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COMPUTATIONAL INVESTIGATION ON SLOTTED- SPLIT FLAP

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Abstract: Airfoil have number of questions must be answered before further development of the new transport aircraft design is approved. The manufacturer needs to knows; it can easily recoup their initial investment. The airline will order this new product only if it can expand its market, reduce costs and increase its revenue. The passenger wants a low-ticket price and high comfort. Society as a whole wants this new technology to improve the economy while protecting the environment. Most often, the camber is designed to increase the lift coefficient rather than decrease the drag coefficient. It is also helpful to shape the wing fold so that the tip will stall more slowly than the root. In unforeseen circumstances, this spin delay may allow the pilot to maintain control of the aircraft. A rounded airfoil has a virtually limitless range of possible designs, which is a fantastic tool in the aerodynamic engineer's toolbox. Practically, however, there is a finite number of common forms from which to choose if good data are available. The best choice depends on the type of aircraft and largely on the speed of the air flow. In this article, a special model for the skirt is proposed. The main goal of the model is to increase the efficiency of take-off of aircraft and to increase the efficiency of maneuvers during flight.

Index Terms – Slotted Split Flaps, Maximize take-off efficiency, NACA 23015

1.INTRODUCTION

The Aviation technology has undergone great development throughout the 20th century. More innovations aimed at improving lift. To increase lift, several aerodynamic devices were studied and developed, depending on the size, speed and complexity of the aircraft project. In this work, a study on high-lift devices and flow variations aimed at increasing the maximum lift coefficient and reducing drag of commercial aircraft is discussed.

HIGH LIFT AERODYNAMIC DEVICES

High lift devices are sophisticated equipment found on commercial aircraft and are designed not only to increase lift but also to improve flight performance. A typical airliner has three stages of flight, takeoff, cruise and landing, during which the high-lift devices are deployed and retracted as needed. Their position can be located either on the leading edge or on the trailing edge of the main wing of the aircraft.

HIGH LIFT SYSTEMS OPERATE ACCORDING TO THE FOLLOWING PRINCIPLES

1) Increasing the airfoil camber.
2) Boundary layer controlled by
(a) Improving pressure distribution;
(b) Feeding high-energy airflow to the boundary layer;
(c) Removing the "old" boundary layer
3) Increasing the wing area.

A distinction is made between
(a) Active high lift systems
(b) Passive high lift systems

This description is restricted to the typical passive high lift systems, which do not require any additional equipment apart from the drive system for retracting and extending the flaps.

FLAPS

Flaps are a high-lift device consisting of a hinged plate or plates mounted on the trailing edge of the wing. They are placed between the fuselage and the wing tip. When extended, they increase the camber and in most cases the chord and area of the wing, resulting in an increase in lift and drag and a decrease in stall speed. They are also an important part of the take-off and landing process. When the plane takes off, the flaps help create more lift. In contrast, flaps allow a steep but controlled angle during landing.

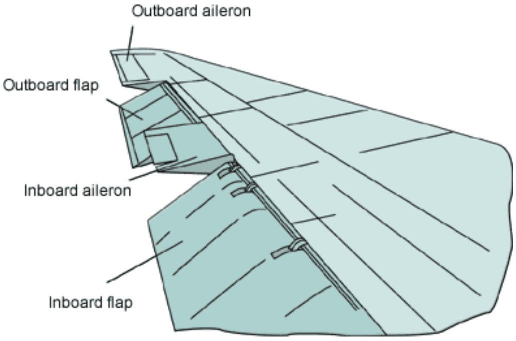


Fig 1.1 Flap

WORKING OF FLAP:

Flaps change the shape of an airplane wing. If necessary, they redirect the air around the wing. The setting of the flaps determines whether they are used to increase lift (as in takeoff) or to increase drag (used in landing). When the plane's flaps are up, the plane's camber is such that the wings can create more lift. Depending on the aircraft, flap settings are usually between five and fifteen degrees. After takeoff, the flaps are fully retracted so that they do not start to create drag. Conversely, extending an airplane's flaps creates a "broken wing," which increases drag. This also reduces the stall speed of the aircraft. It helps the aircraft slow down. Pilots usually set the flaps between twenty-five and forty degrees. This allows the pilot to take a steeper angle of attack to land. Pilots flying high-wing aircraft may notice significant pitch in the nose of the aircraft if the increase in drag is sudden.

