Computational Fluid Dynamic Analysis of aircraft wing with assorted flap angles at cruising speed

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Abstract

An aircraft wing is actually manufactured by the composite materials with the fibre angled in every ply aligned in multi- direction. Dissimilar thickness of the airfoil and layer directions were almost taken to study the result of bending-torsion. These laminated features are usually designed using the different layers, sequence of stacking, geometrical and mechanical properties. Finite number of layers can be integrated to form many laminates, The wing loading was due to its self-weight and weight of other propulsion systems or due to acceleration due to gravity was deliberated and the deflection over here can be found, this actually studied by aero elasticity. The aircraft wing is severely affected by the loads on along wing direction or vertical direction.NACA 2412 airfoil was taken for designing wing, and it was scaled through a profile with a calculated wingspan to obtain wing model. FLUENT and CFX were used for computational fluid dynamic analysis to determine the lift and drag for wing during zero degreed flaps and angled flaps. By this we intend to show how fast retraction flaps effects the drag and lift of aircraft at cruising speed.

Keywords : Finite Element Analysis, airfoil, composite structure, Fluent, CFX.

1 Introduction

Actually popularity of air transportation is reaching beyond the boundaries in innovations, research and development was much faster and more optimized design of wings, fuselage and even components like flaps, slats, stringers, elevator design plays major role[12]. An airfoil is a cross-section of the wing, its main objective is to provide corresponding lift to an aeroplane all through take-off and during flight. It also have an upshot known as drag which opposes the motion

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of the aeroplane. Drag is for aeroplane is not only fallout but also overturn when plane is at landing. The amount of lift needed by a plane depends on the purpose for which it actually used. Heavy aeroplanes postulate more amount of lift while lighter ones require less. Thus, Based on the type of aeroplanes and type of the payload, airfoil section is resolute, Lift force also governs the vertical acceleration of the plane which in turn depends on the horizontal velocity of the aircraft. Thus, determining the coefficient of lift, lift force can be calculated and by knowing the lift force and required vertical acceleration one can determine the essential horizontal speed.
Moreover flaps are the maneuvers used to revise the lift characteristics of a wing and these are mounted on the trailing edge of the aircraft wings of a fixed-wing aircraft to reduce the speed at which the aircraft can be safely flown and to increase the angle of descent for landing. They do this by lowering the stalling of plane and increasing the drag, flaps also minimizes the take-off and landing distances. This particularly allows any aircraft to generate much lift, but this occurs only at a lower speeds during take-off, reducing the stalling speed of the aircraft and the minimum speed at which the aircraft will maintain flight. Outspreading flaps increases the drag, which can be beneficial during approach and landing on short runways or valley runways, because it slows down the aircraft. In most of the aircraft a useful side effect of flap deployment is a reduction in aircraft pitch angle which drops the nose thereby improving the pilot's view of the runway over the nose of the aircraft during landings [1]. However these flaps may also cause pitch-up depending on the type of flaps and the location of the wing to the fuselage.
Aerospace industries are gradually relying on the advanced numerical flow simulation tools in the primary airplanes design phase for testing the design and optimizing them. Today computational fluid dynamics (CFD) has fully-fledged to a point where it is widely recognized as an indispensable and complementary analysis tool to wind tunnel experiments and flight model tests. NavierStokes approaches have matured from specialized and synthesized research techniques to practical engineering tools for a massive number of approaches and industrial problems [2]. Due to these effortless high computational work required for flow simulations forms around realistic three Dimensional configurations, But industrial computational fluid dynamics tools are relatively used for analysis and assessment of given geometries than for shape design and optimization. However within the next few years numerical optimization will play a strategic role for future aircraft designs.

