Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11 – 13 December, 2019, Chittagong, Bangladesh

ICMERE2019-PI-168

A REVIEW OF DIFFERENT SHAPED DIMPLE EFFECTS ON AEROFOIL SURFACES

Sourav Paul[1*], Aoyon Paul[1], Farida Ahmed Koly[1]

[1]Department of Mechanical Engineering, CUET, Bangladesh
sourav@cuet.ac.bd[1*],aoyonpaul@gmail.com[2], faridakoly@gmail.com[3]

Abstract-: *Good aerodynamics characteristic means the improved lift force and less drag force in the body. It also implies better stall angle phenomena. An airfoil is a stream lined body. If the surface containing dimples shows greater aerodynamic characteristic than a plane airfoil. Imposing dimples on airfoil surface create turbulence by creating vorticities which delays the boundary layer separation. And resulting in decrease of pressure drag and increase in the angle of stall. The cross section of the dimples can be semi-spherical, v shaped, square shaped, rectangular shaped, hexagonal shaped. In this paper a review of all kind of dimples effect on airfoil surface are shown in a sequential manner with respect to different angle of attack (AOA).*

Keywords: Airfoil, Angle of attack, Boundary layer separation, Dimple, vorticities

1. INTRODUCTION

Cross section of an aerodynamic wing is called airfoil. This wing can be a wing of airplane wing, turbine, helicopter blade or rotor. This part basically flies with the support of air in atmosphere. Improving aerodynamic efficiency means the improvement of L/D ratio is one of the vital key point to make the aircraft more maneuverable [1]. Aerodynamic characteristics can be improved by focusing on reducing the drag force and the increasing the lift force [2]. This purpose can be served by mating modifications on the surface of airfoil. This modification can be different types. Implementation of flaps and static extended trailing edge show greater lift force improvement at greater angle of attack [3]. Moreover, implementation of dimples on the surface is also very popular modification on airfoil surface. Dimples are of different shapes and sizes. This can be imposed at different position and in different numbers on the surface which shows different lift force improvement and drag force reduction. The concept of dimples basically originated from golf ball. The flows of air over the dimple delay the flow separation point by creating turbulent boundary layer [4-5]. A review on all kind of effects of different kinds of dimple on different position on the surface of the airfoil is demonstrated in this paper.

Fig. 1.1: Golf ball [6]

2. REVIEWS ON DIMPLE EFFECTS

E. Livya, G. Anitha, P. Valli said on his paper that to reduce the takes off distance of the aircraft by generating adequate lift with minimum drag at low velocity was one of the major objectives. Investigation of dimple impact on airplanes wing using NACA 0018 airfoil carried out by modifying the airfoil surface. Semi sphere, hexagon, cylinder, square shaped dimples were introduced on the airfoil surface. Investigation showed in fig. 2.1 and fig. 2.2 that inward semi spherical dimple improved aerodynamic efficiency and reduced drag. For 20° angle of attack C_L increased 750% and C_D decreased 694.12% with respect to plane airfoil. In this investigation 30m/s and 60 m/s were inlet velocity of the air. [7]

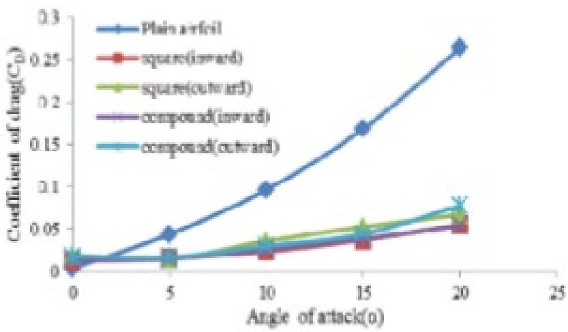

Fig. 2.1: C_D Vs AOA for NACA0018 [7]

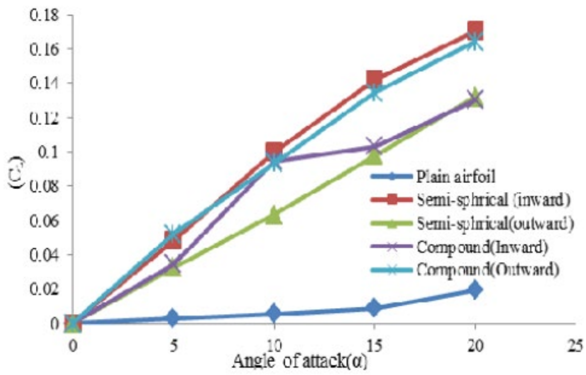

Fig. 2.2: C_L Vs. AOA for NACA0018 [7]

