# TURBULENT FLOW PAST - AN AIRCRAFT FORWARD STEP USING ANSYS

A Project report submitted in partial fulfilment of the requirements for the Award of the Degree of

**BACHELOR OF TECHNOLOGY**

**IN**

**MECHANICAL ENGINEERING**

**SUBMITTED BY**

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# CERTIFICATE

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# ABSTRACT

The conventional metals used in the fabrication of aircraft like aluminium are showing poor performance at elevated temperatures. So, in order to overcome these problems there is a need to try new materials like composite materials. Composite materials can provides a much better strength-to-weight ratio than metals. The lower weight results in lower fuel consumption, emissions and also plastic structures only need fewer riveted joints, which lead to enhanced aerodynamic efficiencies and lower manufacturing costs. So here Carbon-fibre-reinforced polymer (often referred to as carbon fibre) was used as a material for the fabrication of aircraft nose.

This project examines the design of aluminium and carbon fibre made aircraft forward step using Ansys fluent. This study outlines the development of a computational model of the aircraft nose in modelling software and then the creation of a finite computational domain, segmentation of this domain into discrete intervals, application of the boundary condition such as Mach number or velocity and then obtaining the contour plots and results for velocity, temperature and turbulence kinetic energy and heat transfer rate at a speed of Mach 2.The carbon fibre material shown better performance than aluminium which is generally used in aircraft fabrication.

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# CHAPTER 1

# INTRODUCTION

# 1. INTRODUCTION

## 1.1 AIRCRAFT INTRODUCTION

Airplanes come in many different shapes and sizes depending on the mission of the Aircraft, but all modern airplanes have certain components in common. These are the fuselage, wing, tail assembly, control surfaces and landing gear.

For any airplane to fly, it must be able to lift the weight of the airplane, its fuel, the passengers, and the cargo. The wings generate most of the lift to hold the plane in the air. To generate lift, the airplane must be pushed through the air. The engines, which are usually located beneath the wings, provide the thrust to push the airplane forward through the air. Fuselage is the body of the airplane that holds all the pieces of the Aircraft together and many of the other large components are attached to it.

The airframe of a fixed-wing Aircraft consists of the following five major units:

1. Fuselage
2. Wings
3. Stabilizers
4. Flight controls surfaces
5. Landing gear

### 1.1.1 Structural Stresses

The primary factors to consider in Aircraft structures are strength, weight, and reliability. These factors determine the requirements to be met by any material used to construct or repair the Aircraft. Airframes must be strong and light in weight. An Aircraft built so heavy that it couldn't support more than a few hundred pounds of additional weight would be useless. . All materials used to construct an Aircraft must be reliable. Reliability minimizes the possibility of dangerous and unexpected failures.

Many forces and structural stresses act on an Aircraft when it is flying and when it is static. When it is static, the force of gravity produces weight, which is supported by the landing gear. The landing gear absorbs the forces imposed on the Aircraft by takeoffs and landings.

During flight, any manual that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage.

Stresses on the wings, fuselage, and landing gear of Aircraft are tension, compression, shear, bending, and torsion. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage (tail section) absorbs the same stresses and transmits them to the fuselage. These stresses are known as loads, and the study of loads is called a *stress analysis.* Stresses are analysed and considered when an Aircraft is designed.

### 1.1.2 Tension

Tension is defined as pull. It is the stress of stretching an object or pulling at its ends. Tension is the resistance to pulling apart or stretching produced by two forces pulling in opposite directions alongthe same straight line. For example, an elevator control cable is in additional tension when the pilot moves the control column.

### 1.1.3 Compression

If forces acting on an Aircraft move toward each other to squeeze the material, the stress is called compression. Compression is the opposite of tension. Tension is pull, and compression is push. Compression is the resistance to crushing produced by two forces pushing toward each other in the same straight line. For example, when an airplane is on the ground, the landing gear struts are under a constant compression stress.

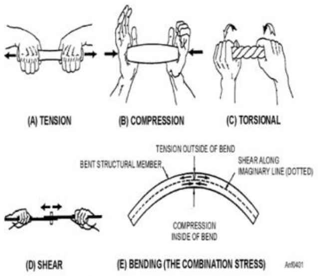


**Fig.1.1 Type of Stresses.**

### 1.1.4 Shear

Cutting a piece of paper with scissors is an example of a shearing action. In an Aircraft structure, shear is a stress exerted when two pieces of fastened material tend to separate. Shear stress is the outcome of sliding one part over the other in opposite directions. The rivets and bolts of an Aircraft experience both shear and tension stresses.

### 1.1.5 Bending

Bending is a combination of tension and compression. For example, when bending a piece of tubing, the upper portion stretches (tension) and the lower portion crushes together (compression). The wing spars of an Aircraft in flight are subject to bending stresses.

### 1.1.6 Torsion

Torsion stresses result from a twisting force. When you wring out a chamois skin, you are putting it under torsion. Torsion is produced in an engine crankshaft while the engine is running. Forces that produce torsion stress also produce torque.

### 1.1.7 Varying Stress

All structural members of an Aircraft are subject to one or more stresses. Sometimes a structural member has alternate stresses; for example, it is under compression one instant and under tension the next. The strength of Aircraft materials must be great enough to withstand maximum force of varying stresses.

### 1.1.8 Specific Action of Stresses

You need to understand the stresses encountered on the main parts of an Aircraft. A knowledge of the basic stresses on Aircraft structures will help you understand why Aircraft are built the way they are. The fuselage of an Aircraft is subject the five types of stress—torsion, bending, tension, shear, and compression.

Torsion stress in a fuselage is created in several ways. For example, torsion stress is encountered in engine torque on turboprop Aircraft. Engine torque tends to rotate the Aircraft in the direction opposite to the direction the propeller is turning. This force creates a torsion stress in the fuselage. Figure shows the effect of the rotating propellers. Also, torsion stress on the fuselage is created by the action of the ailerons when the Aircraft is manual

When an Aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the Aircraft. Bending increases when the Aircraft makes a carrier landing. This bending action creates a tension stress on the lower skin of the fuselage and a compression stress on the top skin. Bending action is shown in figure. These stresses are transmitted to the fuselage when the Aircraft is in flight. Bending occurs because of the reaction of the airflow against the wings and empennage. When the Aircraft is in flight, lift forces act upward against the wings, tending to bend them upward. The wings are prevented from folding over the fuselage by the resisting strength of the wing structure. The bending action creates a tension stress on the bottom of the wings and a compression stress on the top of the wings.

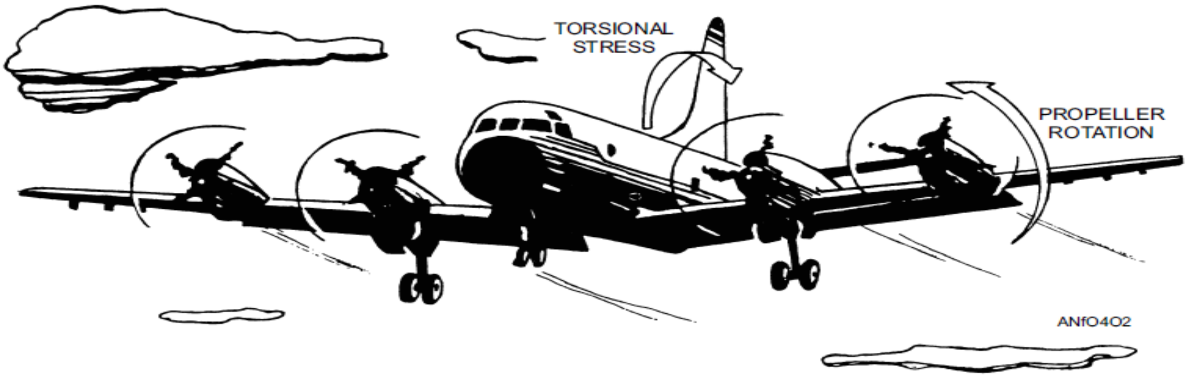


**Fig.1.2Engine torque creates torsion stress in Aircraft fuselages.**

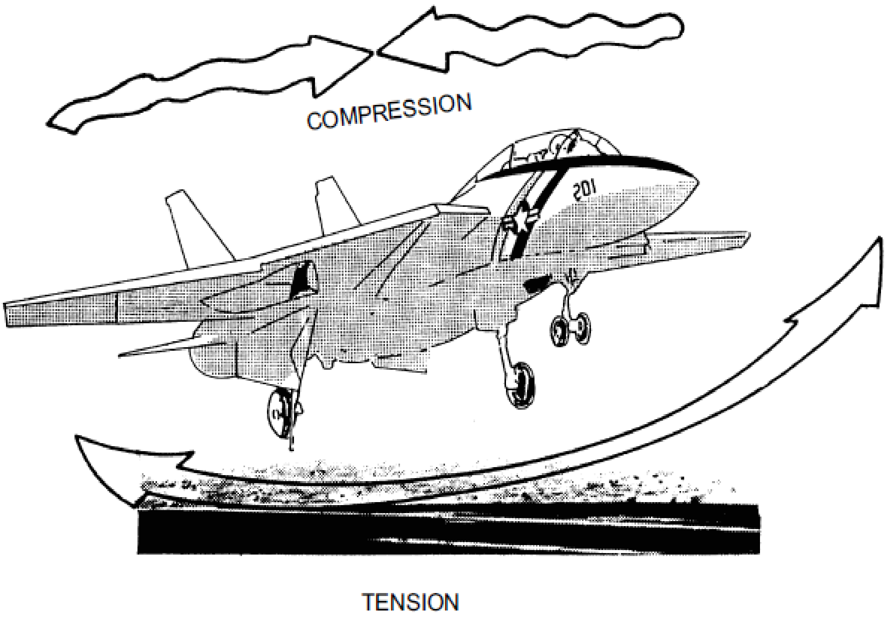


**Fig.1.3Bending action occurring during carrier landing.**

## 1.2 CONSTRUCTION MATERIALS

An Aircraft must be constructed of materials that are both light and strong. Early Aircraft were made of wood. Lightweight metal alloys with a strength greater than wood were developed and used on later Aircraft. Materials currently used in Aircraft construction are classified as either metallic materials or non-metallic materials.

### 1.2.1 Metallic Materials

The most common metals used in Aircraft construction are Aluminium, magnesium, titanium, Steel, and their alloys

### 1.2.2 Alloys

An alloy is composed of two or more metals. The metal present in the alloy in the largest amount is called the *base metal*. All other metals added to the base metal are called *alloying elements*. Adding the alloying elements may result in a change in the properties of the base metal. For example, pure Aluminium is relatively soft and weak. However, adding small amounts or copper, manganese, and magnesium will increase Aluminium strength many times. Heat treatment can increase or decrease an alloy's strength and hardness. Alloys are important to the Aircraft industry. They provide materials with properties that pure metals do not possess.

### 1.2.3 Aluminium

Aluminium alloys are widely used in modern Aircraft construction. Aluminium alloys are valuable because they have a high strength-to-weight ratio. Aluminium alloys are corrosion resistant and comparatively easy to fabricate. The outstanding characteristic of Aluminium is its lightweight.

### 1.2.4 Magnesium

Magnesium is the world's lightest structural metal. It is a silvery-white material that weighs two-thirds as much as Aluminium. Magnesium is used to make helicopters. Magnesium's low resistance to corrosion has limited its use in conventional Aircraft.

### 1.2.5 Titanium

Titanium is a lightweight, strong, corrosion-resistant metal. Recent developments make titanium ideal for applications where Aluminium alloys are too weak and stainless Steel is too heavy. Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere.

### 1.2.6 Steel Alloys

Alloy Steels used in Aircraft construction have great strength, more so than other fields of engineering would require. These materials must withstand the forces that occur on today's modern Aircraft. These Steels contain small percentages of Carbon, nickel, chromium, vanadium, and molybdenum. High-tensile Steels will stand stress of 50 to 150 tons per square inch without failing. Such Steels are made into tubes, rods, and wires.

Another type of Steel used extensively is stainless Steel. Stainless Steel resists corrosion and is particularly valuable for use in or near water.

### 1.2.7 Non-Metallic Materials

In addition to metals, various types of plastic materials are found in Aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and Carbon-fibre materials.

### 1.2.8 Transparent Plastic

Transparent plastic is used in canopies, windshields, and other transparent enclosures. You need to handle transparent plastic surfaces carefully because they are relatively soft and scratch easily. At approximately 225°F, transparent plastic becomes soft and pliable.

### 1.2.9 Reinforced Plastic

Reinforced plastic is used in the construction of wingtips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mildew and rot. Because it is easy to fabricate, it is equally suitable for other parts of the Aircraft.

Reinforced plastic is a sandwich-type material. It is made up of two outer facings and a centre layer. The facings are made up of several layers of glass cloth, bonded together with a liquid resin. The core material (centre layer) consists of a honeycomb.

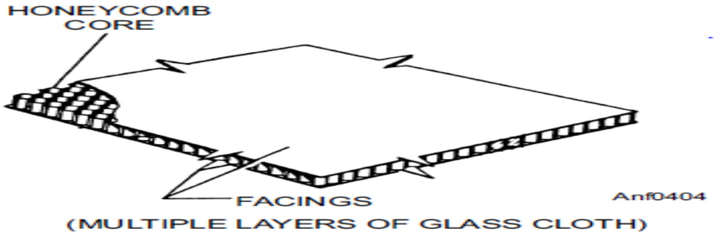
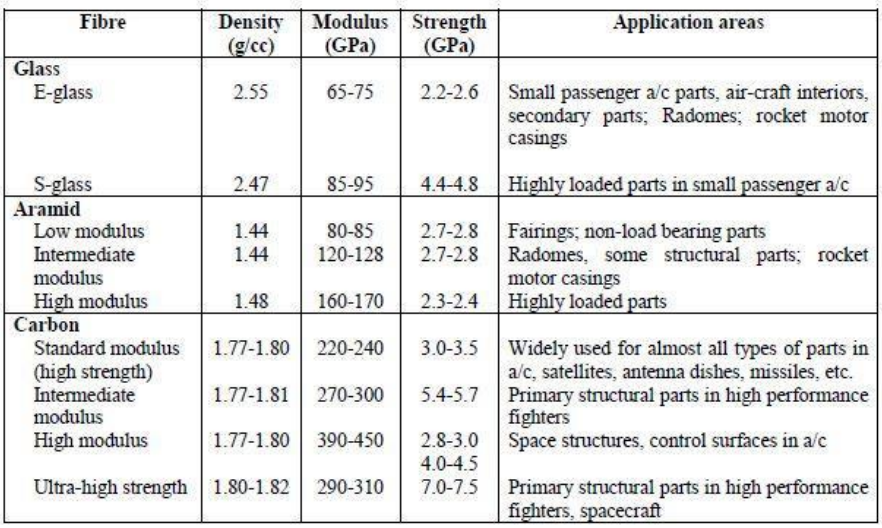


