Escuela Politécnica Superior de Jaén

Grado en Ingeniería Mecánica

UNIVERSIDAD DE JAÉN

Escuela Politécnica Superior de Jaén

Trabajo Fin de Grado

ESTUDIO DE TREN DE ATERRIZAJE TRASERO DE AERONAVE

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Universidad de Jaén
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Don Miguel Angel Rubio Paramio , tutor del Proyecto Fin de Carrera titulado: Estudio de tren de aterrizaje trasero de aeronave, que presenta Dhekra Hamdi, autoriza su presentación para defensa y evaluación en la Escuela Politécnica Superior de Jaén.

Jaén, Septiembre de 2018

El alumno: Los tutores:

Dhekra Hamdi Miguel Angel Rubio Paramio

Jorge Manuel Mercado Colmenero

Dedication

At the best of fathers

To my dear mother

Who have always been there for me

To my sister Basma

Who support me all my life

To my brother Amin

To whom I wish a bright future full of success

To my friends

To all those who are dear to me

Acknowledgments

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.

I would like to express my gratitude to **Dr. Miguel Angel Rubio Paramio**, for agreeing to take the lead of our project.

I would like to thank my supervisor at **ESAT**, **Dr. Ben Jaber Nader**, for the quality of his supervision and his wise advice.

I wish to express our sincere thanks to The Founders, The Dean, and members of the administration of our **ESAT University** for providing us with all the necessary facilities.

Lastly, I also extend my sincere thanks to all the professors, speakers and all those who by their words, their writings, their advice and their critics guided my thoughts and agreed to meet me and answer my questions during my research.

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General Introduction

Landing Gear system is one of the critical subsystems of an aircraft and is often configured along with the aircraft structure because of its substantial influence on the aircraft structural configuration itself. Landing gear detail design is taken up early in the aircraft design cycle due to its long product development cycle time. The need to design landing gear with minimum weight, minimum volume, reduced life cycle cost, and short development cycle time, poses many challenges to landing gear designers and practitioners. These challenges have to be met by employing advanced technologies, materials, analysis methods, processes and production methods. Various design and analysis tools have been developed over the years and new ones are still being developed.

The purpose of the landing gear in an aircraft is to provide a suspension system during taxi, take-off and landing. It is designed to absorb and dissipate the kinetic energy of landing impact, thereby reducing the impact loads transmitted to the airframe. The landing gear also facilitates braking of the aircraft using a wheel braking system and provides directional control of the aircraft on ground using a wheel steering system. It is often made retractable to minimize the aerodynamic drag on the aircraft while flying.

In this context, my project is an example of a Boeing 777 main landing gear and this project is divided into three chapters, the first is the bibliographic studies, the second is the design part and the last is the simulation part.

Presentation of the university

The **University of Jaén** (UJA or UJAEN) is a public university based in Jaén, Andalucía, Spain. It is a young university established by Law 5 / 1993 of the Andalusian Parliament of July 1, 1993. In addition to the principal campus, Campus Lagunillas, located in Jaén, the university has two satellite campuses in Linares and Úbeda. Currently under construction is the Scientific-Technological Campus in Linares. [1]

University of Jaén	
Universidad de Jaén	
Motto	Vniversitas Giennensis
Type	Public
Established	1993
Vice-Chancellor	Juan Gomez Ortega
Students	16,990
Address	Campus Las Lagunillas, Ctra. Torrequebradilla s/n Jaén, Jaén, Linares and Úbeda, Andalusia, Spain
Website	http://www.ujaen.es

CHAPTER I: Bibliographic studies

1. Introduction:

Aviation, or air transport, refers to the activities surrounding mechanical flight and the aircraft industry. Aircraft includes fixed-wing and rotary-wing types, morphable wings, wing-less lifting bodies, as well as lighter-than-air craft such as balloons and airships.

Aviation began in the 18th century with the development of the hot air balloon, an apparatus capable of atmospheric displacement through buoyancy. Some of the most significant advancements in aviation technology came with the controlled gliding flying of Otto Lilienthal in 1896; then a large step in significance came with the construction of the first powered airplane by the Wright brothers in the early 1900s. Since that time, aviation has been technologically revolutionized by the introduction of the jet which permitted a major form of transport throughout the world.

A jet aircraft (or simply jet) is an aircraft (nearly always a fixed-wing aircraft) propelled by jet engines (jet propulsion).

There are thousands of designs and ideas about aircraft which have been developed through aviation history. Despite this some main components became permanent in every aircraft design. As fix-wing aircrafts are the most common aircrafts they will be the most studied.

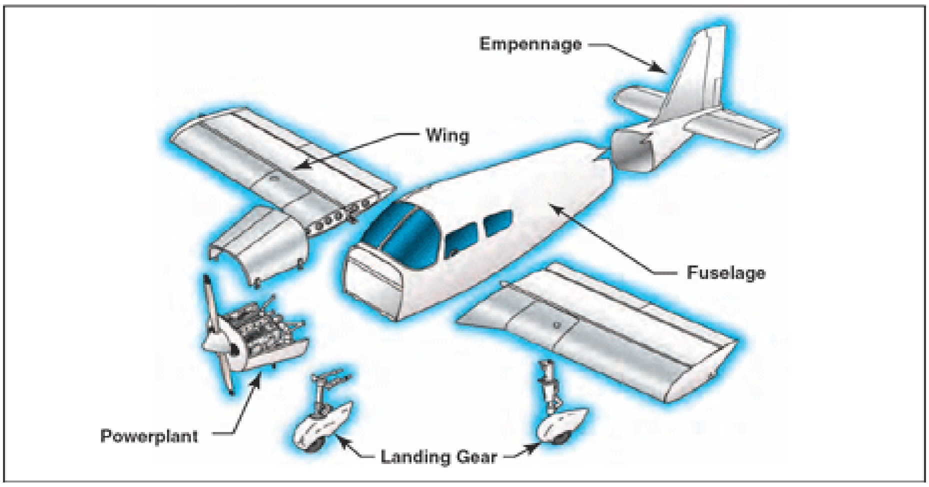


Figure 1: Components of an aircraft

2. Components of an aircraft:

2.1. The wings:

The wings are airfoils attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight. There are numerous wing designs, sizes, and shapes used by the various manufacturers. Each fulfills a certain need with respect to the expected performance for the particular airplane. Wings may be attached at the top, middle, or lower portion of the fuselage. These designs are referred to as high-, mid-, and low-wing, respectively. The number of wings can also vary. Airplanes with a single set of wings are referred to as monoplanes, while those with two sets are called biplanes. Many high-wing airplanes have external braces, or wing struts, which transmit the flight and landing loads through the struts to the main fuselage structure. Since the wing struts are usually attached approximately halfway out on the wing, this type of wing structure is called semi-cantilever. A few high-wing and most low-wing airplanes have a full cantilever wing designed to carry the loads without external struts. **[2]**

2.2. The fuselage:

The fuselage includes the cabin and/or cockpit, which contains seats for the occupants and the controls for the airplane. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components. Some aircraft utilize an open truss structure. The truss-type fuselage is constructed of steel or aluminum tubing. Strength and rigidity is achieved by welding the tubing together into a series of triangular shapes, called trusses.

2.3. The turbojet:

The turbojet is an airbreathing jet engine, typically used in aircraft. It consists of a gas turbine with a propelling nozzle. The gas turbine has an air inlet, a compressor, a combustion chamber, and a turbine (that drives the compressor). The compressed air from the compressor is heated by the fuel in the combustion chamber and then allowed to expand through the turbine. The turbine exhaust is then expanded in the propelling nozzle where it is accelerated to high speed to provide thrust. Two engineers, Frank

Whittle in the United Kingdom and Hans von Ohain in Germany, developed the concept independently into practical engines during the late 1930s.

Turbojets have been replaced in slower aircraft by turboprops because they have better range-specific fuel consumption. At medium speeds, where the propeller is no longer efficient, turboprops have been replaced by turbofans. The turbofan is quieter and has better range-specific fuel consumption than the turbojet. Turbojets are still common in medium range cruise missiles, due to their high exhaust speed, small frontal area, and relative simplicity.

Turbojets have poor efficiency at low vehicle speeds, which limits their usefulness in vehicles other than aircraft. Turbojet engines have been used in isolated cases to power vehicles other than aircraft, typically for attempts on land speed records. Where vehicles are 'turbine powered' this is more commonly by use of a turbo shaft engine, a development of the gas turbine engine where an additional turbine is used to drive a rotating output shaft. These are common in helicopters and hovercraft.

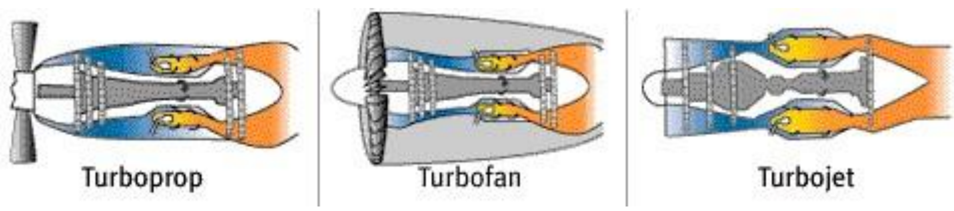


Figure 2: type of aircraft engine

2.4. Aircraft flight control surfaces:

As aircraft move in three dimensions we need various control devices to control it. Fix-wing aircrafts have control surfaces for each one of these dimensions. Usually these are placed in the extremes of the aircraft (tail and wings) to get the maximum strength and response using small moving parts thanks to the lever concept.

Note that an airplane is easier to maneuver the more unstable it is. Stability can be provided by stabilizers and fuselage and wing design.

2.4.1. Vertical stabilizer and rudder:

The vertical stabilizer functions with the same principle a wing does, but being symmetrical. It is a main control surface of airplanes (fix-wing aircraft). Obviously, it has a vertical position, usually in the tail of the aircraft. There can be multiple vertical stabilizers (in large aircraft usually).

The vertical stabilizer has a moving part which is called Rudder. This acts as an aileron does in the wing. When it is moved to one or other side it produces a pressure difference over the stabilizer since it's movement is equal to change the angle of attack of this 'wing'.

The rudder controls the Y-axis or Yaw of the plane and it is controlled from the cockpit with the pedals. In a coordinated turn, rudder and ailerons must be coordinated, but you can use rudder only to 'slide' the aircraft.

Some rudders are mixed with elevators in the same control surface, creating V-tail aircraft.

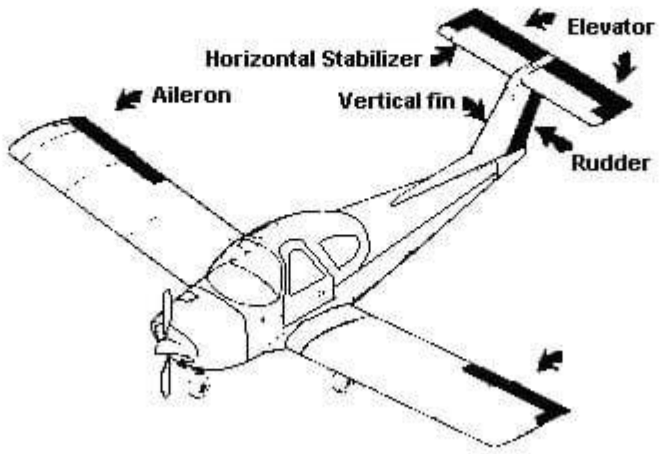


Figure 3: Aircraft flight control surfaces

2.4.2. Horizontal stabilizer and elevator:

The horizontal stabilizer is the main control surface of the aircraft, mainly of airplanes (fixed-wing aircraft). It functions as a wing does, creating a second point of lift along the fuselage which provides stability to the aircraft in the Z-axis. Its function is not to provide more lift but to control the Pitch of the aircraft (by modifying the angle of attack of the wing). This is thanks to a moving part or parts called Elevators, which act like an aileron, and are controlled by the longitudinal axis of the joystick or wheel.

Obviously, the horizontal stabilizer has a horizontal position, usually in the tail of the aircraft. It can be on top of the vertical stabilizer (T-tail aircraft), or divided in two parts crossing the vertical stabilizer. Some horizontal stabilizers have no elevators but are a whole elevator (mainly in gliders, since it has a better aerodynamic performance). In Canard-configuration planes, the horizontal stabilizer is positioned not in the tail but in the nose of the aircraft (note that its movement to reduce or increase pitch will be inverted from the one it does when it's placed in the tail).

Sometimes, elevators are mixed with rudders in the same control surface, creating V-tail aircraft. It also can be combined with ailerons, mainly in delta-wing planes.

2.4.3. Aileron:

Ailerons are moving surfaces usually placed near the tips of the wings. The function of an aileron is simple, by moving upwards or downwards it modifies the angle of attack of that section of the wing, sinking or lifting it. This change in the aerodynamic is due to the modification of relative curve of the airfoil. Note that ailerons are complementary, so if one moves the other will move on the other direction in the same proportion. This improves the effect as one wing is lifted and the other sunk. Ailerons control the X-axis or roll movement of the aircraft.

Ailerons are controlled by the pilot from the cockpit, with the lateral axis of the joystick. To make coordinated turns the movement must be combined with rudder in the same direction. In some planes ailerons are just divided elevators, being possible to use the same surface as aileron or elevator (delta-wing airplanes).

2.5. The empennage:

The empennage (also called tail) is the rear part of the aircraft. Usually it includes the stabilizers, rudder and elevator as many other components. In fighter jets it may be constructed around the exhaust nozzle, as in some three-engine airplanes (with the third engine in the fuselage). In commercial aircrafts the empennage is built from the cabin pressure-cone and may contain the Flight Data Recorder ("black box"), Cockpit Voice Recorder and the pressure out-flow valve. [2]

2.6. Landing gear:

A landing gear is the set of components involved in the landing, taxiing, steering, braking and takeoff functions of the aircraft.

If the mission of an airplane is to fly, several phases of its operating cycle take place on the ground. Thus, at the end of the flight, the plane must be able to land and slow down on the airstrip of his destination, before heading to his parking spot. He must then be able to leave again to go to the runway, launch and take off to a new destination.

2.6.1 History:

- At the beginning of aviation the problem of the landing gear does not arise. The machines are very light and the pilot's legs are sufficient for takeoff and return on the ground.

Figure 4: Lilienthal-1895

- With the mounting of an engine the machines become heavier, a device of replacement of the legs becomes necessary. A first solution is to place the machine on rails for takeoff and skates are enough for landing.

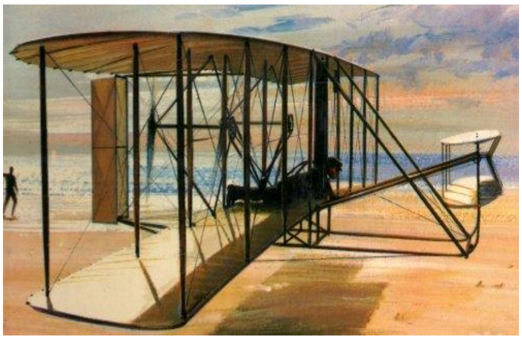


Figure 5: Wright-1903

- The first landing gear will be inspired by the emerging car with four wheels.

Figure 6: Quadricycle

- But very quickly the so-called "classic" train with two main wheels in front of the center of gravity and a wheel or a skate on the back will prevail on virtually all planes for obvious reasons: lighter and less drag .

Figure 7: S-l300

- This train keeps its advantages: lightness, finesse. Any time for the piloting on the ground the plane proves flighty and requires a great attention not to leave the track.