2 Airfoil

One of the most enormous things to consider was the structure and the body of an aircraft. Its concept has always been scintillating and technical, all of us do know that only when any object overcomes the earths natural gravitational pull it tends to fly high. So the wings of an aircraft helps in gliding the entire fuselage through the wind and also during its landing and take-off. The shape of such a significant module of the aircraft makes a proportion of impact on its movements, this shape is known as an airfoil [3]. And component of this particular force perpendicular to the direction of motion is called as the lift, however the lift on an airfoil is mainly due to the result of its angle of attack and shape of the component [4]. This turning of the air in the locality of the airfoil creates curved streamlines, resulting in lower pressure on one side actually below the

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wing and higher pressure on the other at top of the wing. This pressure difference is convoyed by a velocity difference via Bernoulli's principle, so the subsequent flow field about the airfoil has a developed higher average velocity on the upper surface than on the lower surface. Also Newtonian law have a different approach for lift produced by the wings, it mainly claims that no two particles meet again (at trailing edge) in their life time once they are separated (at leading edge).Both the Bernoulli and Newtonian laws seem to prominent about the theory behind the lift produced. But Coanda effect and flow curvature principle gives a perfect and non-ambiguous theory. The lift force can be associated directly to the average top and the bottom velocity difference.[14]

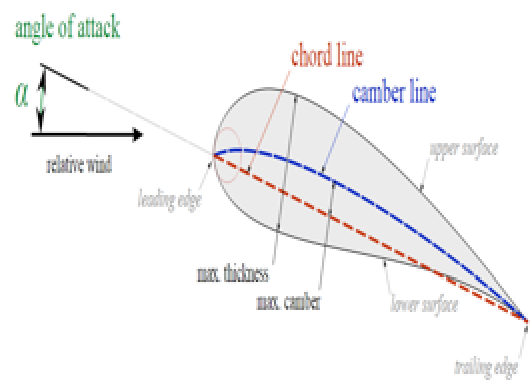

Fig.1: Airfoil nomenclature

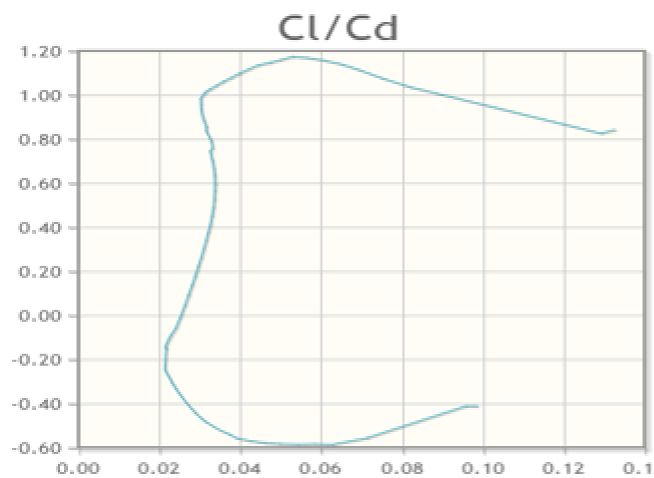

Fig.2: coefficient of lift to drag plot for the NACA 2412 airfoil

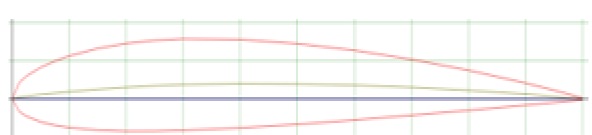

Fig.3: Representation of the NACA 2412 airfoil

NACA (National Advisory Committee for Aeronautics) 2412 airfoil was as the profile to generate the wing. This NACA 2412 airfoil has Max thickness 12% at 30% chord, Max camber 2% at 40% chord and angle of attack() is 7.25.Reynolds number ranging from the 50,000 for this foil[5], Chord is the extend from leading edge to trailing edge of the wing and camber is Points halfway between chord and upper wing surface whereas angle of attack is Angle between direction of airflow and the chord.

