Archives of Materials Science and Engineering

Volume 77
Issue 2
February 2016
Pages 72-77

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

CFD analysis of aerofoil using dimples and prevent radar signals using stealth technology

R. Maheswaran*, R. Manikandan

Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, Virudhunagar, Tamil Nadu 626005, India

* Corresponding e-mail address: rmahes@mepcoeng.ac.in

ABSTRACT

Purpose: 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.

Design/methodology/approach: This project includes computational analysis of dimple effect on aircraft wing, using NACA 0018 airfoil. Dimple shapes are circular which locates the inward, outward are selected for the analysis; airfoil is tested under the inlet velocity of 30m/s at different angle of attack (-5°, 0°, 5°, 10°, and 15°).

Findings: 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.

Practical implications: Stealth technology is based on the principle of reflection and absorption that makes the objects' observability lower and stealthy. A 'stealth' vehicle will generally have been designed from the motive to reduce RCS (Radar Cross Section) of aircrafts i.e. radar signature of aircrafts.

Keywords: Airfoil; Boundary layer; Dimple effect; Flow separation; Stall reduction

Reference to this paper should be given in the following way:

R. Maheswaran, R. Manikandan, CFD analysis of aerofoil using dimples and prevent radar signals using stealth technology, Archives of Materials Science and Engineering 77/2 (2016) 72-77.

METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

Wing is a type of fin with a surface that produces aerodynamic force for flight or propulsion through the atmosphere, or through another gaseous or liquid fluid. As such, wings have an airfoil shape, a streamlined cross-sectional shape producing lift.

Wings aerodynamic qualities are expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift.

An airfoil is a body of such a shape that when it is placed in an airstreams, it produces an aerodynamic force. This force is used for different purposes such as cross sections of wings, propeller blades, windmill blades, compressor and turbine Blades in a jet engine and hydrofoils are examples of airfoils.

At present, different kinds of surface modifications are being studied to improve the manoeuvrability 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. 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 [1-16].

2. Stealth technology

Stealth refers to the act of trying to hide or evade detection. Stealth technology is ever increasingly becoming a paramount tool in battle especially “high technology wars” if one may occur in the future where invincibility means invincibility.

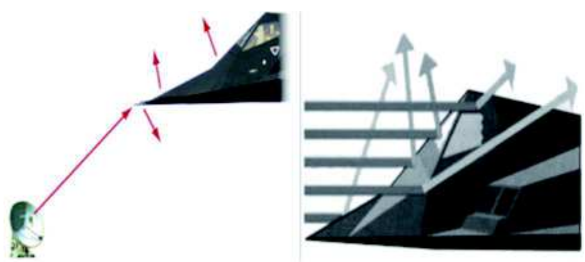

Fig. 1. Stealth technology

Able to strike with impunity, stealth aircraft, missiles and warships are virtually invisible to most types of military sensors. The experience gained at the warfront emphasizes the need to incorporate stealth features at the design stage itself (Fig. 1).

2.1. Six disciplines of stealth technology

- RCS: Aircrafts, Missiles, Ships, Land Vehicles.
- Infrared signature: Aircraft, Missiles, Ships, Land Vehicles, Submarines.
- Acoustic Signature: Predominantly for Submarines (SONAR), Ships, Aircrafts etc.
- Visible Signature: Predominantly for Land Vehicles, Aircrafts, and Ships.
- Laser Cross Section: Aircrafts, Missiles, Ships, and Land Vehicles.
- Magnetic Signature: Submarines, Ships.

2.2. Corner reflector

The possibility of designing aircraft in such a manner as to reduce their radar cross-section was recognized in the late 1930s. Radar waves penetrating the skin of the aircraft get trapped in these structures, bouncing off the internal faces and losing energy. This approach was first used on the F-117 aircraft (Fig. 2).

Fig. 2. Corner reflector

3. Design and analysis

The Figures 3-7 shows a geometrical model for normal NACA0018 aerofoil and turbulence analysis with mainstream flow area of 300×150 mm² and has a length of 160 mm. This was modelled by using CATIA-V5R20 software. The model is designed for different Angle of attack i.e. -5°, 0°, 5°, 10°, 15°.