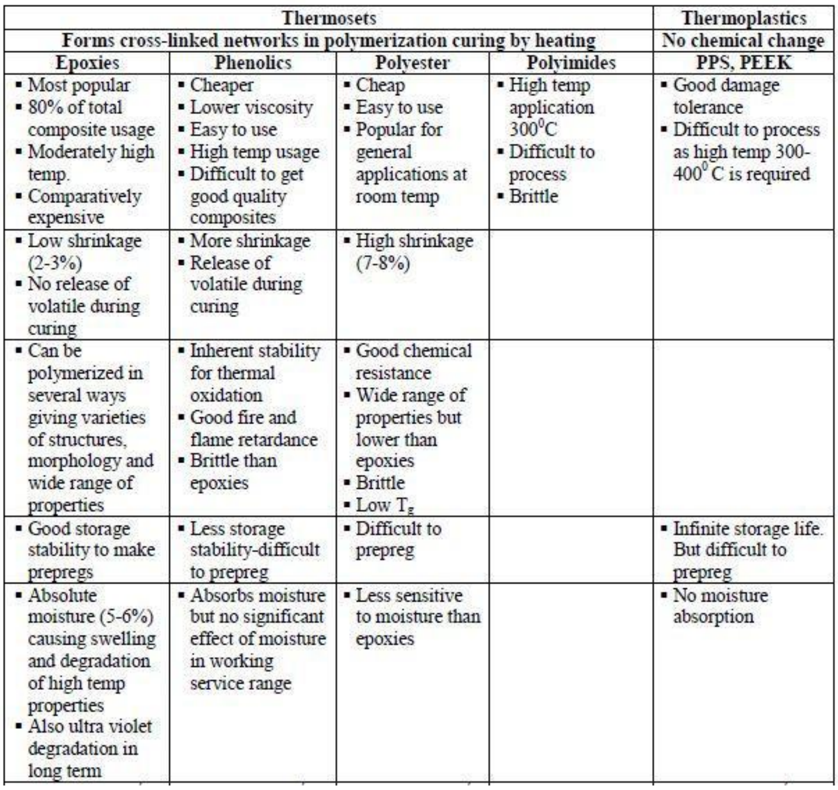
**Fig.1.4. Structure of Reinforced Plastic.**

**Table 1. Reinforcing fibers commonly used in aerospace applications.**



| Fibre | Density (g/cc) | Modulus (GPa) | Strength (GPa) | Application areas |
|---|---|---|---|---|
| **Glass** | | | | |
| E-glass | 2.55 | 65-75 | 2.2-2.6 | Small passenger a/c parts, air-craft interiors, secondary parts; Radomes; rocket motor casings |
| S-glass | 2.47 | 85-95 | 4.4-4.8 | Highly loaded parts in small passenger a/c |
| **Aramid** | | | | |
| Low modulus | 1.44 | 80-85 | 2.7-2.8 | Fairings; non-load bearing parts |
| Intermediate modulus | 1.44 | 120-128 | 2.7-2.8 | Radomes, some structural parts; rocket motor casings |
| High modulus | 1.48 | 160-170 | 2.3-2.4 | Highly loaded parts |
| **Carbon** | | | | |
| Standard modulus (high strength) | 1.77-1.80 | 220-240 | 3.0-3.5 | Widely used for almost all types of parts in a/c, satellites, antenna dishes, missiles, etc. |
| Intermediate modulus | 1.77-1.81 | 270-300 | 5.4-5.7 | Primary structural parts in high performance fighters |
| High modulus | 1.77-1.80 | 390-450 | 2.8-3.0<br>4.0-4.5 | Space structures, control surfaces in a/c |
| Ultra-high strength | 1.80-1.82 | 290-310 | 7.0-7.5 | Primary structural parts in high performance fighters, spacecraft |

**Table 2. Polymeric matrices commonly used in aerospace sector.**



| Thermosets | | | | Thermoplastics |
|---|---|---|---|---|
| Forms cross-linked networks in polymerization curing by heating | | | | No chemical change |
| **Epoxies** | **Phenolics** | **Polyester** | **Polyimides** | **PPS, PEEK** |
| ▪ Most popular<br>▪ 80% of total composite usage<br>▪ Moderately high temp.<br>▪ Comparatively expensive | ▪ Cheaper<br>▪ Lower viscosity<br>▪ Easy to use<br>▪ High temp usage<br>▪ Difficult to get good quality composites | ▪ Cheap<br>▪ Easy to use<br>▪ Popular for general applications at room temp | ▪ High temp application 300$^0$C<br>▪ Difficult to process<br>▪ Brittle | ▪ Good damage tolerance<br>▪ Difficult to process as high temp 300-400$^0$ C is required |
| ▪ Low shrinkage (2-3%)<br>▪ No release of volatile during curing | ▪ More shrinkage<br>▪ Release of volatile during curing | ▪ High shrinkage (7-8%) | | |
| ▪ Can be polymerized in several ways giving varieties of structures, morphology and wide range of properties | ▪ Inherent stability for thermal oxidation<br>▪ Good fire and flame retardance<br>▪ Brittle than epoxies | ▪ Good chemical resistance<br>▪ Wide range of properties but lower than epoxies<br>▪ Brittle<br>▪ Low $T_g$ | | |
| ▪ Good storage stability to make prepregs | ▪ Less storage stability-difficult to prepreg | ▪ Difficult to prepreg | | ▪ Infinite storage life. But difficult to prepreg |
| ▪ Absolute moisture (5-6%) causing swelling and degradation of high temp properties<br>▪ Also ultra violet degradation in long term | ▪ Absorbs moisture but no significant effect of moisture in working service range | ▪ Less sensitive to moisture than epoxies | | ▪ No moisture absorption |

## 1.3 PARTS OF FIXED WING AIRCRAFT

The principal structural units of a fixed-wing Aircraft are the fuselage, wings, stabilizers, flight control surfaces, and landing gear.

### 1.3.1 Fuselage

The fuselage is the main structure, or body, of the Aircraft. It provides space for personnel, cargo, controls, and most of the accessories. The power plant, wings, stabilizers, and landing gear are attached to it.

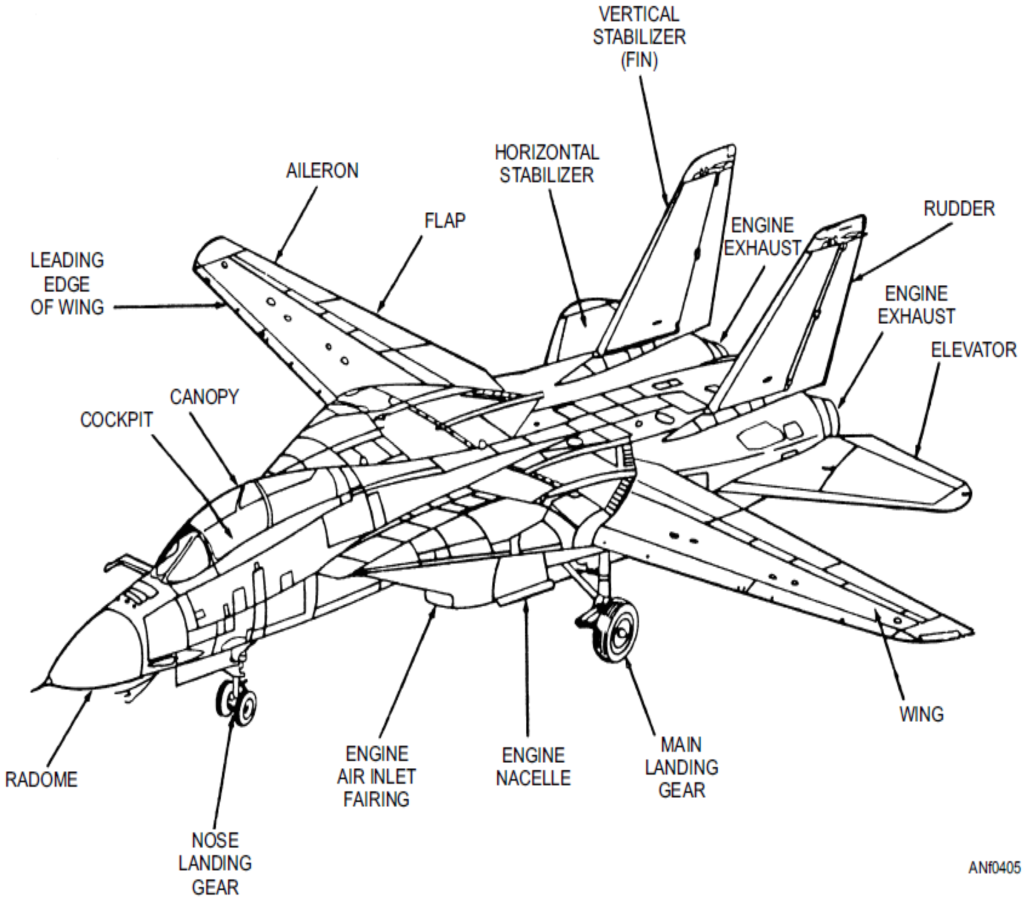


**Fig.1.5 Nomenclature of Aircraft.**

### 1.3.2 Wings

Wings develop the major portion of the lift of a heavier-than-air Aircraft. Wing structures carry some of the heavier loads found in the Aircraft structure. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the Aircraft. The wing must be constructed so that it holds its aerodynamics shape under the extreme stresses of combat maneuvers or wing loading.

Spars are the main structural members of the wing. They extend from the fuselage to the tip of the wing. The entire load carried by the wing is taken up by the spars. The spars are designed to have great bending strength. Ribs give the wing section its shape, and they transmit the air load from the wing covering to the spars. Ribs extend from the leading edge to the trailing edge of the wing.

The wings of most naval Aircraft are of all metal, full cantilever construction. Often, they may be folded for carrier use. A full cantilever wing structure is very strong. The wing can be fastened to the fuselage without the use of external bracing, such as wires or struts.

A complete wing assembly consists of the surface providing lift for the support of the Aircraft. It also provides the necessary flight control surfaces.

### 1.3.3 Stabilizers

The stabilizing surfaces of an Aircraft consist of vertical and horizontal aerofoils. They are called the vertical stabilizer (or fin) and horizontal stabilizer. These two aerofoils, along with the rudder and elevators, form the tail section. For inspection and maintenance purposes, the entire tail section is considered a single unit called the empennage.

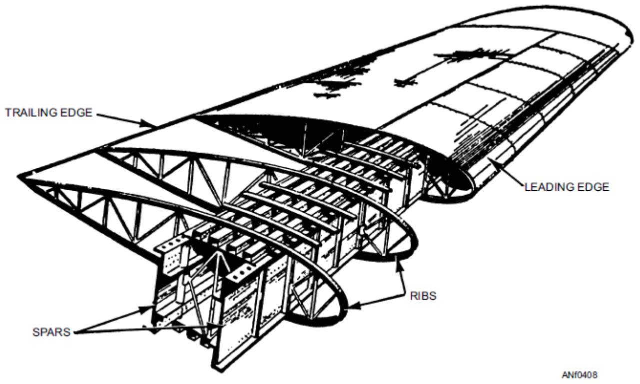


**Fig.1.6 Two-spar wing construction.**

The main purpose of stabilizers is to keep the Aircraft in straight-and-level flight. The vertical stabilizer maintains the stability of the Aircraft about its vertical axis (fig. 4-9). This is known as directional stability. The vertical stabilizer usually serves as the base to which the rudder is attached. The horizontal stabilizer provides stability of the Aircraft about its lateral axis. This is known as longitudinal stability. The horizontal stabilizer usually serves as the base to which the elevators are attached. On many newer, high-performance Aircraft, the entire vertical and/or horizontal stabilizer is a movable aerofoil. Without the movable aerofoil, the flight control surfaces would lose their effectiveness at extremely high altitudes.

Stabilizer construction is similar to wing construction. For greater strength, especially in the thinner aerofoil sections typical of trailing edges, a honeycomb-type construction is used. Some larger carrier-type Aircraft have vertical stabilizers that are folded hydraulically to aid Aircraft movement aboard Aircraft carriers.

**Table 3. Features of Aircraft structure.**

| Requirement | Applicability | Effect |
|---|---|---|
| • Light-weight | All Aerospace Programmes | ♦ Semi-monocoque construction<br>* Thin-walled-box or stiffened structures<br>♦ Use of low density materials:<br>* Wood * Al-alloys * Composites<br>♦ High strength/weight, High stiffness/weight |
| • High reliability | All Aerospace Programmes | ♦ Strict quality control<br>♦ Extensive testing for reliable data<br>♦ Certification: Proof of design |
| • Passenger safety | Passenger vehicles | ♦ Use of fire retardant materials<br>♦ Extensive testing: Crashworthiness |
| • Durability-Fatigue and corrosion | Aircraft | ♦ Extensive fatigue analysis/testing<br>* Al-alloys do not have a fatigue limit!!!<br>♦ Corrosion prevention schemes |
| Degradation:<br>Vacuum<br>Radiation<br>Thermal | Spacecraft | ♦ Issues of damage and safe-life, life extension<br>♦ Extensive testing for required environment<br>♦ Thin materials with high integrity |
| • Aerodynamic performance | Aircraft<br>Reusable spacecraft | ♦ Highly complex loading<br>♦ Thin flexible wings and control surfaces<br>* Deformed shape-Aeroelasticity * Dynamics<br>♦ Complex contoured shapes<br>* Manufacturability: N/C Machining; Moulding |
| • Multi-role or functionality | All Aerospace Programmes | ♦ Efficient design<br>♦ Use: composites with functional properties |
| • Fly-by-wire | Aircrafts, mostly for fighters but also some in passenger a/c | ♦ Structure-Control Interactions<br>* Aero-servo-elasticity<br>♦ Extensive use of computers and electronics<br>* EMI shielding |
| • Stealth | Specific Military Aerospace Appl | ♦ Specific Surface and Shape of aircraft<br>* Stealth coatings!!! |
| • All-weather operation | Aircraft | ♦ Lightning protection, erosion resistance |

## 1.4 Nose of an Aircraft

Found at the foremost point of an aircraft, a nose cone must be aerodynamic in order to reduce drag on a plane. On most commercial and military aircraft, the nose cone also houses radar and other instruments that might be used to detect meteorological phenomena, track enemy aircraft or transmit communication signals.

The Nose of an airplane is very important to flight. Like the tip of an arrow, it decides where the plane is going to go. All of the elements of flight depend on keeping the nose pointed in the right direction.

It also pays a key role in limiting drag around the aircraft. It slices through the air, allowing it to flow around the aircraft in a gentle way that won't slow it down. In that way, it's very important in keeping the plane efficient.

**Fig.1.7 Nose of Boeing aircraft.**

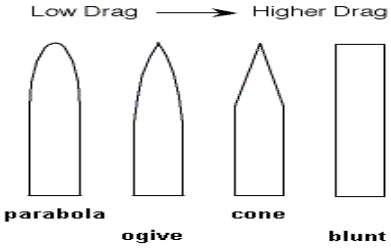


**Fig.1.8 Different shapes of nose of aircraft.**

**Fig.1.9 Lift and Drag Forces on Aircraft.**

The ideal nose shape for a rocket that minimizes its drag and maximizes its altitude depends on how fast the Aircraft is designed to travel. Most model Aircrafts fly well below the speed of sound. As a result, the ideal nose for a model Aircraft is not the pointed cone or ogive shape you might expect, but the more rounded parabola. The shape that produces the highest drag is the blunt, or flat-face shape.

The shape of the nose does indeed have a significant impact on the height it can reach. For most model rockets that fly at speeds far less than the speed of sound, a rounded, parabolic shape is ideal to minimize drag and reach the highest altitude. If you are designing a high-performance Aircraft that can reach supersonic speeds, however, a more pointed nose like the ogive is the ideal shape.

# CHAPTER 2

# LITERATURE REVIEW

# 2. LITERATURE REVIEW

1. N. Anjaneyulu, J. Laxmi Latha et al. studied that the minor cracks on wings of A380 were related to production. The minor cracks –no more than two centimetres long were discovered on some of the wing brackets and were caused by manufacturing issue and not the turbulence. The modelling of the entire flight and wing were done separately and steady state thermal analysis and transient thermal analysis were carried out on the wing. Under the given input conditions stress and strain values are within the limiting range. The maximum stress that the wing can withstand is 700Pa but the obtained stress was 400Pa. So the design of the wing is safe.

Prof. S. R. Zaweri, Nikhil A. Khadse studied the modal analysis of Aircraft wing using ANSYS WORKBENCH14.0. Modal analysis has been carried out by fixing one end (root chord) of aircraft while the other end (tip chord) is free. The interest is to find 6 modes of vibration with its respective natural frequency and mode shapes. This investigation revealed that natural frequency obtained from numerical and theoretical approach are in close agreement which proves that the procedure opted for numerical modal analysis of Aircraft wing and its results are correct.

