IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 7.105 ⁜ Vol. 9, Issue 8, August 2022

DOI: 10.17148/IARJSET.2022.9825

Analysis on Aircraft Wing

Dr. S.R.Patil[1], Rupashree Gajbe[2], Gauri Sakhare[3], Pratiksha Shinde[4], Prajakta Shinde[5]

Professor, Mechanical Engineering, AISSMS COE, Pune[1]

Student, Mechanical Engineering, AISSMS COE, Pune[2,3,4,5]

Abstract: This workflow includes study of airfoils for BOEING 737, NACA 2412, EPPLER 1098. Wings are created using these airfoils. This consists of a CAD model of the wing with and without dimples which are prepared using Solidworks and its analysis is done in Ansys fluent. Computational Fluid Dynamics [CFD] is carried out on all three wings with the boundary conditions as the original.

Keywords: Airfoil, BOEING 737, NACA 2412, EPPLER 1098, Dimples

I. INTRODUCTION

Aerodynamics focuses on interaction of air with moving bodies. It mainly focuses on the forces of drag and lift, which is the result of air passing over and around solid bodies. The most important effects to be considered during designing an aircraft are the inflow of air over the airfoils, bullet sport vehicles or any other aerodynamic objects. Wings are defines as the airfoils that, when moved rapidly through the air, create lift. A cross-sectional shape of a wing or a blade of a propeller, rotor, or turbine is defined as an airfoil. When an airfoil-shaped body moves through any medium such as air or fluid it produces an aerodynamic force. Lift is considered as the vertical element to the direction of stir of this force and drag is the resemblant element to the direction of stir of this force.
An airfoil is a plane form designed to achieve lift from the air through which it moves. Consequently, any part of the plane that converts air resistance to lift is an airfoil. The airfoil choice significantly effects the performance and flying characteristics of the airplane and should be made carefully. Choosing an airfoil to maximize performance while the flight regime will usually hurt performance in another. For example, choosing an airfoil with very high maximum lift to get a low stall speed will usually causes increased cruise drag. It mile's very important that the airfoil should be selected on the basis of project of the plane. Some important points to be considered for the selection are-

1. Camber 2. Thickness-to-chord ratio (T/C)
3. Angle of attack (AOA) 4. Lift 5. Drag

Wings are airfoils that creates lift when moved rapidly through the air. They are constructed in many shapes and sizes. Fig. 1.1 shows the simple BOEING 737 cad model. Wing design can change to meet certain desirable flight characteristics. Control at various operating speeds, the amount of lift generated, balance, and stability all changes as the shape of the wing is altered. Fig. 1.2 shows the cad model of NACA 2412 which is modeled in Solidworks while fig. 1.3shows CAD model of EPPLER 1098.

