Escuela Politécnica Superior de Jaén

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Trabajo Fin de Grado

ESTUDIO DE TREN DE ATERRIZAJE DELANTERO DE AERONAVE

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Jaén, Septiembre de 2018

El alumno: Los tutores:

Khedder Ben Rais

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Dedication

I dedicate this project:

To my dear mother,

To my dear father,

To my dear grandmother,

To my dear brother and my dear sister,

Who never stopped to make prayers to me, supporting me to reach my goals.
For their moral support and valuable advice throughout my studies.

for their moral support and valuable advice throughout my studies.

*To **Dr. Nawel Souissi** and **Dr. Ali Chibeni,***

for giving me the chance to have the experience in Spain,

To my dear friends

For their help and support in difficult times.

For all the members of ESAT, they were like a second family,

To all my family,

To all those I love and those who love me.

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They gave us upon our arrival, their invaluable help and support throughout the traineeship

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They have been inspiring role models during the last months, and i look forward to learn more from them.

I wish to express my most faithful gratitude to ***Dr. Ali Chibani*** *and the principal founder of ESAT,* ***Mr. Abderrazzak Ben Amara*** *and* ***Mrs. Aman Ben Amara****.*

I gratefully acknowledge my teachers and all the members who helped me during that period.

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General Introduction

Landing gear is one of the important parts of an aircraft; often referred to as undercarriage. Landing gear is a structure which is installed on the aircraft for the purpose to support the weight of the aircraft while it is on the ground and also allows the aircraft for smooth maneuver such as takeoff and landing. Landing gear also provides mobility to the aircraft on ground or water. It is capable of reaching the largest local load on the plane. The landing gear's main function is to control the rate of compression/extension and to prevent further damage to itself as well as other parts of an aircraft when a load is applied. Loads can be either static or dynamic in both cases the structure must withstand applied loads and deformation and continue to do its purpose. Among the available configuration the most common type of landing gear arrangement is tri-cycle arrangement. Considering the nose landing gear configuration of a tri cycle the stress distribution and deformation is noted for an executive jet aircraft for applied loads.

In this project the nose landing gear is modeled using CATIA. It is important to check the strength and stiffness of designed landing gear, so the same geometry is imported to ANSYS Workbench and Explicit; Static structural has been carried out for designed geometry. Stress distribution and deformation was noted for three distinct materials such as steel, aluminum alloy and Titanium and finally the results has been compared in the static case.

This project consists of three parts: a bibliographic study in the first part (Chapter 1), a mechanical design in the second part (Chapter 2) and the results in the third part (Chapters 3).

Presentation of the University of Jaen

UNIVERSIDAD DE JAÉN

The Universidad de Jaén (UJA) is located in the south of Spain in the Andalusia region of Spain in the city of Jaén. The city has a lot for students to enjoy from historical sites, parks, shopping, and restaurants. The University offers courses in English so students do not need to know Spanish to study at UJA.

The Universidad de Jaén is a medium-sized, public university with about 14,500 students and over 800 faculty members. Established in 1993 at Campus Las Lagunillas, the Universidad de Jaén has more than 30 departments related to almost any university field of knowledge: business administration, anthropology, geography, history, chemistry, etc.

The Universidad de Jaén welcomes international students as part of a conscious effort to increase its international profile, which is of utmost importance, an institution that is constantly striving to widen both its knowledge and its horizons. No doubt, and thanks to an outstanding undergraduate and postgraduate international incoming and outgoing students population (which amount to approximately 650 students during the academic year), the Universidad de Jaén is becoming one of the leading exchange universities in the south of Spain.

The University is also part of the Erasmus Student Network (ESN). This organization operates as a support group to all International Students. It provides a forum for the students to meet and get to know one another better. It also provides trips to nearby cities including Malaga, Seville, Granada, and Cordoba.

Students gain a great deal about Spanish culture by experiencing day-to-day life in Spain with a conversation partner. UJA's buddy program will pair UNI students with a local UJA student to assist them during their first few days in-country.

Chapter I : Bibliographic studies

1- Introduction

The objective of this chapter is to make a bibliographic search on all the components of an aircraft in a general way, the history of aviation and some landing gear projects that are already done and on different types of landing gear and specifically the landing gear before to acquire the maximum of information allowing a better choice and a better understanding of the study of my project.

2- The history

2.1. The history of aviation

The history of aviation extends for more than two thousand years, from the earliest forms of aviation such as kites and attempts at tower jumping to supersonic and hypersonic flight by powered, heavier-than-air jets.

The history of aviation can be divided into six periods:

- The time of the precursors: until the beginning of the 18th century the human imagine what could be a flying machine and Then from the end of the 18th century, this period sees the beginning of the conquest of the air with the development of ballooning and many attempts at gliding.
- The pioneers of the heavier than the air: it is the period of the first flights of engine able to take off. Almost every flight is a first or a record attempt : a little faster, a little further, a little higher. Aviators are most often and designers or adventurers.
- The first World War (WWI) (1914–1918): only a few years after the first flight, this period sees the appearance of a new weapon on the battlefield. We pass abruptly to a mass production, some models of aircraft being even built to more than a thousand copies; pilots become "professionals", even if the adventure fragrance has not completely disappeared.
- Between two wars (1918–1939): The years between World War I and World War II saw great advancements in aircraft technology. Airplanes evolved from low-powered

biplanes made from wood and fabric to sleek, high-powered monoplanes made of aluminum, based primarily on the founding work of Hugo Junkers during the World War I period and its adoption by American designer William Bushnell Stout and Soviet designer Andrei Tupolev. Aviation is developing and is assisting in the creation of an air force in the number of countries. Military aviation is pushing automakers to break new records. The progress of civil aviation is a fallout from military studies.

- The Second World War (WWII) (1939–1945): aviation is widely used on the battlefield. This period can be considered the apogee of aircraft using a piston engine and a propeller as a means of propulsion. The end of the war sees the birth of the jet engine and radar.
- The second half of the twentieth century: This is the beginning of regular commercial (all weather) air transport able to overcome the weather conditions and practice the flight without visibility. Military aeronautics pushes the development of the reactor, this is called the jet era, and then goes on to conquer supersonic flight. The civil repercussions allow the development of the first airliners four-engined and the air transport opens to all.**[1]**

2.2. The history of some landing gear simulation

- The International Journal Of Engineering And Science (IJES) did a project on the front landing gear titled "Design and Analysis Aircraft Nose and Nose Landing Gear" and in this project the executive jet aircraft are studied thoroughly and a nose landing gear similar to those of executive jets is modeled using CATIA. The same geometry is imported to ANSYS APDL and Explicit; Static structural and Impact test has been carried out for designed geometry. Stress distribution and deformation was noted for two distinct materials such as steel and aluminum alloy and primary results of acoustics has been compared with the available data.

They get like results from ANSYS :

firstly they began testing the nose landing gear with the steel material and they noticed from the figure entitled (Static Deformation for Steel) which they obtained it in the static case : The maximum deformation of 0.78 mm which is indicated in red color region, and a minimum deformation of 0.000087 mm as shown in blue color region for applied loads. And landing gear assembly is suggested to be safe for a given material and load.

The landing gear assembly has undergone a deformation, when the aircrafts lands on hard runway. An impact load is induced on landing gear which is then transferred to axle and then to strut. from the figure (Impact Deformation for Steel) who got it in the case where the aircraft touches the ground : Maximum deformations of 4.1 mm which is indicated in red color region, and a minimum deformation of 0.46 mm as shown in blue color region for applied loads. And landing gear assembly is suggested to be safe for a given material and load.

Secondly they repeated the same works using aluminum and they made a comparison using the following two tables:

Table 1: Static analysis results

MATERIAL	MAX VON-MESIS STRESS (M Pa)	MAX DEFORMATION (MM)
STEEL	15.9	0.78
ALUMINUM ALLOY	12.9	2.1

Table 2: Impact Analysis results

MATERIAL	MAX VON-MESIS STRESS (MPA)	MAX DEFORMATION (MM)
STEEL	82.6	4.1
ALUMINUM ALLOY	65.7	10.96

They concluded from **Table 1** which explains the results of static analysis that the maximum deformation occurs in case of aluminum alloy and a maximum stress distribution is for steel.

And in the During impact test at a given loading condition they conclude from the table 2 a maximum deformation occurs for aluminum alloy and stress distribution is maximum in case of steel. **[2]**

- In the project entitled “Vibration Modal Analysis of Landing gear Based on ANSYS” realized by Yong Ge Tianjin University of Technology and Education on 07

July 2017, his goal is to determine the vibration characteristics of the structure or machine part in the design, the natural frequency and mode. Modal analysis is a linear analysis, which can be modal analysis of pre-stressed method structures and modal analysis of cyclic symmetry structures. It is the starting point of harmonic analysis, transient dynamics analysis and harmonic analysis.

The three-dimensional solid model of landing gear is established in CATIA environment and then imported into ANSYS finite element software.

And then they made a mesh that the element are divided into more regular parts, when the partition to set the global seed size, and in the key parts of the definition of local seeds in order to refine the grid, and finally get the total number of nodes 222971, the total number of 119552 units. And after they calculated the results and Analyses with ANSYS, with using the Lanczos method they extracted the first four order modes when the analyses step is set, and the first four natural frequencies obtained are shown in **table 3 :**

Table 3: The natural frequency for many shapes

modal	natural frequency Hz	shape description
1	21.140	bending vibration
2	52.311	twist and swing
3	57.647	torsional vibration
4	69.095	bending and twisting

Finally they concluded that :

- The whole landing gear system is more complex, the performance of the pillars, brackets and rocker parts such as complex bending, twisting and swing, and the direction, amplitude, etc. are different.
- The dynamic characteristics of the landing gear can be seen through the vibration pattern of the landing gear, which provides a theoretical basis for the further improvement of the landing gear structure.

- The inherent frequency of the landing gear is about 48Hz, so the excitation frequency should be kept away from the natural frequency of the landing gear, so as to prevent the resonance phenomenon from occurring and ensure the safe and smooth operation of the landing gear **[3]**

3- Aircraft components:

3.1 The fuselage:

The fuselage or body of the airplane located centrally to the entire aircraft , includes the cabin and cockpit which holds all the pieces together. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components. **[4]**

3.1.1 Types of Fuselage Construction:

The construction of aircraft fuselages evolved from the early wood truss structural arrangements to monocoque shell structures to the current semimonocoque shell structures.

- **Truss Structure:**

In this construction method, strength and rigidity are obtained by joining tubing (steel or aluminum) to produce a series of triangular shapes , called trusses.

Lengths of tubing, called longerons, are welded in place to form a well-braced framework.

Vertical and horizontal struts are welded to the longerons and give the structure a square or rectangular shape when viewed from the end. Additional struts are needed to resist stress that can come from any direction. Stringers and bulkheads, or formers, are added to shape the fuselage and support the covering **(figure 1)**.

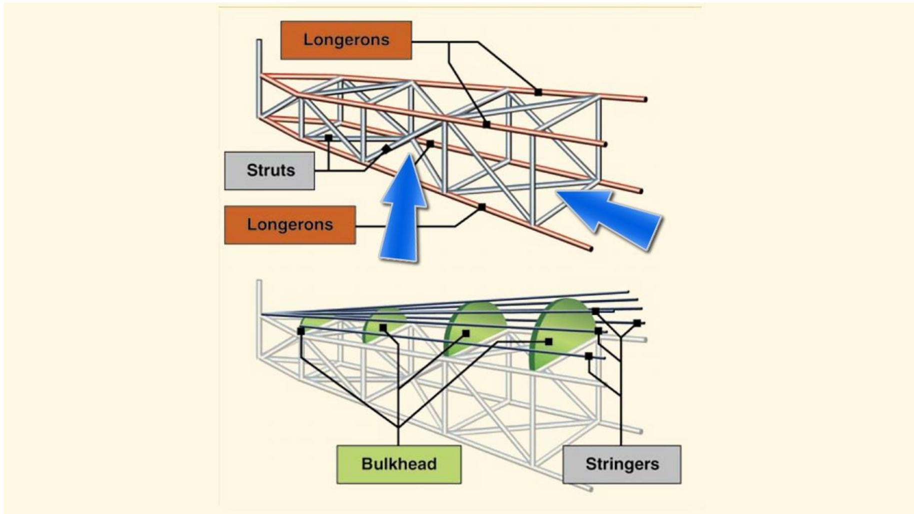


Figure 1: truss structure aircraft

As technology progressed, aircraft designers began to enclose the truss members to streamline the airplane and improve performance. This was originally accomplished with cloth fabric, which eventually gave way to lightweight metals such as aluminum. In some cases, the outside skin can support all or a major portion of the flight loads. Most modern aircraft use a form of this stressed skin structure known as monocoque or semimonocoque construction.

- **Monocoque:**

Monocoque construction uses stressed skin to support almost all loads much like an aluminum beverage can. Although very strong, monocoque construction is not highly tolerant to deformation of the surface. For example, an aluminum beverage can supports considerable forces at the ends of the can, but if the side of the can is deformed slightly while supporting a load, it collapses easily **(Figure 2)**. Because most twisting and bending stresses are carried by the external skin rather than by an open framework, the need for internal bracing was eliminated or reduced, saving weight and maximizing space. One of the notable and innovative methods for using monocoque construction was employed by Jack Northrop. In 1918, he devised a new way to construct a monocoque fuselage used for the Lockheed S-1 Racer. The technique utilized two molded plywood half-shells that were glued together around wooden hoops or stringers. To construct the half shells, rather than gluing many strips of plywood over a form, three large sets of spruce strips were soaked with glue and laid in a semi-circular concrete mold that looked like a bathtub. Then, under a tightly clamped lid, a rubber balloon was inflated in the cavity to press the plywood against the mold. Twenty-four hours later, the smooth half-shell was ready to be joined to another to create the fuselage. The two halves were each less than a quarter inch thick. Although employed in the early aviation period, monocoque construction would not reemerge for several decades due to the complexities involved. Every day examples of monocoque construction can be found in automobile manufacturing where the unibody is considered standard in manufacturing. **[5]**

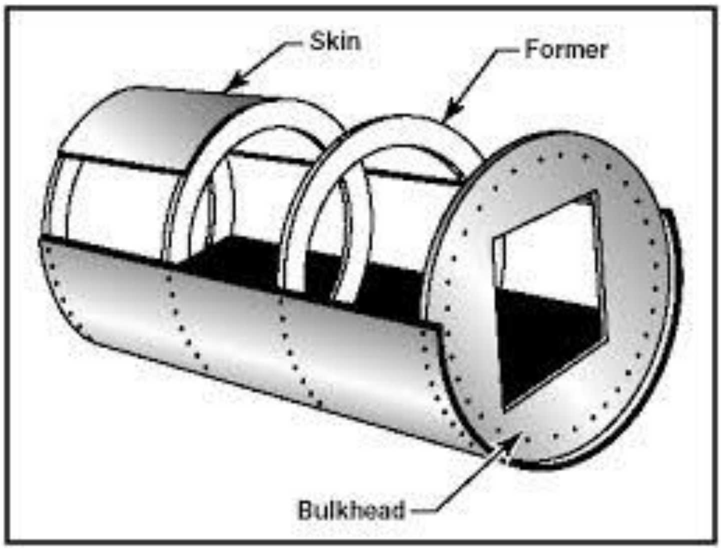


Figure 2: monocoque fuselage design

- **Semimonocoque**

Semimonocoque construction, partial or one-half, uses a substructure to which the airplane's skin is attached. The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage. The main section of the fuselage also includes wing attachment points and a firewall. On single-engine airplanes, the engine is usually attached to the front of the fuselage. There is a fireproof partition between the rear of the engine and the flight deck or cabin to protect the pilot and passengers from accidental engine fires. This partition is called a firewall and is usually made of heat-resistant material such as stainless steel. However, a new emerging process of construction is the integration of composites or aircraft made entirely of composites (**figure 3**). **[5]**

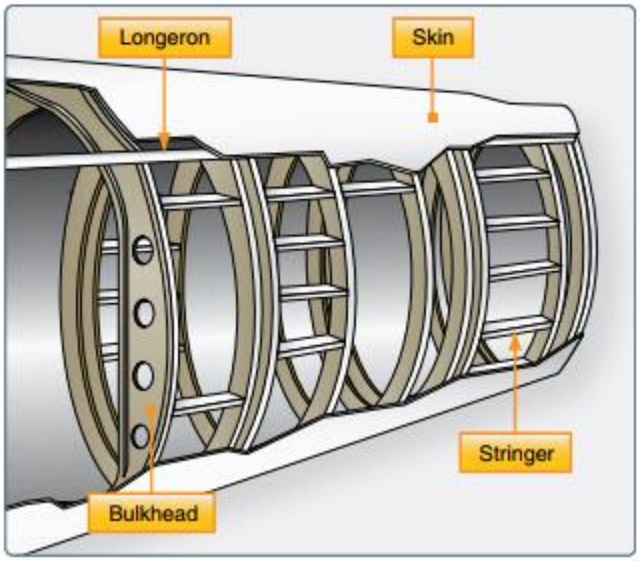


Figure 3 semi monocoque fuselage design

3.2. Wings:

The wings of an aircraft are airfoils designed to create this force of vertical motion called lift force. Any surface that alters the airflow to the advantage of a produced force in a particular direction is termed as an airfoil. Airplane wings, designed as airfoils, achieve this by interacting with the remote airflow to produce the desired lift.**[6]**

3.2.1 wing position

The wings of an aircraft can be attached to the fuselage at the top, mid-fuselage, or at the bottom. They may extend perpendicular to the horizontal plain of the fuselage or can angle up or down slightly. This angle is known as the wing dihedral. The dihedral angle affects the lateral stability of the aircraft. **(Figure 4)** shows some common wing attach points and dihedral angle. **[7]**

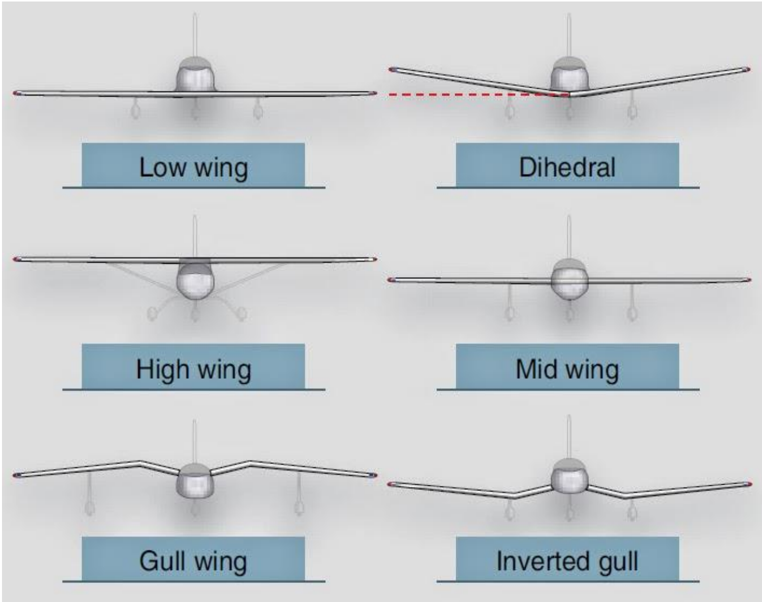


Figure 4: wing attach points and wing dihedrals

3.2.2 Airfoil [8] [9]

An airfoil is any surface producing more lift than drag when passing through the air at a suitable angle , they are employed on aircraft as wings to produce lift or as propeller blades to produce thrust and they are most often associated with production of lift.

Airfoils are also used for stability (fin), control (elevator), and thrust or propulsion (propeller or rotor).

- #### Shape of the Airfoil

The shape of the airfoil is perhaps the main characteristic that allows the Bernoulli Principle to hold true. The shape of airfoils, for the most part, curve up instead of curve down. This is important because this positive camber requires the air to increase its velocity above the airfoil because the curvature increases the distance from the leading edge to the trailing edge. This increase in velocity is associated with a decrease in pressure above the airfoil. The bottom surface of the airfoil is also curved, but does not alter the velocity of the air as much. This means that a net pressure force acts on the airfoil pushing up, which is the lift force. **[10]**

Aerofoil Terminology

Several terms are used to describe aerofoils **(Figure 5)** :

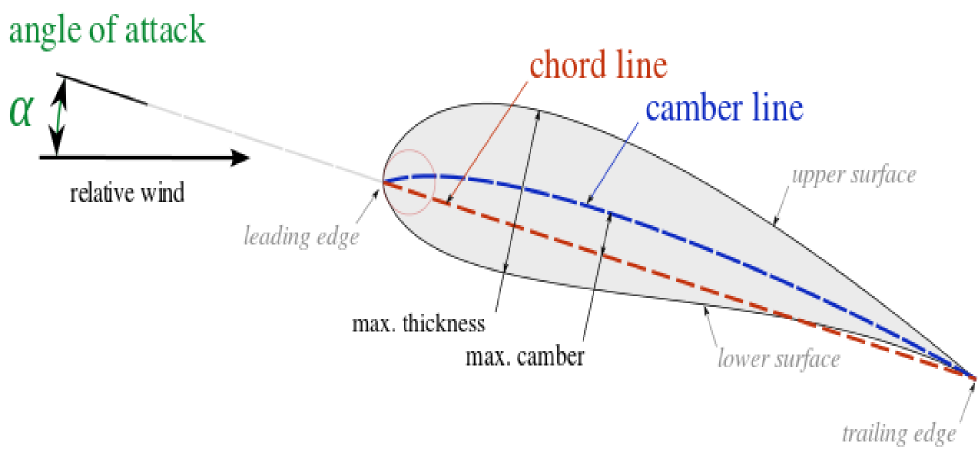


Figure 5: Aerodynamic terms of an airfoil

- **Leading Edge :** Is the front edge of an airfoil.
- **Trailing Edge :** Is the rearmost edge of an airfoil.
- **Chord :** The length of the chord line from leading edge to trailing edge; it is the characteristic longitudinal dimension of the airfoil section**.**
- **Mean Camber Line** : Is a line that connects the leading edge to the trailing edge, but it also shows the curve of the airfoil. Generally, it is midway from the top surface and the bottom surface at every location on the line.
- **The maximum thickness of the wing :** Is the maximum distance between the camber of upper surface and the camber of lower surface.
- **The angle of attack** : Is defined as the angle between the free stream air and the chord line connecting the leading edge and the trailing edge. For most cases, increasing the angle of attack increases the coefficient of lift. There is however a critical angle where the coefficient of lift becomes a maximum and an increase in lift is no longer possible. This creates separation of airflow

behind the airfoil and can be thought of as an aerodynamic stall, causing no lift generation and a large drag force on the airfoil. **(previous figure)**

3.3. Empennage

3.3.1 Definition

The empennage is a structure at the rear of an aircraft that provides stability during flight, in a way similar to the feathers on an arrow , it consists of the front (usually fixed) section of the tail plane is called the tail plane or horizontal stabiliser that is used to provide pitch stability , the rear section is called the elevator which is attached to the back of the horizontal stabilizer , The rudder that is attached to the back of the vertical stabilizer and of Trim tabs Trim tabs may be installed on the ailerons, the rudder, and/or the elevator. **[11] (figure 6)**

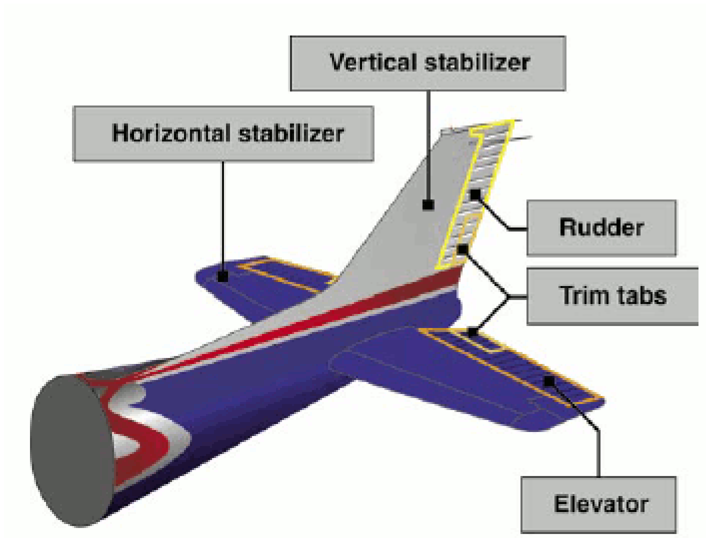


Figure 6: Empennage design

3.3.2 The function of all components of the empennage [12]

- **The horizontal stabilizer** : is a fixed wing section whose job is to provide longitudinal stability for the aircraft, to keep it flying straightis.

- **The vertical stabilizer :** Is also a fixed wing section and is intended to reduce aerodynamic side slip and provide direction stability.

- **The elevator :** creates a moment around the lateral axis (pitch) to move the nose of the airplane up and down during flight.
- **Trim tabs :** Are small, movable portions of the trailing edge of the control surface. These movable trim tabs, which are controlled from the flight deck, reduce control pressures.
- **The rudder:** principally creates a moment around the vertical axis (yaw) , it is used to move the airplane's nose left and right.

3.4. The landing gear

3.4.1 Definition

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear have wheels to facilitate operation to and from hard surfaces, such as airport runways.

3.4.2 Landing gear functions

The purpose of the landing gear is obvious - to allow the aircraft to return to the ground without causing damage to the structure. To accomplish this, the landing gear must not only react substantial forces and moments, but also provide a means to deliver the load safely into the airframe. In addition to this primary function, the landing gear must also permit the secondary functions listed below:

- It must allow the airplane to maneuver easily on the ground, and during taxi, take-off, and landing (steering).
- It must provide a means to slow down after touch-down or when maneuvering on the ground (braking).

- Large aircraft must feature a means for being towed and pushed by airport vehicles.down or when maneuvering on the ground (braking) and pushed by airport vehicles.
- It must feature enough wheels to allow the weight of the airplane to be distributed so that domage will not be inflicted on taxi and runways.

3.4.3 Landing Gear Disposition

The positioning of the landing gear is based primarily on stability considerations during taxiing, liftoff and touchdown, i.e., the aircraft should be in no danger of turning over on its side once it is on the ground. Compliance with this requirement can be determined by examining the takeoff/landing performance characteristics and the relationships between the locations of the landing gear and the aircraft cgcharacteristics and the relationships between the locations of the landing gear and the aircraft cg. **[13]**

3.4.4 Landing gear types:

All current high speed transport aircraft use the tricycle layout, but there are different general wheel arrangements possible. The tailwheel and the bicycle layout are other design solutions that could be considered.

- **Tricycle-Type Landing Gear:**

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear. In this type of Gears the main gears are mounted below the wings. COG is exactly in between the nose wheel nose Gear and main Gear **[14]**. **(Figure 7)**

Figure 7: Tricycle Landing Gear

The main gear on a tricycle-type landing gear arrangement is attached to reinforced wing structure or fuselage structure. The number and location of wheels on the main gear vary. Many main gear have two or more wheels. **(figure 8)**

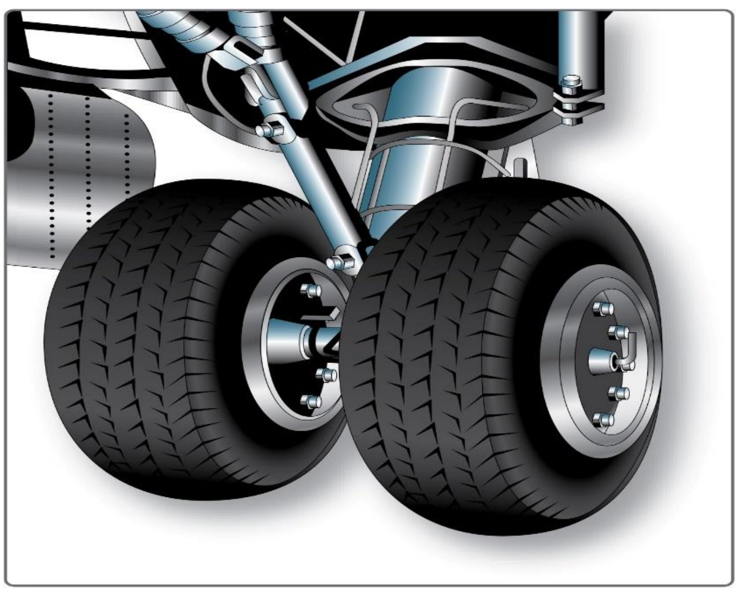


Figure 8: Dual main gear of a tricycle-type landing gear

Multiple wheels spread the weight of the aircraft over a larger area. They also provide a safety margin should one tire fail. Heavy aircraft may use four or more wheel assemblies on each main gear. When more than two wheels are attached to a landing gear strut, the attaching mechanism is known as a bogie. The number of wheels included in the bogie is a function of the gross design weight of the aircraft and the surface type on which the loaded aircraft is required to land **[15]**.

(Figure 9)

Figure 9: Triple bogie main landing gear assembly

The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gear is directed through mechanical linkage to the rudder pedals.

Advantages : [16] [17]

A tricycle gear airplane has many advantages:

- Dyniamically stable on the ground so it is easier to maneuver.
- Good ground control in crosswinds.
- Propeller better protected from ground strike.

- It allows more forceful application of the brakes during landings at high speeds without causing the aircraft to nose over.
- It permits better forward visibility for the pilot during takeoff, landing, and taxiing because of low deck angle.
- It tends to prevent ground looping (swerving) by providing more directional stability during ground operation since the aircraft's center of gravity (CG) is forward of the main wheels. The forward CG keeps the airplane moving forward in a straight line rather than ground looping.

Disadvantages : [17] [18]

- The tail is unprotected from land-scratching, so any over-inclination during take off or landing can cause a tailstrike which could end in serious structural damage.
- If the front wheel hits the ground first, it could end in a wheel-barrowing that could push all the aircraft weight over the front wheels to damage.
- Requires a minimum airspeed before the airplane can be rotated for T-O.
- Higher structural weight due to three highly loaded landing gear legs.
- More costly for the same reason.
- Higher cruise drag for the same reason .
- More complex steering mechanism.
- Subject to nosewheel shimmy that can be very damaging.
- Nosewheel shimmy more likely a design problem than on a tailwheel.

- **Tail Wheel-Type Landing Gear:**

Tail wheel-type landing gear is also known as conventional gear because many early aircraft use this type of arrangement. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly. A few early aircraft designs use a skid rather than a tail wheel. This helps slow the aircraft upon landing and provides directional stability. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design. The increased clearance of the forward fuselage offered by tail wheel-type landing gear is also advantageous when operating in and out of non-paved runways. Today, aircraft are manufactured with conventional gear for this reason and for the weight savings accompanying the relatively light tail wheel assembly **[16]. (Figure 10)**

Figure 10: Tail Wheel-Type Landing Gear

Advantages:

- Due to its position much further from the center of gravity, a tailwheel supports a smaller part of the aircraft's weight allowing it to be made much smaller and lighter than a nosewheel. As a result, the smaller wheel weighs less and causes less parasitic drag.
- Because of the way airframe loads are distributed while operating on rough ground, tailwheel aircraft are better able to sustain this type of use over a long period of time, without cumulative airframe damage occurring.
- If a tailwheel fails on landing, the damage to the aircraft will be minimal. This is not the case in the event of a nosewheel failure, which usually results in a prop strike. **[19]**
- Due to the increased propeller clearance on tailwheel aircraft less stone chip damage will result from operating a conventional geared aircraft on rough or gravel airstrips, making them well suited to bush flying.
- Tailwheel aircraft are more suitable for operation on skis.

- Tailwheel aircraft are easier to fit into and maneuver inside some hangars.

Disadvantages:

- Tailwheel aircraft are more subject to "nose-over" accidents due to injudicious application of brakes by the pilot.
- Tailwheel aircraft generally suffer from poorer forward visibility on the ground, compared to nose wheel aircraft. Often this requires continuous "S" turns on the ground looking out the side window to see where you are going .
- Tailwheel aircraft are more difficult to taxi during high wind conditions, due to the higher angle of attack on the wings which can then develop more lift on one side, making control difficult or impossible. They also suffer from lower crosswind capability and in some wind conditions may be unable to use crosswind runways or single-runway airports. **[19]**

- **Tandem Landing Gear:**

Few aircraft are designed with tandem landing gear. As the name implies, this type of landing gear has the main gear and tail gear aligned on the longitudinal axis of the aircraft.

Sailplanes commonly use tandem gear, although many only have one actual gear forward on the fuselage with a skid under the tail. A few military bombers, such as the B-47 and the B-52, have tandem gear, as does the U2 spy plane. The VTOL Harrier has tandem gear but uses small outrigger gear under the wings for support. Generally, placing the gear only under the fuselage facilitates the use of very flexible wings **[20]**. **(figure 11)**

Figure 11: Tandem Landing Gear

Advantages: [17]

- Eliminates reinforcement for landing gear hard points from the wing.
- Low weight due to a single main landing gear versus multip.
- Less costly for the same reason.
- Less cruise drag for the same reason.
- ground loads transferred directly to fuselage throught a short load path.

Disadvantages: [17]

- Requires outriggers or wingtip skids for ground stability.
- Outriggers may require wider taxiways.
- Poor ground control, especially in crosswind.
- Reduced propeller ground clearance.
- Reduced AOA (Angle of attack) for flare.
- Retraction of main gar forward of CG (center of gravity) is challenging because of space constraints .
- Higher T-O (Take-off) speed to make up for the limited ability to rotate.
- Not intended for extensive taxiing.

3.4.5 Classification

Further classification of aircraft landing gear can be made into two types of landing gear systems are used in aircraft. One is a fixed type and the other one is a retractable type.

- **Fixed Gear:**

Fixed landing gear systems are generally used for small and slow-speed aircraft. In this type the landing gears remain extended throughout the flight phase. This type of system induces friction or parasitic drag, imposing some limitations on the aircraft performance. However, this system involves fewer components, giving an overall weight advantage and also being relatively simple in construction.

In order to overcome the limitation of aircraft speeds due to the onset of parasitic drag, retractable landing gear types are used. **[21]**

The advantage of fixed: [22] [23]

The advantage of fixed gears compared to retractable gears is:

- the low weight
- low complexity
- low cost
- Always deployed
- The advantage of simplicity combined with low maintenance

The disadvantage of fixed: [22] [23]

The main disadvantage is the high aerodynamic drag.

- **Retractable Landing Gear:**

A retractable gear is designed to streamline the airplane by allowing the landing gear to be stowed inside the structure during cruising flight.

aircraft fly at supersonic speed, it is essential to reduce the drag imposed by landing gears and other structural elements protruding outside the aircraft. Hence mechanisms are provided to retract and stow the landing gear either in the fuselage structure or in wing compartments. Retraction and extension actuators are used for this purpose. The contour surfaces of the follow-up doors of the landing gear are flush with the fuselage or wing surfaces for ensuring a smooth flow of air during flight, thereby reducing the drag. The doors are operated by hydraulic jacks. Suitable up-locks and down-locks are used to hold the landing gear firmly in the retracted and extended modes. respectively. These locks are attached to the airframe surfaces and are operated either hydraulically or electrically. The sequence of landing gear operation is monitored and controlled by an electronic control unit (ECU). This type of system is highly complex in nature and greatly increases the part count. The reliability of this type of system must be very high to avoid catastrophic failures. Emergency Exteusion Systems Design must have a provision for emergency extension of the landing gear if the main system fails for any technical reasons. Some aircraft will have a handle inbuilt in the cockpit and connected to the up-locks through mechanical linkages. Upon pulling the handie, it releases the up-locks and allows the landing gear to free-fall to the extended position, which is then firmly held by down-locks. Other means of emergency extension include pneumatic power to unlock the up-locks. **[21]**

Advantages: [22] [23]

The primary benefits of being able to retract the landing gear are:

- Increased climb performance.
- Higher cruise airspeeds due to the resulting decrease in drag.

Disadvantages: [22] [23]

- Increased weight.
- Increased cost.
- Limited to high performance aircraft.

4- Main and nose Landing Gear

4.1. Nomenclature of landing gear

Landing gears are located on the under carriage of aircraft. The front landing is called as nose landing gear while main landing gear is located on rear side of aircraft. Nose landing gear consists of actuators to retract and extension; drag brace to lock the pins metering pin extension; trunnion; rotation lockpins; aft braces; oleo cylinder; oleo piston; brake assembly; tires and wheels.**[24]**

4.2 Main Landing Gear

The landing gear is electrically controlled and hydraulically operated by the green hydraulics system. Two Landing Gear Control Interface Units (LGCIU) control and monitor the landing gear and landing gear doors. The hydraulic actuators move the landing gear to its up/down position. The landing gear indication panel and the Electronic Centralized Aircraft Monitor (ECAM) display the position of the landing gear during extension and retraction.

The main landing gears are mounted under the wing and retract sideways into the fuselage. The retraction of the landing gear legs is done by hydraulic actuators. The gears are kept retracted in the landing gear bay by an up lock mechanism. **[25]**

4.3 Nose landing gear

4.3.1 Definition

The main difference between the main gears and nose gear is the forward retraction motion into the fuselage. The nose landing gear is also electrically controlled and hydraulically operated by the green hydraulic system. **[25]**

4.3.2 Mechanical construction

The nose gear is equipped with two wheels and retracts forward into the front fuselage of the airplane. A two-piece drag strut assembly with a lock stay keeps the gear locked in extension position. A hydraulic actuator in normal operation controls the lock stay. If the hydraulic actuator has a failure the two springs will pull the gear down for down lock. When the nose gear retracts, the hydraulic cylinder of the lock stay retracts which will fold the lock stay. The nose gear actuator retracts the gear into the front fuselage. **[25]**

4.3.3 Nose Wheel Steering Systems [26]

The nose wheel on most aircraft is steerable from the flight deck via a nose wheel steering system. This allows the aircraft to be directed during ground operation. A few simple aircraft have nose wheel assemblies that caster. Such aircraft are steered during taxi by differential braking.

- **Small Aircraft**

Most small aircraft have steering capabilities through the use of a simple system of mechanical linkages connected to the rudder pedals. Push-pull tubes are connected to pedal horns on the lower strut cylinder. As the pedals are depressed, the movement is transferred to the strut piston axle and wheel assembly which rotates to the left or right. **[Figure 12]**

Figure 12: Nose wheel steering on a light aircraft often uses a push-pull rod system connected to the rudder pedals.

- **Large Aircraft**

Due to their mass and the need for positive control, large aircraft utilize a power source for nose wheel steering. Hydraulic power predominates. There are many different designs for large aircraft nose steering systems. Most share similar characteristics and components. Control of the steering is from the flight deck through the use of a small wheel, tiller, or joystick typically mounted on the left side wall. Switching the system on and off is possible on some aircraft. Mechanical, electrical, or hydraulic connections transmit the controller input movement to a steering control unit. The control unit is a hydraulic metering or control valve. It directs hydraulic fluid under pressure to one or two actuators designed with various linkages to rotate the lower strut. An accumulator and relief valve, or similar pressurizing assembly, keeps fluid in the actuators and system under pressure at all times. This permits the steering actuating cylinders to also act as shimmy dampers. A follow-up mechanism consists of various gears, cables, rods, drums, and/or bell-crank, etc. It returns the metering valve to a neutral position once the steering angle has been reached. Many systems incorporate an input subsystem from the rudder pedals for small degrees of turns made while directing the aircraft at high speed during takeoff and landing. Safety valves are typical in all systems to relieve pressure during hydraulic failure so the nose wheel can swivel. The following explanation accompanies **Figures 13, 14, and 15**, which illustrate a large aircraft nose wheel steering system and components. These figures and explanation are for instructional purposes only. The nose wheel steering wheel connects through a shaft to a steering drum located inside the flight deck control pedestal. The rotation of this drum transmits the steering signal by means of cables and pulleys to the control drum of the differential assembly. Movement of the differential assembly is transmitted by the differential link to the metering valve assembly where it moves the selector valve to the selected position. This provides the hydraulic power for turning the nose gear. As shown in **Figure 14**, pressure from the aircraft hydraulic system is directed through the open safety shutoff valve into a line leading to the metering valve. The metering valve then routes the pressurized fluid out of port A, through the right turn alternating line, and into steering cylinder A. This is a one-port cylinder and pressure forces the piston to begin extension. Since the rod of this piston connects to the nose steering spindle on the nose gear shock strut which pivots at point X, the extension of the piston turns the steering spindle gradually toward the right. As the nose wheel turns, fluid is forced out of steering cylinder B through the left turn alternating line and into port B of the metering valve. The metering valve directs this return fluid into a compensator that routes the fluid into the aircraft hydraulic system return manifold.

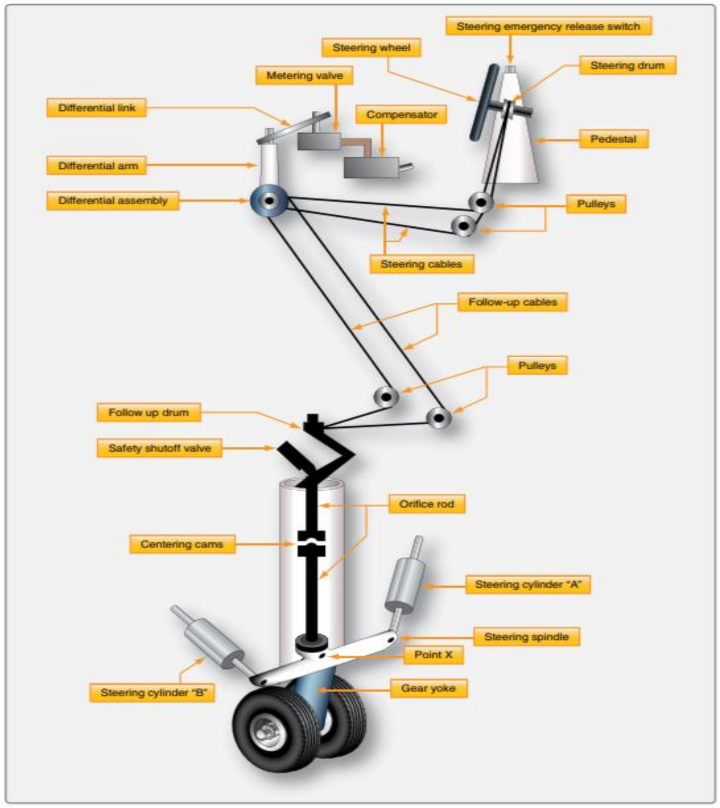


Figure 13: Example of a large aircraft hydraulic nose wheel steering system with hydraulic and mechanical units

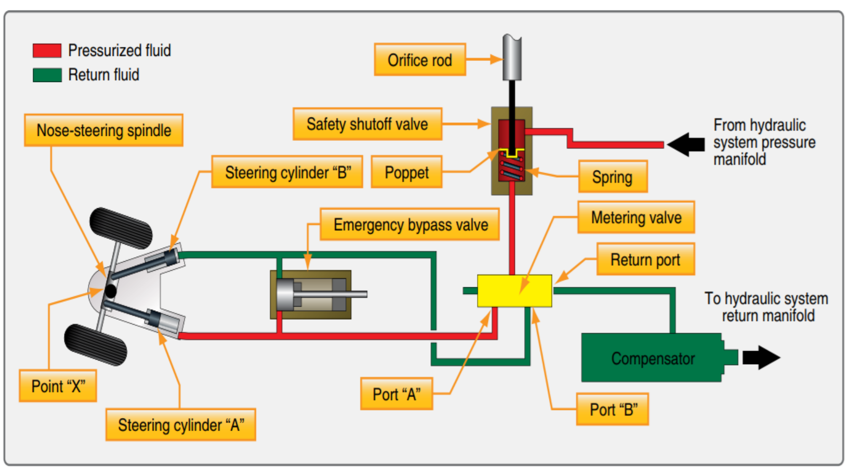


Figure 14: Hydraulic system flow diagram of large aircraft nose wheel steering system.

