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Flow Analysis over an Airplane with Swept and Unswept Wings

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ABSTRACT

Aircrafts wings may be swept back, or occasionally forward, for a variety of reasons. A small degree of sweep is sometimes used to adjust the center of lift when the wing cannot be attached in the ideal position for some reason, such as a pilot's visibility from the cockpit. The shock wave boundary of a supersonic aircraft is stretched across the nose and wing leading edge to the aircraft. The swept wings allows all parts of the aircraft that create lift to remain in sonic flow, thereby allowing designers to create one airfoil that allows for both high and low speed handling qualities. Sweeping the wing can change the critical mach for a given airspeed. The chord length allows the designers to move the center of pressure thereby changing the point at which supersonic flow starts.

The project deals with the design of an airplane swept and unswept wing configurations. Once the design process is completed the flow over the two configurations is simulated using ANSYS FLUENT Software and further the results (pressure distribution and shear stress distribution) from both the configurations are noted for comparison.

INTRODUCTION

The main purpose of aerodynamic analysis of an airplane is to optimize aerodynamic performance. That is to maximize lift for a given amount of drag, and conversely to minimize drag for a given amount of lift. Shapes and contours of individual components and parts on aircraft affect the amount of total aircraft drag. Nevertheless, the total drag further rises when combining these parts into an airplane.

This increment in drag is called interference drag. It is known to contribute significantly to overall drag of aircraft. Flow fields generated by complex wing-fuselage junction geometries have yet remained to be understood and controlled. Therefore, the investigation of various configurations of aircraft is needed to reach the goal of optimum aerodynamic design.

Changing the wing location in horizontal or vertical fashion changes forces and moments acting on the aircraft wing and body. Although this matter has been widely studied, a specific wing and fuselage may not behave as others that seem to be similar.

The investigation in this paper concentrates on the determination of aerodynamic forces, especially effects on drag and lift to drag ratio, of a selected set or family of configurations of single wing geometry and single fuselage geometry.

The aircraft is designed for high-lift, low Reynolds's number flight in the low speed incompressible flow regime. Five configurations were defined which are distinguished primarily by variation of wing height.

If the airplane is of the low wing or of high wing type, the entire wing structure can continue in the way of the airplane body. However in the mid wing type or of semi low wing type limitations may prevent extending the entire wing trough the fuselage and some of the shear webs as well as the wing cover must be terminated at the side of the fuselage. However, for the mid wing type the wing box structure does not allow to carry trough the fuselage structure therefore heavy forging structures are designed to carry through the wing loads.

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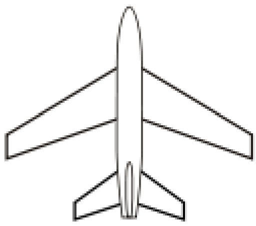
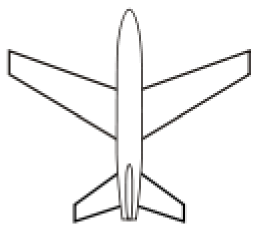
LITERATURE SURVEY

Swept back, (aka "swept wing") - The wing sweeps rearwards from the root to the tip. In early tailless examples, such as the Dunne aircraft, this allowed the outer wing section to act like a conventional empennage (tail) to provide aerodynamic stability. At transonic speeds swept wings have lower drag, but can handle badly in or near a stall and require high stiffness to avoid aero elasticity at high speeds. Common on high-subsonic and early supersonic designs e.g. the Hawker Hunter.



Swept

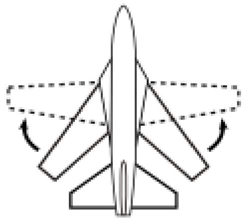
Forward swept - the wing angles forward from the root. Benefits are similar to backwards sweep; also it avoids the stall problems and has reduced tip losses allowing a smaller wing, but requires even greater stiffness to avoid aero elastic flutter as on the Sukhoi Su-47. The HFB-320 Hansa Jet used forward sweep to prevent the wing spar passing through the cabin. Small shoulder-wing aircraft may use forward sweep to maintain a correct CoG.



Forward swept

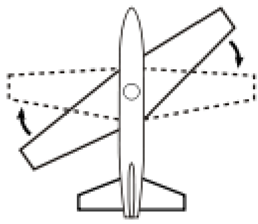
Some types of **variable geometry** vary the wing sweep during flight:

Swing-wing - also called "variable sweep wing". The left and right hand wings vary their sweep together, usually backwards. Seen in a few types of military aircraft, such as the General Dynamics F-111.



Variable sweep (swing-wing)

Oblique wing - a single full-span wing pivots about its midpoint, so that one side sweeps back and the other side sweeps forward. Flown on the NASA AD-1 research aircraft.