At the time of the "airfields" with a large surface without tracks delimited this "inconvenient" had less importance than with the current tracks.

This is probably why in 1912 one of the first tricycle train appears. Two main wheels behind the center of gravity and one forward often steering.

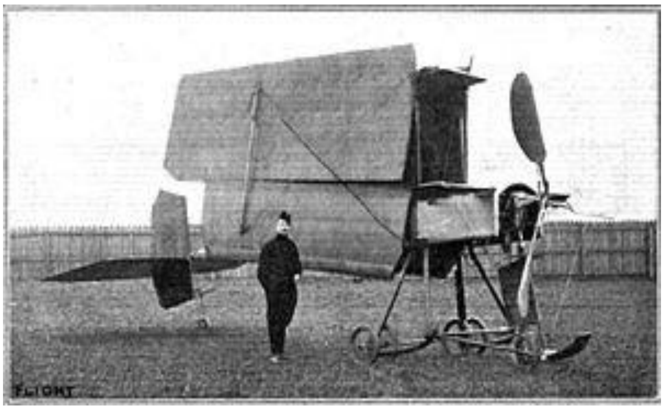


Figure 8: Breguet-Tricycle-1912

- In 1920, the legendary Gordon Bennett Cup was held in Estampes. But this year, the competition offers a curiosity. For the first time in history, a pilot, Howard Rinehart, is flying a retractable landing gear. This racing aircraft was specially designed for the Gordon Bennett Cup by the company Dayton-Wright.

Figure 9: Dayton-Wright_XPS-1

- Hydraulic powered Landing Gear , He-70 , 1932.

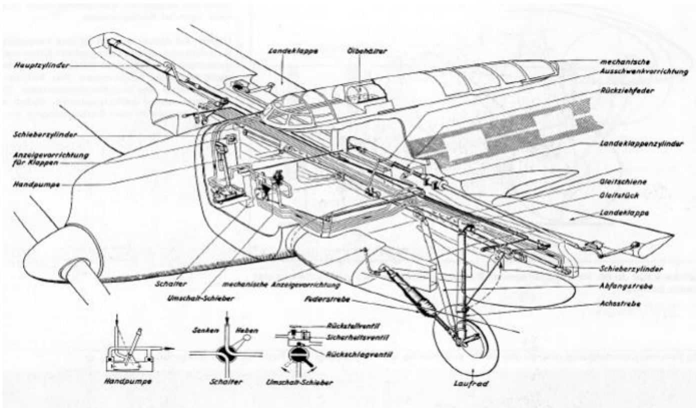


Figure 10: He-70 , 1932

- Tandem Gear , Boeing B-52 , 1954.

Figure 11: Tandem Gear

- And then the development got according to these requirements:
  - Comfortable shock absorption,
  - Short stopping distance (braking),
  - High rolling stability during ground maneuvering,
  - Low drag (specially for fixed landing gears),
  - High reliability and safety,
  - Low maintenance,
  - Low weight.
- Future Trends:
  - Smart Shock Absorbers,
  - Integrated Control Units,
  - Improved Materials for Struts and Brakes,
  - Maintenance-free components,
  - More electrical Actuation. [3]

2.6.2. Types of landing gear:

- **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 centre 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. The proliferation of hard surface runways has rendered the tail skid obsolete in favor of the tail wheel. Directional control is maintained through differential braking until the speed of the aircraft enables control with the rudder. A steerable tail wheel, connected by cables to the rudder or rudder pedals, is also a common design. Springs are incorporated for dampening.

Figure 12: Tail wheel-type Landing Gear

- **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. The tailwheel aircraft also sits with its nose higher than tricycle gear airplane, lowering forward visibility for the pilot during ground operations. It's more difficult to taxi without being able to see directly in front of you, which is why you'll often see pilots of tailwheel aircraft do S-turns while taxiing. And steering a tailwheel aircraft is different than steering a nosewheel aircraft since steering is accomplished from behind the pilot instead of in front. There are certainly benefits to a taildragger, as well. The nose-high attitude on the ground means that the propellors on tailwheel aircraft often have more clearance from the ground, making them better suited for grass or dirt runways. And they're often designed and configured for slow flight, making them easier to land on short runways. Many are high-design and are better suited for backcountry flying than nosewheel aircraft are. Tailwheel airplanes are without a doubt the favorite airplane among bush pilots.

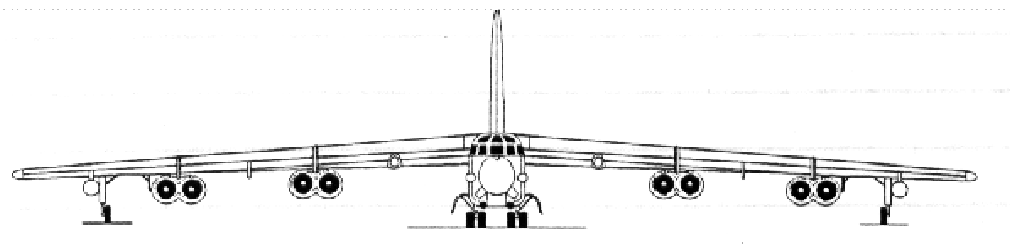


Figure 13: Tandem Landing Gear

- **Tri-Cycle 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. Tricycle-type landing gear is used on large and small aircraft with the following benefits:

1. Allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.

2. Provides better visibility from the flight deck, especially during landing and ground maneuvering.

3. Prevents ground-looping of the aircraft. Since the aircraft centre of gravity is forward of the main gear, forces acting on the centre of gravity tend to keep the aircraft moving forward rather than looping, such as with a tail wheel type landing gears.

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. Heavy aircraft typically utilize hydraulic power to steer the nose gear. Control is achieved through an independent tiller in the flight deck. 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.

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.

Figure 14: Tri-Cycle Type Landing Gear

2.6.3. Main and nose landing gear:

The main landing gear is usually located near the center of gravity of the aircraft. They absorb the kinetic energy due to the vertical component of the speed of the aircraft during contact with the ground, bear the bulk of the weight of the aircraft and ensure the suspension of the aircraft during the taxi phase. The gap between the landing gear is called a track and that between the main and the auxiliary is called wheelbase.

The undercarriage is positioned under the nose of the aircraft. He is called then, lander before. Its role is to ensure the longitudinal balance of the aircraft on the ground, statically and dynamically. It is also used to maneuver the plane with the rudder. The front trains are often equipped with 2 wheels carried by an axis (the rocket) the whole is called a diabolo.

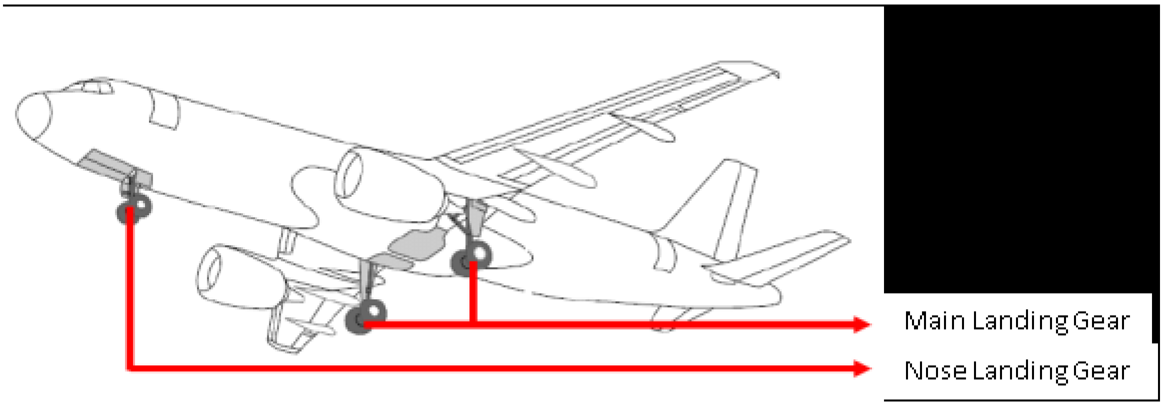


Figure 15: Main and nose landing gear

2.6.4. Fixed and Retractable Landing Gear:

Further classification of aircraft landing gear can be made into two categories: fixed and retractable. Many small, single engine light aircraft have fixed landing gear, as do a few light twins. This means the gear is attached to the airframe and remains exposed to the slipstream as the aircraft is flown. As discussed in Chapter 2 of this handbook, as the speed of an aircraft increases, so does parasite drag. Mechanisms to retract and stow the landing gear to eliminate parasite drag add weight to the aircraft. On slow aircraft, the penalty of this added weight is not overcome by the reduction of drag, so fixed gear is used. As the speed of the aircraft increases, the drag caused by the landing gear becomes greater and a means to retract the gear to eliminate parasite drag is required, despite the weight of the mechanism.

A great deal of the parasite drag caused by light aircraft landing gear can be reduced by building gear as aerodynamically as possible and by adding fairings or wheel pants to streamline the airflow past the protruding assemblies. A small, smooth profile to the oncoming wind greatly reduces landing gear parasite drag. A Cessna aircraft landing gear used on many of the manufacturer’s light planes. The thin cross section of the spring steel struts combine with the fairings over the wheel and brake assemblies to raise performance of the fixed landing gear by keeping parasite drag to a minimum.

Retractable landing gear stow in fuselage or wing compartments while in flight. Once in these wheel wells, gear are out of the slipstream and do not cause parasite drag. Most retractable gear have a close fitting panel attached to them that fairs with the aircraft skin when the gear is fully retracted. Other aircraft have separate doors that open, allowing the gear to enter or leave, and then close again.

In addition to supporting the aircraft for taxi, the forces of impact on an aircraft during landing must be controlled by the landing gear. This is done in two ways: 1) the shock energy is altered and transferred throughout the airframe at a different rate and time than the single strong pulse of impact, and 2) the shock is absorbed by converting the energy into heat energy. Many aircraft utilize flexible spring steel, aluminium, or composite struts that receive the impact of landing and return it to the airframe to dissipate at a rate that is not harmful. The gear flexes initially and forces are transferred as it returns to its original position. The most common example of this type of non-shock absorbing landing gear are the thousands of single-engine Cessna aircraft that use it. Landing gear struts of this type made from composite materials are lighter in weight with greater flexibility and do not corrode. [4]

Figure 16: Fixed and Retractable Landing Gear

2.6.5. Missions assured:

The missions performed by the landing gear are multiple:

- Absorption of the residual vertical kinetic energy of the aircraft during the impact on the ground on landing, to mitigate the corresponding ground forces;

- braking of the aircraft on the runway after landing, that is absorption of horizontal kinetic energy, with optimization of the stopping distance;

- Taxiing the aircraft on the runway at speeds from zero to take-off speed (which may exceed 360 km / h);

- Maneuver on the ground up to very low speeds (turns or swings on site), facilitated by the possibility of orienting the wheels of the aircraft;

- Immobilization of the aircraft at its parking point (parking);

- Retraction of flight of the landing gear in the airplane.

2.6.6. Landing Gear Dimensions:

When the airplane is in flight line, on a horizontal ground, the dimensions of the train must be sufficient not to rub the ground at takeoff or landing with the wingtips, the tail or worse, the propeller.

- Train height:

For a tricycle or classic train, it must be sufficient compared to the ends of the wings and with respect to the tail:

• 8 ° between the right wheel-ends and the ground

• 10 to 16 ° between the right-hand wheels and the ground

(airplane in flight line and horizontal ground).

- Width of the train:

The distance between wheels (Wheel track) must be at least:

• 1.5 times the height of the train and,

• 1/5 of the wingspan.

Wheel base: for a tricycle train, the wheel base, distance between the axes of the front wheel and main wheels, must be at least:

• L = 1 to 1.5 times the wheel track. [6]

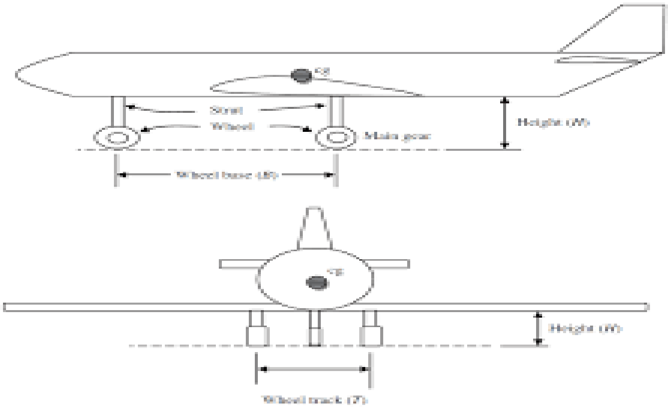


Figure 17: Landing Gear Dimensions

3. Finite element calculation:

3.1. 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.

3.2. 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.

3.3. Definition of a finite 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.

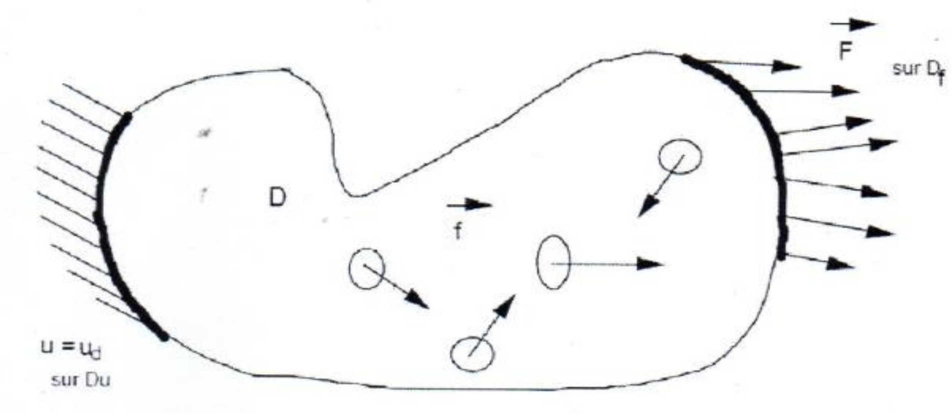


Figure 18: Continuous medium and discretized medium

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

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

3.4. Formulation of a finite element:

3.4.1 Definitions and notations:

3.4.1.1. Displacement:

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

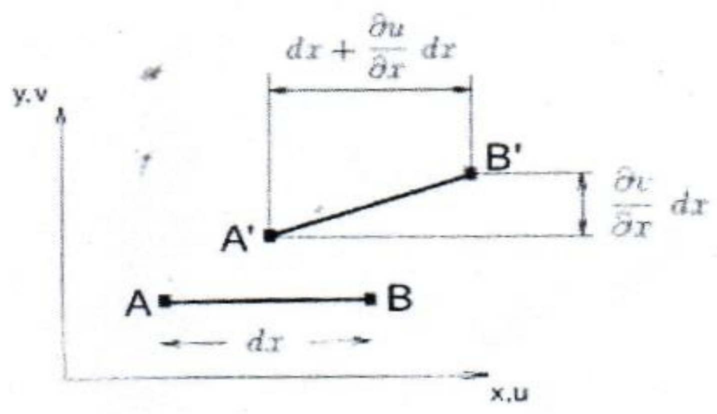
- 3 dof of translation: Ux, Uy, Uz
- 3 dof of rotation: θx, θy, θz

3.4.1.2. Deformation:

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

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

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

3.4.1.3. 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:

$$[\sigma] = \begin{bmatrix} \sigma_x & 0 & 0 \\ 0 & \sigma y & 0 \\ 0 & 0 & \sigma z \end{bmatrix}$$

$\sigma x, \sigma y, \sigma z$: are called the main constraints.