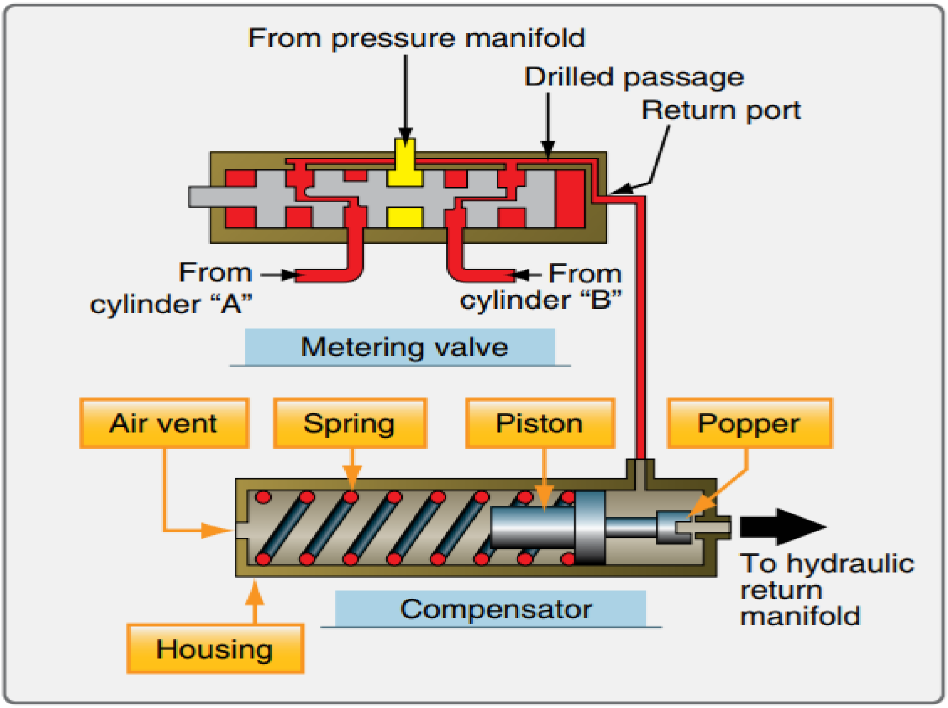


Figure 15: Hydraulic system flow diagram of large aircraft nose

As described, hydraulic pressure starts the nose gear turning. However, the gear should not be turned too far. The nose gear steering system contains devices to stop the gear at the selected angle of turn and hold it there. This is accomplished with follow-up linkage. As stated, the nose gear is turned by the steering spindle as the piston of cylinder A extends. The rear of the spindle contains gear teeth that mesh with a gear on the bottom of the orifice rod. **[Figure 13]** As the nose gear and spindle turn, the orifice rod also turns but in the opposite direction. This rotation is transmitted by the two sections of the orifice rod to the scissor follow-up links located at the top of the nose gear strut. As the follow-up links return, they rotate the connected follow-up drum, which transmits the movement by cables and pulleys to the differential assembly. Operation of the differential assembly causes the differential arm and links to move the metering valve back toward the neutral position. The metering valve and the compensator unit of the nose wheel steering system are illustrated in **Figure 15**. The compensator unit system keeps fluid in the steering cylinders pressurized at all times. This hydraulic unit consists of a three-port housing that encloses a spring-loaded piston and poppet. The left port is an air vent that prevents trapped air at the rear of the piston from interfering with the movement of the piston. The second port located at the top of the compensator connects through a line to the metering valve return port. The third port is located at the right side of the compensator. This port connects to the hydraulic system return manifold. It routes the steering system return fluid into the manifold when the poppet valve is open. The compensator poppet opens when pressure acting on the piston becomes high enough to compress the spring. In this system, 100 psi is required. Therefore, fluid in the metering valve return line is contained under that pressure. The 100 psi pressure also exists throughout the metering valve and back through the cylinder return lines. This pressurizes the steering cylinders at all times and permits them to function as shimmy dampers.

4.3.4 Shimmy

- **Definition**

Shimmy is an oscillation in aircraft landing gear that can occur both on landing and take-off, typically in a band of velocities**.** It causes excessive wear on components and can cause accidents. The nose wheel is roughly like a caster on a shopping trolley: the horizontal axle of the wheel is mounted in an assembly that is free to rotate about a vertical axis. Shimmy is (or at least includes) oscillation of the wheel assembly about this vertical axis.

- **CAUSES OF SHIMMY:**
  - Uneven tyre pressures.
  - Unevenly worn tyres.
  - Unbalanced wheels.
  - Worn shimmy damper or wheel bearings.
  - Worn torque link will make things worse.
- **ANTI-SHIMMY DESIGNS :**
  - Twin wheels.
  - Marstrand tyres.
  - Shimmy damper (Light aircraft - friction damper Large aircraft - Hydraulic dampers or within steering apparatus).
  - Limiting the castoring ability of the nosewheel.

5- Center of Gravity (CG)

In an aircraft, the centre of gravity (CG) is the point at which the aircraft would balance were it possible to suspend it at that point. As the location of the centre of gravity affects the stability of the aircraft, it must fall within specified limits that are established by the aircraft manufacturer. Both lateral and longitudinal balance are important, but the primary concern is longitudinal balance; that is, the location of the CG along the longitudinal axis. **[27]**

6- Mean Aerodynamic Chord (MAC)

IS the width of the wing, or straight-line distance from the leading edge to the trailing edge, on an airplane is known as the chord. If the leading edge and the trailing edge of a wing are parallel, the chord is equal at all points along the entire length of the wing. The average length of the chord, or MAC, of a tapered wing is more complicated to define.

The MAC, as seen in **Figure**, is the chord of an imaginary airfoil that has the same aerodynamic characteristics as the actual airfoil. You can also think of it as the chord drawn through the geographic center of the plan area of the wing.

the MAC is established by the manufacturer, defining its leading edge (LEMAC) and trailing edge (TEMAC) in terms of inches from the datum. **[Figure]** The CG location and various limits are then expressed in percentage of the chord or percent MAC. In order to relate the percent MAC to the datum, all weight and balance information includes two items: the MAC length in inches and the location of the LEMAC in inches from the datum. **[28]**

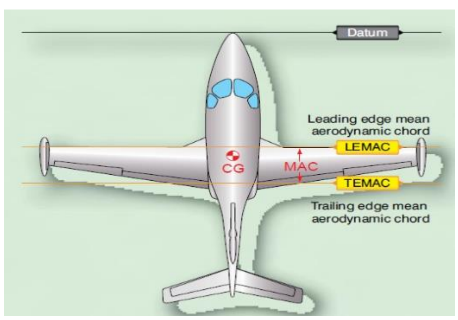


Figure 16: The MAC is the chord drawn through the geographic center of the plan area of the wing.

The relative positions of the CG and the aerodynamic center of lift of the wing have critical effects on the flight characteristics of the aircraft. Consequently, relating the CG location to the chord of the wing is convenient from a design and operations standpoint. Normally, an aircraft has acceptable flight characteristics if the CG is located somewhere near the 25 percent average chord point. This means the CG is located one-fourth of the distance back from the LEMAC to the TEMAC. Such a location places the CG forward of the aerodynamic center for most airfoils.

7- Newton’s Third Law of Motion : Law of Action Reaction

This is Newton's third law of motion in Latin. It is commonly referred to as the law of action-reaction. This law states, "To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal and directed to contrary parts. Newton used the words action and reaction to mean force. The term reaction force refers to the force that one object exerts on another. This law explains the origin of the external forces required to change motion. More simply stated, Newton's third law says that if an object (A) exerts a force on another object (B). the other object (B) exerts the same force on the first object (A) but in the opposite direction. The effects of these forces are not canceled by cach other because they act on different objects. Another important point is that it is the forces that are equal but opposite, not the effects of the forces.

If an object exerts a force on another object, the other object exerts the same force on the first object but in the opposite direction.

8- Tricycle Landing gear reaction Loads

this figure shows loads acting on a Tricycle Landing Gear Reaction Loads gear configuration as it moves at a constant speed during the ground run.

We want to determine the reactin loads of the nose and main landing gear , denoted by RN and RM , respectively.

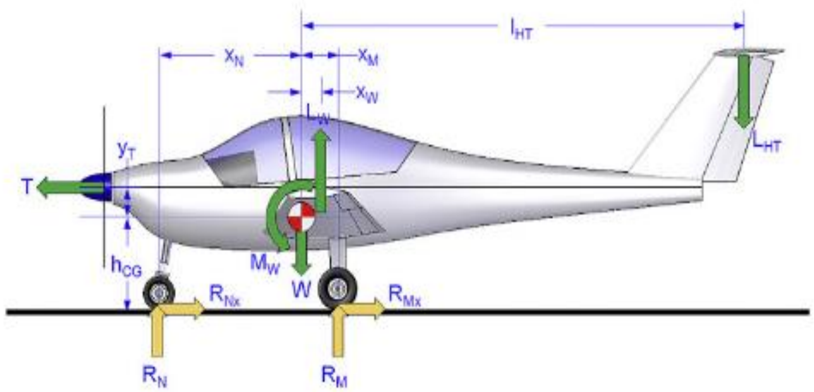


Figure 17: Landing gear configuration

RNX: The horizontal ground friction applied to the Nose Landing Gear

RMX: The horizontal ground friction applied to the Main Landing Gear

RN: The reaction load of the nose landing gear

RM: The reaction load of the main landing gear

W: The weight of aircraft

MW: Moment of wing about the center gravity

YT: The distance between the center gravity and thrust

hcg: Height of center of gravity above ground

T: The thrust :

Lw: Lift force of wing

LHT: Lift of horizontal tail

lht : The distance from the gravity center to the center of the center of horizontal tail

XM : The distance from the center of garvity to the main landing gear

XN : The distance from the center of garvity to the nose landing gear

XW : The distance from the gravity center to the center of the wing

- **Begin by defining the horizontal ground friction force:**

$$RNX+RMX= \mu.(RN+RM)$$

- **Sum forces in the vertical (z) direction, such that positive forces act upward:**

$$\sum FZ=0 \qquad RN+RM+LW-W-LHT=0$$

- **This yields the main landing gear reaction force RM:**

$$RM=W+LHT-LW-RN$$

- **Sum moments about the center of gravity (CG), such that nose pitch-up moments are positive (note that the ground friction RMX, and RNX are written explicitly as μ.(RN+RM).hcg:**

$$\sum MCG=0 \qquad -\cancel{T.YT}+RN.XN-RM.XM-LW.XW+LHT.lht- \mu.(RN+RM).hcg+MW=0$$

- **Note that typically the value of the wing pitching moment, Mw, is negative. Expand and rearrange the RN and RM terms:**

$$-T.YT+RN.XN- \mu.RN.hcg-RM.XM- \mu.RM.hcg-LW.XW+LHT.lht+MW=0$$

- **Simplify in terms of RN and RM:**

$$-T.YT+RN.(XN- \mu.hcg)-RM.(XM- \mu.hcg)-LW.XW+LHT.lht+MW=0$$

- **Inserting Equation (III) for RM yields:**

$$-T.YT+RN.(XN- \mu.hcg)-(W+LHT-LW-RN).(XM- \mu.hcg)-LW.XW+LHT.lht+MW=0$$

- **Rearrange to combine the term RN yields:**

$$-T.YT+RN.(XN- \mu.hcg)+ RN.(XM- \mu.hcg)-(W+LHT-LW).(XM- \mu.hcg)-LW.XW+LHT.lht+MW=0$$

- **Simplify further tonyield:**

$$-T.YT+RN.(XN +XM-2. \mu.hcg)-(W+LHT-LW).(XM- \mu.hcg)-LW.XW+LHT.lht+MW=0$$

- **Finally , solving for the nose gear reaction force, RN, yields:**

$$RN = \frac{T.YT + (W + LHT - LW).(XM - \mu.hcg) + LW.XW - LHT.lHT - MW}{XN + XM - 2.\mu.hcg}$$

9- Properties of materials

9.1 Physical properties

- **Melting temperature** .
- **Density:** the amount of material per unit volume normally expressed in kg /m^3 but often in kg / dm^3.
- **Coefficient of linear expansion:** It is the elongation experienced by the metal during a scaling.
- **Thermal conductivity:** It is the ability of a body to transmit heat more or less well. Good drivers are: copper, silver, aluminum ...
- **Magnetism:** It is the classification of materials according to the value of their induction and the direction of the field: ferromagnetic, diamagnetic, paramagnetic or nonmagnetic materials.

9.2. Mechanical Properties

Mechanical properties including elasticity, yield strength, ultimate tensile strength and ductility are usually part of material specifications and are obtained by tensile testing. These properties are described in more detail below as well as being shown on the diagram.

- **Elasticity/Stiffness :** This is a measure of elastic deformation of a body under stress which is recovered when the stress is released. The ratio of stress to strain in the elastic region is known as stiffness or modulus of elasticity (Young's Modulus). When the stress goes beyond the elastic limit the material will no longer return completely to its original dimension.
- **Toughness:** It is the ability of a Corp to resist deformation or breakage under a continuous effort.
- **Hardness :** The resistance to abrasion, deformation, scratching or to indentation by another hard body. This property is important for wear resistant applications.

- **Resilience:** Ability to withstand sudden stresses or shocks without breaks.
- **Endurance:** Ability of a body to undergo variable efforts in size and direction with repetition of these efforts.
- **Plasticity:** It is the ability of a body to deformation without tension or rupture (examples: boiler parts).
- **Ductility:** It is the ability of a body to be stretched into thin threads.
- **Fluidity:** It is the ability of a body to be melted and to easily fill the mold in which it is poured (castings).

9.3. The chemical properties:

- **Composition:** pure metal or alloy, nature and content of constituents, heterogeneity.
- **Corrosion resistance:** behavior of the metal against acids or corrosive agents (moisture, steam, dissolved salts ...)

10- Conclusion

At the beginning of this chapter 1 gave an overview of the history of the aviation and some landing gear projects that are already done, and the role of the landing gear and how it has developed throughout the years.

And finally this chapter discussed Properties of materials, all the forces applied on the nose and main landing gear and how to calculate them in a general way.

Chapter II: General principle of finite element method

1- Introduction:

The current evolution of the technology leads the engineer to carry out more and more complex projects costly and subject to security constraints more and more severe. We are thinking of space projects, aeronautics in which safety is vital.

To dominate these projects, the engineer needs models that allow him to simulate the behavior of complex physical systems through partial differential equations.

The finite element method and one of the most used methods today to effectively solve these equations. This is a very general method that applies to the majority of problems encountered in practice: stationary or non-stationary, linear or non-linear problems.

2- Historical

- Analysis of structures born around 1850.
- RDM (Material Resistance) "manual" calculations.
  MAXWELL, CASTIGLIANO, MOHR

- Concept of finite elements born around 1940.
  NEWMARK, HRENIKOFF, MC HENRY, CURRENT

- Real development since 1960.
  Numerical calculation on computer.

3- Definition of a finished element

Finite Element Method (FEM) is one of the applied mathematics tools. The aim of setting up, using the principles inherited from the variational formulation, makes it possible to discretely solve a partial differential equation (PDE) for which a "sufficiently" reliable approximate solution is sought. In general, this EDP relates to a function u, defined on a domain. It includes conditions at the edges to ensure existence and uniqueness of a solution.

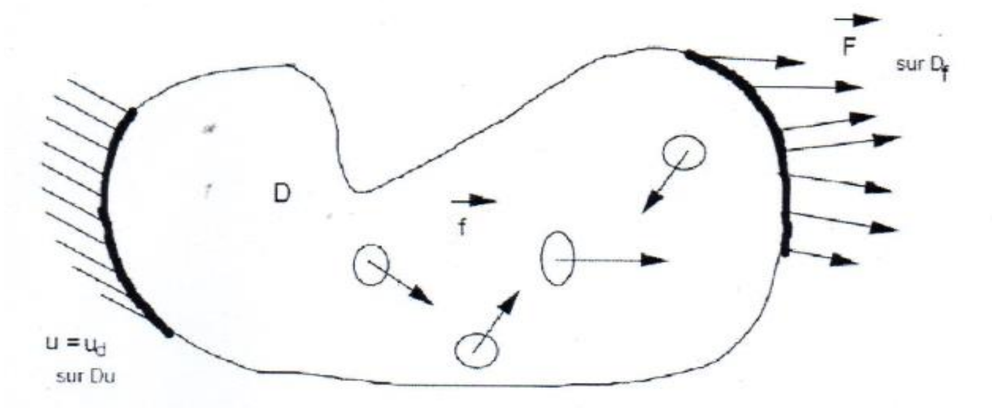


Figure 18: Continuous medium and discretized medium

In structural computation, a finite element is characterized by two matrices:

- The stiffness matrix [K]
- The mass matrix [M]

4- Formulation of a finite element:

4.1. Definitions and notations:

4.1.1 Displacement: {U}

It is a vector of which each component is also called degree of freedom (dof).

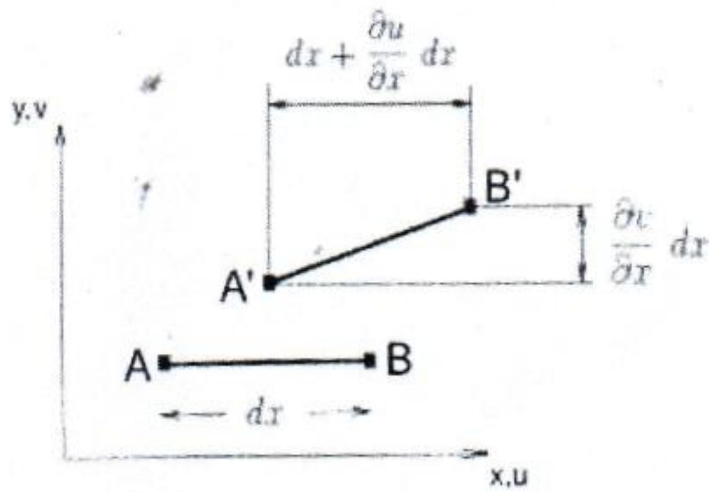
- dof of translation: Ux, Uy, Uz
- dof of rotation: θx, θy, θz

4.1.2 Deformation: {ε}

This is the ratio of elongation to initial length.

$$(A'B')^2 = (dx + \frac{\partial u}{\partial x}dx)^2 + (\frac{\partial u}{\partial x}dx)^2$$

In small deformations, we have :



$\epsilon_x = \frac{A'B' - AB}{AB}$

As AB= dx,

We have A'B'= (1+ ϵ_x) dx

=> $2\,\epsilon_x + \epsilon_x^{\,2} = 2\frac{\partial u}{\partial x} + \frac{\partial u^2}{\partial x} + \frac{\partial v^2}{\partial x}$

$\epsilon_x = \frac{\partial u}{\partial x}$

4.1.3. Constraint:

Represent the internal forces that apply in the structure.

- **σ_{11}, σ_{22}, σ_{33}:** Normal constraints
- **σ_{12}, σ_{13}, σ_{23}:** Shear stress

A stress is homogeneous at a pressure (N/m²).

There is a coordinate system in which [σ] is a diagonal matrix:

$$[\sigma] = \begin{pmatrix} \boldsymbol{\sigma}_x & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{\sigma y} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{\sigma z} \end{pmatrix}$$

$\boldsymbol{\sigma}_x, \boldsymbol{\sigma y}, \boldsymbol{\sigma z}$: are called the main constraints.

4.1.4. Stress-strain relationships

$$\begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{31} \end{pmatrix} = \frac{E\,(1-\nu)}{(1+\nu)(1-2\nu)} \begin{pmatrix} 1 & \frac{\nu}{1-\nu} & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & 1 & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & & 1 & 0 & 0 & 0 \\ & & & \frac{(1-2\nu)}{2(1-\nu)} & 0 & 0 \\ & & & & \frac{(1-2\nu)}{2(1-\nu)} & 0 \\ & & & & & \frac{(1-2\nu)}{2(1-\nu)} \end{pmatrix} \begin{pmatrix} \epsilon_{11} \\ \epsilon_{22} \\ \epsilon_{33} \\ \gamma_{12} \\ \gamma_{23} \\ \gamma_{31} \end{pmatrix}$$

E : young module (N/m^2)

υ : Poisson coefficient (without unit)

we sometimes use the shear modulus : $\boldsymbol{G} = \frac{\boldsymbol{E}}{\boldsymbol{2(1+\upsilon)}}$ For an isotropic material, there are only 2 independent parameters. There are 6 for a transverse isotropic material, 9 for an orthotropic material and 21 for an anisotropic material

In matri*x* notation, we write: $\{\boldsymbol{\sigma}\} = [\boldsymbol{D}]\,\{\epsilon\}$

[D] called the elasticity matrix of the material.

4.1.5 Deformation energy: W

$$\boldsymbol{W} = \frac{\mathbf{1}}{\mathbf{2}} \int_{v} \boldsymbol{\sigma}. \in \cdot\, \boldsymbol{dv}$$

4.1.6 Work of a force:

It is the product of force by moving its point of application:

$$\boldsymbol{T}_{\mathrm{F}} = \frac{\mathbf{1}}{\mathbf{2}}\mathrm{F}.\boldsymbol{U}_{\mathrm{F}}$$

4.1.7 Moment

It is a force applied a degree of freedom of rotation type.

4.2 Fundamental Equations

Local equilibrium equations :

$$\frac{\partial\sigma_{\mathrm{x}}}{\partial x} + \frac{\partial\sigma_{\mathrm{xy}}}{\partial y} + \frac{\partial\sigma_{\mathrm{xz}}}{\partial z} + \boldsymbol{F}_{\mathrm{x}} = \mathbf{0}$$

$$\frac{\partial\sigma_{\mathrm{y}}}{\partial y} + \frac{\partial\sigma_{\mathrm{xy}}}{\partial x} + \frac{\partial\sigma_{\mathrm{yz}}}{\partial z} + \boldsymbol{F}_{\mathrm{y}} = \mathbf{0}$$

$$\frac{\partial\sigma_{\mathrm{z}}}{\partial z} + \frac{\partial\sigma_{\mathrm{zx}}}{\partial x} + \frac{\partial\sigma_{\mathrm{zy}}}{\partial y} + \boldsymbol{F}_{\mathrm{z}} = \mathbf{0}$$

- **Deformation-displacement relationships :**

$$\in_{\mathrm{x}} = \frac{\partial U}{\partial x} \qquad \in_{\mathrm{y}} = \frac{\partial U}{\partial y} \qquad \in_{\mathrm{z}} = \frac{\partial U}{\partial z}$$

$$\boldsymbol{\gamma}_{\mathrm{xz}} = \frac{\partial w}{\partial x} + \frac{\partial \mu}{\partial z}$$

$$\boldsymbol{\gamma}_{\mathrm{xy}} = \frac{\partial \mu}{\partial y} + \frac{\partial v}{\partial x}$$

$$\boldsymbol{\gamma}_{\mathrm{yz}} = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}$$

Symbolically, we write : $\{\in\} = [\boldsymbol{S}]\{\boldsymbol{U}\}$

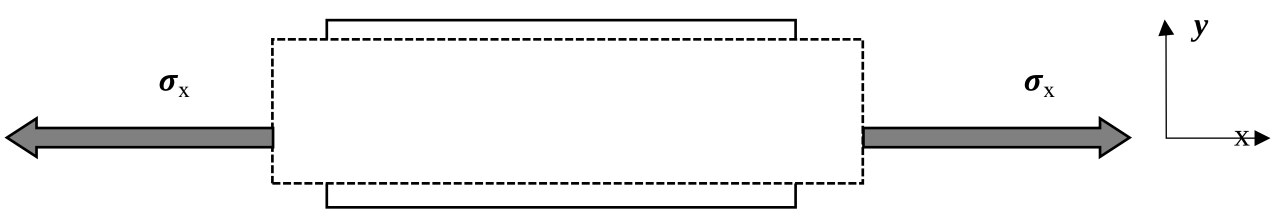


Figure 19: Meaning of the Poisson's ratio

If a stress is applied to the bar $\boldsymbol{\sigma}_x$, a narrowing is observed in the y direction corresponding to a deformation $\frac{-\boldsymbol{\nu}\boldsymbol{\sigma}_x}{\boldsymbol{E}}$.

Some common values:

Steel : E = 2,1E11 N/m^2 = 210 000 MPa ν =0,3

Aluminum : E = 7E10 N/m^2 = 70 000 MPa ν =0,3

Note :

We always have $-1 \leq \nu \leq 0{,}5$ when $\nu \longrightarrow 0{,}5$, the material is said to be incompressible.

IV. Calculation process (static case)

- Mesh
- Construction of the stiffness matrix of each element $[K^e]$
- Assembly of the global matrix [K]
- Construction of the loader {F}
- Elimination of certain degrees of freedom (if necessary)
- Resolution : $\{U\} = [K^{-1}]\,\{F\}$
- Calculation of quantities derived from {U}

$\{\in^e\} = [B^e]\,\{U^e\}$

$\{\sigma^e\} = [D^e]\,\{\in^e\}$

$W^e = \frac{\mathbf{1}}{\mathbf{2}}\,\{\in^e\}^T\{\sigma^e\}$

5- General formulation (direct method)

The approach is as follows:

We express the displacement {u(x)} at any point of the element as a function of displacements at the nodes $\{u(x)\} = [N(x)]\,\{U\}$

Deformations are expressed as a function of displacements $\{\in^e\} = [S]\,\{u(x)\}$

Hence

$\{\in\boldsymbol{(x)}\} = [S]\,\{N(x)\}\,\{U\} = [B(x)]\,\{U\}$

We write the constitutive law of the material that links the constraints to deformation:

$\{ \sigma (x) \} = [D] \{\epsilon(x)\}$

It is written that the work of the external forces applied to the structure for a virtual displacement where δU is equal to the work of constraints for the same displacement:

$$\{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}\{F\} = \int_{V}\{ \boldsymbol{\delta\epsilon}\}^{\boldsymbol{T}}\{\sigma\}\, dv$$

By explaining, we have:

$$\{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}\{F\} = \{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}.\left(\int_{V}[\boldsymbol{B}]^{\boldsymbol{T}}[D][B]\, dv\right).\{U\}$$

As this relation is true for any virtual displacement, we deduce:

$$\{F\} = [K]\{U\}$$

With[k] in its more general form

$$[k] = \int_{V}[\boldsymbol{B}]^{\boldsymbol{T}}[D][B]\, dv$$

Note:

The relation above shows that [K] is symmetrical.

The current term Kij of the matrix corresponds to the force exerted on the node j when a unit displacement of the node i is imposed.

The symmetry of [K] which is written Kij = Kji corresponds mechanically to Maxwell-Betti's reciprocity theorem.

What will differentiate the different types of finite elements?

The choice of N (x) functions

The nature of the operator S (connecting deformations and displacements) which depends on the type of elastic theory used:

- Theory of beams
- Plate theory
- Theory of stress or plane strain

- Shell theory
- Theory of the bodies of revolution
- Theory of 3D elasticity

Note:

We have described the process of formulation of a finite element within the framework of the direct method (also called method of displacements). There are other approaches:

- The weighted residue method,
- The application of the principle of virtual work or virtual powers,
- Minimization of potential energy.

All these approaches are equivalent and lead to the construction of the same stiffness matrix.

6- Choice of a mesh

The mesh of the domain makes it possible to define a paving whose pavements are the finite elements. A finite element is the data of an elementary cell and basic functions of the approximation space whose support is the element, and defined in such a way as to be interpolating

<u>Example of the mesh:</u>

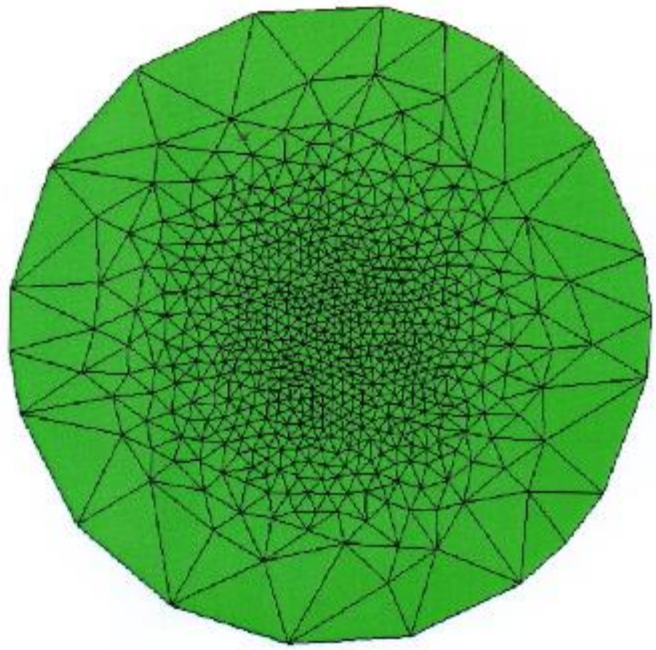


Figure 20: Triangular surface mesh

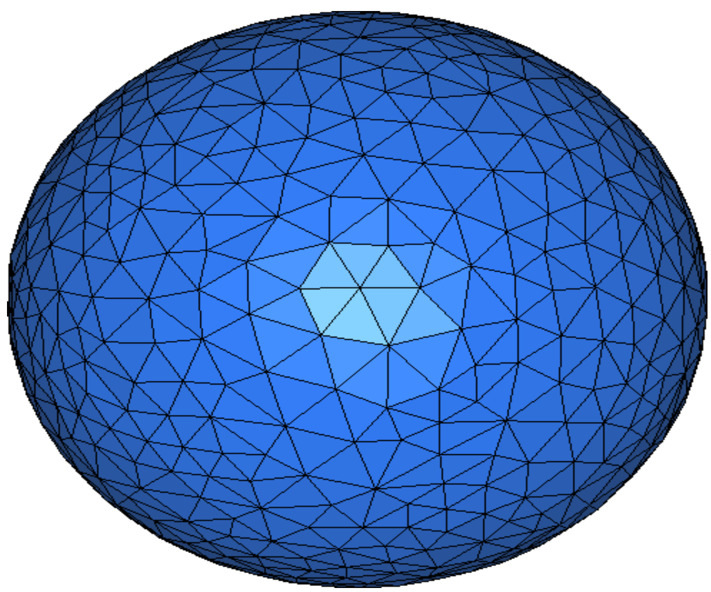


Figure 21: Triangular mesh volume

The finite element method is based on a division of the space according to a mesh. Usually one chooses a square or triangular mesh but nothing forbids to choose meshes more complex. It is also not necessary that the mesh is regular and there is a tendency to tighten the mesh near the places of interest (for example in places where one thinks that the solution will vary a lot), however it is necessary to make sure you have weakly distorted elements (move closer to a regular polygon). The more this mesh is narrowed, the more the solution obtained by the finite element method will be precise and close to the "real" solution of the partial derivative equation.

7- Basic function:

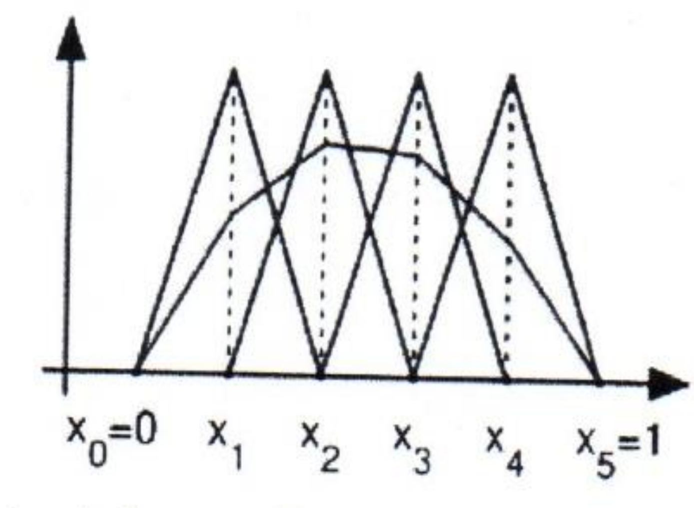


Figure 22: Basic function in dimension 1

The x_i are the nodes of the network.

We must then take a base of functions "adapted" to the mesh. Several choices are then possible. In general, the basic functions used for the finite elements are interpolating, that is, the nodal values are the values of quantities unknown to the nodes.

The simplest is the use of Lagrange polynomials. In this method the basic functions are worth 1 to one node of the mesh and 0 to all others. The base function i is then the function of 1 at node i and 0 on the other nodes and which is polynomial on each element. An example of such functions is shown in dimension 1 beside. There are as many basic functions by elements as number of nodes.

We call element the data of a geometry (often polygonal in 2D, polyhedral in 3D) and basic functions associated with this geometry.

Other solutions may exist for basic functions. We quote here only one example the finite elements of Hermite which have the peculiarity to have two basic functions associated with each node. In this version, the value of the solution is adjusted with the first function while the second one makes it possible to adjust the value of the derivative. This type of basic function may be of interest for the resolution of some partial differential equations (for example the equation of the plates in continuous media mechanics) even if it requires having twice as many functions for a given mesh.

❖ Some classic elements:

- In 2D
- Triangles of degree 1, (triangles with 3 nodes, linear functions)
- Triangles of degree 2 (triangles with 6 nodes, polynomials of degree 2)
- Quadrangles of degree 1 (squares with four nodes, linear functions)
- Quadrangles of degree 2 (squares with 8 or 9 knots, polynomials of degree 2)
- In 3D
- Tetrahedron of degree 1, (four knots, linear)
- Cube of degree 1, (eight nodes, linear)

8- Geometric discretization:

This operation consists in dividing the continuous domain into sub domain

$\boldsymbol{D} = \sum_{e=1}^{ne} \boldsymbol{De}$ such as $\lim\limits_{e}(\boldsymbol{UeDe}) = \boldsymbol{D}$

It is therefore necessary to be able to represent at best the often complex geometry of the domain studied by the elements of simple geometrical form. There must be no overlap or hole between two elements having a common border.

When the boundary of the domain is complex, a geometric discretization error is inevitable. This error must be estimated, and possibly reduced by modifying the shape or decreasing the size of the elements concerned as proposed in the figure. On each element we will try to define an approximation of the solution function.

9- CONCLUSION

Although there is a lot of software that uses this method and can "solve" problems in various fields, it is important that the user has a good idea of what he is doing, especially with regard to the choice of mesh and type. elements that must be adapted to the problem: no software will do everything for the user, and we must always keep a critical eye vis-à-vis solutions approached.

Using CATIA design software that helps us specify easily damaged parts or areas, and another software for ANSYS finite element analysis that offers the best solutions for linear, non-linear problems. linear, explicit and dynamic.

Chapter III : Mechanical concept

1- Introduction

In this chapter, I'm going to do the functional study and the design of the Nose Landing Gear.

I will start by the functional study, then I will create the Nose Landing Gear parts using "Part Design" and then I will assemble all the parts we created using "Assembly Design".

2- Functional study

Functional analysis is an approach that consists in seeking and characterizing the functions offered by a product to satisfy the needs of its user.
The approach is usually conducted in project mode and can be used to create (design) or improve (redesign) a product.

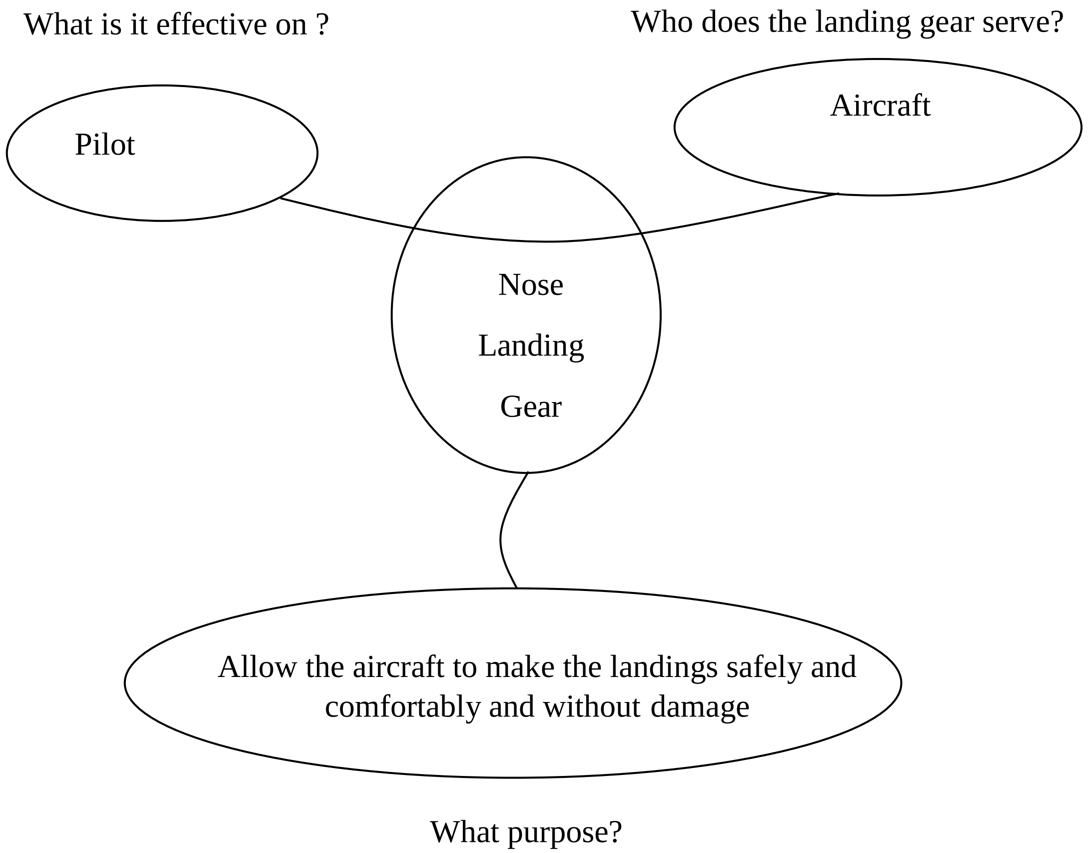
2.1 First step: bull chart/diagram/map "bête à cornes"

2.1.1 State the need:

Who does the landing gear serve? ➔ It renders service to the pilot.

he's acting on whom? ➔ It acts on the aircraft.

What purpose? ➔ Allow the aircraft to make the landings safely and comfortably and without damage.



2.2 Second step: Modeling a technical system

Modeling a technical system consists of giving it a graphic representation that lists the four sets of elements below, distinguishing them from each other and showing the relationships between them:

- The global function, which brings added value to the work material.

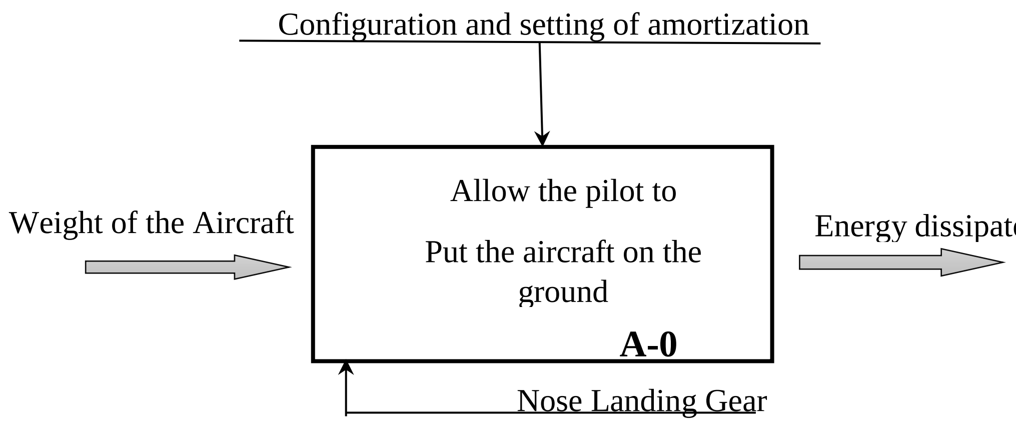
- The constituent elements (the processor or processors) that are included in the boundary and support the global function.

- The material of work on which its action is exercised.

- The control data, which causes or modifies the implementation of the function.

- **SADT (Structured analysis and design technique):**

Is a systems engineering and software engineering methodology for describing systems as a hierarchy of functions. It was developed in the late 1960s by Douglas T. Ross, and was formalized and published as IDEF0 in 1981.



2.3 Third step: Identify the service functions "octopus diagram"

The octopus diagram (or APTE) allows us to list all the functions of our product. Indeed we recall that during the design, the technicians will seek for each function to satisfy, the best solution. It is the set of solutions that will give the final product. There are two types of function:

- Fp = Main function: link between the product and two surrounding objects.

- Fc = Constraint function: link between the product and a surrounding object.

