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Design and Analysis of Flexible Wing

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Abstract - *Modern transport aircrafts are introducing high lift devices to overcome the contradiction between economic considerations and low flight speed lift requirements. The flaps are known as high lifting devices. This paper contains an exploration of the analysis of aerodynamics characteristics and other characteristics properties of flaps. with the help of the CAD modelling software's such as CATIA and SOLIDWORK . the modelled geometry is analyzed in the CFD software ANSYS. Flexible wing has great potential to improve overall aircraft performance, just as natural aircraft do by adjusting the shape or dynamically optimizing for various flight conditions, and there are many untapped opportunities beyond the current proof-of-concept demonstration. This review discusses the most important examples of the application of the concept of deformation to 2D and 3D airfoil models. The methods and tools commonly used to design and analyze these concepts are discussed, ranging from structural analysis to aerodynamic analysis, from control aspects to optimization. Throughout the review, it became clear that the use of the concept of Flexible for everyday use in aircraft is still rare, and some reasons were given which hindered its mainstreaming for industrial use. Finally, promising concepts for future use are identified..these are also analyzed in the CFD software.*

I INTRODUCTION

Modern transport aircraft introduce high lift devices to overcome the contradiction between economic considerations and low flight speed lift requirements. When the aircraft design process begins, there are many aspects to consider. Since the cruise phase of flight occupies the majority of the overall mission profile, modern wings are optimized for efficiency in cruise flight, reducing direct operating costs (DOC) of the aircraft and thus reducing fuel consumption. However, this airfoil is rather inefficient at low speeds and does not provide enough lift [1]. Therefore The purpose of having a high-lift device is to provide more lift to the wing at low speeds, i.e. during the take-off and landing phases. The process of designing a high-lift unit is more empirical than analytical . First, the basic profile of the wing must be determined , then the maximum lift coefficient (CLmax) of this basic profile can be obtained by the approximate calculation of empirical and statistical formulas or existing experimental data . Initial field performance parameters, such as aircraft take-off and landing distance, are related to the aircraft mission type and can be set according to the airport situation [2].The CLmax increment due to the high-lift device during the take-off and landing phases can then be calculated from these parameters. Therefore, the appropriate type of lifting device can be selected considering its lifting capacity, weight, complexity cost reliability and maintain ability The movement of the Fowler and the deflection of the high-lift surfaces (flaps or slats) during the take-off and landing phases can also be determined separately [3]. Once the trajectory of the specific surface pattern is defined, the next task is the preliminary design of the drive mechanism of the device. CAD software such as CATIA will be used to facilitate modeling and analysis. After estimating the aerodynamic loads on the shiny surfaces, we can calculate the stresses in the mechanism and analyze their resistance to see if the size of the structure is practical [4].

A flap is a high-light device used to reduce the speed of an aircraft wing for a given weight. Flaps are usually mounted on the trailing edges of the wings of fixed-wing aircraft. Flaps are used to reduce takeoff distance and landing distance. Flaps also add drag, so they retract when not needed. The flaps fitted to most aircraft are partial span flaps; the point that extends from near the root of the wing to the inside of the aileron [5]. When partial span flaps are deployed, they change the span wise distribution of lift on the wing causing the inner half of the wing to provide a greater proportion of lift and the inner half exterior provides a smaller proportion of lift. The reduction in the lift ratio provided by the outer half of the wing is accompanied by a reduction in the angle of attack of the outer half This is advantageous because it increases the margin above the outer half-stall, which preserves aileron effectiveness and reduces the likelihood of asymmetric stalls and spins [6].