3.4.1.4. 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 : $\boldsymbol{G} = \frac{\boldsymbol{E}}{\mathbf{2(1+\boldsymbol{v})}}$

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.

3.4.1.5. Deformation energy:

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

3.4.1.6. Work of a force:

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

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

3.4.1.7. Moment:

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

3.4.2 Fundamental Equations:

Local equilibrium equations:

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

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

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

Deformation- displacement relationships :

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

$$\gamma_{xz} = \frac{\partial w}{\partial x} + \frac{\partial \mu}{\partial z}$$

$$\gamma_{xy} = \frac{\partial \mu}{\partial y} + \frac{\partial \boldsymbol{v}}{\partial x}$$

$$\gamma_{yz} = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}$$

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

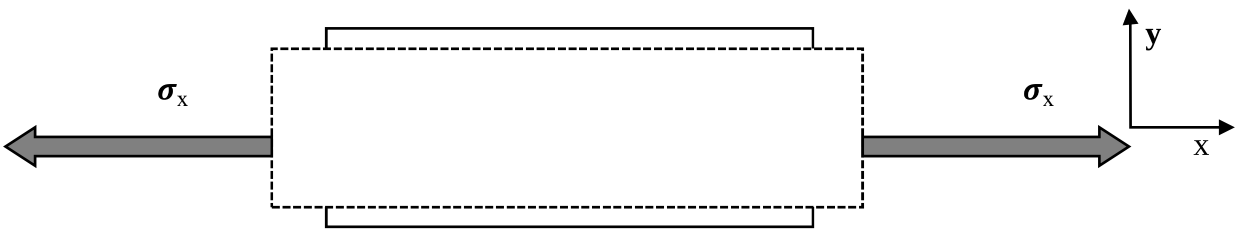


Figure 19: Meaning of the Poisson's ratio

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

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.

3.5. 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}

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

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

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

3.6. 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 $\{\epsilon(x)\} = [S]\ \{u(x)\}$

Hence

$\{\epsilon(\mathbf{x})\} = [S]\ \{N(x)\}\{U\} = [B(x)]\{U\}$

We write the constitutive law of the material which 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:

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

By explaining, we have:

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

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

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

With [k] in its more general form; $[k] = \int_V [B]^T[D][B]\, dv$

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.

3.7. 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:

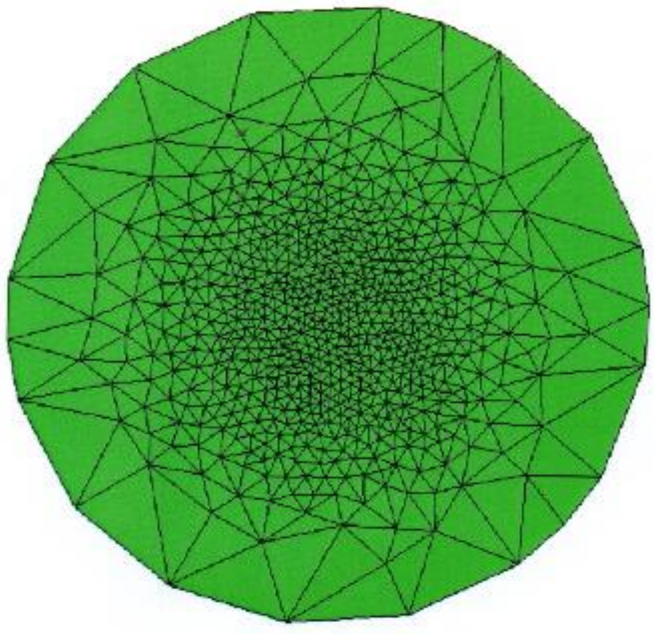


Figure 20: Triangular surface mesh

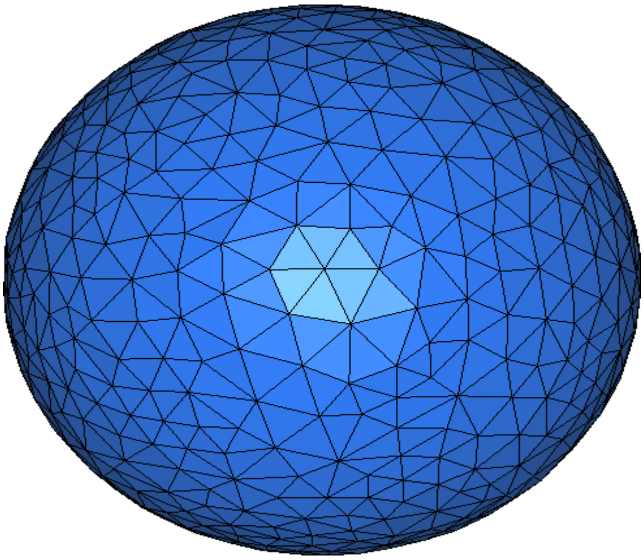


Figure 21: Triangular mesh volume

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.

3.8. Basic function:

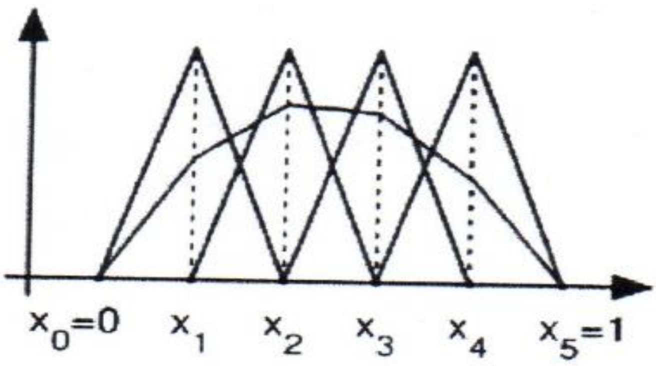


Figure 22: Basic function in dimension 1

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)

3.9. Geometric discretization:

This operation consists in dividing the continuous domain into sub domain

$D = \sum_{e=1}^{ne} De$ such as $\lim_{e}(DeUe) = D$

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.

4. some examples of landing gear simulation:

4.1. Material based structural analysis of a typical landing gear:

Initially, they designed and meshed a typical landing gear of Boeing 747 aircraft using ANSA software tool, and then analyzed for structural safety using ANSYS software. The maximum possible load (1473950N – 1/3 of Maximum landing load of Boeing 747) is given as design load. Landing gear is analyzed for the traditional metallic materials like Aluminum Alloy 7075, Alloys Steel 4340, Titanium 6AL-4V, Titanium 6AL-6V-2Sn, and Titanium 10Al-2Fe-3V. While comparing the results of the above mentioned materials, Titanium 10Al-2Fe-3V has the maximum factor of safety, and the minimum value of maximum stress developed and deflection. So, the modelled landing gear will be safer for the Titanium 10Al- 2Fe-3V material to avoid the structural failure. [6]

4.2. Vibration Modal Analysis of Landing Gear Based on ANSYS:

In this paper, ANSYS finite element modal analysis is carried out on the aircraft landing gear. The first four natural frequencies and modes are obtained and compared with the brake vibration test. The following conclusions are obtained.

Table 1: Result

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

1) 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.

2) 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.

3) 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. [7]

5. Conclusion:

The main purpose of this chapter was to make a bibliographic search to acquire the maximum information about the landing gear. At the beginning I gave an overview of the components of the aircraft specially the landing gear. Then, I introduce the finite elements method. Finally, some examples of landing gear simulation.

CHAPTER II: The modeling part

1. Introduction:

In this chapter I'm going to create the landing gear model. First I start by creating the landing gear parts using "part design" in CATIA. Then, I will assemble all the parts I creates using "assembly design". finally, I will do the plan of each part.

2. Presentation of the software CATIA:

2.1 Introduction:

CATIA an acronym of computer-aided three-dimensional interactive application, is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), PLM and 3D, developed by the French company Dassault Systèmes.

CATIA assist the engineer in his product design activities and associated processes (production, assembly, maintenance, etc.). It is thus much more than a simple software allowing the geometrical definition of a mechanical assembly. It is a real multidisciplinary platform for modeling and optimizing the product / process pair.

2.2 CATIA interface:

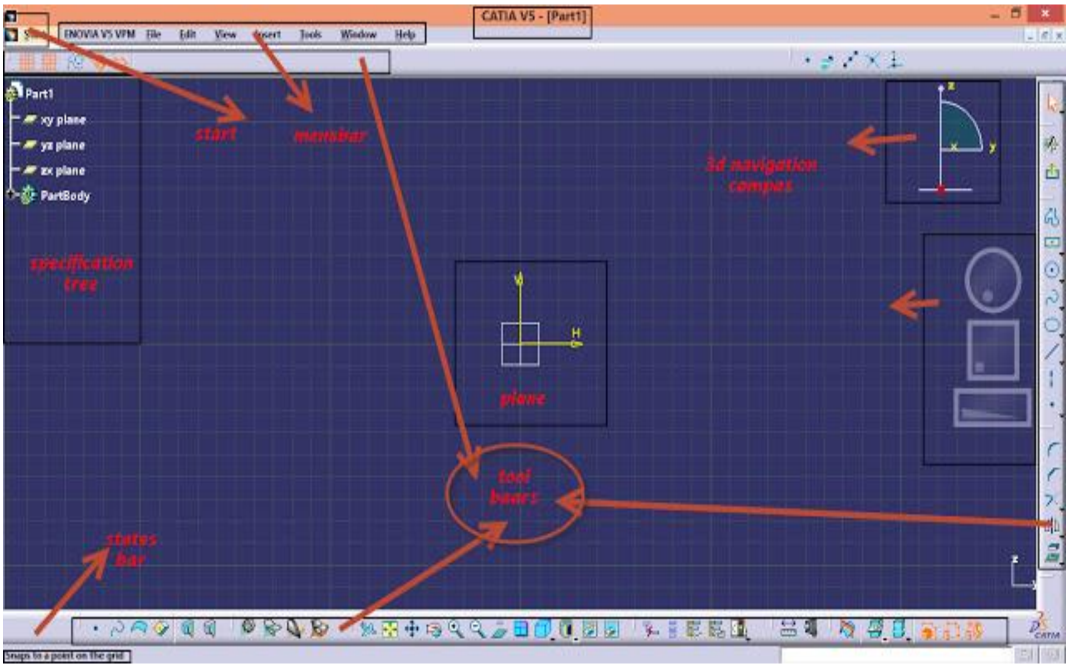


Figure 23: Catia interface

2.3 The mechanical design module:

The mechanical design module includes several workshops such as:

- Part Design: Voluminal modeling of mechanical parts.

- Assembly Design: Modeling assemblies of mechanical parts.

- Sketcher: 2D sketch.

- Drafting: Drawing of parts (definition drawing) and assemblies (overall drawing).

- Wireframe and Surface Design: Modeling of surfaces and wire elements. Workshop complementary to the workshop "Part design".

- Sheetmetal Design: Sheet Metal Workshop.

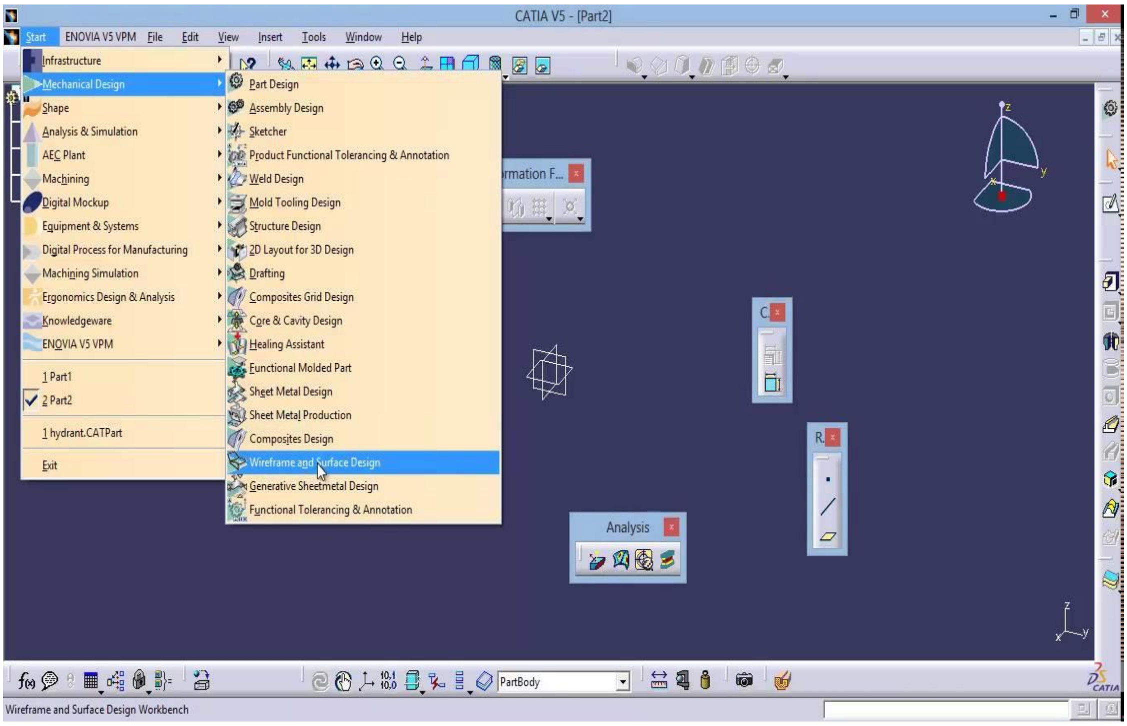


Figure 24: Catia interface

3. System presentation:

At impact, the absorption of energy must be done quickly to avoid excessive loads on the structure.

Figure 25: Boeing 777 landing gear

The tire touches the ground first, it is he who is in direct contact with the road and who undergoes sudden and extreme variations of temperatures which are due to the speed of rolling, the flattening of the tire, the heat, the load permissible pressure and the inflation pressure. The tires are said to be "tubeless" or tubeless, that is to say that the air chamber is a waterproof coating adhered to the inside of the tire.

The rim that surrounds it in its center is made in two parts called half-wheels. The brake-side half-wheel is made of an alloy that withstands high temperatures. The other half-wheel is made of an alloy that is less resistant to temperature but has better mechanical characteristics. The half-wheel brake side is larger and therefore welcomes the brake. The rim is assembled by an extremely strong bolt belt to withstand high vertical and lateral loads.

During braking, the pads are pushed on the disc via pistons driven in translation by a hydraulic system. The friction of the pads on the disc causes braking of the aircraft.

In order to increase the number of wheels and better distribute the load of the aircraft is used a balance that can accommodate on both sides of its two trains two wheels.

The damper uses a gas to ensure the elasticity function and a very slightly compressible liquid (hydraulic fluid) to ensure damping function. It is constituted by a cylinder (box of the leg) in which a piston integral with the wheel (rod of the damper) forces the compressed hydraulic fluid between a piston and a diaphragm to pass through it, through calibrated orifices whose opening is caused by the oil pressure. Located between the balance and the damper, the compass prevents the rotation of the sliding rod relative to the box. The strut allows to take up the lateral forces of the stem due to the yaw trajectory of the aircraft, the rolling resistance of the tires and braking.

The compression is completed, under the effect of the pressure energy stored by the gas, the damping is relaxed. To avoid oscillations, this relaxation must be done slowly.

