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Title of the note :

**A numerical study of the effect of the speed of rotation of the propeller
on the takeoff of the helicopter**

Supplementary memorandum for obtaining a bachelor's degree

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﴿ وَإِذْ تَأَذَّنَ رَبُّكُمْ لَمْ شَكَرْتُمْ لَأَزِيَّنَّكُمْ وَلَئِنْ كَفَرْتُمْ إِنَّ عَذَابِي لَشَدِيدٌ ﴾ [ابراهيم: 7]

Thanks and praise to God Almighty first for the blessing of patience, perseverance and the ability to accomplish this work, praise be to God for these blessings.

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الملخص بالعربية

تتناول هذه الدراسة تحليلًا عدديًا لتأثير سرعة دوران المروحة على أداء إقلاع المروحة باستخدام برمجية ANSYS Fluent، إحدى أدوات الديناميكا الحاسوبية للموائع (CFD). يتم في هذا البحث محاكاة سلوك تدفق الهواء حول شفرات المروحة في ظروف مختلفة من السرعات الدورانية، بهدف فهم العلاقة بين سرعة الدوران وقوة الرفع الناتجة.

بدأت الدراسة بتقديم خلية نظرية حول المروحيات، والقوى الإيروديناميكية المؤثرة أثناء الطيران، مع التركيز على مبادئ توليد الرفع والدفع. تم استخدام نموذج مبسط لشفرات المروحة لإنشاء شبكة هندسية باستخدام برنامج ANSYS Fluent، تلتها إعدادات المحاكاة في Gambit.

تم تحليل نتائج المحاكاة لتحديد القيمة الحرجة لسرعة الدوران التي تتيح للمروحة الإقلاع بكفاءة دون استهلاك مفرط للطاقة أو تعریض المكونات لإجهادات ميكانيكية. كما تم احتساب الرفع، القوة المعاكسة، العزم، واستهلاك الطاقة، بالإضافة إلى تحليل سرعة الإقلاع والاستهلاك التقديري للوقود.

خلصت الدراسة إلى وجود علاقة طردية بين السرعة الدورانية وقوة الرفع، وأوصت بتحسين تصميم الشفرات لتحقيق أداء أفضل عند سرعات دوران معينة.

Summary in English:

This study presents a numerical analysis of the effect of propeller rotational speed on helicopter takeoff performance using ANSYS Fluent, a Computational Fluid Dynamics (CFD) software. The research simulates the airflow around helicopter blades under various rotational speeds to understand how these speeds affect the generated lift force.

The study begins with a theoretical background on helicopters and the aerodynamic forces involved in flight, emphasizing the principles of lift and thrust generation. A simplified blade model was created using Gambit for mesh generation, followed by simulation setup in ANSYS Fluent.

Simulation results were analyzed to identify the critical RPM value that allows for efficient takeoff without excessive energy consumption or mechanical stress. The study included the calculation of lift, drag, torque, power consumption, takeoff speed, and estimated fuel usage.

The findings demonstrate a direct relationship between rotational speed and lift force. The study recommends optimizing blade design to achieve better performance at specific RPM ranges.

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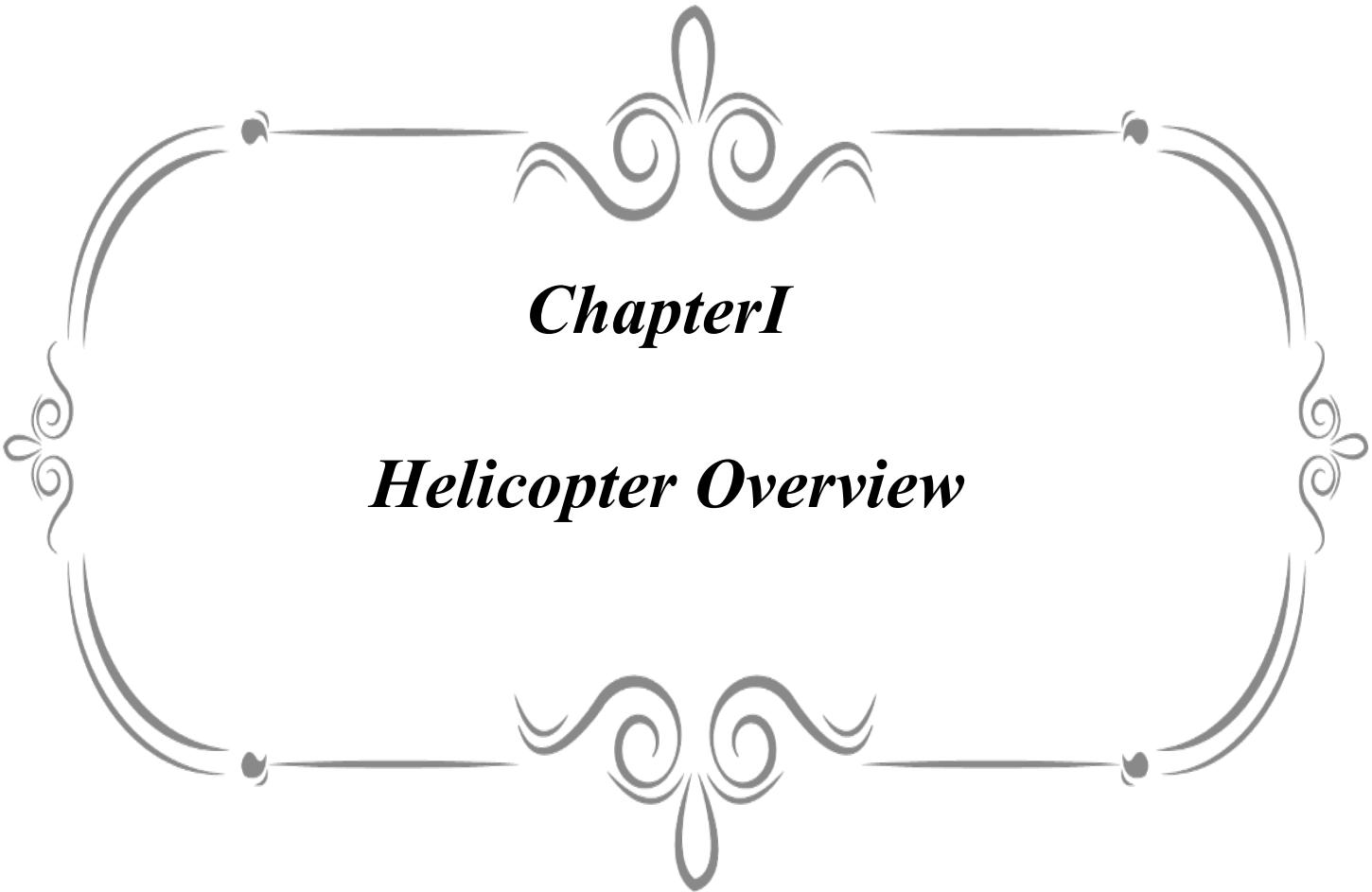
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Chapter I

Helicopter Overview

1 INTRODUCTION

A helicopter, also known as a hovercraft, helicopter, or hovercraft (French: Hélicoptère), is a sea-going aircraft capable of flight and elevation from the ground using two or more blades mounted on top of its fuselage, which rotate around their axes to maintain altitude and hover in the air. It is classified as a rotary-wing aircraft, distinguishing it from a fixed-wing aircraft, because the helicopter derives lift from the rotation of the blades around the shaft. The word "helicopter" is originally French and came into use in 1861. It is derived from the Greek word helix (ἕλιξ), meaning "circular spiral," and petrón (Greek: πτερόν), meaning wing. The basic rotor of the Spirit rotates around itself and maintains lift without the need to move. It can take off and land vertically without the need for a rung. This is why it rarely reaches dense areas or areas where fixed-wing aircraft cannot.

The first aircraft with a rotary wing was built by German Anton Feltner in 1936 and was named the FL-185.

Although helicopters were invented and built at the beginning of the first half of aviation, they were produced in limited numbers until 1942, when Igor Sikorsky's 400 became the first mass-produced helicopter. Even early designs used more than one main rotor, a current practice that uses two sets of anti-rotor rotors. This design is what has become known worldwide as the Spirit.

Helicopters are used to perform tasks that other aircraft cannot perform due to their unique operational characteristics, such as their ability to take off and land vertically, remain airborne for extended periods of time, and handle low airspeed conditions. Current uses of helicopters include transportation, construction, firefighting, search and rescue, and military applications.

1.1 Research Problem

The research problem lies in understanding the relationship between propeller rotational speed and the lift force produced during takeoff, and determining the critical RPM value that allows for efficient takeoff without unnecessary energy consumption or exposing the system to mechanical hazards.

1.2 Motivations for Choosing the Topic

I conducted this study out of my desire to deepen my understanding of the aerodynamic interactions that occur during helicopter takeoff, and to utilize numerical simulation tools to approximate reality in a scientific and effective manner. This topic is also of great importance in the field of aeronautical engineering and serves as a basis for developing more efficient and stable propulsion systems.

1.3 Study Objectives

This study aims to:

Study the effect of propeller rotational speed (RPM) on a helicopter's takeoff capability.

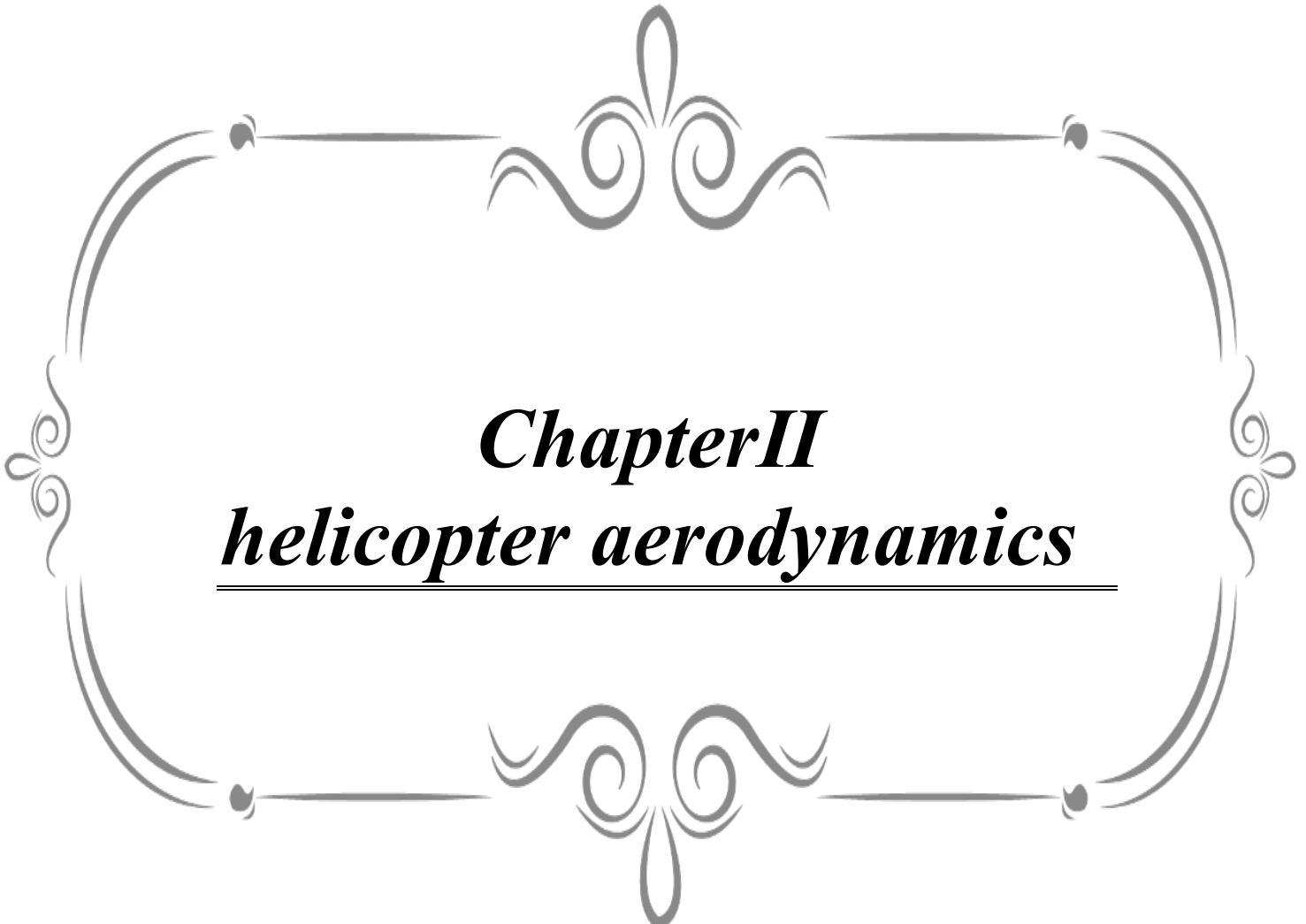
Determine the relationship between RPM and the propeller's lift coefficient.

