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Título del proyecto:

ANALYSIS AND DESIGN OF A MOTORBIKE CHASSIS

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ABSTRACT

The objective of this project is to establish a method of calculation for designing a chassis of a motorbike in a manner in which can be measured all the parameters that are related to the design to get a chassis as light, strong and economical as possible, taking into account that the time available is limited.

It is first necessary to know when you can give as valid a chassis in their resistance. This is essential to know the criteria used by tubular chassis designers in different competitions such as MotoGP or Superbikes.

Once you are aware of the limits that must not be exceeded we must decide how it will be done the calculation. The theory of finite elements would be ideal if the geometry was easy to obtain.

The idea is not create a final design for manufacturing; it is validating a first design for the construction of a prototype on which if perform the testes that will lead to production.

For the purposes of these theories is necessary to make a rough drawing of the chassis. To carry out this approach correctly, it is essential to keep in mind the methods of manufacture which provides a worker when constructing a structure such as this. The usefulness of the project is evident. It is absolutely necessary to know how carry out the calculation of a chassis to design a tough motorbike, that, behave properly and be as light as possible.

Nowadays, in the world of motorbike competition, the solution for the construction of a chassis could be: the cheapest one, the lightest one or the most resistant one. A lot of money is being spent on the construction of the motorbikes, big teams don't care about the money, and they care about the weight and strength of the motorbike. In this project the final solution desired would be a combination of the 3 previous solutions.

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1. INTRODUCTION

Increasingly, many people who are fond of the motor world want to put in practice their driving skills, without endangering their life or people's life on the roads.

The motorbike is a great way to enjoy motor racing, because you can enjoy driving it intensely and they are cheaper than a car

These are the reasons why I decided to make this project. The design of a chassis could be a great idea if you love motorbikes world.

The history of this vehicle starts in 1867, at first it worked with a steam engine and later in 1885 was changed to an internal combustion engine. The history of motorcycling like a sport start in 1896, it was held the first motorcycle race, France. At the beginning the motorbike reaches 18 km/h and the engine developed 0.5 horse power.

At the beginning of the eighties the chassis weren't stiff enough and during some years designers were looking to increase stiffness. In a few years they arrived to a point in which the chassis were too much stiff. Then the objective was to find the optimum stiffness values. Currently we are going into a new stage in which dynamic factors are playing a more important role (stiffness is a static concept).

The objective of this project is to establish a method of calculation for designing a chassis of a motorbike in a manner in which can be measured all the parameters that are related to the design to get a chassis as light, strong and economical as possible, taking into account that the time available is limited.

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1.1 WHAT IS A MOTORBIKE?

A motorbike is a vehicle driven by an engine that drives the rear wheels, except in rare cases. The chassis and wheels are the fundamental structure of the vehicle. The guideline wheel is the front wheel.

Normally the motorbike is powered by a gasoline engine of two or four stroke (2T and 4T). Although recently the two stroke engine are being reserved for smaller motorbikes due to environmental reasons. Formerly air cooling was the normal, but today it has taken extraordinary growth the liquid cooling.

The engine is positioned generally transverse mode; the crankshaft is perpendicular to the motion, regardless of the number of cylinders. The number of cylinders varies from one, usually in smaller motorbikes, up to 6 in line, being very common provisions inline-4 V with two different angles. Speaking about the capacity, traditionally the most frequent were: 125cc, 250cc, 500cc. Although are common large ones like 900cc, 1000cc, 1200cc.

2. THE OBJECTIVE OF THE PROJECT

The objective of this project is to establish a method of calculation for designing a chassis of a motorbike in a manner in which can be measured all the parameters that are related to the design to get a chassis as light, strong and economical as possible, taking into account that the time available is limited.

Nowadays, in the world of motorbike competition, the solution for the construction of a chassis could be: the cheapest one, the lightest one or the most resistant one. A lot of money is being spent on the construction of the motorbikes, big teams don’t care about the money, and they care about the weight and strength of the motorbike. In this project the final solution desired would be a combination of the 3 previous solutions.

The objectives in this project are:

2.1. **Prototype choice:** It will be studied how the chassis behaves in flexion and torsion analysis to know which the best prototype is. It will do with the software SolidWorks. With these studies it will be known which the parts of the chassis that suffer more are.

2.2. **Material choice:** It will be studied how the chassis behaves in flexion and torsion analysis for difference materials. It will do with the software SolidWorks. The analysis of the chassis should be made with different materials that they have different properties. I order to choose the best suited.

2.2. **Statics calculation:** They will be held the load distribution when the motorbike is stationary. The total weight of the chassis is equal to the sum of reactions at the supports, in our case, the axles of the wheels.

2.3. **Dynamics calculation:** They will be held the load distribution when the motorbike accelerates, when the motorbike brakes and when the motorbike is cornering. When braking or boot appears an inertial force that opposes the force that tends to set in motion or stops the motorbike and modifying the loads on axles of the wheels.