Prasath. M.S and Irish Angelin. S. investigated on NACA 0018 by creating 13 dimples located at 40% of chord length on both surfaces. Inlet velocity taken for this experiment were 18m/s and 33m/s. They have found that flow separation takes place at 10° angle of attack in the regular airfoil surface. But flow separation occurs at 15° angle of attack for surface having dimple.[8]

Amit Kumar Saraf, Dr. Mahendra Pratap Singh and Dr. Tej Singh Chouhan shared their article on Effect of dimple on aerodynamic behavior of airfoil in International Journal of Engineering and Technology (IJET). NACA 0012 non cambered airfoil has been used for their investigation. Dimple has been introduced on the smooth airfoil at 10%, 25%, 50% and 75% of chord length. Inlet velocity of air was chosen 7.3 m/s and density was 1.225kg/m3. For 75% of chord length, they have found that co- efficient of lift (C_L) has been increased about 7%. And co-efficient of drag (C_D) has been decreased by 3%, compared to smooth airfoil. Finally, they concluded that, airfoil having dimple at 75% of chord length is the best compared to others.[9]

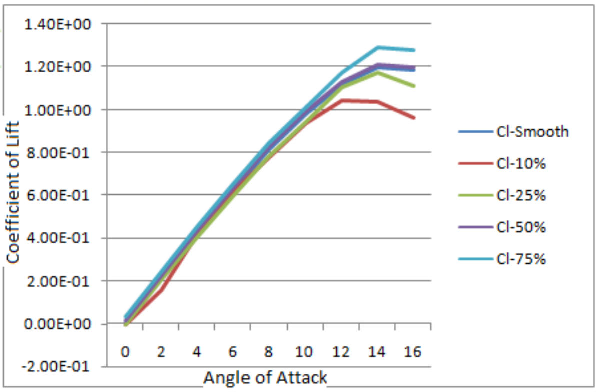

Fig. 2.3: C_L Vs. AOA [9]

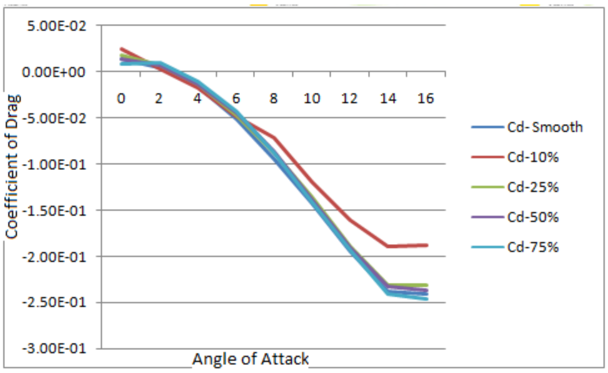

Fig. 2.4: C_D Vs. AOA [9]

Eusebious T. Chullai, Jasdeep Singh, Anshul Chandel and Umang Singhal presented a research paper on effects of V-shaped dimples on NACA 0012 airfoil. The whole experiment has been conducted by simulation software called ANSYS. They have created V shape dimple at 80% of chord length of smooth airfoil. Inlet air velocity was taken as U_x =43.822 m/s. Aerodynamic efficiency has been increased by 13.25%, 47% and 18.24 % respectively for 14°,16°,18° angel of attack.[10]

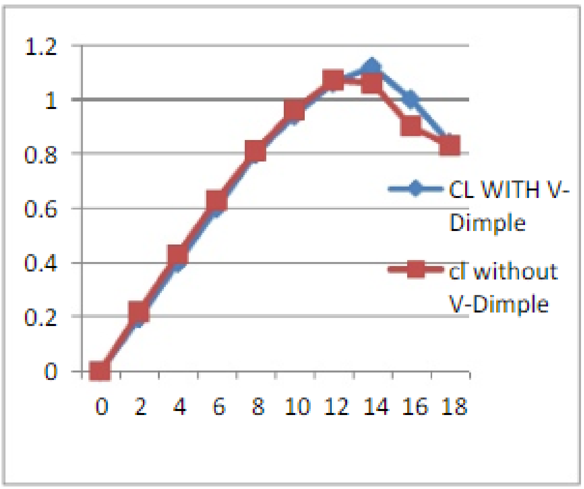

Fig. 2.5: C_L Vs. AOA [10]