Use CFD numerical simulation software to simulate takeoff conditions and analyze the results.

Determine the critical RPM value required for efficient takeoff

1.4 Methodology

The methodology of this study is based on numerical analysis of the effects of propeller rotation speed on takeoff performance using Fluent software. The helicopter takeoff condition will be simulated under specific conditions of speed, pressure, and temperature. Computational Fluid Dynamics (CFD) techniques will be used to model the airflow around the propeller, taking into account forces such as lift and drag. The simulation will be performed at several different rotation speeds to determine the relationship between these speeds and the resulting lift force.



Chapter II
helicopter aerodynamics

2 Helicopters

A helicopter is a special type of aircraft that relies on a main rotor rotating around a vertical axis to generate the lift needed for takeoff and flight. Unlike conventional aircraft, helicopters are capable of vertical takeoff and landing and hovering in confined spaces, making them ideal for rescue, surveillance, and special maneuvering missions.

A helicopter typically has a main rotor responsible for lift and propulsion, and a tail rotor used to counteract the torque generated by the rotation of the main rotor.



figure II 1: Helicopters

2.1 Helicopter Aerodynamics

During flight, a helicopter is subject to four basic forces that control its motion and stability: lift, weight, thrust, and drag.

The main rotor produces lift by rotating its blades, creating low pressure above the blades and high pressure below them, thus lifting the fuselage.

In contrast, the weight of the helicopter, which results from its mass and the mass of the payload, acts in the opposite direction to lift.

Thrust, on the other hand, is produced by the forward-leaning motion of the blades, overcoming the drag caused by air resistance on the fuselage and external components.

To counteract the torque generated by the rotation of the main rotor, a tail rotor is used, which generates an opposing force that prevents the fuselage from rotating about its axis.

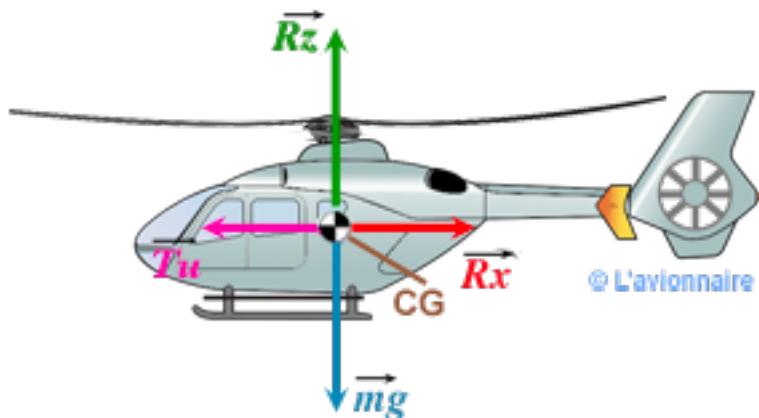


figure II 2: Forces Acting on a Helicopter During Flight

During flight, a helicopter has sufficient aerodynamic and mechanical forces on the aircraft and its movement. To understand flight dynamics, it is necessary to identify and analyze these forces.

Main Forces:

The main forces acting on a helicopter can be summarized as follows:

Force	Symbol	Direction	Description
Lift	L	Upward (Vertical)	Generated by the main rotor to counteract the weight and allow the helicopter to rise.
Weight	W	Downward (Vertical)	Caused by gravity; depends on the helicopter's mass.
Thrust	T	Forward / Sideways	Produced by tilting the rotor disc; enables movement in different directions.
Drag	D	Opposite to motion	Air resistance that opposes the helicopter's motion.
Torque	τ	Around vertical axis	Reaction to the rotation of the main rotor; countered by the tail rotor.

2.2 Hover

Hovering is the state in which a helicopter maintains a constant altitude and position above a specific point.

To achieve this balance, the lift force must equal the weight of the aircraft, and the thrust force must equal the opposing force caused by drag.

Hovering is one of the most difficult modes of helicopter flight, requiring precise and continuous coordination between various controls, including:

Collective pitch: To uniformly change the angle of the rotor blades, affecting the amount of lift.

Cyclic pitch: To control the forward, backward, or sideways pitch.

Tail rotor pedals: To control yaw by adjusting the force of the tail rotor.

Governor: To maintain a constant rotor RPM.

Any change in one of these elements requires adjustments in the others, requiring the pilot to make constant corrections.

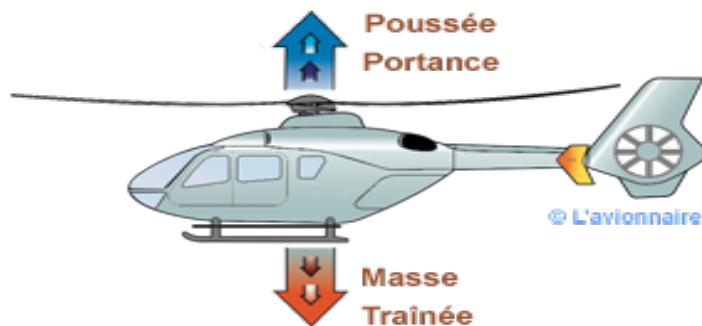


figure II 3 : Hovering Control Inputs

2.3 Lateral Lean and Drift

During hovering, a helicopter may drift sideways due to the tail rotor force, which pushes the fuselage in the opposite direction to the main rotor torque.

To counter this drift, the rotor disc is tilted slightly to the opposite side.

Or the transmission is designed to be angled, which compensates for the lateral drag.

In some cases, the fuselage is tilted slightly to balance the forces.

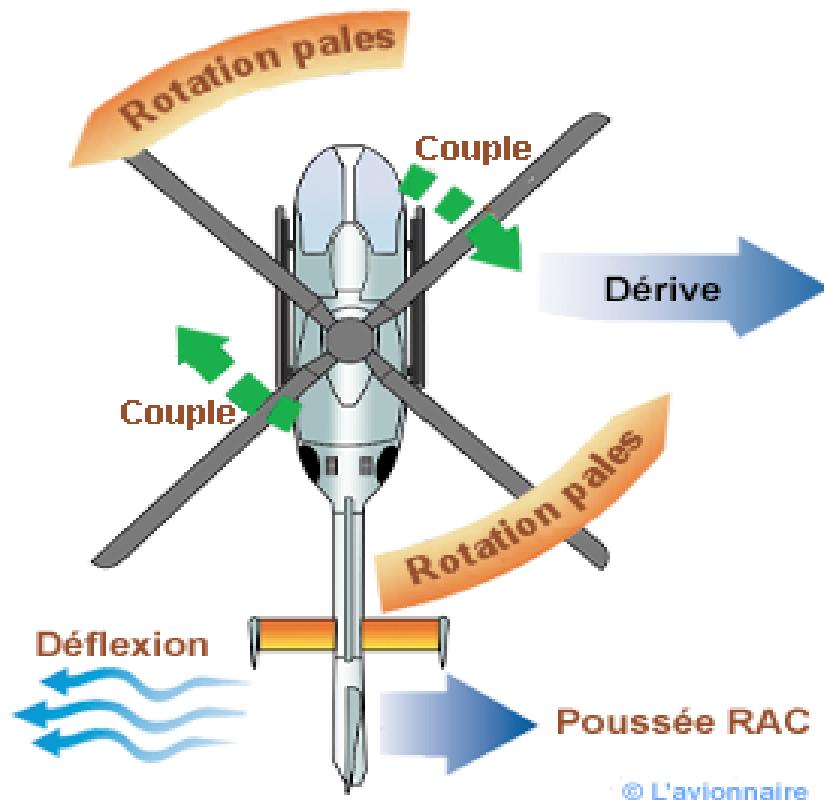


figure II 4: Lateral Drift Due to Tail Rotor Thrust

Pendulum Motion

Because the helicopter is suspended from a single point (the mast head), it is susceptible to longitudinal or transverse swing like a pendulum.

This phenomenon is exacerbated by over-control, especially in semi-rigid rotor systems, where forces are transmitted directly to the fuselage.

Therefore, the pilot must maintain smooth, controlled movements of the controls to minimize these swings.



figure II 5 : Pendulum Motion of the Helicopter Fuselage

2.4 Conical Path of Rotor Blades

When the blades rotate, two basic forces operate:

Centrifugal force: pushes the blades outward.

Lift force: pushes the blades upward.

The interaction of these two forces causes the blades to follow a conical path. Increasing the angle of attack to increase lift can lead to excessive blade bending, known as "excessive taper," which must be avoided to maintain the integrity of the rotor's structural system.

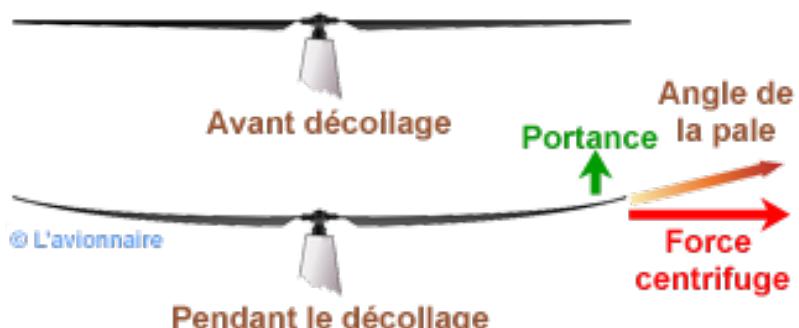


figure II 6 : Coning Path of Main Rotor Blad 1

2.5 The Coriolis Effect

Also known as the law of conservation of angular momentum. When the center of mass of a blade changes position during movement (inward or outward from the axis of rotation), its angular velocity changes to conserve momentum.