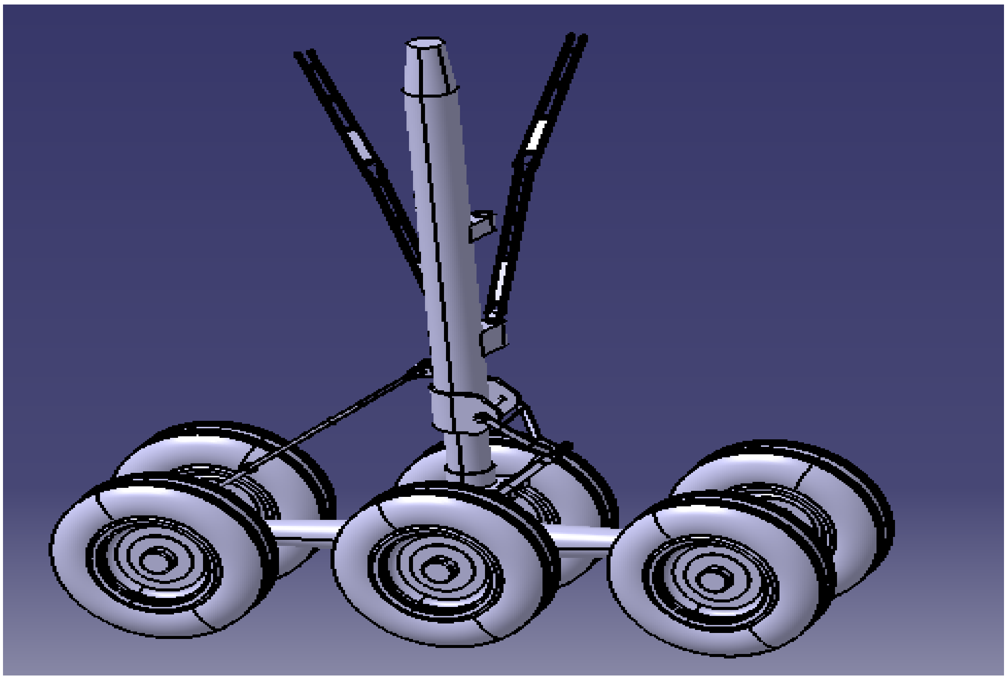


Figure 26: 3D Catia model of landing gear

4. Components of landing gear:

A landing gear is composed of:

4.1 The master cylinder:

The master cylinder of the landing gear, along with the connecting elements, provides the suspension and absorbs impact during landing. The complex design enables the landing gear to be extended and retracted within seconds.. Since these components must satisfy the most rigorous safety standards, only very few materials qualify for use, principally titanium alloys and 300M.

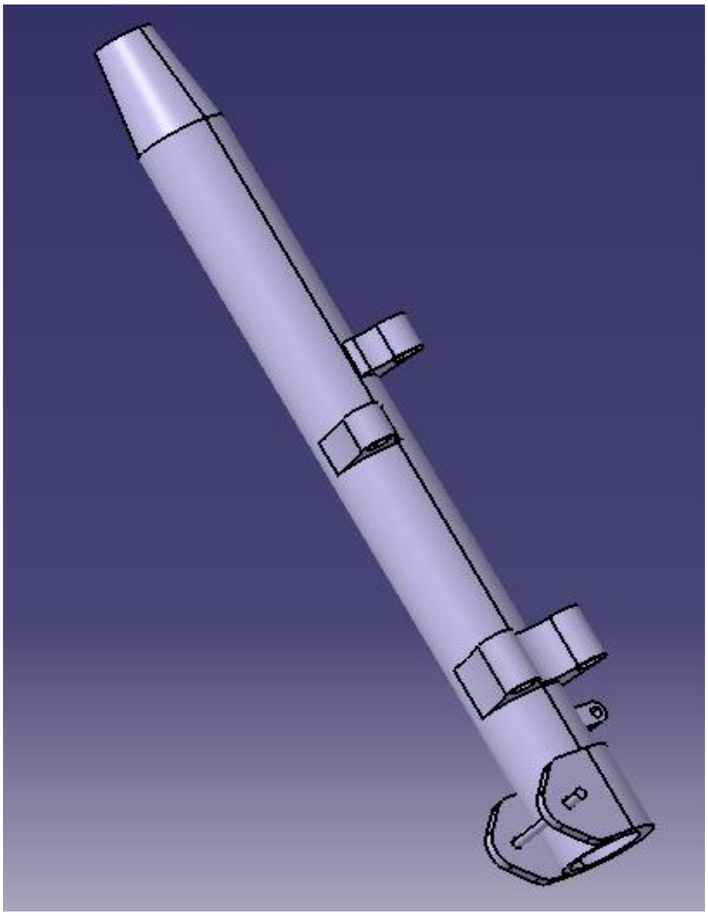


Figure 27: 3D Catia model of the master cylinder

4.2 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.

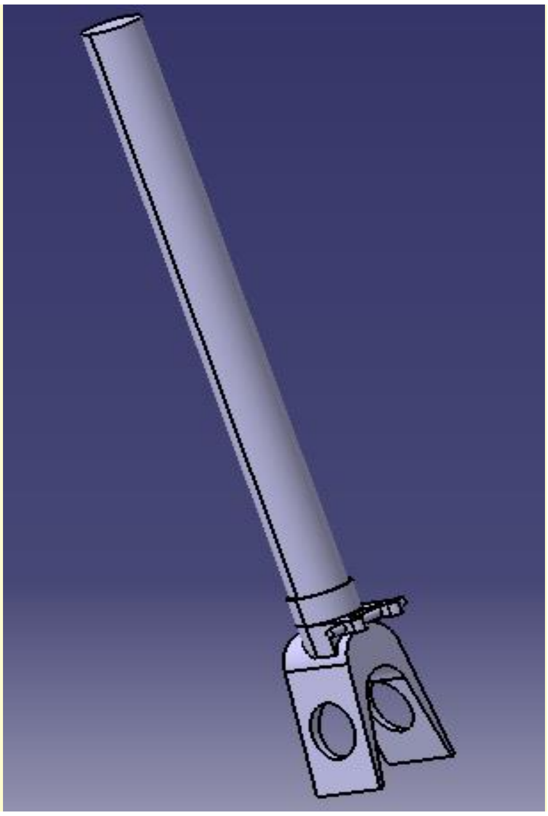


Figure 28: 3D Catia model of the oleo strut

4.3 Torque Link:

Each main landing gear is equipped with an upper and a lower torque link, mounted behind the landing gear and connecting the lower strut to the main strut. Because it is hinged at a central point (the apex), the torque link allows the lower strut to move up and down while keeping the landing gear wheels in proper alignment.

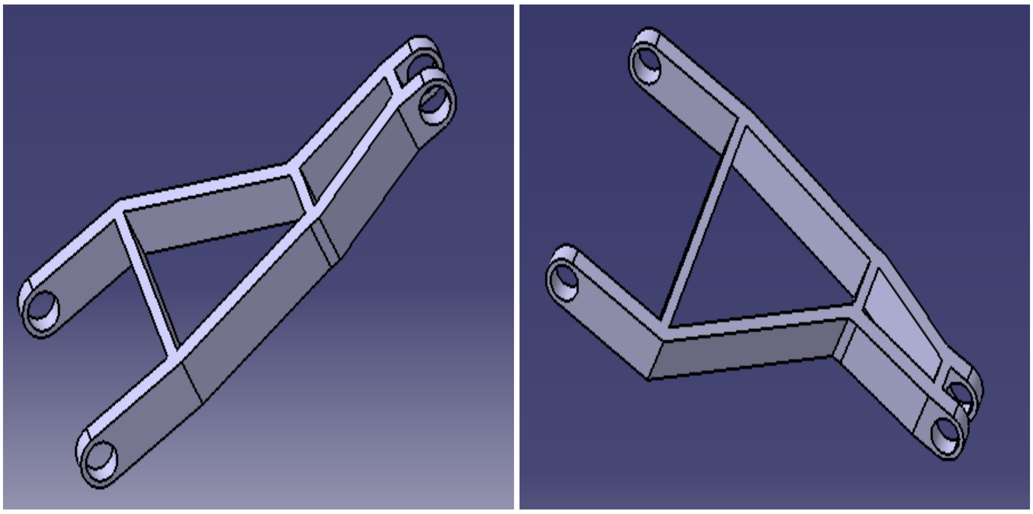


Figure 29: 3D Catia model of the torque link

4.4 Truck beam:

which is in pivot connection with the damper rod at its center this allows the wheels to be in contact with the ground regardless of the ground. This also allows to give a slight hunting angle to the undercarriage to better cash the braking effort.

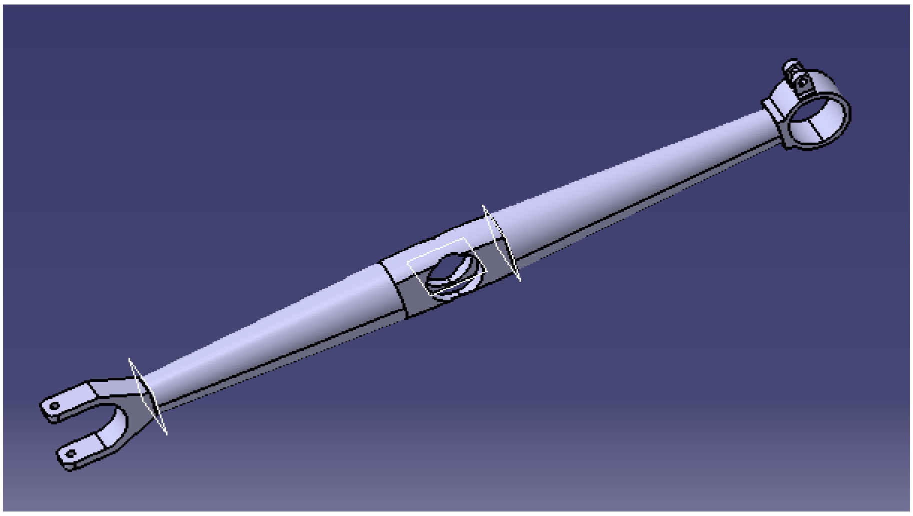


Figure 30: 3D Catia model of the truck beam

4.5 Wheel axle:

Is the shaft that supports the wheels.

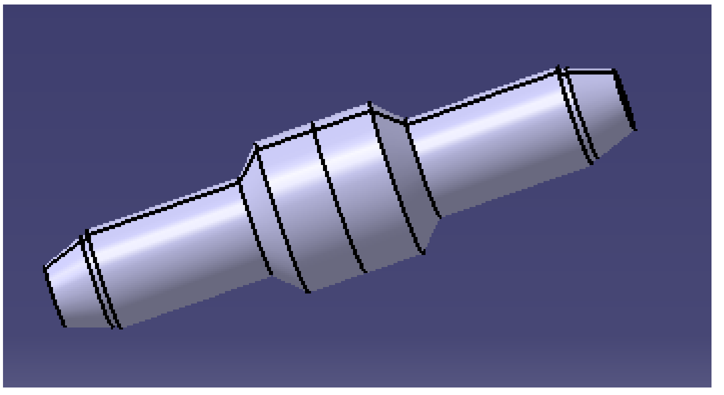


Figure 31: 3D Catia model of Wheel axle

4.6 Tire:

that provides the connection between the ground and the aircraft.

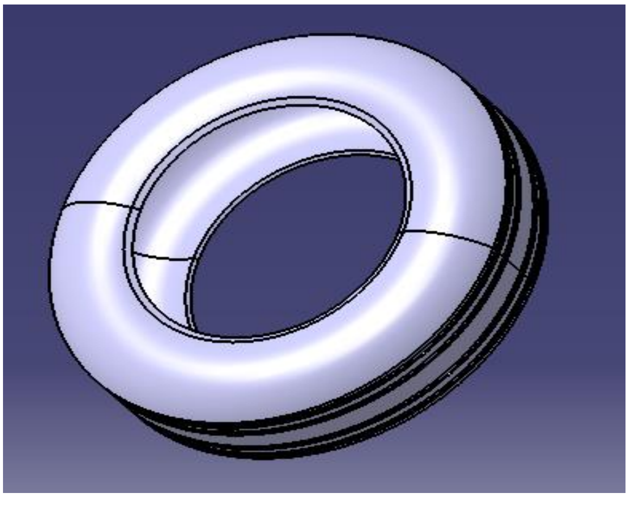


Figure 32: 3D Catia model of tire

4.7 Rim:

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

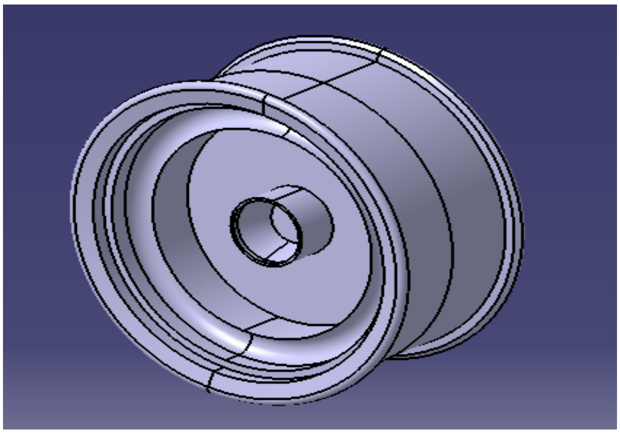


Figure 33: 3D Catia model of the rim

4.8 Aircraft disc brakes:

Aircraft disc brakes in the landing gear, used to brake the wheels while touching the ground. These brakes are operated hydraulically or pneumatically. In most modern aircraft they are activated by the top section of the rudder pedals ("toe brakes"). In some older aircraft the bottom section is used instead ("heel brakes"). Levers are used in a few aircraft. Most aircraft are capable of differential braking.

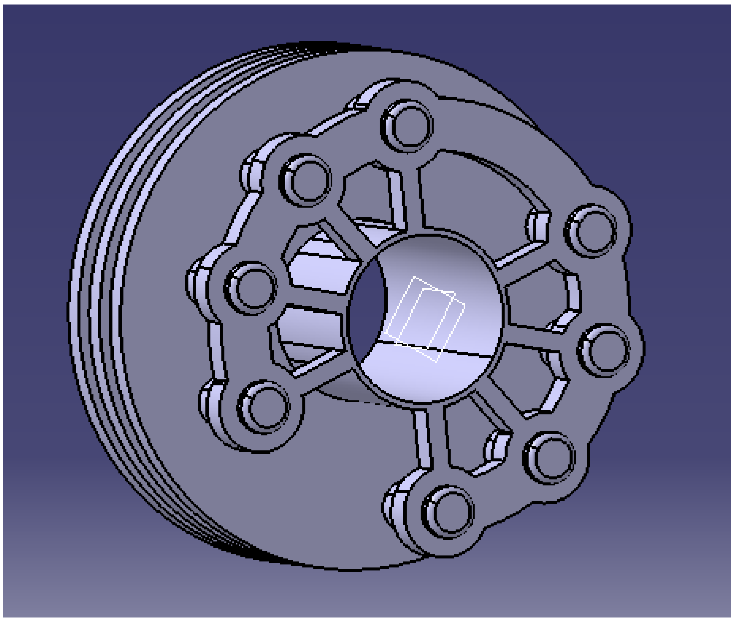


Figure 34: 3D Catia model of the disc brakes

4.9 strut:

Is a structural component generally work by resisting longitudinal compression, but they may also serve in tension.