When the motorbike accelerates the inertial force is higher on the rear wheel than when the motorbike is stationary. The opposite happens on the front wheel, because the weight is transferred from the front wheel to the rear wheel.

For braking, the inertial force is higher on the front wheel than when the motorbike is stationary. The opposite happens on the rear wheel, because when it's braking, the weight is transferred from the rear wheel to the front wheel.

Finally, when the motorbike is cornering there is also a load transfer. This aspect will be studied later. When the motorbike is cornering, it is changing its trajectory, so it is changing also the loads of the motorbike.

3. DESIGN OF A TUBULAR CHASSIS

The most important in a motorbike is the chassis. A chassis can be defined as a structure whose purpose is to rigidly connect to main elements of the motorbike.

A motorbike frame has two basic functions: static (this involves supporting the weight of the rider, engine and transmission, etc) and dynamic (which is critically important). Dynamic functions of the frame (in conjunction with the suspension and wheels) include precise steering, good road holding, handling and comfort.

To design the chassis, first I need to know which those main elements are, they are the following:

- In the front, the chassis is directly attached to the axis of the motorbike direction.
- Below, the chassis must be attached to the engine.
- Above, it shall be subject to the docking pilot seat.
- On the back, it must be well designed for coupling the swing arm that hold the rear wheel to the chassis and make the buffer.

For the realization of the chassis we have to take into account stiffness, weight, space and cost criteria. . It should be considered static and fatigue resistance, stability of structural members, the load bearing capacity of the unions, manufacturing and assembly. But in this project only will be considered static efforts.

3.1 DESIGN CRITERIA

3.1.1 Stiffness criteria

The overall expression of the stiffness is: $K = P / \Delta$

Where: P: applied load

Δ: deformation

The stiffness supplies the followings proportionalities: **$K \propto ExI$** and **$K \propto ExA$**

Where: E: modulus of elasticity or Young's modulus

I: moment of inertia

A: sectional area

In the stiffness of a chassis, it will take into account two aspects: Bending stiffness and torsion rigidity.

3.1.2 Weight criteria

In terms of weight when we are designing a chassis, we must take in account the following points:

- The less the chassis weights, respecting the rigidity, the best engine power the motorbike will have.
- The center of gravity should be as low as possible, and in the middle of the motorbike to improve the stability of it.

Below, they will be given some values obtained:

- weight of the motorbike: 105 kg
- pilot weight: 70 kg
- weight of gasoline, lubricants and cooling fluids: 15 kg

3.1.3 Space criteria

To design the chassis we have to consider space terms. Seeing other models on the market I estimate some geometry parameters like:

- Long wheelbase: 1410 mm
- Center of gravity height: 650 mm. And it is in the middle o the motorbike
- Advance: 80 mm

The chassis must have sufficient space to put the engine in the middle, as shown in the picture below.