As the mass approaches the axis, its rotational speed increases, potentially increasing lift.

Conversely, as the mass moves away from the axis, its velocity decreases.

These changes are absorbed by shock absorbers or the blade design itself, depending on the type of helicopter.

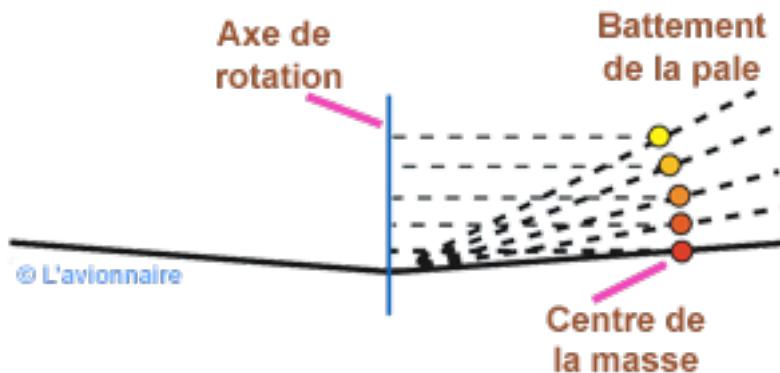


figure II 7: Coriolis Effect on Rotor Blades

2.6 The Principle of Lift Generation by a Propeller

The principle of lift generation by a propeller is based on the principle of aerodynamics, specifically the lift generated by changes in air speed around the wings or blades of a

helicopter. When talking about a helicopter propeller, the force is distributed as follows:

The effect of the propeller's circular motion: When the propeller rotates, its blades cut through the air at high speed. According to Bernoulli's principle, this results in a lower pressure on the upper side of the blade compared to the lower side. This pressure difference between the two sides produces lift.

Pressure difference: As mentioned, the pressure is lower on the upper side of the blade due to the acceleration of the air above the blade. On the lower side, the pressure is higher due to the slower air movement, generating lift that acts perpendicular to the blade surface and, consequently, to the propeller as a whole.

Angle of Attack: The angle of attack is the angle between the direction of airflow and the front surface of the blade. If the angle is too large, the blade will generate more lift, but with an increased likelihood of stalling or unstable airflow, reducing lift efficiency.

Blade Speed and Fan Rotational Speed: The faster the fan rotates, the faster the airflow around the blades, enhancing lift generation. Also, the length of the blades significantly affects the amount of air cut and, consequently, the lift force.

2.7 Effect of rotor speed RPM on lift and thrust

2.7.1 The Effect of RPM on Lift

Lift Increases with RPM:

The higher the rotor rotation speed, the faster the airflow around the blades increases, resulting in increased dynamic pressure on the surface. This increased pressure translates into higher lift. Theoretically, lift depends on the square of the flow velocity (according to the lift equation),

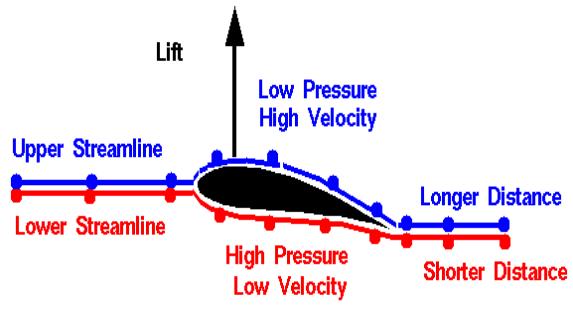


figure II 8 : feather spinner



figure II 9 : fan rotor

meaning that doubling the rotor speed can increase lift by approximately four times if other factors remain constant.

Balancing the Angle of Attack and Blade Design:

Achieving optimal lift also depends on the angle of attack and blade design. If the blades are not designed to handle high rotation speeds, flow separation may occur, reducing lift efficiency.

Lift Equation:

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

Where:

L is the lift force.

ρ is the air density.

V is the air velocity around the blade.

S is the surface area of the blade.

C_l Lift coefficient, which depends on the angle of attack and wing shape.

2.7.2 The Effect of RPM on Thrust

Thrust Increases with RPM:

In rotor-based propulsion systems (such as propellers or helicopter blades), increasing RPM increases the relative velocity of the air and thus generates greater thrust. Thrust is primarily determined by an equation based on the propeller's rotational speed (RPM) and other design factors such as rotor diameter and thrust coefficient.

Exponential Relationship:

Thrust increases exponentially with increasing RPM, meaning that an increase in rotational speed results in a significant increase in thrust. However, as this speed

increases, challenges arise such as compressibility effects when approaching sonic speeds at the blade tips, as well as increased mechanical stress and noise.

Thrust Equation:

Where:

$$T = \frac{1}{2} C_t S n^2 \rho$$

T is the thrust.

ρ is the air density.

n is the fan speed (rpm).

D is the rotor diameter.

C_t Thrust coefficient.

2.7.3 Important Considerations When Using High RPM

Aerodynamic Efficiency:

Achieving a balance between increased RPM and angle of attack is vital to avoid airflow disturbances and loss of efficiency.

Mechanical Stress:

Excessively high RPM increases centrifugal forces on the blades, which can lead to wear or even damage to components if the design is improper.

Noise and Consumption:

Increased RPM can lead to higher noise levels and increased power consumption, which can negatively impact performance in some applications.

- Example:

Study this helicopter if you have the following data

Helicopter data:

Number of blades: 4 Blade

length: 3 m

Blade chord: 0.25 m

Rotor rotational speed: 400 rpm

Air density: 1.225 kg/m³ (at sea level)

Lift coefficient (,C-L.): 0.5

Coefficient of drag (,C-D.): 0.02

Helicopter weight (m): 1500 kg

Gravitational acceleration (g): 9.81 m/s²

Blade area: 0.75 m² (calculated from the length of the blade and chord)

2.7.4 Calculation of lift generated by the blades

General formula for lift per blade :

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

$$\omega = \frac{2\pi r}{60} = 41.89$$

$$V = \omega * r = 41.89 * 3 = 125.67$$

$$L = \frac{1}{2} * 1.225 * (125.67)^2 * 0.5 * 0.75 \gg L = 4852.91 \text{ N}$$

2.5.2 Calculation of the drag generated by the blades

Drag is the air resistance that opposes the movement of the helicopter. It can be calculated using the drag coefficient C_D and the relative air velocity.

Formula for drag :

$$D = \frac{1}{2} \rho v^2 C_D S$$

$$D = \frac{1}{2} * 1,225 * (125,67)^2 * 0,02 * 0,75 \quad D = 485,29 \text{ N}$$

2.7.5 calculation of the rotational moment (Torque) on the rotor

The rotational moment is the force that causes the rotor to rotate. It is caused by the drag and lift of the blades and must be balanced by the helicopter engine to maintain constant rotation.

The rotational moment can be calculated from the drag generated by each blade.

$$T = \sum (D_i \times r_i)$$

$$T = D * V = 485,29 * 1,5$$

$$T = 727,94 \text{ N,m}$$

2.7.6 Calculation of the power required to rotate the rotor

The power required to rotate the rotor depends on the drag generated and the rotational speed.

Formula for the required power :

$$P = T \cdot \omega$$

$$P = 727,94 * 41,89$$

$$P = 30493,4066 \text{ w}$$

2.7.7 Helicopter weight calculation

For the helicopter to take off, the lift must equal the total weight of the aircraft. Weight is the gravitational force acting on the helicopter.

Formula for Weight :

$$P_{poids} = m \cdot g$$

$$P_{poids} = 1500 * 9,81 \quad \ggg \quad P_{poids} = 14715 \text{ N}$$

2.7.8 Take-off speed calculation

Take-off speed is the speed at which the lift generated by the rotor balances the weight of the helicopter. For analytical calculation, it is possible to solve this relationship to determine the take-off speed as a function of lift and weight.

$$L_{total} = P_{poids}$$

$$L_{total} = l * 4 \quad \ggg \quad L_{total} = 19411.64$$

2.7.9 Estimated fuel consumption and range

Fuel consumption depends on the power required to maintain stable flight, usually based on the power calculated to rotate the rotor and the efficiency of the engine.

Estimated fuel consumption :

$$m_f = \frac{P}{\eta \cdot LHV}$$

$$LHV = 43 * 10^6 \text{ MJ/kg}$$

And we have $P=30493,4066 \text{ W}$ $n=0,3$

$$m_f = \frac{30493,4066}{0,3 * 43 * 10^6} = 8,506 \text{ kg/h}$$



Chapter III

Digital study

3 Introduction

Gambit and Fluent are commercially licensed software packages for performing 2D or 3D fluid mechanics simulations, ranging from mesh construction with Gambit to solving Navier Stokes equations and post-processing with Fluent.

Widely used in industry (automotive, aeronautics, space, etc.) due to their powerful graphical interface and extensive options, they allow simulations on all types of complex geometries (fixed or moving) associated with fixed or adaptive meshes and with various physical models (two-phase, turbulent, etc.).

3.1 Introduction to Gambit and Fluent

3.1.1 Gambit

Gambit (Geometry And Mesh Building Intelligent Toolkit) is a 2D/3D mesher; a preprocessor that allows meshing geometry domains of a CFD problem. It allows you to generate a structured or unstructured mesh in Cartesian, polar, cylindrical, or axisymmetric coordinates. It can create complex two- or three-dimensional meshes with rectangular or triangular meshes. Gambit's generation options offer flexibility. Geometry can be decomposed into several parts to generate a structured mesh. Otherwise, Gambit automatically generates an unstructured mesh adapted to the type of geometry being constructed. With mesh verification tools, defects are easily detected.

It can be used to construct geometry and optionally generate a mesh for it; geometry from other CAD software can be imported into this preprocessor. It generates *.msh files for Fluent.

3.1.2 Gambit Interface and Steps:

a/ Launch Gambit: After launching the software, the user interface appears.

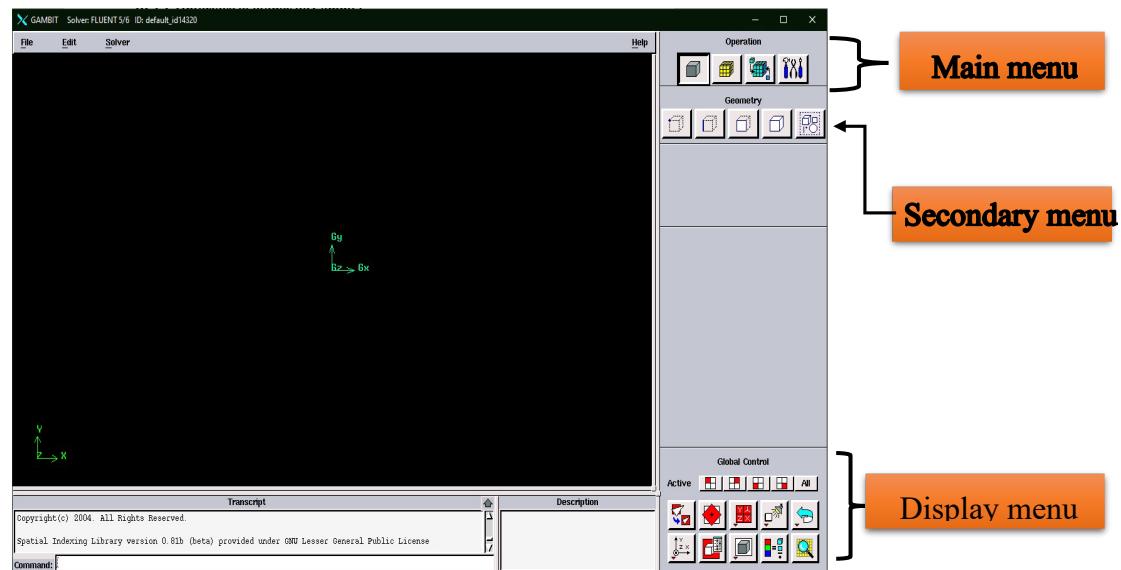


figure III 10 : The Gambit interface

b/ Construction of the geometry: To create our geometry, we choose the geometry operation.