TYPES OF FLAPS:

Trailing edge flaps:
a. Plain flap
b. Split flap
c. Slotted flap
d. Fowler flap
Leading edge flaps:
a. Krueger flaps
b. Zap flaps
c. Junkers flaps
Of all these we have chosen slotted and split flaps because of smooth air flow and good aerodynamic characteristics.

LIMITATIONS OF USING FLAPS:

In aviation, the use of flaps has several limitations. They are essential for both takeoff and landing, but their use must be within certain parameters to ensure safety and efficiency. One of the most common limitations is related to flight speed. Each aircraft has a designated speed range, indicated by a white arc on the speed indicator, within which full flaps can safely be deployed. Exceeding these speeds with flaps extended can cause structural damage. Altitude of aircraft also affect the Flap usage. Flaps are normally used only below 20,000 feet. This is due to potential compressibility issues that can occur at higher altitude.

The requirement of flaps used during takeoff varies by aircraft type. The aircraft manufacturer usually provides specific guidelines and limitations for the use of flaps. For example, in the Cessna 172, flaps are not often used because its takeoff pitch in sea level conditions is about 1,000 feet. However, up to 10° flaps can be used if desired. While few airplanes prohibit using flaps on takeoff, it’s not always a good idea, especially when trying to achieve maximum performance. Strong crosswinds might necessitate the reduction of flap use during landing to maintain control over the aircraft. In hot weather, overheating around the wing’s bleed ducts could pose problems if flaps are deployed. Cold weather conditions, especially with ice or snow, limit how far flaps can be retracted post-landing to prevent damage from ice accumulation.

OBJECTIVE

PROBLEM DEFINITION:

As a device for creating high lift, flaps require a laminar flow of air without the formation of turbulence. For buoyancy, however, a large deflection is required. Compared to other flaps, slotted flaps are the ones that produce high lift coefficients. Not only the lift coefficient, it also creates drag. As already known, both spoilers and flaps are used for landing. But this project aims to eradicate the complicated mechanism of using spoilers and flaps.

SOLUTION TERMINOLOGY:

Because of this, the introduction of the new design should increase our efficiency needs. When landing, the aircraft must approach at extreme nose height, which reduces visibility. Flaps can be used to increase maximum lift coefficient, increase wing area, or both. Changing the maximum lift coefficient can be done by changing the shape of the airfoil selection or by increasing the camber. A trailing edge flap is one way to achieve this. The maximum lift coefficient for a simple flap airfoil is greater than that for an unflapped airfoil.

LITERATURE REVIEW:

The presence of high lift devices either at inboard or outboard regions along aircraft wingspan improves the aerodynamic and flight performance significantly. The maximum lift coefficient has direct impact on take-off, landing performances of aircraft. The aspect ratio of wing is the key design feature to improve the flight Mach number for long range flights. High aspect ratio wing shows reduced skin friction drag but dramatically increase pressure drag and contribute to the fuel efficiency of aircrafts. Ascent or descent rate during take-off or landing stages are function of thrust to weight ratio, aerodynamic performance and maximum lift coefficient and vary with number of slots deployable on aircraft wing. The kinematic mechanism plays a major role to control the motion of flaps on aircraft wings. [1]. The lift force generated by aircraft wings depends on the shape of an airfoil, the area of the lifting surface and the speed of the aircraft in relation to the air. During take-off and landing, the speed of the aircraft is relatively low, so to obtain the required value of lift force, devices are used to change airfoil shapes, the area of the lifting surface and circulation. Such devices include trailing-edge wing flaps. Their main task is to increase the lift force on the wing. They differ for their design and influence on changes in the aerodynamic force co-efficient. As a result of flap deflection, the lift value is increased and the angle of attack for a given value of the lift force coefficient is decreased. The deflection of flaps is also accompanied by an increase in the drag force coefficient, and as a result, despite the increase in the value, lift-to-drag ratio K decreases. [2]. During the takeoff and landing of an aircraft, the performance of high lift devices has strong impact on the operating cost and environment around airports, such as improvement of payload, fuel consumption and noise emission. The take-off and landing distances, and the design maneuvering speed-VA, the speed with flaps fully deflected- VF, and the stall speed with flaps fully deflected-VSF, depends on aerodynamic characteristics of the wing with a flaps deflected. Computational Fluid Dynamics (CFD) is widely used for the prediction of the aerodynamic performance of the wing, at least in cruise flight. The computational of the flow over a multi-element wing in high lift configuration remains, however, one of the most difficult problems encountered in CFD. The computational normally include a comprehensive code, coupled to Euler or Navier Stroke solver. High lift configurations considerably complicate the flow physics by boundary layer transition, separations and reattachments. Therefore, it is very important to generate the appropriate mesh around it. The mesh can be structured, unstructured or hybrid. The structured mesh is identified by regular connectivity. The possible element choices are quadrilateral in 2D and hexahedral in 3D. The unstructured mesh is identified by irregular connectivity. This grid typically employs triangles in 2D and tetrahedral in 3D. The structured mesh has many coding advantages, but it may be difficult to conform a single block to a complicated shape. A hybrid mesh contains a mixture of structured portions and unstructured portions. It integrates the structured meshes and the unstructured meshes in an efficient manner. Another important step is the choice of a turbulent model. The turbulence is the most challenging area in fluid dynamics and the most limiting factor in accurate computer simulation of the flow.[3]. First, the influence of the Lift and Load scatterings on the overall performance characteristics of the wing are discussed. It is established that the optimization is achieved by designing a wing geometry that yields elliptical lift and load distributions. Second, the reference trapezoidal wing is considered the base line geometry used to outline the wing shape layout. Third, the integrated design method is introduced through an evocative flowchart that describes the wing design process, whose objectives are essentially the determination and the optimization of the different wing parameters, essentially: Wing Area, Sweep Angle, Aspect Ratio, Taper Ratio, Thickness and Twist. Furthermore, refined and assessed formulas identified from an exhaustive literature study and historical trends yielding accurate and logical estimation of each parameter described in the optimization flowchart are provided. Finally, the capability of the proposed method is investigated through two design examples for jet and propeller aircrafts [4]. The surface streamline of the aircraft in flight is studied by CFD simulation, and the skin scheme is determined based on it. Profile, a professional airfoil analysis software is applied to analyze parameters of airfoil, it finally results that the change of wingspan of rectangular wing has no effect on lift coefficient, drag coefficient and lift drag ratio, but it has obvious effect on lift, it proves that the aerodynamic layout of the wing is reasonable. Through the load test, it shows that the increase of lift is consistent with the theoretical prediction by about 50%. [5].

2.METHODOLOGY

This is the study of Slotted-Split Flap attached with NACA-23015 type of airfoil at the trailing edge were designed and analyzed to increase the take-off efficiency of aircraft and to increase the efficiency of flight maneuvers during flight. And also slotted-split flap is compared with the performance of the split flap and slotted flap. The designed airfoil undergoes the analytical procedure which includes the following progress.

- **Step 1 –** Literature Survey
- **Step 2 –** Parameter selection for design
- **Step 3 –** Designing 3D model
- **Step 4 –** Analytical Process
- **Step 5 –** Results
- **Step 6 –** Conclusion

DESIGN CONSIDERATIONS

The general parameters for the design of NACA –23015 airfoil is selected in respect to wing shape, wing span, thickness, chord length, chamber, weight was considered as the design parameters in this chapter.

WING DESIGN PARAMETERS

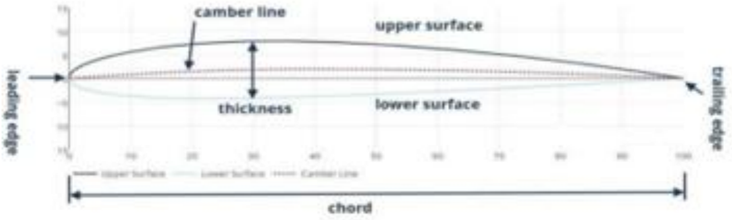


Fig – 2.1 Wing Design Parameters

DESIGN PARAMETER OF NACA 23015 AIRFOIL

- 2-lift coefficient (*0.15)
- 3- Location of maximum camber for leading edge (*3%)

- 0-whether the camber is simple or reflex
- 15- % of maximum thickness to chord (t/c)

SELECTION OF AIRFOIL

NACA 23015 airfoil profile is considered for modelling FLAP.