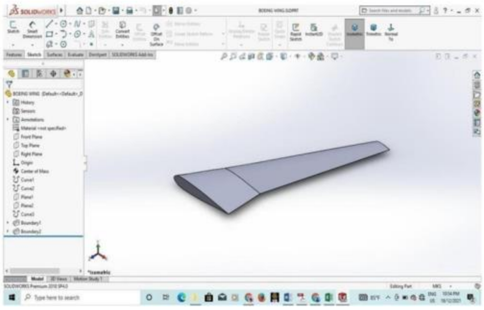


Fig. 1.1 CAD Model of BOEING 737 wing

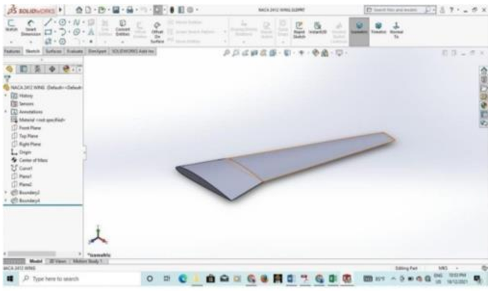


Fig. 1.2 CAD Model of NACA 2412 wing

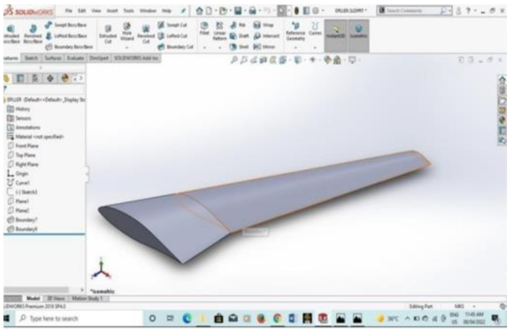


Fig. 1.3 CAD Model of EPPLER 1098 wing

II. ANALYSIS

Ansys is used for CFD analysis of wings of the aircraft. Here the CFD is done on the wings of the aircraft without dimples and later CFD is done on the wings with dimples. Various forces are determined from this which will help to study the effects with and without dimples.

1. BOEING 737

Figures below show different stages in the CFD of the wing. Firstly fig. 2.1(a) shows the CAD model of Boeing 737 while the mesh generation on the wing is shown in fig. 2.1(b) after mesh generation, the model is taken into Ansys solversoftware to analyze contours of static pressure and velocity. Further the result of velocity contour of the Boeing 737 wing is shown in fig. 2.1(c) and pressure contour is shown in fig. 2.1(d).

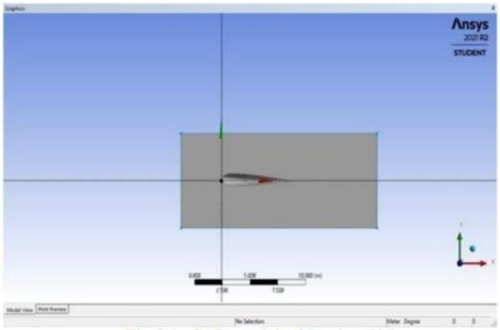


Fig 2.1. CAD model of Boeing 737

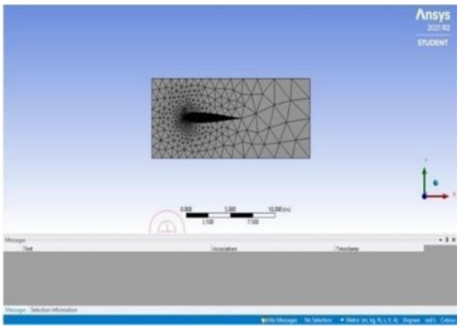


Fig 2.2. Mesh generation on Boeing 737

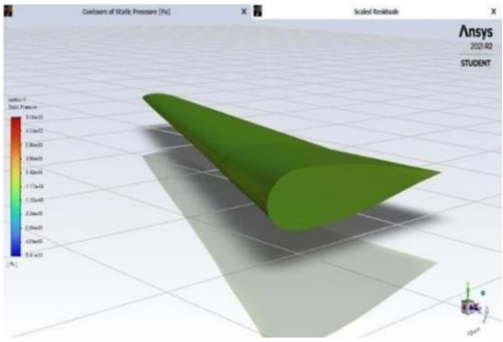


Fig 2.3 Contours of static pressure for Boeing737

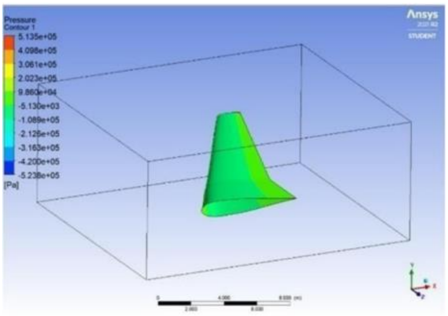


Fig 2.4. Pressure contours for Boeing 737

2. NACA 2412

The same process was followed for the CFD on NACA 2412. The obtained results are as shown by the figures below. Fig. 2.2(a) shows the geometry of NACA 2412 wing while fig. 2.2(b) explains the mesh generation. Afterwards fig. 2.2(c) shows static pressure contour results on Ansys solver and fig. 2.2(d) shows the results for pressure contour on NACA 2412.