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3 Parts of wing and wing structure

An aileron is a hinged flight control surface usually establishing part of the trailing edge of each wing of a fixed-wing aircraft. Slats are the aerodynamic surfaces on the leading edge of the wings of fixed wing aircraft, stringer is also known as the stiffener used to hold and stiff the sheet metal of the wing the internal ribs[11]. Ribs are the internal foiled shape supports for wing. In addition to this, aircraft wings consists of the fuel tank[6]. Amazingly Airbus 320 aircrafts fuel capacity is 23858 litres, of this half was equally stored in two wing for maintaining equilibrium in the aircraft structure and remaining half was stored in the aircraft fuselage. In rear cases for modern aircrafts little amount of fuel can be stored in tail section which is an auxiliary tank, used when emergency fuel dumping due to temperature raising occurs.

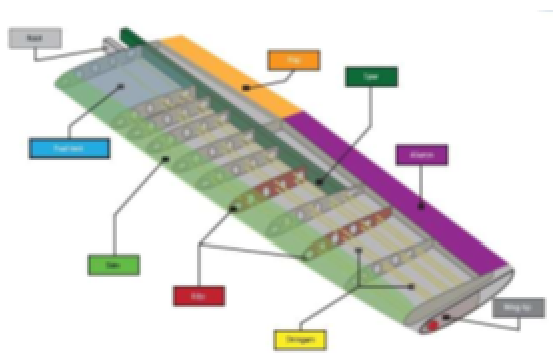

Fig.4: Parts of wing and wing structure

4 Design of the wing

Wing design was made by using the NACA profile with the wingspan of 60m, which is substantial for BOEING 747 wingspan. By considering the real-time profile of airfoil its co-ordinates[7] were formed and they were imported to SOLIDWORKS by MACROS importing format. Then required dimensional aircraft wing was formed by using that profile, and completed model was imported to ANSYS for analysis of model. Initially wingspan was calculated and profiles were scaled on the guide curve from leading edge to trailing edge starting from fuselage intersection to the ailerons tip.[13] And then by lofting this wing was sheeted, so internal ribs, stringers, flaps were designed and assembled for this wing section. Basic flaps were designed to interpret the data on it with miscellaneous flap angles.[2]

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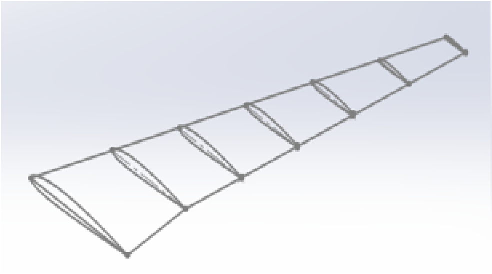

Fig.5: Wingspan with profiles and guide curve

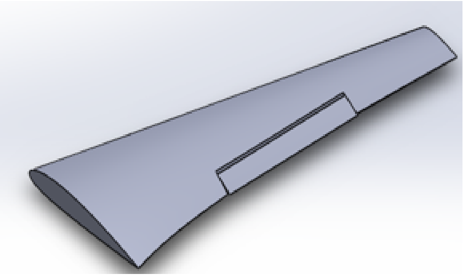

Fig.6: Lofted wing with the flap section assembled

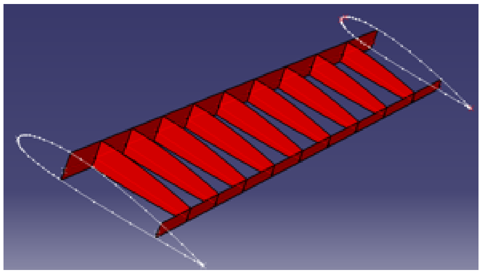

Fig.7: Section and ribs viewed in the wing

5 Analysis

Computational Fluid Dynamics (CFD) is to provide a qualitative and quantitative estimation of fluid flow by means of required mathematical modeling (partial differential equations), numerical methods. Software tools (solvers, pre and post processing utilities) CFD empowers scientists and engineers to perform numerical experiments (i.e. computer simulations) in a virtual flow laboratory.The area of Fluidization incorporate those expression of numerical analysis relevant to the numerical solution of partial differential equations,the progress of physically based models for those development that cannot be computed precisely, and the application of these tools to important problems in fluid flow[8].CFD actually gives a vision into flow patterns that are difficult, expensive or impossible to study using traditional (experimental) techniques by wind tunnels. The results of a CFD simulation are never completely reliable because the input data may comprise too much appraising data or imprecision the mathematical model of the problem at hand may be inadequate the accuracy of the results is inadequate by the available computing power.[9]