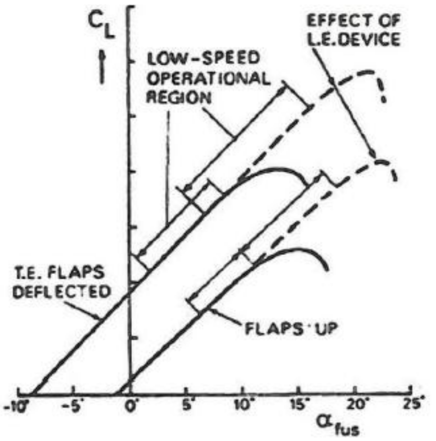


Figure 1: Lift Curve with and without Flap

Flexi blewing structures are widely considered to be one of the most promising technologies for improving the aerodynamic performance of large civil aircraft. The controllable adaptation of the wing shape to external operating conditions naturally maximizes the aerodynamic efficiency of the aircraft positively affecting the amount of fuel burned and the amount of pollution emitted [7]. Along with the benefits of wing replacement at the aircraft level come key aspects of enabling technology primarily related to weight loss excess power consumption and safety concerns. Efforts to address these critical points ensure the integration of reliable and mature enough structural solutions for certification and flight operations by developing new design methods. In this work, the development phases of a multi-mode curved Flexible wing flap suitable for large civil aircraft applications are described in detail, with specific reference to the authors' activities within the Clean Sky Initiative [8]. The flaps are modified according to the target shape of the aircraft's flight conditions and are set to improve high lift performance during takeoff and landing and wing aerodynamic efficiency during cruise [9]. An innovative system based on a robotic finger-like rib actuated by electromechanical actuators is proposed as a technology enabling deformation; the maturation of the device is then followed by proof of concept for integration into a full-scale demonstrator for validation on the ground before the test flight. A step-by-step approach involving the design and testing of intermediate demonstrators is then followed to demonstrate compliance of the adaptive system with industry standards and safety requirements [10]. The technical problems encountered during the development of each intermediate demonstrator are critically analyzed and justifications are provided for all the engineering solutions employed. Finally, the layout of the scale demonstrator

II DESIGN PROCEDURE

- Comparing the analysis of the different flaps using Ansys
- Determining the aerodynamics characteristics of flaps
- Designing a Flexible wing using CAD software
- Analyzing the Flexible wing characteristics Ansys

III HIGH LIFTING DEVICES; FLAPS

A flap is a high-light device used to reduce the speed of an aircraft wing for a given weight. Flaps are usually mounted on the trailing edges of the wings of fixed-wing aircraft. Flaps are used to reduce take off distance and landing distance. Flaps also add drag, so they retract when not needed. The flaps fitted to most aircraft are partial span flaps; the point that extends from near the root of the wing to the inside of the aileron. When partial span flaps are deployed, they change the span wise distribution of lift on the wing causing the inner half of the wing to provide a greater proportion of lift and the inner half exterior provides a smaller proportion of lift. The reduction in the lift ratio provided by the outer half of the wing is accompanied by a reduction in the angle of attack of the outer half This is advantageous because it increases the margin above the outer half-stall, which preserves aileron effectiveness and reduces the likelihood of asymmetric stalls and spins. Extending the wing flaps increases the arc, or curvature, of the wing, which increases the maximum lift coefficient, or the upper limit of lift the wing can produce. This allows the aircraft to generate the required lift at a lower speed, thereby reducing the minimum speed at which the aircraft can safely maintain flight (called the stall speed). Increasing camber also increases wing drag, which can be beneficial during approach and landing as it allows the aircraft to descend at a steeper angle. A useful side effect of deploying the flaps for most aircraft configurations is a reduction in the aircraft's pitch angle, which lowers the nose improving the pilot's view of the run way from above the aircraft's nose the plane during landing. However another side effect depends on the type of flap, its position on the wing and the deployment speed when deployed, the flaps cause the angle of attack indicated (or relative to the unmodified wing) to decrease. For a short period of time, because for all trailing edge flaps and leading edge flaps the nose down pitch moment increases, then nose up (pitch) due to the increased lift blurs vision of the pilot if no action is taken on the pitch entry path. Flaps are available in many different designs, and the choice depends on the size, speed, and complexity of the aircraft that will be used, as well as the era in which the aircraft was designed Single flaps, split flaps and Fowler flaps are the most common Kruger flaps are located on the leading edge of the wing and are used on many jet aircraft

Principles of Operation

The general airplane lift equation demonstrates these relationships

$$L = \frac{1}{2}\rho V^2 S C_L$$

Here, it can be seen that increasing the area (S) and lift coefficient (CL) allow a similar amount of lift to be generated at a lower airspeed(V).

Extending the flaps also increases the drag coefficient of the aircraft. Therefore, for any given weight and airspeed, flaps increase the drag force. Flaps increase the drag coefficient of an aircraft due to higher induced drag caused by the distorted span wise lift distribution on the wing with flaps extended. Some flaps increase the wing area and, for any given speed, this also increases the parasitic drag component of total drag. Thus, flaps are extensively in use for short takeoffs and landings (STOL).