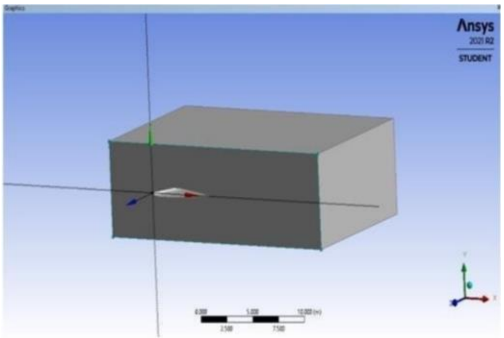


Fig 2.2(a) Geometry of NACA 2412 wing

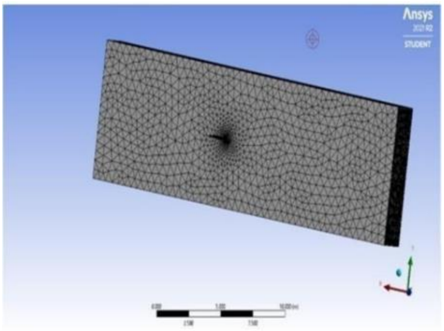


Fig 2.2(b) Mesh generation on NACA 2412 wing

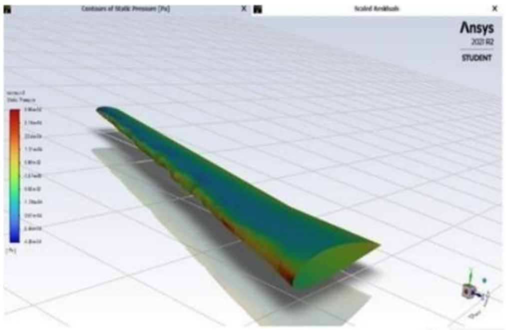


Fig 2.2(c) Static pressure contour on NACA 2412 wing

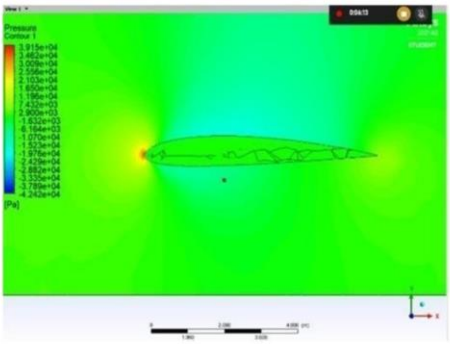


Fig 2.2(d) Pressure counter on NACA 2412 wing

3. EPPLER 1098

The process of CFD is followed for EPPLER 1098. Here, fig. 2.3(a) shows the geometry of EPPLER 1098 while fig 2.3(b) shows mesh generated on EPPLER 1098. Fig. 2.3(c) shows static pressure contour on EPPLER 1098 and fig. 2.3(d) shows results for pressure contour on EPPLER 1098.