Salu Kumar Das, Sandipan Roy were analysed the wing of an aircraft using Carbon Fibre Reinforced Polymer (CRFP), Glass Fibre Reinforced Polymer (GRFP) and compared it with Al alloy to find out the suitable material for the wing. The wing is designed in solid modelling software CATIA V5 R20 and analysis is done using finite element method by using ANSYS. Static Structural analysis and Modal analysis is done to find out the stress, strain, deformation and natural frequency of the wing to reduce noise and avoid vibration. From the comparision of the results it can be seen that Epoxy-Carbon UD has better structural characteristics than other materials. It has less deformation, high strength, light weight as compared to Aluminium 2024 T3 and other materials.

P. Venkata Suresh, K. Ayappa, V et al. concluded that the Titanium material is having optimum deformation range of 49.674 (Min) and 238.14 (Max). Along with these materials Titanium alloy having better properties is now a day most popularly used in various fields is chosen for nose cone of Aircraft for yielding better results. Analysis is carried out with different materials having slightly varying properties by using simulation of ANSYS software.

K. Ravindra, P. V. Divakar Raju studied how high-end CAD software's can be used in early stages of an Aircraft design process, especially for the wing and its structural entities. The finite element mesh is generated and updated based on any changes in geometry and the shape of the wing panels, wing spars and ensure that all the mesh elements are properly attached at the nodes. The automated FE mesh generation can be used for performing the structural analysis on Aircraft wing. The project is concluded by saying that the material most suitable for the Aircraft wing is found as Aluminium 7075-T6 when compared to Carbon Epoxy and Steel. Aluminium is having less deformation whenever there is self-weight acting on it. Finally Aluminium is the efficient material.

Jerome Pora studied the applications of composite materials and technologies on A380. Part of the goal is to select the most appropriate material for the specific application, which would lead to the lightest possible structure. For this purpose, composite materials are good competitors, and their use is foreseen on many areas of the airframe. Due to their mechanical behaviours, design criteria are different for metallic and composite structures. Second, the initiation and growth of damage and the failure modes are more difficult to predict analytically on composites. Due to these complications, the best practices are fully understood only by those engineers that are experienced at designing composite structures. The A380 will be the first aircraft ever to boast a CFRP (Carbon Fibre Reinforced Plastic) composite central wing box, representing a weight saving of up to one and a half tonnes compared to the most advanced aluminium alloys. But composite materials and technologies must contribute to competitive aircraft performance at affordable costs. On A380 advanced manufacturing technologies such as Automated Tape Laying, Resin Film Infusion and Resin Transfer Moulding are expected to contribute to cost reductions manufacture. Finally, the size of A380 components will generate the possibility to design huge composite parts, reducing the assembly costs and moving A380 one step further in the development by Airbus of composite applications on airframes.

Nikhil V Nayak concluded that Composite materials offer high fatigue and corrosion resistance, high strength to weight ratio. So they are best suited for various aerospace applications. Fiber-reinforced polymer composite materials are fast gaining ground as preferred materials for construction of aircrafts and spacecrafts.

Ceramics outstrip metals and polymers in their favourable melting points, ability to withstand high temperatures, strength and thermal expansion properties, but due to their brittleness they are often unsatisfactory as structural materials. The materials systems which have been considered useful in aerospace sector are based on reinforcing fibers and matrix resins. The carbon fiber technology continues to improve harnessing the versatility of carbon fibre and new varieties in terms of better combinations of modulus and strength are becoming available

P. D. Mangalgiri studied that Fibre-reinforced polymer composite materials are fast gaining ground as preferred materials for construction of aircraft and spacecraft. In particular, their use as primary structural materials in recent years in several technology-demonstrator front-line aerospace projects world-wide has provided confidence leading to their acceptance as prime materials for aerospace vehicles. The structure has to meet the requirements of fuel sealing and provide access for easy maintenance of equipment. Passenger carriage requires safety standards to be followed and these put special demands of fire retardance and crash-worthiness on the materials and design used. The composites in particular, the advanced fibre reinforced composites using carbon or aramid fibres in polymer matrices--offer several advantages.

# CHAPTER 3

# MATERIALS USED IN AIRCRAFT

# 3. MATERIALS USED IN AIRCRAFT

Different aircrafts require different building materials. Aircraft can be constructed from wood, fabric, many types of metal or even composite materials (e.g. Carbon-fibre, fibreglass).

Early Aircraft such as the Wright Flyer were built with wood and fabric. The frame of the Wright Flyer was made from spruce and ash and many surfaces were covered with muslin, a fabric.

Most airplanes today are made out of Aluminium, a strong, yet lightweight metal. The Ford Tri-Motor, the first passenger plane from 1928, was made out of Aluminium. The modern Boeing 747 is an Aluminium airplane as well.

Other metals, such as Steel and titanium, are sometimes used to build Aircraft. Steel is heavy though, so not too much is used. Titanium is almost as strong as steel, has a medium weight, is heat resistant, and is corrosion resistant. The Lockheed SR-71 Blackbird, the world's fastest jet-propelled Aircraft, is made of titanium.
Did you know that Aluminium makes up 75%-80% of a modern Aircraft?!

## 3.1 ALUMINIUM

Aluminium is ideal for Aircraft manufacture because it's lightweight and strong. Aluminium is roughly a third the weight of Steel, allowing an Aircraft to carry more weight and or become more fuel efficient. Furthermore, Aluminium's high resistance to corrosion ensures the safety of the Aircraft and its passengers.

### 3.1.1 History of Aluminium in the Aircraft Industry

On December 17, 1903, the Wright brothers made the world's first human flight with their airplane, the Wright Flyer.

**Fig.3.1 The Wright Brother's Wright Flyer**

At the time, automobile engines were very heavy and didn't deliver enough power to achieve take off, so the Wright brothers built a special engine in which the cylinder block and other parts were made from Aluminium.

As Aluminium was not widely available and was prohibitively expensive, the airplane itself was made from a Sitka spruce and bamboo frame covered with canvas. Due to the low airspeeds and limited lift-generating capability of the plane, keeping the frame extremely lightweight was essential and wood was the only feasible material light enough to fly, yet strong enough to carry the required load. It would take over a decade for the use of Aluminium to become more widespread.

### 3.1.2 World War I

Wooden Aircraft made their mark in the earliest days of aviation, but during World War I, lightweight Aluminium began to replace wood as the essential component for aerospace manufacture.

In 1915 the German Aircraft designer Hugo Junkers built the world's first full metal Aircraft; the Junkers J 1 monoplane. Its fuselage was made from an Aluminium alloy that included copper, magnesium and manganese.

**Fig.3.2 Junkers J 1 monoplane.**

The period between World War I and World War II came to be known as the Golden Age of Aviation

During the 1920s, Americans and Europeans competed in airplane racing, which led to innovations in design and performance. Biplanes were replaced by more streamlined monoplanes and there was a transition to all-metal frames made from Aluminium alloys.

**Fig.3.3 The “Tin Goose”.**

In 1925, the Ford Motor Co. went into the airline industry. Henry Ford designed the 4-AT, a three-engine, all-metal plane using corrugated Aluminium. Dubbed “The Tin Goose”, it became an instant hit with passengers and airline operators.

By the mid-1930s, a new streamlined Aircraft shape emerged, with tightly cowled multiple engines, retracting landing gear, variable-pitch propellers, and stressed-skin Aluminium construction.

### 3.1.3 World War II

During World War II, Aluminium was needed for numerous military applications – particularly the construction of Aircraft frames – which caused Aluminium production to soar.

The demand for Aluminium was so great that in 1942, WOR-NYC broadcast a radio show “Aluminium for Defence” to encourage Americans to contribute scrap Aluminium to the war effort. Aluminium recycling was encouraged, and “Tinfoil Drives” offered free movie tickets in exchange for Aluminium foil balls.

In the period from July 1940 to August 1945, the U.S. produced a staggering 296,000 Aircraft. More than half were made predominantly from Aluminium. The U.S. aerospace industry was able to meet the needs of the American military, as well as American allies including Britain. At their peak in 1944, American Aircraft plants were producing 11 planes every hour. By the end of the war, America had the most powerful air force in the world

### 3.1.4 The modern era

Since the end of the war, Aluminium has become an integral part of Aircraft manufacture. While the composition of the Aluminium alloys has improved, the advantages of Aluminium remain the same. Aluminium allows designers to build a plane that is as light as possible, can carry heavy loads, uses the least amount of fuel and is impervious to rust.

**Fig.3.4 The Concorde.**

In modern Aircraft manufacture, Aluminium is used everywhere. The Concorde, which flew passengers at over twice the speed of sound for 27 years, was built with an Aluminium skin.

The Boeing 737, the best-selling jet commercial airliner which has made air travel for the masses a reality, is 80% Aluminium.

Today's planes use Aluminium in the fuselage, the wing panes, the rudder, the exhaust pipes, the door and floors, the seats, the engine turbines, and the cockpit instrumentation.

### 3.1.5 Space exploration

Aluminium is invaluable not just in airplanes but in spacecraft, where low weight coupled with maximum strength is even more essential. In 1957, the Soviet Union launched the first satellite, the Sputnik 1, which was made from an Aluminium alloy.

**Fig.3.5 Skylab Space Station**

All modern spacecraft are comprised of 50% to 90% Aluminium alloy. Aluminium alloys have been used extensively on the Apollo spacecraft, the Skylab space station, the Space Shuttles and the International Space Station.

### 3.1.6 Why Aluminium Used In Aircrafts

27% of all Aluminium consumed occurs in the transportation industry, according to Aluminium Leader. This chemical element in the boron group is characterized by a silver-white colour and soft, ductile texture. While it's used in many different applications, one of the most common is aerospace. In fact, Aluminium is one of the most common materials used in the construction of airplanes. So, why is Aluminium used for this purpose instead of Steel or other materials?

Some of the first airliners weren't made of metal, but instead were made of wood. Although cheap and readily available, wood has a serious flaw that made it hazardous in airplanes: it rotted. There was one instances in which a wooden airliner crashed, killing everyone on board. The cause of the crash was later found to be rotten wood. This prompted manufacturers to quickly phase out wood in favour of metal.

Aluminium is the perfect material to use when manufacturing airplanes, thanks in part to its unique properties and characteristics. It's strong, lightweight, predictable and inexpensive. Steel and iron are both stronger than Aluminium, but strength alone isn't enough to justify its use in aerospace manufacturing. The problem with Steel and iron is its weight. Both of these metals are much heavier than Aluminium — and too much weigh restricts an airplane's ability to take-off and fly. It's estimated that up to 80% of the materials used in modern-day Aircraft is Aluminium. The Wright brothers used a Steel engine in their early-model Flyer plane, which was not only heavy but lacked the power necessary for takeover. As a result, they acquired a special engine made of cast Aluminium, which allowed their Flyer-1 to take-off with ease.

There are several different types of Aluminium used in aerospace engineering, some of which include the following:

Aluminium 2024
Aluminium 3003
Aluminium 5052
Aluminium 6061
Aluminium 7075

Note: the number refers to the Aluminium's "grade."

Of course, Aluminium isn't the only metal used to manufacture airplanes. Carbon-alloy Steel is often used for his application as well. When Carbon is added to Steel, it becomes stronger and more resistant to rust and corrosion. Titanium is another metal that's commonly used in aerospace engineering. It’s strong, lightweight, and naturally resistant to corrosion. Some companies alloy titanium with iron or manganese to construct the frame and engines for airplanes. These use of these metals, however, is typically less than that of Aluminium. Aluminium isn’t the strongest metal, but it maintains a perfect balance of strength and low weight that make it ideal for airplanes.

Aluminium is used due to its low density (2.7 g/cm3), high strength properties, good thermal and electric conductivity, technological effectiveness and high corrosion resistance. But because Aluminium loses its strength at high temperatures, it is not used in the skin surface of an Aircraft. Steel is an alloy of iron and carbon and can be three times stronger and heavier than Aluminium. It is usually used in a landing gear due to its strength and hardness as well as in the skin surface of Aircrafts due to its high heat resistance.

### 3.1.9 Other materials Used in Aircraft Manufacturing

**Fig.3.6 Building an Aircraft.**

Titanium and its alloys are commonly used in the construction of Aircraft due to its high strength properties, high temperature resistance and high corrosion resistance compared to Steel and

Aluminium. Despite being expensive, titanium is used in aircraft construction due to its excellent material properties. It is used in panel and swivel wing assemblies, hydraulic systems and other parts. Product manufacturing company also favours composite materials in the production of Aircrafts due to their high tensile strength, high compression resistance, low weight and high resistance to corrosion. Composite materials are composed by a base material and resin that strengthens the material as a whole. Composite materials improve fuel efficiency and performance of the Aircraft as well as lessen direct operating costs of Aircrafts. The most common composite material used is fiberglass that is made up of glass fibres as the base material and a resin matrix. The disadvantages of using composite materials, however, include high cost and immediate repair are needed in case of damage. It is also important to avoid fire when using composite materials because the resin used weakens and causes release of toxic fumes. Now, Aluminium, Steel, titanium and composite materials are preferred in the construction of aerospace structures.

### 3.1.10 Future materials for Aircraft building

Magnesium had been gaining popularity again due to new developments regarding its corrosion and flammability properties. Magnesium is a lightweight metal but was banned in Aircraft construction because it easily catches fire. Now, various research studies made progress in developing magnesium alloys that can meet aerospace corrosion and flammability requirements and succeeded in lifting the ban of magnesium usage. Due to its low weight property, high strength and ductility, magnesium alloys improve efficiency of the Aircraft.

Nano Adaptive Hybrid Fabric (NAHF-X) or fuzzy fibres have good structural, electrical and thermal properties. Once incorporated into resin products, it will have the ability to be produced in continuous sheets to desired sizes like other fabrics. Fuzzy fibres can be used in small Unmanned Aerial Vehicles (UAVs) where weight will be reduced when the conductive “skin” of fuzzy fibre serves for the aircraft’s power, sensor systems and communications.
Fibre metal laminates (FML) have high strength, low density and high elasticity modulus with improved toughness, corrosion resistance, good fire resistance and fatigue properties. Furthermore, fibre metal laminates have low weight compared to other metallic structures. Lesser amounts of FML is needed to build a component compared to other materials. With these properties, cost is dramatically reduced in the construction and maintenance of Aircrafts.

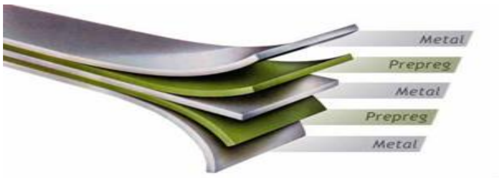


**Fig.3.7 Fibre metal**

## 3.2 COMPOSITE MATERIALS IN AIRCRAFTS

Composite materials are widely used in the aircraft industry and have allowed engineers to overcome obstacles that have been seen when using the materials individually. The constituent materials retain their identities in the composites and do not otherwise merge completely into each other. Together, the materials create a 'hybrid' material that has improved structural properties. Common composite materials used on airplanes include fiberglass, Carbon fibre, and fibre-reinforced matrix systems or any combination of any of these.

Of all these materials, fiberglass is the most common composite material and was first widely used in boats and automobiles in the 1950s.

### 3.2.1 Composite Material makes its way into Aviation

According to the Federal Aviation Agency, the composite material has been around since World War II. Over the years, this unique blend of material has become ever more popular, and today can be found in many different kinds of airplanes, as well as gliders. Aircraft structures are commonly made up of 50 to 70 percent composite material.

Fiberglass was first used in aviation by Boeing in its passenger jet in the 1950s. When Boeing rolled out its new 787 Dreamliner in 2012, it boasted that the Aircraft was 50 percent composite material. New Aircraft rolling off the line today almost all incorporate some kind of composite material into their designs.