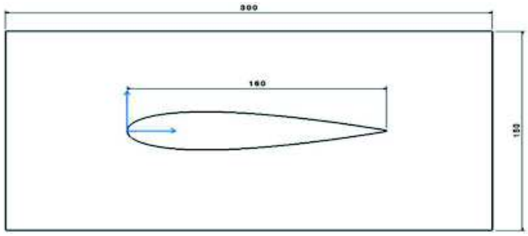

Fig. 3. Rectangular domain with normal aerofoil

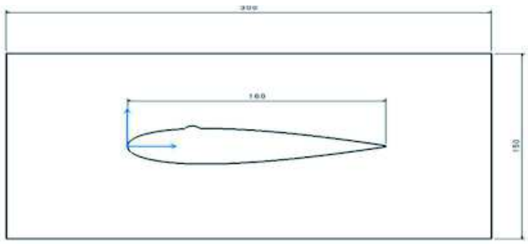

Fig. 4. Rectangular domain with outward dimple in C/4

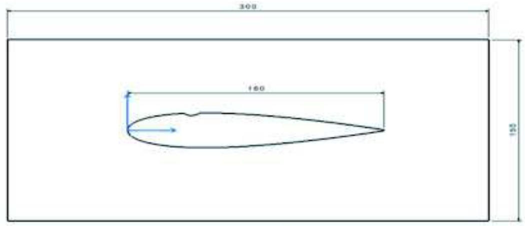

Fig. 5. Rectangular domain with inward dimple in C/4

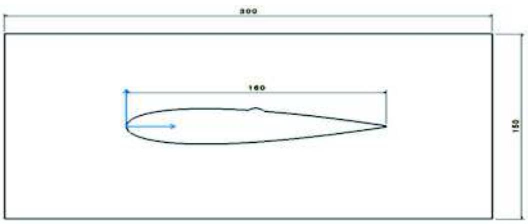

Fig. 6. Rectangular domain with outward Dimple in C/2

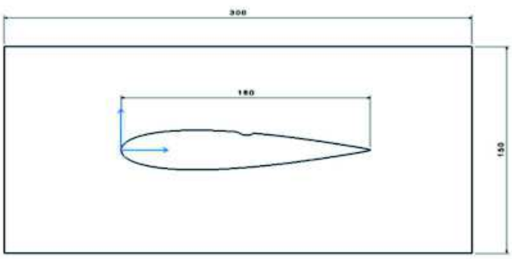

Fig. 7. Rectangular domain with inward dimple in C/2

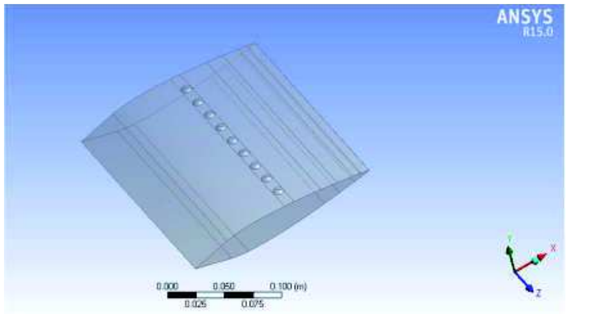

Fig. 8. 3D model of aerofoil with dimple

The 3D model of aerofoil with dimple is shown in Figure 8.

The inlet boundary conditions for the mainstream flow quantities are,

Pressure	- 5.782e^002 Pa.
Velocity	- 30 m/s
Reynolds no	- 3.2*10^5
Air density	- 1.2 kg/m^3
Dynamic viscosity	- 1.2e^-5Pa-S

3.1. Numerical result

The Figures 9-11 shows the turbulence at leading edge of the aerofoil. The wall and wing section has no slip condition. The formations of main stream have the 30 m/s velocity inlet and 15° angle of attack.