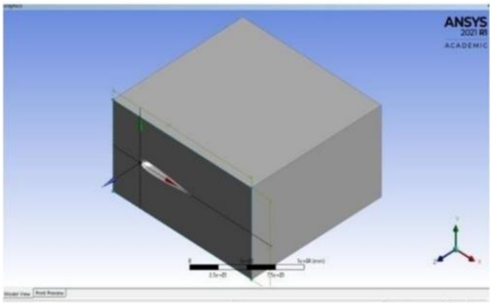


Fig 2.3(a) Geometry of EPPLER 1098 wing

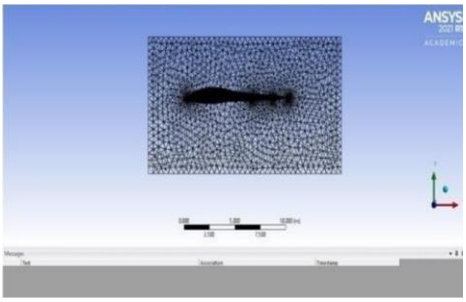


Fig 2.3(b) Mesh generation on EPPLER 1098 wing

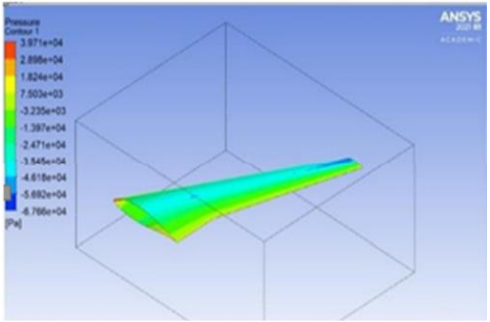


Fig 2.3(c) Static pressure contour EPPLER 1098 wing

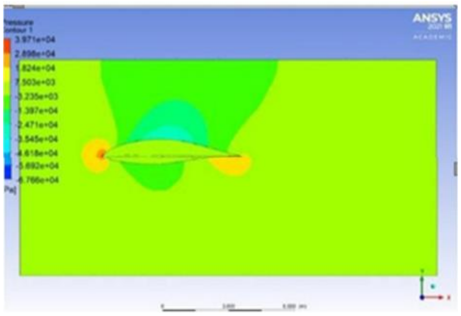


Fig 2.3(d) velocity contour on EPPLER 1098 wing

Table I shows the lift forces on wings in absence of dimples at different AOA i.e Angle of Attack while table II shows drag forces on the wings considering different angle of attack. Table III compares the lift to drag ratio of these wings atthat angle of attacks.

TABLE I COMPARISON OF LIFT FORCE ON WINGS

Sr. No	ANGLE (degree)	BOEING 737(N)	NACA 2412(N)	EPPLER 1098(N)
1	0	3.12E+05	5.34E+05	1.35E+06
2	2	8.34E+05	9.24E+05	1.87E+06
3	4	1.25E+06	1.34E+06	2.35E+06
4	6	1.47E+06	1.75E+06	2.78E+06
5	8	1.92E+06	2.01E+06	3.09E+06
6	10	2.01E+06	2.12E+06	3.27E+06
7	12	2.68E+06	3.32E+06	3.32E+06

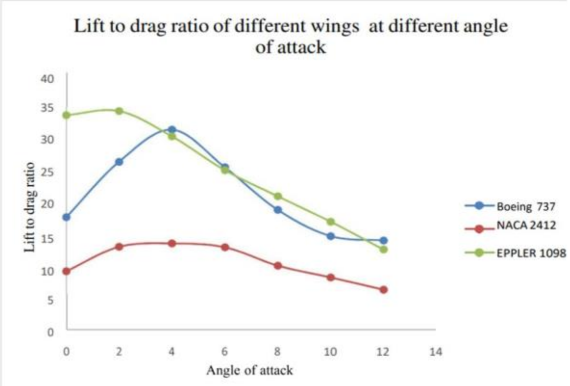
TABLE II COMPARISON OF DRAG FORCE ON WINGS

Sr. No	ANGLE (degree)	BOEING 737(N)	NACA 2412(N)	EPPLER 1098(N)
1	0	17855	58557	36366
2	2	32003	71668	49043
3	4	40299	1.03E+05	70382
4	6	58456	1.36E+05	98653
5	8	1.03E+05	2.01E+05	1.36E+05
6	10	1.38E+05	2.68E+05	1.84E+05
7	12	1.93E+05	3.68E+05	2.77E+05

TABLE III COMPARISON OF LIFT TO DRAG RATIO ON WINGS

Sr. No	ANGLE (degree)	BOEING 737(N)	NACA 2412(N)	EPPLER 1098(N)
1	0	17.47	9.11	33.27
2	2	26.06	12.90	33.91
3	4	31.02	13.42	29.99
4	6	25.21	12.83	24.76
5	8	18.62	9.99	20.72
6	10	14.56	8.17	16.79
7	12	13.88	6.27	12.49

The graph 1 shows the changes in lift to drag ratio at different angle of attacks. For BOEING 737 lift to drag ratio increases up to particular angle called stall angle then goes on decreasing with increase in angle of attack.



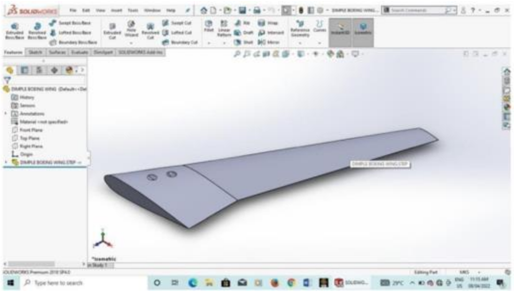
Graph 1. Lift to drag ratio of different wings at different angle of attack

III. DIMPLES

The main objective of aircraft aerodynamics is to enhance the aerodynamic characteristics of the aircraft. This enhancement includes the reduction in drag and stall phenomenon. The airfoil with dimples has relatively lesser drag in comparison to plain airfoil. Introducing dimples on the aircraft wing will create turbulence by creating vortices which is useful to delay the boundary layer separation. This results in decrease of pressure drag and also increase in the angle of stall.

