex generator by creating vortex generators by creating vortices that inturn creates the turbulence around the region. This turbulence helps flow remain attach with the surface by delaying flow separation and laminar boundary layer separation. At higher angle of attacks also dimples helps airfoils to by reducing drag production especially the pressure drag. By increasing the kinetic energy of the flow at various angle of attack. In this study, dimples are placed in the leading edge, middle of the wing, end of the wing to see which position is optimum for the efficient usage of the dimples parameters analysed by using streamline plots for understanding the boundary layer separation. Velocity and pressure plots also provide the parametric variation in along the suction side of the air foil.[1-8].

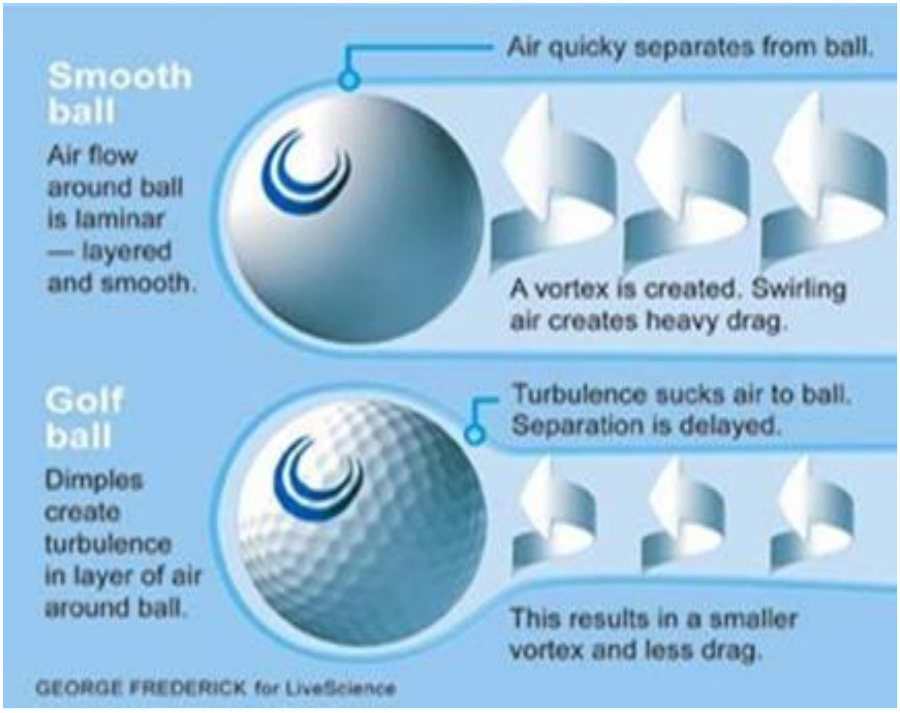


Fig.1: flow separation delay because of Golf ball dimple

2. Research Methodology

For the computational study of flow field around the dimpled airfoil. Dimples inspired by Golf balls are created on the suction side surfaces of the airfoil with diameter of 8mm placing at 40mm, 55 mm, 70 mm, 85 mm, from the leading edge of the airfoil. The computational domain is sub-divided into number of small element or cells called as grid. Structured and unstructured mesh. We can apply the unstructured mesh for our solution domain in ANSYS Meshing as shown in figure.4. Square mesh is created based up on the chord length of the airfoil for the laminar glow around the airfoil. Mesh size ranges from 0.513mm to 102.64mm. Mesh has the transition ratio of 0.77 with growth rate of 1.2 with 102076 nodes and 562699 elements.