Types of Flaps

- Plain flap
- Split flap
- Slotted flap
- Fowler flap
- Junkers flap
- Gouge flap
- Fairey-Youngman flap
- Zap flap
- Krueger flap
- Gurney flap
- Leading edge flap
- Blown flap
- Flexible flap
- Flaperon
- Continuous trailing-edge flap

IV MODELLING AND ANALYZING OF FLAPS

Among the different types of flaps we have selected three types of flap

- Plain Flap
- Slotted Flap
- Flexible Flap

These three flaps are designed in the CATIA V5 software by referring the dimensions from the journals and previous reports and it is analyzed with the help of CFD analyze software ANSYS

Plain Flap

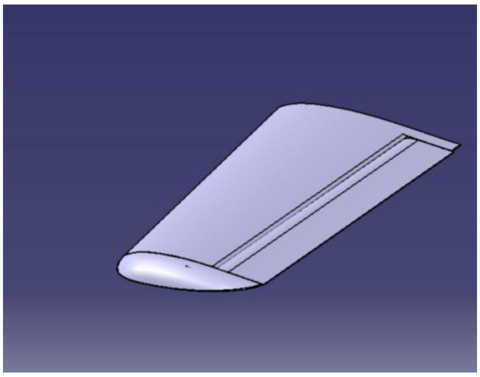


Figure 2: CATIA Model of Plain Flap

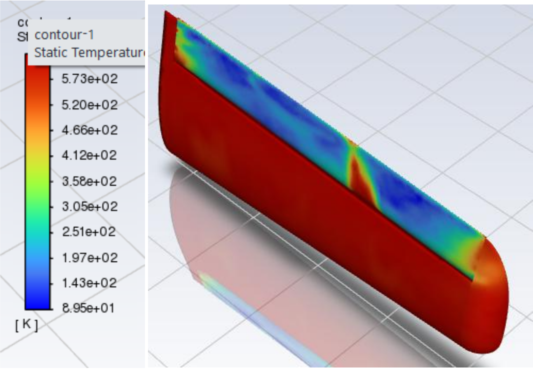


Figure 3: Meshed Model of Plain Flap

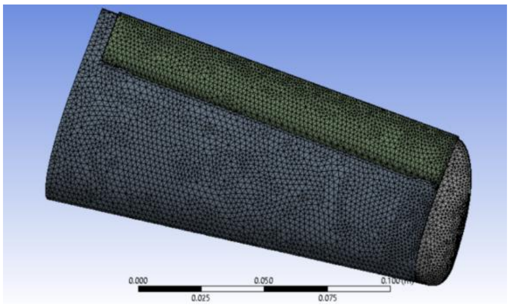