Although composites continue to be used with great frequency in the aviation industry due to their numerous advantages, some say that these materials also pose a safety risk to aviation. Below, we balance the scales and weigh the advantages and disadvantages of this material.

### 3.2.2 Advantages

Weight reduction is the single greatest advantage of composite material usage and is the key factor in using it in Aircraft structure. Fibre-reinforced matrix systems are stronger than traditional aluminium found on most Aircraft, and they provide a smooth surface and increase fuel efficiency, which is a huge benefit.

Also, composite materials don't corrode as easily as other types of structures. They don't crack from metal fatigue and they hold up well in structural flexing environments. Composite designs also last longer than Aluminium, which means fewer maintenance and repair costs.

### 3.2.3 Limitations

Because composite materials don’t break easily and this of course, is the single most concerning disadvantage for using the composite material. In contrast, because of Aluminium bends and dents easily, it is quite easy to detect structural damage. Additionally, repairs can be much more difficult when a composite surface is damaged, which ultimately becomes costly.

Also, the resin used in composite material weakens at temperatures as low as 150 degrees, making it important for these aircraft to take extra precautions to avoid fires. Fires involved with composite materials can release toxic fumes and micro-particles into the air, causing health risks. Temperatures above $300^0$ can cause structural failure.

Finally, composite materials can be expensive, although it can be argued that the high initial costs are typically offset by long-term cost savings.

## 3.3 Introduction of carbon fibre

Carbon fibres or Carbon fibres (alternatively CF, graphite fibre or graphite fibre) are fibres about 5–10 micrometres in diameter and composed mostly of Carbon atoms. Carbon fibres have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made Carbon fibre very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibres, such as glass fibres or plastic fibres.

To produce a Carbon fibre, the Carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fibre as the crystal alignment gives the fibre high strength-to-volume ratio (making it strong for its size). Several thousand Carbon fibres are bundled together to form a tow, which may be used by itself or woven into a fabric.

Carbon fibres are usually combined with other materials to form a composite. When impregnated with a plastic resin and baked it forms Carbon-fibre-reinforced polymer (often referred to as Carbon fibre) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. Carbon fibres are also composited with other materials, such as graphite, to form reinforced Carbon-Carbon composites, which have a very high heat tolerance.

### 3.3.1 Carbon Fibre Usage in Aircrafts

There are a lot of elements that exist in the planet Earth. They already exist even before humans know what these elements are. As time goes by, humans began to know how to develop these elements into useful things that they can utilize for their everyday lives. One of these elements is Carbon. Carbon is top six when it comes to abundance all over the world. The most common way for people to obtain Carbon is through coal deposits.

One such form is a Carbon fibre composite. A Carbon fibre has high tensile strength, high chemical resistance, high stiffness, low thermal expansion, and low weight properties. However, Carbon fibre is most famous for being a strong yet lightweight material. A Carbon fibre has enough good properties which makes it a very good material for different industries to use. One industry that benefits a lot in the use of Carbon fibre is the aerospace industry. This particular industry is responsible in designing, assembling, and manufacturing various types of Aircrafts.

Aluminium is a strong type of metal, it is also a heavy element. In most cases, about 65%, even up to 75% of the total weight of an Aircraft is attributed to the Aluminium material. Since this is the case, the cost of purchasing the fuel that the airlines have to spend will definitely be high. In order to gain profits, the airline will pass a portion of this cost to the passengers. Aside from that, the distance that the Aircraft can cover will definitely be short. However, in such short distance, fuel consumption is already high.

In order to address these key concerns, the aerospace industry switched from Aluminium to Carbon fibre in terms of the primary material for the construction of the Aircrafts. Since Carbon fibre is known for its lightweight properties yet can still offer durability, the switch has been welcomed by the companies belonging to the aerospace industry. With the Carbon fibre being light, there will definitely be a significant reduction in the fuel consumption of the Aircraft. As a result, the cost of the fuel will also be lower. The Aircraft will burn and consume lesser amount of fuel as it is already very light.

With regards to the durability of the Carbon fibre, it also becomes very beneficial to the airline companies. Using Carbon fibre as the primary Aircraft construction material also lessens maintenance costs. Fatigue and corrosion are the two most common problems that plague most metals. Metallic components in an Aircraft easily experience stress or fatigue, especially with the frequent use of the Aircraft for flights. These components also corrode at a faster rate than Carbon fibres. Carbon fibre can definitely resist corrosion as well as fatigue.

Throughout history, the 787 Dreamliner that was developed and constructed by the Boeing Commercial Airplanes is the top selling passenger airplane. This plane uses Carbon fibre reinforced composites for its different parts. The wings, the fuselage, the interiors, the doors, and the tail, among many others, are all made from these composites. Each 787 Dreamliner manufactured and sold by Boeing has around 35 metric tons of the said composite or polymer, making it lightweight yet durable.

There is also a bit of an environmental benefit when using Carbon fibre as a construction material for Aircrafts, especially with regards to the long term environmental impact. This is because Carbon fiber has a long useful life due to it being resistant to corrosion and stress. This means that it does not have to be produced and replaced a number of times. However, it needs a lot of energy in order to produce Carbon fibre.

With all these benefits that the aerospace industry can take advantage of in the use of Carbon fibre for constructing and building Aircrafts, they also face a couple of challenges or obstacles in this field. One of these challenges is de-lamination where the layers of Steel or another composite material slowly separate from each other. In most cases, the separation is due to impact and repeated cyclic stresses. Aside from de-lamination, the Carbon fibres may also wrinkle while they are in the fabrication phase which causes the fibres to become less stiff, and, as a domino effect, become weak.

The aerospace industry has taken a lot of steps in order to overcome these challenges or obstacles. They definitely spend financial resources for the research and development of Carbon Fibre. They try to improve the quality of these Carbon fibres and follow certain steps to help them produce better Carbon fibres.

Indeed, Carbon fibre is beneficial to the aerospace industry. However, the industry alone is not the only one that can feel its effects. The consumers, especially those who love to travel and prefer planes over buses or ships, will also be able to benefit from the use of Carbon fibre in the aerospace industry.

# CHAPTER 4

# INTRODUCTION TO SPACECLAIM

# 4. INTRODUCTION TO SPACECLAIM

## 4.1 Spaceclaim

SpaceClaim Professional 2007 is the 3D productivity tool for engineers who need to focus on their core competencies while also benefiting from working in 3D. The software provides a highly flexible design environment coupled with a modern user experience that speeds contributions to the product development process. Space Claim Professional 2007 is for those who collaborate in the design and manufacture of mechanical products across a broad range of industries. The online help, tutorials, and training materials are provided to help you become productive with Space Claim as quickly as possible. We strongly recommend that you review the Getting Started section and step through the tutorial provided in the online help before beginning your own work. Additional self-paced tutorial videos are available on MySpaceClaim.com. You can also begin by exploring a library of Space Claim models. This User's Guide begins with a focus on the basics and on simple concepts. Space Claim is all about adding and manipulating the faces of a design model, primarily through pull and move operations. If there is a face, you can pull on it.

If you need a new face, draw an edge or copy an existing one. Design clutter is minimized wherever possible. This guide communicates these simple, but powerful concepts so that you can extrapolate them to your real-world designs. This guide also provides useful shortcuts to use as you progress, and animations of tools in action to help you understand their function.

SpaceClaim Corporation was founded in 2005 to develop 3D solid modelling software for mechanical engineering. Its first CAD application was launched in 2007 and used an approach to solid modelling where design concepts are created by pulling, moving, filling, combining and reusing 3D shapes Space Claim’s 3D direct modelling technology is primarily expressed through its user interface in four tools: pull, move, fill and combine

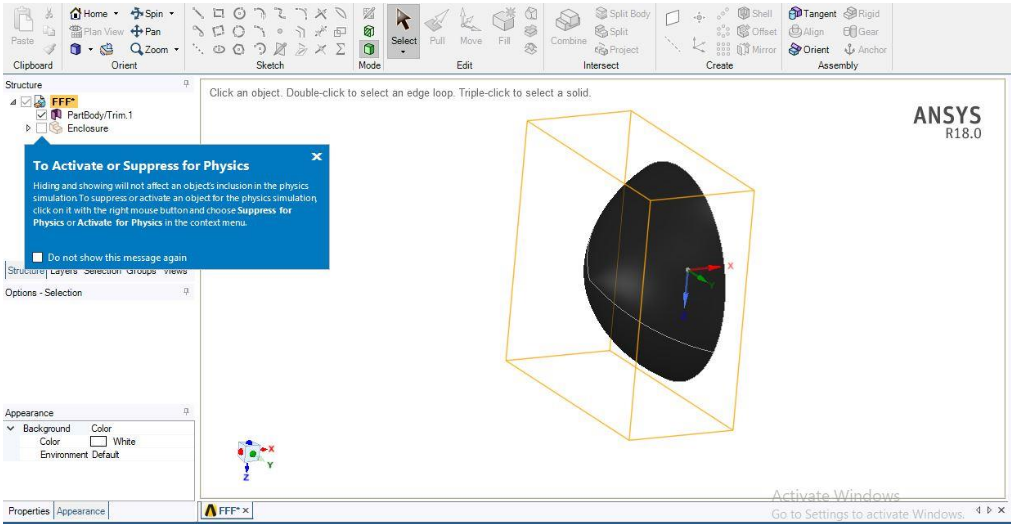
- Pull contains most certain features found in traditional CAD systems, determining its behaviour through user’s selection and though the use of secondary tool guides. For example the pull tool on a face by default offsets the face, but using the pull tool on an edge rounds the edge.

- Move repositions the components and geometry, and can also be used to create patterns (often called arrays).

- Fill primarily removes geometry from a part by extending geometry to fill in the surrounding area. Popular uses include deleting rounds and holes from a model. Space Claim engineer also includes more specialized tools for model preparation.

- Combine performs Boolean and splitting operations, such as merging parts and subtracting parts from each other.

## 4.2 SPACECLAIM IMAGE



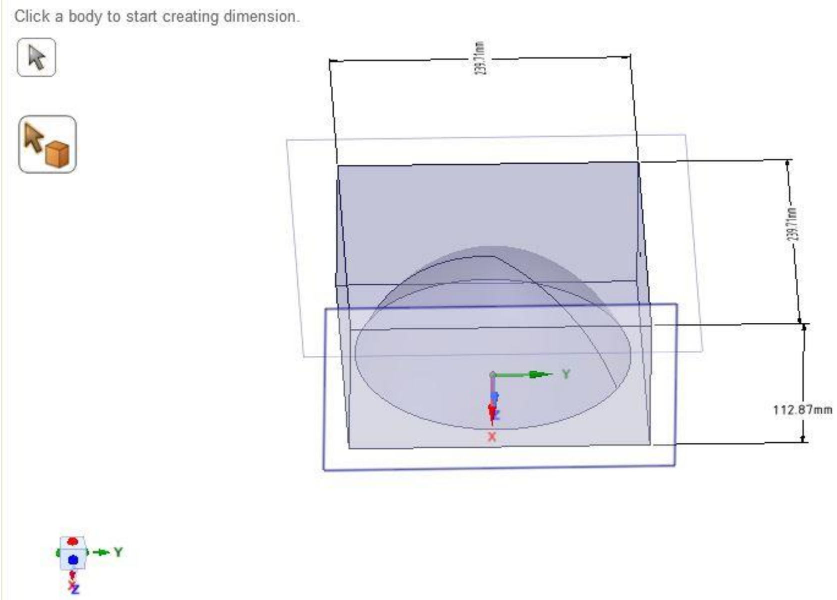
Click an object. Double-click to select an edge loop. Triple-click to select a solid.

**To Activate or Suppress for Physics**

Hiding and showing will not affect an object's inclusion in the physics simulation. To suppress or activate an object for the physics simulation, click on it with the right mouse button and choose **Suppress for Physics** or **Activate for Physics** in the context menu.

☐ Do not show this message again

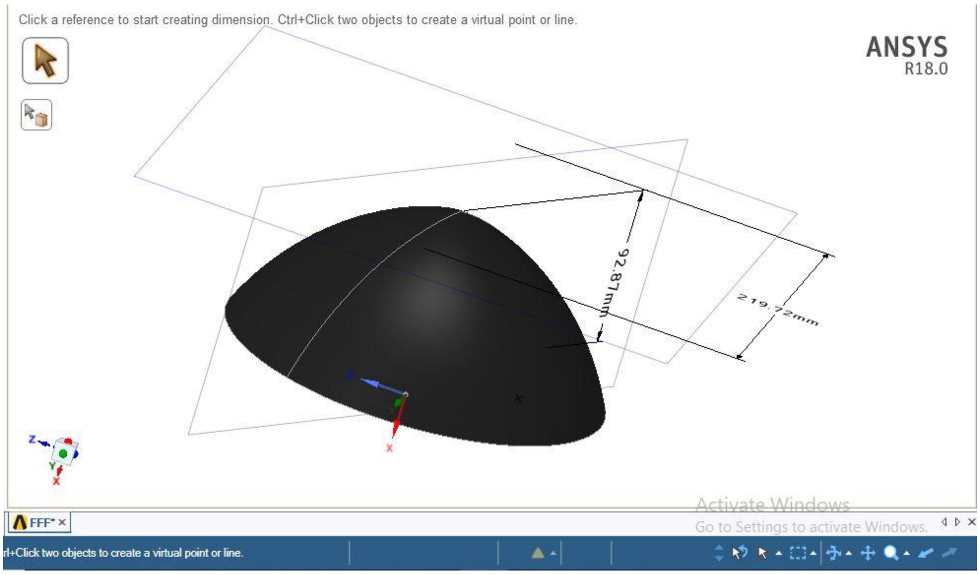
Fig.4.1 Solid Modelling of Nose.



Click a body to start creating dimension.

Fig.4.2 Dimensional figure of enclosure

Form the above figure the dimensions of enclosure are along X-axis:0.11287m, along Y-axis:0.23971m and along Z-axis:0.23971m



Click a reference to start creating dimension. Ctrl+Click two objects to create a virtual point or line.

rl+Click two objects to create a virtual point or line.

Activate Windows
Go to Settings to activate Windows.

**Fig.4.3 Dimensional figure of nose**

The above figure is provided with an annotation plane and dimensions are specified. The diameter of the nose is 0.21972m and the height from the tip of the nose to the base is 0.09287m

# CHAPTER 5

# INTRODUCTION TO ANSYS

# 5. INTRODUCTION TO ANSYS

## 5.1 ANSYS

ANSYS is a large-scale multipurpose finite element program developed and maintained by ANSYS Inc. to analyse a wide spectrum of problems encountered in engineering mechanics**.**

### 5.1.1 Program organization:

The ANSYS program is organized into two basic levels:

Begin level

Processor (or Routine) level

- The Begin level acts as a gateway into and out of the ANSYS program. It is also used for certain global program controls such as changing the job name, clearing (zeroing out) the database, and copying binary files. When you first enter the program, you are at the Begin level. At the Processor level, several processors are available. Each processor is a set of functions that perform a specific analysis task.
- For example, the general pre-processor (PREP7) is where you build the model, the solution processor (SOLUTION) is where you apply loads and obtain the solution, and the general postprocessor (POST1) is where you evaluate the results of a solution. An additional postprocessor, POST26, enables you to evaluate solution results at specific points in the model as a function of time.

### 5.1.2 Material models

ANSYS allows several different material models like:

- Linear elastic material models (isotropic, orthotropic, and anisotropic).
- Non-linear material models (hyper elastic, multi linear elastic, inelastic).
- Heat transfer material models (isotropic and orthotropic).
- Temperature dependent material properties and Creep material models.

**Loads:** The word loads in ANSYS terminology includes boundary conditions and externally or internally applied forcing functions, as illustrated in Loads. Examples of loads in different disciplines are:

**Structural:** Displacements, forces, pressures, temperatures (for thermal strain), Gravity.

**Thermal:** temperatures, heat flow rates, convections, internal heat generation, Infinite surface.

**Magnetic:** magnetic potentials, magnetic flux, magnetic current segments, source current density, and infinite surface.