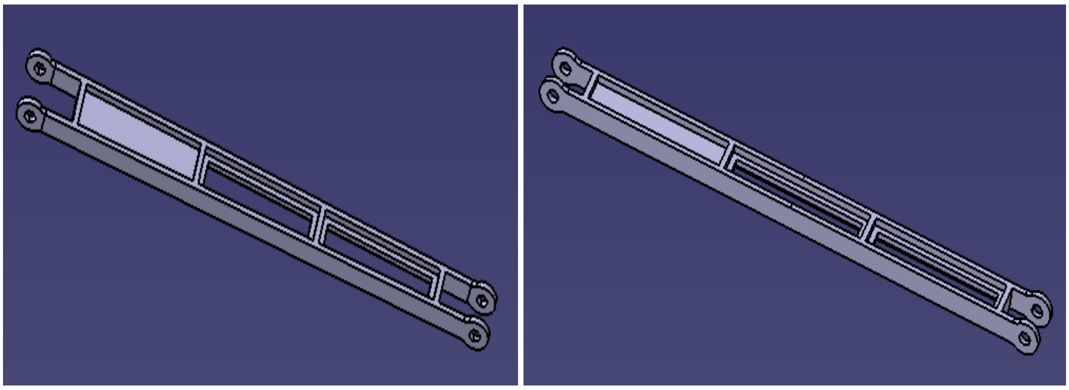


Figure 35: 3D Catia model of the strut

5. Conclusion:

For this chapter, I drew each piece of the landing gear with the CATIA software and made each drawing of each piece. And now I go on to the next chapter to compare their behavior after applying loads using ANSYS.

CHAPTER III: The simulation part

1. Introduction:

In this chapter I will import the main landing gear assembly as a file form "stp" in Ansys, and analyze for the following materials to find out the best material to suggest.

2. Presentation of the software ANSYS:

2.1 Introduction:

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. [6]

2.2 ANSYS interface:

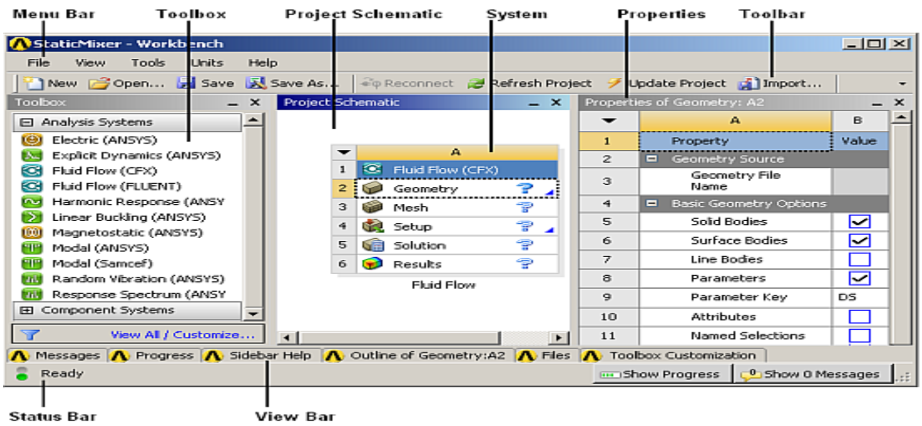


Figure 36: Ansys interface

3. Calculation of forces applying to the landing gear:

The mass considered in this part is the total mass under load, that is to say the maximum mass that we can have on this aircraft.

3.1. On the ground:

The mass of the aircraft is spread over all the landing gear but not uniformly: 80% of the mass is on the main trains and 20% on the nose gear.

My landing gear is a Boeing 777 main landing gear, its max. takeoff weight is 351 tons.

100% $\Rightarrow$ 351 tons = 351 000 kg

80% (2 main landing gear) $\Rightarrow$ 280.8 tons = 280 800 kg

$\|\vec{P}\| = m.\|\vec{g}\| = 140\ 400 * 9.81 = 1\ 337\ 324$ N

Thus, the total mass of the aircraft being 351 tons, so each main landing gear undergoes a vertical force of 1 337 324 N. [5]

4. Simulation:

In this part the above modelled landing gear is analyzed for the following materials to find out the best material to suggest.

4.1 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. The alloy melting temperature is 635°C. At low temperatures the material maintains its properties.

Density = 2880 Kg/m^3

Poisson's ratio= 0.33

Yield strength = 95MPa Young's modulus = 80GPa

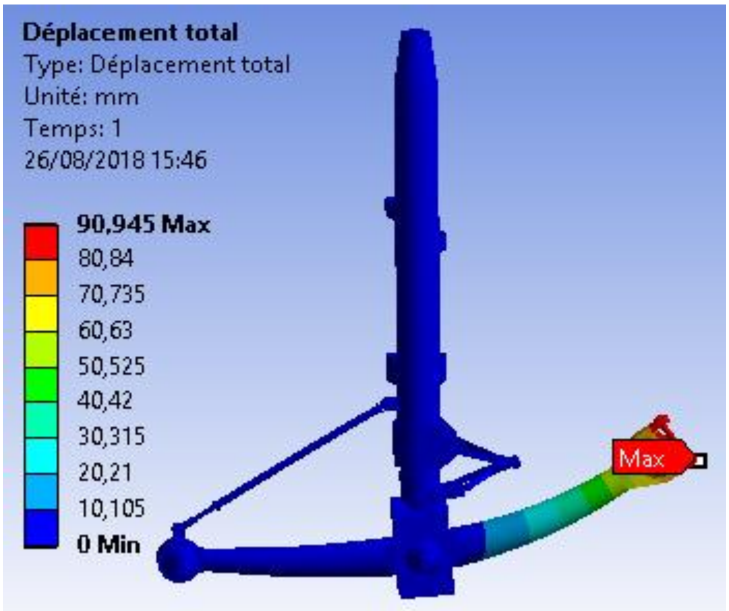


Figure 37: Aluminum Alloy 7075 - Deformation distribution

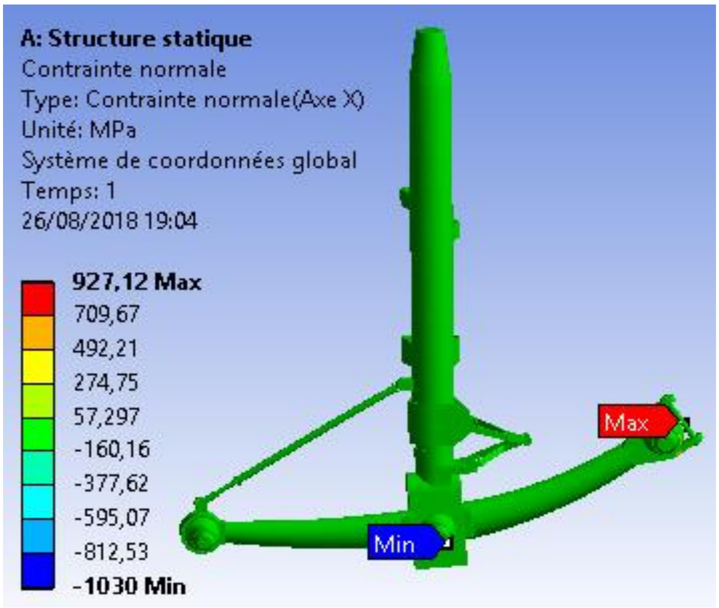


Figure 38: Aluminum Alloy 7075 – Stress Distribution

Table 2: Aluminum Alloy 7075 – Result

Maximum stress (MPa)	Maximum Deformation (mm)
927,12 MPa	90,945 mm

4.2 Alloys Steel 4340:

Alloy 4340 is a low alloy steel with a high strength, toughness and good fatigue strength. The added materials are nickel, chromium and molybdenum. The alloy can easily be shaped at a high strength in the right form. Alloy 4340 has a melting point of 1427°C and the properties will be retained when there is a low temperature. [8]

Density = 7850 Kg/m^3

Poisson’s ratio = 0.33

Young’s modulus = 200GPa

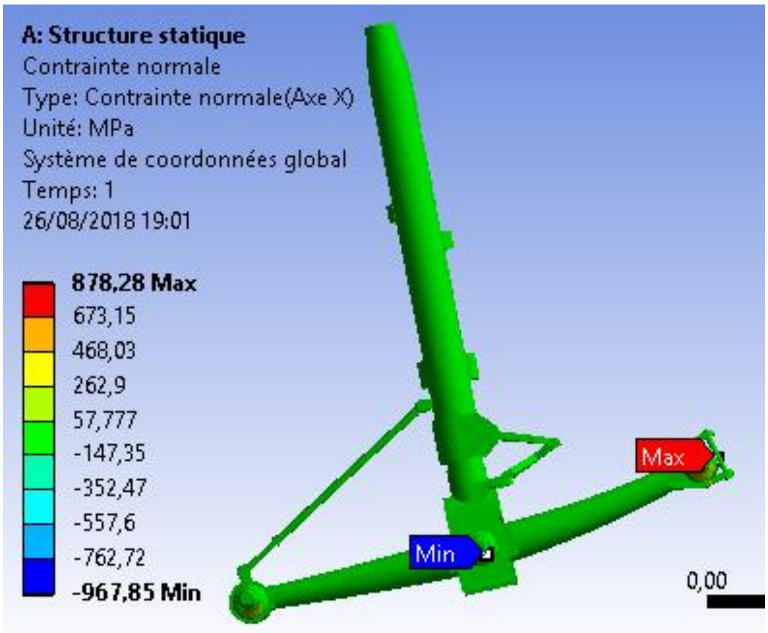


Figure 39: Alloys Steel 4340 – Stress distribution

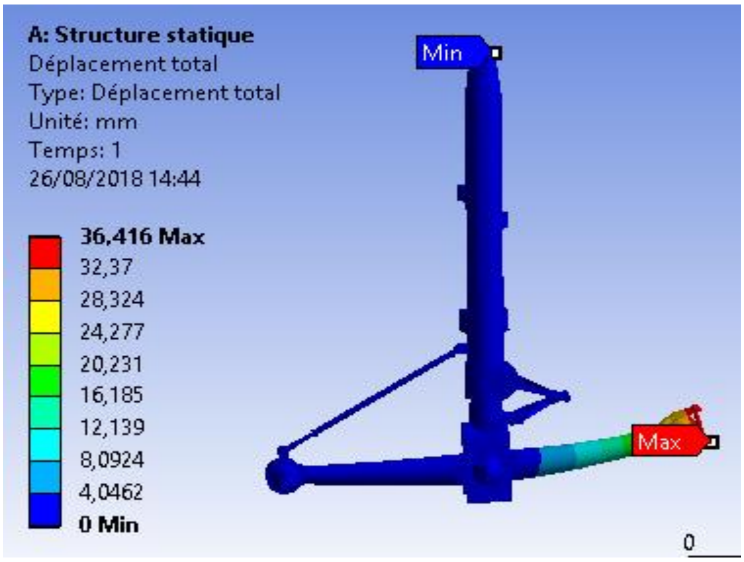


Figure 40: Alloys Steel 4340 – Deformation distribution

Tableau 3: Alloys Steel 4340 - Result

Maximum stress (MPa)	Maximum Deformation (mm)
878,28 MPa	36,416 mm

4.3 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. The density is 4650kg/m3. Therefore Ti 10-2-3 is a high strength alloy and exists of titanium, aluminum, iron and vanadium. To ensure that material will not be damaged, the aircraft designers have to construct a landing gear were the forces will not exceed the maximum strength of 1105 MPa. For Ti 10-2-3 the melting point is 1649°C. Corrosion resistance of titanium is high.

Density = 4650 Kg/m^3

Poisson's ratio = 0.32

Young's modulus = 108GPa

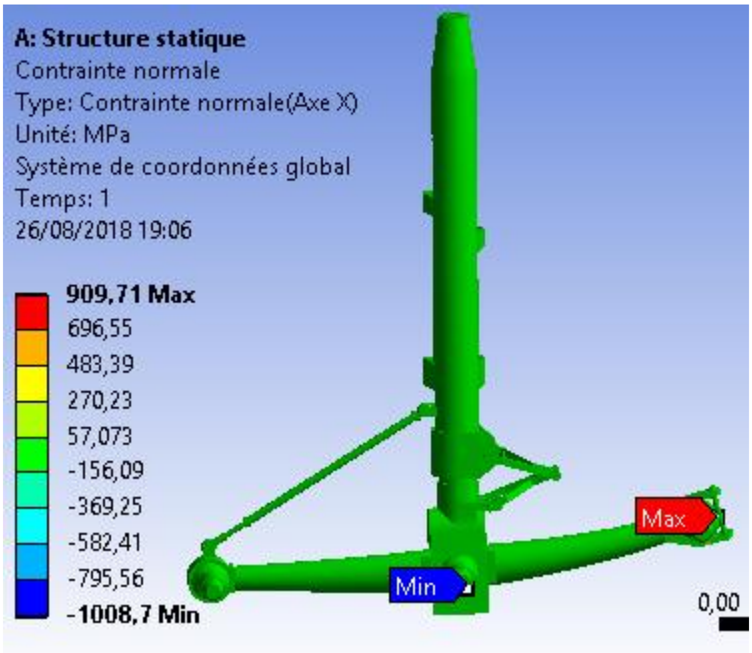


Figure 41: Titanium 10Al-2Fe-3V – Stress distribution

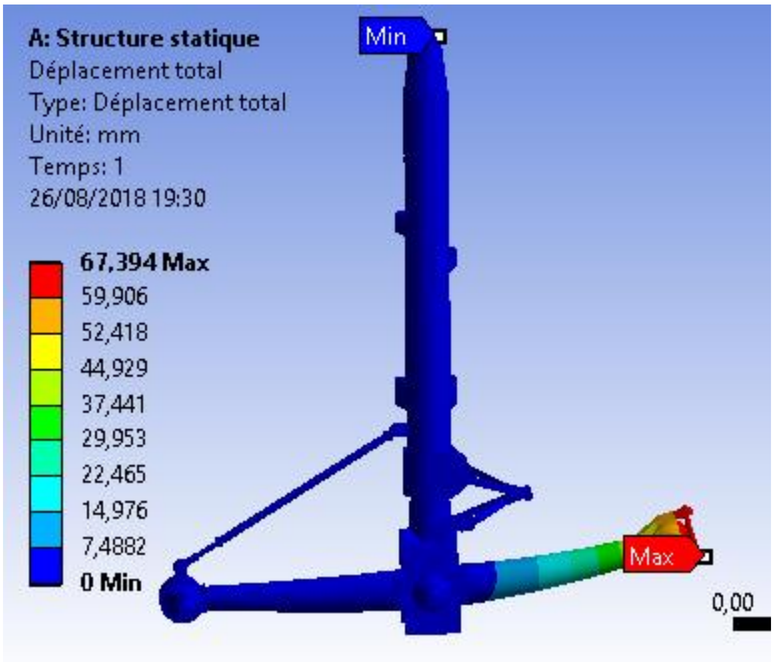


Figure 42: Titanium 10Al-2Fe-3V - Deflection Distribution

Tableau 4: Titanium 10Al-2Fe-3V - Result

Maximum stress (MPa)	Maximum Deformation (mm)
909,71 MPa	67,394 mm

5. Results and Discussion:

Tableau 5: Results

Material	Maximum stress (MPa)	Maximum Deflection (mm)
AA7075	927,12	90,945
AISI 4340	878,28	36,416
Ti 10Al-2Fe-3V	909,71	67,394

- The Alloys Steel 4340 has the minimum value of maximum stress and deformation.
- The Aluminum Alloy 7075 has the maximum value of maximum stress and deformation.