Figure 4: Temperature Contour of Plain Flap

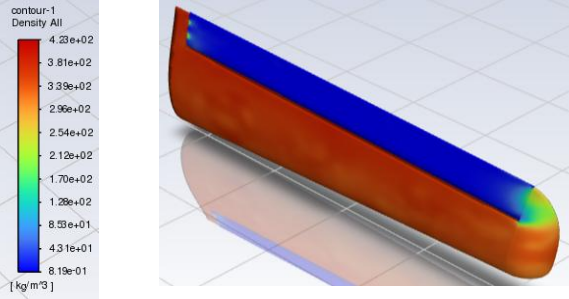


Figure 5: Density Contour of Plain Flap

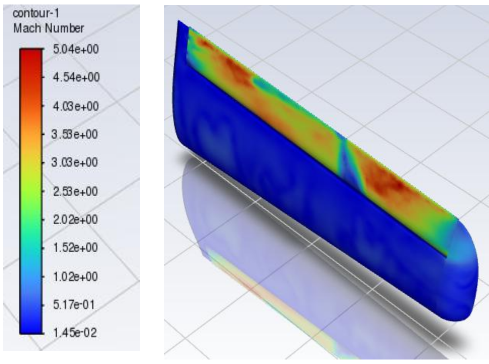


Figure 6: Velocity Contour of Plain Flap

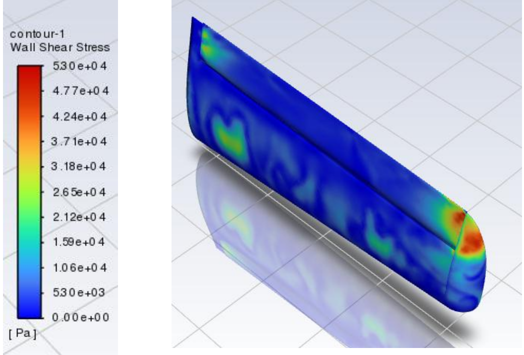


Figure 7: Wall Shear Stress of Plain Flap

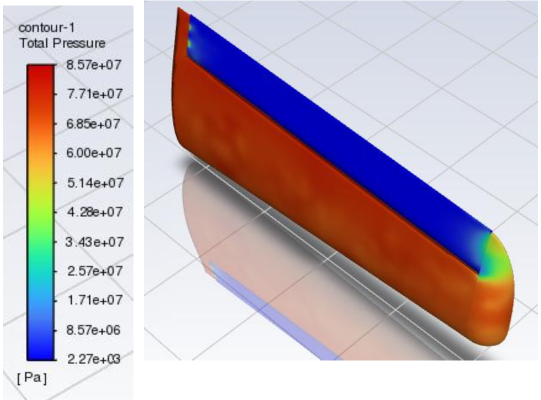


Figure 8: Pressure Contour of Plain Flap

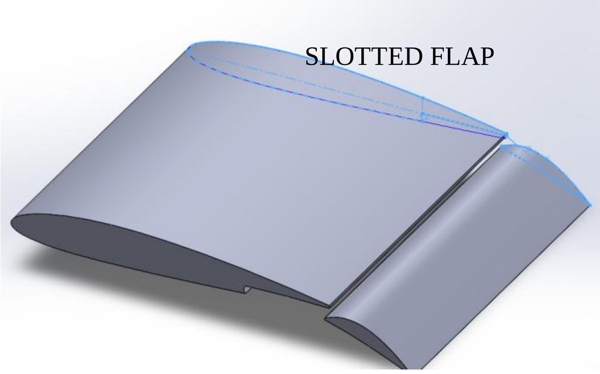


Figure 9: Solid Work Model of Slotted Flap

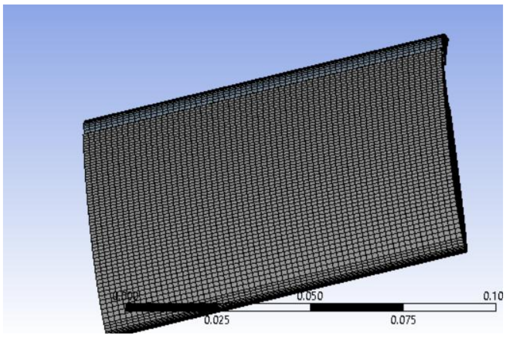


Figure 10: Meshed Model of Slotted Flap

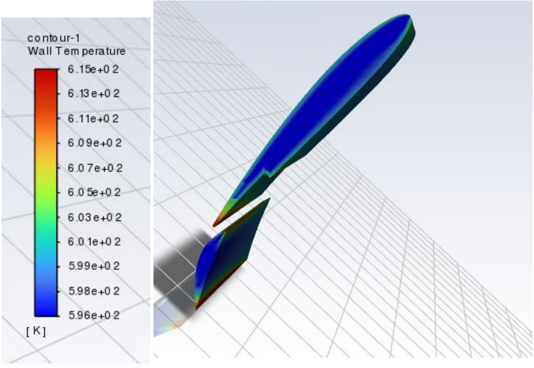


Figure 11: Temperature Contour of Slotted Flap

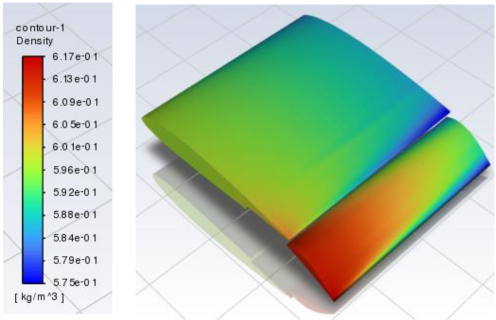


Figure 12: Density Contour of Slotted Flap

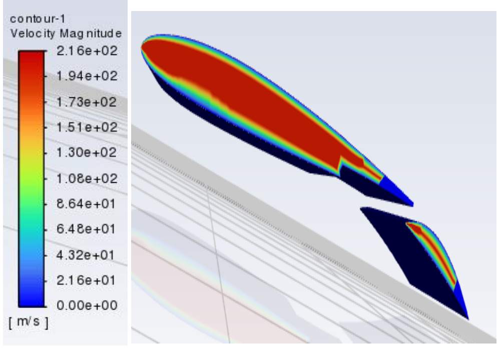
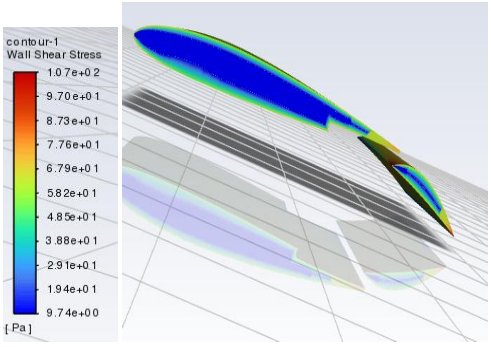