Octopus diagram :

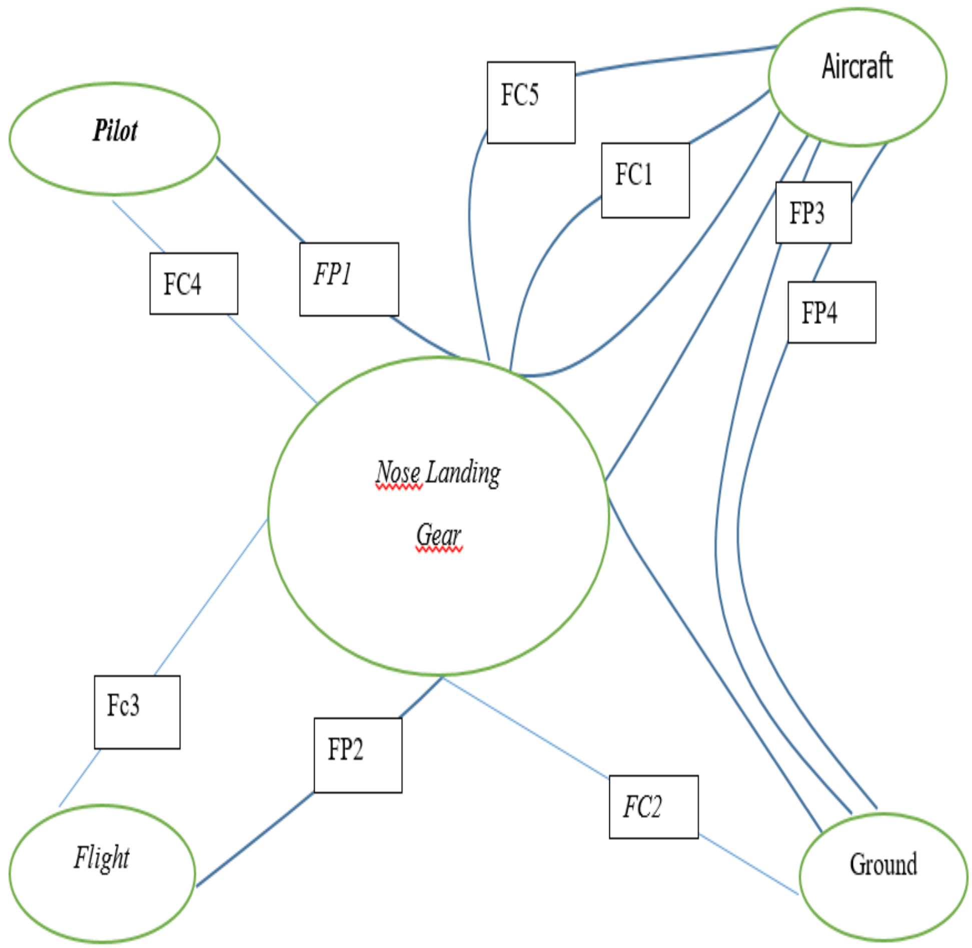


Table 4: The service functions and Criteria

The service functions:	**Criteria**
FP1: Allow the pilot to land the aircraft without damaging it	- Ability to withstand speed. - Impact.
FP2: Preserving aerodynamics of the plane in flight.	- Aerodynamic drag added.
FP3: Ensure taxiing the plane.	- Taxing effort. - Maneuverability.
FP4: dampen ground irregularities transmitted to the airplane.	- Shock absorber performance. - Tire resistance
FC1: To be adapted to the plane.	- The mass. - Congestion.
FC2: To be adapted with the ground.	- Hardness of the ground.
FC3: To be adapted to flight environment.	- Resistance to saline atmosphere.
FC4: Allow order by the pilot.	- The steering control.
FC5: limit disturbances on the flight of the plane.	- A retraction system that allows the landing gear to enter the fuselage.

3. CATIA

3.1 Definition

Initially CATIA name is an abbreviation for Computer Aided Three-dimensional Interactive Application. The French Dassault Systems is the parent company and IBM participates in the software and marketing, and CATIA is invades broad industrial sectors, and has been explained in the previous post position of CATIA between 3d modeling software programs. CATIA was started in 1977 by French Aircraft Manufacturer Avions Marcel Dassault System (**Figure)**.

Figure 23: Dassault System

CATIA is classified under the following software packages :

CAD (Computer Aided Design)

CAM (Computer Aided Manufacturing)

CAE (Computer Aided Engineering)

Version that most of the people works on it now is CATIA V5 or fifth version, which is a rewriting and revision the code of the fourth edition. For the fifth version, there are versions from 1 to 20. for example, CATIA V5 R17, it Means CATIA fifth edition version seventeenth, While years system was adoption in the sixth edition, for example, CATIA V6 2011 means CATIA sixth edition version of Year 2011.

3.2 CATIA Modules

- **Sketcher:**

  This module is responsible for the implementation of two-dimensional shapes, in preparation for make a three dimensional commands on it.

- **Part Design :**

This module is responsible for converting two-dimensional graphics to three dimensional objects which is most famous in Catia and is closely linked with sketcher module. The part design Module it is considered from most important modules, that used by the designer to get the additional advantage from cad programs, which is stereotaxic drawing or three-dimensional drawing.

- **WireFrame and Surface Design:**

With this module surfaces can be drawing with zero size and weight and has its uses in the aerospace, automotive, ships and Mold Design.

- **Generative Sheet Metal Design:**

This module is responsible of converting two-dimensional graphics to thin sheets or walls having a particular ratio between thickness and its radius.

- **Assembly:**

This module is responsible for assembling the parts previously produced in Part Design, and it is most important for those who work in the field of machinery design or design in general because it is the one who shows the inter-relationships between the parts of the machine or many mechanical establishment.

- **Drafting:**

This module is responsible for converting what you see the screen to standard engineering drawings can be traded in the workshop for manufacturing or save them for documentation.

3- The components of the Nose landing gear Shock Struts

It is worth noting that my design parameters are roughly inspired from Boeing 777-300ER with some design changes.

I will create each component using “Part Design” in CATIA.

- **Torque links:**

Transfer moments between main fitting and sliding member and prevent rotation of the sliding member with respect to the main fitting. **[30]**

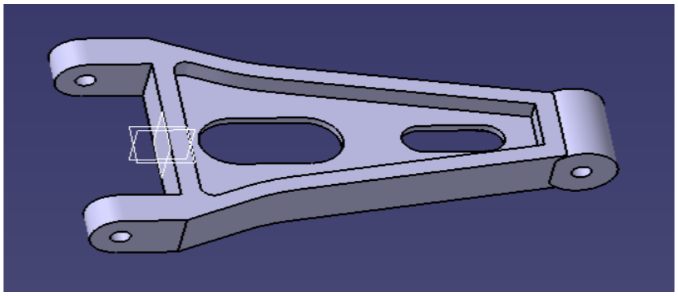


Figure 24: 3D CATIA model of Upper torque link

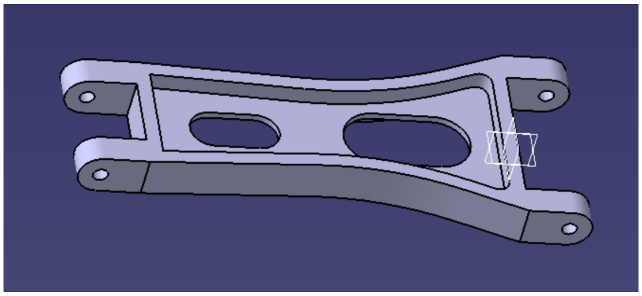


Figure 25: 3D CATIA model of Lower torque link

- **Tire:**

That provides the connection between the ground and the aircraft.

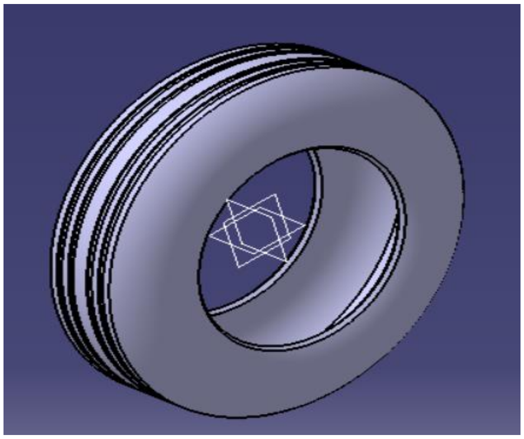


Figure 26: 3D CATIA model of tire

- **Rim:**

That acts as a thin envelope on which the load of the aircraft is distributed via the nitrogen contained in the tire.

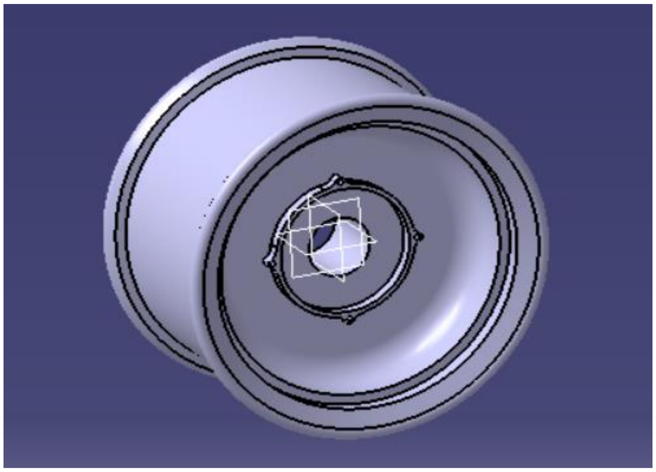


Figure 27: 3D CATIA model of the rim

- **Oleo strut:**

Is a pneumatic air–oil hydraulic shock absorber used on the landing gear of most large aircraft and many smaller ones. This design cushions the impacts of landing and damps out vertical oscillations.

It is undesirable for an airplane to bounce on landing—it could lead to a loss of control. The landing gear should not add to this tendency. A steel coil spring stores impact energy from landing and then releases it. An oleo strut absorbs this energy, reducing bounce. As the strut compresses, the spring rate increases dramatically, because the air is being compressed, while the viscosity of the oil dampens the rebound movement.

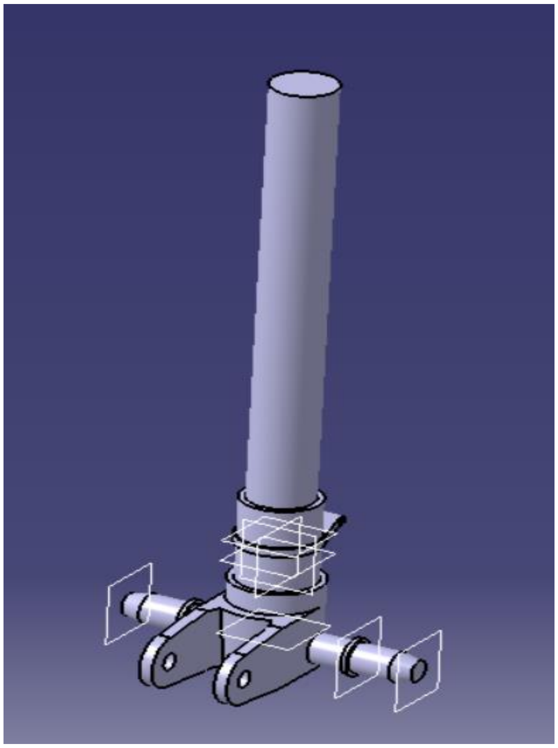


Figure 28: 3D CATIA model of the oleo strut

- **The landing gear support :**

Is a structural component generally works in resisting longitudinal compression, it allows to fix the landing gear in the fuselage

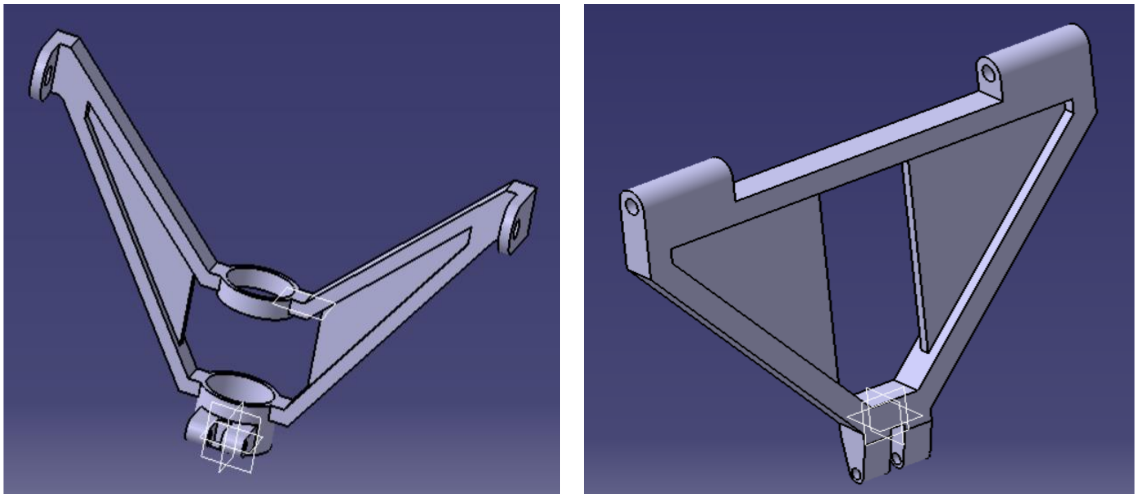


Figure 29: 3D CATIA model of the landing gear support

- **Steering system assembly:**

This allows the aircraft to be directed during ground operation.

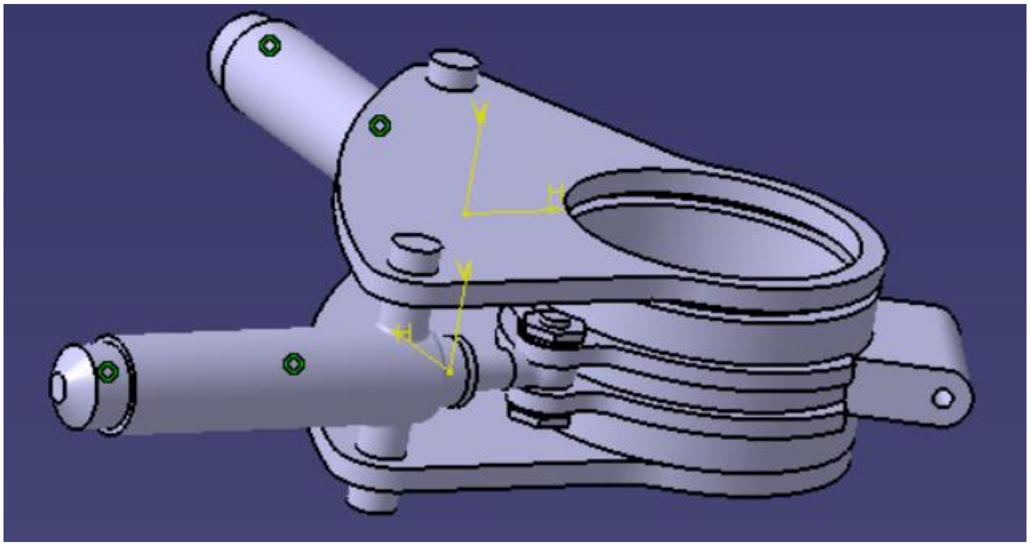


Figure 30: 3D Catia model of the steering system assembly

- **Nose Landing Gear assembly:**

After finishing from designing all the parts of the Nose Landing Gear I assembled them using Assembly Design in CATIA.**(Figure 30)**

This Nose landing gear **(figure 30)** Is the undercarriage of an aircraft and is used for either takeoff or landing, it is located at the front of the aircraft.

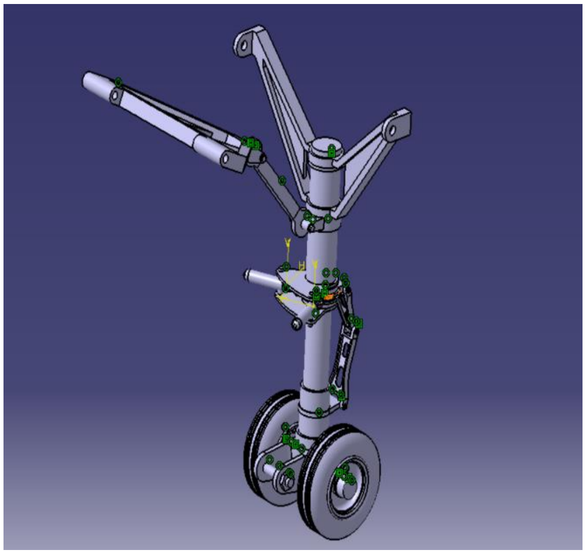


Figure 31: 3D CATIA model of nose landing gear

4- Conclusion

In this chapter, I managed to create the design of the Nose Landing Gear.

At first I did the functional study, then I created the Nose Landing Gear parts using “Part Design” and then I assembled all the parts that I created it using “Assembly Design”.

Chapter IV: Results

1- Introduction

In this chapter, I will calculate the forces applied on the front landing gear in the cases: static, dynamic and when the plane touches the ground and after I will interpret the results in the static case with the ansys by changing the material each time.

2- Force calculation

2.1 Dimensioning of Boeing 777-300er

We Consider the dimensions of the aircraft in **Figure and figure** and whose pertinent characteristics are listed below.

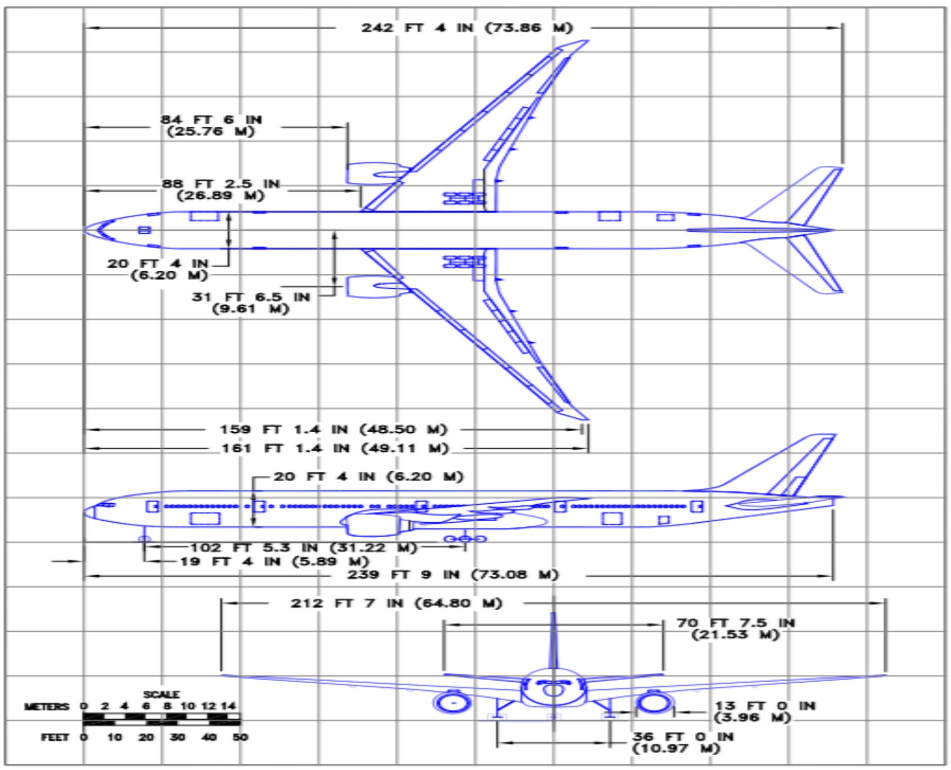
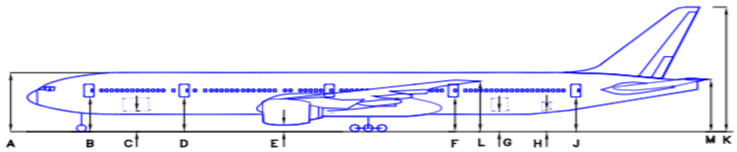


Figure 32: General Dimensions: Model 777-300ER



Dimension	MINIMUM*		MAXIMUM*	
	FT - IN	M	FT - IN	M
A	27 - 9	8.46	28 - 10	8.78
B	15 - 9	4.80	16 - 10	5.13
C	9 - 5	2.88	10 - 6	3.19
D	16 - 2	4.92	17 - 1	5.20
E	2 - 5	0.73	3 - 3	0.99
F	16 - 9	5.11	17 - 5	5.32
G (LARGE/SMALL DOOR)	10 - 6	3.19	11 - 9	3.58
H	10 - 11	3.32	12 - 4	3.76
J	17 - 0	5.19	18 - 7	5.66
K	59 - 10	18.24	61 - 10	18.85
L	23 - 11	7.29	25 - 11	7.90
M	25 - 7	7.79	27 - 8	8.43

Figure 33: Ground Clearances: Model 777-300ER

I'm going to determine the following :

- The static ground reaction loads without engine power.
- Dynamic ground reaction loads on the NLG and MLG, assuming no rotation at V = 79,16 m/s.
- The airspeed at which the pilot can (slowly) rotate the nose of the aircraft to lift off, assuming the constant airspeed formulation.
- The ground reaction loads on the NLG and MLG when the aircraft touchdown the ground.

So we have :

- Maximum Takeoff Weight (MTOW) = 351535 Kilograms **[31]**
- MAC(Mean Aerodynamic Chord) = 8,75m
- The distance between the nose and the Leading Edge Mean=26,89m

2.2 Static ground reaction loads without power:

Is the case when the aircraft is on the ground, the weight of the aircraft is the only force that is working on the aircraft. The main landing gear carries more weight than the nose landing gear because the centre of gravity is closer to it. The arm between the CG and the main landing gear is smaller than the arm between the CG and the nose landing gear.

The Nose reaction (RN)

$$\boldsymbol{RN = \frac{W.XM}{XN + XM}}$$

To determine the distances XM and XN,

firstly we have to konow the distance (LEM) between the nose of the airplane and the Leading Edge Mean that equal to 26,89m.

Secondly we have to determine the distance (COG) between the nose of the airplane and the center of gravity :

COG = 25 % MAC + LEM

= 2,1875 + 26,89

$\boxed{\text{COG = 29,0775}}$

We have also : $\boxed{\text{XN+XM = 31,22m}}$ ıe distance between the main landing gear and the nose landing gear)

And we have the distance (NANLG) between the nose of the airplane and the nose landing gear that equal to 5,89m

So XM = NANLG + (XN+XM) – COG

= 5,89 + 31,22 - 29,0775

$\boxed{\text{XM = 8,0325m}}$

XN = COG – NANLG

= 29,0775 – 5,89

$\boxed{XN = 23{,}1875m}$

$RN = \frac{W.XM}{XN+XM}$ with W= MTOW.g

= 351535 . 9,81

$\boxed{W = 3448558{,}35\ N}$

$$RN = \frac{3448558{,}35\ .8{,}0325}{31{,}22}$$

$\boxed{RN = 887269{,}2167\ N}$

W= 3448558,35 N $\Rightarrow$ 100%

RN = 887269,2167 N $\Rightarrow$? %

Then the Nose landing gear reaction is : $\frac{887{,}2692.100}{3445{,}043}$ = 25,7286 percent of the total weight of the aircraft.

RM = W – RN

= 3448558,35 – 887269,2167

$\boxed{RM = 2561289{,}133\ N}$

2.3 Dynamic ground reaction loads

In this case the reaction load of the nose landing gear **RN** is defined by this formula :

$$RN = \frac{T.YT + (W + LHT - LW).(XM - \mu.hcg) + LW.XW - LHT.lHT - MW}{XN + XM - 2.\mu.hcg}$$

We have as data :

- Take off distance = 3200m **[23]**
- The speed at the beginning of the taxi VA= 0 km/h (at point A)
- The Speed of the aircraft at the end of the taxi phase (at point B) VB=285km/h
- We assume that the drag force is negligible

To determine all these unknowns we have to go through all these steps :

- Calculation of the kinetic energy ***Δ* EC** of the aircraft between the beginning and the end of the taxi phase.

Δ EC = EC(B) $= \frac{1}{2}$.m.$(VB^2 - VA^2)$

We have VB = 285 km/h $= \frac{285.1000}{60.60}$ = 79,16 m/s

So Δ EC $= \frac{531{,}535.10^3.(79{,}16)^2}{2}$ = 1,665.10^9 J

$$\boxed{\Delta\ EC = 1{,}665\ GJ}$$

- Determine the value of a force from his work:

It is known that this variation of kinetic energy ***Δ* EC** is equal to the sum of the work of the forces exerted on the airplane during this trip

We assume that the friction force and the drag force are negligible.

we can count three forces that the aircraft undergoes during taxi:

- The weight.
- The reaction of the ground

- The Thrust force

The work of a force is given by the relation : $W_{rAB}(\vec{F}) = \vec{F}.\overrightarrow{AB}$

We know that the work of the weight and that of the reaction of the ground are null because the displacement is always perpendicular to these two forces.

So we have :

Δ EC = Wr_{AB} (Thrust Force)

$= \overrightarrow{Th}.\overrightarrow{AB}$

$= ||\overrightarrow{Th}||.||\overrightarrow{AB}||.\cos(\overrightarrow{Th}.\overrightarrow{AB})$

Knowing that the Thrust force and displacement have the same direction so the angle between these vectors is zero, hence:

Δ EC = $||\overrightarrow{Th}||.||\overrightarrow{AB}||$ $\Rightarrow$ $\overrightarrow{Th} = \frac{\Delta EC}{AB} = \frac{1{,}665.10^9}{3200}$

$= 0{,}5203125.10^6$ N

$$\boxed{\overrightarrow{Th} = 520312{,}5 \text{ N}}$$

Conclusion:

The maximum thrust of a single Boeing 777-300er reactor is 512000 N. In our case we need a total thrust of 520312.5 N to reach a speed of 285km / h for a distance of 3200m, so both reactors must to be used.

- Wing lift (L_{W}) :

The wing lift is defined by this formula : $L_W = q.S_W.C_L$

$q = \frac{1}{2}\rho.v^2$ with **q** is the dynamic pressure and ρ is the air density.

ρ=1,225kg/m3

so $q = \frac{1{,}225.(79{,}16)^2}{2}$

$$\boxed{q = 3838{,}11218 \; Pascal}$$

we assume that $C_{L=}$ 0,9

$L_W = \mathbf{3838{,}11218}.427{,}80.0{,}9$

$\boxed{L_W = 1477749{,}9515\ N}$

- Horizontal Lift (L_{HT})

S_{HT} = 101,26 m^2

We assume that $C_{H\,=}$ -1,2

The wing lift is defined by this formula : $L_{HT} = q.S_{HT}.C_H$

$L_{HT} = \mathbf{3838{,}11218}.\ 101{,}26.\ |-1{,}2|$

$\boxed{L_{HT} = 466376{,}6872\ N}$

- Pitching moment (M_W) : Is the moment of wing about the center of gravity

  The Pitching moment is defined by this formula : $M_W = q.S_w.C_{MGC}.C_M$

With **C_{MGC} :** Is the Mean Geometric Chord length .

And **C_M :** Is the pitching moment coefficient .

We assume that C_M = -0,2

$M_W = \mathbf{3838{,}11218}.\ 427{,}80.8{,}75.(-0{,}2)$

$\boxed{M_W = -2873402{,}6835\ Nm}$

We assume that h_{cg} = 5m

And we define l_{HT} : The distance between the gravity center and the center of horizontal tail

l_{HT} = 73,08 - 29,0775

$\boxed{l_{HT} = 44{,}0025\ m}$

X_W = 26,89 + 50%MCA – COG

= 26,89 +0.5.8,75-29,0775

$\boxed{X_W = 2{,}1875\ m}$

We assume that μ = 0,25

Y_T = COG – 25,76

= 29,0775 – 25,76

$\boxed{Y_T = 3{,}3175\ m}$

Finally we have $\boxed{\boldsymbol{RN} = 133725{,}10746511}$

Main landing gear reaction loads :

RM = W + L_{HT} – L_W – RN

= 3448558,35 + 466376,6872 - 1477749,9515 - 133725,10746511

$\boxed{\boldsymbol{RM} = 2303459{,}9782348}$

2.4 Aircraft touchdown

During touchdown the main landing gear touches the ground first. When the main landing gear touches the ground, there are several forces that work on the main landing gear.

There is a vertical force that needs to be absorbed by the shock strut. The shock strut should be able to ab-sorb a maximum vertical landing force of 3.70 m/s vertical speed (CS-25).

V_{app} = 149 KTS = 275,948 km/h = 76,6522 m/s

This landing is done with an vertical speed V_0 of 3 fps (0.9144 m/s)

The acceleration speed can be calculated with this formula :

$$(V_t)^2 = (V_0)^2 + 2.a.ds$$

With :

- V_t= vertical speed reaching the ground (m/s)
- V_0= vertical speed descending (m/s)
- a = acceleration / deceleration (m/s^2)
- ds = distance difference between the shock strut extended and extracted when touching the ground.

We assume that ds =0,356 m , $V_t = 0$ and $V_0 = 0.9144$ m/s

$0^2 = (0.9144)^2 + 2.a.0,356$

$$a = -1,2848 \text{ m/s}^2$$

The negative value means there is a deceleration . With the deceleration the force can be calculated :

Knowing that MLW = 251000,29 kg

F= MLW.a

= 251000,29 . 1,2848

$$F = 322485,1725$$

2.5 Determine the rotation airspeed

The rotation airspeed can be determined by calculating the reaction loads for the nose landing gear for a range of airspeeds and then identifying where the NLG reaction load becomes zero. The calculations are easily implemented in a spreadsheet. The calculation shown in tis Part was implemented for airspeeds ranging from 0 through 150 m/s using Microsoft Excel. The results have been plotted in **Figure 34**.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	v	v^2	q	⊿ EC	T	L_W	L_{HT}	M_W	l_{HT}	X_W	Y_T	µ	h_{cg}	W	XM	XN	RN	RM
2	0	0	0	0	0	0	0	0	44,0025	2,1875	3,3175	0	5	3448558,4	8,0325	23,1875	887269,22	2561289,1
3	5	25	15,3125	6644187,5	2076,3086	5895,6188	1860,6525	-11463,7	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	811694,12	2632829,3
4	10	100	61,25	26576750	8305,2344	23582,475	7442,61	-45854,81	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	803547,32	2628871,2
5	15	225	137,8125	59797688	18686,777	53060,569	16745,873	-103173,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	789969,33	2622274,3
6	20	400	245	106307000	33220,938	94329,9	29770,44	-183419,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	770960,13	2613038,8
7	25	625	382,8125	166104688	51907,715	147390,47	46516,313	-286592,6	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	746519,74	2601164,4
8	30	900	551,25	239190750	74747,109	212242,28	66983,49	-412693,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	716648,16	2586651,4
9	35	1225	750,3125	325565188	101739,12	288885,32	91171,973	-561721,5	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	681345,37	2569499,6
10	40	1600	980	425228000	132883,75	377319,6	119081,76	-733677	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	640611,39	2549709,1
11	45	2025	1240,3125	538179188	168181	477545,12	150712,85	-928560	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	594446,21	2527279,9
12	50	2500	1531,25	664418750	207630,86	589561,88	186065,25	-1146370	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	542849,84	2502211,9
13	55	3025	1852,8125	803946688	251233,34	713369,87	225138,95	-1387108	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	485822,26	2474505,2
14	60	3600	2205	956763000	298988,44	848969,1	267933,96	-1650773	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	423363,49	2444159,7
15	65	4225	2587,8125	1,123E+09	350896,15	996359,57	314450,27	-1937366	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	355473,52	2411175,5
16	70	4900	3001,25	1,302E+09	406956,48	1155541,3	364687,89	-2246886	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	282152,35	2375552,6
17	75	5625	3445,3125	1,495E+09	467169,43	1326514,2	418646,81	-2579333	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	203399,99	2337291
18	80	6400	3920	1,701E+09	531535	1509278,4	476327,04	-2934708	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	119216,42	2296390,6
19	85	7225	4425,3125	1,92E+09	600053,18	1703833,8	537728,57	-3313010	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	29601,664	2252851,4
20	90	8100	4961,25	2,153E+09	672723,98	1910180,5	602851,41	-3714240	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-65444,29	2206673,6
21	95	9025	5527,8125	2,399E+09	749547,4	2128318,4	671695,55	-4138397	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-165921,4	2157857
22	100	10000	6125	2,658E+09	830523,44	2358247,5	744261	-4585481	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-271829,8	2106401,7
23	105	11025	6752,8125	2,93E+09	915652,09	2599967,9	820547,75	-5055493	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-383169,4	2052307,6
24	110	12100	7411,25	3,216E+09	1004933,4	2853479,5	900555,81	-5548432	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-499940,1	1995574,8
25	115	13225	8100,3125	3,515E+09	1098367,2	3118782,3	984285,17	-6064299	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-622142	1936203,3
26	120	14400	8820	3,827E+09	1195953,8	3395876,4	1071735,8	-6603093	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-749775,2	1874193
27	125	15625	9570,3125	4,153E+09	1297692,9	3684761,7	1162907,8	-7164814	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-882839,5	1809544
28	130	16900	10351,25	4,491E+09	1403584,6	3985438,3	1257801,1	-7749463	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1021335	1742256,2
29	135	18225	11162,813	4,844E+09	1513629	4297906,1	1356415,7	-8357040	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1165262	1672329,8
30	140	19600	12005	5,209E+09	1627825,9	4622165,1	1458751,6	-8987543	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1314620	1599764,5
31	145	21025	12877,813	5,588E+09	1746175,5	4958215,4	1564808,8	-9640974	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1469409	1524560,6
32	150	22500	13781,25	5,98E+09	1868677,7	5306056,9	1674587,3	-10317333	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1629629	1446717,9

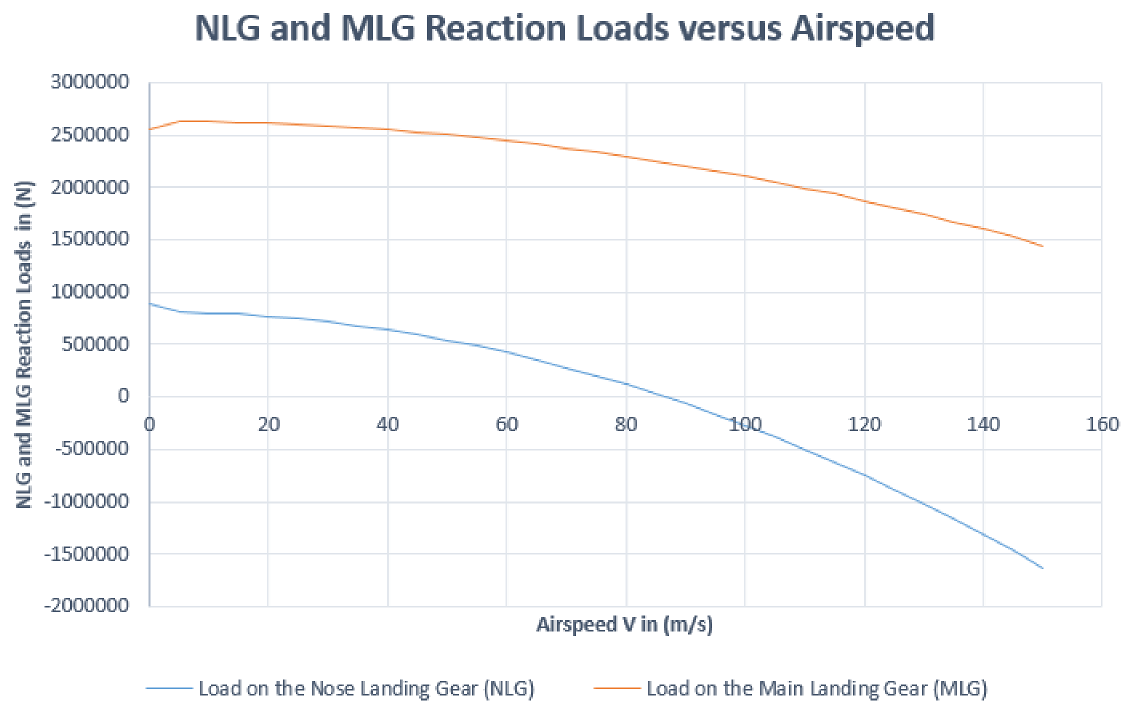


Figure 34: NLG and MLG Reaction Loads Airspeed

Note that the NLG reaction load goes to zero at around v = 87m/s. This means the aircraft must be accelerated to that airspeed before rotating the airplane is possible.

3- Presentation of the software ANSYS

ANSYS develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. ANSYS is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, ANSYS software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

Most ANSYS simulations are performed using the ANSYS Workbench software, which is one of the company's main products. Typically ANSYS users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the ANSYS software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time. ANSYS also develops software for data management and backup, academic research and teaching. ANSYS software is sold on an annual subscription basis.

4- Analysis By Using ANSYS 15.0 Software:

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. Structural Analysis is a multi-discipline Computer Aided Engineering (CAE) tool that analyzes the physical behavior of a model to better understand and improve the mechanical performance of a design. It can be used to directly calculate stresses, deflections, thus to predict the behavior of the design in the real world.

5- Setting up the Model

5.1 Import the assembly geometry

I'm going to import the geometry that I made in CATIA form STP passing with these steps:

Select on geometry with the right button ⟶ select import

5.2 Material selection

Three type of materials are used for obtaining the best results. The three materials are:

- Steel alloy : E4340

- Aluminum Alloy 7075
- Titanium alloy

- **Material Definition**

4340 (E4340) Alloy Steel :

4340 Alloy Steel is an Iron-based alloy containing Nickel, Chromium and Molybdenum. The relatively high Carbon content provides this alloy with superior strength in applications where severe service conditions exist. **[32]**

4340 Alloy Steel has high strength, superior toughness and good ductility. In addition, the alloy is immune to embrittlement.**[32]**

4340 steel alloy is used primarily for structural applications such as aircraft landing gears. 4340 alloy steel is also used in the manufacturing of structural parts like gears, sprockets, chucks, molds, and more. **[33]**

Aluminum Alloy 7075

Aluminum alloy 7075 is often used in the airspace industry, because it has a lightweight construction and a relative high tensile strength. It is so light and strong because the alloy has a high zinc and copper value.

Aluminum alloys have strong corrosion resistance. At subzero temperatures, their strength increases, thus making them a useful low-temperature alloy. Their strength decreases if they are subjected to very high temperatures. **[34]**

Titanium 10Al-2Fe-3V

Titanium 10-2-3 (Ti 10-2-3) is used in the landing gear instead of steel. The main reason for this change is the reduction of 600 pounds in the aircraft, because the strength to weight ratio of titanium is higher than steel.

- **Material Properties**

I have injected all these parameters into ANSYS case by case.

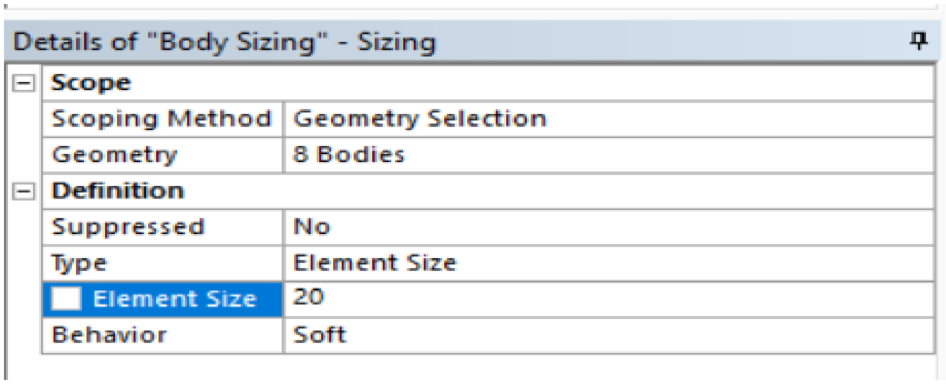
Table 5: Material properties

	Material	**Tensile strength (MPa)**	**Yield strength (MPa)**	**Density (kg/m3)**	**Poisson's ratio**	**Young's modulus (Gpa)**
1	Steel alloy : E4340	745	470	$7{,}85.10^3$	0.30	200
2	Aluminum Alloy 7075	503	95	$2{,}8.10^3$	0,33	80
3	Titanium 10Al-2Fe-3V	1260	1050	$4{,}65.10^3$	0,32	108

5.3 Meshing

The next pre-processing step is concerned with discretizing the continuous solid body geometry, also known as meshing.

According to the performance of my PC I will make a mesh for the whole body with the size of an element equal to 20 mm **(figure 27)** and after I will make a refinement between the pieces which have um contact between them.



Details of "Body Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	8 Bodies
Definition	
Suppressed	No
Type	Element Size
Element Size	20
Behavior	Soft

Figure 35: Element size

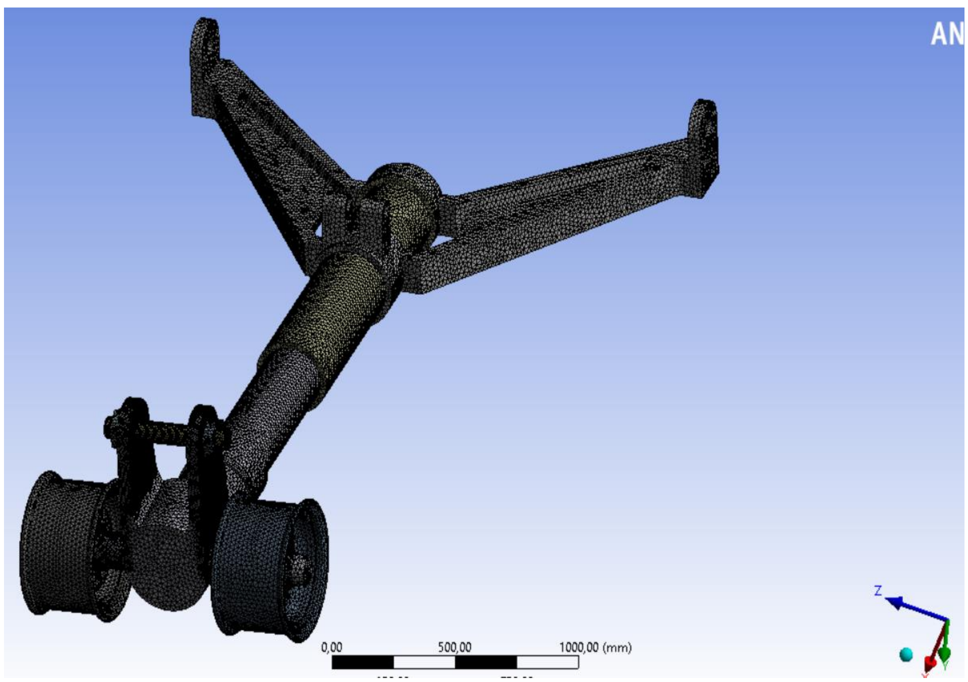


Figure 36: Meshed landing gear in ANSYS Mechanical (627362 elements and 938452 nodes)

5.4 Applying Loads and Boundary Conditions

○ Boundary Conditions

I put two fixed supports in two faces that will fix the nose landing gear in the fuselage.