" Steel is preferred in industries where strength is more important than weight. ... In unalloyed condition, titanium is 45% lighter, and as strong as steel. We can presume that the same rod of steel will be 5% stronger than titanium, but titanium will be 40% lighter."

==> We can use Titanium 10Al-2Fe-3V for less weight.

6. Conclusion:

Initially, a typical landing gear of Boeing 777 aircraft is designed using CATIA software tool, and then analyzed for structural safety using ANSYS software. The maximum possible load (1 337 324 N) is given as design load. Landing gear is analyzed for the traditional metallic materials like Aluminum Alloy 7075, Alloys Steel 4340, and Titanium 10Al-2Fe-3V. While comparing the results , Alloys Steel 4340 has the minimum value of maximum stress developed and deformation. So, the modelled landing gear will be safer for the Alloys Steel 4340 and also for Titanium 10Al-2Fe-3V materials to avoid the structural failure.

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 landing gear have been modeled with CATIA design software and assembled to obtain the complete structure of our model.

Second, the case of the stationary regime was numerically solved using the ANSYS software. Several materials have been varied to determine the best.

Finally this project has simulated to simulate the most real possible case of a landing gear.

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Netography

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ABSTRACT

Landing gear is a most important component in an aircraft system and it is observed from the literature that majority failures of aircraft structure takes place due to malfunction of landing gear. In this work, a typical landing gear of Boeing 777 aircraft is designed using CATIA software tool, and then analyzed for structural safety using ANSYS. The maximum possible load is given as design load.

Landing gear is analyzed for the traditional metallic materials like Aluminum Alloy 7075, Alloys Steel 4340, and Titanium 10Al-2Fe-3V. While comparing the results of the materials, Alloys Steel 4340 has the minimum value of maximum stress developed and deformation. At last, from the analysis, Alloys Steel 4340 material is suggested to avoid structural failures of the modeled landing gear.

Keywords :

Main landing gear, CATIA, ANSYS, Materials, Stress analysis, Deformation

RESUME

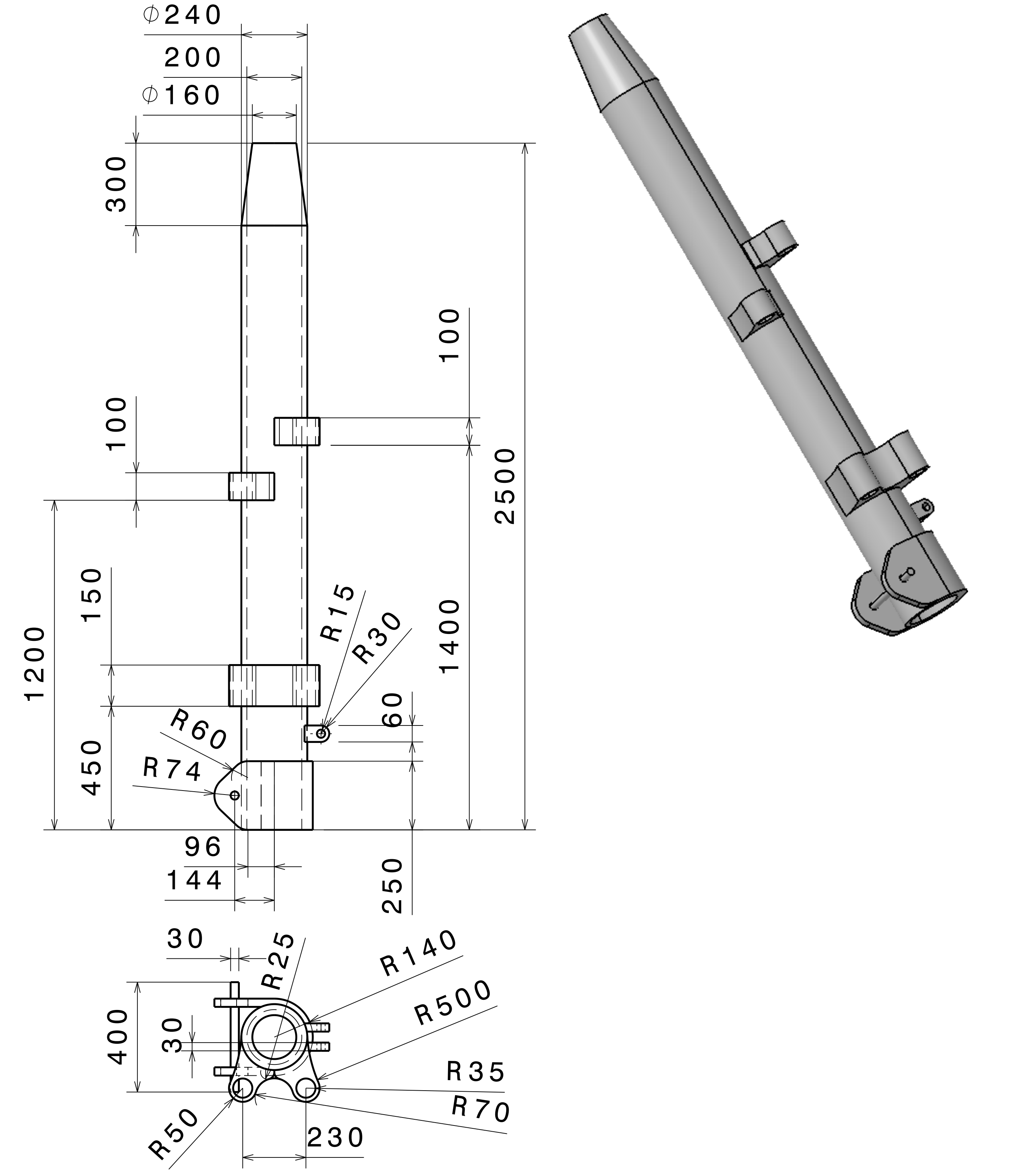
Le train d'atterrissage est un composant très important dans un système d'aéronef et il ressort de la littérature que les défaillances de la structure de l'aéronef sont dues en grande partie au mauvais fonctionnement du train d'atterrissage.

Dans ce travail, un train d’atterrissage typique des avions Boeing 777 est conçu à l’aide de l’outil logiciel CATIA, puis analysé pour la sécurité structurelle à l’aide d’ANSYS. La charge maximale possible est donnée comme charge de conception.

Le train d'atterrissage est analysé pour les matériaux métalliques traditionnels tels que l'alliage d'aluminium 7075, les alliages d'acier 4340 et le titane 10Al-2Fe-3V. En comparant les résultats des matériaux mentionnés, les alliages d'acier 4340 a la valeur minimale de contrainte maximale développée et de déformation. Enfin, d'après l'analyse, le matériau les alliages d'acier 4340 est suggéré pour éviter les défaillances structurelles du train d'atterrissage modélisé.

Mots clés :

Train d'atterrissage principale, CATIA, ANSYS, Matériaux, Analyse de contrainte , Déformation



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Dhekra Hamdi
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07/07/2018
CHECKED BY:
Ms Naser ben jaber
DATE:
07/07/2018

Study of main lnding gear

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UJA - ESAT

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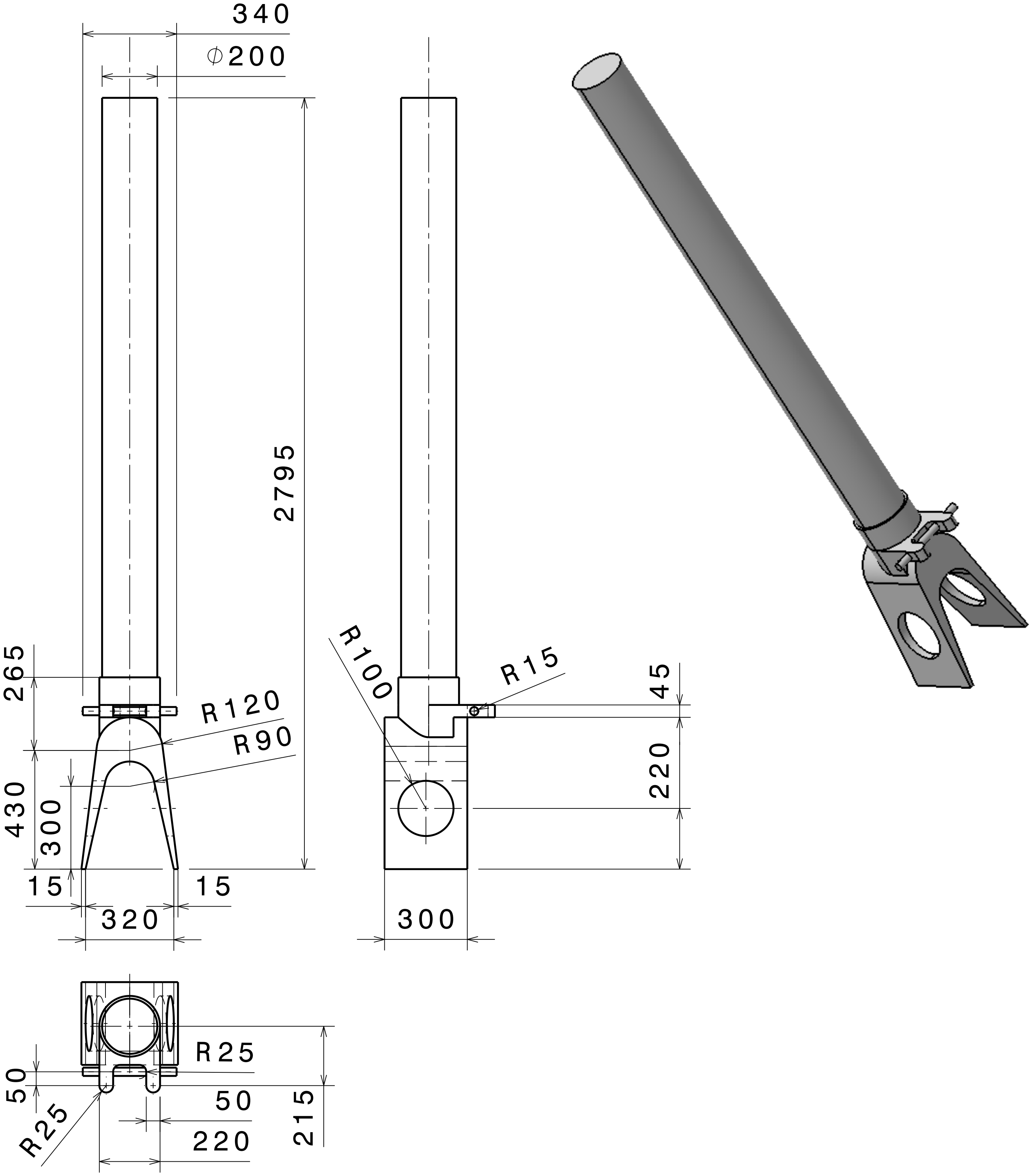

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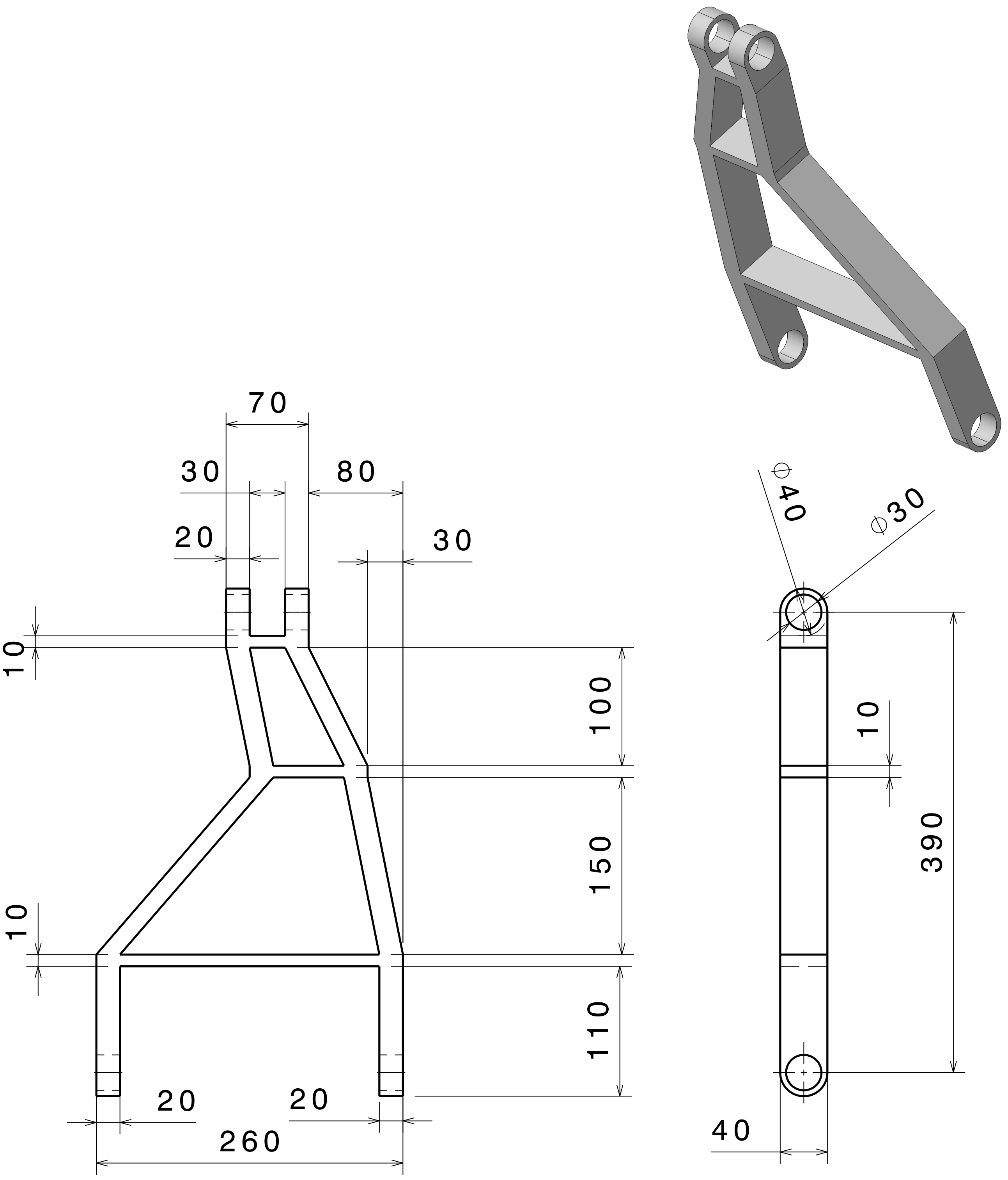