However, this point is rarely reached for several reasons.

a. The flap in combination with an airfoil appears to be one of the most generally satisfactory high-lift devices investigated to date.
b. At low lift coefficients it gives very nearly as low values of profile drag as a good plain airfoil of comparable thickness.
c. Structural and stability problems associated with the large negative pitching moments occurring at high lift coefficients may be slightly greater than in case of ordinary and split flaps.

DESIGN PARAMETERS FOR WING MODEL

Wing shape, Wing span, Wing area, Thickness, Camber, Chord length and Weight were selected as the parameters for the designing of the winglet.

Airfoil used	**NACA- 23015**
Wing Shape	Swept Back
Wing Span	500 mm
Wing Area	11.2E+04 mm^2
Thickness	15% at 30% of chord
Camber	1.8% at 15% of chord
Root Chord Length	150 mm
Tip Chord Length	100 mm
Weight	6.2 kg

Table 2.1 Design parameters for Wing

3D MODEL OF AIRFOIL

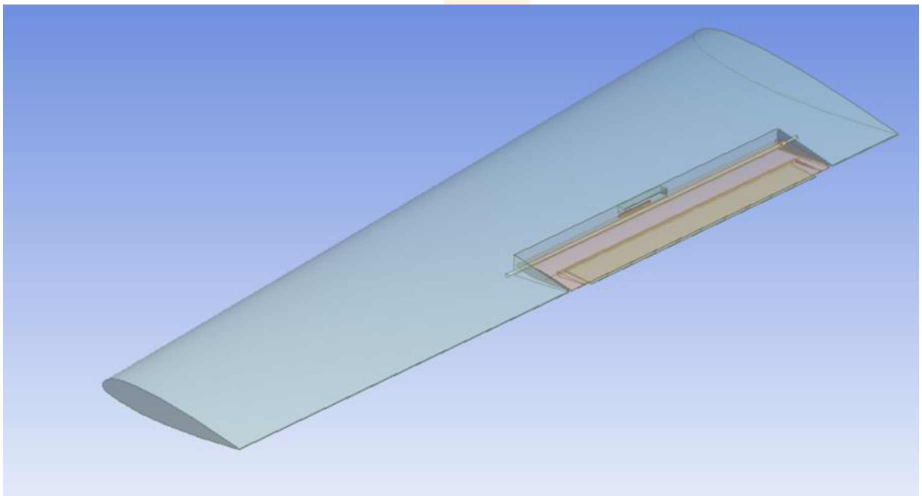


Fig – 2.2 3D Model of airfoil

STEPS INVOLVED IN DESIGN

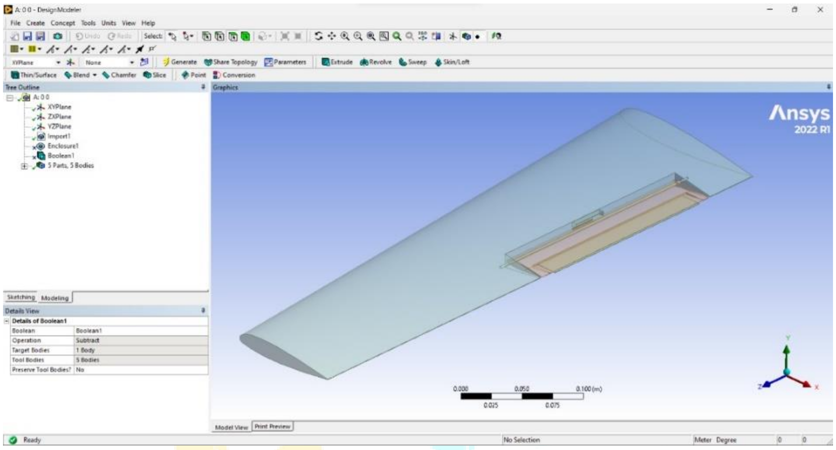
Step 1: Download airfoil data from tools.
Step 2: Generating airfoil coordinate in excel spreadsheet with the aboveformat.
Step 3 : Importing data in design software and using spline to connect everypoint together to form close loop sketch.
Modeling the 3D model as per the design parameters shown above.