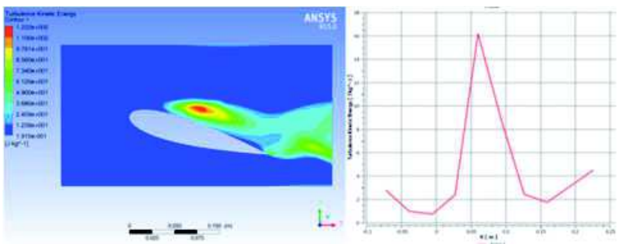

Fig. 9. Turbulence Plot and Graph for Normal NACA 0018 at 15°

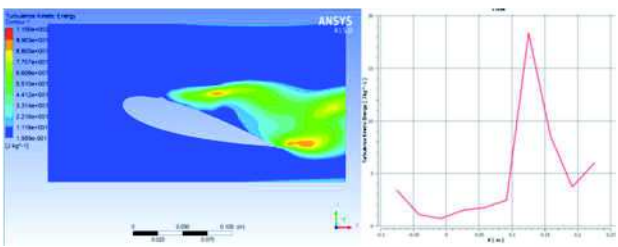

Fig. 10. Turbulence plot and graph outward c/4 at 15°

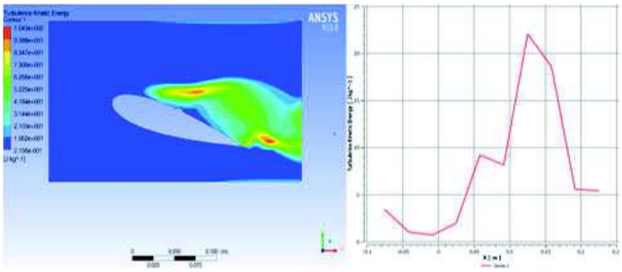

Fig. 11. Turbulence plot and graph outward c/2 at 15°

All simulations of NACA 0018 are carried out at different angle of attack, taking inlet velocity 30 m/s Uy and Uz are taken to be zero. One of the objectives of this computational study is also to shorter the take-off distance of the aircraft by creating sufficient lift with minimum low velocity. For this reason aerofoil model is simulated at such low velocity. A 2-D simulation is carried out to draw comparison between Inward and outward dimples also both are compared to plain aerofoil NACA 0018 without any dimple. Analysis is done at -5°, 0°, 5°, 10°, 15° angle of attack.

Figure 12 illustrates that the variation of the drag co-efficient with respect to the angle of attack for different location of dimples. As expected, placing dimples would bring drag value down to minimum. Plain airfoil experiences the maximum drag value of nearly 0.75 at 15 degree angle of attack, but for the case of outward c/2 location dimples drops 0.41. Finally, outward c/2 location experiences the minimum drag co-efficient among other location of dimple. Other configuration of outward c/4 location dimples experiences the lower value of drag at 15 degree compare to other locations.

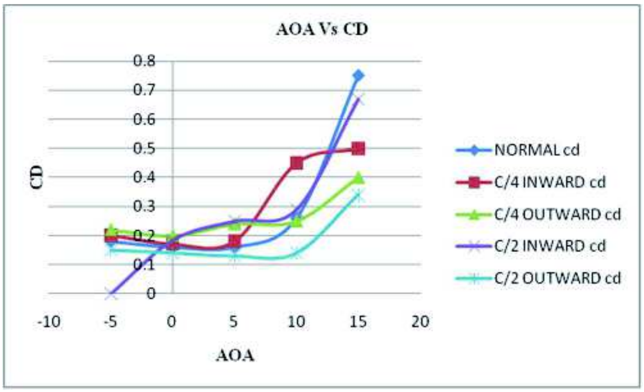

Fig. 12. Angle of attack vs. coefficient of drag

Figure 13 shows the significant improvement of lift increment over the different values of angle of attack. Outward c/2 location dimple configuration gives the maximum value of co-efficient of lift 1.25 and another configuration of outward c/4 location dimples gives the closer value of co-efficient of lift 1.005 (i.e., 25% lower from peak lift co-efficient). The inward c/2 location dimples are observed to stall 15 degree angle of attack from the lift value is -1.75. All the graphs show outward dimples shows the better aerodynamic efficiency than that of inward configuration.