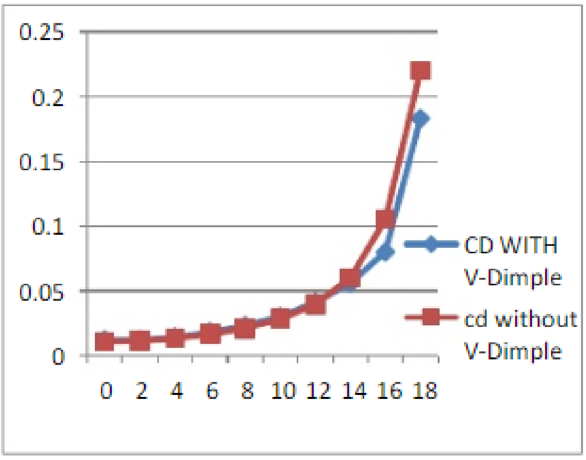

Fig. 2.6: C_D Vs. AOA [10]

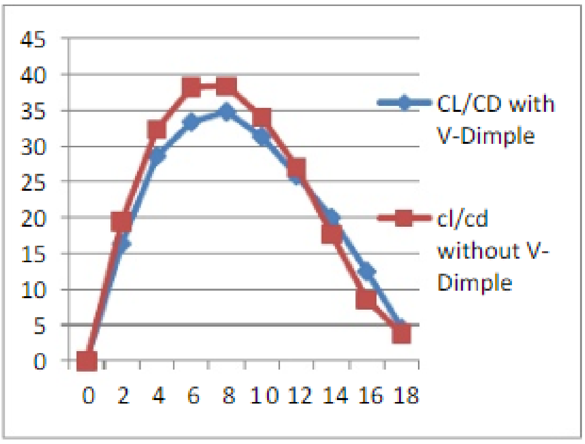

Fig. 2.7: C_L/C_D Vs. AOA [10]

Rubiat Mustak, MD. Nizam Uddin and Mohammad Mashud investigated on airfoil NACA 4415.They have found that, flow separation takes place at 12° angle of attack for smooth airfoil surface. On the other hand, surface having dimple, flow separation occurs at 16° angle of attack. For 10° angle of attack C_D decreased for surface having outward dimple 26.92% and 11.54% for inward dimple, compared to smooth airfoil surface. For the same angle of attack C_L increased for surface having outward dimple 5.66% and 10.38% for inward dimple with respect to smooth surface.[11]

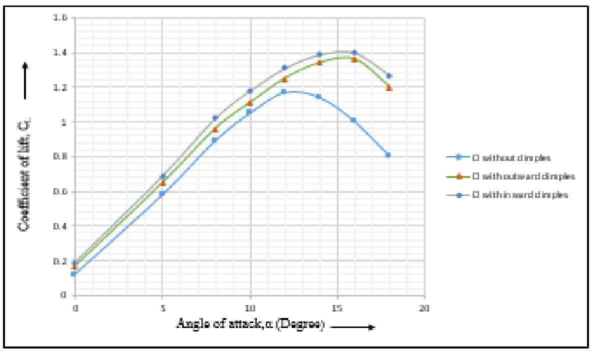

Fig. 2.8: C_L Vs. AOA [11]

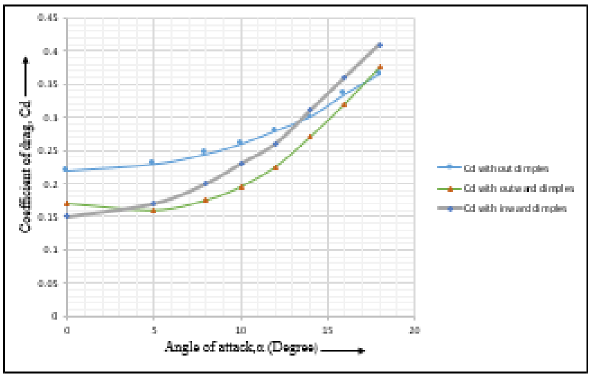

Fig. 2.9: C_D Vs. AOA [11]

Vishal Kaushik, Manoj Mahore, Sandeep Patil have taken NACA 0018 for the investigation. Dimple has been introduced on the airfoil surface at 40% from the leading edge. At 10° angle of attack, surface having inward dimple C_L has been increased 28.57%. C_D also increased about 4.08% at same angle of attack. For outward dimple C_L and C_D decreased respectively 14.29% and 12.24%. Here all data are compared with the airfoil surface having no dimple. [12]