Figure 13: Velocity Contour of Slotted Flap



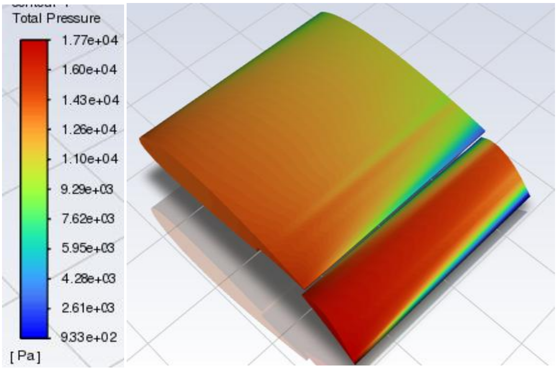
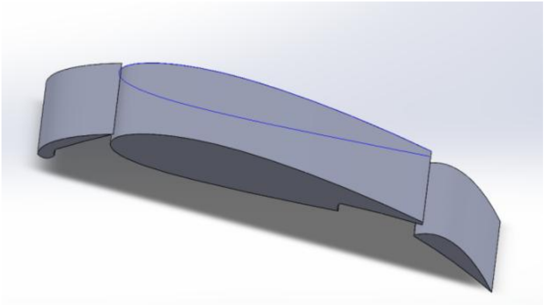