Variable-geometry oblique wing

SWEPT WINGS:

A swept wing is a wing plan form favored for high subsonic and supersonic speeds, and is found on almost all jet aircraft in one form or another, as well as some high speed propeller aircraft. Compared with straight wings common to slower aircraft, they have a "swept" wing root to wingtip direction angled beyond (usually aft ward) the span wise axis. This has the effect of delaying the drag rise caused by fluid compressibility near the speed of sound, increasing performance.

The concept was first investigated in Germany as early as 1935, but it found no application until just before the end of the Second World War. Swept wings became common on second-generation post-war fighters like the MiG-15 and F-86 Sabre, which demonstrated a decisive superiority over the slower first generation of straight-wing jet fighters during the Korean War. Since then swept wings have become almost universal on all but the slowestjets (such as the A-10).

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The term "swept wing" is normally used to mean "swept back", but other swept variants include forward sweep, variable sweep wings and pivoting wings. The delta wing also incorporates the same advantages as part of its layout.

The characteristic "sweep angle" is normally measured by drawing a line from root to tip, 25% of the way back from the leading edge, and comparing that to the perpendicular to the longitudinal axis of the aircraft. Typical sweep angles vary from 0 for a straight-wing aircraft, to 45 degrees or more for fighters and other high-speed designs.

METHODOLOGY

INTRODUCTION TO CATIA V5

CATIA stands for computer aided three dimensional interactive application is a multi platform CAD/CAM/CAE commercial software suite developed by the French company Dassault system and marketed worldwide by IBM. Written in the C++ programming language, CATIA is cornerstone of the Dassault system product life cycle management software suite.

The was created in the late 1970's and early 1980's to develop Dassault's mirage fighter jet and then was adapted in the aerospace, automotive, shipbuilding and other industries.

CATIA competes in the CAD/CAM/CAE market with Siemens NX, pro/ENGINEERING, Autodesk inventor and solid edge.

MODELLING OF WING AND FUSELAGE IN CATIA

The following section deals with the modeling of the designed fuselage for its given specifications. The modeling has been carried out using CATIA V5 R20 student's edition design software.

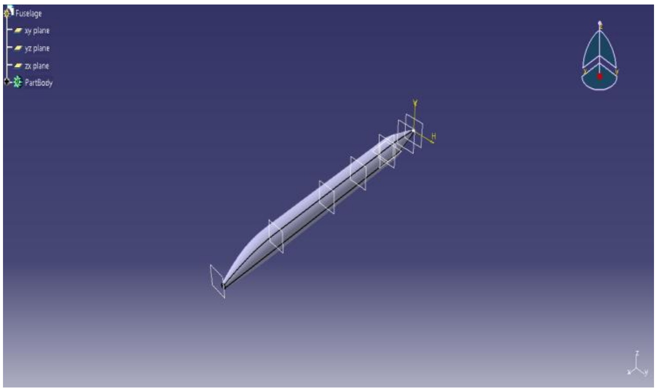
To NACA 16 series airfoils are used here, whose coordinates have been generated using software called DESIGN-FOIL demo version, which generates the required airfoil and directly transfers the coordinates of the airfoil profile to excel sheets. Now to import this airfoil coordinates from excel sheets to CATIA we have used a MICRO.CATVBA FILE, which imports the points and generates them in CATIA. The following subsections define a detailed procedure of how to model a wings and fuselage using this software.

The following subsections describe a procedure of how we have designed an unswept using a combination of the above mentioned software's. Note that to understand the procedure below you should have a basic knowledge about the software's used here and the NACA series airfoil and their destinations. You can get this information from the help files as well.

For example if you want to know the NACA airfoil designations just click on the help menu in the design foil software and you will get a complete description of these airfoils.

Fuselage Specifications:

Total fuselage length	37.57m
Front section	6.40m
Midsection	17.47m
Rare section	13.70m
Fuselage max.depth	3.95m
Fuselage max.width	3.99m
Wetted area, total fuselage	400.65 sq.m
Wetted area front section	59.75sq.m
Wetted area mid section	217.74sq.m
Wetted area rear section	123.16 sq.m



screenshot of Solid Fuselage designed in CATIA

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Designing fuselage in catiav5R20:

Step1: start → mechanical design → part design → name the part as fuselage → ok.

Step2: select YZ plane → go to sketch → draw a circle of radius 2820mm at center (0,0) → exit work bench.

Step3: go to reference tool bar select reference plane → select YZ axis → offset plane1 toa distance of 12700mm → ok → exit work bench.

Step4: go to reference tool bar select reference plane → select YZ plane → offset plane2 to a distance of 25400mm from YZ plane similarly plane3 to a offset distance of 18350 mm from plane2 and repeat the same process for plane4 at distance of 18350mm from plane3.

Step5: Repeat step5 to draw an offset plane5 and 6 at a distance of -9000mm from YZ plane and -3800mm from plane5.

Step6: Repeat the step2 at plane1, plane2 and plane3.

Step7: Select plane4 go to sketch → draw a circle at center (2160,0) of radius 600mm → ok.

Step8: Select plane5 → sketch → draw a circle of radius 1300mm → ok → exit work bench.