To set up the necessary support it is necessary to go through these following steps:

Static structural ⟶ insert (with right click) ⟶ Fixed support ⟶ Select the Face I want to assign as a fixed support.

Figure 37: Fixed support

- ## Applying the Loads

I'm going to apply two equal forces on landing gear wheels that equals $R_N/2$.

To apply these forces it is necessary to go through these following steps:

Static structural ⟶ insert (with right click) ⟶ Force ⟶ select the face where I want to apply the force ⟶ define the value of the force ⟶ choose the direction of Force, (and the same thing for the other force) **(Figure 30)**

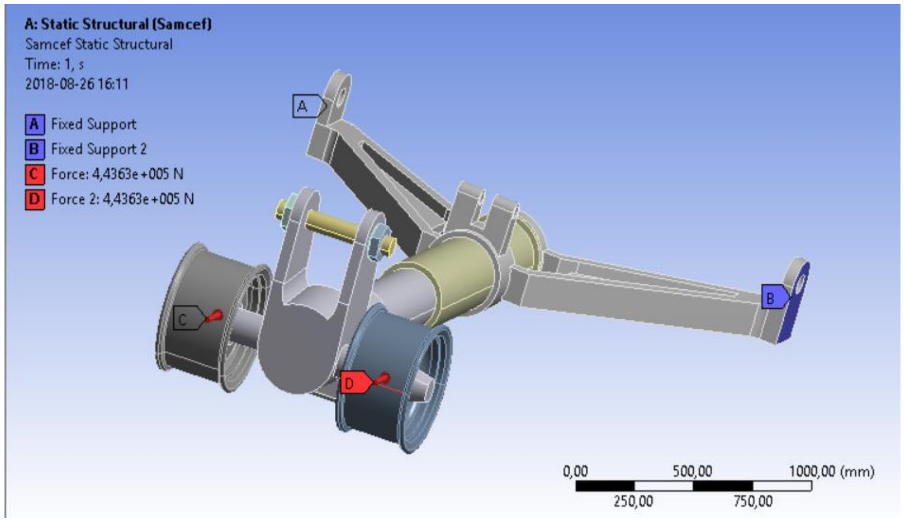


Figure 38: Application of forces

5.5 Results

- **Steel alloy: E4340:**

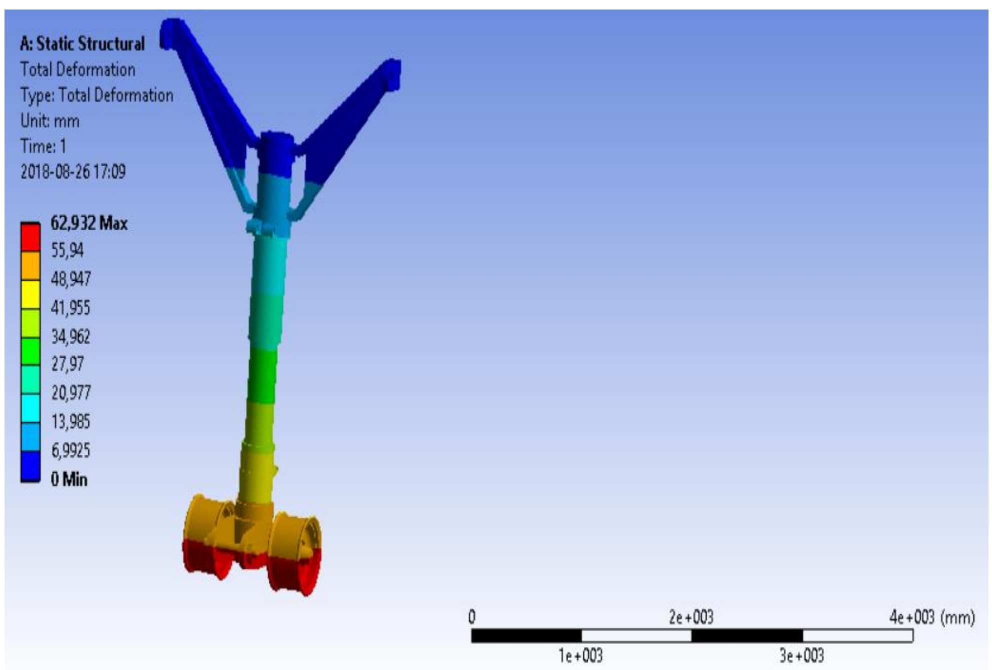


Figure 39: Total deformation of Steel alloy: E4340

The landing gear assembly has undergone a deformation, when a constant load is applied on the assembly which is at static condition. From **figure 31** maximum deformation of 62,932 mm which is indicated in red color region, and a minimum deformation of 0 mm as shown in blue color region for applied loads.

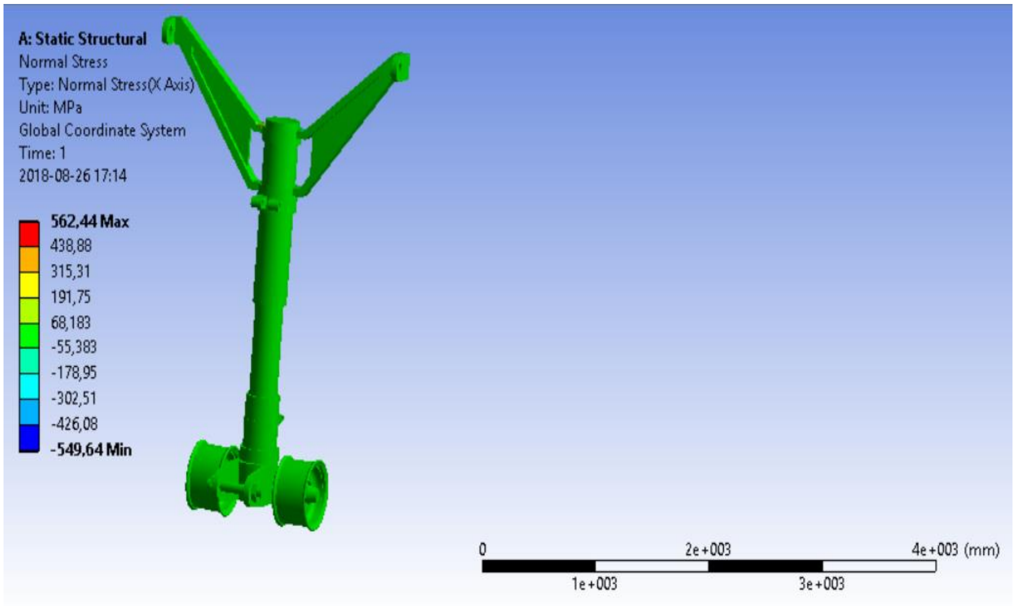


Figure 40: Normal Stress

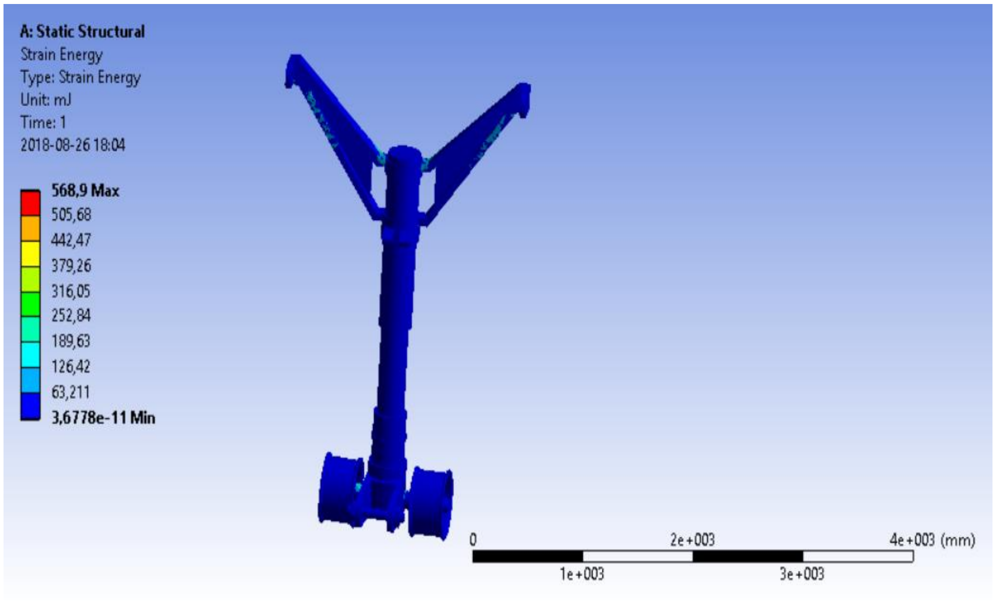


Figure 41: Strain Energy

Table 6: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Steel	62,932	562,44	568,9

Aluminum Alloy 7075

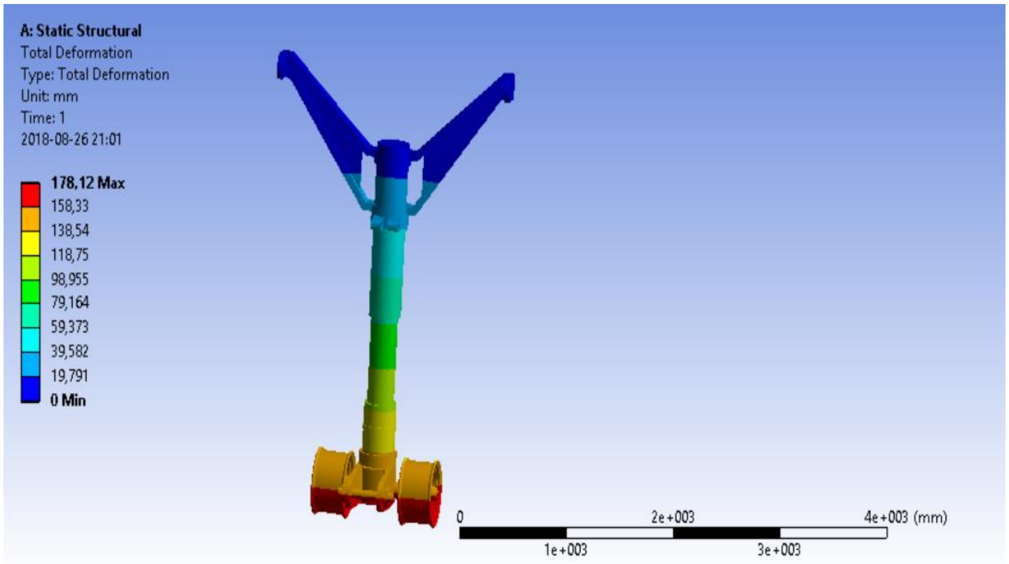


Figure 42: Total Deformation of Aluminum Alloy 7075

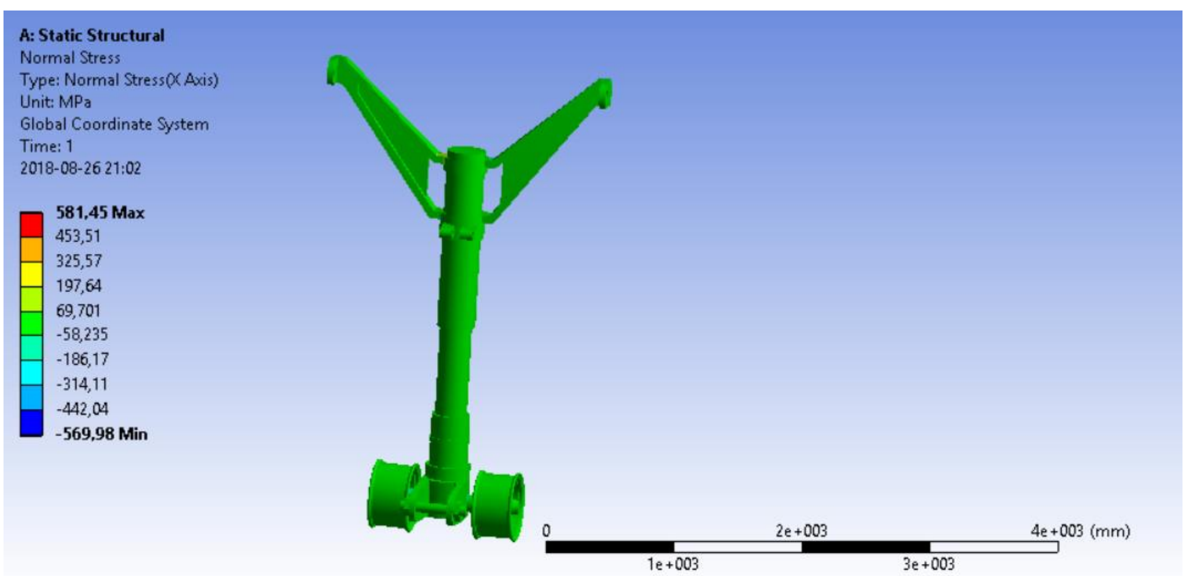


Figure 43: Normal Stress of Aluminum Alloy 7075

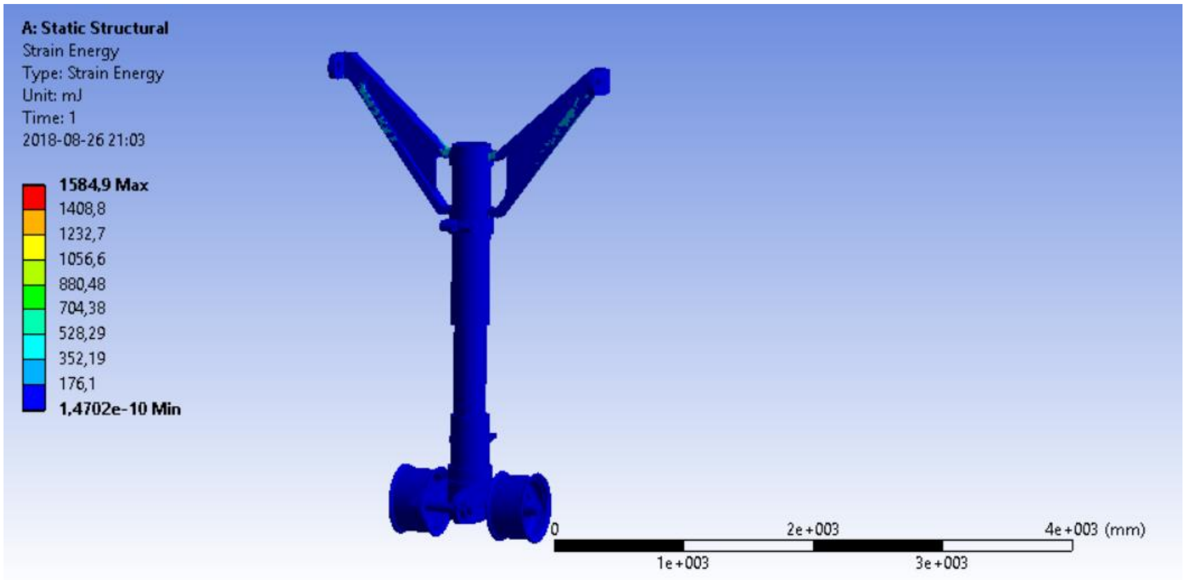


Figure 44: Strain Energy of Aluminum Alloy 7075

Table 7: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Aluminum Alloy 7075	178,12	581,45	1584,9

- **Titanium 10Al-2Fe-3V**

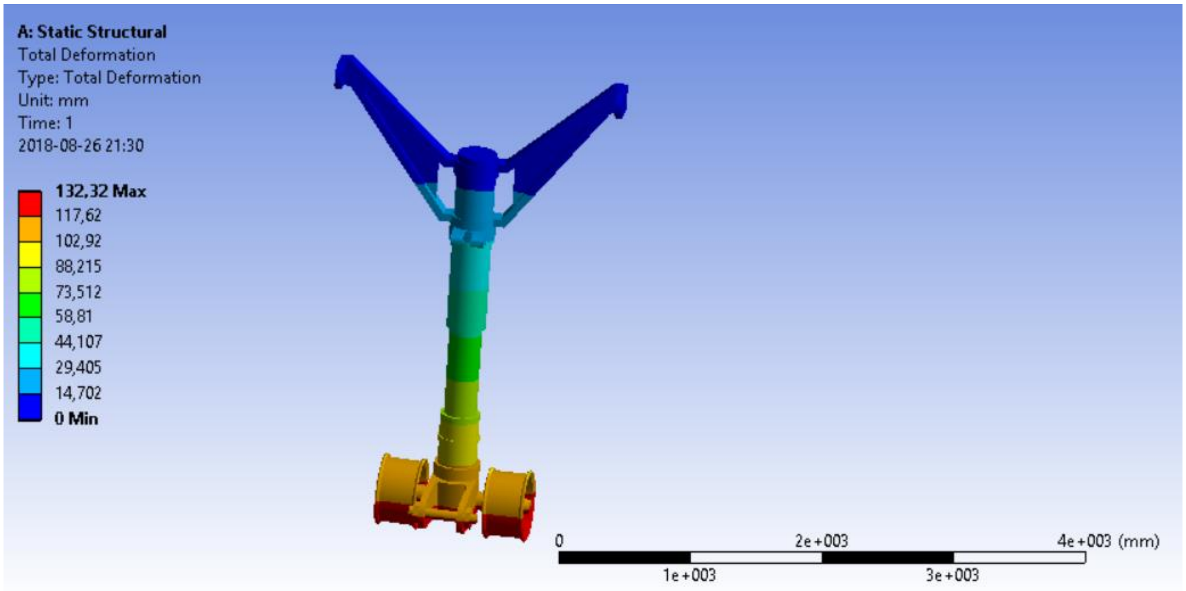


Figure 45: Total Deformation of Titanium 10Al-2Fe-3V

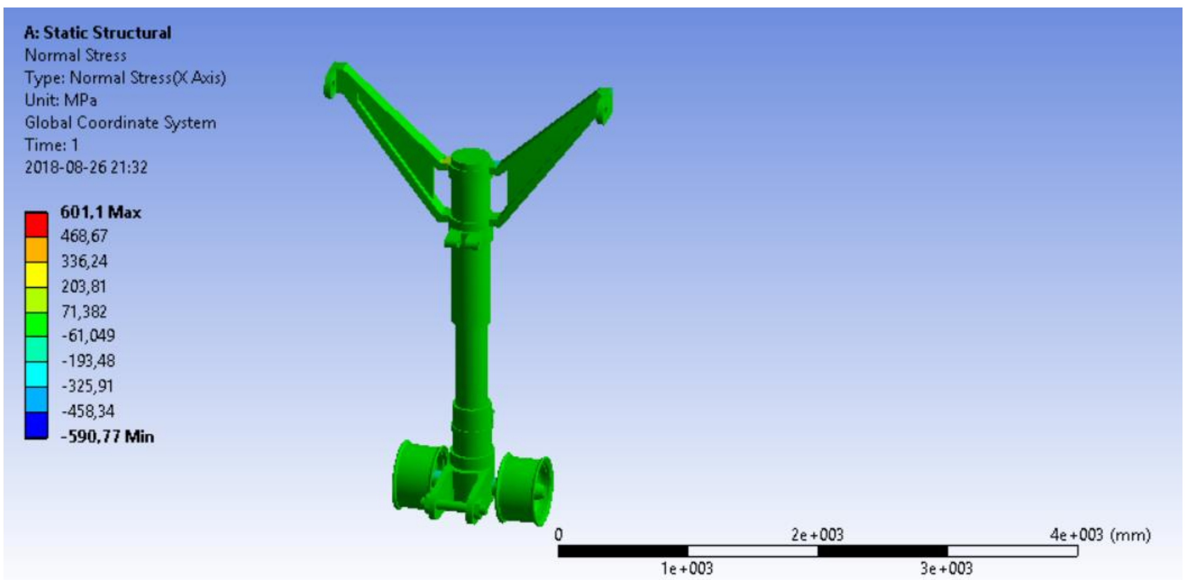


Figure 46: Normal Stress of Titanium 10Al-2Fe-3V

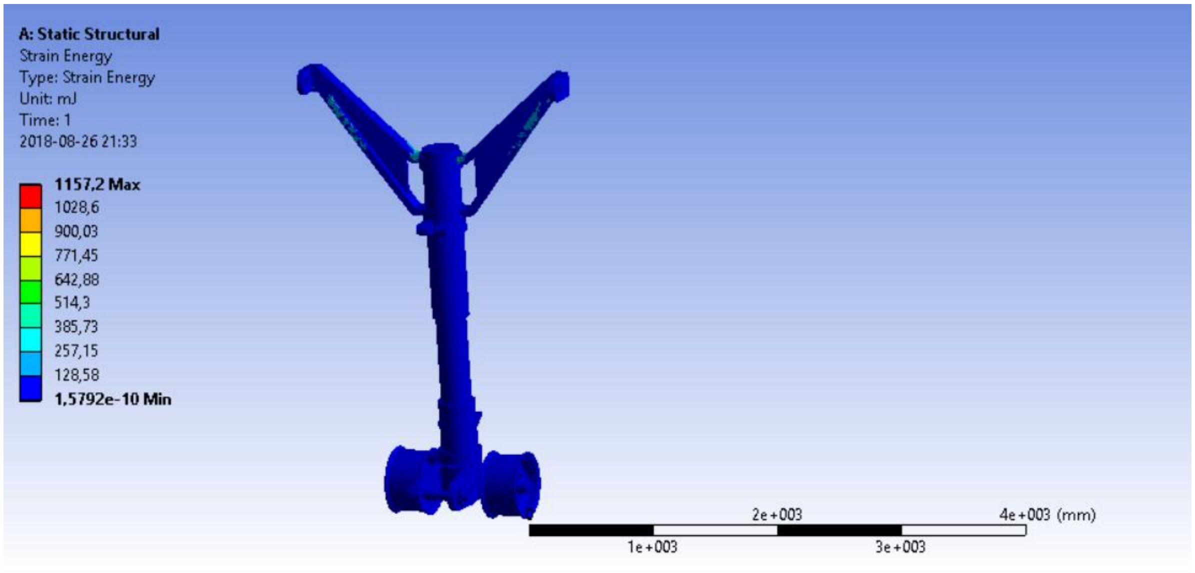


Figure 47: Strain Energy of Titanium 10Al-2Fe-3V

Table 8: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Titanium 10Al-2Fe-3V	132,32	601,1	1157,2

- ## Interpretation

Table 9: The Results of all materials

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)

Steel alloy: E4340	62,932	562,44	568,9
Aluminum Alloy 7075	178,12	581,45	1584,9
Titanium 10Al-2Fe-3V	132,32	601,1	1157,2

- The Steel alloy: E4340 has the minimum value of maximum normal stress, deformation and strain energy.
- The Aluminum Alloy 7075 has the maximum value of maximum stress and strain energy.
- The Titanium 10Al-2Fe-3V has the maximum value of maximum normal stress.

1. Conclusion

in this chapter I calculated the forces that are applied on the nose landing gear and I interpreted the following results in the static case from the ansys:

- The steel alloy E4340 resists normal stress, deformation and strain energy better than other materials (Aluminum Alloy 7075 and Titanium 10Al-2Fe-3V).
- The Aluminum Alloy 7075 doesn’t resist well the stress and strain energy.
- The Titanium 10Al-2Fe-3V resists the least the normal stress than other materials (E4340 and Alloy 7075)

General conclusion

This project compiles numerical studies to determine the distribution of deformations and constraints that will appear in a main landing gear (in three- dimensional). To carry out this study, we considered different stages.

First of all, all the main parts of the nose landing gear have been modeled with CATIA design software and assembled to obtain the complete structure of our model.

Secondly, was numerically solved Static ground reaction loads without power: using the ANSYS software. Several materials have been varied to determine the best one.

Finally this project we chose the best material.

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ABSTRACT

Landing gear is one of the important parts of an aircraft; often referred to as undercarriage. Landing gear is a structure which is installed on the aircraft for the purpose to support the weight of the aircraft while it is on the ground and also allows the aircraft for smooth maneuver such as takeoff and landing.

In this work, I designed a typical nose landing gear of Boeing 777-300ER using CATIA software tool, and then I calculated the reactions of nose and main landing gear in the cases: Static case (without power), Dynamic case and in the case when the aircraft touchdown the ground.

Finally, I analyzed the landing gear structure for three materials in the static case using ANSYS and I interpreted the results.

Keywords:

Nose landing gear, Forces, CATIA, ANSYS, Materials, Stress analysis, Deformation, Energy…

RESUME

Le train d'atterrissage est l'une des parties importantes d'un avion. Le train d'atterrissage est une structure qui est installée sur l'aéronef afin de supporter le poids de l'aéronef pendant qu'il est au sol et permet également à l'aéronef de manœuvrer en douceur, comme le décollage et l'atterrissage.

Dans ce travail, j'ai conçu un train d'atterrissage avant typique du Boeing 777-300ER à l'aide de l'outil logiciel CATIA, puis j'ai calculé les réactions du train d’atterrissage avant et du train d’atterrissage principal dans les cas suivants: Cas statique (sans puissance), cas dynamique et dans le cas lorsque l’appareil touche au sol.

Enfin, j'ai analysé la structure du train d'atterrissage avant pour trois matériaux dans le cas statique à l'aide d'ANSYS et j'ai interprété les résultats.

Mots clés :

Train d'atterrissage avant, Forces, CATIA, ANSYS, Matériaux, Analyse du stress, Déformation, Energie…

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AVIATION & TECHNOLOGY

ESAT UNIVERSITY

الجمهورية التونسية
المدرسة العليا
الخاصة للطيران و
التكنولوجيا

GRADUATION RESEARCH PROJECT
National Engineering Diploma in AERONAUTICS

Title :

Study of Nose Landing Gear

Place of the Internship / Training

❒ ***University of Jaen***

UNIVERSIDAD DE JAÉN

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Academic Year 2017/2018

Dedication

I dedicate this project:

To my dear mother,

To my dear father,

To my dear grandmother,

To my dear brother and my dear sister,

Who never stopped to make prayers to me, supporting me to reach my goals.
For their moral support and valuable advice throughout my studies.

for their moral support and valuable advice throughout my studies.

To ***Dr. Nawel Souissi*** *and* ***Dr. Ali Chibeni,***

for giving me the chance to have the experience in Spain,

To my dear friends

For their help and support in difficult times.

For all the members of ESAT, they were like a second family,

To all my family,

To all those I love and those who love me.

Acknowledgements

First I would like to thank the entire team of the University of Jaen, for the warm welcome

They gave us upon our arrival, their invaluable help and support throughout the traineeship

and foremost i would like to express my heartfelt gratitude to my supervisors, ***Mr. Nader Ben Jaber*** *and* ***Mr. Miguel Angel Rubio Paramio*** *for their enduring guidance, encouragement, patience and support throughout my final project.*

They have been inspiring role models during the last months, and i look forward to learn more from them.

I wish to express my most faithful gratitude to ***Dr. Ali Chibani*** *and the principal founder of ESAT,* ***Mr. Abderrazzak Ben Amara*** *and* ***Mrs. Aman Ben Amara****.*

I gratefully acknowledge my teachers and all the members who helped me during that period.

I also want to thank all my friends for their support, help and encouragement.

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General Introduction

Landing gear is one of the important parts of an aircraft; often referred to as undercarriage. Landing gear is a structure which is installed on the aircraft for the purpose to support the weight of the aircraft while it is on the ground and also allows the aircraft for smooth maneuver such as takeoff and landing. Landing gear also provides mobility to the aircraft on ground or water. It is capable of reaching the largest local load on the plane. The landing gear's main function is to control the rate of compression/extension and to prevent further damage to itself as well as other parts of an aircraft when a load is applied. Loads can be either static or dynamic in both cases the structure must withstand applied loads and deformation and continue to do its purpose. Among the available configuration the most common type of landing gear arrangement is tri-cycle arrangement. Considering the nose landing gear configuration of a tri cycle the stress distribution and deformation is noted for an executive jet aircraft for applied loads.

In this project the nose landing gear is modeled using CATIA. It is important to check the strength and stiffness of designed landing gear so the same geometry is imported to ANSYS Workbench and Explicit; Static structural and Impact test has been carried out for designed geometry. Stress distribution and deformation was noted for two distinct materials such as steel and aluminum alloy and primary results of acoustics has been compared with the available data.

This project consists of three parts: a bibliographic study in the first part (Chapter 1), a mechanical design in the second part (Chapter 2) and the results in the third part (Chapters 3).

Presentation of the University of Jaen

The Universidad de Jaén (UJA) is located in the south of Spain in the Andalusia region of Spain in the city of Jaén. The city has a lot for students to enjoy from historical sites, parks, shopping, and restaurants. The University offers courses in English so students do not need to know Spanish to study at UJA.

The Universidad de Jaén is a medium-sized, public university with about 14,500 students and over 800 faculty members. Established in 1993 at Campus Las Lagunillas, the Universidad de Jaén has more than 30 departments related to almost any university field of knowledge: business administration, anthropology, geography, history, chemistry, etc.

The Universidad de Jaén welcomes international students as part of a conscious effort to increase its international profile, which is of utmost importance, an institution that is constantly striving to widen both its knowledge and its horizons. No doubt, and thanks to an outstanding undergraduate and postgraduate international incoming and outgoing students population (which amount to approximately 650 students during the academic year), the Universidad de Jaén is becoming one of the leading exchange universities in the south of Spain.

The University is also part of the Erasmus Student Network (ESN). This organization operates as a support group to all International Students. It provides a forum for the students to meet and get to know one another better. It also provides trips to nearby cities including Malaga, Seville, Granada, and Cordoba.

Students gain a great deal about Spanish culture by experiencing day-to-day life in Spain with a conversation partner. UJA's buddy program will pair UNI students with a local UJA student to assist them during their first few days in-country.

Chapter I : Bibliographic studies

1- Introduction

The objective of this chapter is to make a bibliographic search on all the components of an aircraft in a general way, the history of aviation and some landing gear projects that are already done and on different types of landing gear and specifically the landing gear before to acquire the maximum of information allowing a better choice and a better understanding of the study of my project.

2- The history

2.1. The history of aviation

The history of aviation extends for more than two thousand years, from the earliest forms of aviation such as kites and attempts at tower jumping to supersonic and hypersonic flight by powered, heavier-than-air jets.

The history of aviation can be divided into six periods:

- The time of the precursors: until the beginning of the 18th century the human imagine what could be a flying machine and Then from the end of the 18th century, this period sees the beginning of the conquest of the air with the development of ballooning and many attempts at gliding.
- The pioneers of the heavier than the air: it is the period of the first flights of engine able to take off. Almost every flight is a first or a record attempt : a little faster, a little further, a little higher. Aviators are most often and designers or adventurers.
- The first World War (WWI) (1914–1918): only a few years after the first flight, this period sees the appearance of a new weapon on the battlefield. We pass abruptly to a mass production, some models of aircraft being even built to more than a thousand copies; pilots become "professionals", even if the adventure fragrance has not completely disappeared.
- Between two wars (1918–1939): The years between World War I and World War II saw great advancements in aircraft technology. Airplanes evolved from low-powered

biplanes made from wood and fabric to sleek, high-powered monoplanes made of aluminum, based primarily on the founding work of Hugo Junkers during the World War I period and its adoption by American designer William Bushnell Stout and Soviet designer Andrei Tupolev. Aviation is developing and is assisting in the creation of an air force in the number of countries. Military aviation is pushing automakers to break new records. The progress of civil aviation is a fallout from military studies.

- The Second World War (WWII) (1939–1945): aviation is widely used on the battlefield. This period can be considered the apogee of aircraft using a piston engine and a propeller as a means of propulsion. The end of the war sees the birth of the jet engine and radar.
- The second half of the twentieth century: This is the beginning of regular commercial (all weather) air transport able to overcome the weather conditions and practice the flight without visibility. Military aeronautics pushes the development of the reactor, this is called the jet era, and then goes on to conquer supersonic flight. The civil repercussions allow the development of the first airliners four-engined and the air transport opens to all.**[1]**

2.2. The history of some landing gear simulation

- The International Journal Of Engineering And Science (IJES) did a project on the front landing gear titled "Design and Analysis Aircraft Nose and Nose Landing Gear" and in this project the executive jet aircraft are studied thoroughly and a nose landing gear similar to those of executive jets is modeled using CATIA. The same geometry is imported to ANSYS APDL and Explicit; Static structural and Impact test has been carried out for designed geometry. Stress distribution and deformation was noted for two distinct materials such as steel and aluminum alloy and primary results of acoustics has been compared with the available data.

They get like results from ANSYS :

firstly they began testing the nose landing gear with the steel material and they noticed from the figure entitled (Static Deformation for Steel) which they obtained it in the static case : The maximum deformation of 0.78 mm which is indicated in red color region, and a minimum deformation of 0.000087 mm as shown in blue color region for applied loads. And landing gear assembly is suggested to be safe for a given material and load.

The landing gear assembly has undergone a deformation, when the aircrafts lands on hard runway. An impact load is induced on landing gear which is then transferred to axle and then to strut. from the figure (Impact Deformation for Steel) who got it in the case where the aircraft touches the ground : Maximum deformations of 4.1 mm which is indicated in red color region, and a minimum deformation of 0.46 mm as shown in blue color region for applied loads. And landing gear assembly is suggested to be safe for a given material and load.

Secondly they repeated the same works using aluminum and they made a comparison using the following two tables:

Table 1: Static analysis results

MATERIAL	MAX VON-MESIS STRESS (M PA)	MAX DEFORMATION (MM)
STEEL	15.9	0.78
ALUMINUM ALLOY	12.9	2.1

Table 2: Impact Analysis results

MATERIAL	MAX VON-MESIS STRESS (MPA)	MAX DEFORMATION (MM)
STEEL	82.6	4.1
ALUMINUM ALLOY	65.7	10.96

They concluded from **Table 1** which explains the results of static analysis that the maximum deformation occurs in case of aluminum alloy and a maximum stress distribution is for steel.

And in the During impact test at a given loading condition they conclude from the table 2 a maximum deformation occurs for aluminum alloy and stress distribution is maximum in case of steel. **[2]**

- In the project entitled “Vibration Modal Analysis of Landing gear Based on ANSYS” realized by Yong Ge Tianjin University of Technology and Education on 07

July 2017, his goal is to determine the vibration characteristics of the structure or machine part in the design, the natural frequency and mode. Modal analysis is a linear analysis, which can be modal analysis of pre-stressed method structures and modal analysis of cyclic symmetry structures. It is the starting point of harmonic analysis, transient dynamics analysis and harmonic analysis.

The three-dimensional solid model of landing gear is established in CATIA environment and then imported into ANSYS finite element software.

And then they made a mesh that the element are divided into more regular parts, when the partition to set the global seed size, and in the key parts of the definition of local seeds in order to refine the grid, and finally get the total number of nodes 222971, the total number of 119552 units. And after they calculated the results and Analyses with ANSYS, with using the Lanczos method they extracted the first four order modes when the analyses step is set, and the first four natural frequencies obtained are shown in **table 3 :**

Table 3: The natural frequency for many shapes

modal	natural frequency Hz	shape description
1	21.140	bending vibration
2	52.311	twist and swing
3	57.647	torsional vibration
4	69.095	bending and twisting

Finally they concluded that :

- The whole landing gear system is more complex, the performance of the pillars, brackets and rocker parts such as complex bending, twisting and swing, and the direction, amplitude, etc. are different.
- The dynamic characteristics of the landing gear can be seen through the vibration pattern of the landing gear, which provides a theoretical basis for the further improvement of the landing gear structure.

- The inherent frequency of the landing gear is about 48Hz, so the excitation frequency should be kept away from the natural frequency of the landing gear, so as to prevent the resonance phenomenon from occurring and ensure the safe and smooth operation of the landing gear **[3]**

3- Aircraft components:

3.1 The fuselage:

The fuselage or body of the airplane located centrally to the entire aircraft , includes the cabin and cockpit which holds all the pieces together. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components. **[4]**

3.1.1 Types of Fuselage Construction:

The construction of aircraft fuselages evolved from the early wood truss structural arrangements to monocoque shell structures to the current semimonocoque shell structures.

- **Truss Structure:**

In this construction method, strength and rigidity are obtained by joining tubing (steel or aluminum) to produce a series of triangular shapes , called trusses.

Lengths of tubing, called longerons, are welded in place to form a well-braced framework.

Vertical and horizontal struts are welded to the longerons and give the structure a square or rectangular shape when viewed from the end. Additional struts are needed to resist stress that can come from any direction. Stringers and bulkheads, or formers, are added to shape the fuselage and support the covering **(figure 1)**.

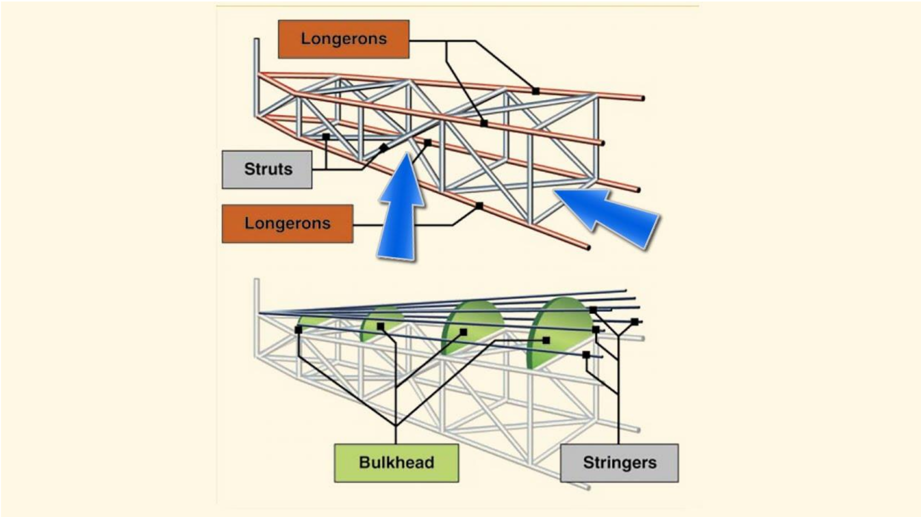


Figure 1: truss structure aircraft

As technology progressed, aircraft designers began to enclose the truss members to streamline the airplane and improve performance. This was originally accomplished with cloth fabric, which eventually gave way to lightweight metals such as aluminum. In some cases, the outside skin can support all or a major portion of the flight loads. Most modern aircraft use a form of this stressed skin structure known as monocoque or semimonocoque construction.