**Electric:** electric potentials (voltage), electric current, electric charges, charge densities, infinite surface.

**Fluid:** velocities, pressures Loads are divided into six categories: DOF constraints, forces (concentrated loads), surface loads, body loads, inertia loads, and coupled field loads.

- A DOF constraint fixes a degree of freedom (DOF) to a known value. Examples of constraints are specified displacements and symmetry boundary conditions in a structural analysis, prescribed temperatures in a thermal analysis, and flux-parallel boundary conditions.
- A force is a concentrated load applied at a node in the model. Examples are forces and moments in a structural analysis, heat flow rates in a thermal analysis, and current segments in a magnetic field analysis.
- A surface load is a distributed load applied over a surface. Examples are pressures in a structural analysis and convections and heat fluxes in a thermal analysis.
- A body load is a volumetric or field load. Examples are temperatures and fluencies in a structural analysis, heat generation rates in a thermal analysis, and current densities in a magnetic field analysis.
- Inertia loads are those attributable to the inertia (mass matrix) of a body, such as gravitational acceleration, angular velocity, and angular acceleration. Coupled-field loads are simply a special case of one of the above loads, where results from one analysis are used as loads in another analysis. For example, you can apply magnetic forces calculated in a magnetic field analysis as force loads in a structural analysis.

### 5.1.3 Analysis types

The following types of analysis are possible using ANSYS

- Structural Analysis: Static Analysis, Modal Analysis, Harmonic Analysis, Transient Dynamic Analysis, Spectrum Analysis, Buckling Analysis, Explicit Dynamic Analysis, Fracture mechanics, and Beam Analysis.

- Thermal Analysis: Steady-state thermal analysis, transient thermal analysis.

- CFD (Computational Fluid Dynamics) Analysis: Laminar or turbulent, Thermal or adiabatic, Free surface, Compressible or incompressible, Newtonian or Non-Newtonian, Multiple species transport.
- Several types of Electromagnetic field analysis and Coupled field analysis.

## 5.2 Mesh generation

### Mesh generation approach

To analyse fluid flow in an area of interest, the partial differential equations (Euler equations, Navier-Stokes etc.) need to be solved. These equations cannot be solved for the entire region at once except for the very simple cases. So, in order to get numerical solution describing fluid flow in a domain, the domain must be split into smaller sub domains called cells or elements and equations are solved for each of these cells. Collection of these cells in a region is called Mesh or Grid and the process of splitting the domain into cells is called mesh generation. Grid generation is an essential tool in computational simulation of physical field phenomena and process. Unfortunately, grid generation process is not unique; it can be seen something which involves art as well as science. Therefore, it requires intensive user interaction in selection and development of high quality reliable grid. Automation of grid generation process requires understanding of the underlying principles, mathematics and technology involved in the process and a careful analysis of problem domain. In 2D case domain is split into quadrilaterals and triangular cells and for 3D case in hexahedral and tetrahedral cells.

### 5.2.1 Mesh classification

Mesh can be classified on the bases of connectivity of the elements as follows.

#### a) Structured mesh

Structured meshes are widely used in many real CFD applications. In structure mesh all interior vertices are topologically alike. This can be generated algebraically by interpolation from boundaries for example transfinite interpolation. In structured meshes points are laid in the region of interest in a regular pattern; these points form quadrilateral cells in 2D and hexahedral in 3D. A structured mesh generated in 2D region.

There are some significant advantages associated with structured meshes due to which they are preferred over other grid methods in many applications. These advantages are listed below:

- From the solver point of view, they have simplicity and easy data access.
- From user point of view, they possess high degree of control. For example user can easily control the refinement level in a particular region by placing more dense points on the boundaries of that region.
- Memory requirement to simulate flow in a structured domain is less as compared to other methods.
- Element could easily be flow aligned in structured meshes which offer more accuracy of the results.
- Examination of flow field in post processing is easier with structured mesh.

### b) Unstructured mesh

Unstructured meshes are used in many FEA and CFD applications which have irregular shape of object or region of interest. Unlike structured mesh, they can have elements of arbitrary topology in a confined region. In unstructured meshes points are laid in the region of interest in a random order forming triangular subdivision of the region. Unstructured mesh in its most basic form contains triangles in 2D and tetrahedral cells in 3D, but may be made of hexahedral or elements of any shape in general. Unstructured meshes are more easily generated and adapted but require a much more complex solution data structure. In generation of unstructured mesh user control is limited as interior nodes are generated automatically without any interaction of user. An unstructured mesh generated around aerofoil in 2D region.

The advantages of unstructured grid methods are given below:

- They have the ability to adopt better around the complex geometries.
- They can be generated with less efforts and interactions.
- They can be easily adopted by the applications which require automation of the mesh generation process.

### c) Hybrid mesh

General configurations can conceivably be treated with either type of mesh, and hybrid combinations are also possible, using individual structured meshes near boundaries, with the sub-regions being connected by an unstructured mesh. Thus, hybrid mesh is a positive combination of both structured and unstructured mesh and possesses the advantages of both. A hybrid mesh generated around aerofoil in 2D region.

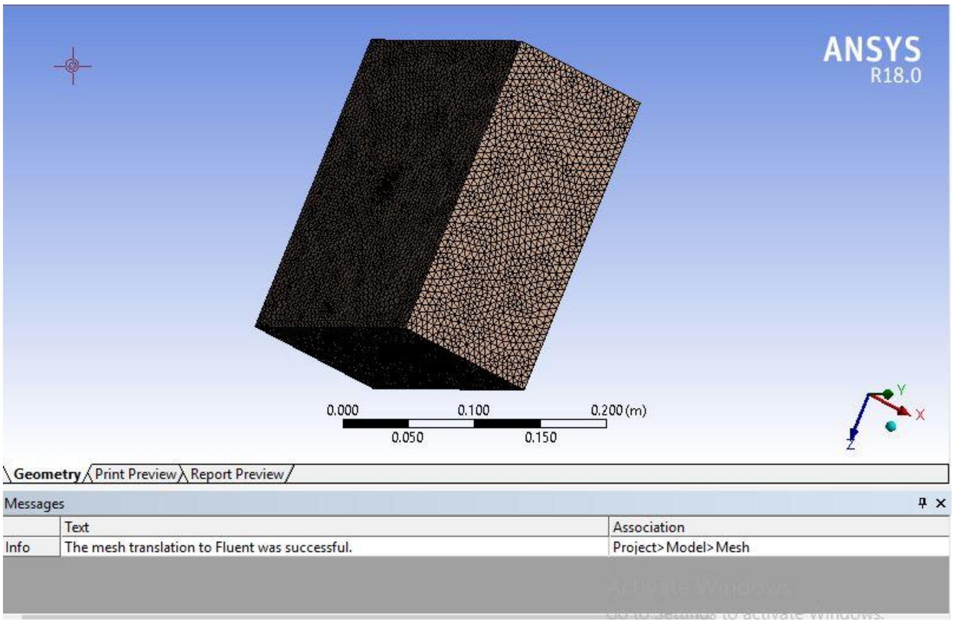
Storage requirement per point for a flow simulation on an unstructured grid is about four times that of structured grid. Even if the unstructured grid is coarser in the far-field the storage of the un-structured grid, with its greater total number of points would typically be 40 times greater than that for a structured grid. Thus, for hybrid grid there is a clear indication that the extent of un-structured grid employed should be as minimum as possible.

### d) Grid generation approach

Grid generation is an important aspect a good grid can accelerate the convergence of the solution, while a poor grid can lead to divergent iteration history. Grid generation process proceeds from first defining the boundary geometry and distribution of the points on the curves that form the edges of boundary sections.

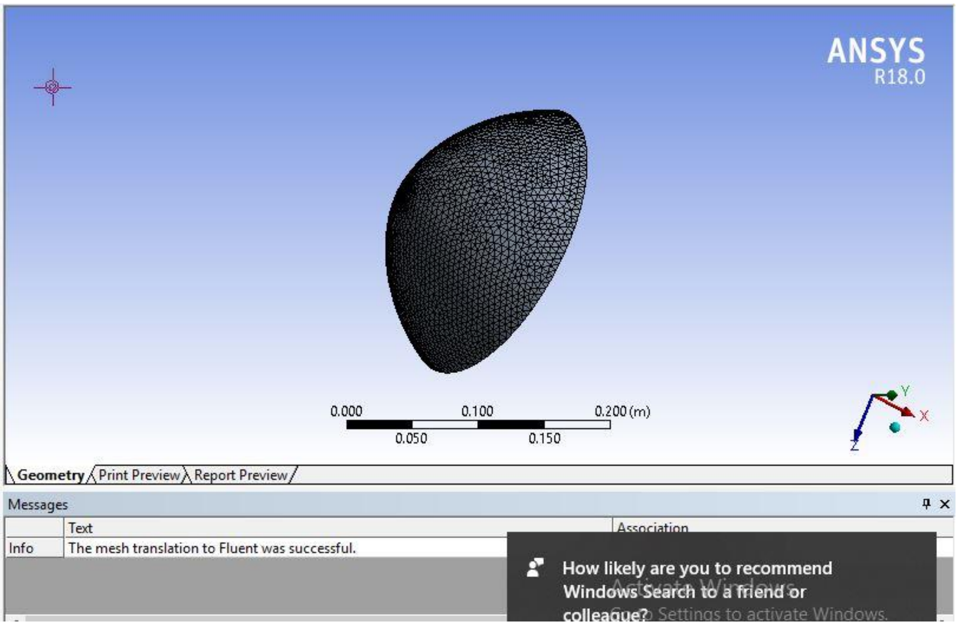
A surface grid is generated on the boundary surface. Finally a volume grid is generated in case of 3D domain. This project utilizes the power of commercial software ANSYS ICEM CFD to automate the process of mesh generation.

## 5.2.2 MESH IMAGES



|  | Text | Association |
|---|---|---|
| Info | The mesh translation to Fluent was successful. | Project>Model>Mesh |

Fig.5.1 Meshing.



| | Text |
|---|---|
| Info | The mesh translation to Fluent was successful. |

Fig.5.2 Meshing of wall plane.

### 5.2.3 Details of Meshing

Sizing

1. Size Function – Curvature
2. Relevance centre-Fine
3. Span angle Centre-Fine
4. Minimum size-5.2161e-005m
5. Maximum Face size-5.2161e-003m
6. Maximum tetrahedral size-1.0432e-002m
7. Automatic mesh-ON

Statistics

1. Number of Nodes-56626
2. Number of Elements-286525

Patch Conformation Method

1. Algorithm- Patch Confirming(Patch Dependent)

# CHAPTER 6

# INTRODUCTION TO CFD

# 6. INTRODUCTION TO CFD

## 6.1 CFD

The Computational Fluid Dynamics (CFD) provides numerical approximation to the equations that govern fluid motion. Application of the CFD to analyse a fluid problem requires the following steps. First, the mathematical equations describing the fluid flow are written. These are usually a set of partial differential equations. These equations are then discretized to produce a numerical analogue of the equations. The domain is then divided into small grids or elements. Finally, the initial conditions and the boundary conditions of the specific problem are used to solve these equations. The solution method can be direct or iterative. In addition, certain control parameters are used to control the convergence, stability, and accuracy of the method. All CFD codes contain three main elements: (1) A pre-processor, which is used to input the problem geometry, generate the grid define the flow parameter and the boundary conditions to the code. (2) A flow solver, which is used to solve the governing equations of the flow subject to the conditions provided. There are four different methods used as a flow solver: (i) finite difference method; (ii) finite element method, (iii) finite volume method, and (iv) spectral method, (3) A post-processor, which is used to massage the data and show the results in graphical and easy to read format.

## 6.2 FLUENT

Analysis is carried out on Aircraft Forward Step at different variants, so that following results are obtained from (CFD) FLUENT analysis for further discussions.

## 6.3 Post processor

**Post–processor:** Post-processor is versatile data visualization tools.

These include:

Domain geometry and grid display

- Vector plots
- Vectors
- Line and shaded contour plots
- 2D and 3D surface plots
- Particle tracking
- View manipulation (translation, rotation, scaling etc.)
- Colour postscript output

## 6.4 Boundary conditions

**Inlets:** At an inlet, fluid enters the domain and, therefore, its fluidvelocity or pressure or the mass flow rate may be known. Also, the fluid may have certain characteristics, such as the turbulence characterizes which needs to be specified.

**Inlet:** mass flow inlet.

**Outlet:** pressure outlet.

**No-slip impermeable wall:** Wall boundary conditions are used to bound fluid and solid regions. In viscous flows, the no-slip boundary condition is enforced at walls by default, but you can specify a tangential velocity component in terms of the translational or rotational motion of the wall boundary, or model a "slip" wall by specifying shear.

(You can also model a slip wall with zero shears using the symmetry boundary type, but using a symmetry boundary will apply symmetry conditions for all equations.

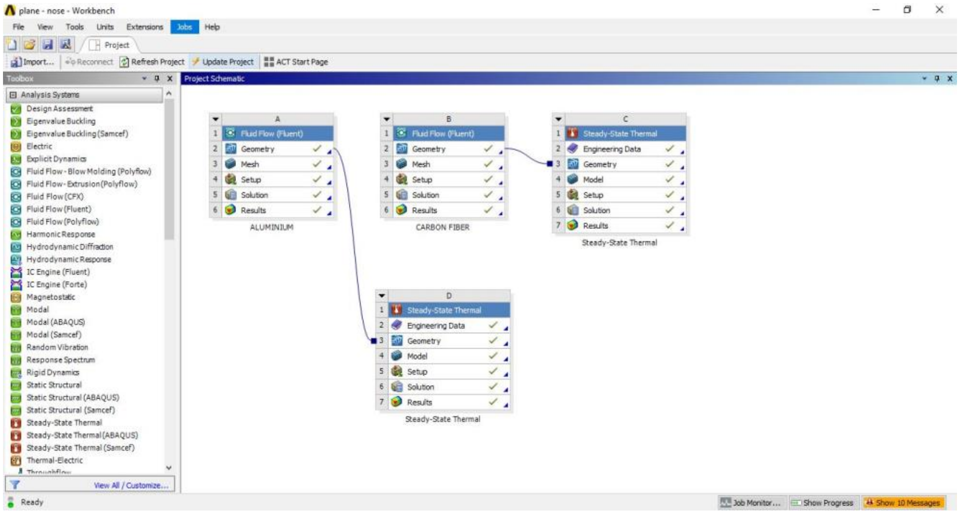
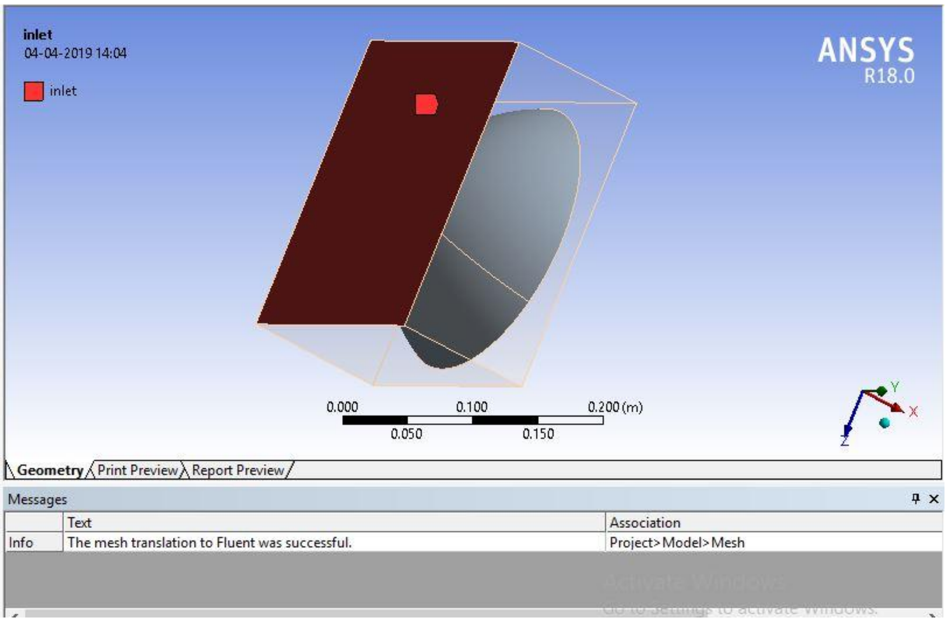