3. MODEL ANALYSIS

The analysis of the airfoil was performed using the ANSYS analysis tool and the steps involved in this process were explained. Meshing and model analysis was performed. And the analytical results for the wings which is employed with Slotted Flap, Split Flap, Slotted-Split Flap and tabulated.

STEPS INVOLVED IN ANALYSING MODEL

Step 1: Insert the model

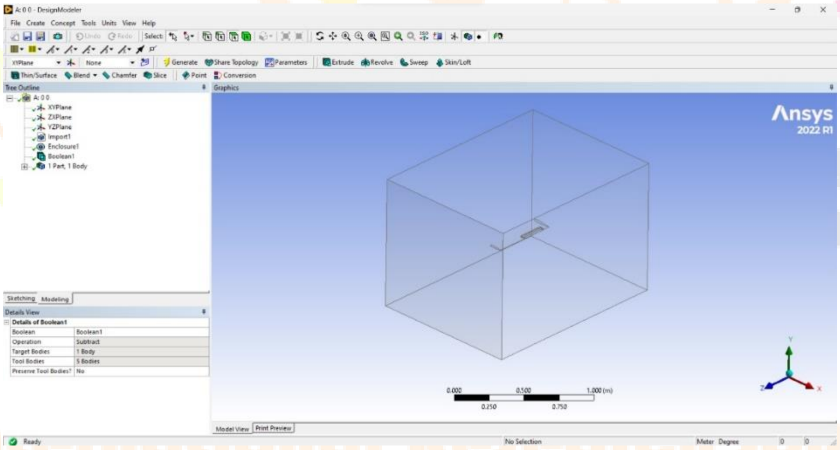


Details of Boolean1	
Boolean	Boolean1
Operation	Subtract
Target Bodies	1 Body
Tool Bodies	5 Bodies
Preserve Tool Bodies?	No

Fig – 3.1 Inserting airfoil

Step 2: Create **Enclosure** to create the control volume around the airfoil model.

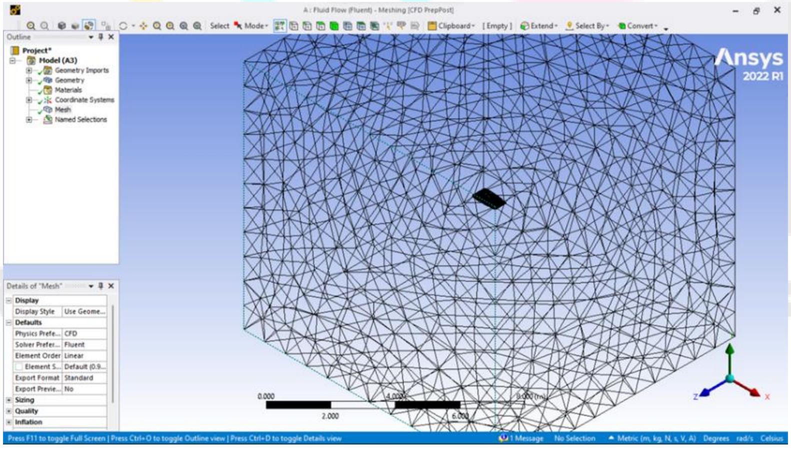
Step 3: Apply the **Boolean** to subtract the parts



Details of Boolean1	
Boolean	Boolean1
Operation	Subtract
Target Bodies	1 Body
Tool Bodies	5 Bodies
Preserve Tool Bodies?	No

Fig – 3.2 Creating Boolean around Model

Step 4: Generate mesh.



Details of "Mesh"	
Display	
Display Style	Use Geome...
Defaults	
Physics Prefe...	CFD
Solver Prefer...	Fluent
Element Order	Linear
Element S...	Default (0.9...
Export Format	Standard
Export Previe...	No
Sizing	
Quality	
Inflation	

Fig – 3.3 Creating Mesh

Step 5: Apply boundary conditions. Boundary conditions,

Medium : Dry air

Temperature: 20 ° c or 293.15 K

Velocity : 250 m/s or 0.72 Mach number

Step 6: Run the analysis for approximate iterations.