The idea of dimples came from golf balls. Golf balls have inner impressions in the form of dimples on their outer surfaces. These dimples on the golf balls to reduce drag. Drag is resisting force from air. A liquid streaming over a protest tends to drag the question along its stream bearing. A question going through a liquid which is stationary there is a propensity to back the protest off. For a stationary question in a liquid which is streaming there is an inclination to move the protest in the liquid streaming heading. Those propensities of streaming liquid is known as drag. While traveling through air planes additionally subjected to a few drags. As dimples reduce drag of golf balls they can be beneficial in reducing wing drag. That grew the attention of several researchers about dimples.

There were a lot of experiments and numerical investigations conducted by several researchers around the world on the dimpled effect on airplane wings. Fig. 3.1 shows the wing of a Boeing 737 with dimples. Fig 3.2 shows the wing of NACA 2412 with dimples while Fig 3.3 shows the wing of EPPLER 1098 with dimples.



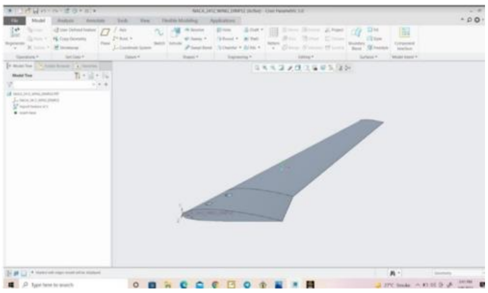
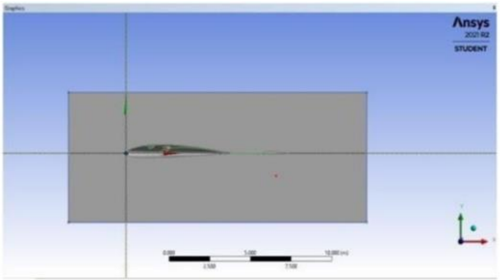


Fig 3.1. Wing of Boeing 737 with dimples Fig 3.2 Wing of NACA 2412 with dimples

To analyze the difference between results of wings without dimples and wing with dimples the CFD is done on the wings with dimples. Here the CAD model for the wings with dimple is created using Solidworks and the CFD is done using Ansys. Fig. 3.2(a) shows geometry for dimpled NACA 2412 wing fig. 3.2(b) shows mesh generation on the wing. Fig 3.2(c) shows static pressure contour results on dimpled NACA 2412 while fig. 3.2(d) shows the result for pressure contour on NACA 2412 wing with dimples.



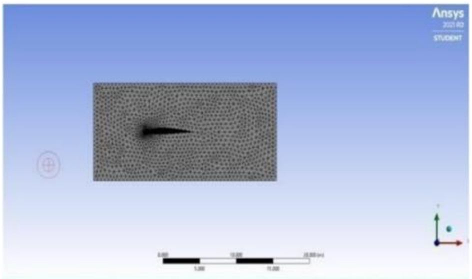
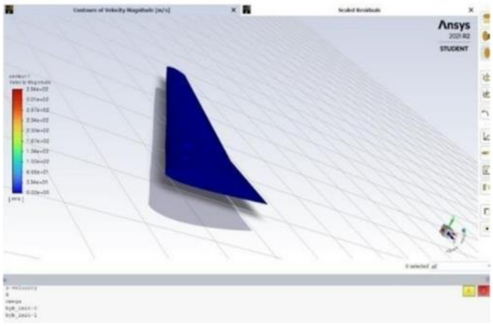


Fig. 3.2(a) Geometry of NACA 2412 with dimple Fig. 3.2(b) Mesh generation NACA 2412 with dimple