Figure 14: Wall Shear Stress of Slotted Flap

Figure 15: Pressure Contour of Slotted Flap

Flexible Flap1



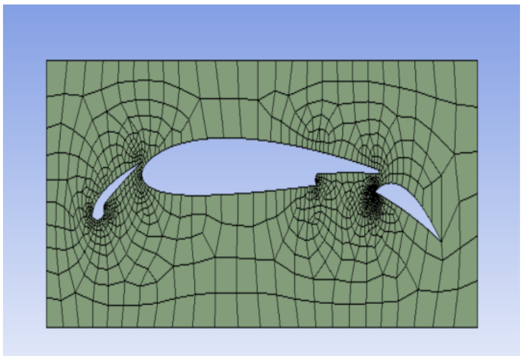


Figure 16: 3D Model of Flexible Flap

Figure 17: Meshed Model of Flexible Flap

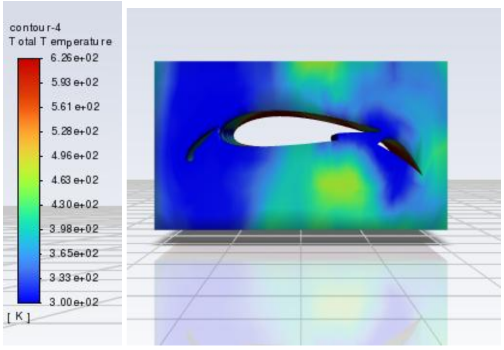


Figure 18: Temperature Contour of Flexible Flap

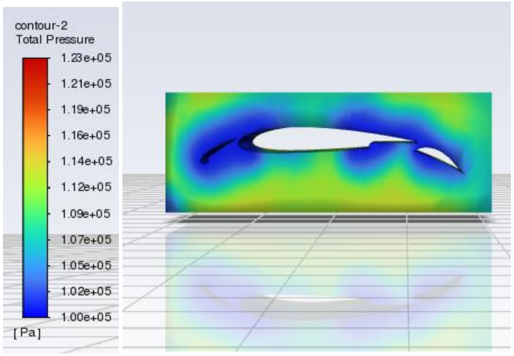


Figure 19: Pressure Contour of Flexible Flap

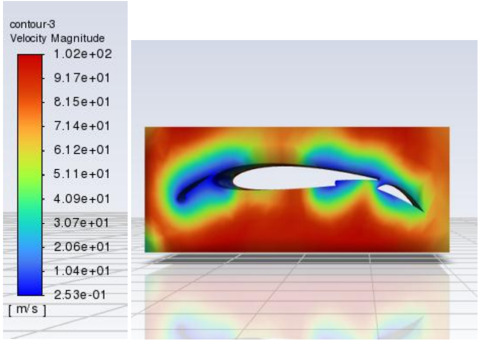


Figure 20: Velocity Contour of Flexible Flap

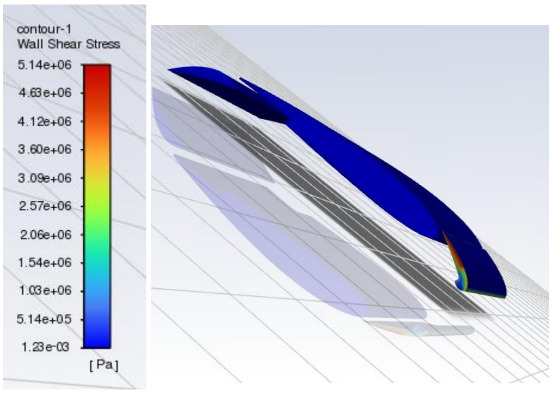


Figure 21: Wall Shear Stress of Flexible Flap

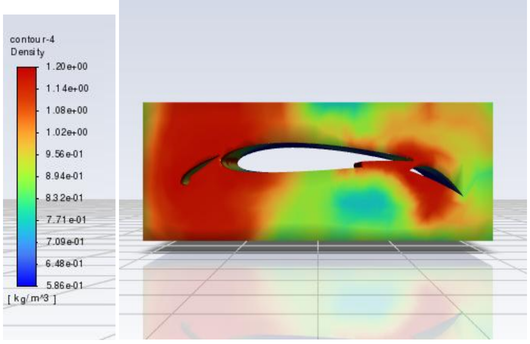


Figure 22: Density Contour of Flexible Flap

The above figures represents the velocity, density, temperature, pressure and wall flux contour of Plain flap, Slotted flap and Flexible flap

Table 1: Comparison Tables of Analyzed Flaps

Parameter	Plain Flap	Slotted Flap	Flexible Flap
Density	4.23×10^{2} Kg/m^{3}	6.17×10^{-1} Kg/m^{3}	1.20 Kg/m^{3}
Temperature	6×10^{2} K	6.15×10^{2} K	6.26×10^{2} K
Pressure	8.57×10^{7} Pa	1.77×10^{4} Pa	1.23×10^{5} Pa
Velocity	5.04m/s	2.16×10^{2} m/s	1.02×10^{2} m/s
Wall Flux	5.30×10^{4} Pa	1.07×10^{2} Pa	5.14×10^{6} Pa

V FLEXIBLE WING

Flexible wings has great potential to improve overall aircraft performance, just as natural aircraft do. By dynamically adjusting or optimizing the shape for various flight conditions, there are many untapped opportunities beyond the current proof-of-concept demonstration. This review discusses the most important examples of the application of the concept of deformation to 2D and 3D airfoil models. The methods and tools commonly used to design and analyze these concepts are discussed, ranging from structural analysis to aerodynamic analysis, from control aspects to optimization. Throughout the review, it became clear that the use of the concept of Flexible for everyday use in aircraft is still rare, and some reasons were given which hindered its mainstreaming for industrial use.Finally, promising concepts for future use are identified.

Compared to traditional aircraft, Flexible aircraft can more effectively control aerodynamic forces and moments during flight. Some designs achieve this by a continuous deflection of the control surface, such as a variable camber trailing edge or a parabolic flap with enough elasticity that the trailing edge can be continuous. The Wright brothers used wing flex to control their aircraft. Later aircraft designs often omit this method of control to simplify the manufacturing process. Using modern manufacturing methods, recent research explores how Flexible control surfaces can be developed for use in current aircraft designs. For example, the Air Force Research Laboratory developed the Variable Camber Compatible Wing (VCCW). NASA developed the VCCTE (Variable Camber Compatible Trailing Edge) and worked together to design the Flexsys aircraft. Some groups have studied the use of piezoelectric materials as propulsion mechanisms for winged aircraft, and others have used internal corrugated continuous structures to induce deformation in the wings. The SABER program has also investigated variable airfoils for helicopters using Fishbone Active Camber (Fish BAC) structures.

Two Flexible wings are designed .one with deflection and one without any deflection with the help of the CATIA and SOLIDWORK . Both are analyzed in ANSYS