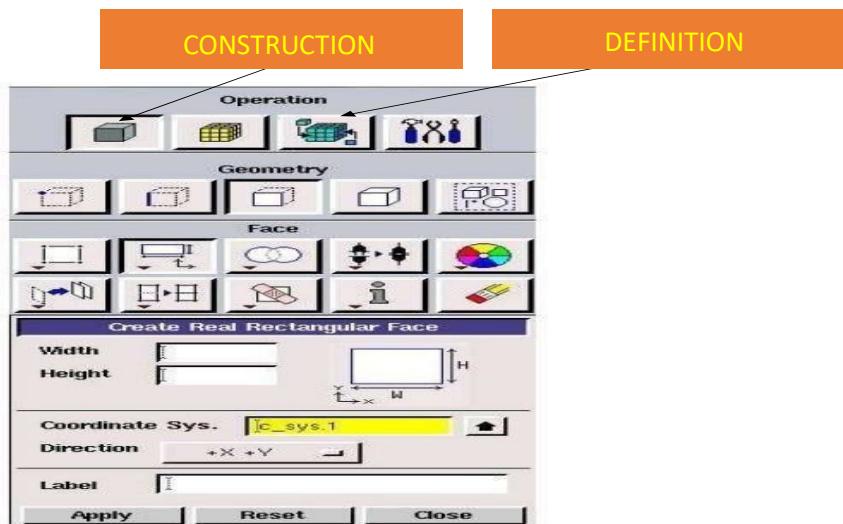


figure III 11: Construction of geometry

C / The mesh:

To mesh the geometry, we proceed by selecting the mesh operation

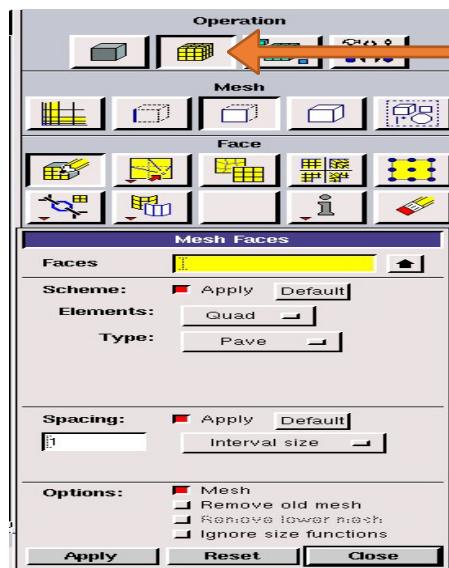


figure III 12: Mesh of a face and a volume 1

3.1.3 Fluent

Fluent is a commercial CFD code widely used in industry. It can solve fluid flows and heat transfer for various types of problems. For example, it can calculate the lift of an aircraft wing, the drag of a car, the cooling of electronic circuits using ventilated air, etc. When starting the Fluent software, you must select the dimensions of the computational domain (2D or 3D) and the precision the software should use: single or double precision.

3.2 Blade Design in Gambit and Boundary Conditions

Workflow in Gambit for mesh generation. Common problems can be solved using two different methods, such as a 2D model and a 3D model. In the case of a 2D model, Gambit consumes less memory and takes less time to solve problems. Gambit software was used to create a 2D mesh to solve a fluid problem on Fluent. Our work in 2D is on a horizontal-axis wind turbine blade with an S809 blade.

3.2.1 Importing Point Coordinates into Gambit

The software will display an S809 profile curve. To convert the curve into a sketch, you can then manipulate it in Gambit: file → file → ICEM Input → file name profile S809 → access

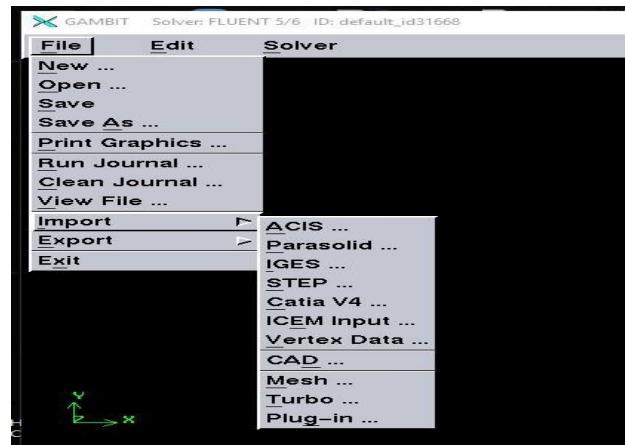


figure III 13: Menu for creating geometry elem

3.2.2 Drawing the geometry of a blade by gambit

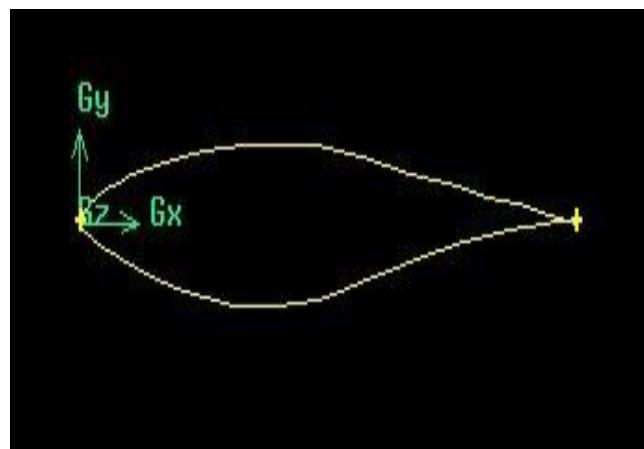


figure III 14:Face of a wind turbine blade Pr 1

3.2.3 Creating the Different Geometry Elements

To create our geometry, we choose the geometry operation (see Figure III-6).

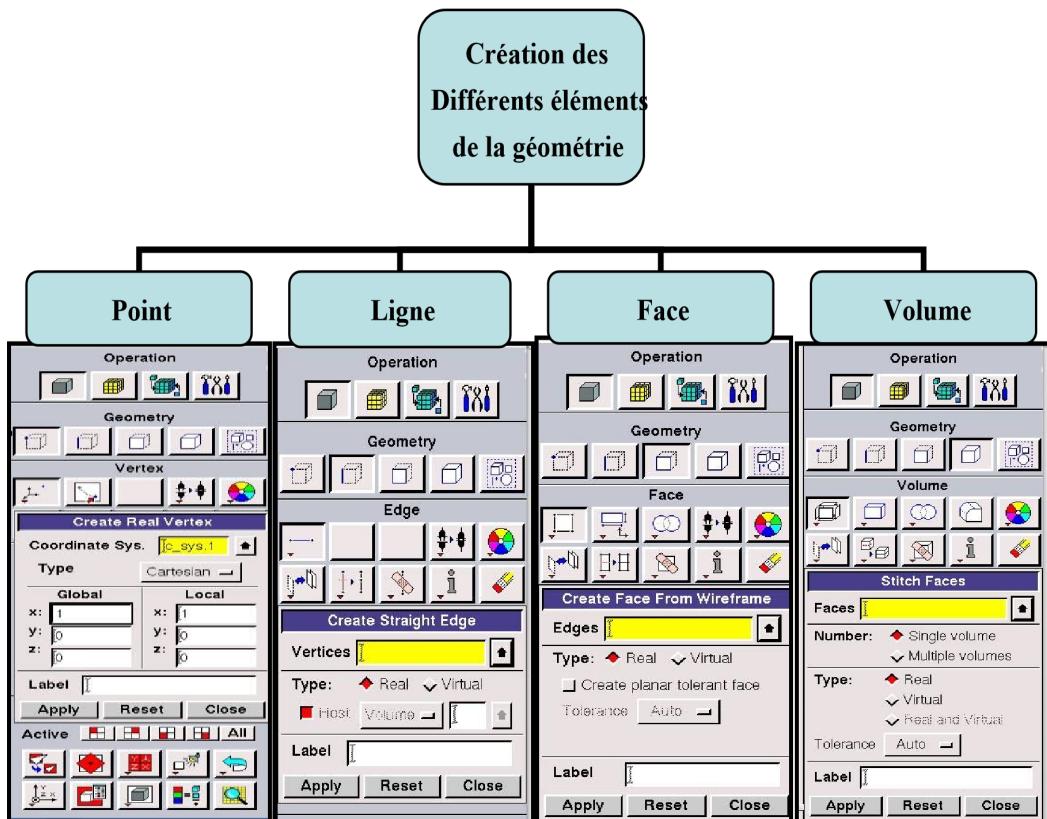


Figure III 6 Création des différents éléments de la géométrie

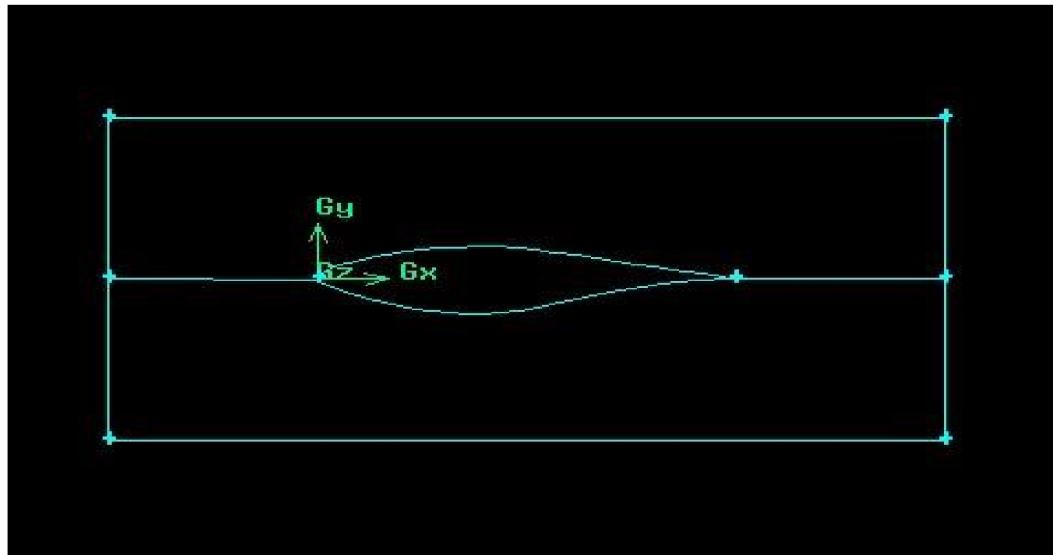


Figure III 7 Géométrie de l'aile en 2D

figure III 15 : (figure 7) (figure 6)

Dynamic Meshing in GAMBIT

Mesh generation is a very important phase, given the influence of its parameters on the calculated solution. A high-quality mesh is essential for obtaining accurate, robust, and meaningful computational results, and has a significant impact on convergence, solution accuracy, and, above all, computation time. To mesh the geometry, we proceed by selecting the mesh operation (see Figure III-7).