5.1 Wing with zero degree flaps

Take-off is the phase of flight in which an aircraft goes through a transition from moving along the ground (taxiing) to flying in the air, usually starting on a runway. Usually the engines are run at full power during take-off. Following the taxi motion, the aircraft stops at the starting line of the runway. So during taxing flaps and spoilers of aircraft are retracted back or at zero degree.

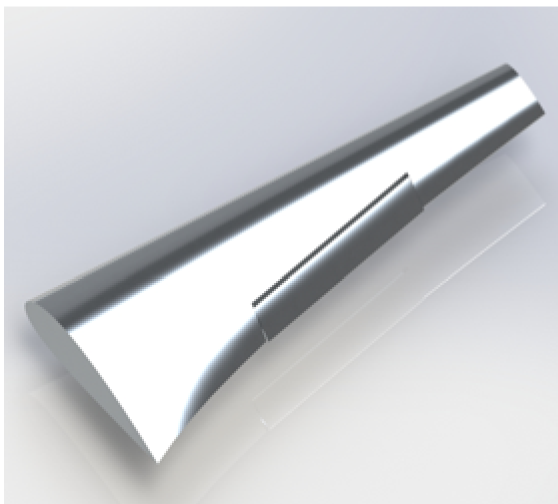

Fig.8: Wing with flaps zero degree

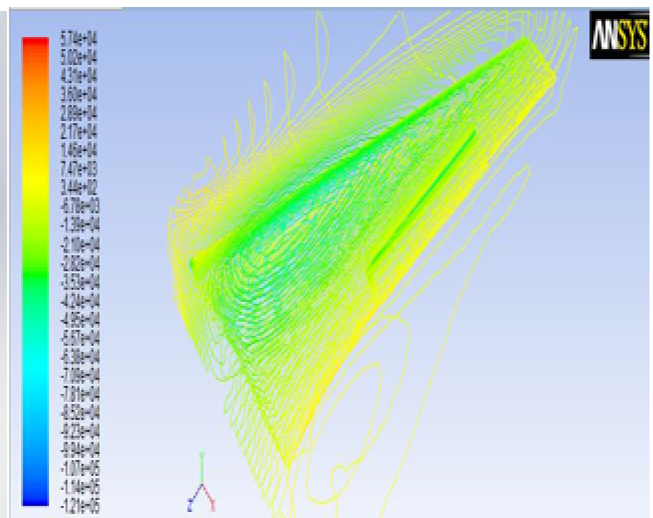

Fig.9: Pressure plot throughout the wing

Lift obtained by this was 2429.80 N with coefficient of lift (Cl) 0.731
Drag obtained was 198.646 N with Drag coefficient (Cd) 0.04302

5.2 Wing when flaps retrieved

Aircraft climb is supported out by increasing the lift of the aircraft until their lifting force exceeds the weight of the aircraft. The increase in lift may be accomplished by increasing the angle of attack of the wings, by increasing the thrust of the engines to increase speed (thereby increasing lift), by increasing the surface area or shape of the wing to produce greater lift, or by some combination of these techniques.so flaps are increased at low aircraft speeds for lift. In most cases, engine thrust and angle of attack are simultaneously increased to produce a climb [10]. And during landing aircraft has to reach a minimum speed of 180 nautical miles per hour or 333.36 kmph so flaps and spoilers are used here to increase the drag and to land on short runways.
Lift obtained by this was -1152.45. N with coefficient of lift (Cl) -1.027
Drag obtained was 817.77N with Drag coefficient (Cd) 0.854