- **Monocoque:**

Monocoque construction uses stressed skin to support almost all loads much like an aluminum beverage can. Although very strong, monocoque construction is not highly tolerant to deformation of the surface. For example, an aluminum beverage can supports considerable forces at the ends of the can, but if the side of the can is deformed slightly while supporting a load, it collapses easily **(Figure 2)**. Because most twisting and bending stresses are carried by the external skin rather than by an open framework, the need for internal bracing was eliminated or reduced, saving weight and maximizing space. One of the notable and innovative methods for using monocoque construction was employed by Jack Northrop. In 1918, he devised a new way to construct a monocoque fuselage used for the Lockheed S-1 Racer. The technique utilized two molded plywood half-shells that were glued together around wooden hoops or stringers. To construct the half shells, rather than gluing many strips of plywood over a form, three large sets of spruce strips were soaked with glue and laid in a semi-circular concrete mold that looked like a bathtub. Then, under a tightly clamped lid, a rubber balloon was inflated in the cavity to press the plywood against the mold. Twenty-four hours later, the smooth half-shell was ready to be joined to another to create the fuselage. The two halves were each less than a quarter inch thick. Although employed in the early aviation period, monocoque construction would not reemerge for several decades due to the complexities involved. Every day examples of monocoque construction can be found in automobile manufacturing where the unibody is considered standard in manufacturing. **[5]**

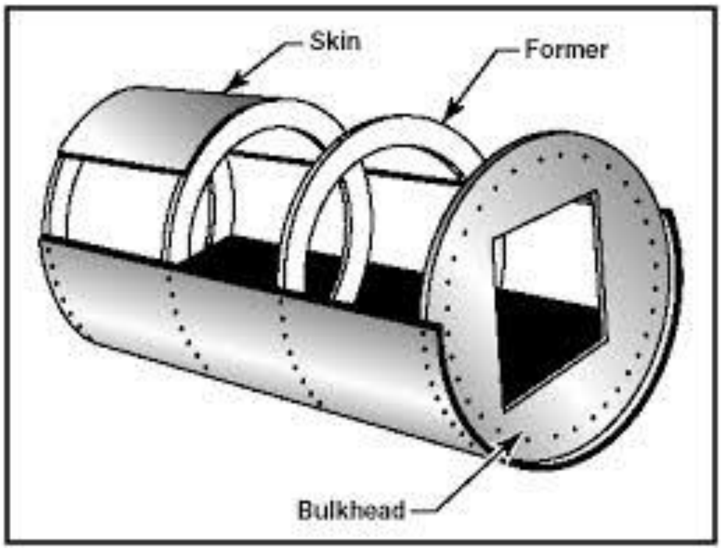


Figure 2: monocoque fuselage design

- **Semimonocoque**

Semimonocoque construction, partial or one-half, uses a substructure to which the airplane's skin is attached. The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage. The main section of the fuselage also includes wing attachment points and a firewall. On single-engine airplanes, the engine is usually attached to the front of the fuselage. There is a fireproof partition between the rear of the engine and the flight deck or cabin to protect the pilot and passengers from accidental engine fires. This partition is called a firewall and is usually made of heat-resistant material such as stainless steel. However, a new emerging process of construction is the integration of composites or aircraft made entirely of composites (**figure 3**). **[5]**

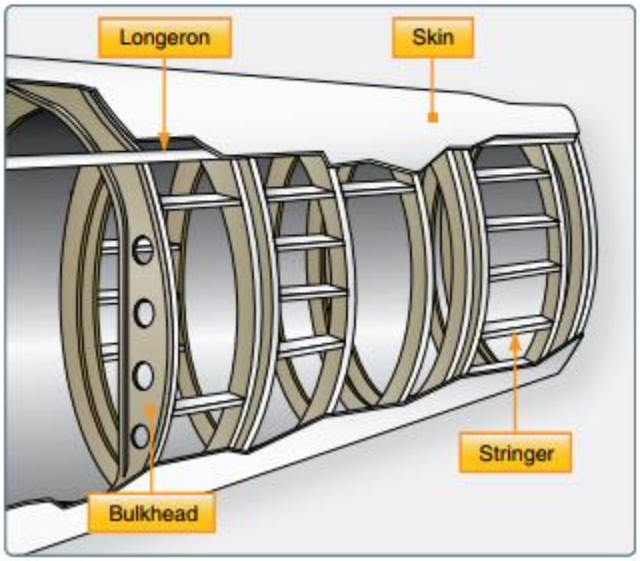


Figure 3 semi monocoque fuselage design

3.2. Wings:

The wings of an aircraft are airfoils designed to create this force of vertical motion called lift force. Any surface that alters the airflow to the advantage of a produced force in a particular direction is termed as an airfoil. Airplane wings, designed as airfoils, achieve this by interacting with the remote airflow to produce the desired lift.**[6]**

3.2.1 wing position

The wings of an aircraft can be attached to the fuselage at the top, mid-fuselage, or at the bottom. They may extend perpendicular to the horizontal plain of the fuselage or can angle up or down slightly. This angle is known as the wing dihedral. The dihedral angle affects the lateral stability of the aircraft. **(Figure 4)** shows some common wing attach points and dihedral angle. **[7]**

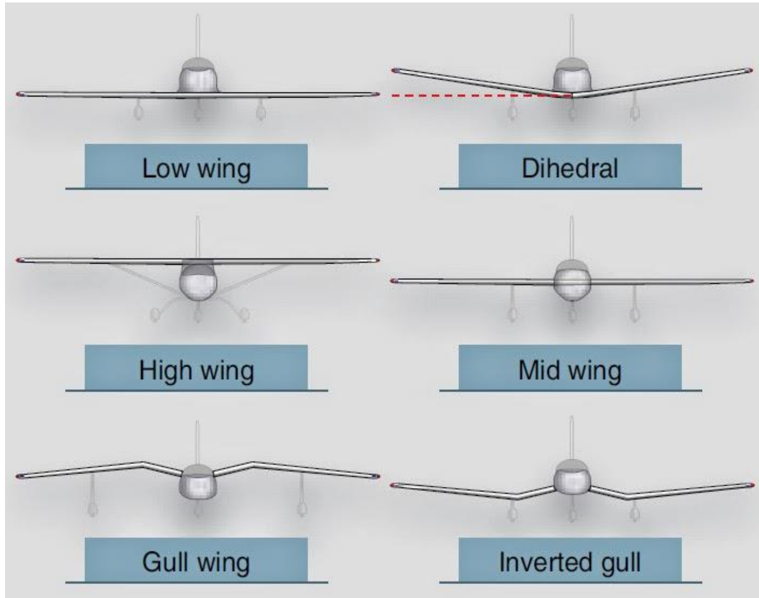


Figure 4: wing attach points and wing dihedrals

3.2.2 Airfoil [8] [9]

An airfoil is any surface producing more lift than drag when passing through the air at a suitable angle , they are employed on aircraft as wings to produce lift or as propeller blades to produce thrust and they are most often associated with production of lift.

Airfoils are also used for stability (fin), control (elevator), and thrust or propulsion (propeller or rotor).

- **Shape of the Airfoil**

The shape of the airfoil is perhaps the main characteristic that allows the Bernoulli Principle to hold true. The shape of airfoils, for the most part, curve up instead of curve down. This is important because this positive camber requires the air to increase its velocity above the airfoil because the curvature increases the distance from the leading edge to the trailing edge. This increase in velocity is associated with a decrease in pressure above the airfoil. The bottom surface of the airfoil is also curved, but does not alter the velocity of the air as much. This means that a net pressure force acts on the airfoil pushing up, which is the lift force. **[10]**

Aerofoil Terminology

Several terms are used to describe aerofoils **(Figure 5)** :

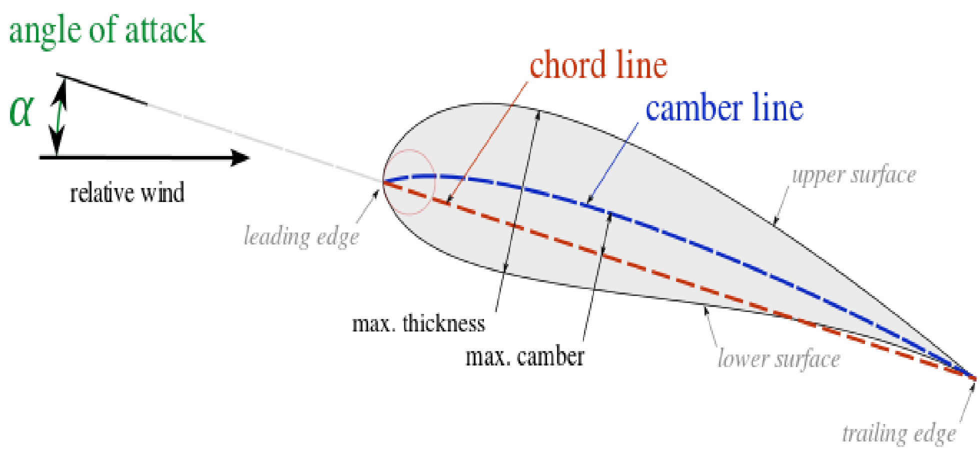


Figure 5: Aerodynamic terms of an airfoil

- **Leading Edge :** Is the front edge of an airfoil.
- **Trailing Edge :** Is the rearmost edge of an airfoil.
- **Chord :** The length of the chord line from leading edge to trailing edge; it is the characteristic longitudinal dimension of the airfoil section**.**
- **Mean Camber Line** : Is a line that connects the leading edge to the trailing edge, but it also shows the curve of the airfoil. Generally, it is midway from the top surface and the bottom surface at every location on the line.
- **The maximum thickness of the wing :** Is the maximum distance between the camber of upper surface and the camber of lower surface.
- **The angle of attack** : Is defined as the angle between the free stream air and the chord line connecting the leading edge and the trailing edge. For most cases, increasing the angle of attack increases the coefficient of lift. There is however a critical angle where the coefficient of lift becomes a maximum and an increase in lift is no longer possible. This creates separation of airflow

behind the airfoil and can be thought of as an aerodynamic stall, causing no lift generation and a large drag force on the airfoil. **(previous figure)**

3.3. Empennage

3.3.1 Definition

The empennage is a structure at the rear of an aircraft that provides stability during flight, in a way similar to the feathers on an arrow , it consists of the front (usually fixed) section of the tail plane is called the tail plane or horizontal stabiliser that is used to provide pitch stability , the rear section is called the elevator which is attached to the back of the horizontal stabilizer , The rudder that is attached to the back of the vertical stabilizer and of Trim tabs Trim tabs may be installed on the ailerons, the rudder, and/or the elevator. **[11] (figure 6)**

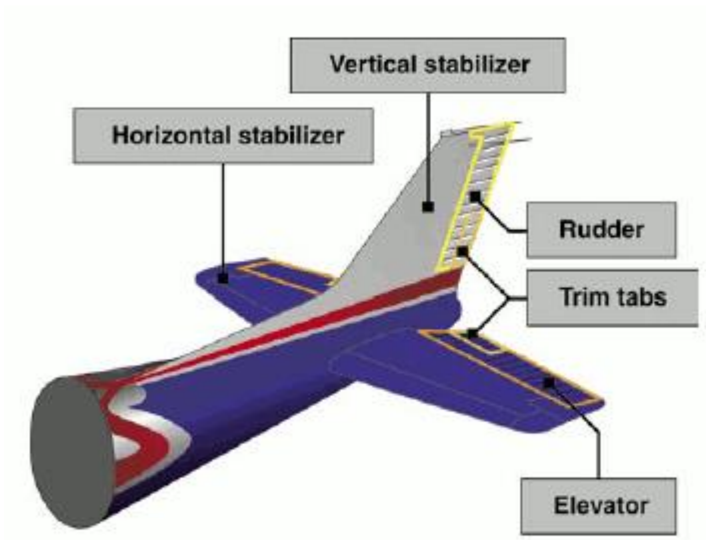


Figure 6: Empennage design

3.3.2 The function of all components of the empennage [12]

- **The horizontal stabilizer** : is a fixed wing section whose job is to provide longitudinal stability for the aircraft, to keep it flying straightis.

- **The vertical stabilizer :** Is also a fixed wing section and is intended to reduce aerodynamic side slip and provide direction stability.

- **The elevator :** creates a moment around the lateral axis (pitch) to move the nose of the airplane up and down during flight.
- **Trim tabs :** Are small, movable portions of the trailing edge of the control surface. These movable trim tabs, which are controlled from the flight deck, reduce control pressures.
- **The rudder:** principally creates a moment around the vertical axis (yaw) , it is used to move the airplane's nose left and right.

3.4. The landing gear

3.4.1 Definition

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear have wheels to facilitate operation to and from hard surfaces, such as airport runways.

3.4.2 Landing gear functions

The purpose of the landing gear is obvious - to allow the aircraft to return to the ground without causing damage to the structure. To accomplish this, the landing gear must not only react substantial forces and moments, but also provide a means to deliver the load safely into the airframe. In addition to this primary function, the landing gear must also permit the secondary functions listed below:

- It must allow the airplane to maneuver easily on the ground, and during taxi, take-off, and landing (steering).
- It must provide a means to slow down after touch-down or when maneuvering on the ground (braking).

- Large aircraft must feature a means for being towed and pushed by airport vehicles.down or when maneuvering on the ground (braking) and pushed by airport vehicles.
- It must feature enough wheels to allow the weight of the airplane to be distributed so that domage will not be inflicted on taxi and runways.

3.4.3 Landing Gear Disposition

The positioning of the landing gear is based primarily on stability considerations during taxiing, liftoff and touchdown, i.e., the aircraft should be in no danger of turning over on its side once it is on the ground. Compliance with this requirement can be determined by examining the takeoff/landing performance characteristics and the relationships between the locations of the landing gear and the aircraft cgcharacteristics and the relationships between the locations of the landing gear and the aircraft cg. **[13]**

3.4.4 Landing gear types:

All current high speed transport aircraft use the tricycle layout, but there are different general wheel arrangements possible. The tailwheel and the bicycle layout are other design solutions that could be considered.

- **Tricycle-Type Landing Gear:**

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear. In this type of Gears the main gears are mounted below the wings. COG is exactly in between the nose wheel nose Gear and main Gear **[14]**. **(Figure 7)**

Figure 7: Tricycle Landing Gear

The main gear on a tricycle-type landing gear arrangement is attached to reinforced wing structure or fuselage structure. The number and location of wheels on the main gear vary. Many main gear have two or more wheels. **(figure 8)**

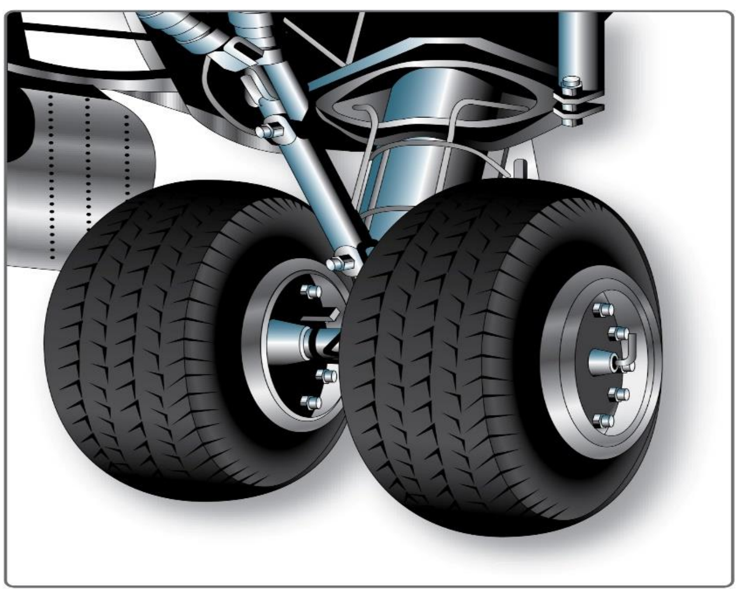


Figure 8: Dual main gear of a tricycle-type landing gear

Multiple wheels spread the weight of the aircraft over a larger area. They also provide a safety margin should one tire fail. Heavy aircraft may use four or more wheel assemblies on each main gear. When more than two wheels are attached to a landing gear strut, the attaching mechanism is known as a bogie. The number of wheels included in the bogie is a function of the gross design weight of the aircraft and the surface type on which the loaded aircraft is required to land **[15]**.

(Figure 9)

Figure 9: Triple bogie main landing gear assembly

The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gear is directed through mechanical linkage to the rudder pedals.

Advantages : [16] [17]

A tricycle gear airplane has many advantages:

- Dyniamically stable on the ground so it is easier to maneuver.
- Good ground control in crosswinds.
- Propeller better protected from ground strike.

- It allows more forceful application of the brakes during landings at high speeds without causing the aircraft to nose over.
- It permits better forward visibility for the pilot during takeoff, landing, and taxiing because of low deck angle.
- It tends to prevent ground looping (swerving) by providing more directional stability during ground operation since the aircraft's center of gravity (CG) is forward of the main wheels. The forward CG keeps the airplane moving forward in a straight line rather than ground looping.

Disadvantages : [17] [18]

- The tail is unprotected from land-scratching, so any over-inclination during take off or landing can cause a tailstrike which could end in serious structural damage.
- If the front wheel hits the ground first, it could end in a wheel-barrowing that could push all the aircraft weight over the front wheels to damage.
- Requires a minimum airspeed before the airplane can be rotated for T-O.
- Higher structural weight due to three highly loaded landing gear legs.
- More costly for the same reason.
- Higher cruise drag for the same reason .
- More complex steering mechanism.
- Subject to nosewheel shimmy that can be very damaging.
- Nosewheel shimmy more likely a design problem than on a tailwheel.

- **Tail Wheel-Type Landing Gear:**

Tail wheel-type landing gear is also known as conventional gear because many early aircraft use this type of arrangement. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly. A few early aircraft designs use a skid rather than a tail wheel. This helps slow the aircraft upon landing and provides directional stability. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design. The increased clearance of the forward fuselage offered by tail wheel-type landing gear is also advantageous when operating in and out of non-paved runways. Today, aircraft are manufactured with conventional gear for this reason and for the weight savings accompanying the relatively light tail wheel assembly **[16]. (Figure 10)**

Figure 10: Tail Wheel-Type Landing Gear

Advantages:

- Due to its position much further from the center of gravity, a tailwheel supports a smaller part of the aircraft's weight allowing it to be made much smaller and lighter than a nosewheel. As a result, the smaller wheel weighs less and causes less parasitic drag.
- Because of the way airframe loads are distributed while operating on rough ground, tailwheel aircraft are better able to sustain this type of use over a long period of time, without cumulative airframe damage occurring.
- If a tailwheel fails on landing, the damage to the aircraft will be minimal. This is not the case in the event of a nosewheel failure, which usually results in a prop strike. **[19]**
- Due to the increased propeller clearance on tailwheel aircraft less stone chip damage will result from operating a conventional geared aircraft on rough or gravel airstrips, making them well suited to bush flying.
- Tailwheel aircraft are more suitable for operation on skis.

- Tailwheel aircraft are easier to fit into and maneuver inside some hangars.

Disadvantages:

- Tailwheel aircraft are more subject to "nose-over" accidents due to injudicious application of brakes by the pilot.
- Tailwheel aircraft generally suffer from poorer forward visibility on the ground, compared to nose wheel aircraft. Often this requires continuous "S" turns on the ground looking out the side window to see where you are going .
- Tailwheel aircraft are more difficult to taxi during high wind conditions, due to the higher angle of attack on the wings which can then develop more lift on one side, making control difficult or impossible. They also suffer from lower crosswind capability and in some wind conditions may be unable to use crosswind runways or single-runway airports. **[19]**

- **Tandem Landing Gear:**

Few aircraft are designed with tandem landing gear. As the name implies, this type of landing gear has the main gear and tail gear aligned on the longitudinal axis of the aircraft.

Sailplanes commonly use tandem gear, although many only have one actual gear forward on the fuselage with a skid under the tail. A few military bombers, such as the B-47 and the B-52, have tandem gear, as does the U2 spy plane. The VTOL Harrier has tandem gear but uses small outrigger gear under the wings for support. Generally, placing the gear only under the fuselage facilitates the use of very flexible wings **[20]**. **(figure 11)**

Figure 11: Tandem Landing Gear

Advantages: [17]

- Eliminates reinforcement for landing gear hard points from the wing.
- Low weight due to a single main landing gear versus multip.
- Less costly for the same reason.
- Less cruise drag for the same reason.
- ground loads transferred directly to fuselage throught a short load path.

Disadvantages: [17]

- Requires outriggers or wingtip skids for ground stability.
- Outriggers may require wider taxiways.
- Poor ground control, especially in crosswind.
- Reduced propeller ground clearance.
- Reduced AOA (Angle of attack) for flare.
- Retraction of main gar forward of CG (center of gravity) is challenging because of space constraints .
- Higher T-O (Take-off) speed to make up for the limited ability to rotate.
- Not intended for extensive taxiing.

3.4.5 Classification

Further classification of aircraft landing gear can be made into two types of landing gear systems are used in aircraft. One is a fixed type and the other one is a retractable type.

- **Fixed Gear:**

Fixed landing gear systems are generally used for small and slow-speed aircraft. In this type the landing gears remain extended throughout the flight phase. This type of system induces friction or parasitic drag, imposing some limitations on the aircraft performance. However, this system involves fewer components, giving an overall weight advantage and also being relatively simple in construction.

In order to overcome the limitation of aircraft speeds due to the onset of parasitic drag, retractable landing gear types are used. **[21]**

The advantage of fixed: [22] [23]

The advantage of fixed gears compared to retractable gears is:

- the low weight
- low complexity
- low cost
- Always deployed
- The advantage of simplicity combined with low maintenance

The disadvantage of fixed: [22] [23]

The main disadvantage is the high aerodynamic drag.

- **Retractable Landing Gear:**

A retractable gear is designed to streamline the airplane by allowing the landing gear to be stowed inside the structure during cruising flight.

aircraft fly at supersonic speed, it is essential to reduce the drag imposed by landing gears and other structural elements protruding outside the aircraft. Hence mechanisms are provided to retract and stow the landing gear either in the fuselage structure or in wing compartments. Retraction and extension actuators are used for this purpose. The contour surfaces of the follow-up doors of the landing gear are flush with the fuselage or wing surfaces for ensuring a smooth flow of air during flight, thereby reducing the drag. The doors are operated by hydraulic jacks. Suitable up-locks and down-locks are used to hold the landing gear firmly in the retracted and extended modes. respectively. These locks are attached to the airframe surfaces and are operated either hydraulically or electrically. The sequence of landing gear operation is monitored and controlled by an electronic control unit (ECU). This type of system is highly complex in nature and greatly increases the part count. The reliability of this type of system must be very high to avoid catastrophic failures. Emergency Exteusion Systems Design must have a provision for emergency extension of the landing gear if the main system fails for any technical reasons. Some aircraft will have a handle inbuilt in the cockpit and connected to the up-locks through mechanical linkages. Upon pulling the handie, it releases the up-locks and allows the landing gear to free-fall to the extended position, which is then firmly held by down-locks. Other means of emergency extension include pneumatic power to unlock the up-locks. **[21]**

Advantages: [22] [23]

The primary benefits of being able to retract the landing gear are:

- Increased climb performance.
- Higher cruise airspeeds due to the resulting decrease in drag.

Disadvantages: [22] [23]

- Increased weight.
- Increased cost.
- Limited to high performance aircraft.

4- Main and nose Landing Gear

4.1. Nomenclature of landing gear

Landing gears are located on the under carriage of aircraft. The front landing is called as nose landing gear while main landing gear is located on rear side of aircraft. Nose landing gear consists of actuators to retract and extension; drag brace to lock the pins metering pin extension; trunnion; rotation lockpins; aft braces; oleo cylinder; oleo piston; brake assembly; tires and wheels.**[24]**

4.2 Main Landing Gear

The landing gear is electrically controlled and hydraulically operated by the green hydraulics system. Two Landing Gear Control Interface Units (LGCIU) control and monitor the landing gear and landing gear doors. The hydraulic actuators move the landing gear to its up/down position. The landing gear indication panel and the Electronic Centralized Aircraft Monitor (ECAM) display the position of the landing gear during extension and retraction.

The main landing gears are mounted under the wing and retract sideways into the fuselage. The retraction of the landing gear legs is done by hydraulic actuators. The gears are kept retracted in the landing gear bay by an up lock mechanism. **[25]**

4.3 Nose landing gear

4.3.1 Definition

The main difference between the main gears and nose gear is the forward retraction motion into the fuselage. The nose landing gear is also electrically controlled and hydraulically operated by the green hydraulic system. **[25]**

4.3.2 Mechanical construction

The nose gear is equipped with two wheels and retracts forward into the front fuselage of the airplane. A two-piece drag strut assembly with a lock stay keeps the gear locked in extension position. A hydraulic actuator in normal operation controls the lock stay. If the hydraulic actuator has a failure the two springs will pull the gear down for down lock. When the nose gear retracts, the hydraulic cylinder of the lock stay retracts which will fold the lock stay. The nose gear actuator retracts the gear into the front fuselage. **[25]**

4.3.3 Nose Wheel Steering Systems [26]

The nose wheel on most aircraft is steerable from the flight deck via a nose wheel steering system. This allows the aircraft to be directed during ground operation. A few simple aircraft have nose wheel assemblies that caster. Such aircraft are steered during taxi by differential braking.

- **Small Aircraft**

Most small aircraft have steering capabilities through the use of a simple system of mechanical linkages connected to the rudder pedals. Push-pull tubes are connected to pedal horns on the lower strut cylinder. As the pedals are depressed, the movement is transferred to the strut piston axle and wheel assembly which rotates to the left or right. **[Figure 12]**

Figure 12: Nose wheel steering on a light aircraft often uses a push-pull rod system connected to the rudder pedals.

- **Large Aircraft**

Due to their mass and the need for positive control, large aircraft utilize a power source for nose wheel steering. Hydraulic power predominates. There are many different designs for large aircraft nose steering systems. Most share similar characteristics and components. Control of the steering is from the flight deck through the use of a small wheel, tiller, or joystick typically mounted on the left side wall. Switching the system on and off is possible on some aircraft. Mechanical, electrical, or hydraulic connections transmit the controller input movement to a steering control unit. The control unit is a hydraulic metering or control valve. It directs hydraulic fluid under pressure to one or two actuators designed with various linkages to rotate the lower strut. An accumulator and relief valve, or similar pressurizing assembly, keeps fluid in the actuators and system under pressure at all times. This permits the steering actuating cylinders to also act as shimmy dampers. A follow-up mechanism consists of various gears, cables, rods, drums, and/or bell-crank, etc. It returns the metering valve to a neutral position once the steering angle has been reached. Many systems incorporate an input subsystem from the rudder pedals for small degrees of turns made while directing the aircraft at high speed during takeoff and landing. Safety valves are typical in all systems to relieve pressure during hydraulic failure so the nose wheel can swivel. The following explanation accompanies **Figures 13, 14, and 15**, which illustrate a large aircraft nose wheel steering system and components. These figures and explanation are for instructional purposes only. The nose wheel steering wheel connects through a shaft to a steering drum located inside the flight deck control pedestal. The rotation of this drum transmits the steering signal by means of cables and pulleys to the control drum of the differential assembly. Movement of the differential assembly is transmitted by the differential link to the metering valve assembly where it moves the selector valve to the selected position. This provides the hydraulic power for turning the nose gear. As shown in **Figure 14**, pressure from the aircraft hydraulic system is directed through the open safety shutoff valve into a line leading to the metering valve. The metering valve then routes the pressurized fluid out of port A, through the right turn alternating line, and into steering cylinder A. This is a one-port cylinder and pressure forces the piston to begin extension. Since the rod of this piston connects to the nose steering spindle on the nose gear shock strut which pivots at point X, the extension of the piston turns the steering spindle gradually toward the right. As the nose wheel turns, fluid is forced out of steering cylinder B through the left turn alternating line and into port B of the metering valve. The metering valve directs this return fluid into a compensator that routes the fluid into the aircraft hydraulic system return manifold.

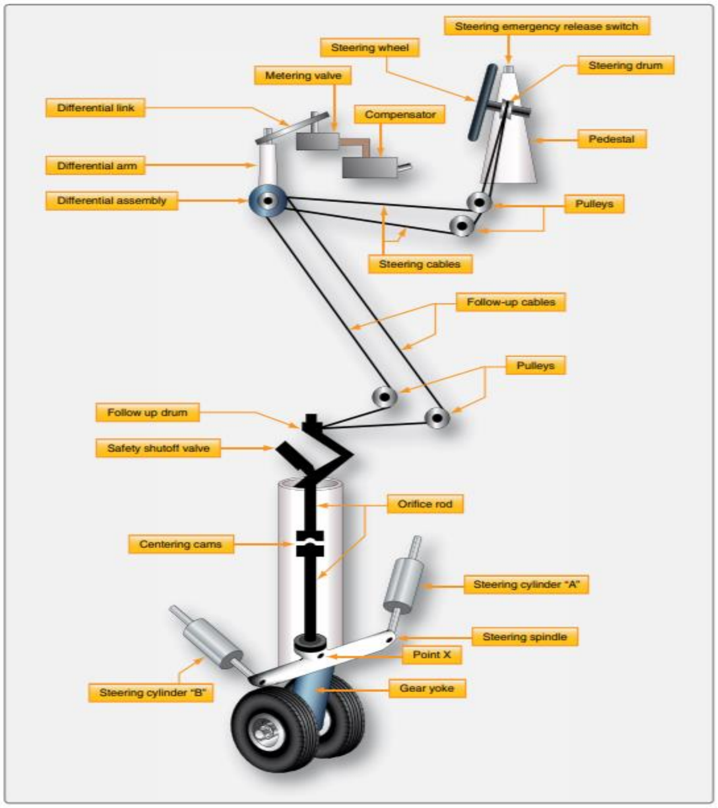


Figure 13: Example of a large aircraft hydraulic nose wheel steering system with hydraulic and mechanical units

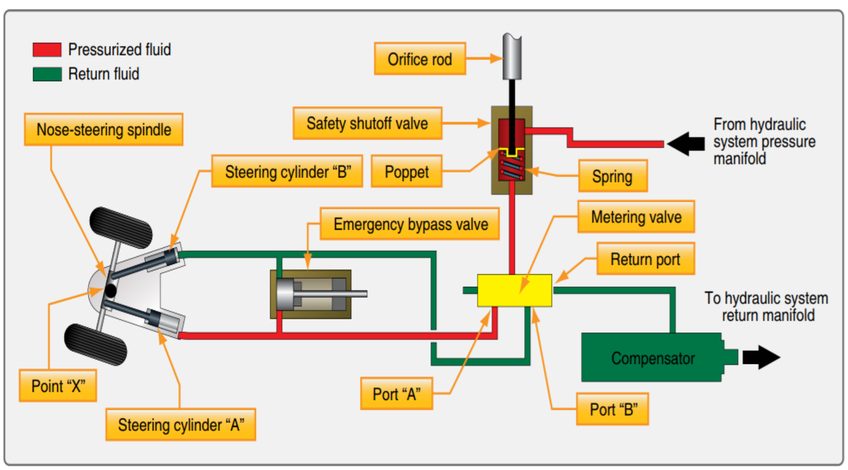


Figure 14: Hydraulic system flow diagram of large aircraft nose wheel steering system.

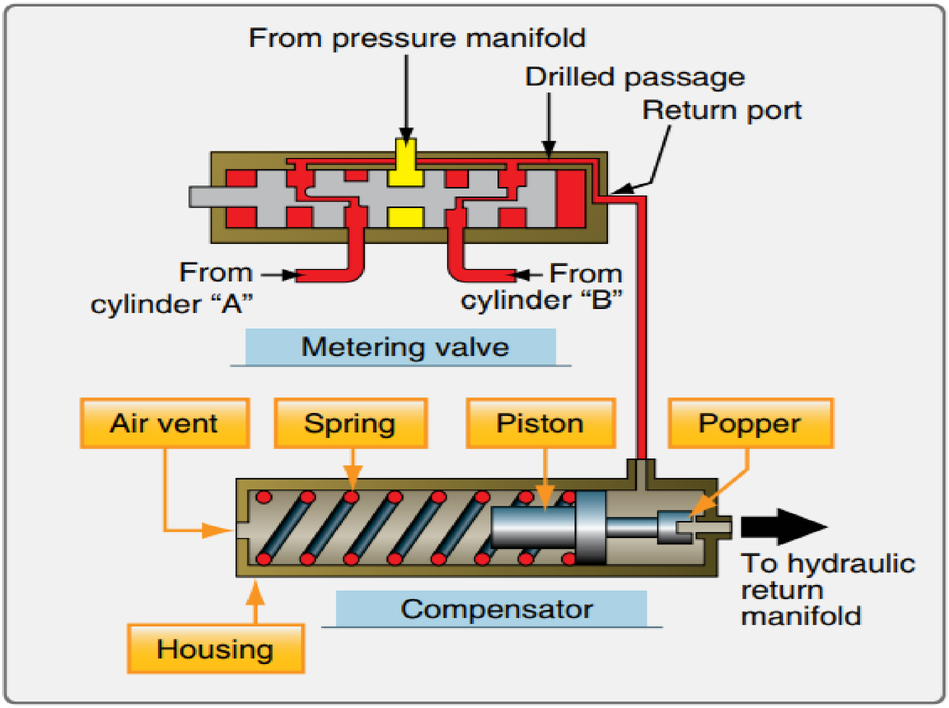


Figure 15: Hydraulic system flow diagram of large aircraft nose

As described, hydraulic pressure starts the nose gear turning. However, the gear should not be turned too far. The nose gear steering system contains devices to stop the gear at the selected angle of turn and hold it there. This is accomplished with follow-up linkage. As stated, the nose gear is turned by the steering spindle as the piston of cylinder A extends. The rear of the spindle contains gear teeth that mesh with a gear on the bottom of the orifice rod. **[Figure 13]** As the nose gear and spindle turn, the orifice rod also turns but in the opposite direction. This rotation is transmitted by the two sections of the orifice rod to the scissor follow-up links located at the top of the nose gear strut. As the follow-up links return, they rotate the connected follow-up drum, which transmits the movement by cables and pulleys to the differential assembly. Operation of the differential assembly causes the differential arm and links to move the metering valve back toward the neutral position. The metering valve and the compensator unit of the nose wheel steering system are illustrated in **Figure 15**. The compensator unit system keeps fluid in the steering cylinders pressurized at all times. This hydraulic unit consists of a three-port housing that encloses a spring-loaded piston and poppet. The left port is an air vent that prevents trapped air at the rear of the piston from interfering with the movement of the piston. The second port located at the top of the compensator connects through a line to the metering valve return port. The third port is located at the right side of the compensator. This port connects to the hydraulic system return manifold. It routes the steering system return fluid into the manifold when the poppet valve is open. The compensator poppet opens when pressure acting on the piston becomes high enough to compress the spring. In this system, 100 psi is required. Therefore, fluid in the metering valve return line is contained under that pressure. The 100 psi pressure also exists throughout the metering valve and back through the cylinder return lines. This pressurizes the steering cylinders at all times and permits them to function as shimmy dampers.

4.3.4 Shimmy

- **Definition**

Shimmy is an oscillation in aircraft landing gear that can occur both on landing and take-off, typically in a band of velocities**.** It causes excessive wear on components and can cause accidents. The nose wheel is roughly like a caster on a shopping trolley: the horizontal axle of the wheel is mounted in an assembly that is free to rotate about a vertical axis. Shimmy is (or at least includes) oscillation of the wheel assembly about this vertical axis.

- **CAUSES OF SHIMMY:**
  - Uneven tyre pressures.
  - Unevenly worn tyres.
  - Unbalanced wheels.
  - Worn shimmy damper or wheel bearings.
  - Worn torque link will make things worse.
- **ANTI-SHIMMY DESIGNS :**
  - Twin wheels.
  - Marstrand tyres.
  - Shimmy damper (Light aircraft - friction damper Large aircraft - Hydraulic dampers or within steering apparatus).
  - Limiting the castoring ability of the nosewheel.

5- Center of Gravity (CG)

In an aircraft, the centre of gravity (CG) is the point at which the aircraft would balance were it possible to suspend it at that point. As the location of the centre of gravity affects the stability of the aircraft, it must fall within specified limits that are established by the aircraft manufacturer. Both lateral and longitudinal balance are important, but the primary concern is longitudinal balance; that is, the location of the CG along the longitudinal axis. **[27]**

6- Mean Aerodynamic Chord (MAC)

IS the width of the wing, or straight-line distance from the leading edge to the trailing edge, on an airplane is known as the chord. If the leading edge and the trailing edge of a wing are parallel, the chord is equal at all points along the entire length of the wing. The average length of the chord, or MAC, of a tapered wing is more complicated to define.

The MAC, as seen in **Figure**, is the chord of an imaginary airfoil that has the same aerodynamic characteristics as the actual airfoil. You can also think of it as the chord drawn through the geographic center of the plan area of the wing.

the MAC is established by the manufacturer, defining its leading edge (LEMAC) and trailing edge (TEMAC) in terms of inches from the datum. **[Figure]** The CG location and various limits are then expressed in percentage of the chord or percent MAC. In order to relate the percent MAC to the datum, all weight and balance information includes two items: the MAC length in inches and the location of the LEMAC in inches from the datum. **[28]**

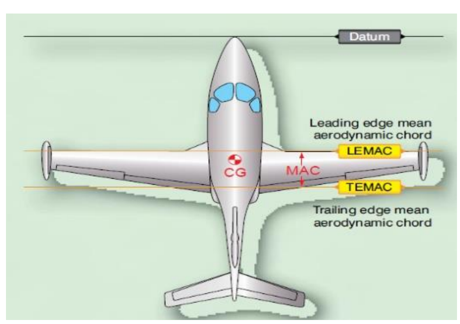


Figure 16: The MAC is the chord drawn through the geographic center of the plan area of the wing.

The relative positions of the CG and the aerodynamic center of lift of the wing have critical effects on the flight characteristics of the aircraft. Consequently, relating the CG location to the chord of the wing is convenient from a design and operations standpoint. Normally, an aircraft has acceptable flight characteristics if the CG is located somewhere near the 25 percent average chord point. This means the CG is located one-fourth of the distance back from the LEMAC to the TEMAC. Such a location places the CG forward of the aerodynamic center for most airfoils.

7- Newton’s Third Law of Motion : Law of Action Reaction

This is Newton's third law of motion in Latin. It is commonly referred to as the law of action-reaction. This law states, "To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal and directed to contrary parts. Newton used the words action and reaction to mean force. The term reaction force refers to the force that one object exerts on another. This law explains the origin of the external forces required to change motion. More simply stated, Newton's third law says that if an object (A) exerts a force on another object (B). the other object (B) exerts the same force on the first object (A) but in the opposite direction. The effects of these forces are not canceled by cach other because they act on different objects. Another important point is that it is the forces that are equal but opposite, not the effects of the forces.

If an object exerts a force on another object, the other object exerts the same force on the first object but in the opposite direction.

8- Tricycle Landing gear reaction Loads

this figure shows loads acting on a Tricycle Landing Gear Reaction Loads gear configuration as it moves at a constant speed during the ground run.

We want to determine the reactin loads of the nose and main landing gear , denoted by RN and RM , respectively.

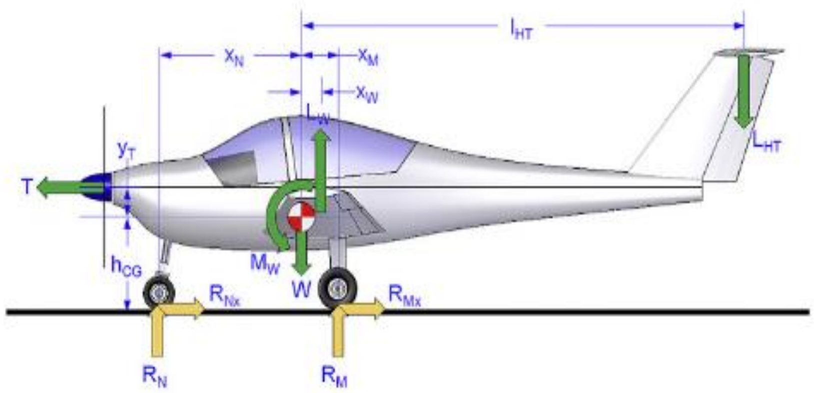


Figure 17: Landing gear configuration

RNX: The horizontal ground friction applied to the Nose Landing Gear

RMX: The horizontal ground friction applied to the Main Landing Gear

RN: The reaction load of the nose landing gear

RM: The reaction load of the main landing gear

W: The weight of aircraft

MW: Moment of wing about the center gravity

YT: The distance between the center gravity and thrust

hcg: Height of center of gravity above ground

T: The thrust :

Lw: Lift force of wing

LHT: Lift of horizontal tail

lht : The distance from the gravity center to the center of the center of horizontal tail

XM : The distance from the center of garvity to the main landing gear

XN : The distance from the center of garvity to the nose landing gear

XW : The distance from the gravity center to the center of the wing

- **Begin by defining the horizontal ground friction force:**

RNX+RMX= μ.(RN+RM)

- **Sum forces in the vertical (z) direction, such that positive forces act upward:**

∑FZ=0 RN+RM+LW-W-LHT=0

- **This yields the main landing gear reaction force RM:**

RM=W+LHT-LW-RN

- **Sum moments about the center of gravity (CG), such that nose pitch-up moments are positive (note that the ground friction RMX, and RNX are written explicitly as μ.(RN+RM).hcg:**

∑MCG=0 - T.YT+RN.XN-RM.XM-LW.XW+LHT.lht- μ.(RN+RM).hcg+MW=0

- **Note that typically the value of the wing pitching moment, Mw, is negative. Expand and rearrange the RN and RM terms:**

-T.YT+RN.XN- μ.RN.hcg-RM.XM- μ.RM.hcg-LW.XW+LHT.lht+MW=0

- **Simplify in terms of RN and RM:**

-T.YT+RN.(XN- μ.hcg)-RM.(XM- μ.hcg)-LW.XW+LHT.lht+MW=0

- **Inserting Equation (III) for RM yields:**

-T.YT+RN.(XN- μ.hcg)-(W+LHT-LW-RN).(XM- μ.hcg)-LW.XW+LHT.lht+MW=0

- **Rearrange to combine the term RN yields:**

-T.YT+RN.(XN- μ.hcg)+ RN.(XM- μ.hcg)-(W+LHT-LW).(XM- μ.hcg)-LW.XW+LHT.lht+MW=0

- **Simplify further tonyield:**

-T.YT+RN.(XN +XM-2. μ.hcg)-(W+LHT-LW).(XM- μ.hcg)-LW.XW+LHT.lht+MW=0

- **Finally , solving for the nose gear reaction force, RN, yields:**

$$RN = \frac{T.YT + (W + LHT - LW).(XM - \mu.hcg) + LW.XW - LHT.lHT - MW}{XN + XM - 2.\mu.hcg}$$

9- Properties of materials

9.1 Physical properties

- **Melting temperature** .
- **Density:** the amount of material per unit volume normally expressed in kg /m^3 but often in kg / dm^3.
- **Coefficient of linear expansion:** It is the elongation experienced by the metal during a scaling.
- **Thermal conductivity:** It is the ability of a body to transmit heat more or less well. Good drivers are: copper, silver, aluminum ...
- **Magnetism:** It is the classification of materials according to the value of their induction and the direction of the field: ferromagnetic, diamagnetic, paramagnetic or nonmagnetic materials.

9.2. Mechanical Properties

Mechanical properties including elasticity, yield strength, ultimate tensile strength and ductility are usually part of material specifications and are obtained by tensile testing. These properties are described in more detail below as well as being shown on the diagram.

- **Elasticity/Stiffness :** This is a measure of elastic deformation of a body under stress which is recovered when the stress is released. The ratio of stress to strain in the elastic region is known as stiffness or modulus of elasticity (Young's Modulus). When the stress goes beyond the elastic limit the material will no longer return completely to its original dimension.
- **Toughness:** It is the ability of a Corp to resist deformation or breakage under a continuous effort.
- **Hardness :** The resistance to abrasion, deformation, scratching or to indentation by another hard body. This property is important for wear resistant applications.

- **Resilience:** Ability to withstand sudden stresses or shocks without breaks.
- **Endurance:** Ability of a body to undergo variable efforts in size and direction with repetition of these efforts.
- **Plasticity:** It is the ability of a body to deformation without tension or rupture (examples: boiler parts).
- **Ductility:** It is the ability of a body to be stretched into thin threads.
- **Fluidity:** It is the ability of a body to be melted and to easily fill the mold in which it is poured (castings).

9.3. The chemical properties:

- **Composition:** pure metal or alloy, nature and content of constituents, heterogeneity.
- **Corrosion resistance:** behavior of the metal against acids or corrosive agents (moisture, steam, dissolved salts ...)

10- Conclusion

At the beginning of this chapter 1 gave an overview of the history of the aviation and some landing gear projects that are already done, and the role of the landing gear and how it has developed throughout the years.

And finally this chapter discussed Properties of materials, all the forces applied on the nose and main landing gear and how to calculate them in a general way.