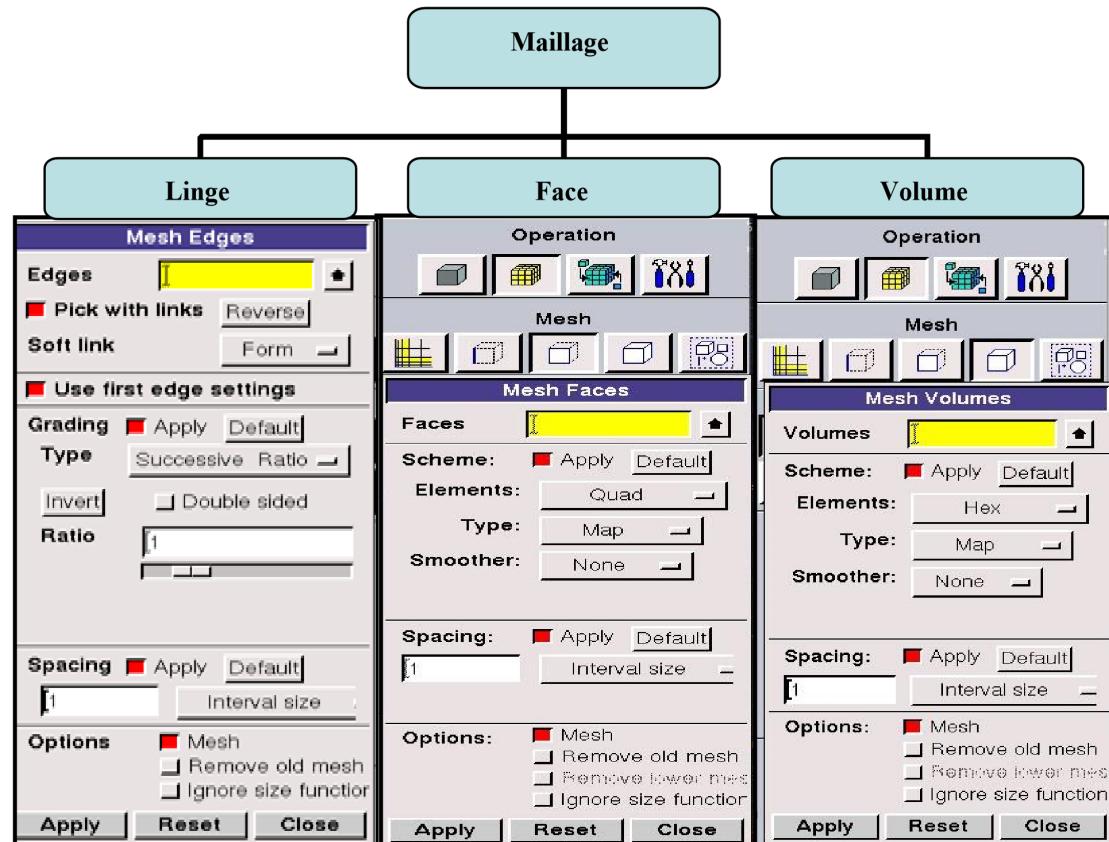


Figure III 8 Maillage Dynamique

figure III 16: malillge dynamique

3.2.4 Boundary Conditions

For boundary conditions, follow these steps: Operation Zones Specify Boundary Types (see Figure III-8). This menu allows you to define the physical boundary conditions of the domain, namely whether the lines (in 2D) are inlets, fluid outlets, free surfaces, axes of symmetry, etc.

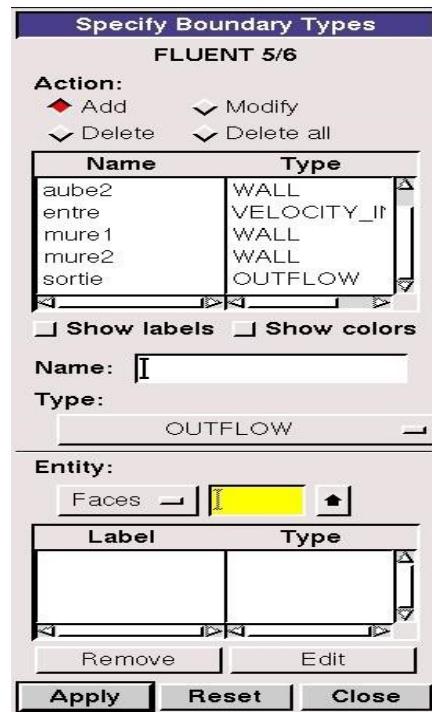


figure III 17:Boundary conditions in 2D

3.2.5 Meshing of the face of the wind turbine blade

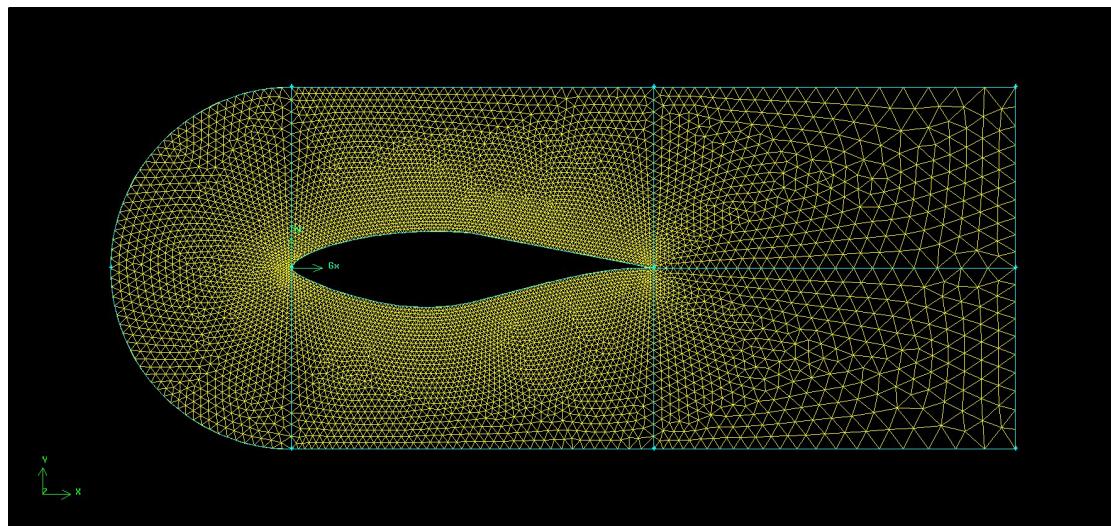


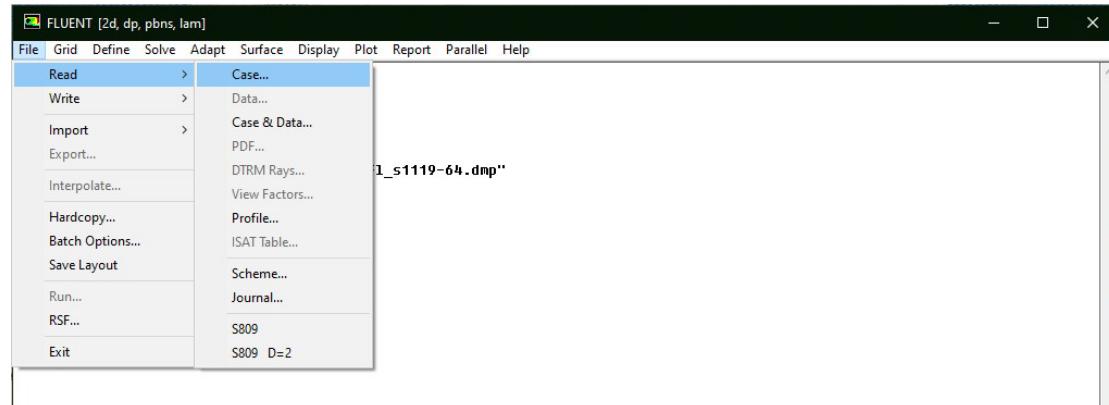
figure III 18: Geometric mesh and boundary conditions

3.3 Calculation in Fluent

a/ Importing the geometry (*.msh) To begin the simulation, you must

.import the file (*.msh) generated by Gambit

File Read Case



```
Building...
grid,
materials,
interface,
domains,
zones,
  default-interior
  entree
  interior_2
  extrados
  intrados
  sortie
  paroi_exterieur
  fluid
shell conduction zones,
Done.
```

figure III 19 :Importing geometry

b/ Checking the imported mesh.

Grid Check

```

Grid Check

Domain Extents:
  x-coordinate: min (m) = -5.000000e-001, max (m) = 2.000000e+000
  y-coordinate: min (m) = -5.000000e-001, max (m) = 5.000000e-001

Volume statistics:
  minimum volume (m3): 1.066344e-005
  maximum volume (m3): 2.523340e-003
  total volume (m3): 2.269178e+000

Face area statistics:
  minimum face area (m2): 4.472337e-003
  maximum face area (m2): 8.462104e-002

Checking number of nodes per cell.
Checking number of faces per cell.
Checking thread pointers.
Checking number of cells per face.
Checking face cells.
Checking bridge faces.
Checking right-handed cells.
Checking face handedness.
Checking face node order.
Checking element type consistency.
Checking boundary types:
Checking face pairs.
Checking periodic boundaries.
Checking node count.
Checking nosolve cell count.
Checking nosolve face count.
Checking face children.
Checking cell children.
Checking storage.
Done.

```

figure III 20 : Mesh verification in Fluent

c/ Vérification de l'échelle.