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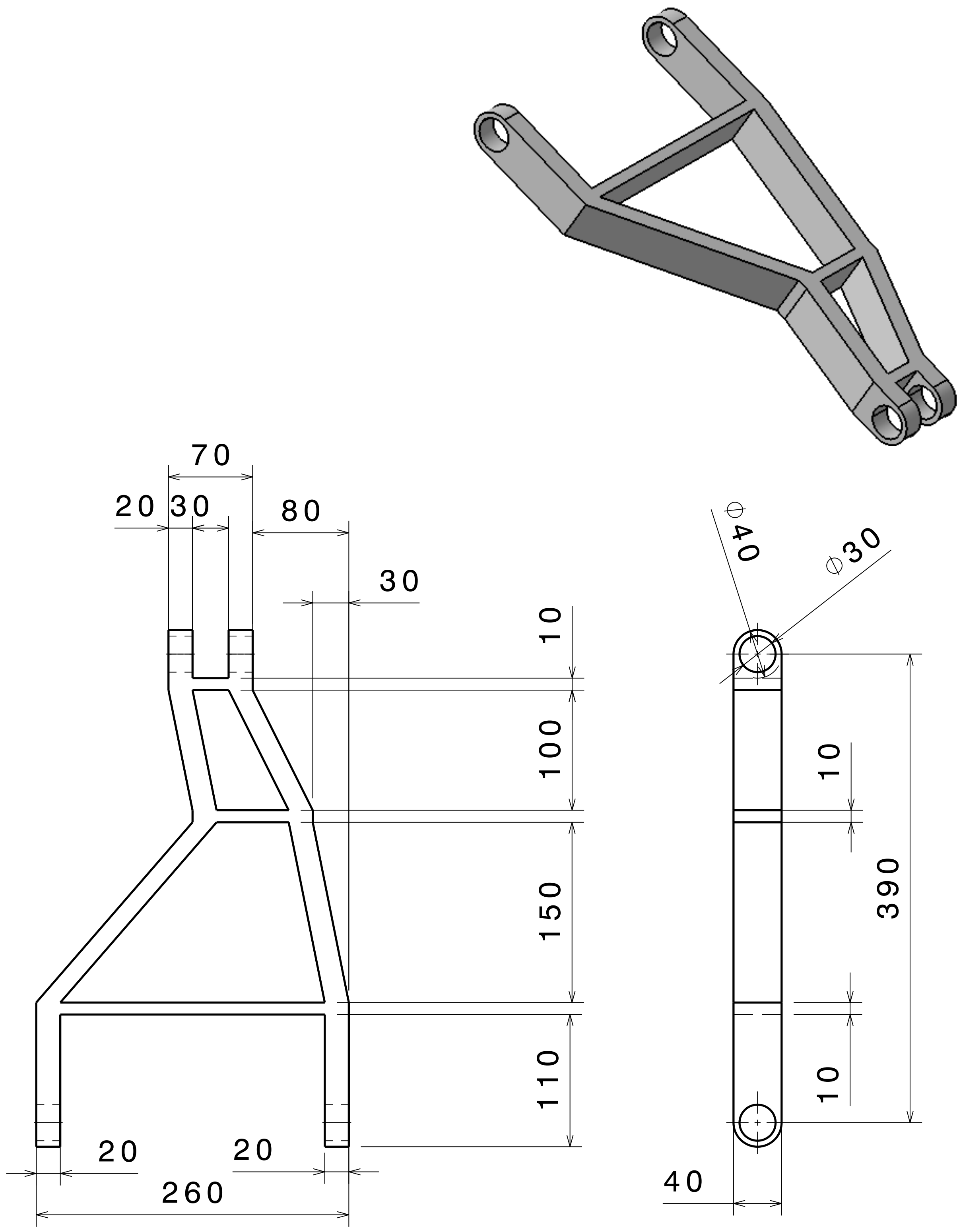

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Study of main landing gear

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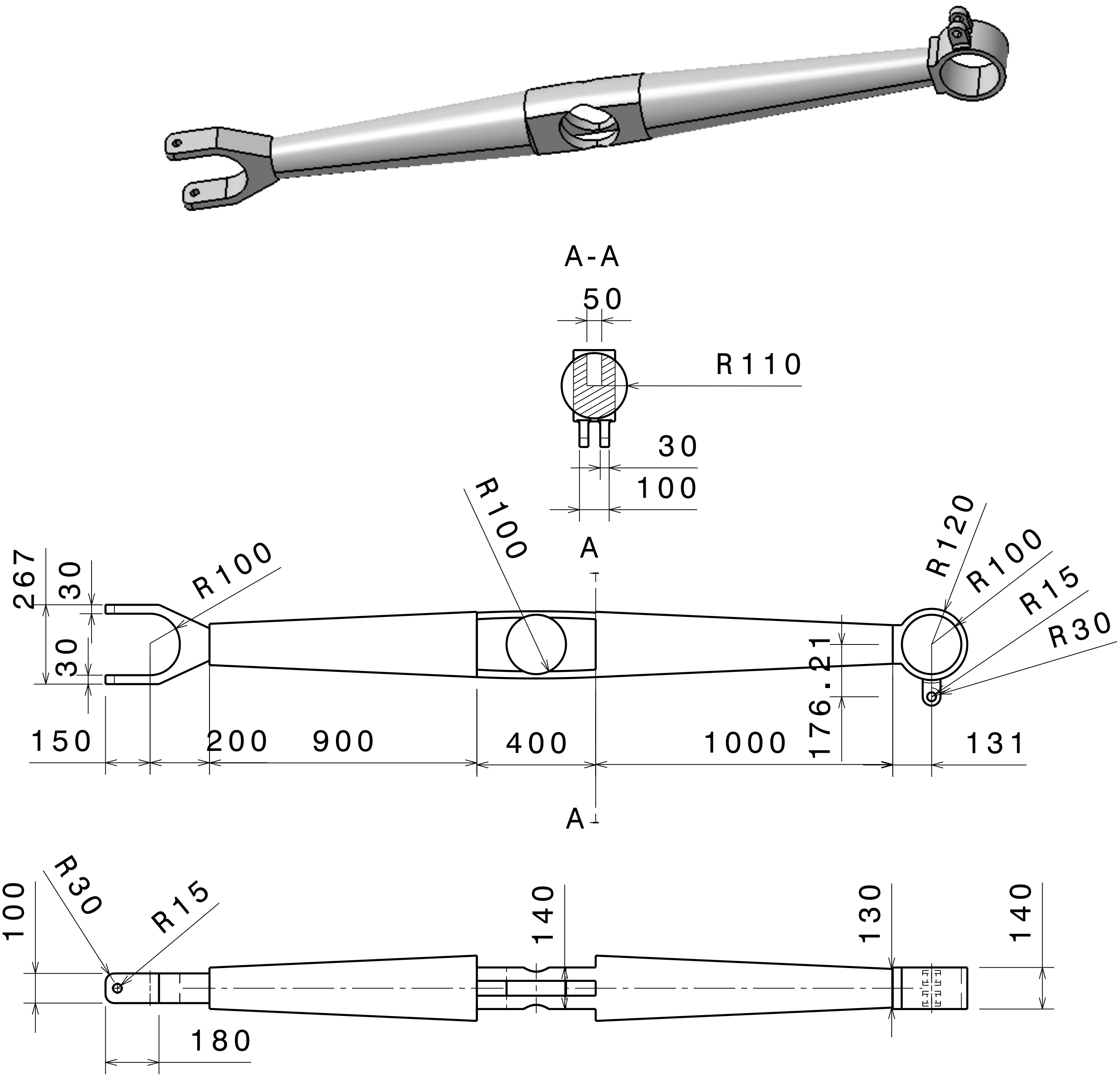

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Study of main landing gear

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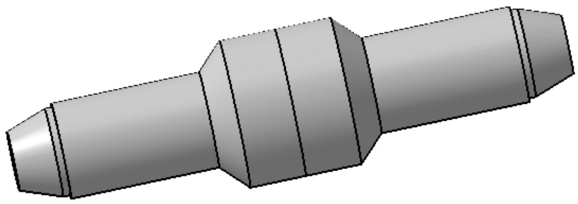

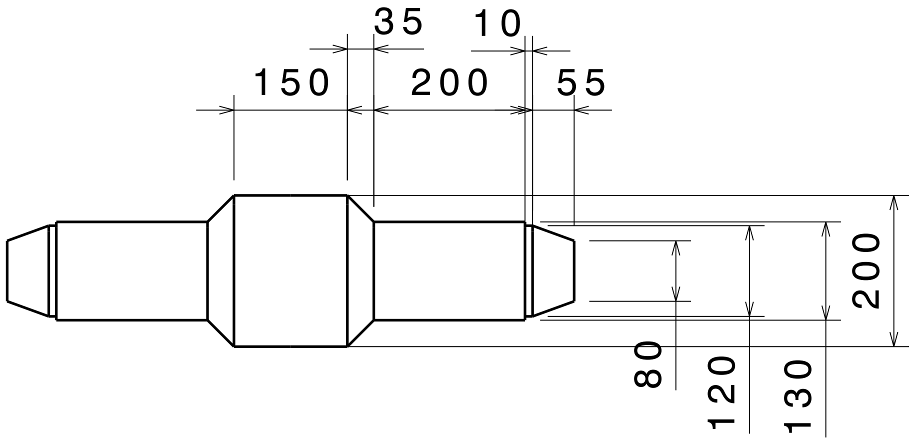

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Study of main landing gear

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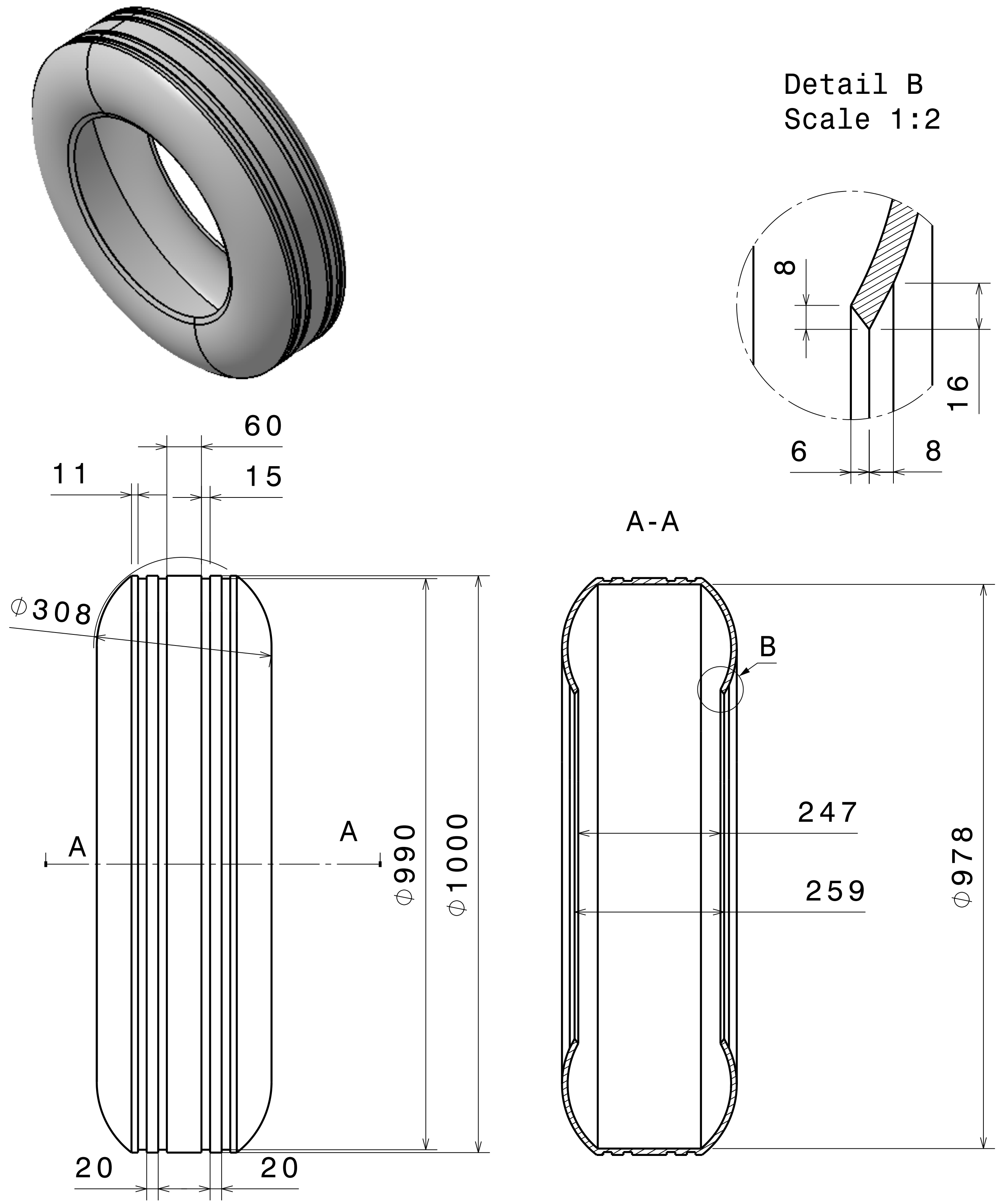

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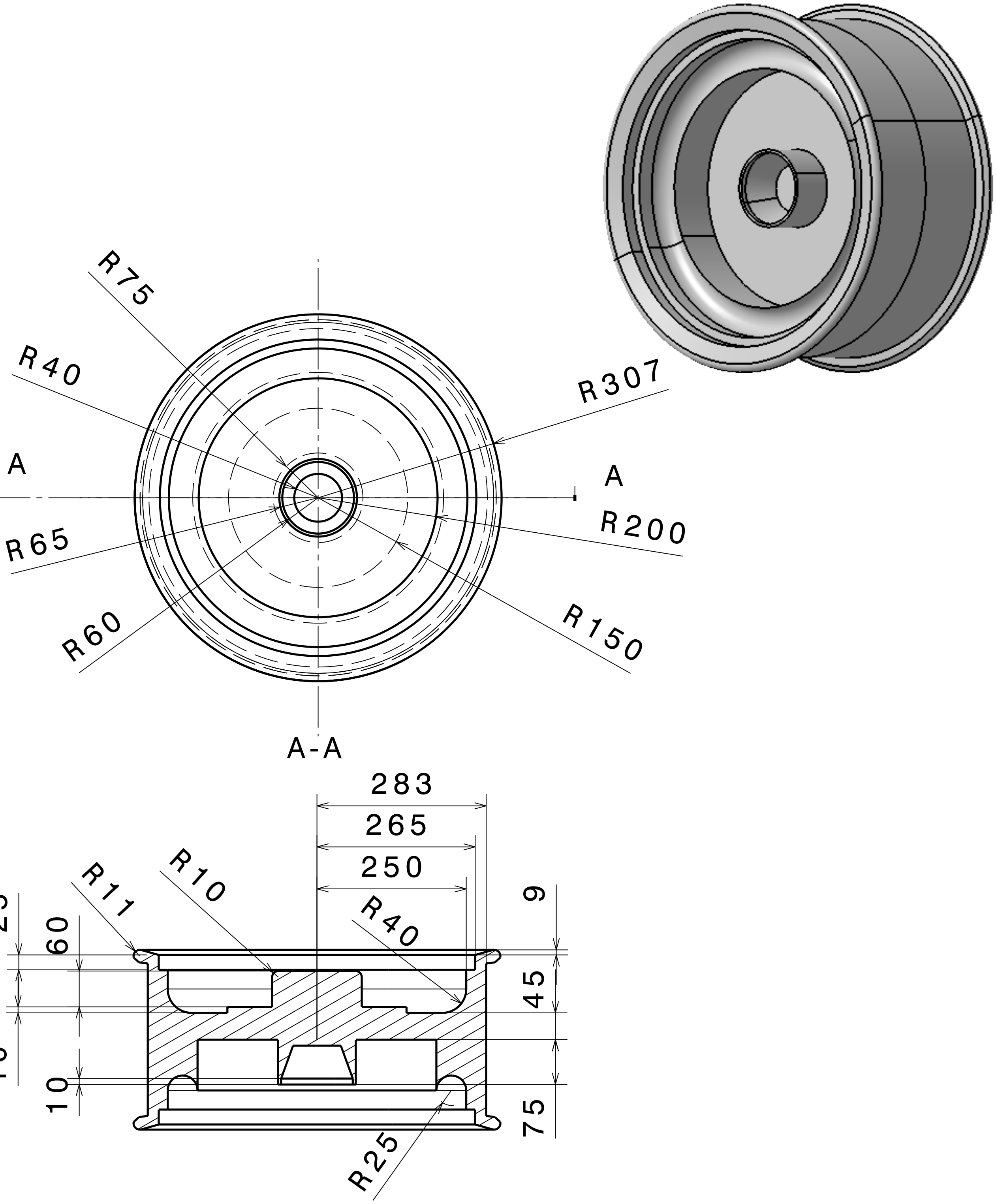