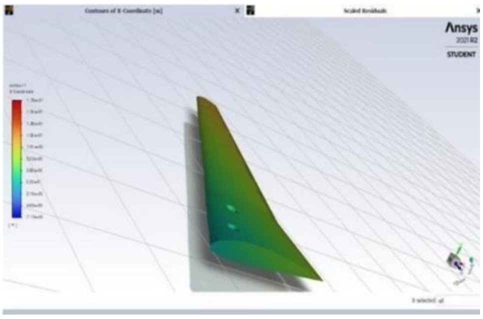


Fig. 3.2(c) Static pressure contour for NACA 2412 with dimples Fig. 3.2(d) Pressure contour on NACA 2412 with dimples

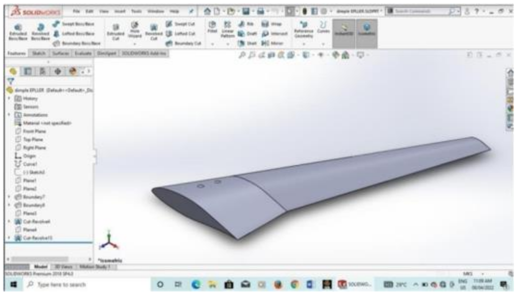


Fig 3.3 Wing of EPPLER 1098 with dimples

The CFD is done on the wing EPPLER 1098 with the dimple. The CAD model of wing with dimple is created using Solidworks and the CFD is done in Ansys Fluent. Fig. 3.3(a) shows the geometry of EPPLER 1098 while the mesh generation is shown in the fig. 3.3(b) The Static pressure contour can be explained using fig 3.3(c) and fig. 3.3(d) showsthe results of pressure contour.

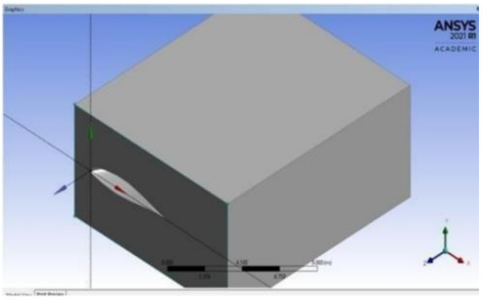


Fig 3.3(a) Geometry of EPPLER 1098 with dimples

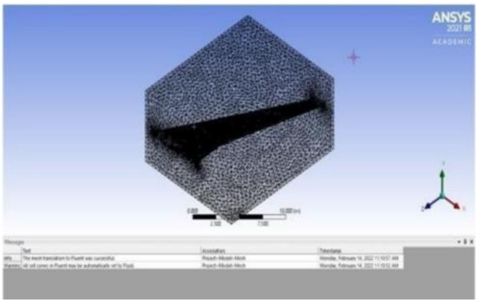


Fig 3.3(b) Mesh generation on EPPLER 1098 with dimples

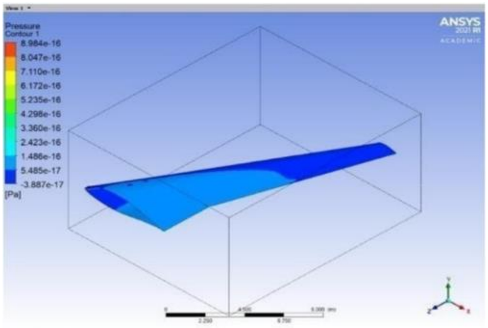


Fig 9.10 Static pressure contour on EPPLER 1098 With dimples

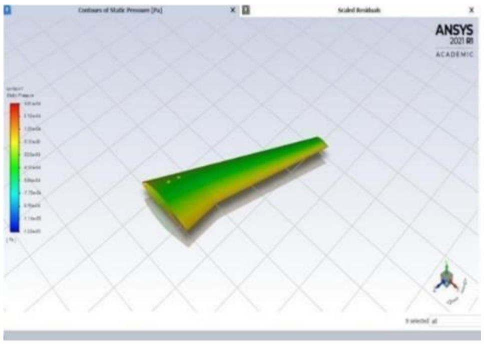


Fig. 9.11 Pressure contour on EPPLER 1098 with dimples

From the CFD analysis, the values of lift and drag forces can be determined. Table IV shows the lift forces on wings with dimples at different AOA i.e Angle of Attack while table V shows drag forces on the wings with dimples considering different angle of attack. Table VI compares the lift to drag ratio of these wings at that angle of attacks.