Grid → Scale

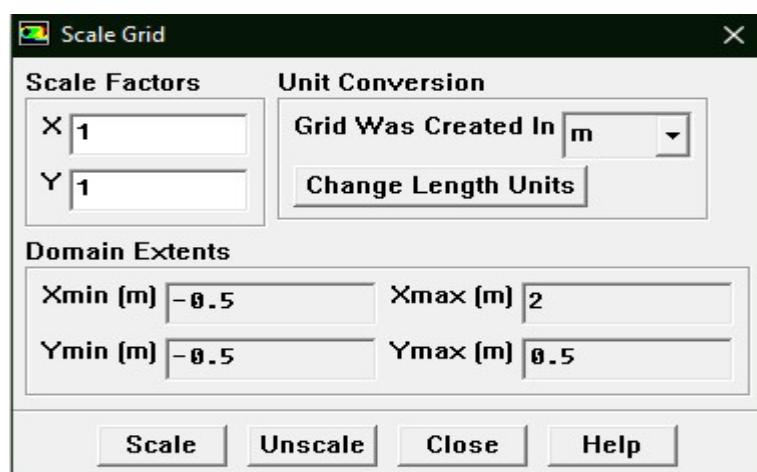


Figure 11B

figure III 21 : Unit verification

d/ Choice of solver

Define Models → Solver

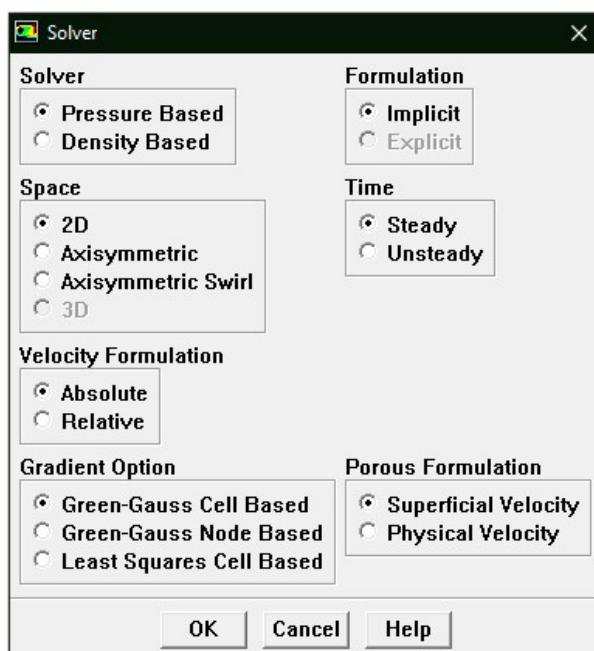


figure III 22: Solver choice in Fluent

e/ The energy equation

Define Models

Operating conditions Define Operating conditions

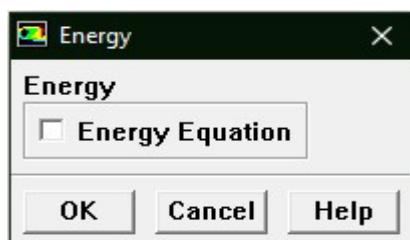


figure III 23 : The energy equation

Operating conditions Define →

Operating conditions

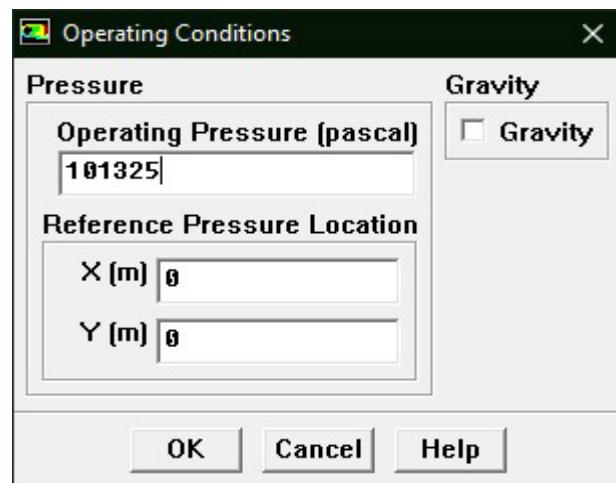


figure III 24 : Choice of reference pressure

g/ Usual boundary conditions

Define → **Boundary Conditions**

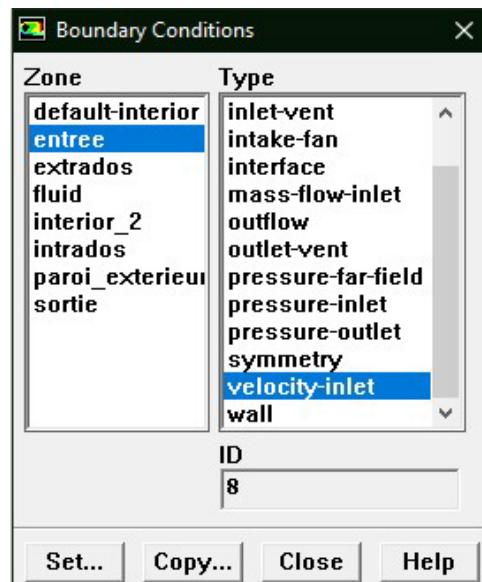


figure III 25 : Values of boundary conditions

h/ Velocity inlet

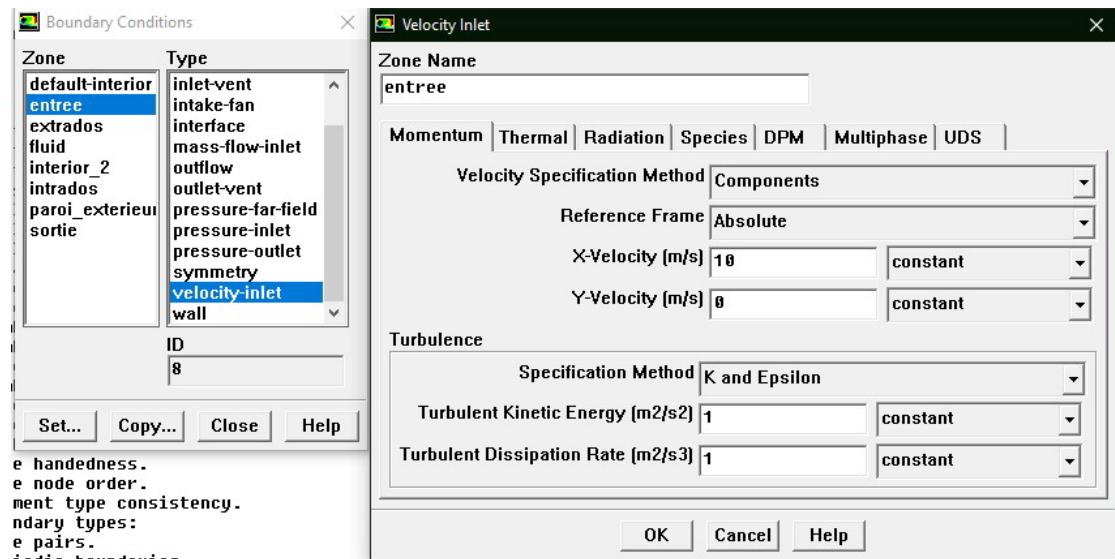


figure III 26 : Input speed

i/ Choice of fashion viscous

Define → Models → viscous ...

In our experiment we chose k-epsilon (2 eqn)