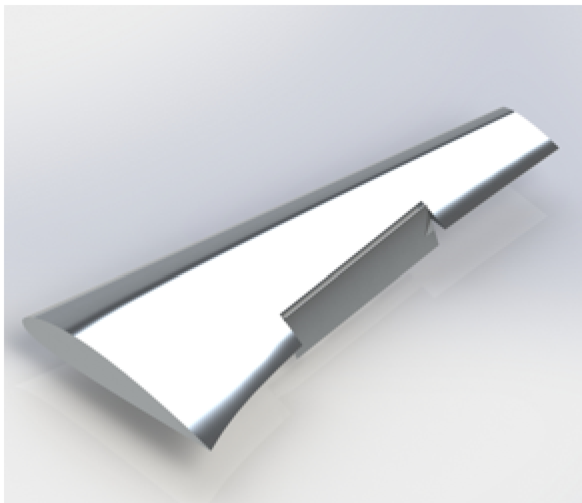

Fig.10: Wing with flaps retrieved

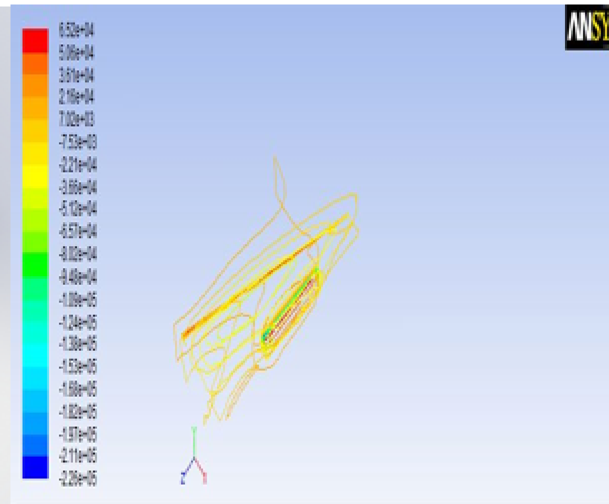

Fig.11: Pressure plot throughout the wing

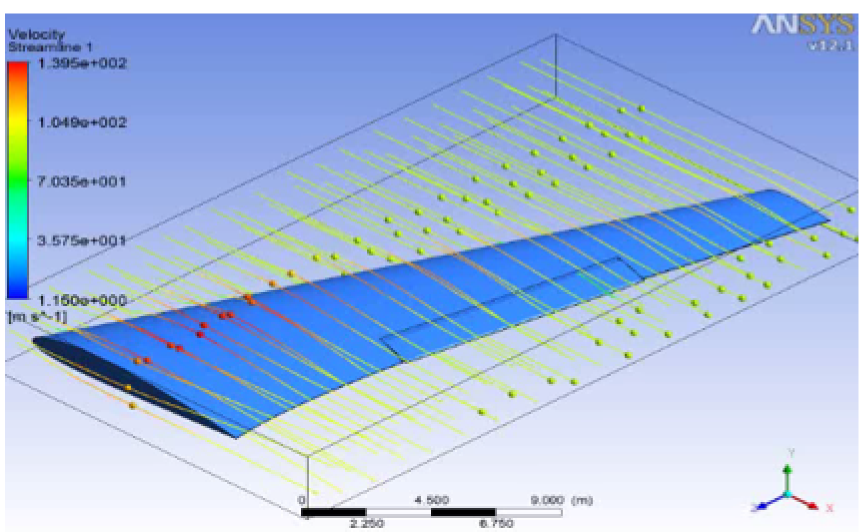

Fig.12: Stream lines and velocity vector plot

6 Conclusion

So by analysing both the zero angled and inclined or retrieved flapped wings it was concluded that wing with zero degreed flaps acts normal by producing positive coefficient of lift and sufficient drag. But for flaps retrieved wing the coefficient of drag was more and increasing, than the lift while in multi-iteration solving in FLUENT. Therefore flaps are used to increase drag while landing. And in addition to that flaps also used to produce lift during take-off to low speeds (on short runways these were used during take-off).And study was completed by considering a zero flap angled wing and flaps retrieved wing as example and this application of the method is prolonged.
1)Mainly it is only pertinent to the concept design stage or the early design stage of aircraft.
2)Although on a single hand computational fluid dynamic analysis of this cannot judge the predominance fields of wing. Method using experimental aerodynamic forces based on extensive wind-tunnel tests has higher accuracy and can be used at the late detailed design phase of aircraft.

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References

[1] B. Saripalli, R. Pandu, and V. John, “Vibration and cfd analysis of hybrid composite wing,” *International Journal of Novel Research in Electrical and Mechanical Engineering*, vol. 2, pp. 105–116, 2015.

[2] N. Kroll, N. R. Gauger, J. Brezillon, R. Dwight, A. Fazzolari, D. Vollmer, K. Becker, H. Barnewitz, V. Schul, and S. Hazra, “Flow simulation and shape optimization for aircraft design,” *Journal of Computational and Applied Mathematics*, vol. 203, p. 397411, 2007.

[3] R. Rajappan and V. Pugazhenthi, “Finite element analysis of aircraft wing using composite structure,” *The International Journal of Engineering and Science*, vol. 2, pp. 74–80, 2013.