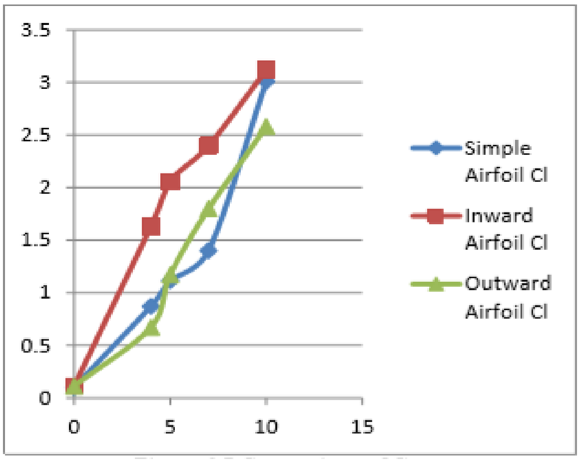

Fig. 2.10: C_L Vs. AOA [12]

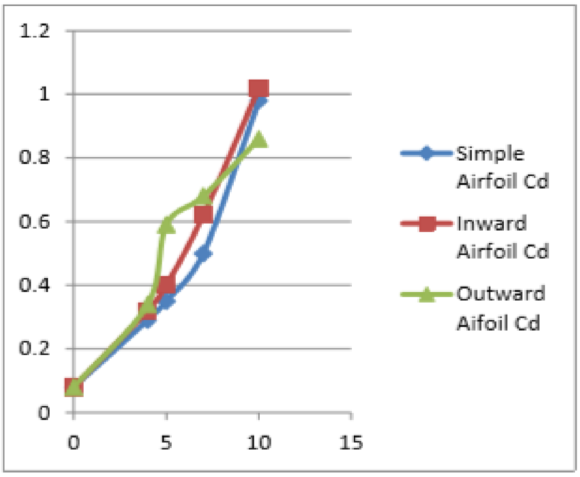

Fig. 2.11: C_D Vs. AOA [12]

Deepanshu Srivastav in 2012 published his research paper on Flow Control over Airfoils using different Shaped Dimples in International Conference on Fluid Dynamics and Thermodynamics Technologies. NACA-0018 was chosen for this study. Investigation was carried out at 0,5,10,15,20 degrees AOA by considering subsonic flows. At 15 AOA C_D increased 5.88% for surface having inward dimple and decreased 8.82% for surface having outward dimple, with respect to plain surface. From this result, he concludes that outward dimples are more suitable for less drag at positive AOA. At 20 AOA, for outward dimples C_D decreased 2.5% for surface having composite shaped (leaf like dome shape) dimple and increased 7.5% for round shaped (semi-hemispherical) dimple. Also, C_L increased 109.52% for round shaped dimple and 166.67% for the surface having round shaped dimple. Aerodynamic efficiency is increased about 98.47% for round shaped dimple and 71.76% for composite shaped dimple.[13]

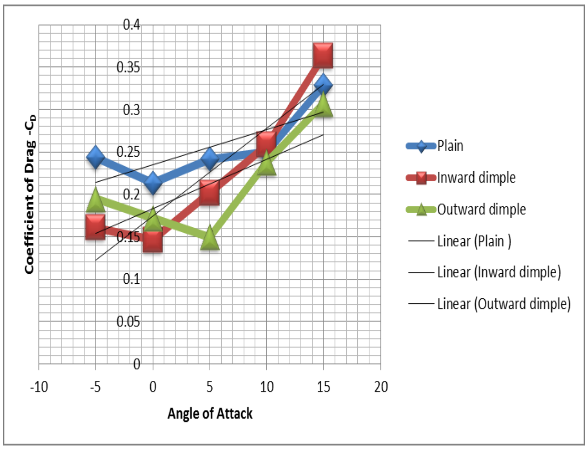

Fig. 2.12: C_D Vs. AOA for different configurations [13]

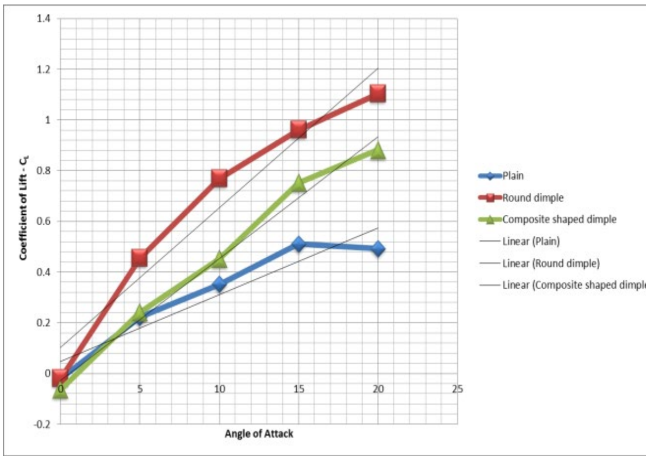

Fig. 2.13: C_L Vs. AOA for different configurations [13]