ANALYTICAL RESULTS

ANALYTICAL RESULTS OF SLOTTED FLAP

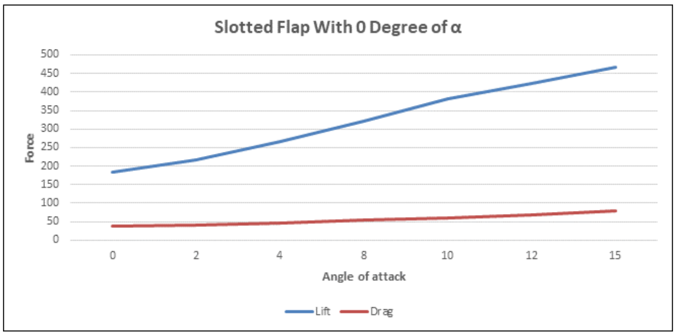


Fig – 3.4 Slotted Flap with 0º α

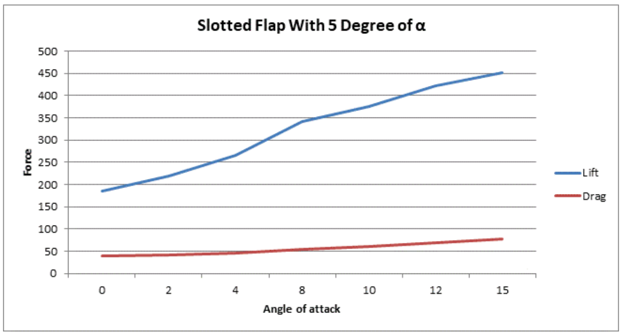


Fig – 3.5 Slotted Flap with 5º α

ANALYTICAL RESULTS OF SPLIT FLAP

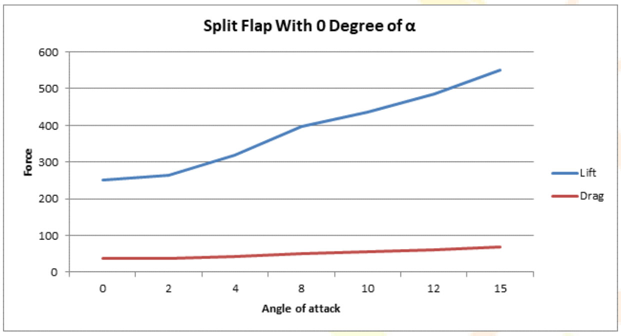


Fig – 3.6 Split Flap with 0º α

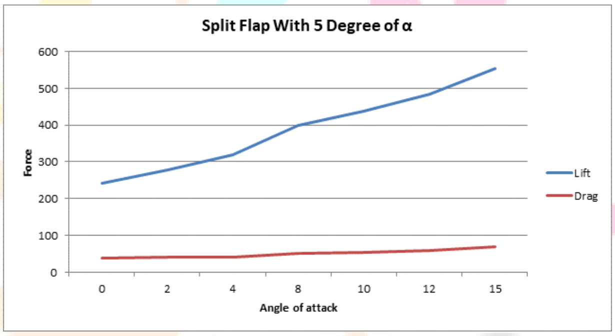


Fig – 3.7 Split Flap with 5º α

ANALYTICAL RESULTS OF SLOTTED-SPLIT FLAP

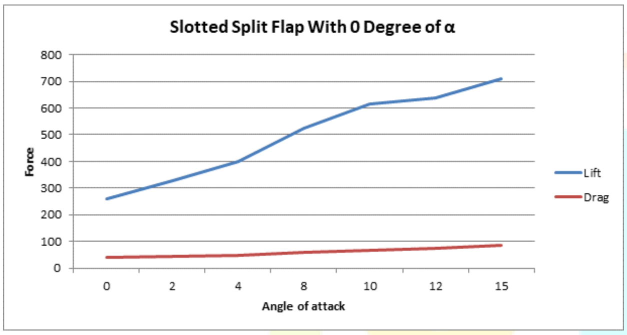


Fig – 3.8 Slotted-Split Flap with 0º α

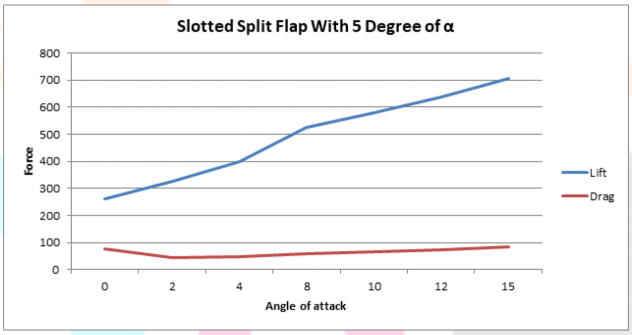


Fig – 3.9 Slotted-Split Flap with 5º α

4. RESULT AND DISCUSSION

RESULTS:

For the same boundary condition all the flap model was evaluated by attached with NACA 23015 airfoil and tabulated.

Type of Flap	**Angle of Attack [Degree]**		**Flap Angle [Degree]**						
			0	**2**	**4**	**8**	**10**	**12**	**15**
Slotted Flap	**0**	**Lift [N]**	185	219	265	320	382	423	466
		Drag [N]	39	41	45	54	61	68	79
	5	**Lift [N]**	185	219	265	342	376	423	451
		Drag [N]	39	41	45	54	60	68	78
Split Flap	**0**	**Lift [N]**	250	265	320	396	437	485	552

		Drag [N]	38	39	42	50	55	60	70
	5	**Lift [N]**	242	279	320	400	437	485	554
		Drag [N]	38	40	42	50	55	60	70
Slotted-Split Flap	**0**	**Lift [N]**	258	328	398	525	614	637	709
		Drag [N]	41	45	48	58	66	73	85
	5	**Lift [N]**	260	325	397	524	581	636	708
		Drag [N]	78	44	48	58	65	72	85

Table 4.1 Results

CONCLUSION:

According to the analytical results and the obtained data, the lift and drag is calculated for the chosen airfoil which is employed with slotted flap, split flap and slotted-split flap. Here the analysis is carried out for all the three combination of flap configuration with the angle of attack 0 and 5 degree between overall model to horizontal plane. Above tabulation represents the analytical result.

By comparing with the other flap configuration (Slotted and Split Flap) with the Slotted-Split Flap configuration shows improvement in lift co-efficient value while altering the Chamber. Hence, it is concluded based on the Coefficient of lift values observed. Comparing to slotted split flap, slotted flap produces high lift. It will reduce runway distance during climbing. But as mentioned already, during landing high lift is not needed. It is clearly proven from the design that slotted split-flap is more efficient than slotted flap during landing. Maneuvering stability of the aircraft also improved with slotted-split flap.