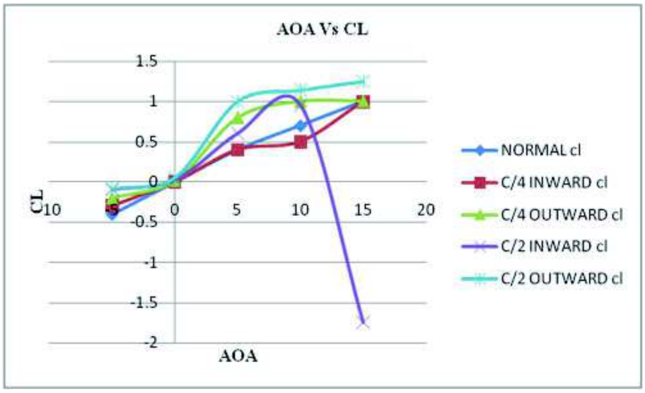

Fig. 13. Angle of attack vs. coefficient of lift

3.2. Stealth design

Corner reflector placed at outward dimples in c/2 of leading edge of NACA0018 for the purpose of low observe technique used for passenger aircraft which is prevent or delays enemies' RADAR detection signal (Fig. 14). Generate the same turbulence at 0°.

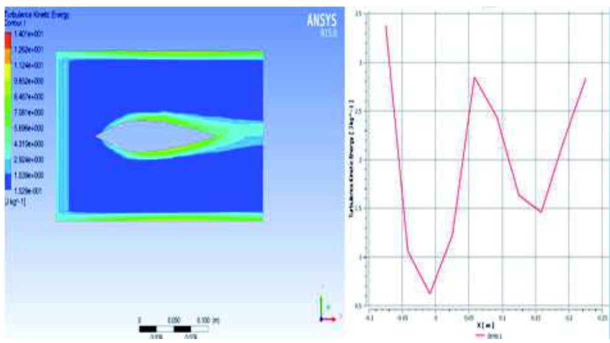

Fig. 14. Stealth design with turbulence plot and graph for outward c/2 location dimple

4. Results and discussion

The maximum co-efficient of lift and minimum co-efficient of drag is obtain from the outward c/2 location dimples compare to the NACA0018 without dimples. Another configuration of outward c/4 location of dimples gives the closer value of c/2 location of dimples.

This graph shows (Fig. 15) that the aerodynamic efficiency for NACA0018 aerofoil for using normal lift and drag formulas are:

- lift equation is:

$$C_L = \frac{F_L}{\frac{1}{2}\rho U^2 A},$$

- drag equation is:

$$C_D = \frac{F_D}{\frac{1}{2}\rho U^2 A}.$$

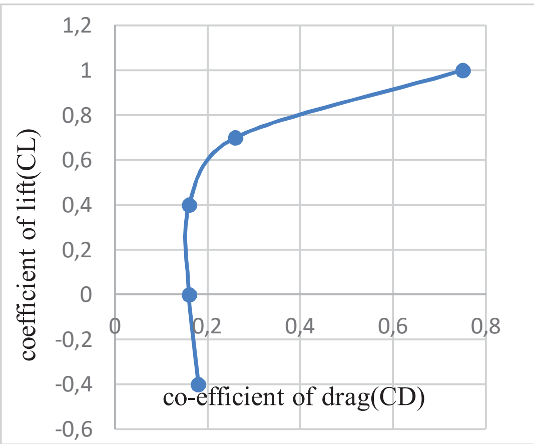

Fig. 15. Aerodynamic efficiency for ANSYS result

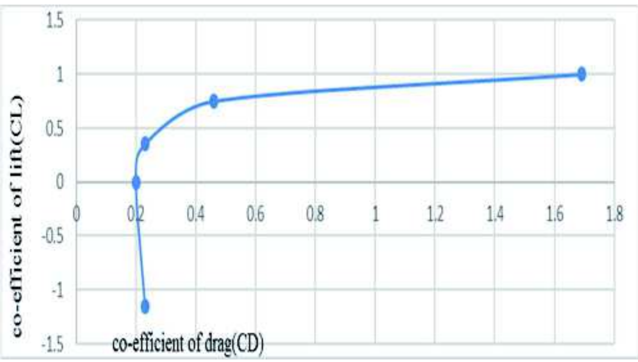

Fig. 16. Aerodynamic efficiency

Figure 16 shows the aerodynamic efficiency increases the 20% compare to the analytical result with various angle of attack.