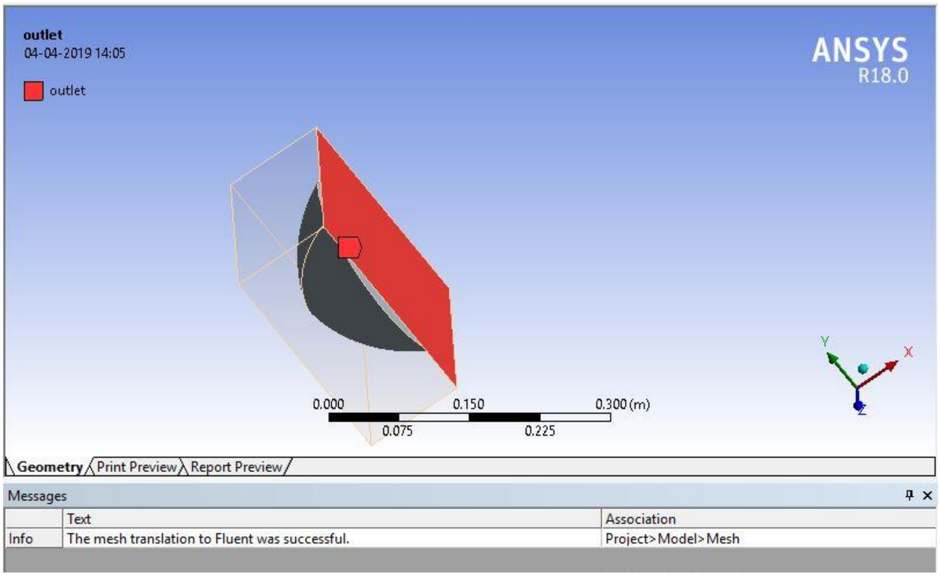
**Fig.6.1 ANSYS work bench.**

## 6.5 Images of boundary conditions



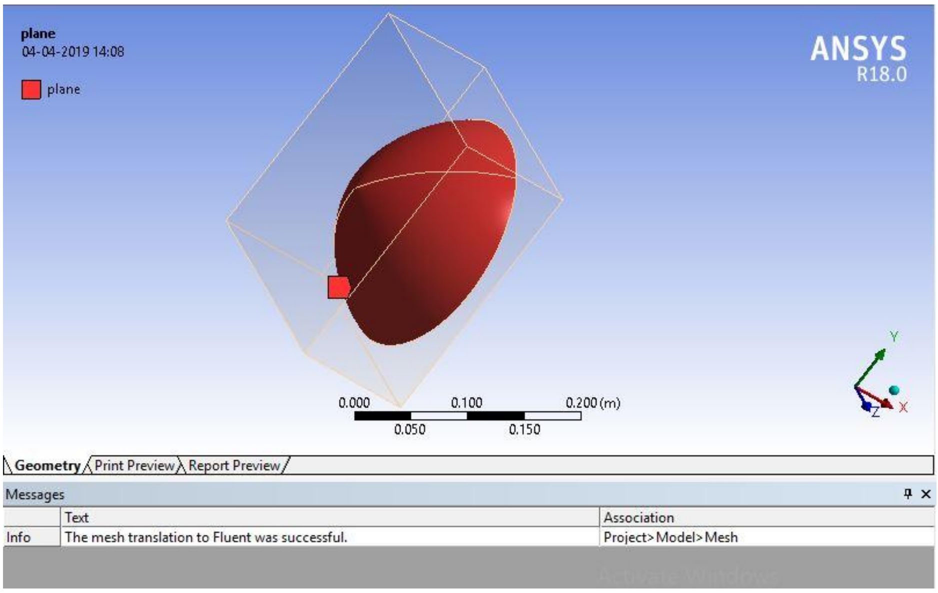
|  | Text | Association |
|---|---|---|
| Info | The mesh translation to Fluent was successful. | Project>Model>Mesh |

Fig.6.2 Inlet.



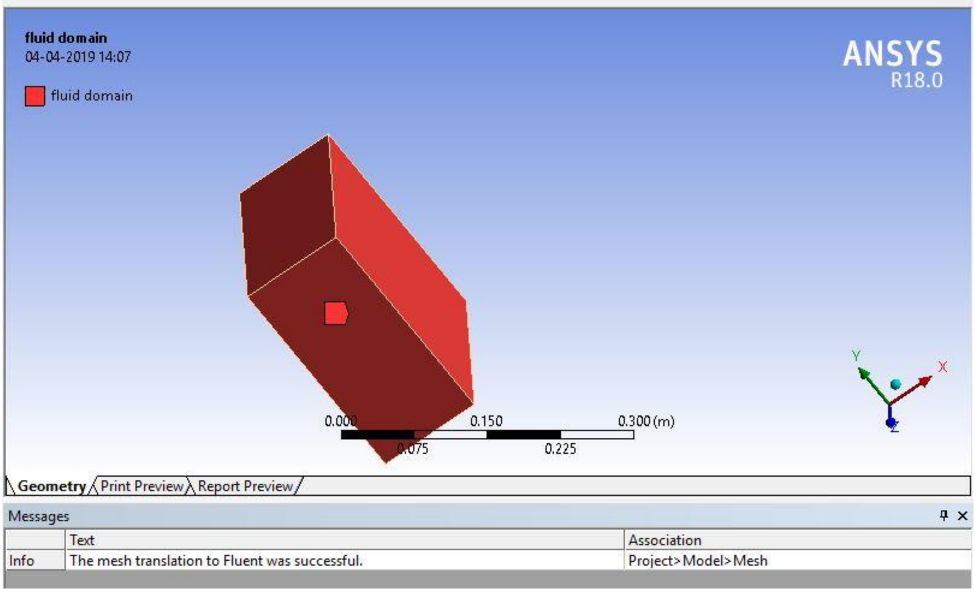
|  | Text | Association |
|---|---|---|
| Info | The mesh translation to Fluent was successful. | Project>Model>Mesh |

Fig.6.3 Outlet.



|  | Text | Association |
|---|---|---|
| Info | The mesh translation to Fluent was successful. | Project>Model>Mesh |

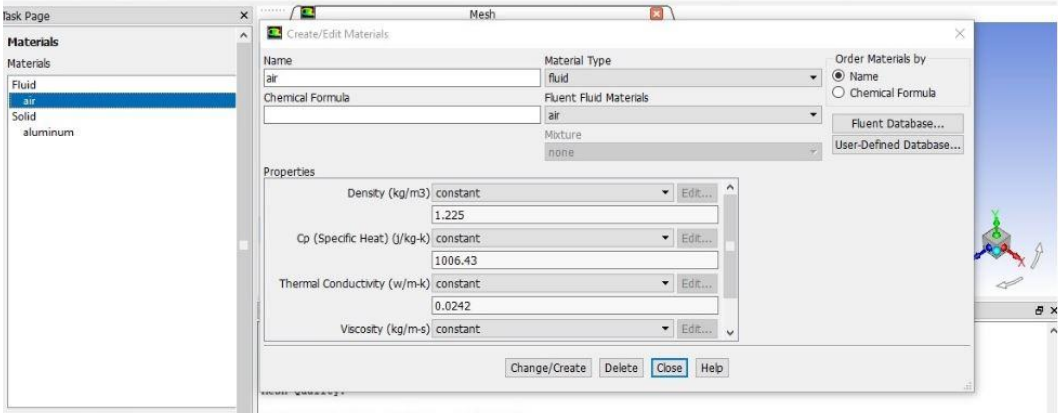
Fig.6.4 Wall plane.



|  | Text | Association |
|---|---|---|
| Info | The mesh translation to Fluent was successful. | Project>Model>Mesh |

Fig.6.5 Fluid Domain.

## 6.6 Input setup conditions



Name: air

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: air

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

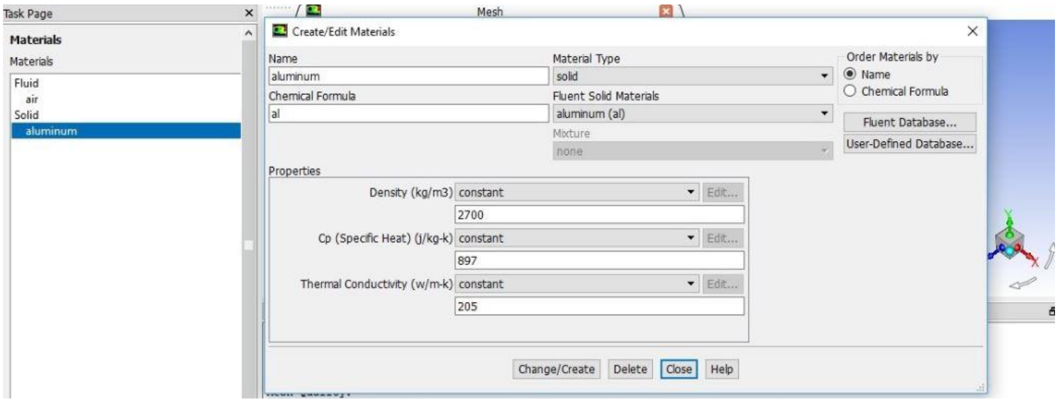
Density (kg/m3): constant, 1.225

Cp (Specific Heat) (j/kg-k): constant, 1006.43

Thermal Conductivity (w/m-k): constant, 0.0242

Viscosity (kg/m-s): constant

Fig6.6 Input parameters of Fluid Domain (Air).



Name: aluminum

Chemical Formula: al

Material Type: solid

Fluent Solid Materials: aluminum (al)

Mixture: none

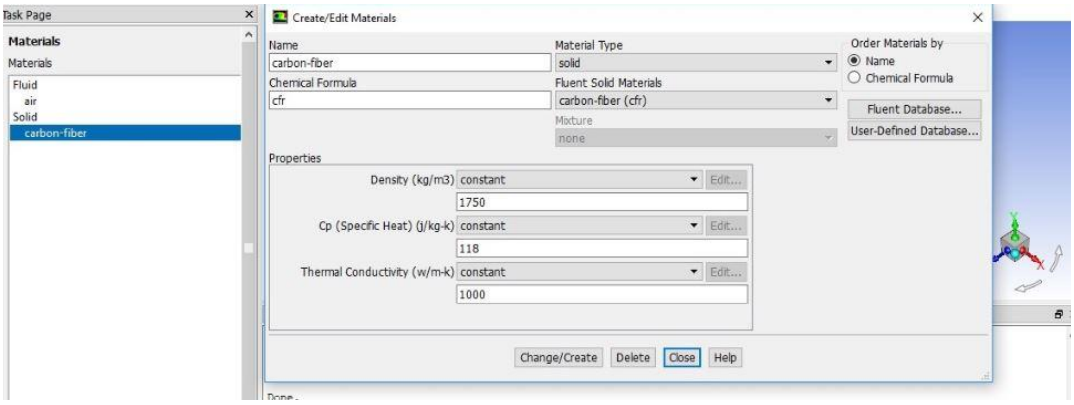
Order Materials by: ● Name ○ Chemical Formula

Density (kg/m3): constant, 2700

Cp (Specific Heat) (j/kg-k): constant, 897

Thermal Conductivity (w/m-k): constant, 205

Fig6.7 Input parameters of Wall Plane (Aluminium).



Name: carbon-fiber

Chemical Formula: cfr

Material Type: solid

Fluent Solid Materials: carbon-fiber (cfr)

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Density (kg/m3): constant, 1750

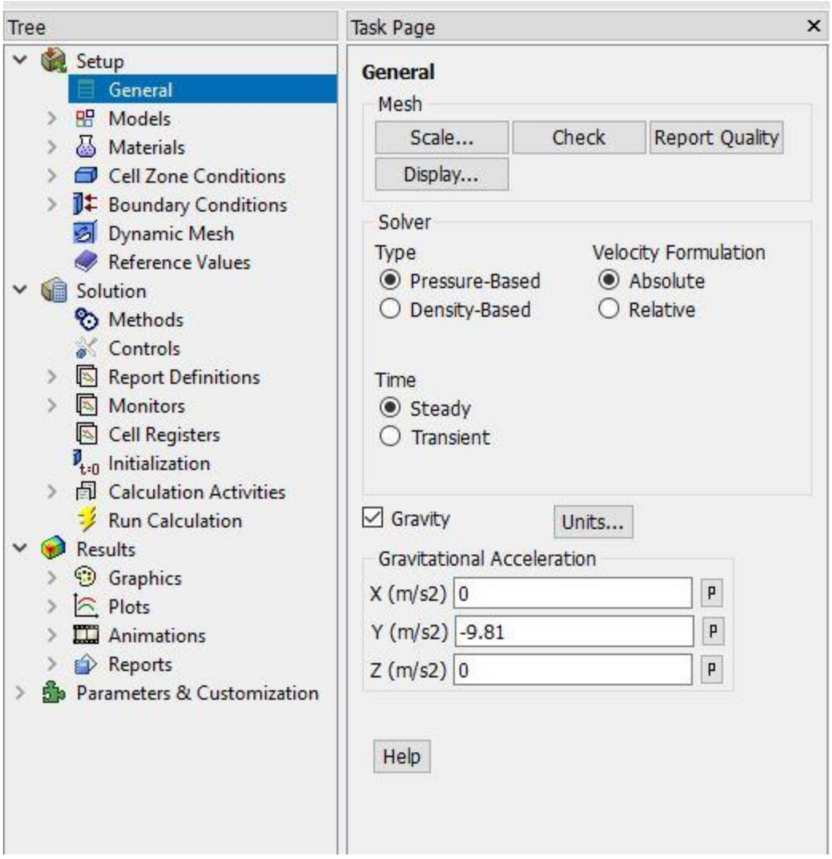
Cp (Specific Heat) (j/kg-k): constant, 118

Thermal Conductivity (w/m-k): constant, 1000

Fig6.8 Input parameters of Wall Plane (Carbon Fibre).

**Table 4. Input Parameters for Material Properties in Setup.**

| S.No. | Material | Density (kg/m^3) | Specific Heat (J/kg-K) | Thermal Conductivity (W/m-K) |
|---|---|---|---|---|
| 1 | Air | 1.225 | 1006.43 | 0.0242 |
| 2 | Aluminium | 2700 | 897 | 205 |
| 3 | Carbon fibre | 1750 | 118 | 1000 |



Solver

Type
● Pressure-Based
○ Density-Based

Velocity Formulation
● Absolute
○ Relative

Time
● Steady
○ Transient

☑ Gravity

Gravitational Acceleration

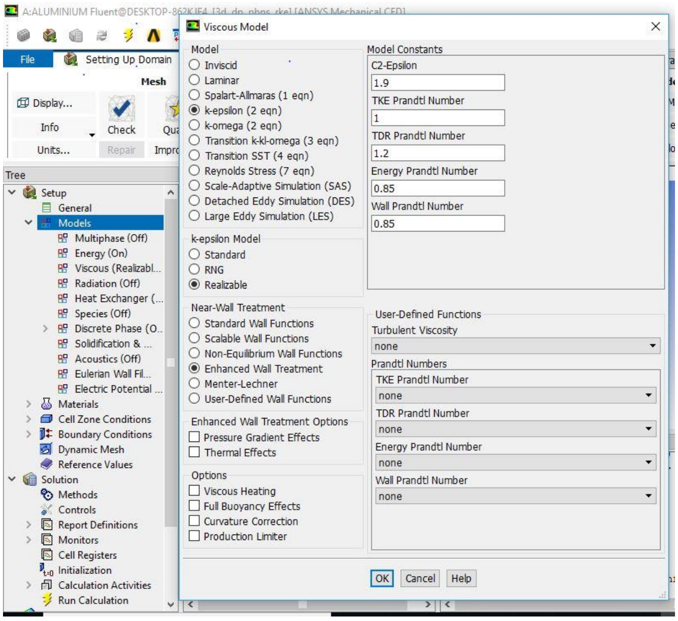
X (m/s2) 0

Y (m/s2) -9.81

Z (m/s2) 0

**Fig.6.9 General Task Page in Setup.**

The solver type and the velocity formulation are specified in the general task page.