Chapter II: General principle of finite element method

1- Introduction:

The current evolution of the technology leads the engineer to carry out more and more complex projects costly and subject to security constraints more and more severe. We are thinking of space projects, aeronautics in which safety is vital.

To dominate these projects, the engineer needs models that allow him to simulate the behavior of complex physical systems through partial differential equations.

The finite element method and one of the most used methods today to effectively solve these equations. This is a very general method that applies to the majority of problems encountered in practice: stationary or non-stationary, linear or non-linear problems.

2- Historical

- Analysis of structures born around 1850.
- RDM (Material Resistance) "manual" calculations.
  MAXWELL, CASTIGLIANO, MOHR

- Concept of finite elements born around 1940.
  NEWMARK, HRENIKOFF, MC HENRY, CURRENT

- Real development since 1960.
  Numerical calculation on computer.

3- Definition of a finished element

Finite Element Method (FEM) is one of the applied mathematics tools. The aim of setting up, using the principles inherited from the variational formulation, makes it possible to discretely solve a partial differential equation (PDE) for which a "sufficiently" reliable approximate solution is sought. In general, this EDP relates to a function u, defined on a domain. It includes conditions at the edges to ensure existence and uniqueness of a solution.

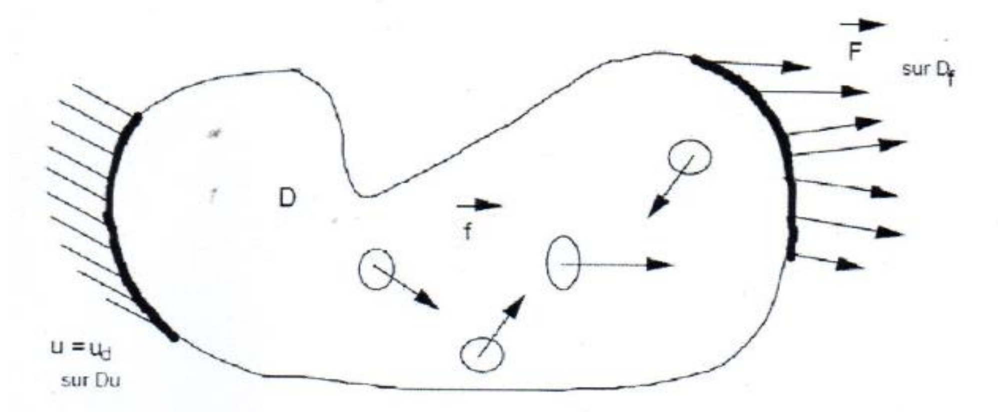


Figure 18: Continuous medium and discretized medium

In structural computation, a finite element is characterized by two matrices:

- The stiffness matrix [K]
- The mass matrix [M]

4- Formulation of a finite element:

4.1. Definitions and notations:

4.1.1 Displacement: {U}

It is a vector of which each component is also called degree of freedom (dof).

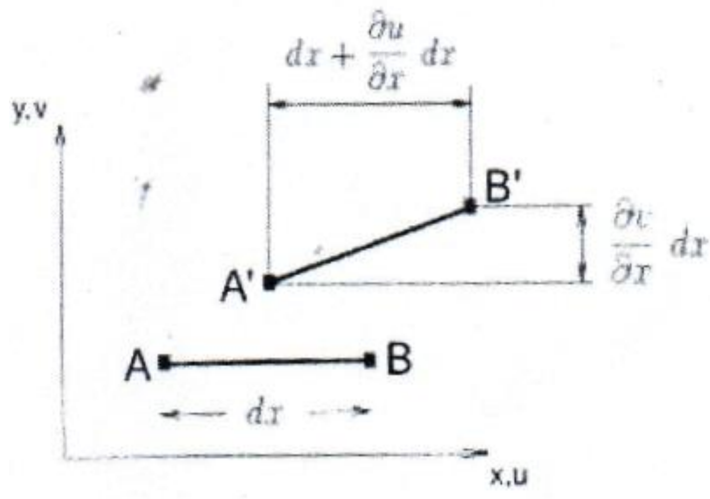
- dof of translation: Ux, Uy, Uz
- dof of rotation: θx, θy, θz

4.1.2 Deformation: {ε}

This is the ratio of elongation to initial length.

$$(A'B')^2 = (dx + \frac{\partial u}{\partial x} dx)^2 + (\frac{\partial u}{\partial x} dx)^2$$

In small deformations, we have :



$\epsilon_x = \frac{A'B' - AB}{AB}$

As AB= dx,

We have A'B'= (1+ ϵ_x) dx

=> 2 ϵ_x +$\epsilon_x{}^2$ = $2\frac{\partial u}{\partial x} + \frac{\partial u^2}{\partial x} + \frac{\partial v^2}{\partial x}$

$\epsilon_x = \frac{\partial u}{\partial x}$

4.1.3. Constraint:

Represent the internal forces that apply in the structure.

- **σ_{11}, σ_{22}, σ_{33}:** Normal constraints
- **σ_{12}, σ_{13}, σ_{23}:** Shear stress

A stress is homogeneous at a pressure (N/m²).

There is a coordinate system in which [σ] is a diagonal matrix:

$$[\sigma] = \begin{pmatrix} \boldsymbol{\sigma}_x & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{\sigma y} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{\sigma z} \end{pmatrix}$$

$\boldsymbol{\sigma}_x, \boldsymbol{\sigma y}, \boldsymbol{\sigma z}$: are called the main constraints.

4.1.4. Stress-strain relationships

$$\begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{31} \end{pmatrix} = \frac{E\,(1-\nu)}{(1+\nu)(1-2\nu)} \begin{pmatrix} 1 & \frac{\nu}{1-\nu} & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & 1 & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ & & 1 & 0 & 0 & 0 \\ & & & \frac{(1-2\nu)}{2(1-\nu)} & 0 & 0 \\ & & & & \frac{(1-2\nu)}{2(1-\nu)} & 0 \\ & & & & & \frac{(1-2\nu)}{2(1-\nu)} \end{pmatrix} \begin{pmatrix} \in_{11} \\ \in_{22} \\ \in_{33} \\ \gamma_{12} \\ \gamma_{23} \\ \gamma_{31} \end{pmatrix}$$

E : young module (N/m^2)

υ : Poisson coefficient (without unit)

we sometimes use the shear modulus : $\boldsymbol{G} = \frac{\boldsymbol{E}}{\mathbf{2(1+\boldsymbol{\upsilon})}}$ For an isotropic material, there are only 2 independent parameters. There are 6 for a transverse isotropic material, 9 for an orthotropic material and 21 for an anisotropic material

In matri***x*** notation, we write: $\{\boldsymbol{\sigma}\} = [\boldsymbol{D}]\ \{\in\}$

[D] called the elasticity matrix of the material.

4.1.5 Deformation energy: W

$$\boldsymbol{W} = \frac{\mathbf{1}}{\mathbf{2}} \int_{\boldsymbol{v}} \boldsymbol{\sigma}. \in \cdot\, \boldsymbol{dv}$$

4.1.6 Work of a force:

It is the product of force by moving its point of application:

$$\boldsymbol{T}_{\mathrm{F}} = \frac{\mathbf{1}}{\mathbf{2}}\mathrm{F}.\boldsymbol{U}_{\mathrm{F}}$$

4.1.7 Moment

It is a force applied a degree of freedom of rotation type.

4.2 Fundamental Equations

<u>Local equilibrium equations :</u>

$$\frac{\partial \sigma_{\mathrm{x}}}{\partial x} + \frac{\partial \sigma_{\mathrm{xy}}}{\partial y} + \frac{\partial \sigma_{\mathrm{xz}}}{\partial z} + \boldsymbol{F}_{\mathrm{x}} = \mathbf{0}$$

$$\frac{\partial \sigma_{\mathrm{y}}}{\partial y} + \frac{\partial \sigma_{\mathrm{xy}}}{\partial x} + \frac{\partial \sigma_{\mathrm{yz}}}{\partial z} + \boldsymbol{F}_{\mathrm{y}} = \mathbf{0}$$

$$\frac{\partial \sigma_{\mathrm{z}}}{\partial z} + \frac{\partial \sigma_{\mathrm{zx}}}{\partial x} + \frac{\partial \sigma_{\mathrm{zy}}}{\partial y} + \boldsymbol{F}_{\mathrm{z}} = \mathbf{0}$$

- **<u>Deformation-displacement relationships :</u>**

$$\in_{\mathrm{x}} = \frac{\partial U}{\partial x} \qquad \in_{\mathrm{y}} = \frac{\partial U}{\partial y} \qquad \in_{\mathrm{z}} = \frac{\partial U}{\partial z}$$

$$\boldsymbol{\gamma}_{\mathrm{xz}} = \frac{\partial w}{\partial x} + \frac{\partial \mu}{\partial z}$$

$$\boldsymbol{\gamma}_{\mathrm{xy}} = \frac{\partial \mu}{\partial y} + \frac{\partial v}{\partial x}$$

$$\boldsymbol{\gamma}_{\mathrm{yz}} = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}$$

Symbolically, we write : $\{\in\} = [\boldsymbol{S}]\{\boldsymbol{U}\}$

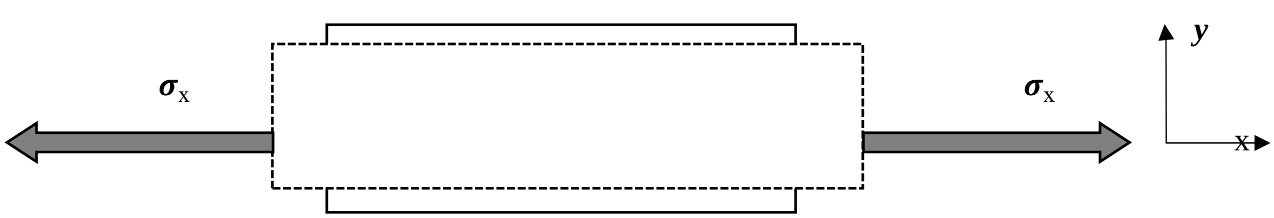


Figure 19: Meaning of the Poisson's ratio

If a stress is applied to the bar $\boldsymbol{\sigma}_x$, a narrowing is observed in the y direction corresponding to a deformation $\frac{-\boldsymbol{\nu\sigma}_x}{\boldsymbol{E}}$.

Some common values:

Steel : E = 2,1E11 N/m^2 = 210 000 MPa ν =0,3

Aluminum : E = 7E10 N/m^2 = 70 000 MPa ν =0,3

<u>Note :</u>

We always have $-1 \leq \nu \leq 0{,}5$ when $\nu \longrightarrow 0{,}5$, the material is said to be incompressible.

IV. Calculation process (static case)

- Mesh
- Construction of the stiffness matrix of each element $[K^e]$
- Assembly of the global matrix [K]
- Construction of the loader {F}
- Elimination of certain degrees of freedom (if necessary)
- Resolution : $\{U\} = [K^{-1}]\ \{F\}$
- Calculation of quantities derived from {U}

$\{\in^e\} = [B^e]\ \{U^e\}$

$\{\ \sigma^e\} = [D^e]\ \{\in^e\}$

$W^e = \frac{\mathbf{1}}{\mathbf{2}}\ \{\in^e\}^T\{\ \sigma^e\}$

5- General formulation (direct method)

The approach is as follows:

We express the displacement {u(x)} at any point of the element as a function of displacements at the nodes $\{u(x)\} = [N(x)]\ \{U\}$

Deformations are expressed as a function of displacements $\{\in^e\} = [S]\ \{u(x)\}$

Hence

$\{\in\boldsymbol{(x)}\} = [S]\ \{N(x)\}\ \{U\} = [B(x)]\ \{U\}$

We write the constitutive law of the material that links the constraints to deformation:

$\{ \sigma (x) \} = [D] \{\epsilon(x)\}$

It is written that the work of the external forces applied to the structure for a virtual displacement where δU is equal to the work of constraints for the same displacement:

$\{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}\{F\} = \int_V \{ \boldsymbol{\delta \epsilon}\}^{\boldsymbol{T}}\{\sigma\}\, dv$

By explaining, we have:

$\{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}\{F\} = \{ \boldsymbol{\delta U}\}^{\boldsymbol{T}}.(\int_V [\boldsymbol{B}]^{\boldsymbol{T}}[D][B]\, dv).\{U\}$

As this relation is true for any virtual displacement, we deduce:

$\{F\} = [K]\{U\}$

With[k] in its more general form

$[k] = \int_V [\boldsymbol{B}]^{\boldsymbol{T}}[D][B]\, dv$

Note:

The relation above shows that [K] is symmetrical.

The current term Kij of the matrix corresponds to the force exerted on the node j when a unit displacement of the node i is imposed.

The symmetry of [K] which is written Kij = Kji corresponds mechanically to Maxwell-Betti's reciprocity theorem.

What will differentiate the different types of finite elements?

The choice of N (x) functions

The nature of the operator S (connecting deformations and displacements) which depends on the type of elastic theory used:

- Theory of beams
- Plate theory
- Theory of stress or plane strain

- Shell theory
- Theory of the bodies of revolution
- Theory of 3D elasticity

Note:

We have described the process of formulation of a finite element within the framework of the direct method (also called method of displacements). There are other approaches:

- The weighted residue method,
- The application of the principle of virtual work or virtual powers,
- Minimization of potential energy.

All these approaches are equivalent and lead to the construction of the same stiffness matrix.

6- Choice of a mesh

The mesh of the domain makes it possible to define a paving whose pavements are the finite elements. A finite element is the data of an elementary cell and basic functions of the approximation space whose support is the element, and defined in such a way as to be interpolating

Example of the mesh:

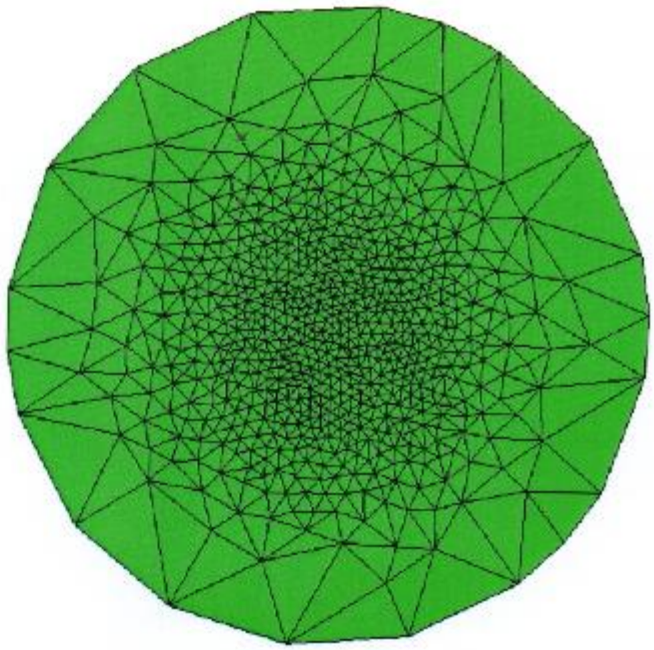


Figure 20: Triangular surface mesh

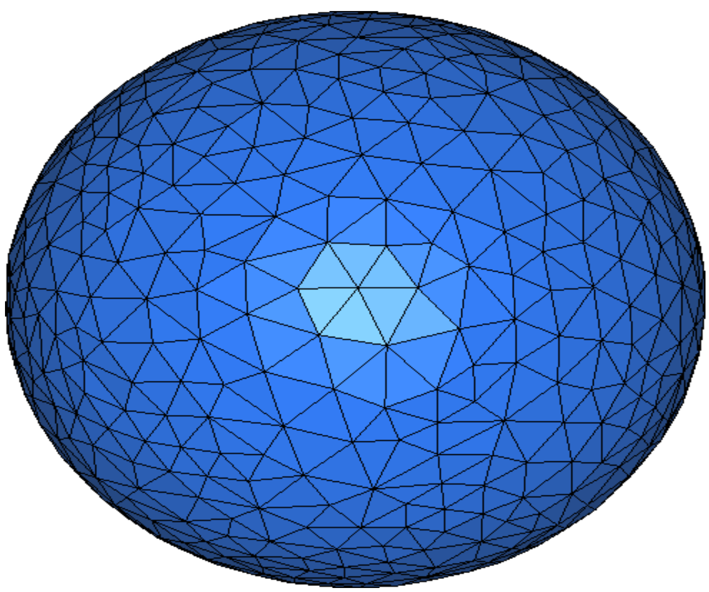


Figure 21: Triangular mesh volume

The finite element method is based on a division of the space according to a mesh. Usually one chooses a square or triangular mesh but nothing forbids to choose meshes more complex. It is also not necessary that the mesh is regular and there is a tendency to tighten the mesh near the places of interest (for example in places where one thinks that the solution will vary a lot), however it is necessary to make sure you have weakly distorted elements (move closer to a regular polygon). The more this mesh is narrowed, the more the solution obtained by the finite element method will be precise and close to the "real" solution of the partial derivative equation.

7- Basic function:

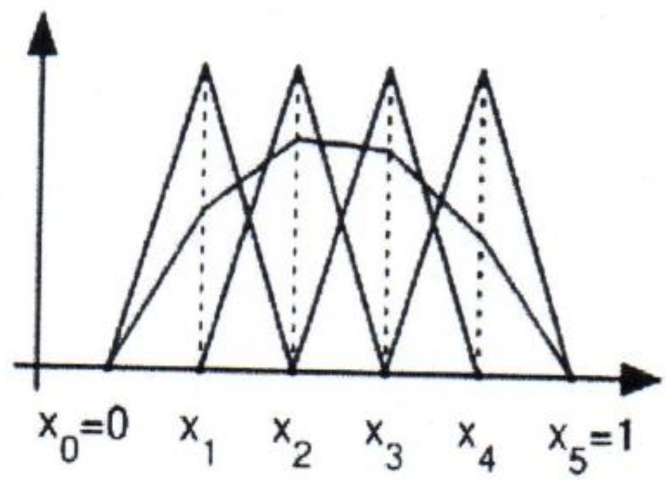


Figure 22: Basic function in dimension 1

The x_i are the nodes of the network.

We must then take a base of functions "adapted" to the mesh. Several choices are then possible. In general, the basic functions used for the finite elements are interpolating, that is, the nodal values are the values of quantities unknown to the nodes.

The simplest is the use of Lagrange polynomials. In this method the basic functions are worth 1 to one node of the mesh and 0 to all others. The base function i is then the function of 1 at node i and 0 on the other nodes and which is polynomial on each element. An example of such functions is shown in dimension 1 beside. There are as many basic functions by elements as number of nodes.

We call element the data of a geometry (often polygonal in 2D, polyhedral in 3D) and basic functions associated with this geometry.

Other solutions may exist for basic functions. We quote here only one example the finite elements of Hermite which have the peculiarity to have two basic functions associated with each node. In this version, the value of the solution is adjusted with the first function while the second one makes it possible to adjust the value of the derivative. This type of basic function may be of interest for the resolution of some partial differential equations (for example the equation of the plates in continuous media mechanics) even if it requires having twice as many functions for a given mesh.

❖ Some classic elements:

- In 2D
- Triangles of degree 1, (triangles with 3 nodes, linear functions)
- Triangles of degree 2 (triangles with 6 nodes, polynomials of degree 2)
- Quadrangles of degree 1 (squares with four nodes, linear functions)
- Quadrangles of degree 2 (squares with 8 or 9 knots, polynomials of degree 2)
- In 3D
- Tetrahedron of degree 1, (four knots, linear)
- Cube of degree 1, (eight nodes, linear)

8- Geometric discretization:

This operation consists in dividing the continuous domain into sub domain

$\boldsymbol{D} = \sum_{e=1}^{ne} \boldsymbol{De}$ such as $\lim\limits_{e}(\boldsymbol{UeDe}) = \boldsymbol{D}$

It is therefore necessary to be able to represent at best the often complex geometry of the domain studied by the elements of simple geometrical form. There must be no overlap or hole between two elements having a common border.

When the boundary of the domain is complex, a geometric discretization error is inevitable. This error must be estimated, and possibly reduced by modifying the shape or decreasing the size of the elements concerned as proposed in the figure. On each element we will try to define an approximation of the solution function.

9- CONCLUSION

Although there is a lot of software that uses this method and can "solve" problems in various fields, it is important that the user has a good idea of what he is doing, especially with regard to the choice of mesh and type. elements that must be adapted to the problem: no software will do everything for the user, and we must always keep a critical eye vis-à-vis solutions approached.

Using CATIA design software that helps us specify easily damaged parts or areas, and another software for ANSYS finite element analysis that offers the best solutions for linear, non-linear problems. linear, explicit and dynamic.

Chapter III : Mechanical concept

1- Introduction

In this chapter, I'm going to do the functional study and the design of the Nose Landing Gear.

I will start by the functional study, then I will create the Nose Landing Gear parts using "Part Design" and then I will assemble all the parts we created using "Assembly Design".

2- Functional study

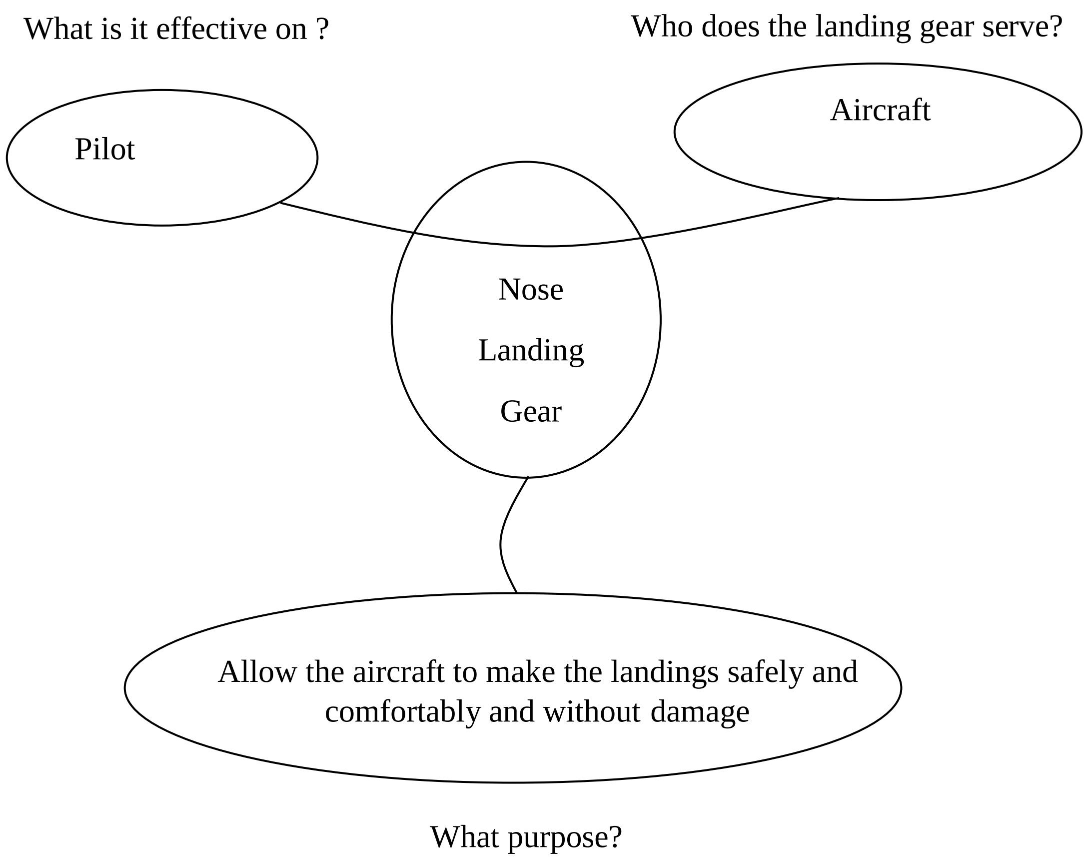
2.1 First step: bull chart/diagram/map "bête à cornes"

2.1.1 State the need:

Who does the landing gear serve? ➔ It renders service to the pilot.

he's acting on whom? ➔ It acts on the aircraft.

What purpose? ➔ Allow the aircraft to make the landings safely and comfortably and without damage.



2.2 Second step: Modeling a technical system

Modeling a technical system consists of giving it a graphic representation that lists the four sets of elements below, distinguishing them from each other and showing the relationships between them:

- The global function, which brings added value to the work material.

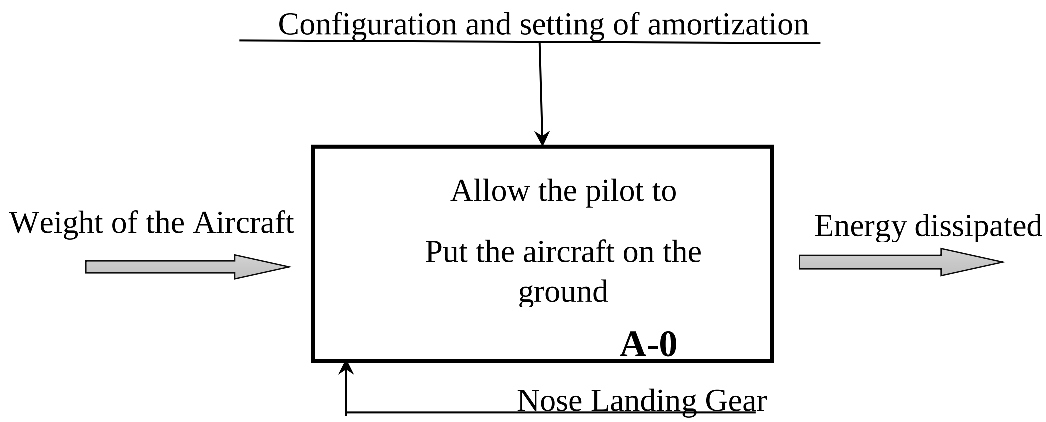
- The constituent elements (the processor or processors) that are included in the boundary and support the global function.

- The material of work on which its action is exercised.

- The control data, which causes or modifies the implementation of the function.

- **SADT (Structured analysis and design technique):**

Is a systems engineering and software engineering methodology for describing systems as a hierarchy of functions. It was developed in the late 1960s by Douglas T. Ross, and was formalized and published as IDEF0 in 1981.



2.3 Third step: Identify the service functions "octopus diagram"

The octopus diagram (or APTE) allows us to list all the functions of our product. Indeed we recall that during the design, the technicians will seek for each function to satisfy, the best solution. It is the set of solutions that will give the final product. There are two types of function:

- Fp = Main function: link between the product and two surrounding objects.

- Fc = Constraint function: link between the product and a surrounding object.

Octopus diagram :

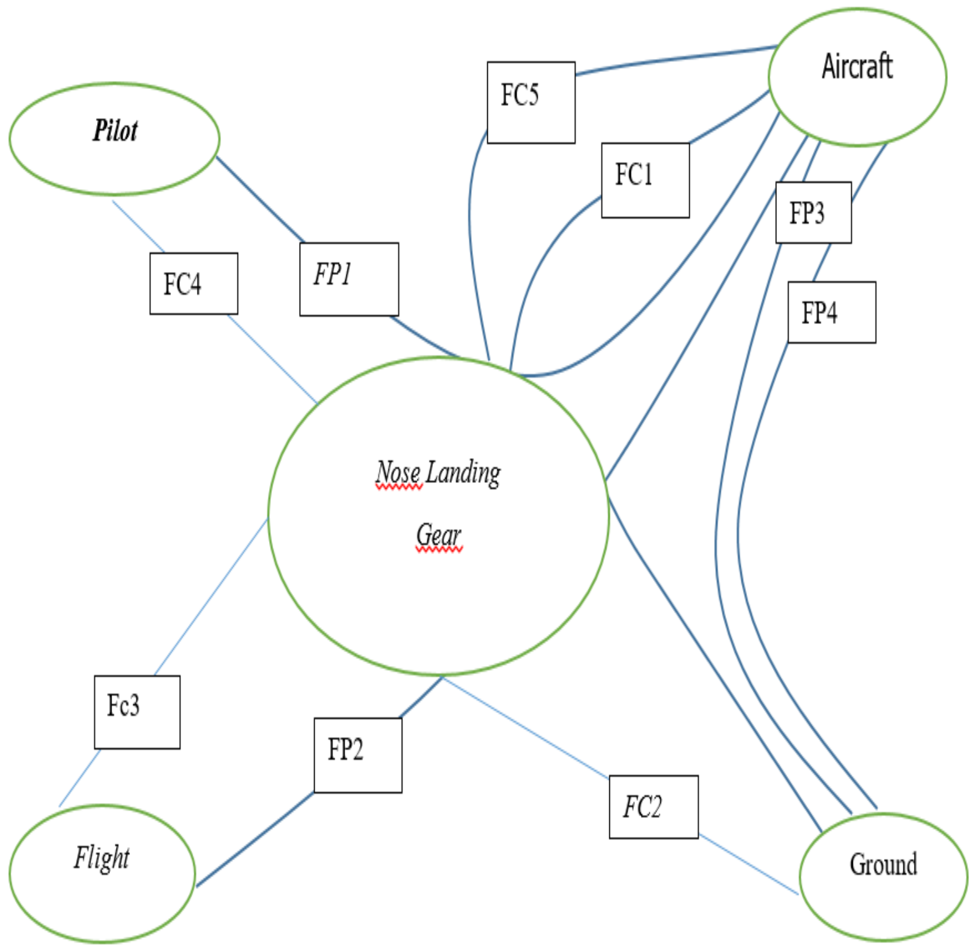


Table 4: The service functions and Criteria

The service functions:	Criteria
FP1: Allow the pilot to land the aircraft without damaging it	- Ability to withstand speed. - Impact.
FP2: Preserving aerodynamics of the plane in flight.	- Aerodynamic drag added.
FP3: Ensure taxiing the plane.	- Taxing effort. - Maneuverability.
FP4: dampen ground irregularities transmitted to the airplane.	- Shock absorber performance. - Tire resistance
FC1: To be adapted to the plane.	- The mass. - Congestion.
FC2: To be adapted with the ground.	- Hardness of the ground.
FC3: To be adapted to flight environment.	- Resistance to saline atmosphere.
FC4: Allow order by the pilot.	- The steering control.
FC5: limit disturbances on the flight of the plane.	- A retraction system that allows the landing gear to enter the fuselage.

3. CATIA

3.1 Definition

Initially CATIA name is an abbreviation for Computer Aided Three-dimensional Interactive Application. The French Dassault Systems is the parent company and IBM participates in the software and marketing, and CATIA is invades broad industrial sectors, and has been explained in the previous post position of CATIA between 3d modeling software programs. CATIA was started in 1977 by French Aircraft Manufacturer Avions Marcel Dassault System (**Figure)**.

Figure 23: Dassault System

CATIA is classified under the following software packages :

CAD (Computer Aided Design)

CAM (Computer Aided Manufacturing)

CAE (Computer Aided Engineering)

Version that most of the people works on it now is CATIA V5 or fifth version, which is a rewriting and revision the code of the fourth edition. For the fifth version, there are versions from 1 to 20. for example, CATIA V5 R17, it Means CATIA fifth edition version seventeenth, While years system was adoption in the sixth edition, for example, CATIA V6 2011 means CATIA sixth edition version of Year 2011.

3.2 CATIA Modules

- **Sketcher:**

  This module is responsible for the implementation of two-dimensional shapes, in preparation for make a three dimensional commands on it.

- **Part Design :**

This module is responsible for converting two-dimensional graphics to three dimensional objects which is most famous in Catia and is closely linked with sketcher module. The part design Module it is considered from most important modules, that used by the designer to get the additional advantage from cad programs, which is stereotaxic drawing or three-dimensional drawing.

- **WireFrame and Surface Design:**

With this module surfaces can be drawing with zero size and weight and has its uses in the aerospace, automotive, ships and Mold Design.

- **Generative Sheet Metal Design:**

This module is responsible of converting two-dimensional graphics to thin sheets or walls having a particular ratio between thickness and its radius.

- **Assembly:**

This module is responsible for assembling the parts previously produced in Part Design, and it is most important for those who work in the field of machinery design or design in general because it is the one who shows the inter-relationships between the parts of the machine or many mechanical establishment.

- **Drafting:**

This module is responsible for converting what you see the screen to standard engineering drawings can be traded in the workshop for manufacturing or save them for documentation.

3- The components of the Nose landing gear Shock Struts

It is worth noting that my design parameters are roughly inspired from Boeing 777-300ER with some design changes.

I will create each component using “Part Design” in CATIA.

- **Shock Struts:**

True shock absorption occurs when the shock energy of landing impact is converted into heat energy, as in a shock strut landing gear. This is the most common method of landing shock dissipation in aviation. It is used on aircraft of all sizes. Shock struts are self-contained hydraulic units that support an aircraft while on the ground and protect the structure during landing. They must be inspected and serviced regularly to ensure proper operation.

- **Torque links:**

Transfer moments between main fitting and sliding member and prevent rotation of the sliding member with respect to the main fitting. **[30]**

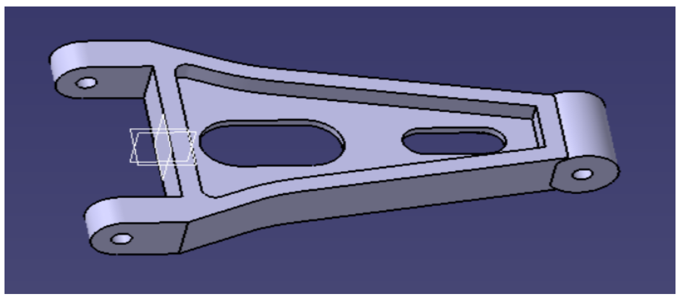


Figure 24: 3D CATIA model of Upper torque link

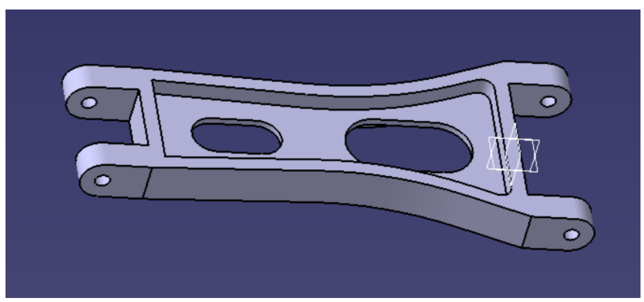


Figure 25: 3D CATIA model of Lower torque link

- **Tire:**

That provides the connection between the ground and the aircraft.

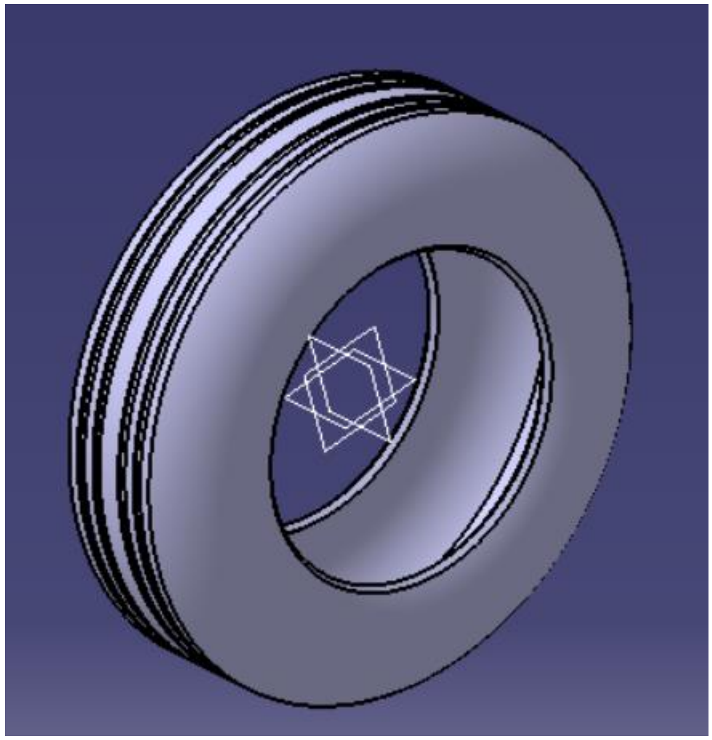


Figure 26: 3D CATIA model of tire

- **Rim:**

That acts as a thin envelope on which the load of the aircraft is distributed via the nitrogen contained in the tire.

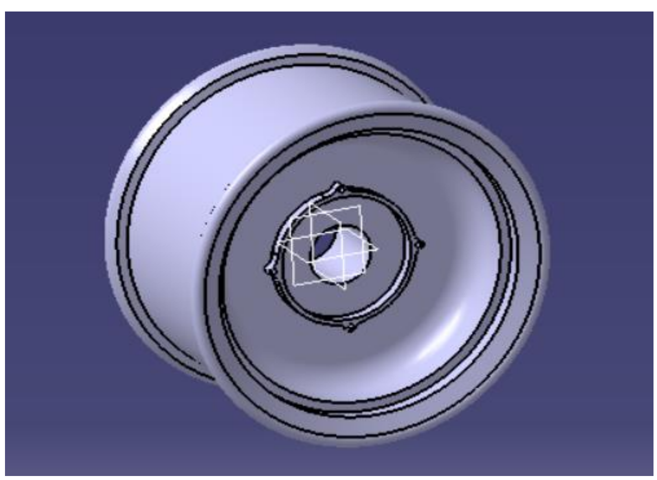


Figure 27: 3D CATIA model of the rim

- **Oleo strut:**

Is a pneumatic air–oil hydraulic shock absorber used on the landing gear of most large aircraft and many smaller ones. This design cushions the impacts of landing and damps out vertical oscillations.

It is undesirable for an airplane to bounce on landing—it could lead to a loss of control. The landing gear should not add to this tendency. A steel coil spring stores impact energy from landing and then releases it. An oleo strut absorbs this energy, reducing bounce. As the strut compresses, the spring rate increases dramatically, because the air is being compressed, while the viscosity of the oil dampens the rebound movement.

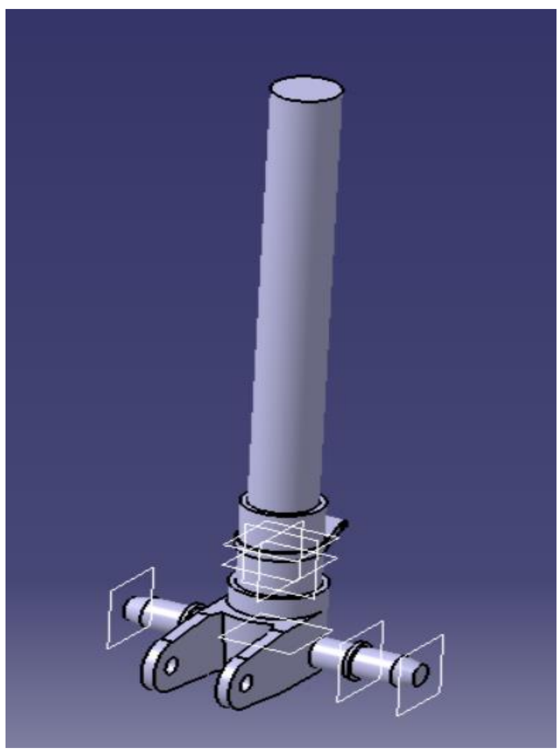


Figure 28: 3D CATIA model of the oleo strut

○ The landing gear support :

Is a structural component generally works in resisting longitudinal compression, it allows to fix the landing gear in the fuselage

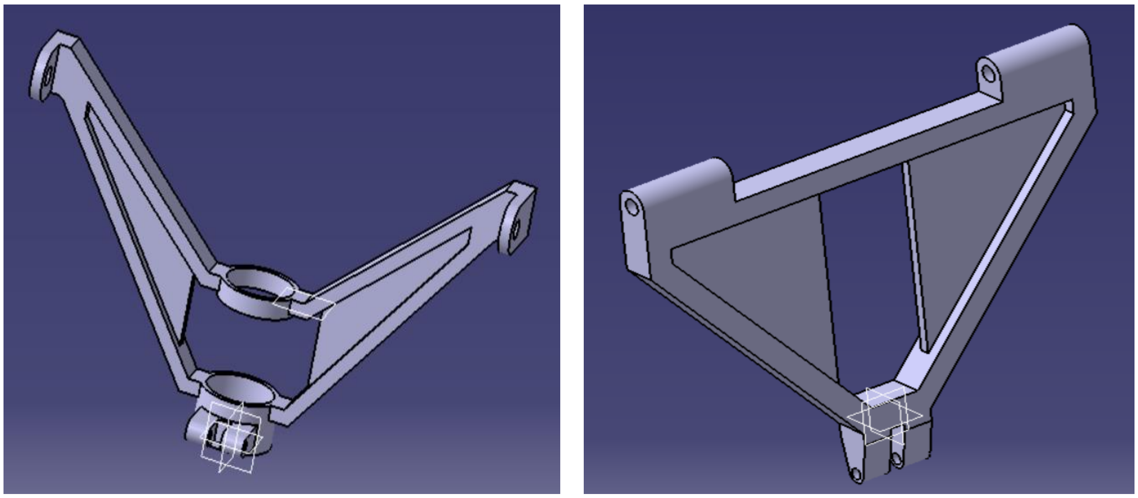


Figure 29: 3D CATIA model of the landing gear support

○ Steering system assembly:

This allows the aircraft to be directed during ground operation.

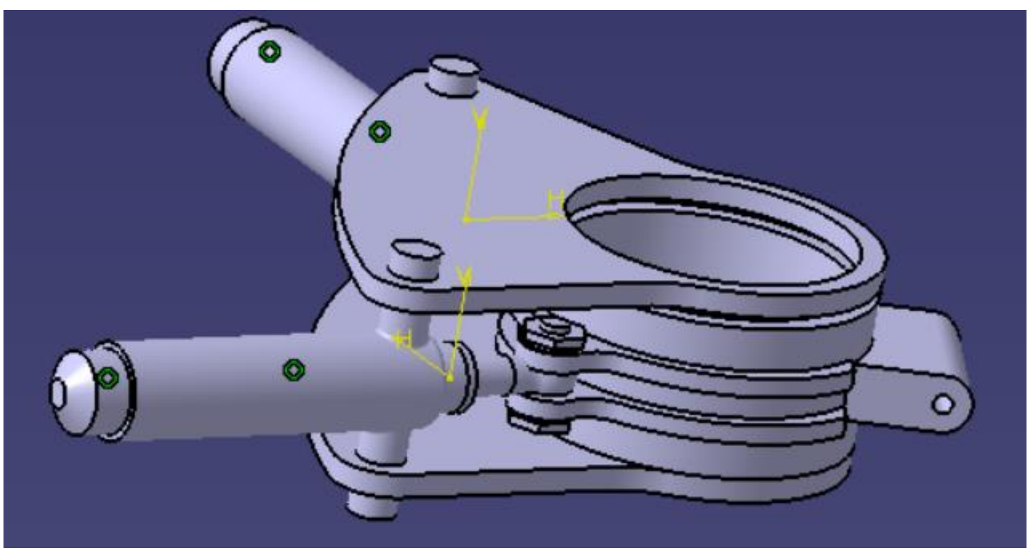


Figure 30: 3D Catia model of the steering system assembly

Nose Landing Gear assembly:

After finishing from designing all the parts of the Nose Landing Gear I assembled them using Assembly Design in CATIA.**(Figure 30)**

This Nose landing gear **(figure 30)** Is the undercarriage of an aircraft and is used for either takeoff or landing, it is located at the front of the aircraft.