VI MODELLING AND ANALYZING OF FLEXIBLE WING WITH DEFLECTION

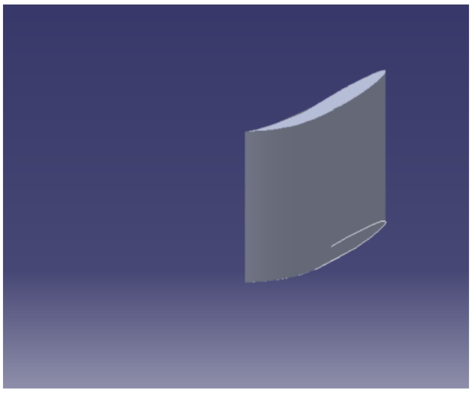


Figure 23: CATIA Model of Flexible Wing

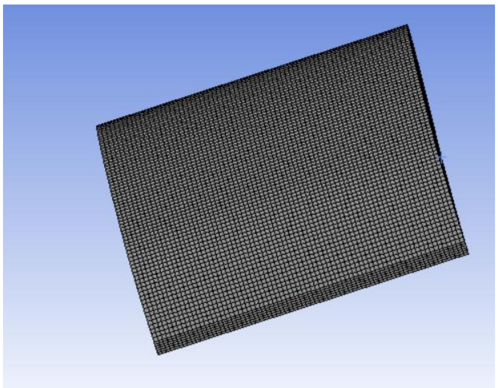


Figure 24: Meshed Model of Flexible Wing

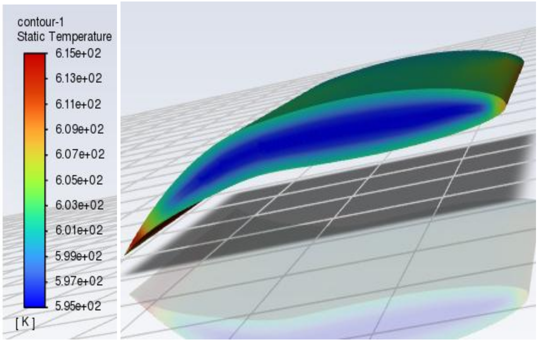


Figure 25: Temperature Contour of Flexible Wing

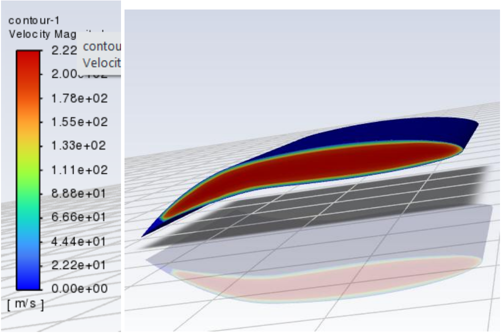


Figure 26: Velocity Contour of Flexible Wing

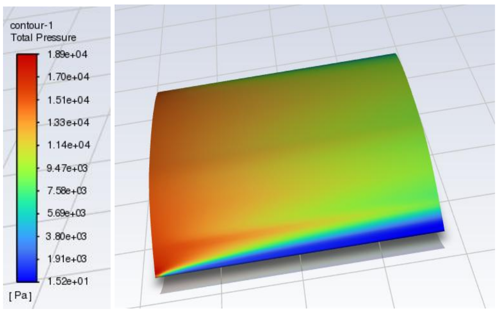


Figure 27: Pressure Contour of Flexible Wing

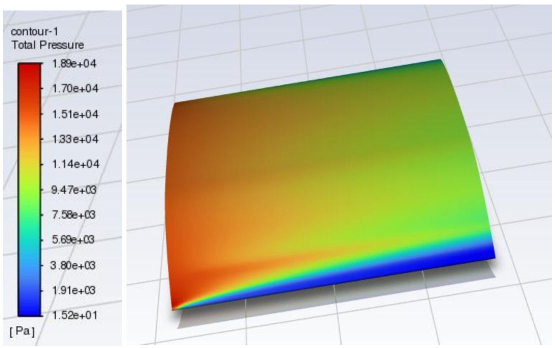


Figure 28: Wall Stress Contour of Flexible Wing

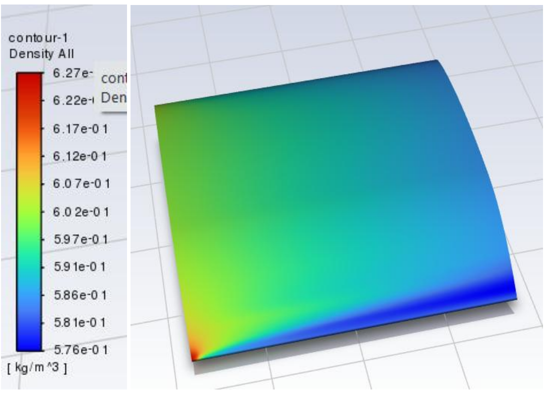


Figure 29: Density Contour of Flexible Wing

VII MODELLING AND ANALYZING OF FLEXIBLE WING WITHOUT DEFLECTION

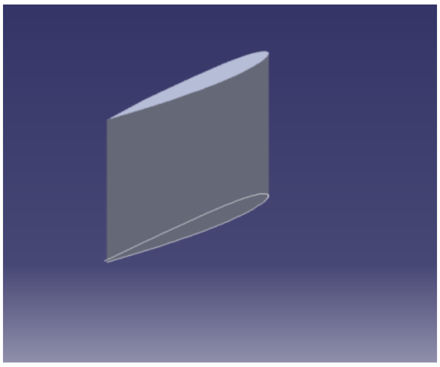


Figure 30: CATIA Model of Flexible Wing with without Deflection

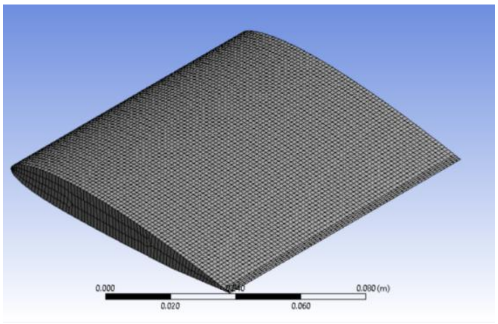


Figure 31: Meshed Model of Flexible Wing with without Deflection

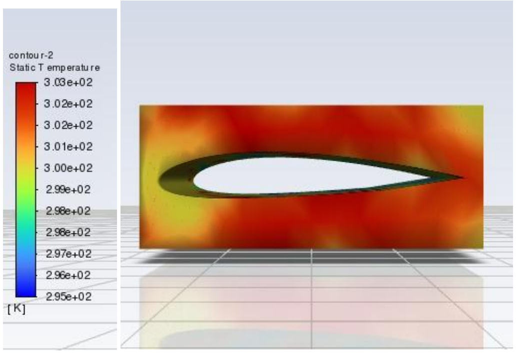


Figure 32: Temperature Contour of Flexible Wing without Deflection

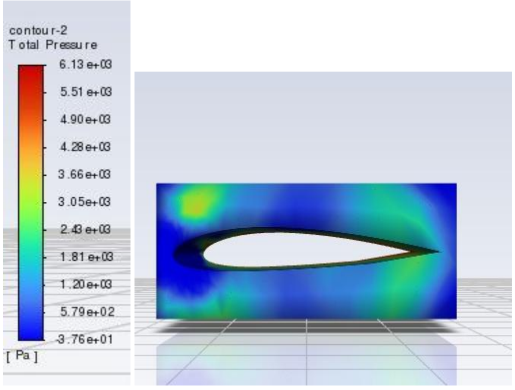


Figure 33: Pressure Contour of Flexible Wing without Deflection

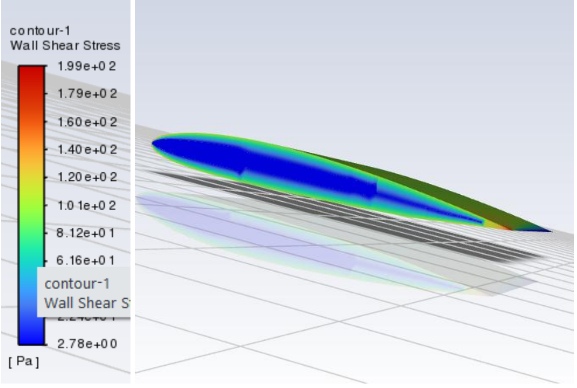