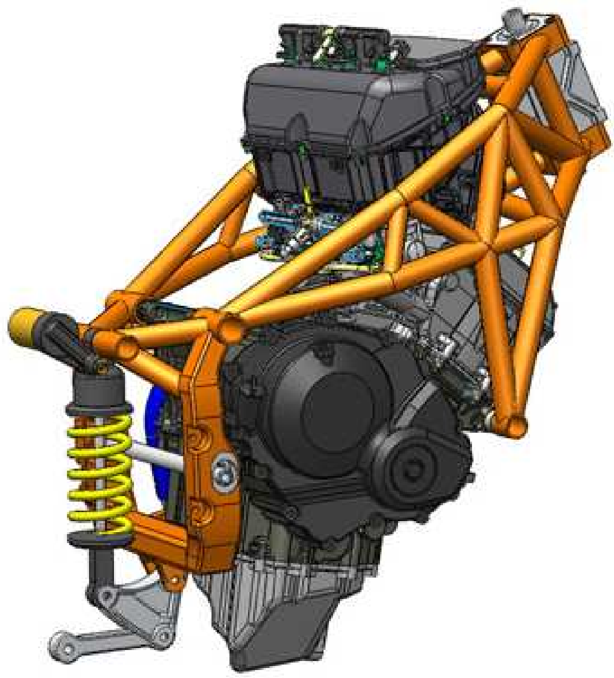


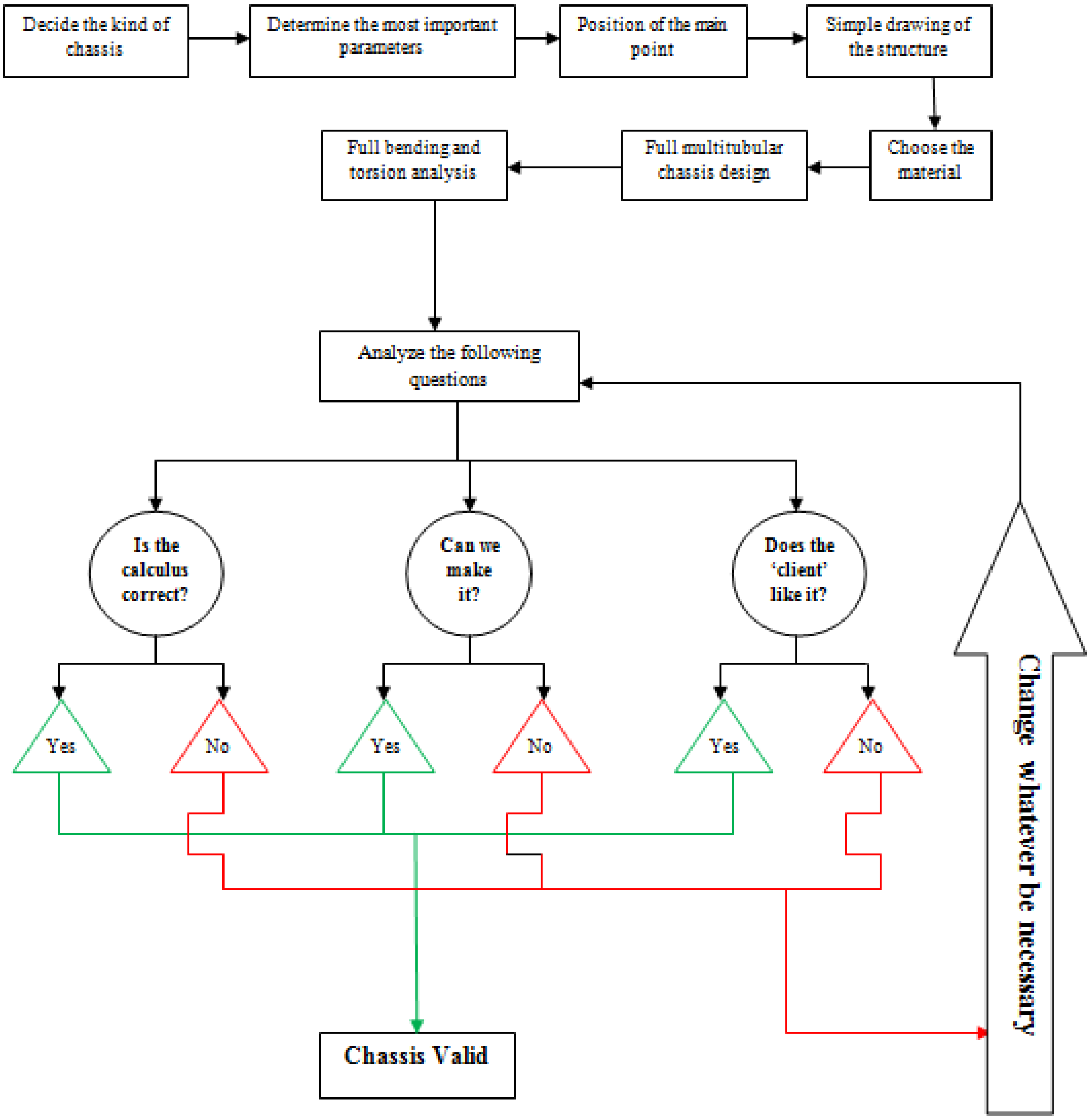
Figure 3.1: Space criteria

3.1.4 Cost criteria

In the design of a chassis, should be taken into account the following aspects to decrease the cost:

- The selection of bars should be the less varied possible in diameters.
- The number of bent bars should be as small as possible.
- The number of joints should be the minimum.
- In a welded construction of a tubular structure, almost all costs manufacturing bars correspond to the filling bars. It has been shown that with K-type joints could be obtained the minimum number of bars and filling joints. The spaced knots are easier to manufacture, because they simply apply a single cut on each end of the filling bar.
- Tubular profiles in extra long lengths. The number of welds should be the minimum. This is achieved asking

3.1.5 Design algorithm



3.2 DESIGN OF THE CHASSIS

3.2.1 PROTOTYPES

They have been done three different prototypes. All of them are multitubular chassis. This kind of chassis is a frame built with tubes. Other options could be simple or double cradle, pressed sheet metal, twin spar and others but trellis chassis is easier to build and cheaper than them.

The different prototype have been designed using SolidWorks software, it is a good program for the design of this kind of piece. And also, it can be use to make the analysis of the chassis.