Viscous Model

Model
○ Inviscid
○ Laminar
○ Spalart-Allmaras (1 eqn)
● k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Transition k-kl-omega (3 eqn)
○ Transition SST (4 eqn)
○ Reynolds Stress (7 eqn)
○ Scale-Adaptive Simulation (SAS)
○ Detached Eddy Simulation (DES)
○ Large Eddy Simulation (LES)

k-epsilon Model
○ Standard
○ RNG
● Realizable

Near-Wall Treatment
○ Standard Wall Functions
○ Scalable Wall Functions
○ Non-Equilibrium Wall Functions
● Enhanced Wall Treatment
○ Menter-Lechner
○ User-Defined Wall Functions

Enhanced Wall Treatment Options
☐ Pressure Gradient Effects
☐ Thermal Effects

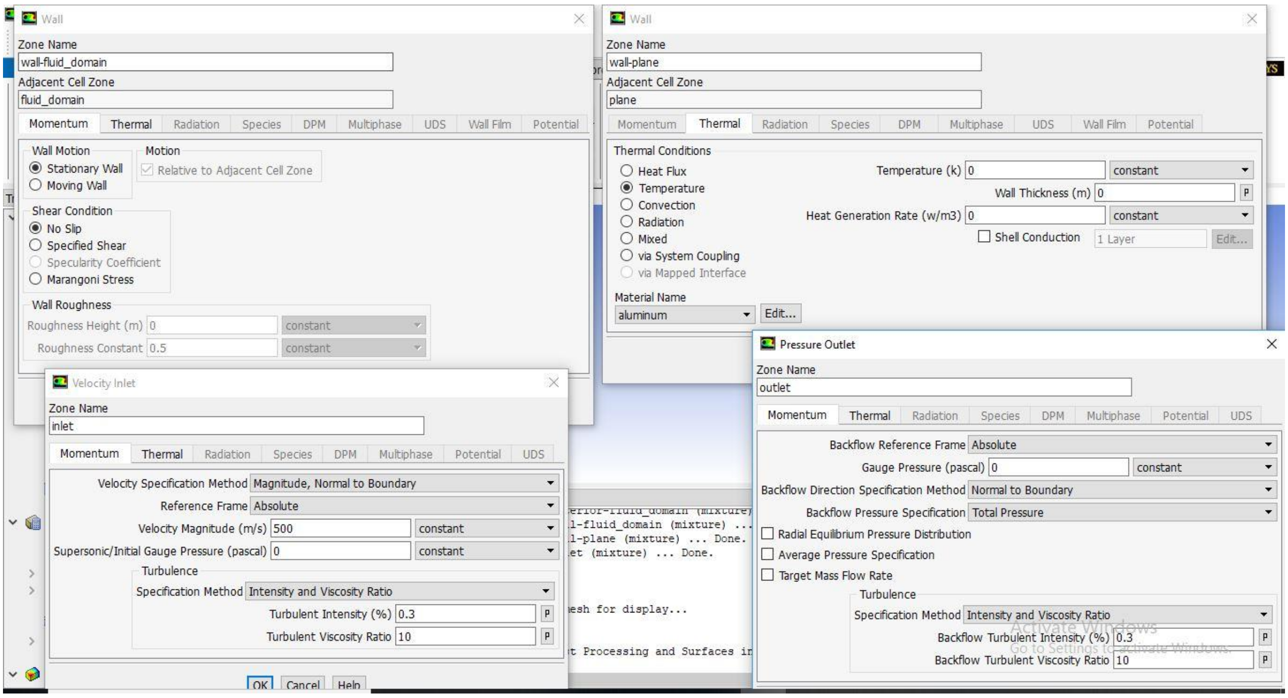
Options
☐ Viscous Heating
☐ Full Buoyancy Effects
☐ Curvature Correction
☐ Production Limiter

Model Constants
C2-Epsilon 1.9
TKE Prandtl Number 1
TDR Prandtl Number 1.2
Energy Prandtl Number 0.85
Wall Prandtl Number 0.85

User-Defined Functions
Turbulent Viscosity none
Prandtl Numbers
TKE Prandtl Number none
TDR Prandtl Number none
Energy Prandtl Number none
Wall Prandtl Number none

**Fig.6.10 Viscous Model**

While specifying the models in the setup the energy equation is kept ON and the viscous model for solving the solution are specified. The near wall treatment considered is the enhanced wall treatment under the modal k-epsilon (realizable). The modal constraints are specified.



Wall

Zone Name wall-fluid_domain
Adjacent Cell Zone fluid_domain

Wall Motion
● Stationary Wall
○ Moving Wall

Motion
☑ Relative to Adjacent Cell Zone

Shear Condition
● No Slip
○ Specified Shear
○ Specularity Coefficient
○ Marangoni Stress

Wall Roughness
Roughness Height (m) 0 constant
Roughness Constant 0.5 constant

Wall

Zone Name wall-plane
Adjacent Cell Zone plane

Thermal Conditions
○ Heat Flux
● Temperature
○ Convection
○ Radiation
○ Mixed
○ via System Coupling
○ via Mapped Interface

Temperature (k) 0 constant
Wall Thickness (m) 0
Heat Generation Rate (w/m3) 0 constant
☐ Shell Conduction 1 Layer

Material Name aluminum

Velocity Inlet

Zone Name inlet

Velocity Specification Method Magnitude, Normal to Boundary
Reference Frame Absolute
Velocity Magnitude (m/s) 500 constant
Supersonic/Initial Gauge Pressure (pascal) 0 constant

Turbulence
Specification Method Intensity and Viscosity Ratio
Turbulent Intensity (%) 0.3
Turbulent Viscosity Ratio 10

Pressure Outlet

Zone Name outlet

Backflow Reference Frame Absolute
Gauge Pressure (pascal) 0 constant
Backflow Direction Specification Method Normal to Boundary
Backflow Pressure Specification Total Pressure
☐ Radial Equilibrium Pressure Distribution
☐ Average Pressure Specification
☐ Target Mass Flow Rate

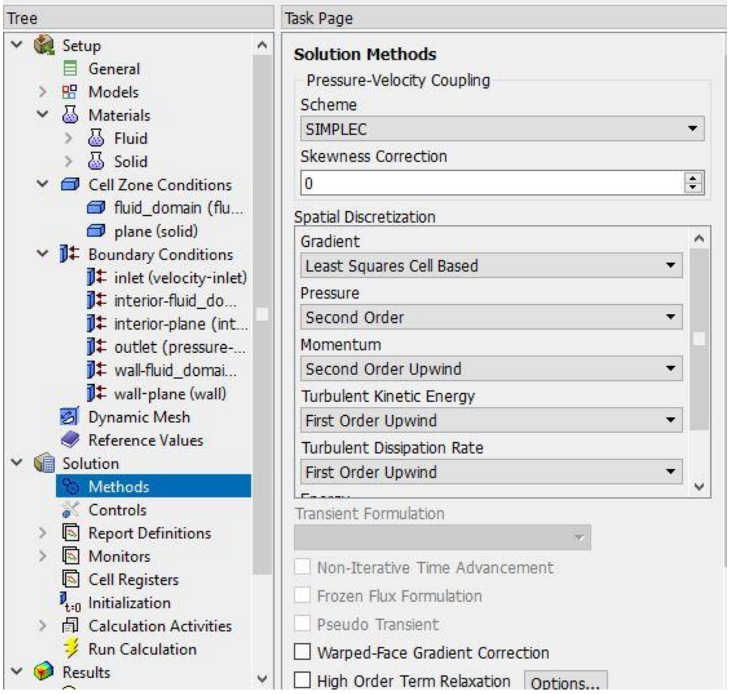
Turbulence
Specification Method Intensity and Viscosity Ratio
Backflow Turbulent Intensity (%) 0.3
Backflow Turbulent Viscosity Ratio 10

```
erior-fluid_domain (mixture)
l-fluid_domain (mixture) ...
l-plane (mixture) ... Done.
et (mixture) ... Done.

esh for display...

t Processing and Surfaces ir
```

Activate Windows
Go to Settings to activate Windows.

**Fig.6.11 Boudary Conditions**

The boundary conditions are specified for the inlet, outlet, wall-fluid domain and the wall plane.



**Solution Methods**

Pressure-Velocity Coupling

Scheme: SIMPLEC

Skewness Correction: 0

Spatial Discretization

Gradient: Least Squares Cell Based

Pressure: Second Order

Momentum: Second Order Upwind

Turbulent Kinetic Energy: First Order Upwind

Turbulent Dissipation Rate: First Order Upwind

Transient Formulation

☐ Non-Iterative Time Advancement

☐ Frozen Flux Formulation

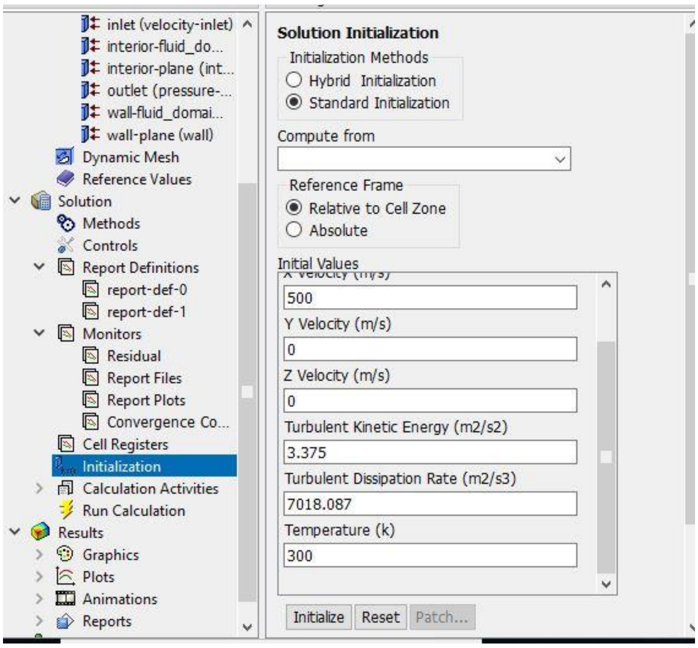
☐ Pseudo Transient

☐ Warped-Face Gradient Correction

☐ High Order Term Relaxation

**Fig.6.12 Solution Methods.**

The solution method used for solving the equation is specified which is SIMPLEC. The C indicates the pressure-velocity coupling. Since in the geneeral conditons the time is specified as a steady state, so we consider the SIMPLEC scheme for solving.



**Solution Initialization**

Initialization Methods

○ Hybrid Initialization

● Standard Initialization

Compute from

Reference Frame

● Relative to Cell Zone

○ Absolute

Initial Values

X Velocity (m/s): 500

Y Velocity (m/s): 0

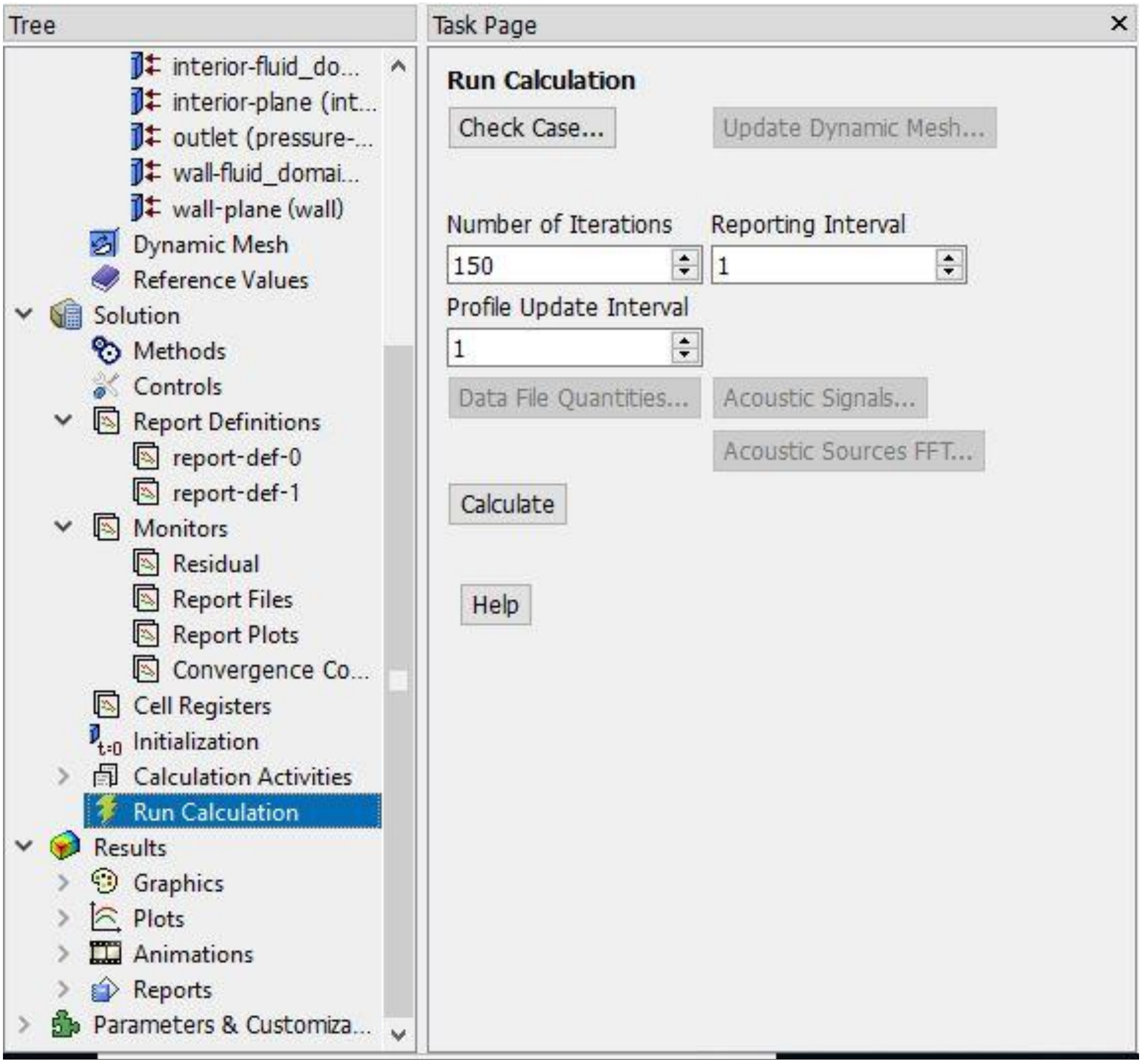
Z Velocity (m/s): 0

Turbulent Kinetic Energy (m2/s2): 3.375

Turbulent Dissipation Rate (m2/s3): 7018.087

Temperature (k): 300

**Fig.6.13 Initialization task page.**



Number of Iterations 150

Reporting Interval 1

Profile Update Interval 1

**Fig.6.14 Run calcualation task page.**

# CHAPTER 7

# RESULTS

# 7. RESULTS

## 7.3 Results

### i) Velocity

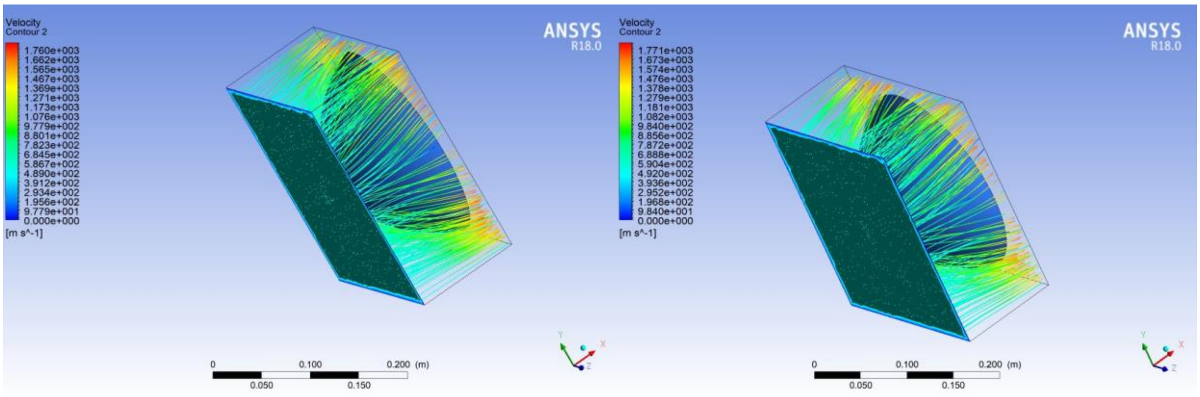


**Fig.7.1 (a)** **Fig.7.1 (b)**

**Fig.7.1 Velocity contour for (a). Aluminium (b). Carbon Fibre**

The value of velocity at the given contour is shown in the figure 7.1, in which the velocity of air flow over the nose of an aircraft ranges from 0 to 1760 m/s in case of Aluminium and 0 to 1771 m/s in case of Carbon Fibre. The velocity of air became zero at centre of the nose, which was converted into stagnation pressure and the velocity of the air gradually increases from centre of the nose to nose to its outer surface.