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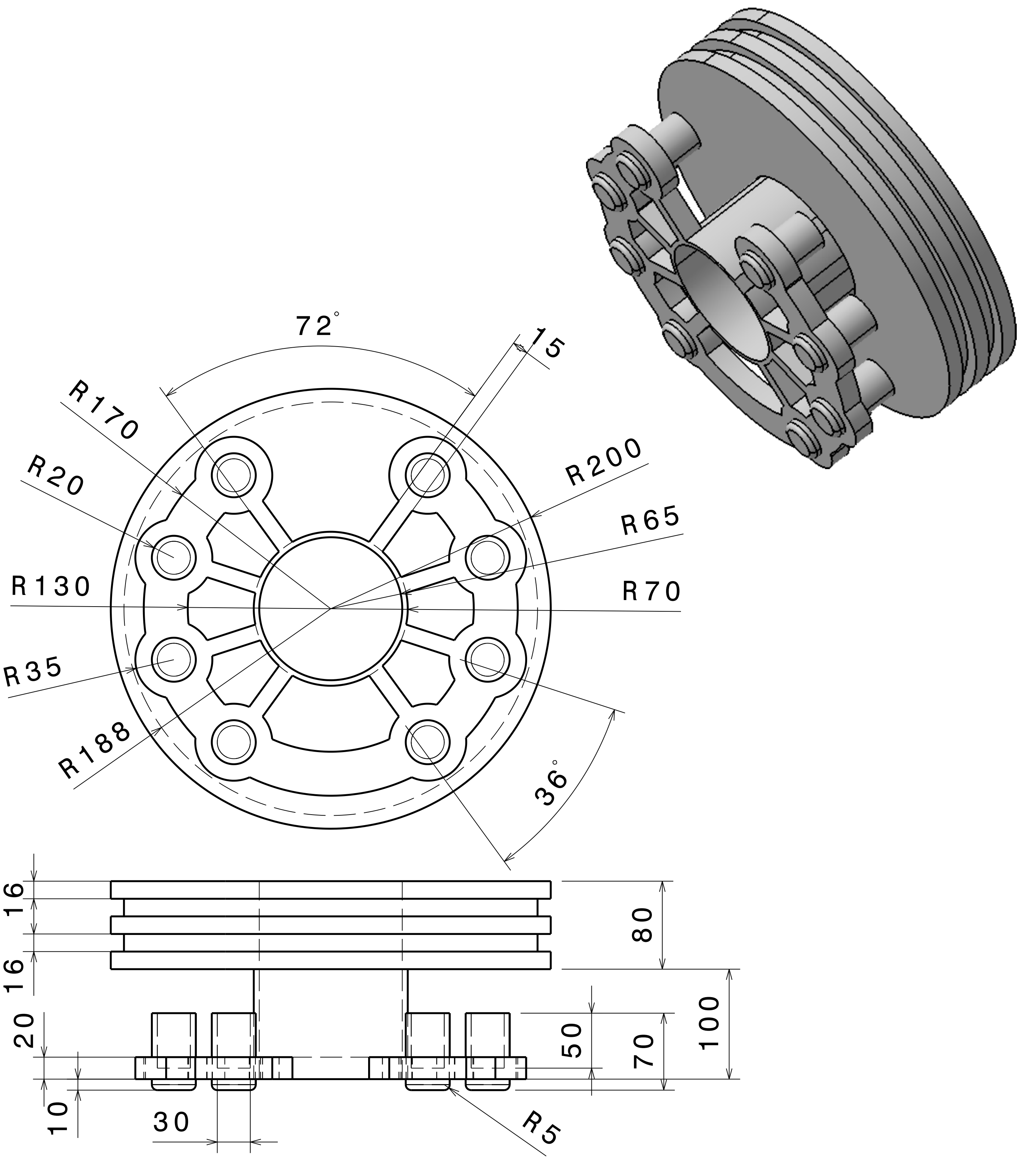

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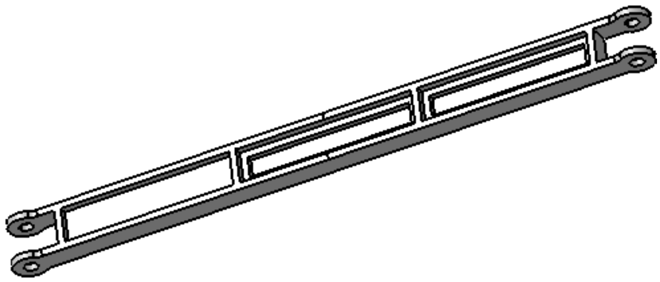

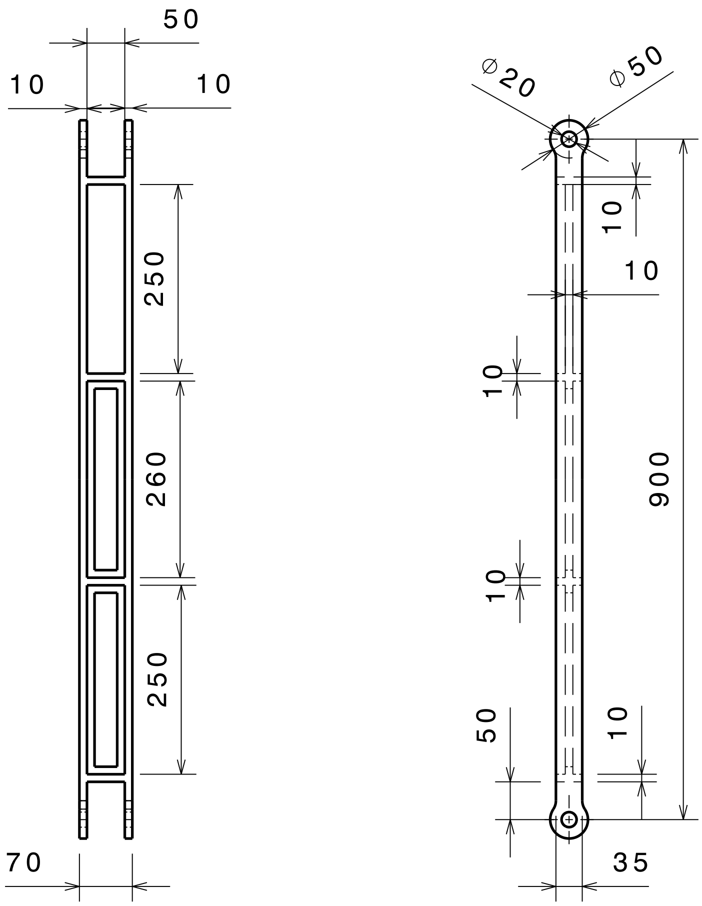

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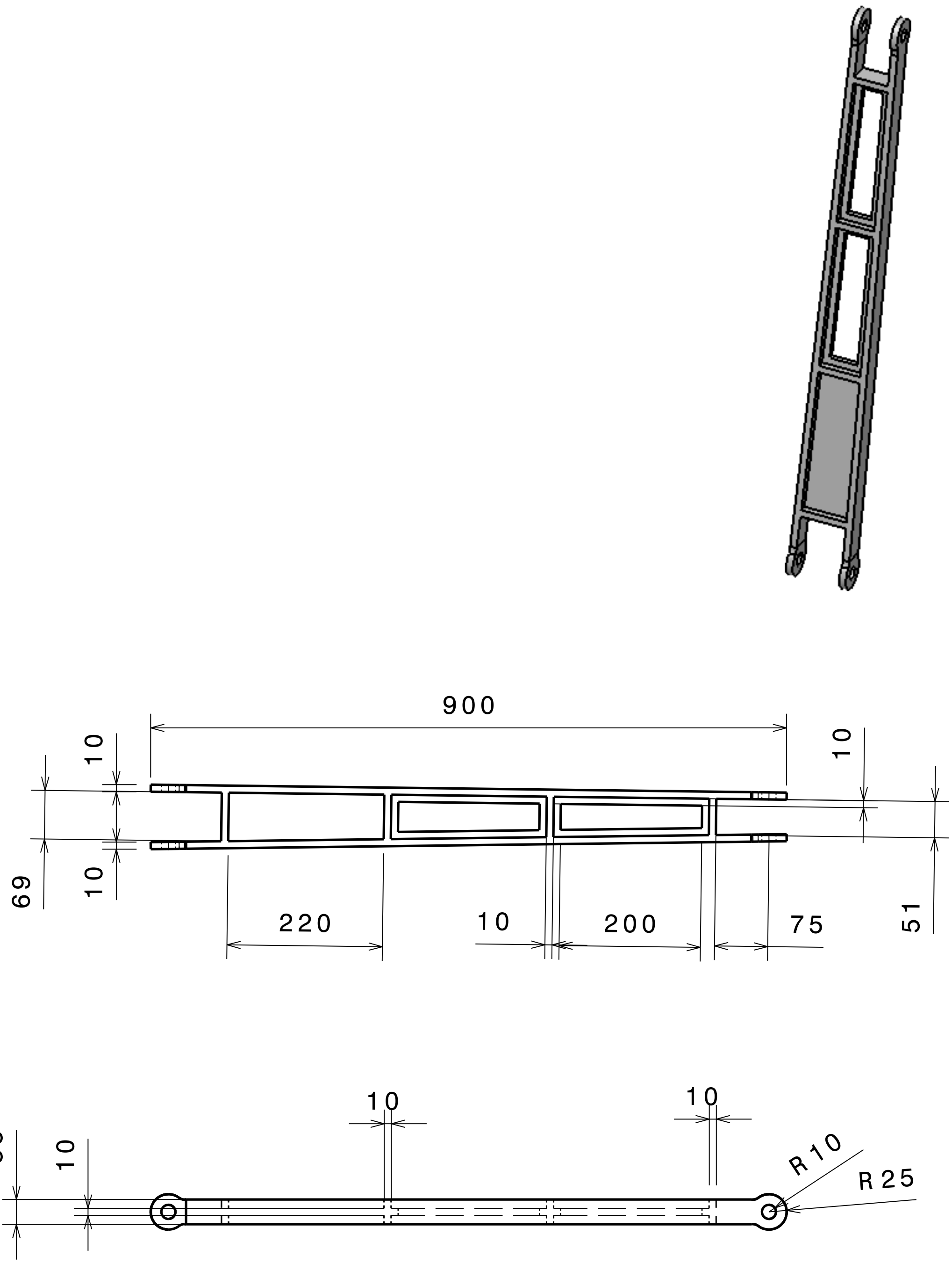

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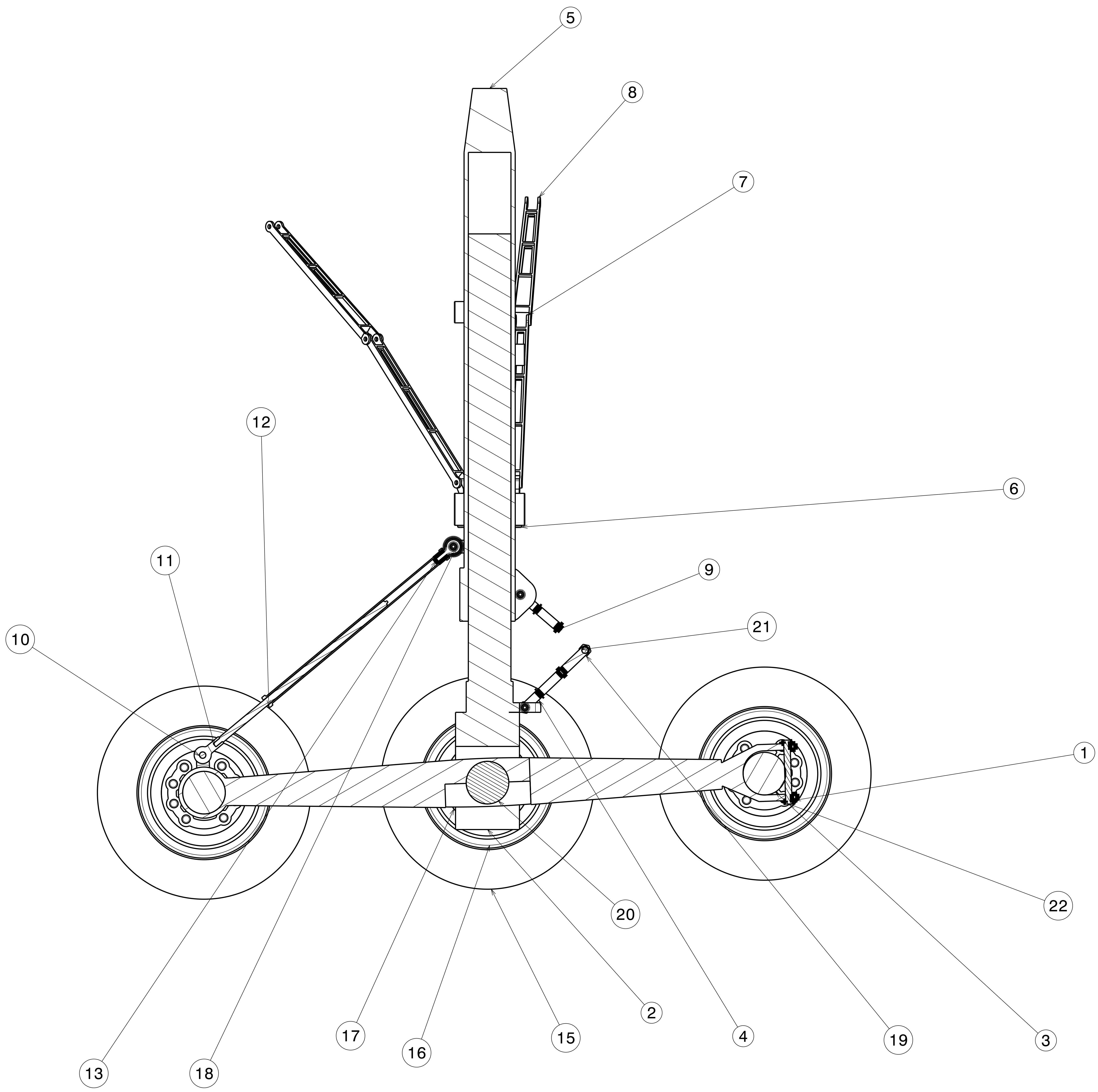

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1	the master cylinder	5
2	axe L50	6
2	strut1	7
2	strut2	8
1	upper link	9
1	close end mounting	10
1	pistion shaft	11
1	cylinder	12
1	open end mounting	13
1	cylinder open end	14
6	tire	15
6	rim	16
6	brake	17
2	axe R15	18
12	nut R15	19
1	axe	20
1	axe L180	21
1	axe L300	22

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DATE: 02/08/2018
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DATE: 02/08/2018

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