TABLE IV COMPARISON OF LIFT FORCE ON WINGS TABLE V COMPARISON OF DRAG FORCE ON

Sr. No	ANGLE (degree)	NACA 2412(N)	EPPLER 1098(N)
1	0	4.68E+05	1.26E+06
2	2	9.95E+05	1.75E+06
3	4	1.46E+06	2.22E+06
4	6	1.89E+06	2.64E+06
5	8	2.32E+06	2.98E+06
6	10	2.70E+06	3.19E+06
7	12	3.12E+06	3.35E+06

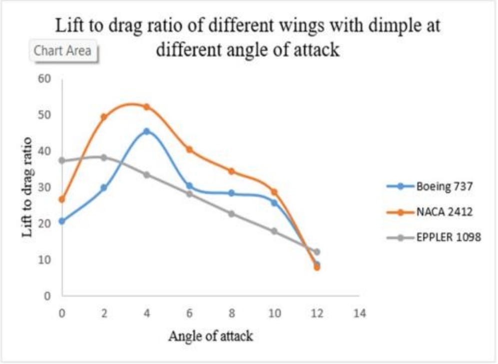
Sr. No	ANGLE (degree)	NACA 2412(N)	EPPLER 1098(N)
1	0	17568	37870
2	2	20165	51603
3	4	28008	74007
4	6	46722	1.05E+05
5	8	67622	1.44E+05
6	10	94767	1.97E+05
7	12	1.19E+05	2.68E+05

WINGS(WITH DIMPLES) (WITH DIMPLES)

TABLE VI COMPARISON OF LIFT TO DRAG RATIO ON WINGS (WITH DIMPLES)

Sr. No	ANGLE (degree)	BOEING 737(N)	NACA 2412(N)	EPPLER 1098(N)
1	0	20.56	26.63	37.23
2	2	29.94	49.34	38.16
3	4	45.36	52.23	33.44
4	6	30.33	40.45	28.13
5	8	28.23	34.45	22.65
6	10	25.67	28.49	17.70
7	12	8.45	7.76	12.07

In table VI, the values for lift to drag ratios for BOEING 737 is taken from the official website of Boeing for more accurate results.



Graph 2. Lift to drag ratio of different wings with dimple at different angle of attack

The comparative study of graphs graph 1 and graph 2 which shows lift to drag ratio of different wings at different angles of attack concludes that when dimples are added to the wing the lift to drag ratio increases. The considerable increase can be seen in the case of NACA 2412.

TABLE VII PERCENTAGE DEVIATION TABLE

	Angles	Cl/Cd ratio of wings with dimples	Cl/Cd ratio of wings without dimples	Deviation	Percentage deviation (%)
NACA 2412	0	26.63	9.11	17.52	192.31
	2	49.34	12.90	36.44	282.48
	4	52.23	13.42	38.81	289.19
	6	40.45	12.83	27.62	215.27
	8	34.45	9.99	24.46	244.84
EPPLER 1098	0	37.23	33.27	3.96	11.90
	2	38.16	33.91	4.25	12.53
	4	33.44	29.99	3.45	11.50
	6	28.13	24.76	3.37	13.61
	8	22.65	20.722	1.92	9.30
BOEING 737	0	20.56	17.47	3.09	17.68
	2	29.94	26.06	3.88	14.88
	4	45.36	31.02	14.34	46.22
	6	30.33	25.21	5.12	20.30
	8	28.23	18.62	9.61	51.61

Table VII shows percentage deviation of Cl/Cd values for different wings. Table clearly show that Cl/Cd ratio increases in significant amount in case of NACA 2412.

From the Table VII it is evident that –

Wing with EPPLER 1098 as the airfoil shows good results as compared to BOEING 737 and NACA 2412 in wingswithout dimples as

- The airfoil of EPPLER 1098 has the highest camber than other airfoils.
- With the increase in camber the flow hitting the airfoil at the leading edge is deflected upwards while the flow at trailing edge is deflected downwards.
- The stagnation point moves downwards.