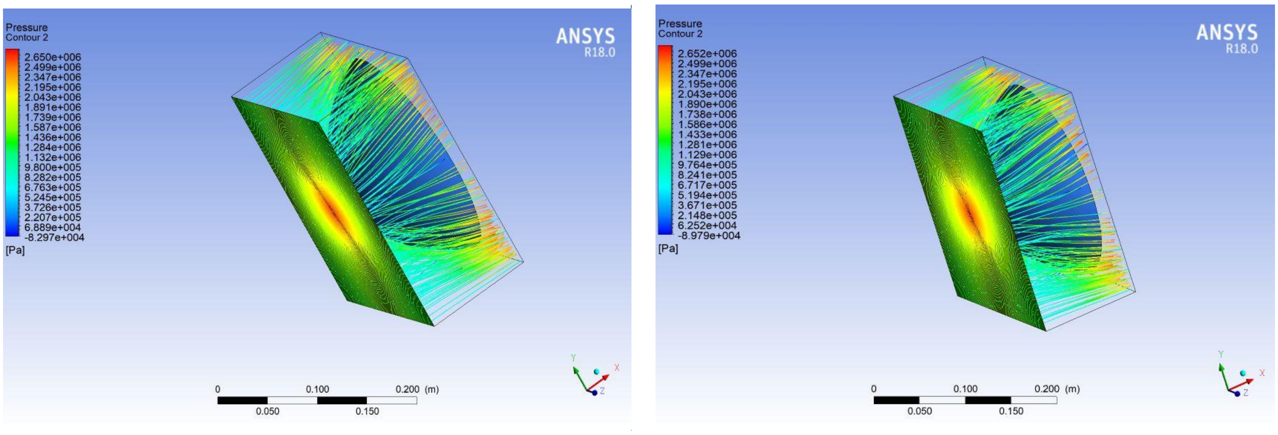


**Fig.7.2 (a)** **Fig.7.2 (b)**

**Fig.7.2 Pressure Contour for (a). Aluminium (b). Carbon Fibre.**

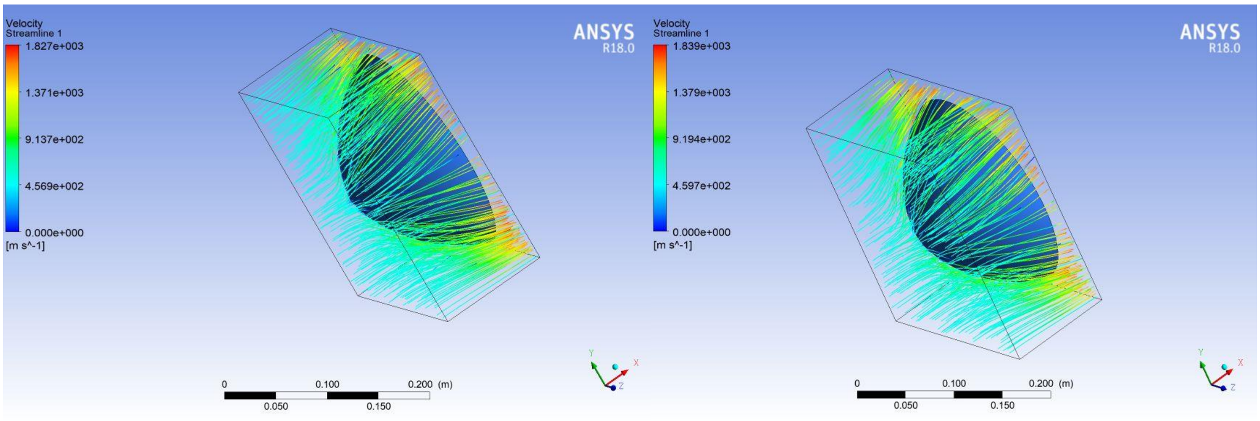


**Fig. 7.3(a)** **Fig. 7.3(b)**

**Fig.7.3 velocity streamline for (a). Aluminium (b). Carbon Fibre**

From the above two figures the velocity streamline for both the materials is determined and the nose designed with the Carbon Fibre is nominal in real time application as it is responsible for producing high velocity when compared to Aluminium.

**ii) Temperature**

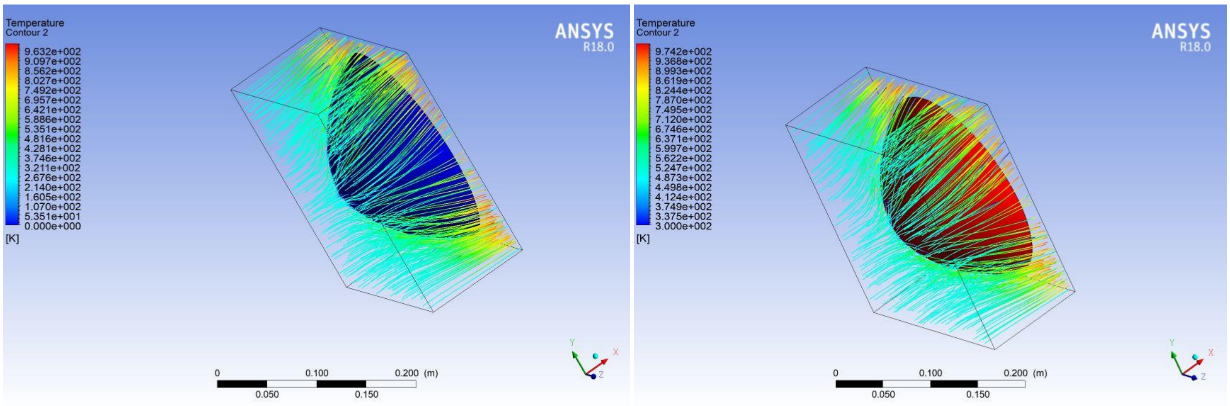


**Fig. 7.4 (a)** **Fig. 7.4 (b)**

**Fig.7.4 Temperature Contour for (a).Aluminium (b).Carbon Fibre**

The value of temperature at the given contour is shown figure 7.3, in which the temperature over the nose of an aircraft ranges from 0°K to 963°K in case of Aluminium and 0°K to 974°K in case of Carbon Fibre. The temperature generated for carbon fibre nose was well below its melting temperature whereas for aluminium the temperature generated was above its melting temperature.

### iii) Turbulence kinetic energy

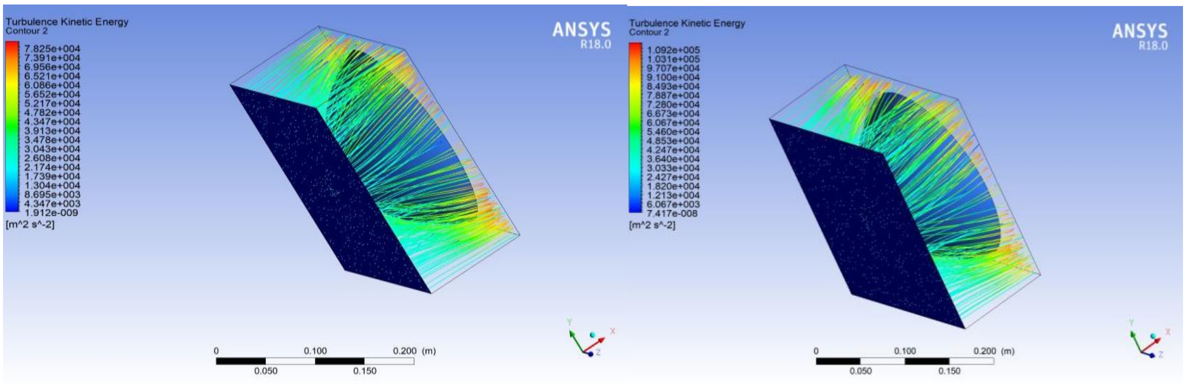
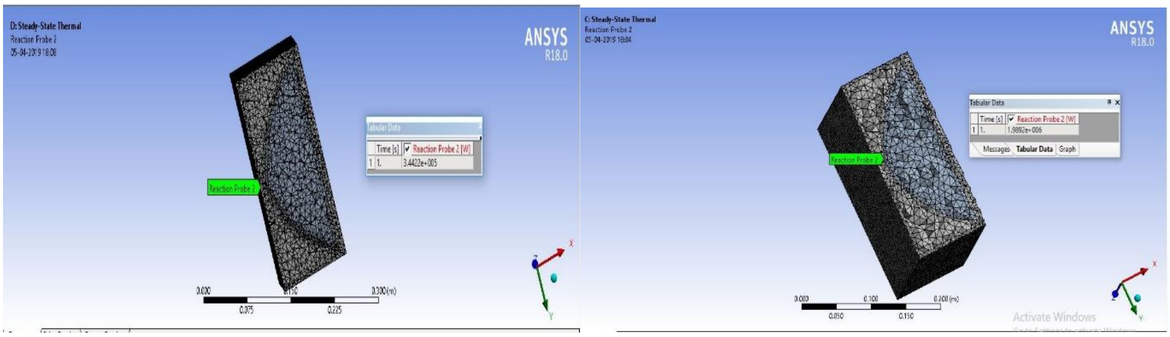


**Fig. 7.5 (a)** **Fig.7.5 (b)**

**Fig.7.5 Turbulence Kinetic Energy Contour.**

**From** figure 7.4 determine the amount of Turbulence Kinetic Energy generated while air is flowing over the nose of aircraft. Since Turbulence Kinetic Energy is a function of velocity, therefore the maximum energy is generated while carbon fibre is used for manufacturing of Nose of Aircraft when compared to aluminium.


D: Steady-State Thermal
Reaction Probe 2
05-04-2019 18:08

Tabular Data

|  | Time [s] | ☑ Reaction Probe 2 [W] |
|---|---|---|
| 1 | 1. | 3.4422e+005 |

C: Steady-State Thermal
Reaction Probe 2
05-04-2019 18:04

Tabular Data

|  | Time [s] | ☑ Reaction Probe 2 [W] |
|---|---|---|
| 1 | 1. | 1.9892e+006 |

**Fig. 7.6 (a)** **Fig. 7.6 (b)**

**Fig.7.6 Reaction Probe at Nose for (a). Aluminium (b). Carbon Fibre**

The Reaction Probe is provided at the tip of the nose to know the exact value of heat generated at a given temperature input. The value of heat generated is 3.4422*10^5 W in case of Aluminium and 1.9892*10^5 W in case of Carbon Fibre.

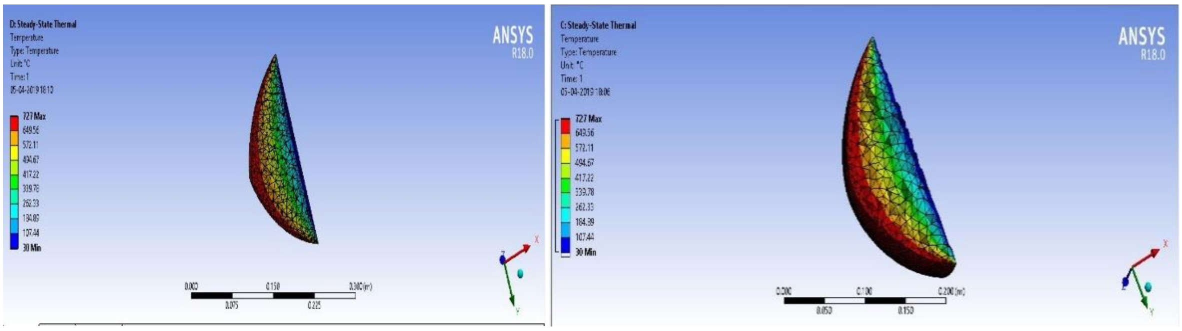


**Fig. 7.7(a)** **Fig. 7.7(b)**

**Fig.7.7 Temperature Distribution over the Nose for (a). Aluminium (b). Carbon Fibre**

From the figure 7.6 the temperature distribution over the nose of Aircraft is shown. Since the thermal conductivity is high for Carbon Fibre therefore the temperature is distributed for the nose rapidly when compared to Aluminium Fibre**.**

## 7.4 Comparison Tables

**Table 5. Results**

| **PARAMETERS** | **ALUMINIUM** | **CARBON FIBRE** |
|---|---|---|
| TEMPERATURE | 9.632*10^2 K, 230.6 K | 9.742*10^2 K, 461.8K |
| TURBULENCE KINETIC ENERGY | 7.825*10^4 M^2 S^-2, 683.4 | 1.092*10^5 M^2 S^-2, 664.4 |
| VELOCITY | 1.76*10^3 M/S | 1.771*10^3 M/S |
| HEAT TRANSFER RATE AT NOSE | 3.4422*10^5 W | 1.9892*10^6W |

# CHAPTER 8

## CONCLUSIONS

# 8. CONCLUSIONS

From the above analysis the following conclusions can be drawn.

i) The velocity of air over nose made of aluminium is comparatively less than that of carbon fibre. So aluminium is better.

ii) The temperature resistance of carbon fibre is more when compared to aluminium. So for higher temperature ranges carbon fibre material is best choice.

iii) Since turbulence kinetic energy is a function of velocity, the maximum energy is generated for carbon fibre material.

iv) The heat transfer rate for carbon fibre material is more, since its thermal conductivity is more.

So, from the analysis, we can conclude that Carbon fibre reinforced composite is a better alternative material to Aluminium. The results shown that Carbon fibre composite has better thermal resistivity than Aluminium.

Because of reduced resistance to UV radiation, and therefore the composite exposed to UV radiation should be protected by top coating, which as an additional application process, makes for higher production cost.

## Future Scope

i) The carbon fibre with different reinforcements and with different compositions can be possibly studied.

ii) The same project can be simulated at different Mach numbers with different angle of attack.

iii) The same project can also be simulated with heat transfer boundary conditions.

# CHAPTER 9

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# 9. REFERENCES

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