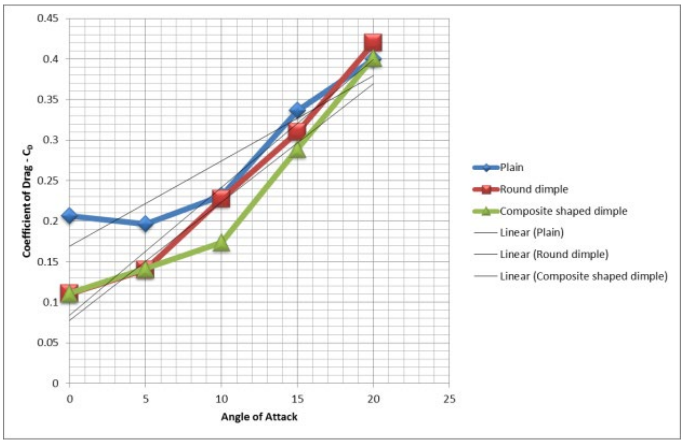

Fig. 2.14: C_D Vs. AOA for different configurations [13]

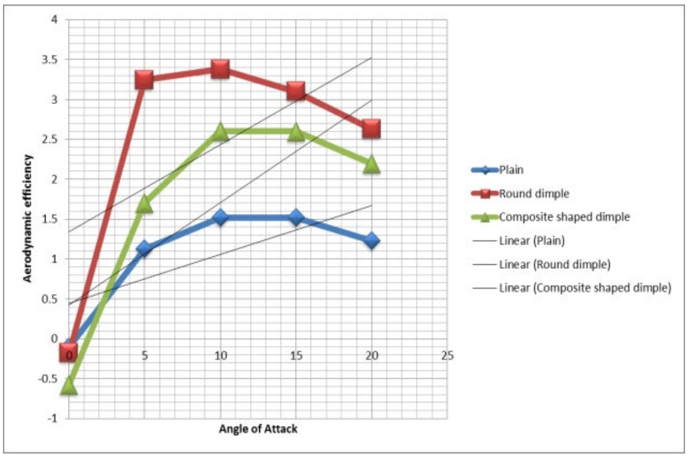

Fig. 2.15: L/D ratio Vs. AOA for different Configurations [13]

Somanagoud Biradar, Anandkumar S Malipatil in 2017 presented their research paper on CFD analysis of Dimple Effect on Airfoil NACA 0015 in International Journal for Research in Applied Science & Engineering Technology. 17 m/s air velocity was taken for numerical analysis. Investigations were carried out for 0° AOA for 8 different positioned dimples on the airfoil surface. At 0° AOA C_L is increased 0% compared to the surface having no dimple. But C_D is increased in the surface having dimple compared to the plain airfoil.[14]

3. CONCLUSION

From the above review study it is completely clear that implementation of dimples on any airfoil surface at any position and of any cross sectioned have great positive effects on the aerodynamic characteristics. The science behind the reason is that dimples delay the separation of flow which increases the lift coefficient and lesser the drag coefficient. It also improves the stall angle effect. But improvement is limited for a certain angle of attack, which is still now a great field of future study.

6. 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 aerofoil”, Journal of Aircraft Vol.No.6: Engineering Notes.

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

[4] 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

[5] 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.

[6] https://www.google.com/search?safe=active&tbm=isch&sxsrf=ACYBGNS2f6ugpiFGU7uO4liVIOcIhhNUtA:1572240117067&q=golf+ball&backchip=g_1:cartoon:nPrIpTa3hng%3D&chips=q:golf+ball&usg=AI4_-kSKtO0HtXmVMdX6aw2iMQRKFuzgsg&sa=X&ved=0ahUKEwijsrftmr7lAhWMknAKHWk4BAIQ3VYIKCgA&biw=1366&bih=608&dpr=1#imgrc=PrBWn77smulNKM: (26-10-2019)

[7] 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.

[8] 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

[9] 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

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

[11] Rubiat Mustak, MD. Nizam Uddin and Mohammad Mashud,” International Conference on Mechanical Engineering and Renewable Energy 2015 (ICMERE2015)”, ICMERE2015-PI-230, 26 – 29 November, 2015.

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

[13] 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.

[14] 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 IX,September 2017.

8. NOMENCLATURE

Symbol	Meaning	Unit
AOA	Angle of Attack	Degree(º)
C_L	Coefficient of lift	Dimensionless
C_D	Coefficient of drag	Dimensionless
NACA	National Advisory Committee for Aeronautics	Dimensionless