First of all, it was done the first prototype that is the following:

3D view:

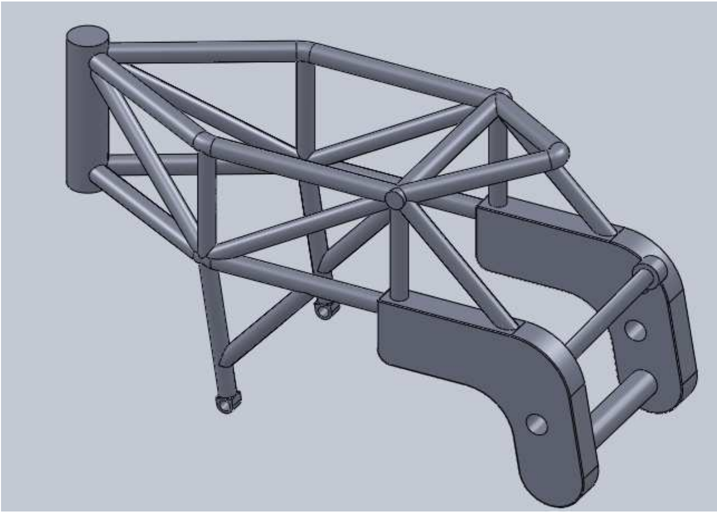


Figure 3.2: Prototype 1, 3D view

The front:

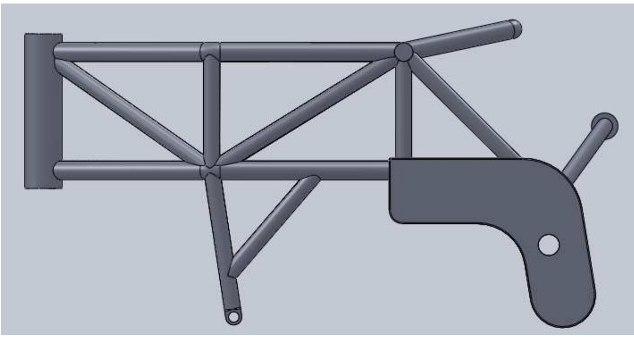


Figure 3.3: Prototype 1, front view

The side:

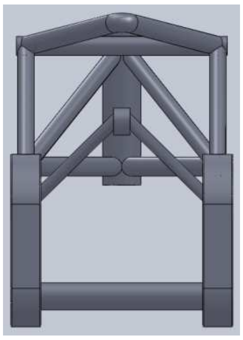


Figure 3.4: Prototype 1, side view

The top:

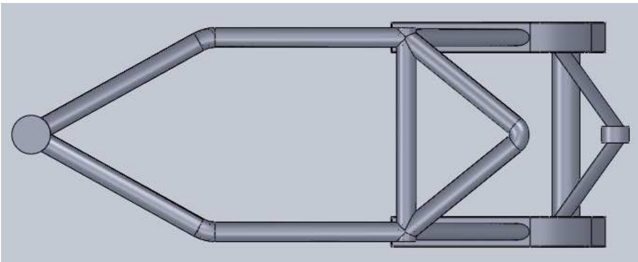


Figure 3.5: Prototype 1, top view

Then they have been done some changes on the chassis to see later the difference between them in the analysis.

So, it was changed the attachment between the engine and the chassis thinking the sustained efforts by the chassis are lower. It was got the second prototype that is the following:

3D view:

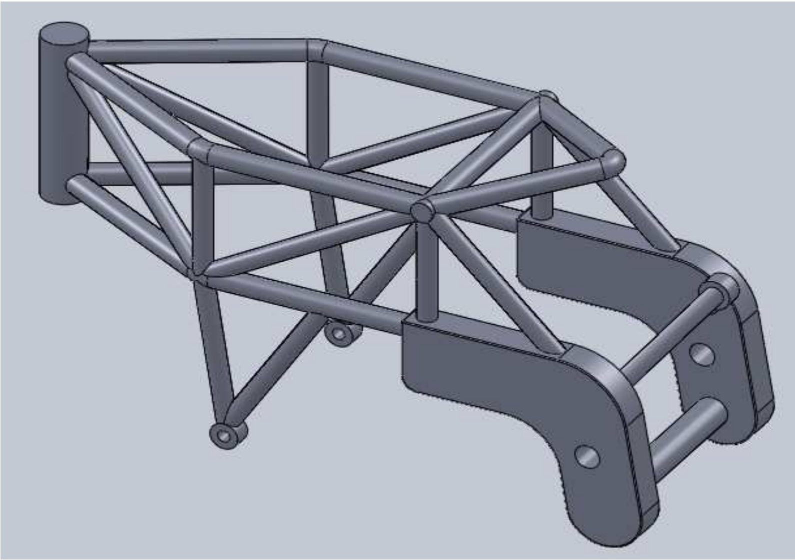


Figure 3.6: Prototype 2, 3D view

The front:

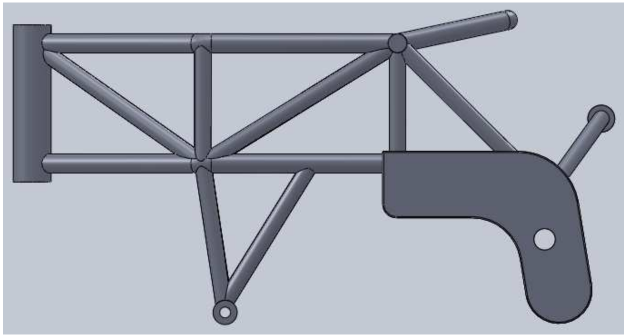


Figure 3.7: Prototype 2, front view

The side:

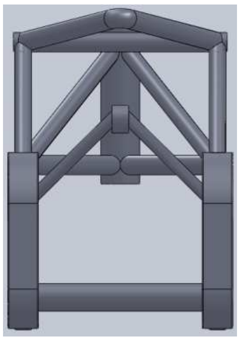


Figure 3.8: Prototype 2, side view

The top:

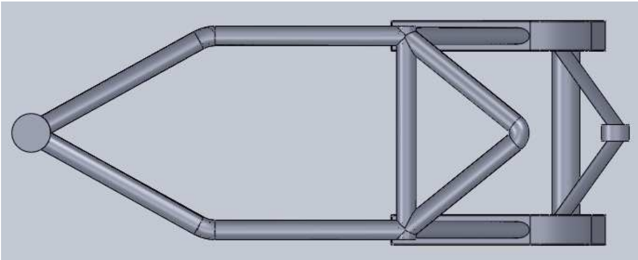


Figure 3.9: Prototype 2, top view

For the third prototype is was taking the first one also and it was added one bar more in the middle of the chassis with the intention to have a stronger and resistant chassis to vibrations.

3D view:

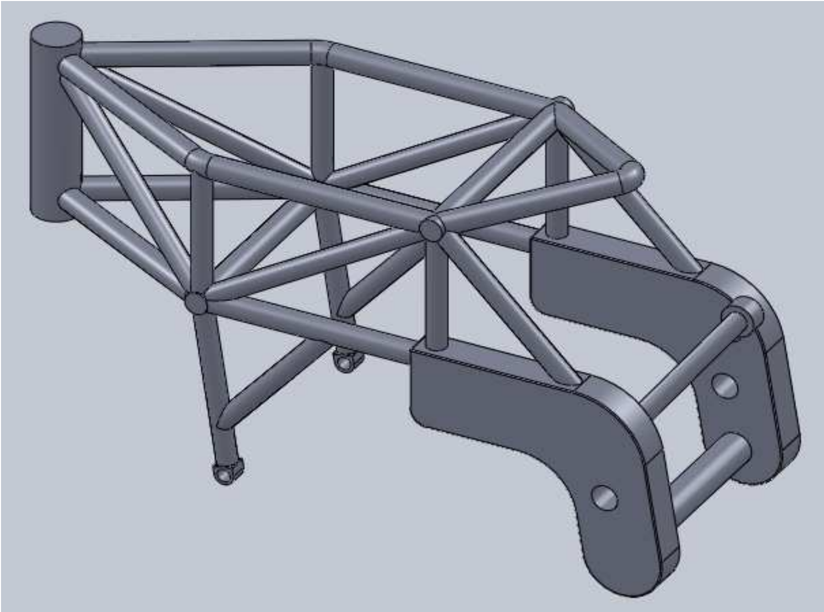


Figure 3.10: Prototype 3, 3D view

The front:

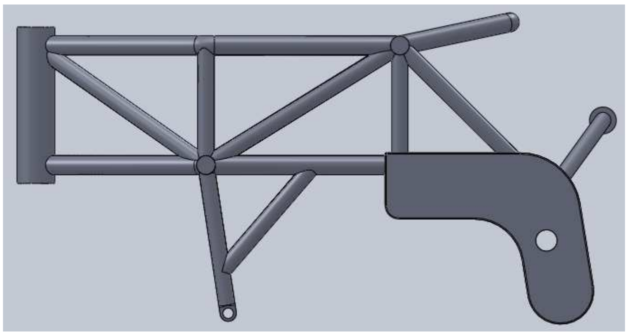


Figure 3.11: Prototype 3, front view

The side:

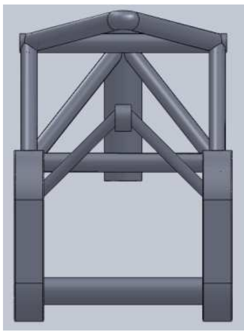


Figure 3.12: Prototype 3, side view

The top:

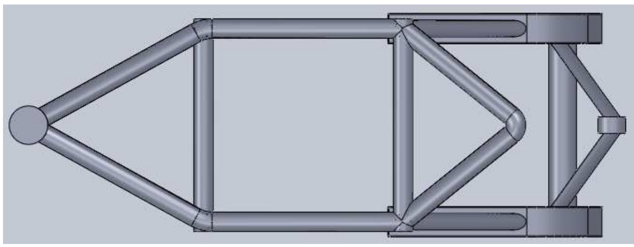


Figure 3.13: Prototype 3, top view

3.2.2 CHASSIS PARAMETERS

The idea is not create a final design for manufacturing; it is validating a first design for the construction of a prototype on which if perform the testes that will lead to production.