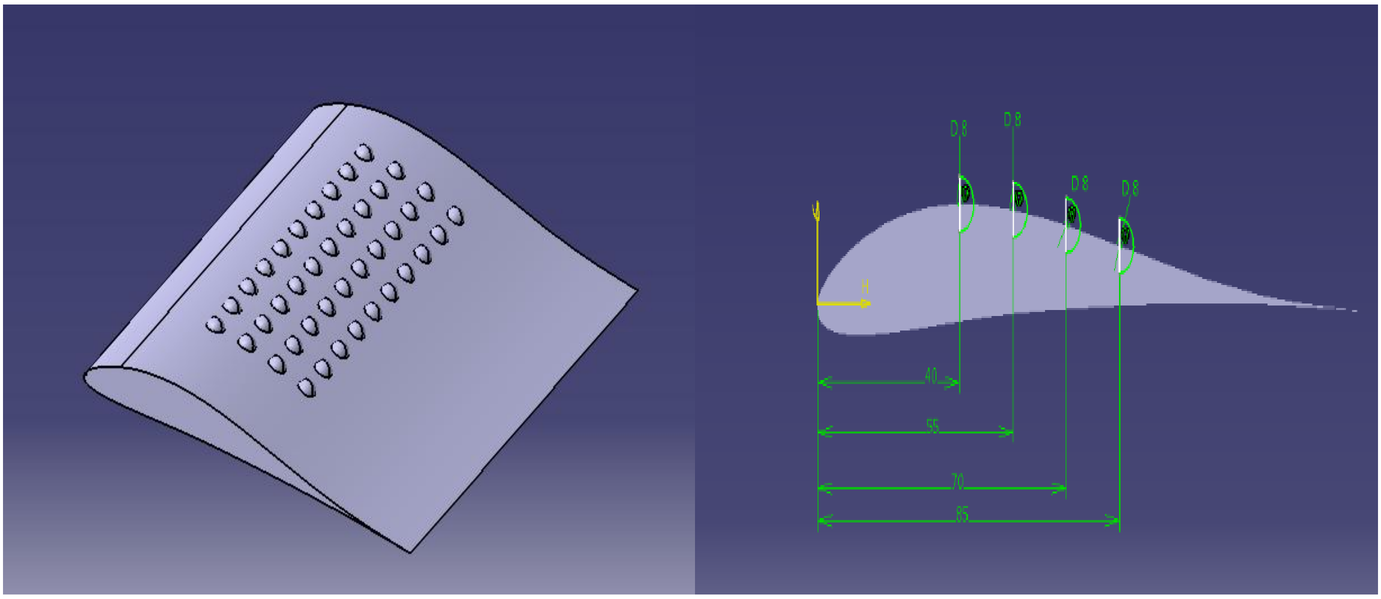


Fig.2: Outwardly Dimples

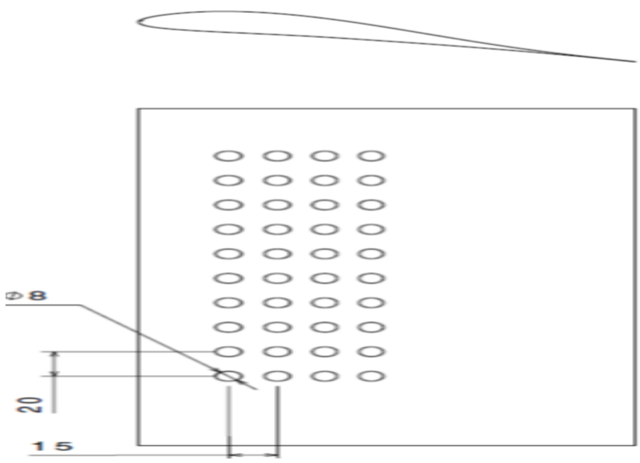


Fig.3: Airfoil Dimple dimensions

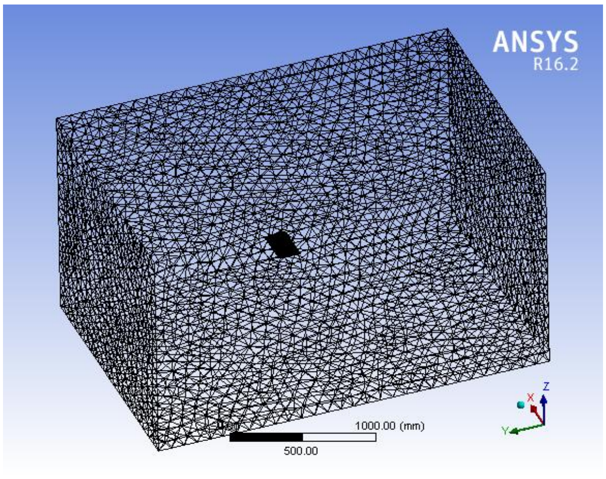
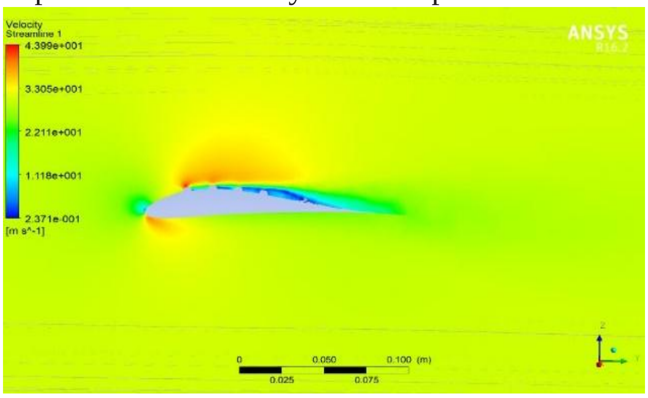


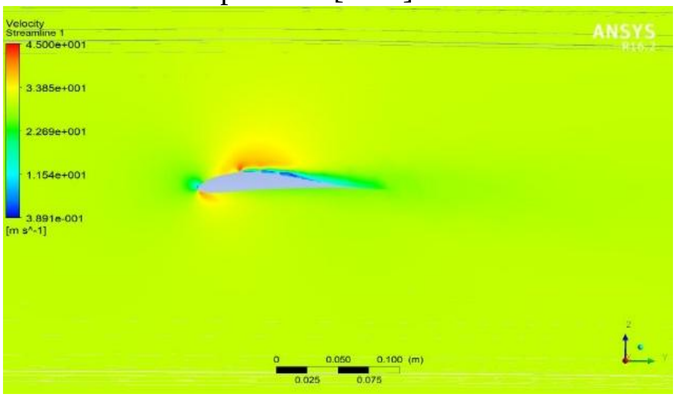
Fig.4: Mesh of the Domain

3. Results and Discussion

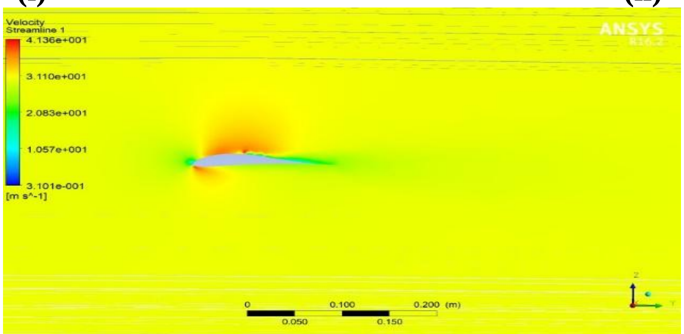
Dimples are created on the surface of the airfoil for the computational study to understand the lift/ drag ratio for the improvement of aerodynamic efficiency of airfoils for the adverse flight conditions. To stimulate flow around the airfoil velocity 30m/s is given to the inlet of the domain with subsonic flow regime for the density-based analysis. Outlet of the domain is with the pressure outlet and wall conditions are initiated with no slip wall and smooth wall in the Ansys fluent. In-order to predict the boundary flow K epsilon turbulence model is chosen. Dimple are arranged on the airfoil leading edge/ middle of flowing edge to see the variation of lift to drag ratio along the length of airfoil. In the velocity stream lines of airfoil positions shows the more reduction in the suction side of airfoil because of dimples present in the leading edge. In the end of wing the because of creation vortex in dimple affects flow to be laminar. In the middle of the wing presence of the dimple has created vortex that energize the flow and make flow to be laminar thus in turn reduces the flow separation.[9-12]