STAGNATION POINT – The point where flow velocity reduces to zero.When dimples are introduced on the surface of wing –

- Small centre of pressure movement across large speed range, is a characteristic of NACA 2412 which results in thesudden increase in the lift to drag ratio.

- CENTRE OF PRESSURE - Center of pressure of an aircraft is the point where the Lift acts. Pitching moments areconstant at the point called aerodynamic centre.
- The centre of pressure shifts towards the leading edge which causes a low pressure region but, low pressure area islarger and stronger in NACA 2412.
- Also good stalling properties of NACA 2412 compensate the slight vortices caused due to dimples on the wing whichfurther increases the lift to drag ratio.

IV. CONCLUSION

The study of wings with and without dimples concludes that when dimples are added to the wing the lift to drag ratio increases. The considerable increase of average 213.79% can be seen in the case of NACA 2412. This study was carriedout at the original working conditions of Boeing 737 aircraft on Ansys Fluent.

REFERENCES

1. Bhadri Rajasai, Ravi Tej, Sindhu Srinath, ‘Aerodynamic effects of dimples on aircraft wings’, International Journal of Advancements in Mechanical and Aeronautical Engineering– IJAMAE Volume 2 : Issue 2 [ISSN : 2372-4153], 2015
2. Vishal Kaushik, Manoj Mahore, Sandeep Patil, ‘Analysis of Dimpled Wing of an Aircraft ‘ IJEDR 2018:| Volume 6, Issue 3 [ISSN: 2321-9939]
3. Firoz Alam, Tom Steiner, Harun Chowdhury, Hazim Moria, Iftekar Khan, Fayaz Aldawi, Alkesandar Subic, ‘A Study of golf ball aerodynamic drag’, journal homepage;https://sci-hub.st/10.1016/j.proeng.2011.05.077 ,2011
4. Jean-Jacques Chattot, ‘Low Speed Design and Analysis of Wing/Winglet Combinations Including Viscous Effects’, JOURNAL OF AIRCRAFT Volume 43, No: 2, March–April 2006
5. E. Livya, G. Anitha, P. Valli, ‘Aerodynamic Analysis of Dimple Effect on Aircraft Wing’, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:9, No:2, 2015
6. Arnav Kulshreshtha, Sanjeev Kumar Gupta , Piyush Singhal, ‘FEM/CFD analysis of wings at different angle of attack’, journal homepage: www.elsevier.com/locate/matpr
7. Sourav Paul, Aoyon Paul, Farida Ahmed Koly, ‘A Review of different shaped dimple effects on airfoil surfaces’, International Conference on MechanicalEngineering and Renewable Energy 2019
8. Y. Sowmyashree , D. I. P. Aishwarya , S. Spurthy , Roshan Sah, ‘Study on Effect of Semi-circular Dimple on Aerodynamic Characteristics of NACA 2412 Airfoil’, AIP Conference Proceedings 2204, 030009 (2020); https://doi.org/10.1063/1.5141572 Published Online: 10 January 2020
9. S.P. Venkatesan, V. Praveen Kumar, M. Sunil Kumar and Suraj Kumar, ‘Computational analysis of aerodynamic characteristics of dimple airfoil NACA 2412 at various angles of attack’, International Journal of Mechanical Engineering and Technology (IJMET)Volume 9, Issue 9, September 2018, pp. 41–49, Article ID: IJMET_09_09_005
10. Sonia Chalia, Manish Kumar Bharti, ‘Design and Analysis of Vortex Generator and Dimple over an Airfoil Surface to Improve Aircraft Performance’, International Journal of Advanced Engineering Research and Applications (IJAERA) Volume – 3, Issue – 4, August – 2017 ISSN: 2454-2377
11. Karthik AK, Abraham Boniface V, Sriram S, Gokul Raj M, ‘Analysis of aerodynamic performance of aircraft attached with dimple using CFD’, International Journal of Advances in Engineering Research

http://www.ijaer.com (IJAER) 2019, Vol.No. 18, Issue No. VI, December e-ISSN: 2231-5152, p-ISSN: 2454-1796