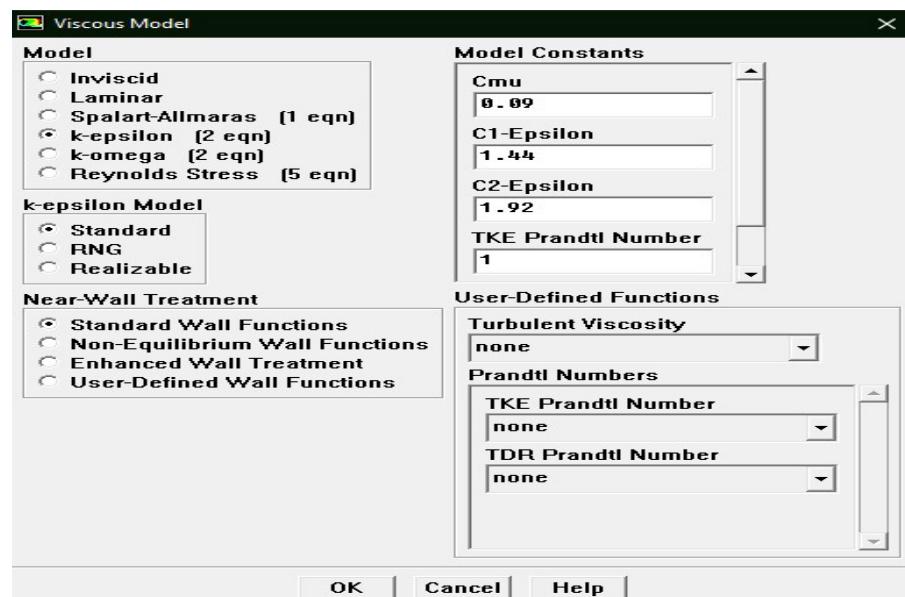


figure III 27 : Choice of viscous model

j/ Choice of order of the equations and the algorithm

Solve → Controls → Solution

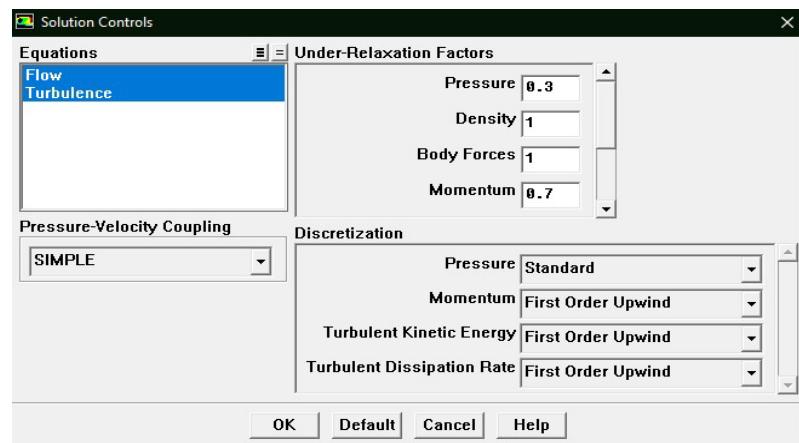


figure III 28 : Choice of order of equations and the algorithm

Solve ————— **Initialize** ————— **Initialize...**

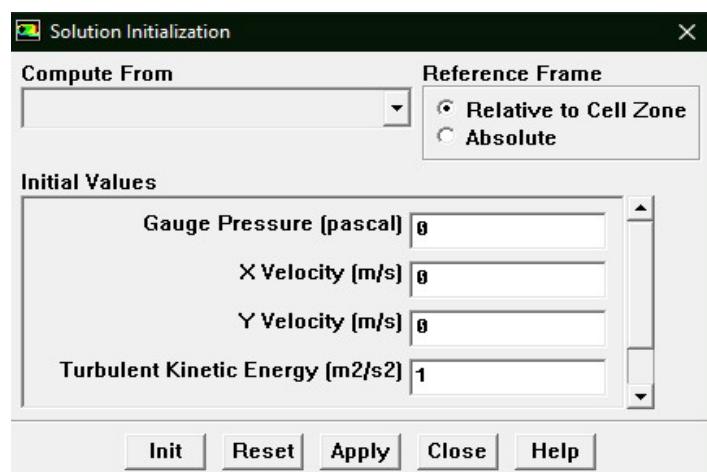


Figure 21

figure III 29 : Initialization of the calculation

L/ Choice of convergence criteria

Solve **Monitors** **Residual...**

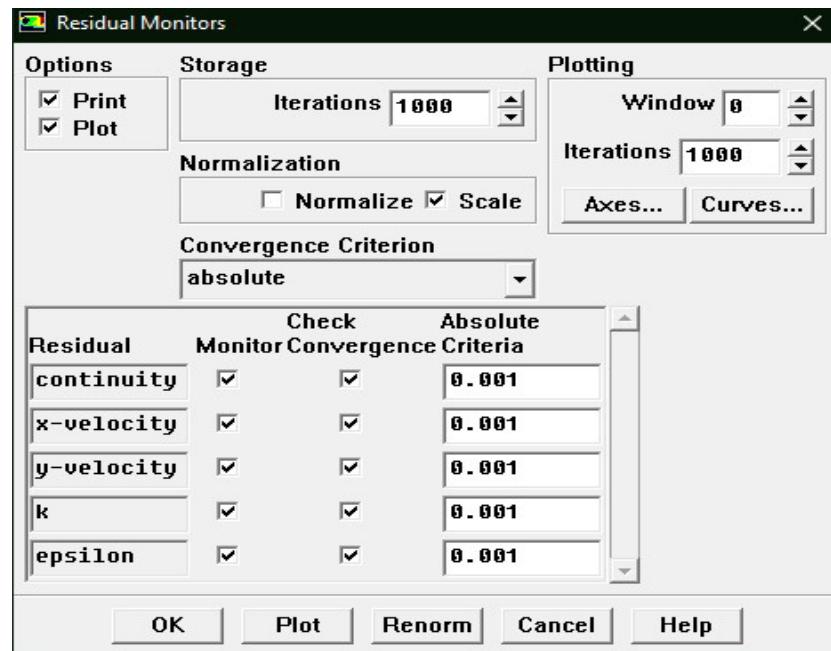


figure III 30 : Residual monitors

m/ Lancement du calcul

Solve → Iterate

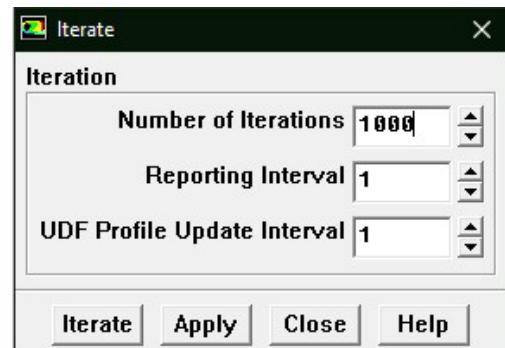


figure III 31 : Choosing the number of iterations

n/ Allures de l'évolution des résidus de calcul

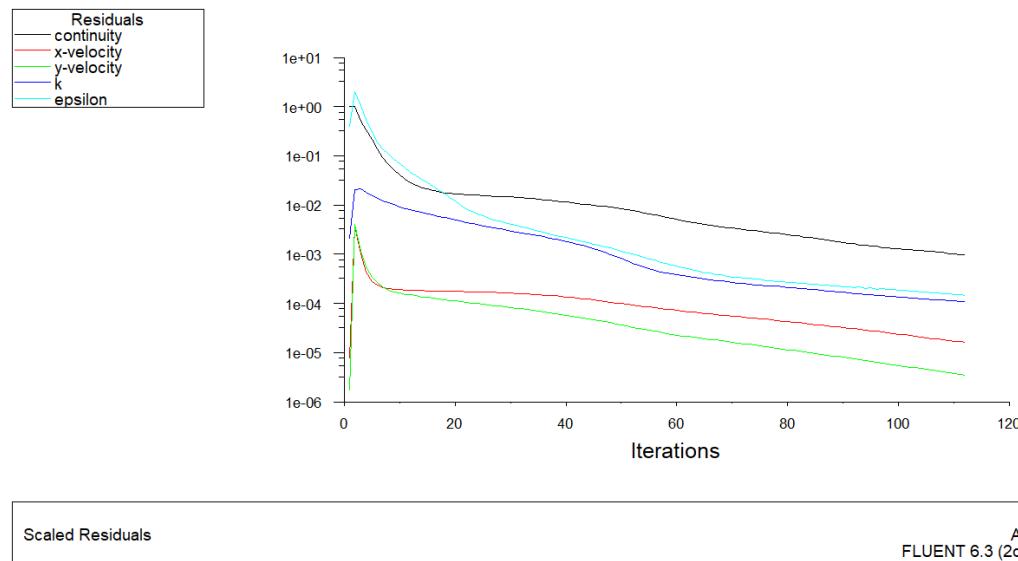


figure III 32: Trends in the evolution of calculation residues

o/ Contours de la pression statique

Display → Contours...

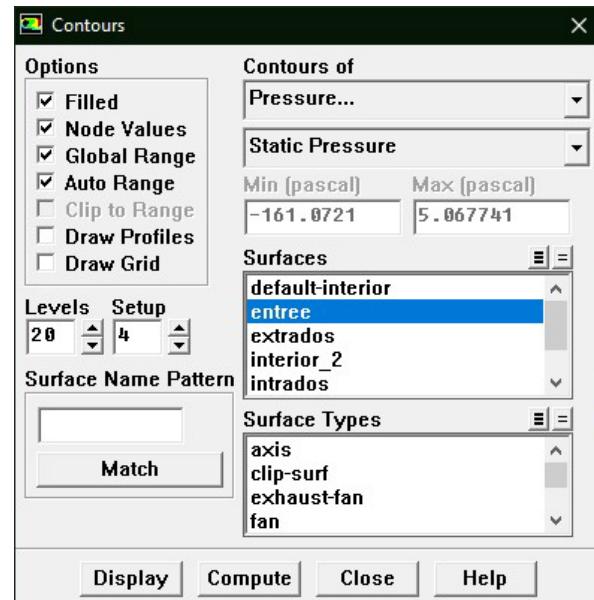


figure III 33 : Contours of static pressure



ChapterIV

Results and discussions

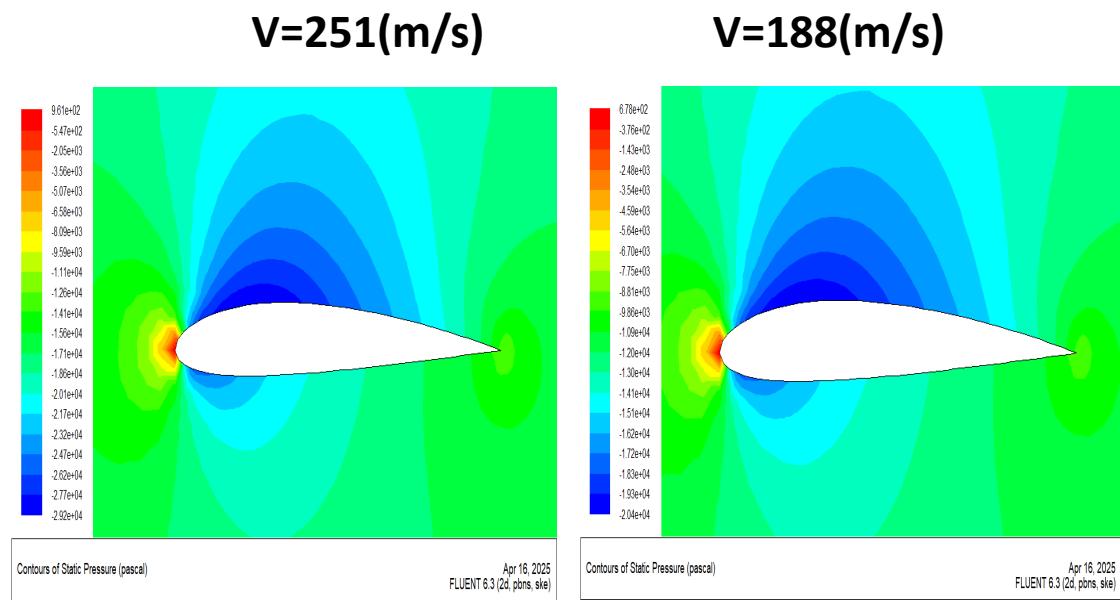


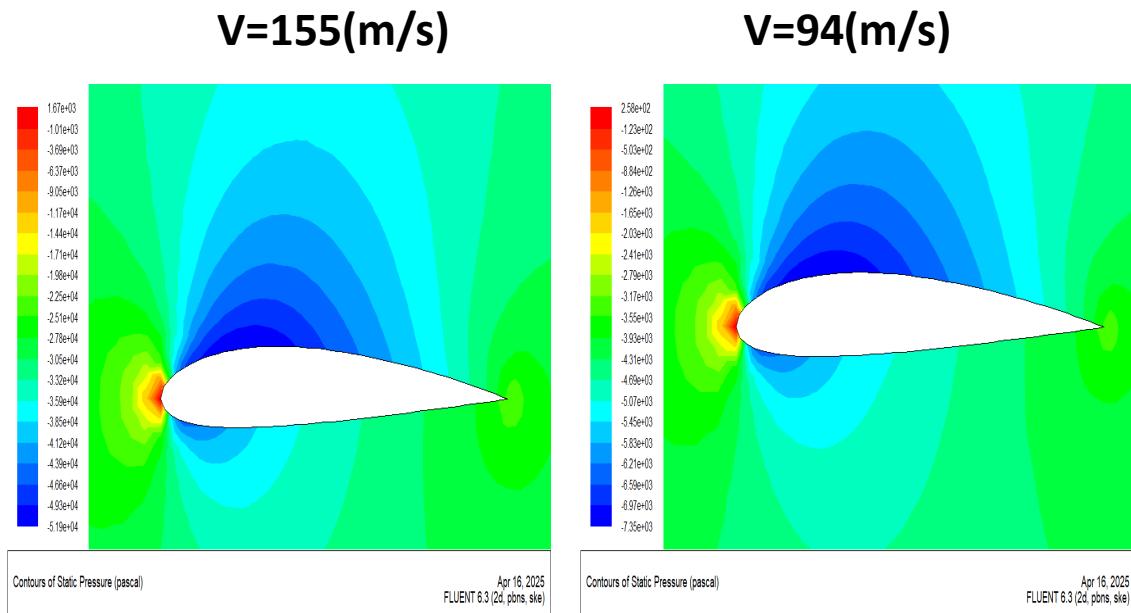
4 Introduction

In this chapter, we present the results of numerical simulations of airflow around a helicopter rotor blade using two-dimensional flow-force distribution (2D CFD). The results include an analysis of the convergence of the numerical calculations, as well as a study of the pressure distribution and velocity changes in the area surrounding the blade. The focus is also on studying the effect of different rotation speeds on blade performance. This section examines the velocity and pressure distribution along the horizontal (X) axis at different rotation speeds.

4.1 Study of the pressure curve at different rotation speeds: $V = 94 \text{ m/s}$, $V = 157 \text{ m/s}$, $V = 188 \text{ m/s}$, and $V = 251 \text{ m/s}$

This section examines the changes in the pressure distribution around a helicopter rotor blade at four different rotation speeds: 94 m/s, 157 m/s, 188 m/s, and 251 m/s. These changes are represented using color maps (pressure contours), where each color reflects the actual pressure value in a specific area. This analysis aims to study the relationship between rotational speed and pressure increase around the blade, which contributes to improving our understanding of the dynamic performance of the blade under various operating conditions.





4.2 Pressure Distribution Analysis for Different Effects

In this section, the static pressure distribution (static pressure) was analyzed as the fan moves independently from four different rotating wheels, respectively: $V=251$, $V=188$, $V=155$, and $V=94$. The results were obtained using ANSYS Fluent by plotting isobars (pressure profiles).