So, it is not necessary exactly the parameters of the rest of the motorbike and it can be done approximation about the parameters of the chassis.

Here they are the parameters of the chassis:

Prototype 1:

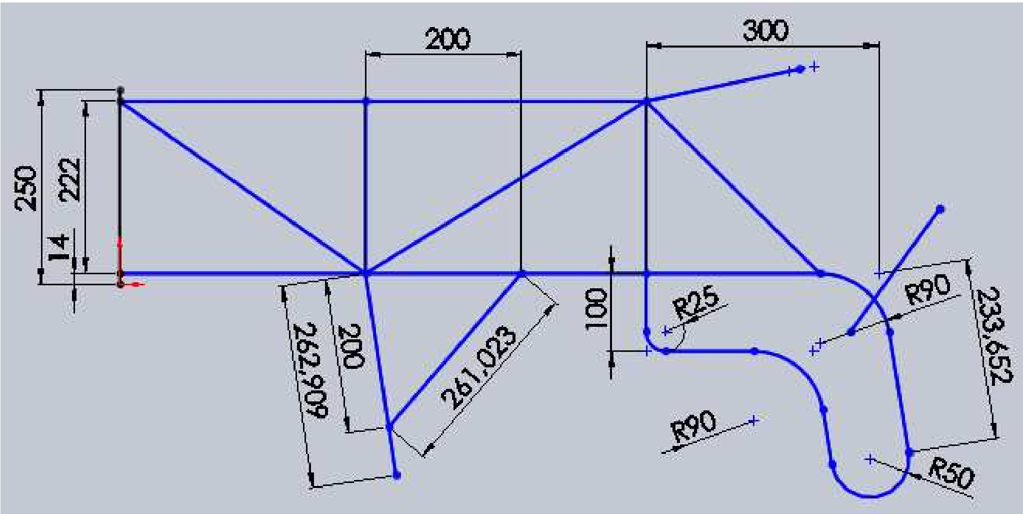


Figure 3.14: Chassis parameters, front

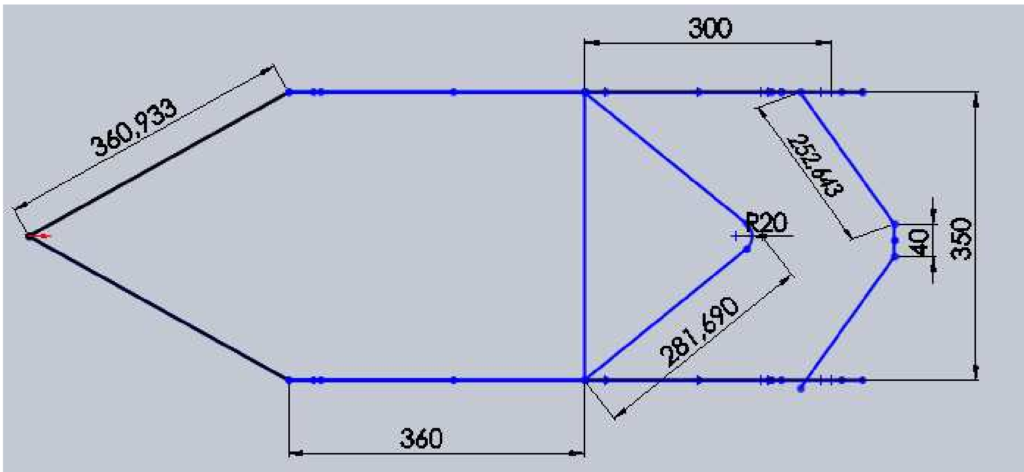


Figure 3.15: Chassis parameters, top

Prototype 2:

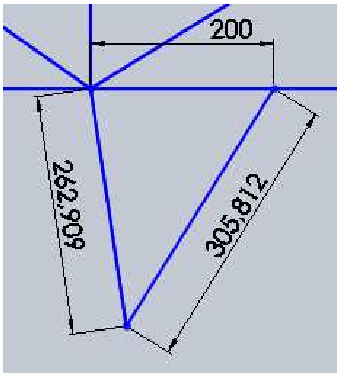


Figure 3.16: Chassis parameters, prototype 1

Prototype 3: There are not variations of the parameters in the third prototype

3.2.3 TYPES OF BARS

Before to start it must be answered which bars do we prefer, solid or hollow bars? we know that thin-walled tubes are kept well in flexion and buckling because the moment of inertia '**I**' is greater than the moment of inertia in a solid tube of the same weight. In conclusion, the best bars to do a chassis are the hollow bars, in other words, the tubes.