(i)

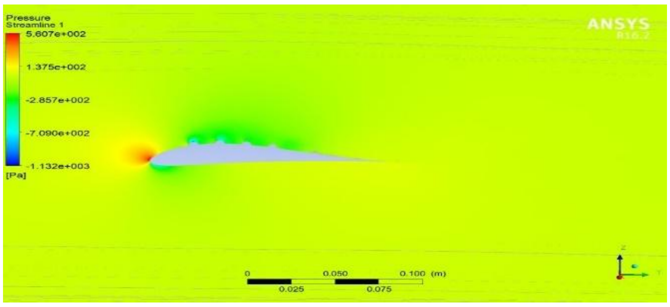


(ii)

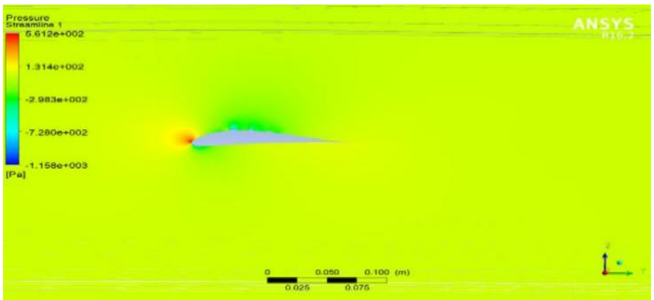


(iii)

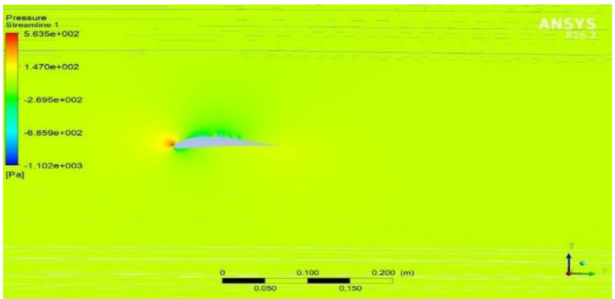
Fig.5: Velocity profile of Dimples of
(i) leading ledge of the Wing (ii) Middle of the wing (iii) Trialling edge of the wing



(i)



(ii)



(iii)

Fig.6: Pressure profile of Dimples of (i) leading ledge of the Wing (ii) Middle of the wing (iii) Trialling edge of the wing

Variation of pressure in the above figure shows that increased pressure value in the profile where the dimples are presented on the leading edge and in the end of wing. Expansion of pressure is shown in the dimple present in the middle of the wing. Due to the expansion of pressure flow regime tends to be more laminar thus in turn delay the flow separation. Lift and drag values calculated for the different positions of dimples on the airfoils shows percentage of drag reduction is more on the dimples present in the middle of the wing. It has capability to reduce or delay the flow separation by the boundary layer.[11-16].

Table No.1 Lift and drag forces of the a Airfoil

Dimple position	Lift	Drag
Leading Edge	0.0293	0.594
Middle	0.02579	1.1009
End	0.044	0.3649

Conclusion

Dimples on surface of the wings are having more beneficiary interms of reducing the flow separation in various angle of attacks. Position of dimples on the surface of the wings has a significant effect in terms of reducing drags. Here three positions chosen to study flow separations effects on the airfoil. In leading edge of the airfoil dimples has created a adverse pressure gradient that didn't help the airflow to energize itself nor the time given for the natural adaption of flow. In the endof the airfoil flow separation already initiated in top suction side of the airfoil so therefore energizing the flow is become too difficultonce vortex created because of flow separation Therefore position of dimples in the middle of the wing has the ability to reduce the flow separation this ability is clearly shown in the calculation of lift and drag forces.