5. Conclusions

- A detailed study on delays the boundary layer separation is selected configurations. Different surface modification exit strategies were studied with inward and outward dimples geometry. Both turbulence and pressure drop analysis effectiveness are analysis using ANSYS fluent.
- It appears both inward and outward geometries reduce the co-efficient of drag at wing section and also provide better aerodynamic efficiency.
- The turbulence, effectively generate closer to the outward dimples at c/2 of the aerofoil surface. Spacing between the dimples is depends on the length of the wing section.
- Turbulence analysis gives the maximum co-efficient of lift in c/2 outward dimples.
- The stealth technology used passenger aircraft wing leading edge (corner reflector).
- The study showed that by providing dimples modification, the co-efficient of lift increases related with angle of attack.
- Provide the stealth design for outward dimples at c/2 of aerofoil surface for prevent the detection RADAR signals.

Acknowledgements

I would like to express my sincere gratitude to Dr. R. Maheswaran for his guidance and assistance in this study work. The reality is that Dr. R. Maheswaran was much more than an advisor for me. He always helped me in all the technical and non-technical issues during the production of this work. His encouragement and efforts led this report to successful completion in a timely fashion.

References

[1] M.B. Patacsil, Dimples on Wings, California Science Fair, 2010.

[2] University of Illinois at Urbana-Champagne (UIUC) Airfoildatabase,ttp://www.ae.illinois.edu/mselig/ads/coord_database.html

[3] R. Chana, P.R. Vishwanathi, Base Drag Reduction Caused by Riblets on a GAW(2) Airfoil, National Aerospace Laboratories, Journal of Aircraft 35/6 (1998) 988-992.
[4] J. Zerihan, An Investigation into the Aerodynamics of Wings in Ground Effect, PhD Thesis, University Southampton, School of Engineering, 2001.
[5] S. Mahon, X. Zhang, Computational analysis of pressure and wake characteristics on an aerofoil in ground effect, Journal of Fluids Engineering-Transactions of the ASME 127 (2005) 290-298.
[6] R. Razenbach, J.B. Barlow, Two dimensional aerofoil in ground effect, an experimental and computational study, Proceeding of the Motorsport Engineering Conference, paper no. 942509, 1994, 241-249.
[7] J.M. Davies, The aerodynamics of golf balls, Journal of Applied Physics 20/9 (1949) 821-828.
[8] D. W. Bechert, R. Meyer, W. Hage, effect of Gurney flaps on the transonic airfoil, Published by the American Institute of Aeronautics and Astronautics, 2000.
[9] M. Mamou, W. Yuan, M. Khalid, R. Wokoeck, R. Radespiel, Transition prediction in low Reynolds airfoil flows using finite element method coupled with the numerical method that improves the aerodynamic efficiency, Proceeding of the 25th AIAA Applied Aerodynamics Conference, San Francisco, 2006.
[10] H.T.C. Pedro, M.H. Kobayashi, Numerical study of stall delay on Humpback whale flippers which use boundary layer separation at airfoil, Proceedings of the 46th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, 2008.
[11] L.S. Miller, K. Hoffmann, K. Krishnan, Conceptual study of performance enhancing devices for an airfoil by using CFD software which results of maximize the lift co-efficient, 2011.
[12] K. Hansen, R. Kelso, C. Doolan, The reduction of tonal noise in induced flow over the airfoil by using the sinusoidal model, Acoustics Australia 40/3 (2012) 172-177.
[13] P. Dhiliban, P.S. Meena, M. Narasimhan, S. Vivek, Nadaraja Pillai, K.M. Parammasivam, Found the surface modification in the lower surfaces to give better aerodynamic efficiency than the one in the upper surfaces, 2013.
[14] K.S. Patel, S.B.Patel, U.B. Patel, A.P. Ahuja, Analysis the aerofoil related with different angle of attack which increases the aerodynamic efficiency by using the CFD software and compares the wind tunnel test, International Journal of Engineering Research 3/3(2014) 154-158.
[15] K. Akhila, Stealth design aircraft.
[16] A. Zachariah, Details for stealth design for military aircraft.