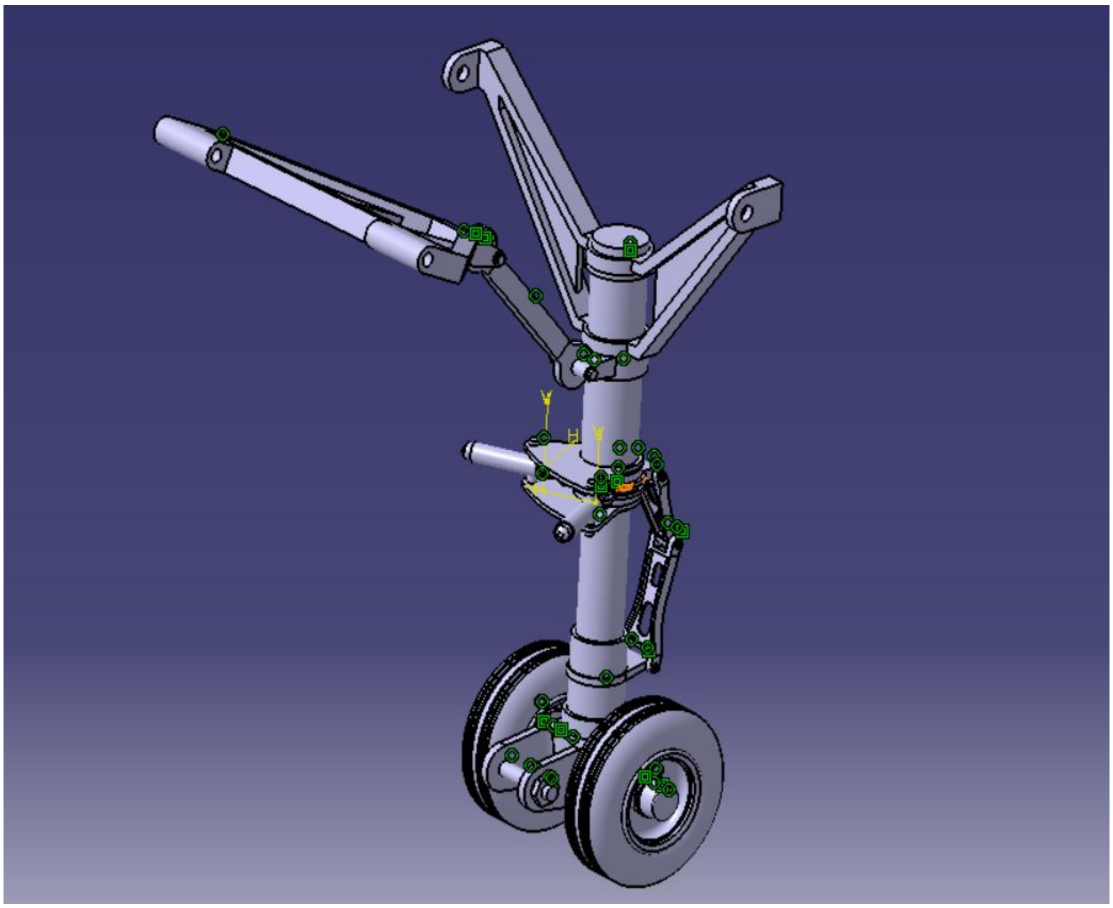


Figure 31: 3D CATIA model of nose landing gear

4- Conclusion

In this chapter, I managed to create the design of the Nose Landing Gear.

At first I did the functional study, then I created the Nose Landing Gear parts using “Part Design” and then I assembled all the parts that I created it using “Assembly Design”.

Chapter IV: Results

1- Introduction

In this chapter, I will calculate the forces applied on the front landing gear in the cases: static, dynamic and when the plane touches the ground and after I will interpret the results in the static case with the ansys by changing the material each time.

2- Force calculation

2.1 Dimensioning of Boeing 777-300er

We Consider the dimensions of the aircraft in **Figure and figure** and whose pertinent characteristics are listed below.

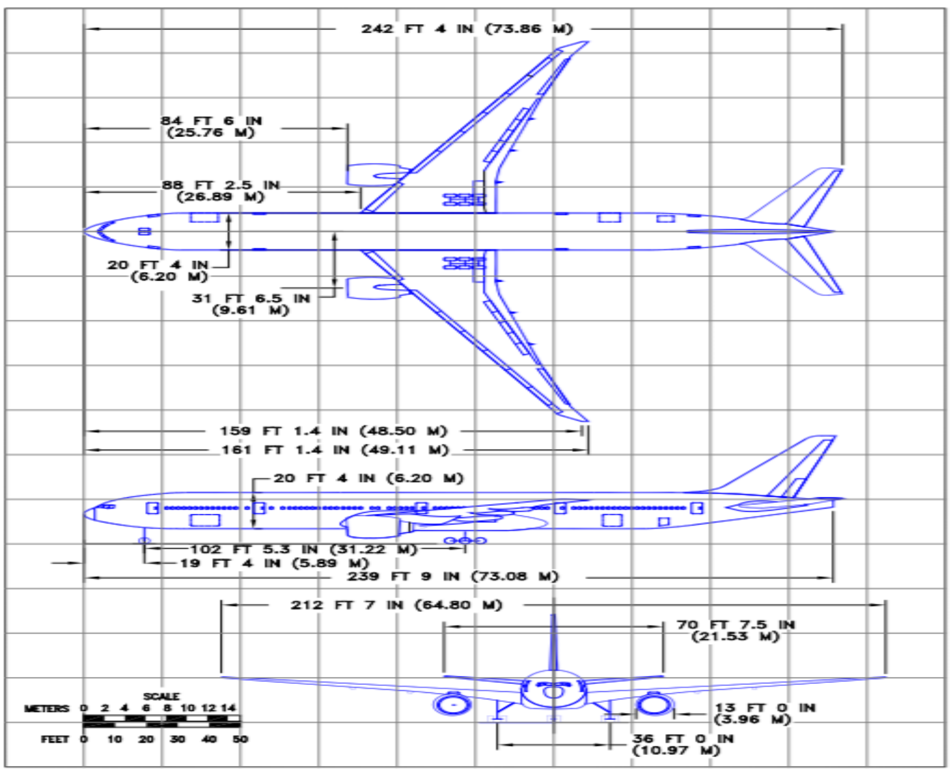
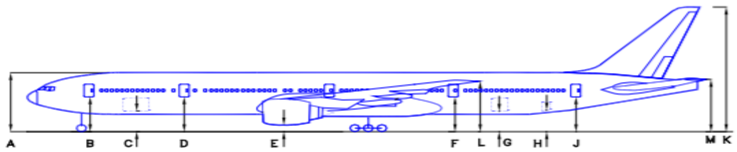


Figure 32: General Dimensions: Model 777-300ER



Dimension	MINIMUM*		MAXIMUM*	
	FT - IN	M	FT - IN	M
A	27 - 9	8.46	28 - 10	8.78
B	15 - 9	4.80	16 - 10	5.13
C	9 - 5	2.88	10 - 6	3.19
D	16 - 2	4.92	17 - 1	5.20
E	2 - 5	0.73	3 - 3	0.99
F	16 - 9	5.11	17 - 5	5.32
G (LARGE/SMALL DOOR)	10 - 6	3.19	11 - 9	3.58
H	10 - 11	3.32	12 - 4	3.76
J	17 - 0	5.19	18 - 7	5.66
K	59 - 10	18.24	61 - 10	18.85
L	23 - 11	7.29	25 - 11	7.90
M	25 - 7	7.79	27 - 8	8.43

Figure 33: Ground Clearances: Model 777-300ER

I'm going to determine the following :

- The static ground reaction loads without engine power.
- Dynamic ground reaction loads on the NLG and MLG, assuming no rotation at V = 79,16 m/s.
- The airspeed at which the pilot can (slowly) rotate the nose of the aircraft to lift off, assuming the constant airspeed formulation.
- The ground reaction loads on the NLG and MLG when the aircraft touchdown the ground.

So we have :

- Maximum Takeoff Weight (MTOW) = 351535 Kilograms **[31]**
- MAC(Mean Aerodynamic Chord) = 8,75m
- The distance between the nose and the Leading Edge Mean=26,89m

2.2 Static ground reaction loads without power:

Is the case when the aircraft is on the ground, the weight of the aircraft is the only force that is working on the aircraft. The main landing gear carries more weight than the nose landing gear because the centre of gravity is closer to it. The arm between the CG and the main landing gear is smaller than the arm between the CG and the nose landing gear.

The Nose reaction (RN)

$$\boldsymbol{RN = \frac{W.XM}{XN + XM}}$$

To determine the distances XM and XN,

firstly we have to konow the distance (LEM) between the nose of the airplane and the Leading Edge Mean that equal to 26,89m.

Secondly we have to determine the distance (COG) between the nose of the airplane and the center of gravity :

COG = 25 % MAC + LEM

= 2,1875 + 26,89

$\boxed{\text{COG = 29,0775}}$

We have also : $\boxed{\text{XN+XM = 31,22m}}$ ıe distance between the main landing gear and the nose landing gear)

And we have the distance (NANLG) between the nose of the airplane and the nose landing gear that equal to 5,89m

So XM = NANLG + (XN+XM) – COG

= 5,89 + 31,22 - 29,0775

$\boxed{\text{XM = 8,0325m}}$

XN = COG – NANLG

= 29,0775 – 5,89

XN = 23,1875m

$$\boldsymbol{RN = \frac{W.XM}{XN+XM}}$$ with W= MTOW.g

= 351535 . 9,81

W= 3448558,35 N

$$\boldsymbol{RN = \frac{3448558{,}35\,.8{,}0325}{31{,}22}}$$

RN = 887269,2167 N

W= 3448558,35 N $\Rightarrow$ 100%

RN = 887269,2167 N $\Rightarrow$? %

Then the Nose landing gear reaction is : $\frac{\mathbf{887{,}2692.100}}{\mathbf{3445{,}043}}$ = 25,7286 percent of the total weight of the aircraft.

RM = W – RN

= 3448558,35 – 887269,2167

RM = 2561289,133 N

2.3 Dynamic ground reaction loads

In this case the reaction load of the nose landing gear **RN** is defined by this formula :

$$RN = \frac{T.YT + (W + LHT - LW).(XM - \mu.hcg) + LW.XW - LHT.lHT - MW}{XN + XM - 2.\mu.hcg}$$

We have as data :

- Take off distance = 3200m **[23]**
- The speed at the beginning of the taxi VA= 0 km/h (at point A)
- The Speed of the aircraft at the end of the taxi phase (at point B) VB=285km/h
- We assume that the drag force is negligible

To determine all these unknowns we have to go through all these steps :

- Calculation of the kinetic energy ***Δ* EC** of the aircraft between the beginning and the end of the taxi phase.

Δ EC = EC(B) = $\frac{1}{2}$.m.$(\boldsymbol{VB^2 - VA^2})$

We have VB = 285 km/h $= \frac{\mathbf{285.1000}}{\mathbf{60.60}}$ = 79,16 m/s

So Δ EC = $\frac{\mathbf{531{,}535.10^3.(79{,}16)^2}}{\mathbf{2}}$ = 1,665.10^9 J

$$\boxed{\Delta \text{ EC} = 1{,}665 \text{ GJ}}$$

- Determine the value of a force from his work:

It is known that this variation of kinetic energy ***Δ* EC** is equal to the sum of the work of the forces exerted on the airplane during this trip

We assume that the friction force and the drag force are negligible.

we can count three forces that the aircraft undergoes during taxi:

- The weight.
- The reaction of the ground

- The Thrust force

The work of a force is given by the relation : $W_{rAB}(\vec{F}) = \vec{F}.\overrightarrow{AB}$

We know that the work of the weight and that of the reaction of the ground are null because the displacement is always perpendicular to these two forces.

So we have :

Δ EC = W_{rAB} (Thrust Force)

$= \overrightarrow{Th}.\overrightarrow{AB}$

$= ||\overrightarrow{Th}||.||\overrightarrow{AB}||.\cos(\overrightarrow{Th}.\overrightarrow{AB})$

Knowing that the Thrust force and displacement have the same direction so the angle between these vectors is zero, hence:

Δ EC = $||\overrightarrow{Th}||.||\overrightarrow{AB}||$ $\Rightarrow$ $\overrightarrow{Th} = \frac{\Delta EC}{AB} = \frac{1{,}665.10^9}{3200}$

$= 0{,}5203125.10^6$ N

$$\boxed{\overrightarrow{Th} = 520312{,}5 \text{ N}}$$

Conclusion:

The maximum thrust of a single Boeing 777-300er reactor is 512000 N. In our case we need a total thrust of 520312.5 N to reach a speed of 285km / h for a distance of 3200m, so both reactors must to be used.

- Wing lift (L_{W}) :

The wing lift is defined by this formula : $L_W = q.S_W.C_L$

$q = \frac{1}{2}\rho.v^2$ with **q** is the dynamic pressure and ρ is the air density.

ρ=1,225kg/m3

so $q = \frac{1{,}225.(79{,}16)^2}{2}$

$$\boxed{q = 3838{,}11218 \; Pascal}$$

we assume that $C_{L=}$ 0,9

$L_W = \mathbf{3838{,}11218}.427{,}80.0{,}9$

$\boxed{L_W = 1477749{,}9515\ N}$

- Horizontal Lift (L_{HT})

S_{HT} = 101,26 m^2

We assume that $C_{H\,=}$ -1,2

The wing lift is defined by this formula : $L_{HT} = q.S_{HT}.C_H$

$L_{HT} = \mathbf{3838{,}11218}.\ 101{,}26.\ |-1{,}2|$

$\boxed{L_{HT} = 466376{,}6872\ N}$

- Pitching moment (M_W) : Is the moment of wing about the center of gravity

  The Pitching moment is defined by this formula : $M_W = q.S_w.C_{MGC}.C_M$

With **C_{MGC} :** Is the Mean Geometric Chord length .

And **C_M :** Is the pitching moment coefficient .

We assume that C_M = -0,2

$M_W = \mathbf{3838{,}11218}.\ 427{,}80.8{,}75.(-0{,}2)$

$\boxed{M_W = -2873402{,}6835\ Nm}$

We assume that h_{cg} = 5m

And we define l_{HT} : The distance between the gravity center and the center of horizontal tail

l_{HT} = 73,08 - 29,0775

l_{HT} = 44,0025 m

X_W = 26,89 + 50%MCA – COG

= 26,89 +0.5.8,75-29,0775

X_W = 2,1875 m

We assume that μ = 0,25

Y_T = COG – 25,76

= 29,0775 – 25,76

Y_T = 3,3175 m

Finally we have $\boldsymbol{RN}$ = 133725,10746511

Main landing gear reaction loads :

RM = W + L_{HT} – L_W – RN

= 3448558,35 + 466376,6872 - 1477749,9515 - 133725,10746511

$\boldsymbol{RM}$ = 2303459,9782348

2.4 Aircraft touchdown

During touchdown the main landing gear touches the ground first. When the main landing gear touches the ground, there are several forces that work on the main landing gear.

There is a vertical force that needs to be absorbed by the shock strut. The shock strut should be able to ab-sorb a maximum vertical landing force of 3.70 m/s vertical speed (CS-25).

V_{app} = 149 KTS = 275,948 km/h = 76,6522 m/s

This landing is done with an vertical speed V_0 of 3 fps (0.9144 m/s)

The acceleration speed can be calculated with this formula :

$$\boxed{(V_t)^2 = (V_0)^2 + 2.a.ds}$$

With :

- V_t= vertical speed reaching the ground (m/s)
- V_0= vertical speed descending (m/s)
- a = acceleration / deceleration (m/s^2)
- ds = distance difference between the shock strut extended and extracted when touching the ground.

We assume that ds =0,356 m , $V_t = 0$ and V_0 = 0.9144 m/s

$0^2 = (0.9144)^2 + 2.a.0,356$

$$\boxed{a = -1,2848 \text{ m/s}^2}$$

The negative value means there is a deceleration . With the deceleration the force can be calculated :

Knowing that MLW = 251000,29 kg

F= MLW.a

= 251000,29 . 1,2848

$$\boxed{F = 322485,1725}$$

2.5 Determine the rotation airspeed

The rotation airspeed can be determined by calculating the reaction loads for the nose landing gear for a range of airspeeds and then identifying where the NLG reaction load becomes zero. The calculations are easily implemented in a spreadsheet. The calculation shown in tis Part was implemented for airspeeds ranging from 0 through 150 m/s using Microsoft Excel. The results have been plotted in **Figure 34**.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	v	v^2	q	Δ EC	T	L_W	L_{HT}	M_W	l_{HT}	X_W	Y_T	μ	h_{cg}	W	XM	XN	RN	RM
2	0	0	0	0	0	0	0	0	44,0025	2,1875	3,3175	0	5	3448558,4	8,0325	23,1875	887269,22	2561289,1
3	5	25	15,3125	6644187,5	2076,3086	5895,6188	1860,6525	-11463,7	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	811694,12	2632829,3
4	10	100	61,25	26576750	8305,2344	23582,475	7442,61	-45854,81	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	803547,32	2628871,2
5	15	225	137,8125	59797688	18686,777	53060,569	16745,873	-103173,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	789969,33	2622274,3
6	20	400	245	106307000	33220,938	94329,9	29770,44	-183419,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	770960,13	2613038,8
7	25	625	382,8125	166104688	51907,715	147390,47	46516,313	-286592,6	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	746519,74	2601164,4
8	30	900	551,25	239190750	74747,109	212242,28	66983,49	-412693,3	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	716648,16	2586651,4
9	35	1225	750,3125	325565188	101739,12	288885,32	91171,973	-561721,5	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	681345,37	2569499,6
10	40	1600	980	425228000	132883,75	377319,6	119081,76	-733677	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	640611,39	2549709,1
11	45	2025	1240,3125	538179188	168181	477545,12	150712,85	-928560	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	594446,21	2527279,9
12	50	2500	1531,25	664418750	207630,86	589561,88	186065,25	-1146370	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	542849,84	2502211,9
13	55	3025	1852,8125	803946688	251233,34	713369,87	225138,95	-1387108	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	485822,26	2474505,2
14	60	3600	2205	956763000	298988,44	848969,1	267933,96	-1650773	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	423363,49	2444159,7
15	65	4225	2587,8125	1,123E+09	350896,15	996359,57	314450,27	-1937366	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	355473,52	2411175,5
16	70	4900	3001,25	1,302E+09	406956,48	1155541,3	364687,89	-2246886	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	282152,35	2375552,6
17	75	5625	3445,3125	1,495E+09	467169,43	1326514,2	418646,81	-2579333	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	203399,99	2337291
18	80	6400	3920	1,701E+09	531535	1509278,4	476327,04	-2934708	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	119216,42	2296390,6
19	85	7225	4425,3125	1,92E+09	600053,18	1703833,8	537728,57	-3313010	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	29601,664	2252851,4
20	90	8100	4961,25	2,153E+09	672723,98	1910180,5	602851,41	-3714240	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-65444,29	2206673,6
21	95	9025	5527,8125	2,399E+09	749547,4	2128318,4	671695,55	-4138397	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-165921,4	2157857
22	100	10000	6125	2,658E+09	830523,44	2358247,5	744261	-4585481	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-271829,8	2106401,7
23	105	11025	6752,8125	2,93E+09	915652,09	2599967,9	820547,75	-5055493	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-383169,4	2052307,6
24	110	12100	7411,25	3,216E+09	1004933,4	2853479,5	900555,81	-5548432	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-499940,1	1995574,8
25	115	13225	8100,3125	3,515E+09	1098367,2	3118782,3	984285,17	-6064299	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-622142	1936203,3
26	120	14400	8820	3,827E+09	1195953,8	3395876,4	1071735,8	-6603093	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-749775,2	1874193
27	125	15625	9570,3125	4,153E+09	1297692,9	3684761,7	1162907,8	-7164814	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-882839,5	1809544
28	130	16900	10351,25	4,491E+09	1403584,6	3985438,3	1257801,1	-7749463	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1021335	1742256,2
29	135	18225	11162,813	4,844E+09	1513629	4297906,1	1356415,7	-8357040	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1165262	1672329,8
30	140	19600	12005	5,209E+09	1627825,9	4622165,1	1458751,6	-8987543	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1314620	1599764,5
31	145	21025	12877,813	5,588E+09	1746175,5	4958215,4	1564808,8	-9640974	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1469409	1524560,6
32	150	22500	13781,25	5,98E+09	1868677,7	5306056,9	1674587,3	-10317333	44,0025	2,1875	3,3175	0,25	5	3448558,4	8,0325	23,1875	-1629629	1446717,9

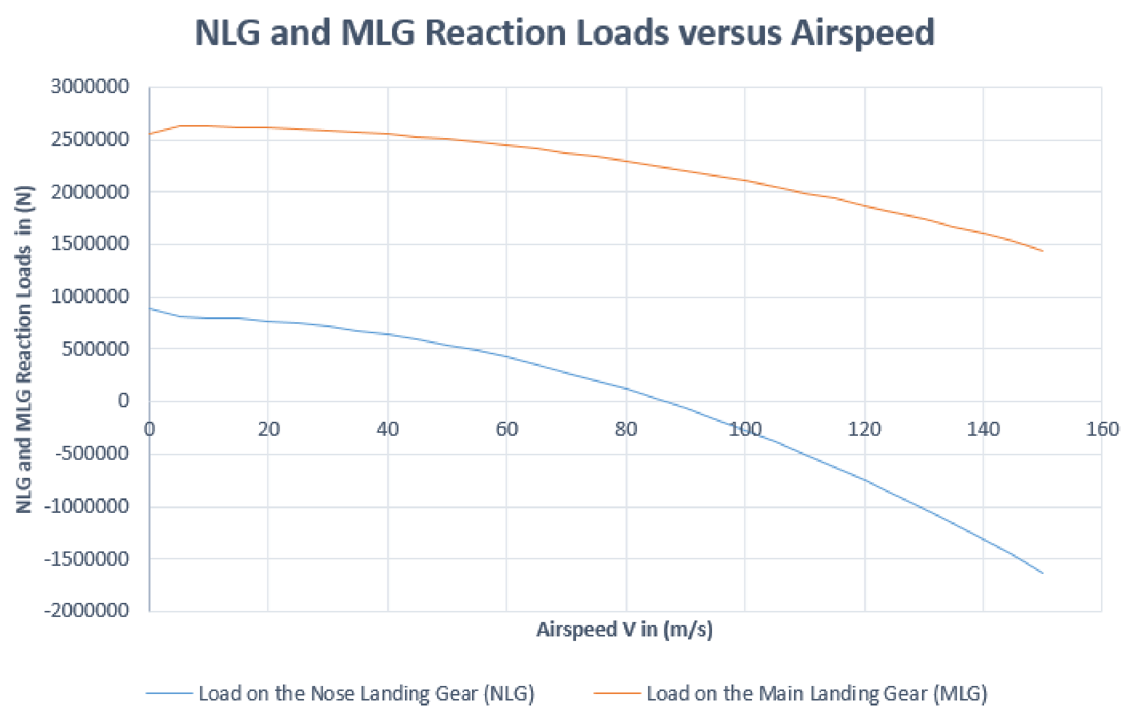


Figure 34: NLG and MLG Reaction Loads Airspeed

Note that the NLG reaction load goes to zero at around v = 87m/s. This means the aircraft must be accelerated to that airspeed before rotating the airplane is possible.

3- Presentation of the software ANSYS

ANSYS develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. ANSYS is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, ANSYS software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

Most ANSYS simulations are performed using the ANSYS Workbench software, which is one of the company's main products. Typically ANSYS users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the ANSYS software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time. ANSYS also develops software for data management and backup, academic research and teaching. ANSYS software is sold on an annual subscription basis.

4- Analysis By Using ANSYS 15.0 Software:

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. Structural Analysis is a multi-discipline Computer Aided Engineering (CAE) tool that analyzes the physical behavior of a model to better understand and improve the mechanical performance of a design. It can be used to directly calculate stresses, deflections, thus to predict the behavior of the design in the real world.

5- Setting up the Model

5.1 Import the assembly geometry

I'm going to import the geometry that I made in CATIA form STP passing with these steps:

Select on geometry with the right button ⟶ select import

5.2 Material selection

Three type of materials are used for obtaining the best results. The three materials are:

- Steel alloy : E4340

- Aluminum Alloy 7075
- Titanium alloy

- **Material Definition**

4340 (E4340) Alloy Steel :

4340 Alloy Steel is an Iron-based alloy containing Nickel, Chromium and Molybdenum. The relatively high Carbon content provides this alloy with superior strength in applications where severe service conditions exist. **[32]**

4340 Alloy Steel has high strength, superior toughness and good ductility. In addition, the alloy is immune to embrittlement.**[32]**

4340 steel alloy is used primarily for structural applications such as aircraft landing gears. 4340 alloy steel is also used in the manufacturing of structural parts like gears, sprockets, chucks, molds, and more. **[33]**

Aluminum Alloy 7075

Aluminum alloy 7075 is often used in the airspace industry, because it has a lightweight construction and a relative high tensile strength. It is so light and strong because the alloy has a high zinc and copper value.

Aluminum alloys have strong corrosion resistance. At subzero temperatures, their strength increases, thus making them a useful low-temperature alloy. Their strength decreases if they are subjected to very high temperatures. **[34]**

Titanium 10Al-2Fe-3V

Titanium 10-2-3 (Ti 10-2-3) is used in the landing gear instead of steel. The main reason for this change is the reduction of 600 pounds in the aircraft, because the strength to weight ratio of titanium is higher than steel.

- **Material Properties**

I have injected all these parameters into ANSYS case by case.

Table 5: Material properties

	Material	Tensile strength (MPa)	Yield strength (MPa)	Density (kg/m3)	Poisson's ratio	Young's modulus (Gpa)
1	Steel alloy : E4340	745	470	$7{,}85.10^3$	0.30	200
2	Aluminum Alloy 7075	503	95	$2{,}8.10^3$	0,33	80
3	Titanium 10Al-2Fe-3V	1260	1050	$4{,}65.10^3$	0,32	108

5.3 Meshing

The next pre-processing step is concerned with discretizing the continuous solid body geometry, also known as meshing.
According to the performance of my PC I will make a mesh for the whole body with the size of an element equal to 20 mm **(figure 27)** and after I will make a refinement between the pieces which have um contact between them.

Details of "Body Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	8 Bodies
Definition	
Suppressed	No
Type	Element Size
Element Size	20
Behavior	Soft

Figure 35: Element size

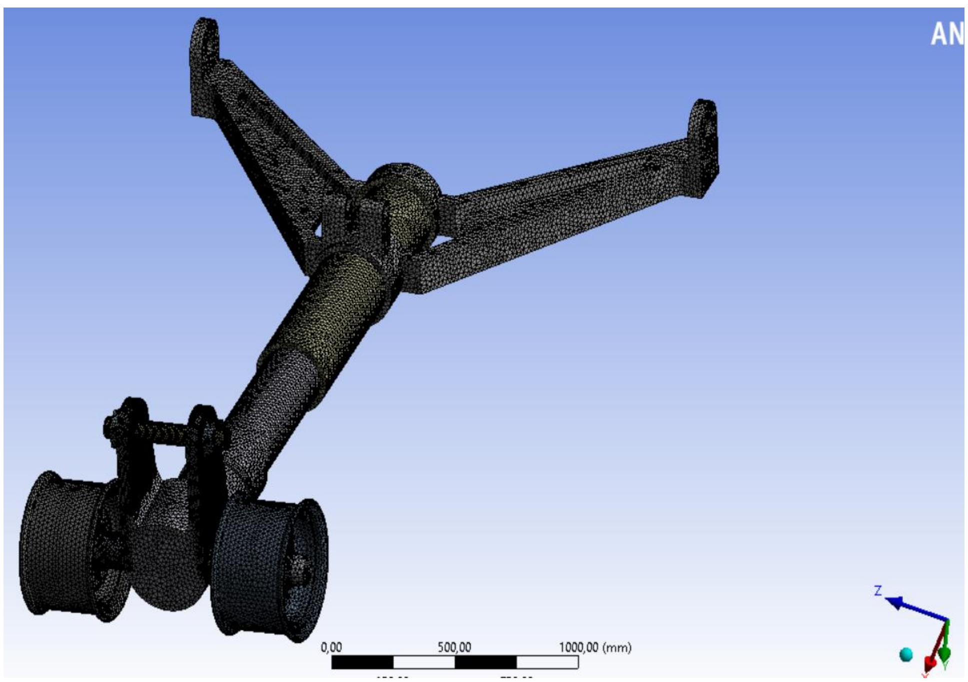


Figure 36: Meshed landing gear in ANSYS Mechanical (627362 elements and 938452 nodes)

5.4 Applying Loads and Boundary Conditions

○ Boundary Conditions

I put two fixed supports in two faces that will fix the nose landing gear in the fuselage.

To set up the necessary support it is necessary to go through these following steps:

Static structural ⟶ insert (with right click) ⟶ Fixed support ⟶ Select the Face I want to assign as a fixed support.

Figure 37: Fixed support

○ Applying the Loads

I'm going to apply two equal forces on landing gear wheels that equals $R_N/2$.

To apply these forces it is necessary to go through these following steps:

Static structural ⟶ insert (with right click) ⟶ Force ⟶ select the face where I want to apply the force ⟶ define the value of the force ⟶ choose the direction of Force, (and the same thing for the other force) **(Figure 30)**

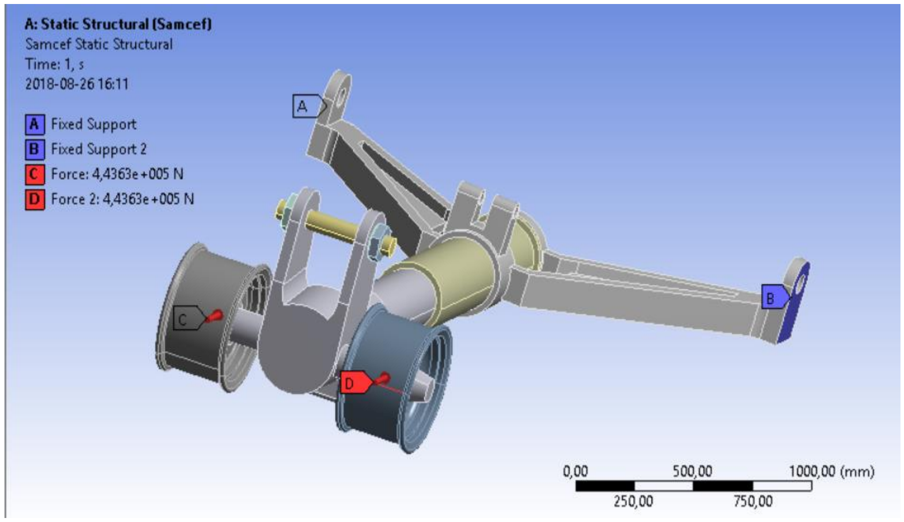


Figure 38: Application of forces

5.5 Results

- **Steel alloy: E4340:**

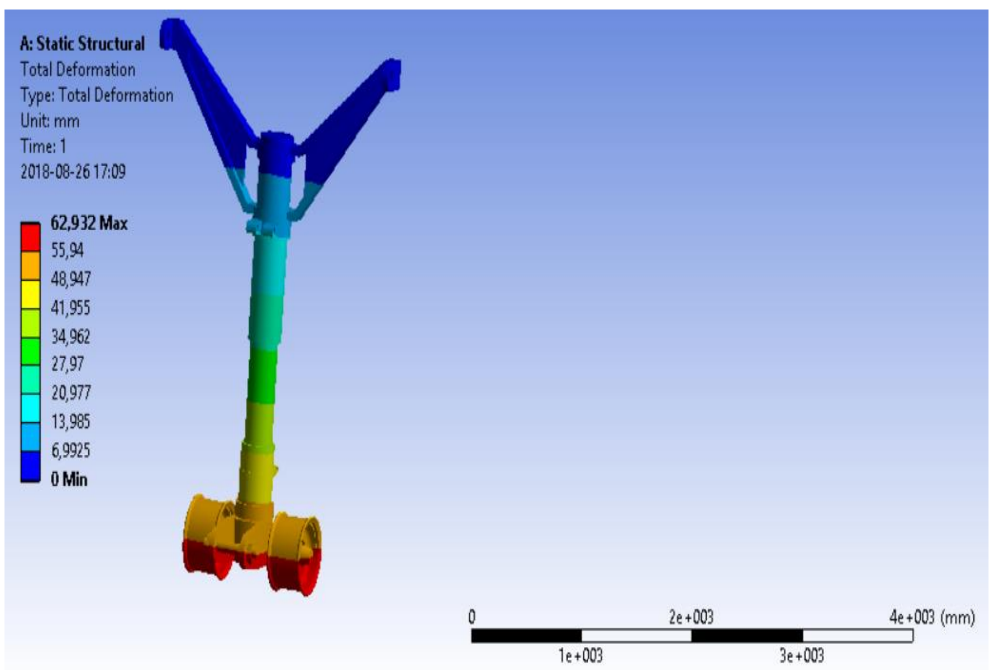


Figure 39: Total deformation of Steel alloy: E4340

The landing gear assembly has undergone a deformation, when a constant load is applied on the assembly which is at static condition. From **figure 31** maximum deformation of 62,932 mm which is indicated in red color region, and a minimum deformation of 0 mm as shown in blue color region for applied loads.

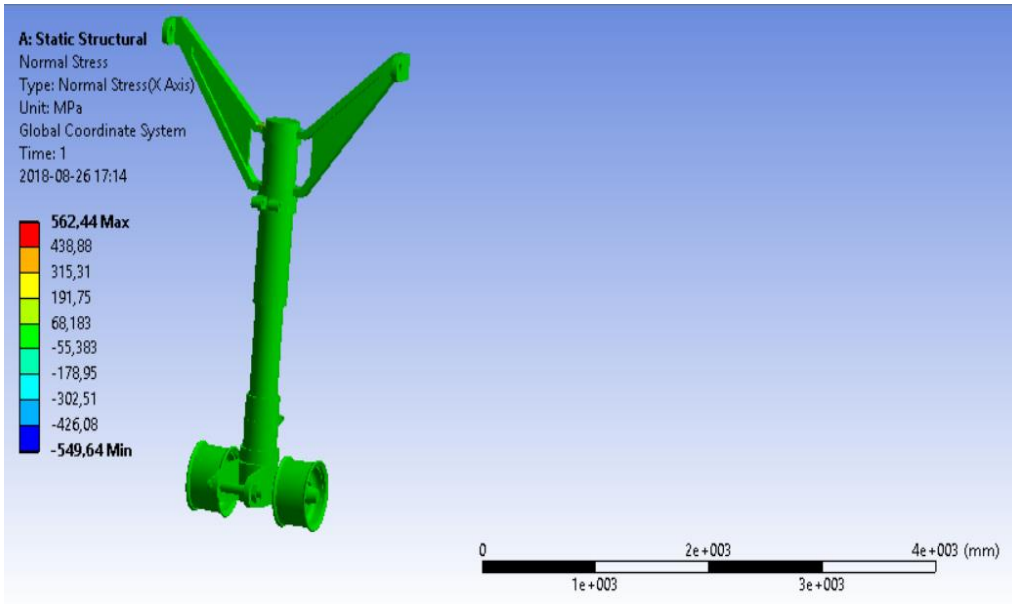


Figure 40: Normal Stress

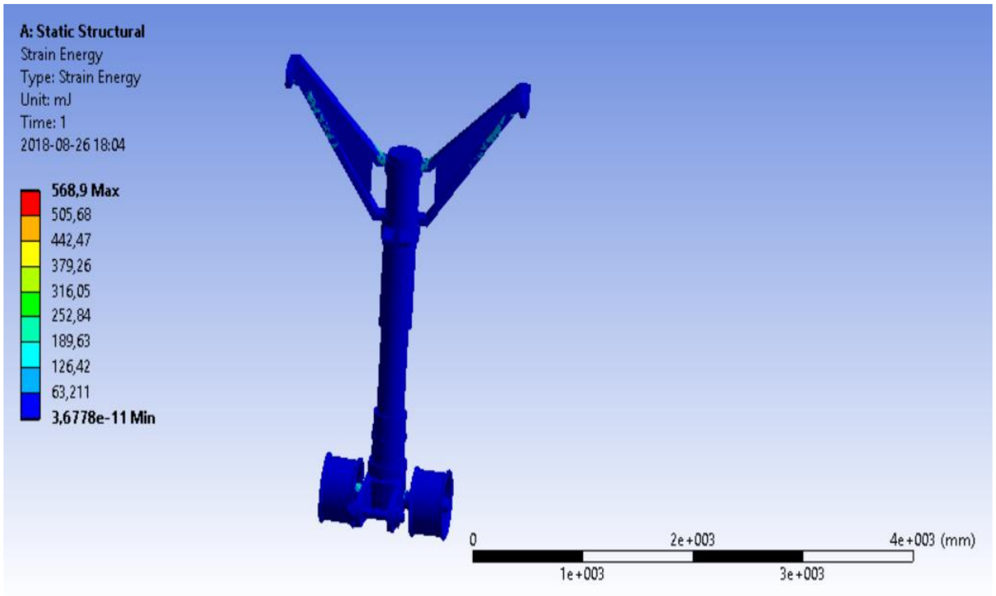


Figure 41: Strain Energy

Table 6: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Steel	62,932	562,44	568,9

Aluminum Alloy 7075

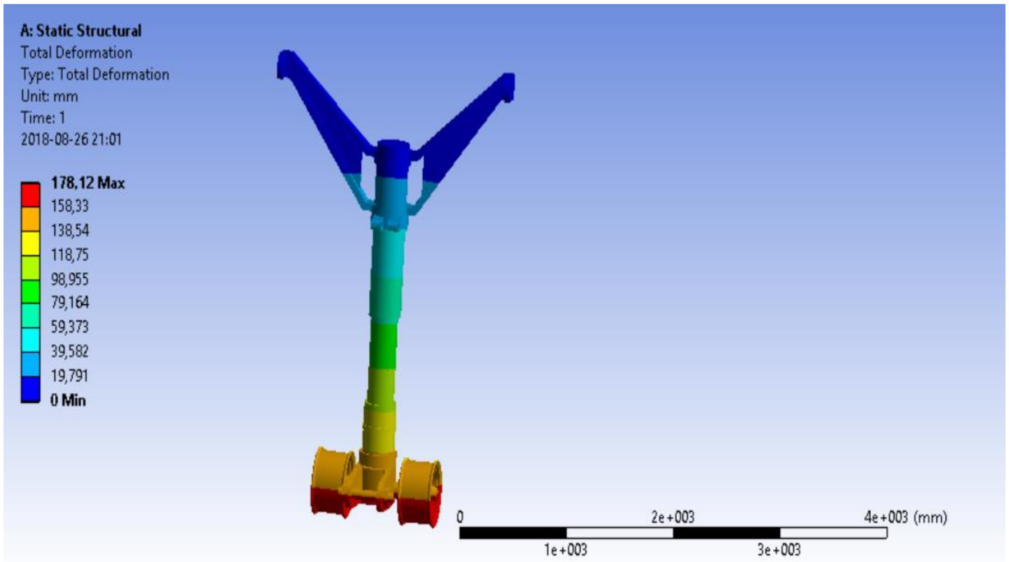


Figure 42: Total Deformation of Aluminum Alloy 7075

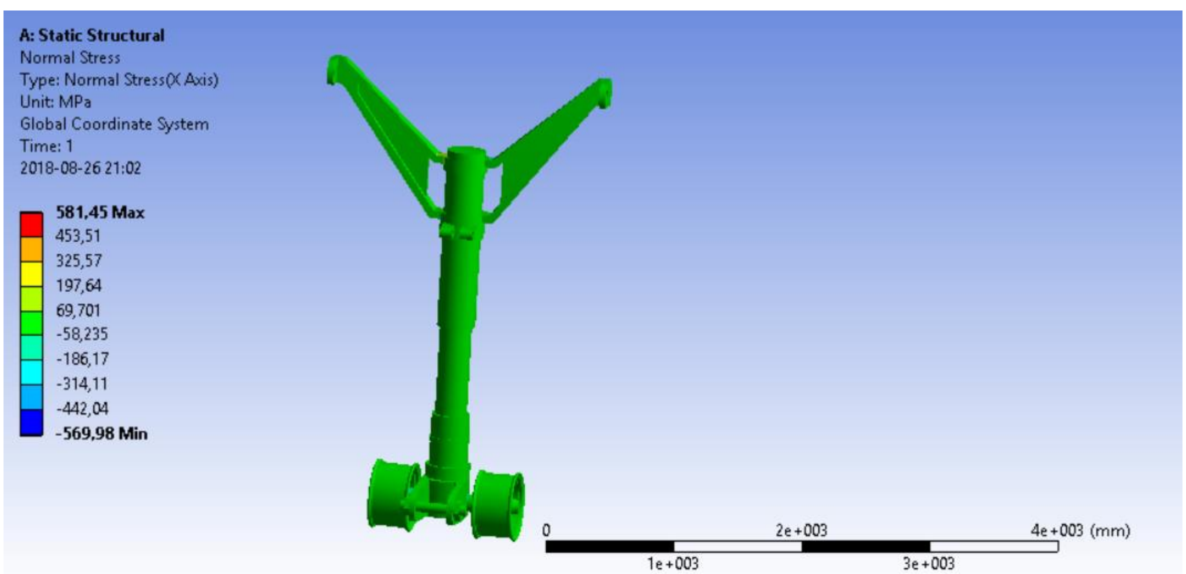


Figure 43: Normal Stress of Aluminum Alloy 7075

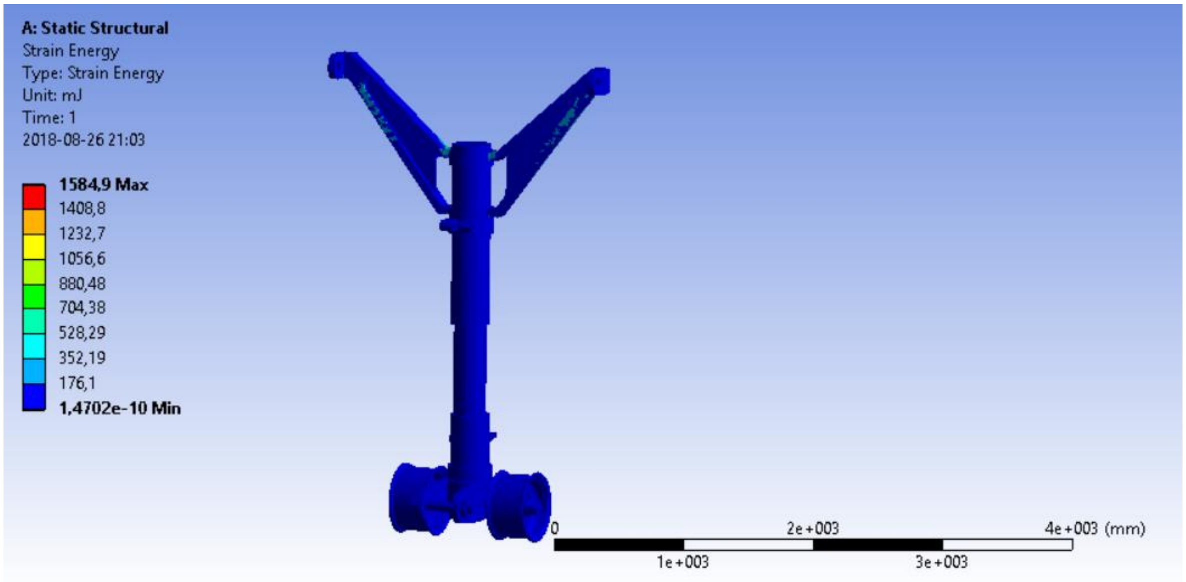


Figure 44: Strain Energy of Aluminum Alloy 7075

Table 7: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Aluminum Alloy 7075	178,12	581,45	1584,9