In comparing with slotted Flap with Split Flap, co-efficient of lift value is high in Split Flap. But in practical slotted flap reduces the boundary layer separation in the upper part of the wing. Because due to the slotted gap in wing section the pressurized air from the bottom part of wing is moved to upward through it. Hence control the boundary layer separation of airfoil. In Split Flap, it seems the part of wing is made to increase the camber of wing. Hence there is no possibility to control the boundary layer. In comparing the co-efficient of drag, values are comparable with each other. There is a slight increment in Slotted Flap, that will not make any changes in flight performance.

Slotted Flap and Slotted-Split Flap were compared means, there is a huge improvement in both the lift and drag values. Approximately around 0.7 time of lift value. In both Flap model lift curves are increased linearly with increase in angle of attack of flaps. It will help in a short take-off region. But in Slotted-Split Flap, at 5 degrees of angle of attack drag value is in abrupt manner. In compared with Slotted and Split Flap, weight of the proposed model is heavy and also the hydraulic and electrical connection in proposed model is complicated.

In comparing Slotted-Split Flap with Split Flap there is improvement in moment values. But at minimum angle of flap the values are comparable with each other, when the angle of flap is increasing, lift and drag values are improved compare to Split flap. It shows that at high angle of flap there is performance variation. Both the advantage of slotted flap and split flap are there, when the airplane has Slotted-Split flap model, like slotted split flap reduces the boundary layer separation and the Split Flap produce high drag at maximum angle of flap. Finally, it is concluded that by using high lifting device (Slotted-Split Flap) the take-off efficiency of the aircraft is improved by improving camber of the airfoil.

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