The next question is; tubes of circular section (CHS) or tubes of rectangular section (RHS)? The CHS is particularly attractive and provide effective distribution of steel around the center axis. This page opposes the minimum resistance to wind and water loads. The problem is that when they have to join with others circular forms it may be required special profiling. Moreover, it is known that the geometric properties of the bars influence the capacity of resistance of the union. It can only be got the best design if the designer understands the behavior of the union and takes it into account from the conceptual design. Is known the properties of the joints between CHS and the joints between RHS, but is not known the properties of mixed unions. In the case of chassis, are preferred the CHS against RHS because of; esthetic, aerodynamic, axial bending and because the number of joints is not very high, so that is not decisive in the total cost.

Taking into account regulation of tubes for this kind of structure, it was decided the dimensions for this one:

- 70 mm the diameter with 6 mm thickness for the tube of the direction axis.

- 35 mm the diameter with 2.5 mm thickness for the mains tubes.

- 30 mm the diameter with 2 mm thickness for the rest of the tubes.

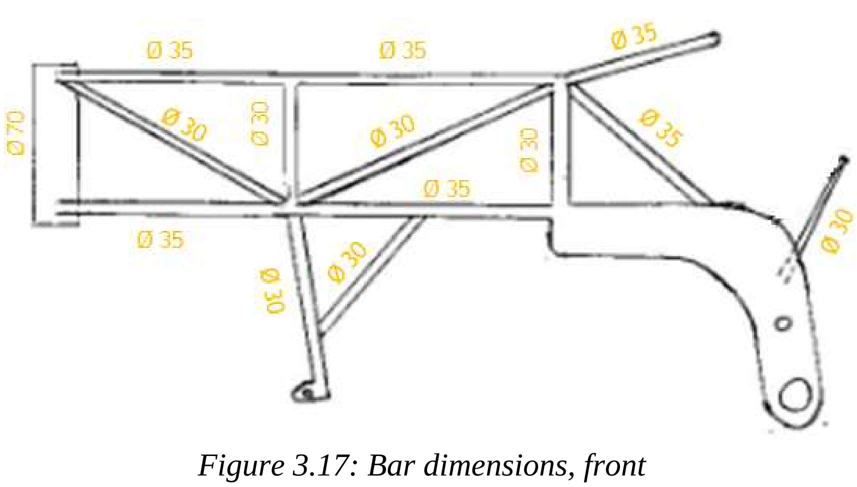


Figure 3.17: Bar dimensions, front

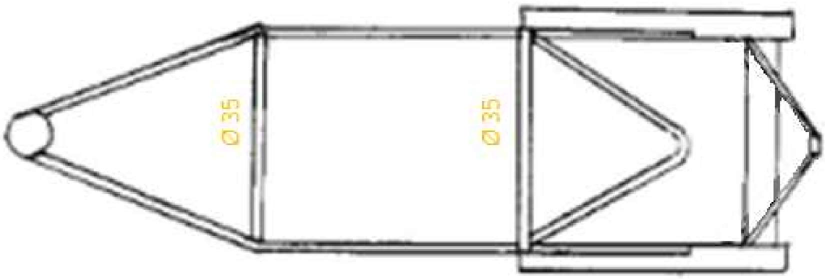


Figure 3.18: Bar dimensions, top

3.2.4 OTHERS

The chassis must be attached to the engine and must be well designed for coupling the swing arm.

The attachment to the engine supports the weight of it. The parameters are the followings:

- 30 mm edge cube
- 20 mm the diameter of the hole
- 20 mm radius the large rounding
- 2 mm radius the small rounding

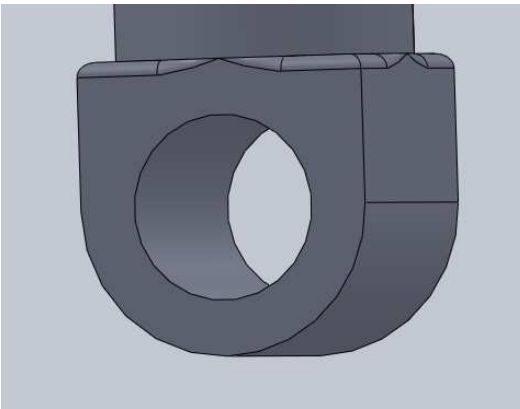


Figure 3.19: Engine attachment

The attachment to the buffer is on the back of the chassis. The function of the buffer is to decrease the efforts of the chassis must support. The buffer has two supports; one of them is coupled to the down tube.

- 50 mm the diameter of the tube

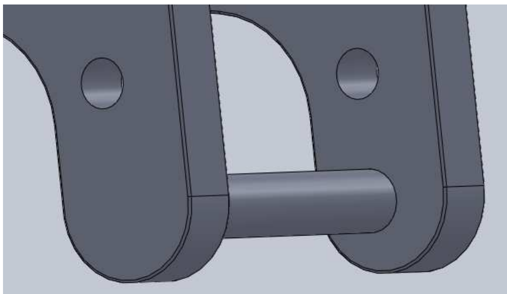


Figure 3.20: Buffer support 1

The other is above

- 50 mm the diameter and 6 mm thickness for plates
- 32 mm the diameter and 18 mm the width of the cylinder.