Figure 34: Wall Stress Contour of Flexible Wing without Deflection

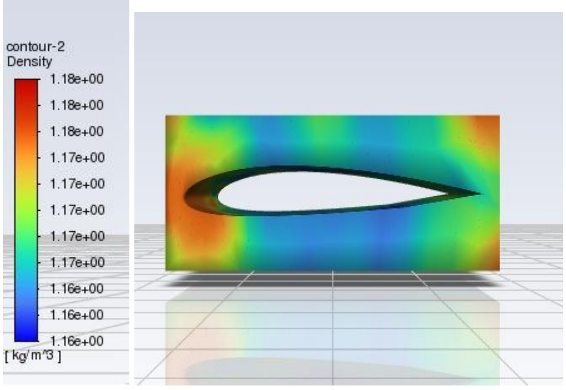


Figure 35: Density Contour of Flexible Wing without Deflection

Thus the two flexible wing are analyzed with the help of CFD software ANSYS and the analyzed results as follows

Table 2: CFD Analysis Results

Parameter	Flexible Wing	Flexible Wing With Deflection
Density	1.18 Kg/m^3	6.27Kg/m^3
Temperature	3.03×10^2 K	6.15×10^2K
Pressure	6.13×10^3 Pa	1.89×10^4Pa
Velocity	1.02×10^2 m/s	2.22×10^2 m/s
Wall Flux	1.99×10^2 Pa	2.17×10^2Pa

VIII CONCLUSION

In this study we have designed and analyzed the different types of flaps using the CAD software CATIA V5 , SOLID WORK etc and analysis software ANYSYS . from this analysis we get the aerodynamic and other characteristics of the flaps like flexible flap slotted flap and plain flap there are a high amount of variations in these three flap parameters . the we demonstrated the Flexible wing . a Flexible wing and other with a different slight variation in the inclination And designed these with the help of CATIA and SOLIDWORK then analyze it with the help of ansys software and we get a conclusion that usage of Flexible wing will a better option over flaps

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