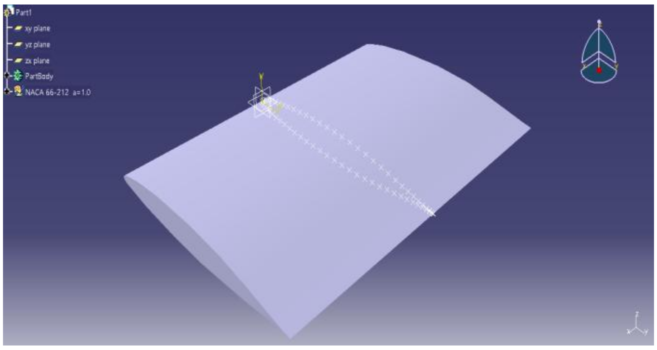
Step9: Select plane6 → sketch → draw a circle of radius 240mm → ok → exit work bench

Step10: Go to sketch based tool bar → multi section solid → select all sketches → ok.

Step11: Go to dress up features → edge fillet → sketch6 → give dimensions as 260mm → ok.

WING SPECIFICATIONS:

Area, reference	112.5square meters
Aspect ratio	10.25 square meters
Span (excluding winglets)	33.91m
Sweep back at ¼ chord	25 degrees
Taper ratio	0.29degrees
t/c at root	0.153
t/c at tip	0.108
Mean aerodynamic chord	3.63m
Wing chord at tip	1.51m
Wing chord at root	6.02m
Wing chord at c/line	7.05m



Screenshot of unswept wing in CATIA V5R20

1 Open CATIAV5R20 workbench → start → mechanical design → assembly design

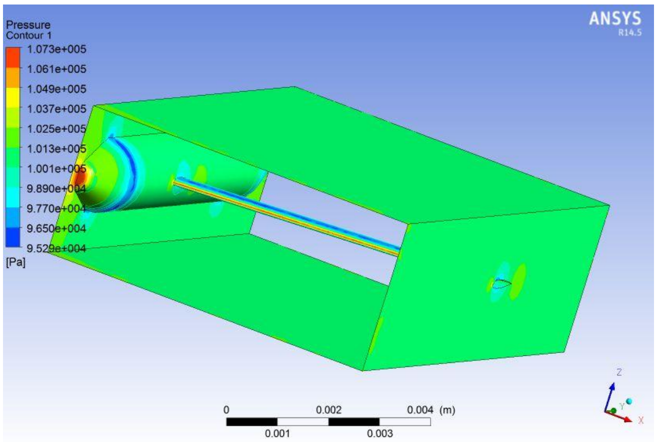
Step: 2 Press right click on Product file → components → existing components → select fuselage

Step: 3 Press right click on Product file → components → existing components with positioning → select unswept wing

Step: 4 Click on the wing and move the wing towards the x direction by selecting the manipulation parameter tool in manipulation tool bar

Step: 5 Select fix together tool and select wing and fuselage → ok

RESULT
Pressure coefficient Vector:
Swept wing



Pressure coefficient vector of sweptwing configuration

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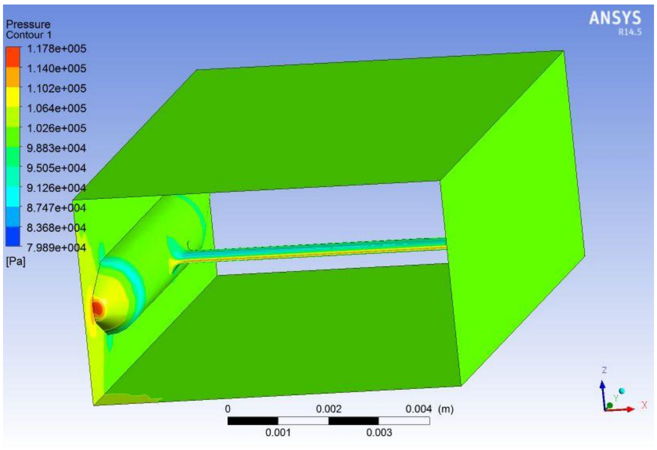
Unswept wing:



Pressure coefficient configuration of unswept wing

CONCLUSION

The initial aim of the project was to analyze the aerodynamic performance parameters of a mid wing configurations for a civil aviation aircraft in both swept and unswept wing mode. The project was done by initially designing the two different configurations in CATIA V5, followed by analyzing it in ANSYS FLUENT.

By the result of the analysis we can conclude the following results.

That the swept wing and unswept wing gave almost equal amount of drag. The swept wing gave more lift than the unswept wing, when considered numerically the sswept wing gave almost twice the lift when compared to the unswept wing.

Hence from these results we can conclude that when considered aerodynamically a swept wing for an aircraft is better than an unswept wing.

FUTURE SCOPE

The swept wings will be used in commercial aircrafts so that they can produce more lift

The swept wings are aerodynamically more efficient, so that there will be swept eingsfor most of the aircrafts.

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