4.3 General Effect:

It is evident from the images that increasing the operating speed significantly reduces the pressure above the fan surface, as it is relative to the downward pressure, resulting in a significant difference in the generated lift force.

4.4 Detailed Analysis for Each Case:

At $V=251$: A significant difference is evident between the pressure on the upper surface (low pressure, dark blue areas) and the lower surface (full pressure, green and yellow colors). This difference generates a significant lift force, demonstrating high efficiency at this speed.

At $V=188$: There is still a clear difference in pressure, but to a lesser extent than in the previous case. The pressures remain constant and low, and the pressure below them is moderate, indicating a good ability to generate lift, but less than in the first case.

At $V = 155$: Noticeable discomfort is reduced. This is evident in the close color gradient between the two sides, indicating that the propeller is capable of generating lift.

At $V = 94$: The pressure difference is very small, with the pressure values above and below V being almost identical. In this case, the generated lift is insufficient for takeoff or maintaining flight.

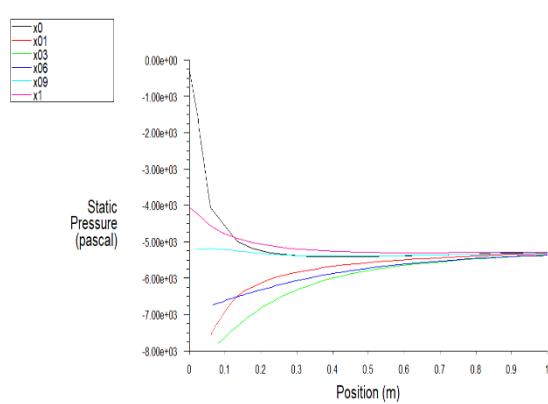
4.5 Conclusion:

Understand, through analyzing the pressure distribution, that increasing the rotational speed directly leads to increased generated lift. This is consistent with fluid mechanics requirements and is essential for understanding propeller performance during takeoff and flight.

4.6 presentation of the pressure and speed curves a function of X at different stations (X=0 to X=1)

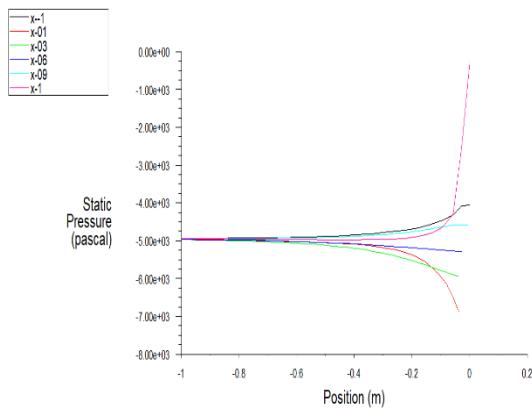
$v=94$ m/s

Extrados



Static Pressure
May 14, 2025
FLUENT 6.3 (2d, pbn, ske)

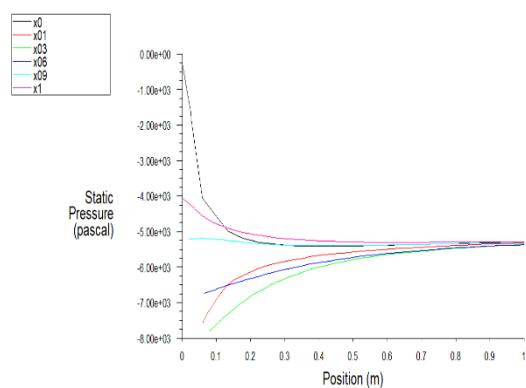
Intrados



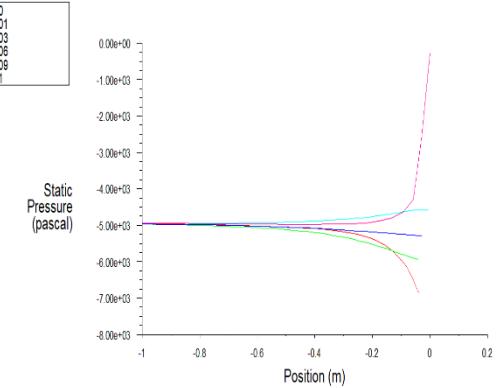
Static Pressure
May 14, 2025
FLUENT 6.3 (2d, pbn, ske)

$V=155\text{m/s}$

Extrados



Intrados



Static Pressure

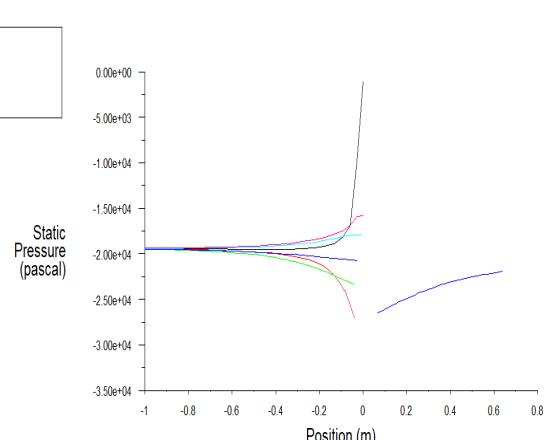
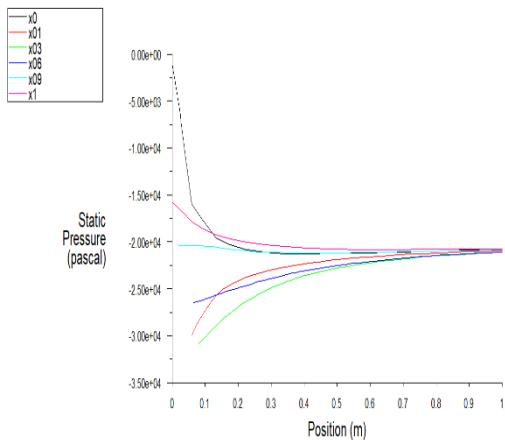
May 14, 2025
FLUENT 6.3 (2d, pbns, ske)

Static Pressure

May 14, 2025
FLUENT 6.3 (2d, pbns, ske)

$V=188\text{m/s}$

Extrados



Static Pressure

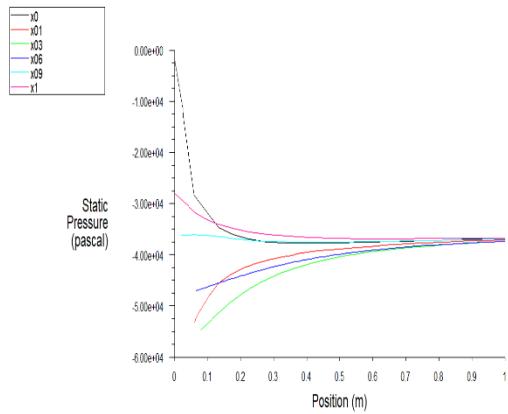
May 14, 2025
FLUENT 6.3 (2d, pbns, ske)

Static Pressure

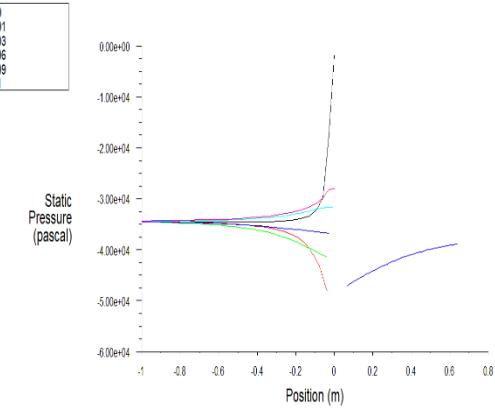
May 14, 2025
FLUENT 6.3 (2d, pbns, ske)

$$V=155\text{m/s}$$

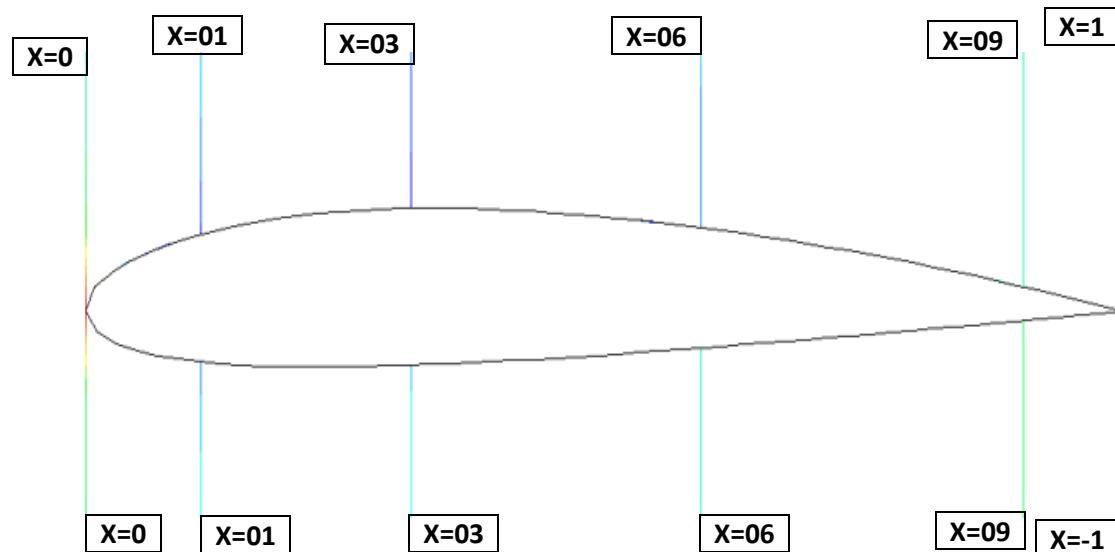
Extrados



Intrados



4.7 Analysis of pressure curves as a function of X for $v=94\text{m/s}$, $v=155\text{m/s}$, $v=188\text{ m/s}$, $v=251\text{ m/s}$



4.8 CONCLUSION

4.9 In this chapter, we study the pressure across several regions in the vane domain and represent it as a function of X as the pressure changes. We see the pressure at each location as a function of X.

GENERAL *CONCLUSION*

General Conclusion :

This numerical study, which utilized computer simulation tools (CFD), specifically ANSYS Fluent, achieved a deeper understanding of the effect of propeller rotational speed (RPM) on a helicopter's takeoff capability. The results showed a clear direct relationship between rotational speed and the generated lift force, with lift force increasing significantly with increasing rotational speed, confirming the theoretical foundations of aerodynamics.

However, increasing rotational speed is not always optimal. Exceeding a certain RPM threshold leads to increased energy consumption, increased noise, and mechanical stress on the blades, which may lead to performance degradation or mechanical failure. Therefore, one of the most important outcomes of this study is determining a critical RPM value that achieves the ideal balance between aerodynamic efficiency, energy consumption, and operational reliability.

The study also emphasized the importance of using numerical simulation tools in the design and analysis of helicopter propulsion systems, as they provide accuracy and efficiency in testing various scenarios without the need for costly physical experimentation.

Thus, this study contributes to paving the way for the development of more efficient and stable helicopters and opens new horizons for improving the performance of vertical takeoff systems by optimizing the aerodynamic design of propellers and determining optimal operational parameters.

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