References:

[1]. Bogdanovic-Jovanovic, B. Jasmina Zivojin M. Stamenkovic and Milos M. Kocic, 2012 “Experimental and Numerical Investigation of flow around a sphere with dimples for various flow regimes,” Thermal Science, Vol.16, No.4, pp.1013-102.

[2]. Channu Raju and P.R. Viswananth, 2001 “Base Drag Reduction Caused by Riblets on a

GAW Airfoil", Vol. no.6 of the Journal of Aircraft: Engineering notes.

[3]. Jeffrey Ryen Kensrud, Colin Smith., August 20 10 "Determining dimple aerodynamic of Sports Balls in SITU" The University of the State of Washington.

[4]. Guglienla. J and Michael S. Selig, July-August 1996 "Span Wise Variation in Profile Drag for Aerofoils at Low Reynolds Number", Journal of Aircraft at Vol.33, No.4.

[5]. Guglielmo. N, K.M. Butter, 1984 "Span wise variation in profile drag for aerofoil at low Reynolds number", in Improvement Of Aerodynamic performance through Boundary Layer Control and High Lift Systems, Bussels, Belgium pp-1-1-26.

[6]. Colin Smith, Jeffrey Ryen Kensrud., August 2010 "Determining dimple aerodynamic of Sports Balls in SITU" Washington State University

[7]. Frank K. Lu and Adam J. Pierce, January 2011 "Review of Micro Vortex Generators in High Speed flow", 49th AIAA Aerospace Sciences meeting including the New Horizons forum and Aerospace Exposition 4-7, Orlando, Florida

[8]. Guglienla. J and Michael S. Selig, July-August 1996 "Span Wise Variation in Profile Drag for Aerofoils at Low Reynolds Number", Journal of Aircraft at Vol.33, No.4.

[9]. E. Livya, G. Anitha and P. Valli, "AerodynamicAnalysis of Dimple Effect on Aircraft Wing",International Journal of Mechanical,Aerospace,Industrial, Mechatronic and Manufacturing Engineering, Vol:9, No:2, 2015.

[10]. Prasath. M.S and Irish Angelin. S., "Effect of Dimples on Aircraft Wing", GRD Journals-Global Research and Development Journal for Engineering, Volume 2, Issue 5, April 2017, ISSN: 2455-5703

[11]. Amit Kumar Saraf, Dr. Mahendra Pratap Singh and Dr. Tej Singh Chouhan, "Effect of Dimple on Aerodynamic Behaviour of Airfoil", International Journal of Engineering and Technology (IJET), Vol 9, No 3, Jun-Jul 2017, ISSN (Print): 2319-8613 ISSN (Online): 0975-4024

[12]. Eusebious T. Chullai, Jasdeep Singh, Anshul Chandel and Umang Singhal,"Effect of V-shaped Dimples on NACA 0012 airfoil", (07-07-2019)

[13]. Vishal Kaushik, Manoj Mahore, Sandeep Patil, "Analysis of Dimpled Wing of an Aircraft", IJEDR 2018, Volume 6, Issue 3, ISSN: 2321-9939.

[14]. Deepanshu Srivastav," Flow Control over Airfoil using Different Shaped Dimples", 2012 International Conference on Fluid Dynamics and Thermodynamics Technologies (FDTT 2012), IPCSIT vol.33(2012), IACSIT Press, Singapore.

[15]. Somanagoud Biradar, Anandkumar S Malipatil," CFD Analysis of Dimple Effect on Airfoil NACA 0015", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 5, Issue IX1sxcn ,September 2017.

[16]. Saravanan R, Sharu sri K, Sundareswaran E, Vyshanavi Krishnamoorthy Sri Balaji S "Numerical Analysis of dimple effect on Aifoils for varied AOA" International research Journal of Advnaced science hub, Volume 02 issue 10s October 2020.