- **Titanium 10Al-2Fe-3V**

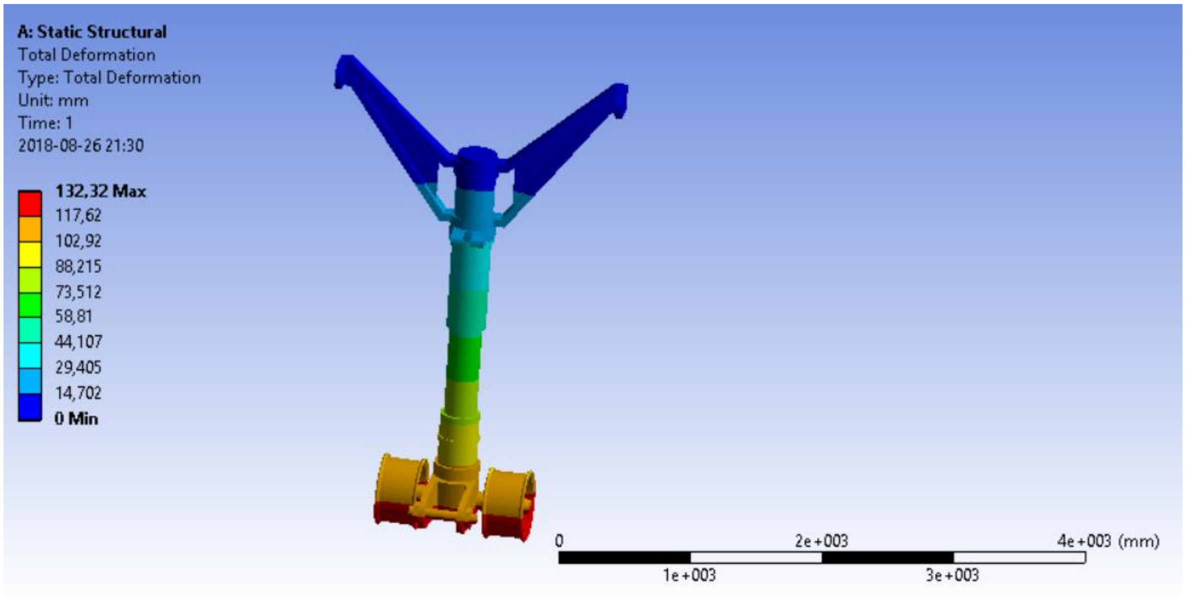


Figure 45: Total Deformation of Titanium 10Al-2Fe-3V

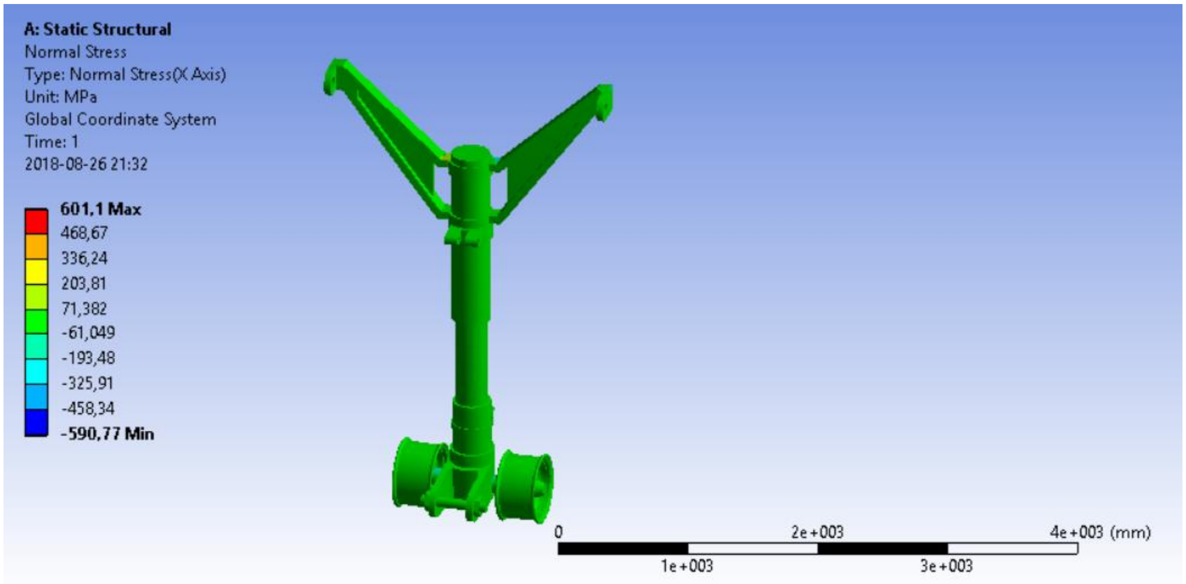


Figure 46: Normal Stress of Titanium 10Al-2Fe-3V

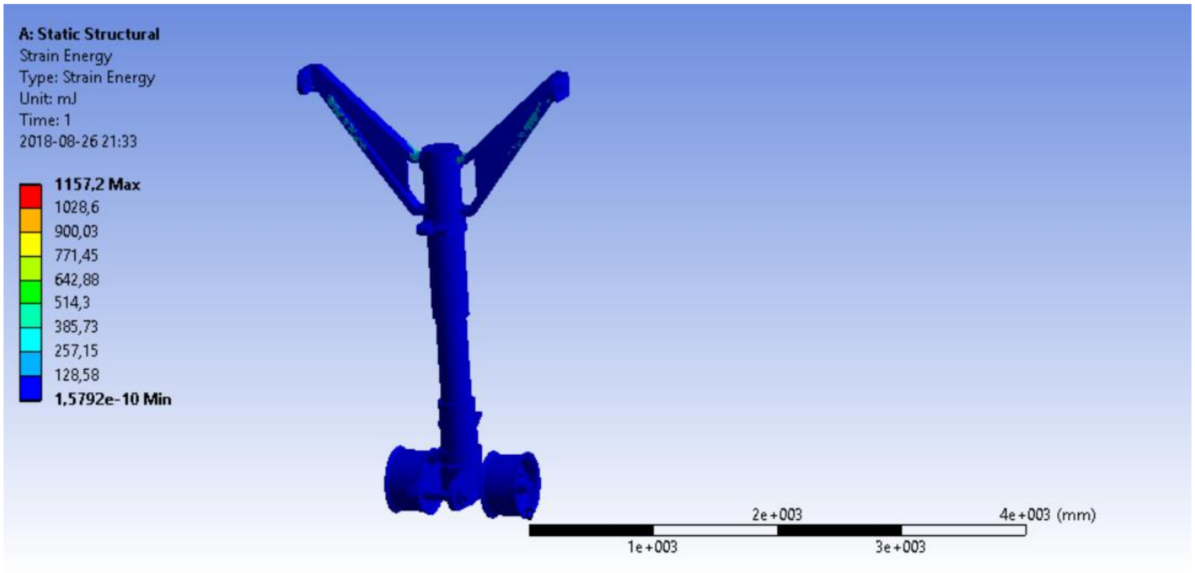


Figure 47: Strain Energy of Titanium 10Al-2Fe-3V

Table 8: Max: deformation, normal stress and strain energy

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)
Titanium 10Al-2Fe-3V	132,32	601,1	1157,2

- **Interpretation**

Table 9: The Results of all materials

Material	Max deformation (mm)	Max Normal Stress (MPa)	Max strain energy (mj)

Steel alloy: E4340	62,932	562,44	568,9
Aluminum Alloy 7075	178,12	581,45	1584,9
Titanium 10Al-2Fe-3V	132,32	601,1	1157,2

- The Steel alloy: E4340 has the minimum value of maximum normal stress, deformation and strain energy.
- The Aluminum Alloy 7075 has the maximum value of maximum stress and strain energy.
- The Titanium 10Al-2Fe-3V has the maximum value of maximum normal stress.

1. Conclusion

in this chapter I calculated the forces that are applied on the nose landing gear and I interpreted the following results in the static case from the ansys:

- The steel alloy E4340 resists normal stress, deformation and strain energy better than other materials (Aluminum Alloy 7075 and Titanium 10Al-2Fe-3V).
- The Aluminum Alloy 7075 doesn't resist well the stress and strain energy.
- The Titanium 10Al-2Fe-3V resists the least the normal stress than other materials (E4340 and Alloy 7075)

General conclusion

This project compiles numerical studies to determine the distribution of deformations and constraints that will appear in a main landing gear (in three- dimensional). To carry out this study, we considered different stages.

First of all, all the main parts of the nose landing gear have been modeled with CATIA design software and assembled to obtain the complete structure of our model.

Secondly, was numerically solved Static ground reaction loads without power: using the ANSYS software. Several materials have been varied to determine the best one.

Finally this project we chose the best material.

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ABSTRACT

Landing gear is one of the important parts of an aircraft; often referred to as undercarriage. Landing gear is a structure which is installed on the aircraft for the purpose to support the weight of the aircraft while it is on the ground and also allows the aircraft for smooth maneuver such as takeoff and landing.

In this work, I designed a typical nose landing gear of Boeing 777-300ER using CATIA software tool, and then I calculated the reactions of nose and main landing gear in the cases: Static ground reaction loads without power, Dynamic ground reaction loads and the reaction force when the aircraft touchdown.

Finally, I analyzed the landing gear structure for three materials using ANSYS and I interpreted the results.

Keywords:

Nose landing gear, Forces, CATIA, ANSYS, Materials, Stress analysis, Deformation, Energy…

RESUME

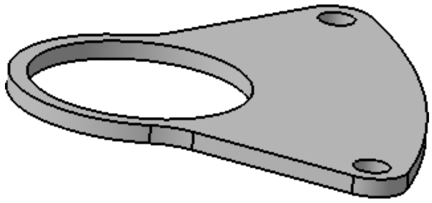
Le train d'atterrissage est l'une des parties importantes d'un avion; souvent appelé train d'atterrissage. Le train d'atterrissage est une structure qui est installée sur l'aéronef afin de supporter le poids de l'aéronef pendant qu'il est au sol et permet également à l'aéronef de manœuvrer en douceur, comme le décollage et l'atterrissage.

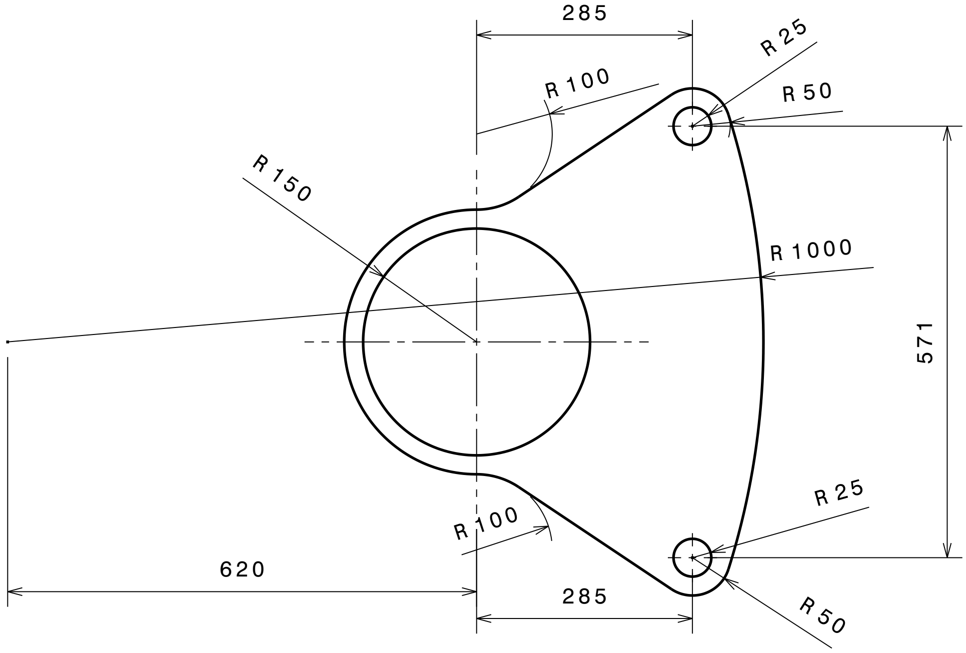
Dans ce travail, j'ai conçu un train d'atterrissage avant typique du Boeing 777-300ER à l'aide de l'outil logiciel CATIA, puis j'ai calculé les réactions du train avant et du train principal dans les cas suivants: La force de réaction du sol dans le cas statique sans puissance, la force de réaction dynamique au sol et la force de réaction lorsque l'appareil touche au sol.

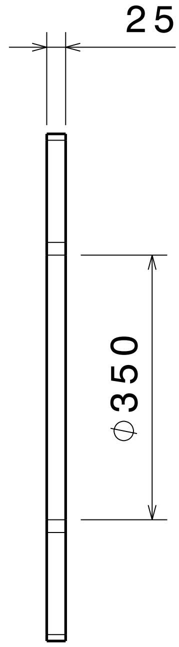
Enfin, j'ai analysé la structure du train d'atterrissage avant pour trois matériaux à l'aide d'ANSYS et j'ai interprété les résultats.

Mots clés :

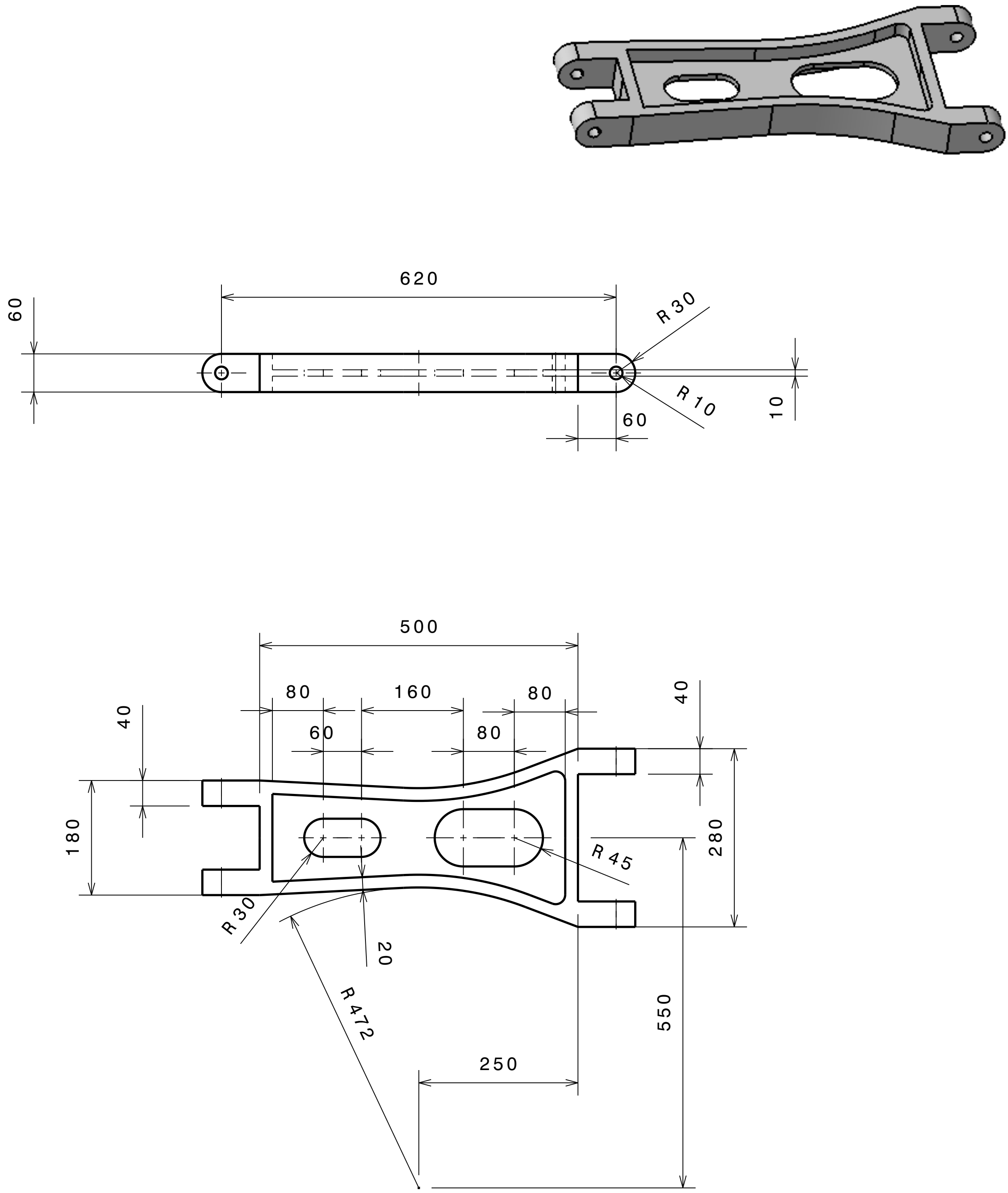
Train d'atterrissage avant, Forces, CATIA, ANSYS, Matériaux, Analyse du stress, Déformation, Energie…







DESIGNED BY: Khedder Ben Rais DATE: 2018-07-01 CHECKED BY: Nader Ben Jaber DATE: 2018-08-10	Study of Nose Landing Gear
SIZE A4	UJA - ESAT
SCALE 1:10	DRAWING NAME STEERING SUPPORT



DESIGNED BY:
Khedder Ben Rais
DATE:
2018-07-01

CHECKED BY:
Nader Ben Jaber
DATE:
2018-08-10

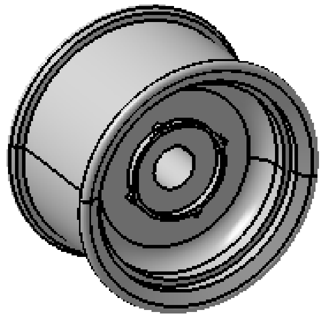
Study of Nose Landing Gear

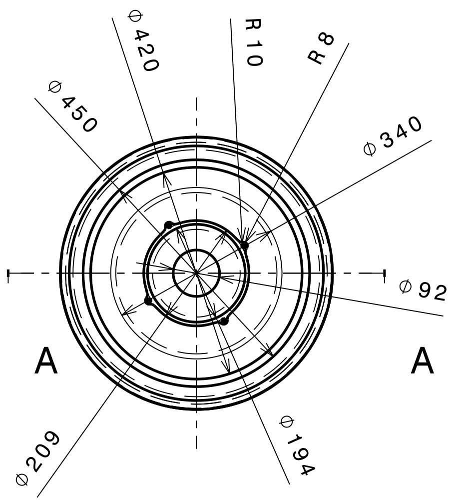
SIZE
A4

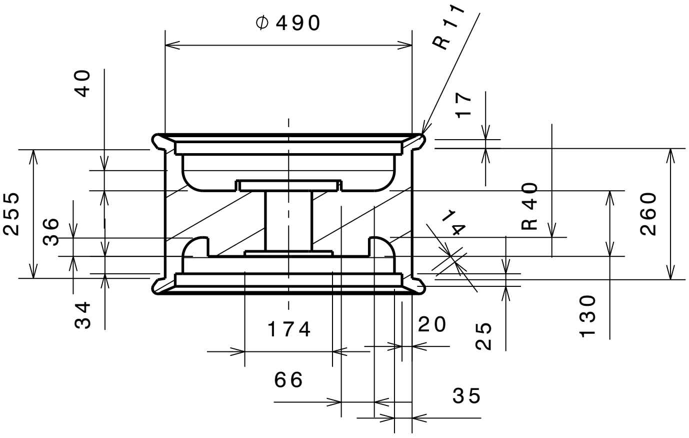
UJA - ESAT

SCALE
1:10

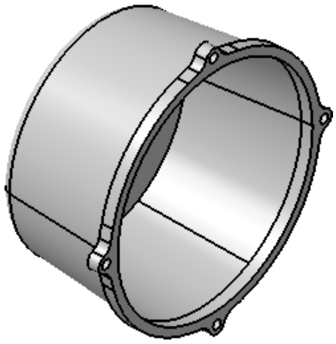
DRAWING NAME
LOWER TORQUE LINKS

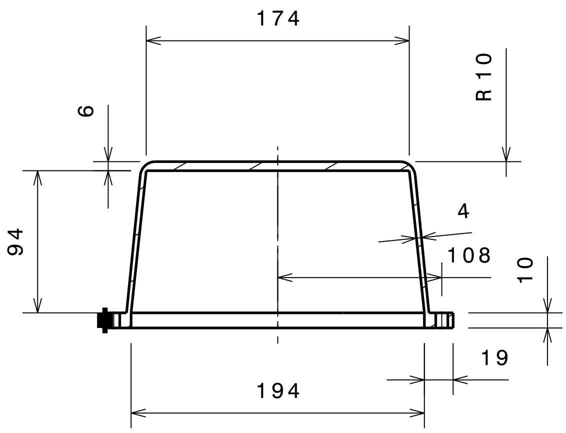


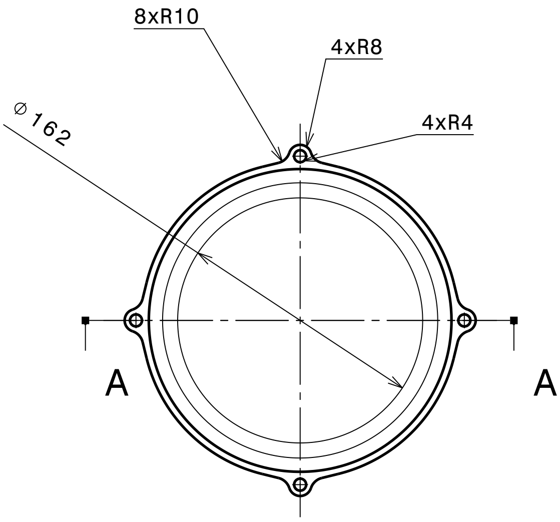




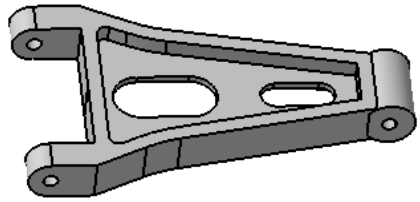
DESIGNED BY: Khedder Ben Rais DATE: 2018-07-01	Study of Nose Landing Gear
CHECKED BY: Nader Ben Jaber DATE: 2018-08-10	
SIZE A4	UJA - ESAT
SCALE 1:15	DRAWING NAME RIM

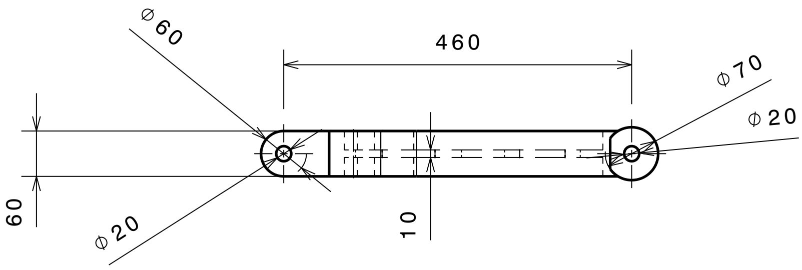


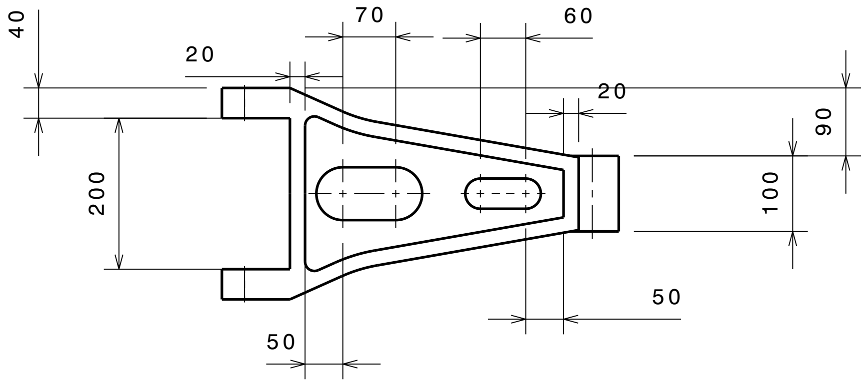




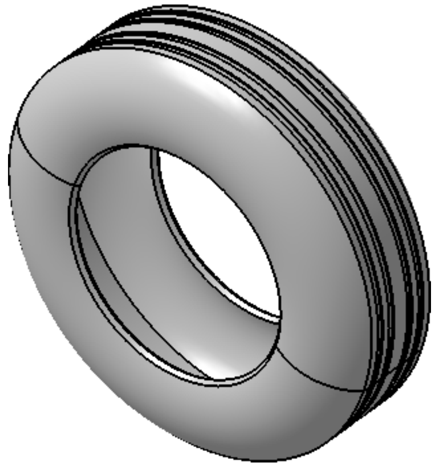
DESIGNED BY: Khedder Ben Rais DATE:	Study Of Nose Landing Gear
CHECKED BY: Nader Ben Jaber DATE: 2018-08-10	
SIZE A4	UJA - ESAT
SCALE 1:5	DRAWING NAME WHEEL COVER

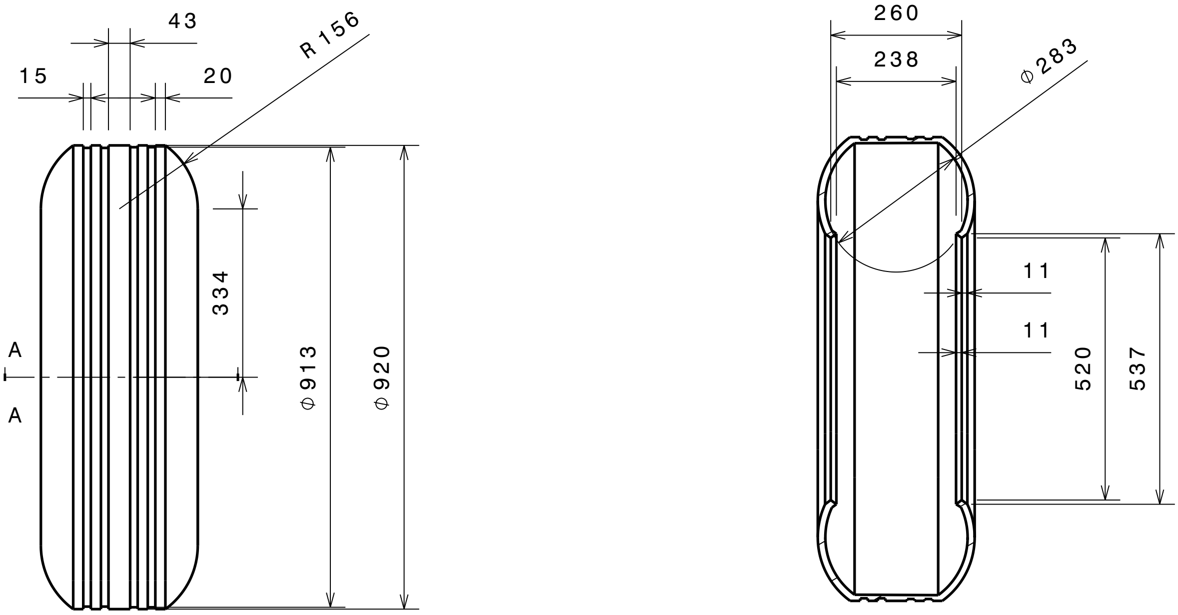






DESIGNED BY: Khedder Ben Rais DATE: 2018-07-01	Study of Nose Landing Gear
CHECKED BY: Nader Ben Jaber DATE: 2018-08-10	
SIZE A4	UJA - ESAT
SCALE 1:10	DRAWING NAME UPPER TORQUE LINKS





DESIGNED BY:
Khedder Ben Rais
DATE:
2018-07-01
CHECKED BY:
Nader Ben Jaber
DATE:
2018-08-10

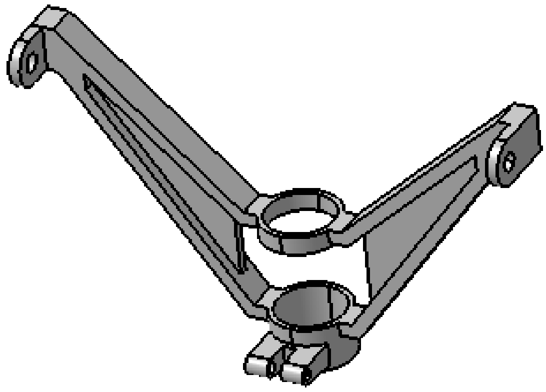
Study of Nose Landing Gear

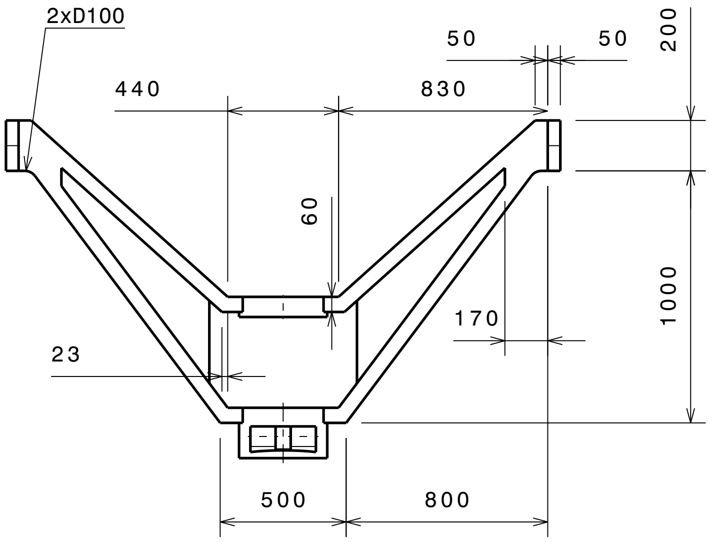
SIZE
A4

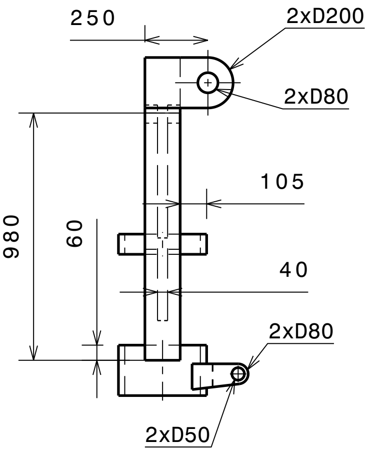
UJA - ESAT

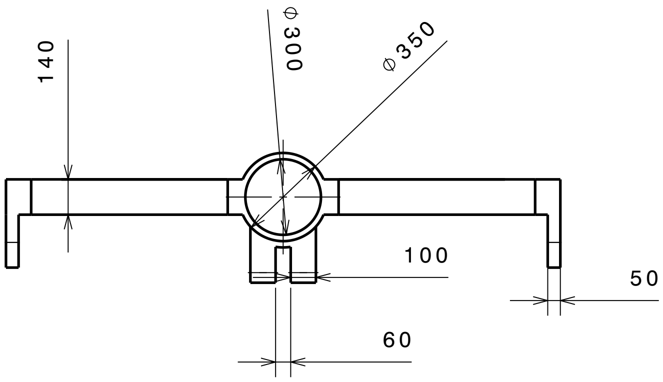
SCALE
1:15

DRAWING NAME
Tire









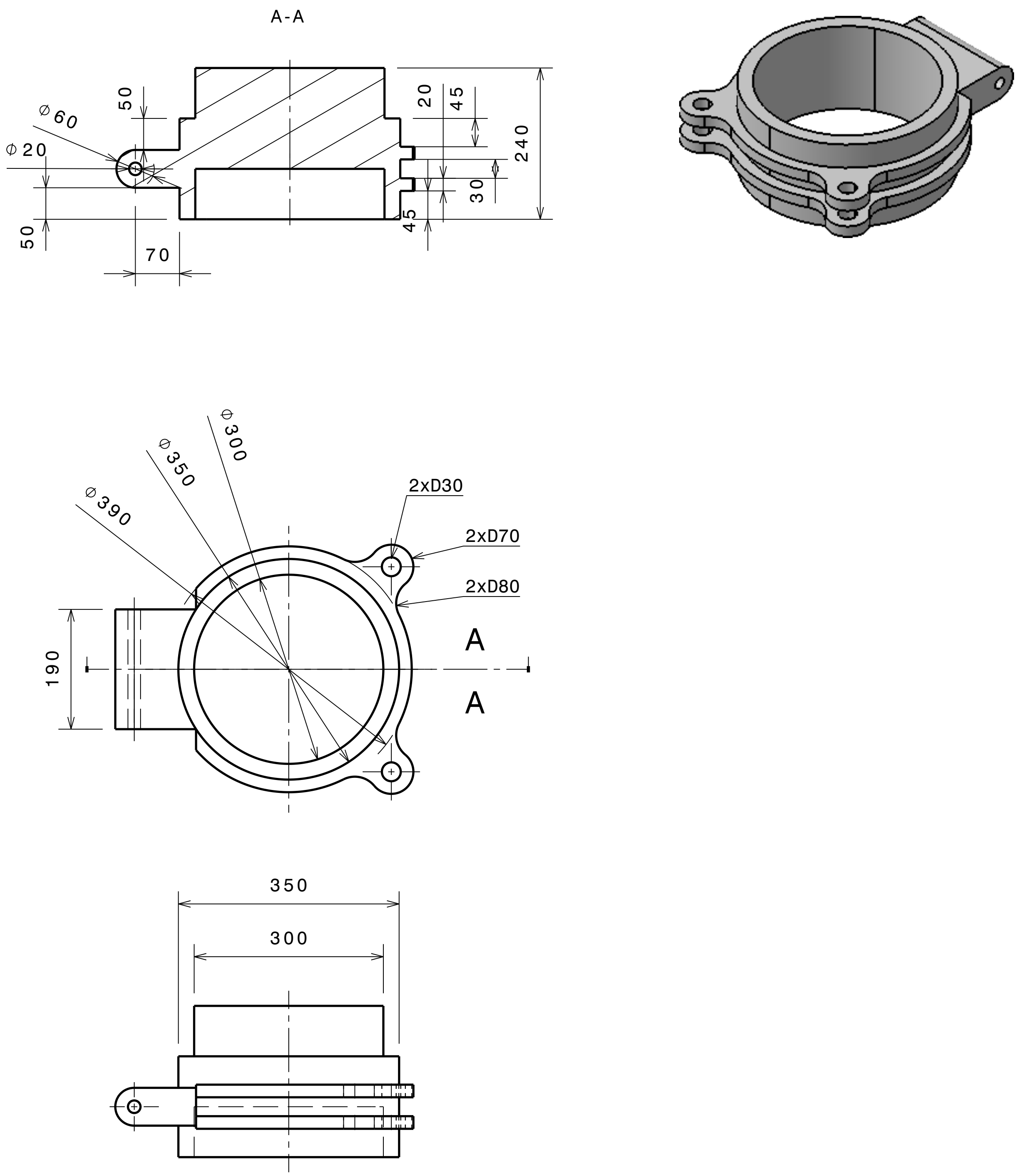
DESIGNED BY:
Khedder Ben Rais
DATE:
2018-07-01
CHECKED BY:
Nader Ben Jaber
DATE:
2018-08-10

Study of Nose Landing Gear

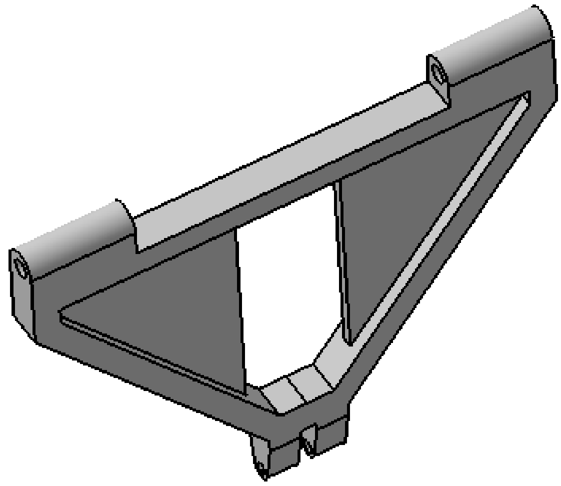
SIZE
A4

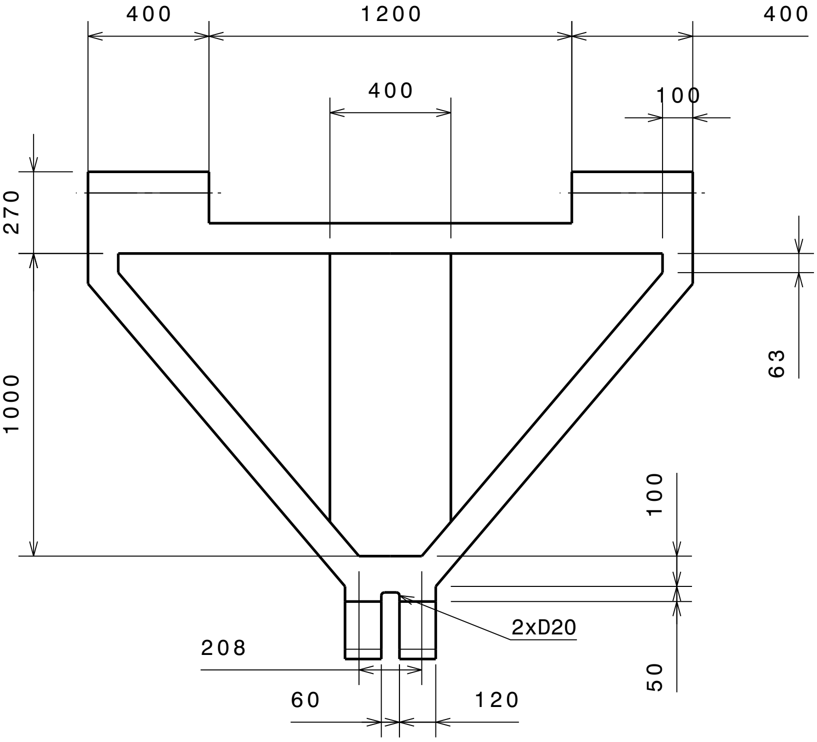
SCALE
1:30

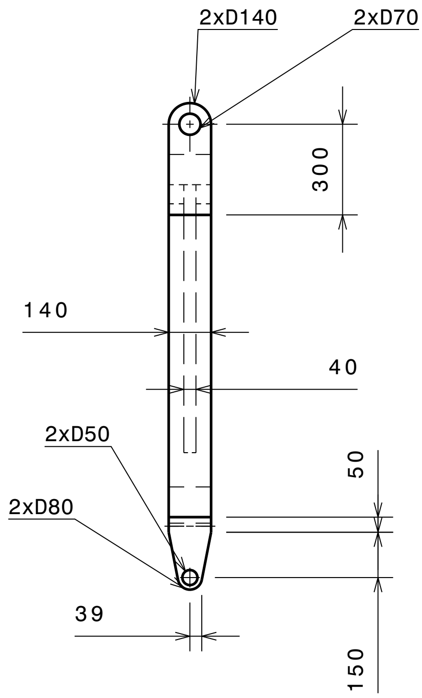
DRAWING NAME
Landing gear support



DESIGNED BY: Khedder Ben Rais DATE: 2018-07-01 CHECKED BY: Nader Ben Jaber DATE: 2018-08-10	Study Of Nose Landing Gear
SIZE A4	UJA - ESAT
SCALE 1:10	DRAWING NAME Rotary Collar







DESIGNED BY:
Khedder Ben Rais
DATE:
2018-07-01

CHECKED BY:
Nader Ben Jaber
DATE:
2018-08-10

Study of Nose Landing Gear

SIZE
A4

UJA - ESAT

SCALE
1:25

DRAWING NAME
Landing Gear Support