[4] P.PrabhakaraRao and V. S. Sampath, “Cfd analysis on airfoil at high angles of attack,” *International Journal of Engineering Research*, vol. 3, pp. 430–434, 2014.

[5] S. V. Singh and M. N. Kumar, “Cfd analysis of different bluff bodies,” *International Journal of Novel Research in Electrical and Mechanical Engineering*, vol. 2, pp. 139–145, 2015.

[6] T. Markandeyulu, T. Naganna, and D. Muppalla, "Design and analysis on flex foil of wing," *International Journal of Novel Research in Electrical and Mechanical Engineering*, vol. 2, pp. 146–153, 2015.

[7] seli, "M.uiuc airfoil coordinates database," 2006. [Online]. Available: http://mselig.ae.illinois.edu/ads/coord_database.html

[8] K. Anish, C. Kalyan, C. Reddy, and C. S. S. Sandeep, "Co2 sequestration influence on low permeable geological formations," *Journal of Basic and Applied Engineering Research*, vol. 3, no. 8, pp. 665–670, 2016.

[9] W. Kieffera, S. Moujaesb, and N. Armbyab, "Cfd study of section characteristics of formula mazda race car wings," *Journal of Mathematical and Computer Modelling*, pp. 1275–1287, 2006.

[10] L. Jianwei and W. Qiang, "Aircraft-skin infrared radiation characteristics modeling and analysis," *Chinese Journal of Aeronautics*, pp. 493–497, 2009.

[11] L. Demasi, A. Dipace, G. Monegato, and R. Cavallaro, "Invariant formulation for the minimum induced drag conditions of nonplanar wing systems," *American Institute of Aeronautics and Astronautics Journal*, vol. 52, no. 10, pp. 2223–2240, 2014.

[12] H. Jiangtao, G. Zhenghong, Z. Ke, and B. Junqiang, "Robust design of supercritical wing aerodynamic optimization considering fuselage interfering," *Chinese Journal of Aeronautics*, pp. 523–528, 2010.

[13] L. Peng, Z. Qijun, and Z. Qiuxian, "Cfd calculations on the unsteady aerodynamic characteristics of a tilt-rotor in a conversion mode," *Chinese Journal of Aeronautics*, pp. 1593–1605, 2015.

[14] Y. Wanga, Z. Wana, and C. Yanga, "Application of high-order panel method in static aeroelastic analysis of aircraft," *International Conference on Advances in Computational Modeling and Simulation*, pp. 136–144, 2012.

[15] *Analysis and design of flight vehicle structures*, 1965.