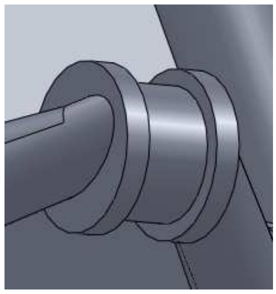


Figure 3.21: Buffer support 2

The swing arm is attached to the chassis and to the buffer. It can see on the *figure 3.20*, the support between the chassis and the swing arm. The diameter of the hole is 40 mm

4. PROTOTYPE CHOICE

4.1 INTRODUCTION

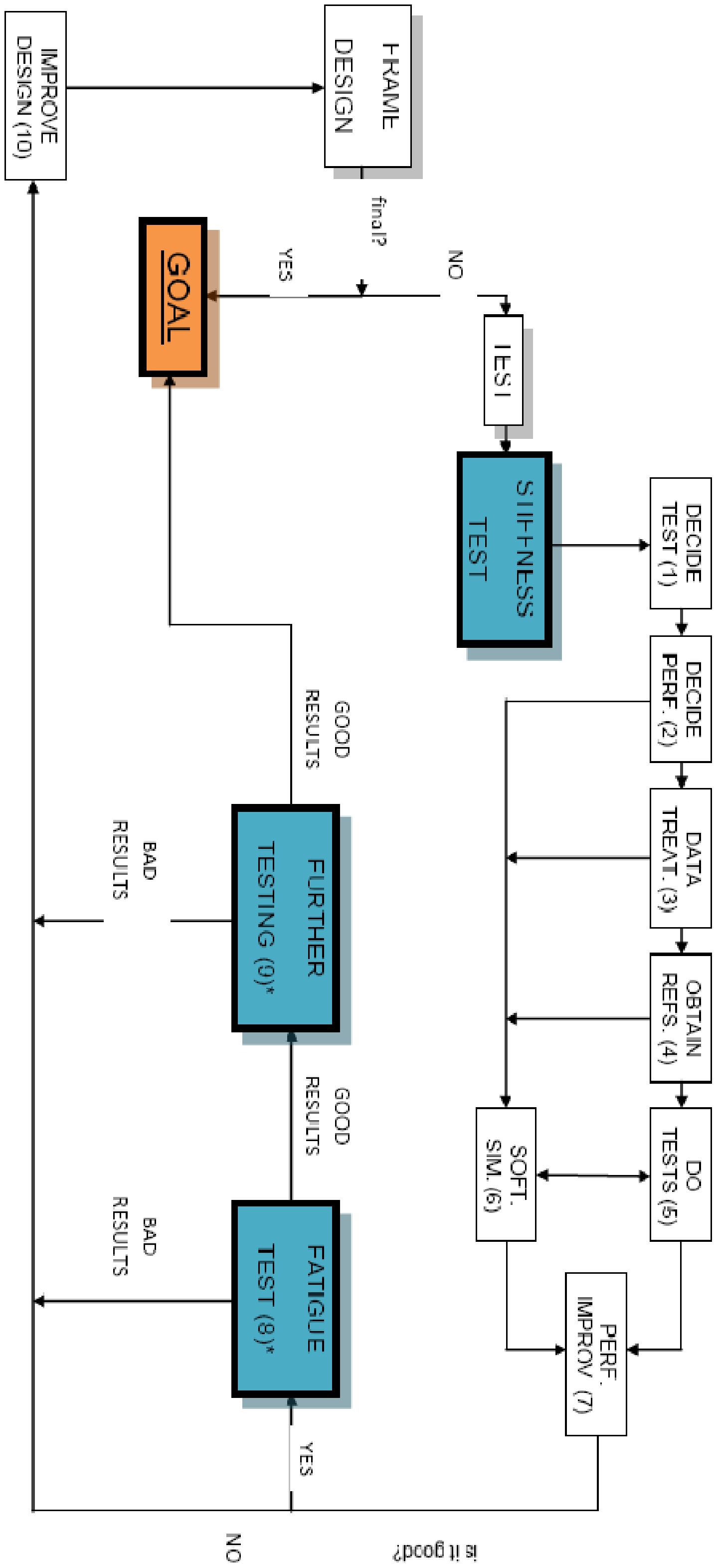
The choice of the best prototype must be chosen after to do a comparison between the prototypes designed.

The dynamic behaviour of a motorcycle is strongly influenced by bending and torsional stiffness of its frame; moreover the frame has to withstand the stresses due to the forces transmitted by the rear suspension and by the steering headstock. Modern frame design techniques incorporate simulations and experimental testing.

For precise steering, the frame must resist twisting and bending sufficiently to keep the steering axis in the same plane as the rear wheel (to maintain the desired steering geometry in all conditions) regardless of the considerable loads imposed by power transmission, bumps, cornering and braking. Good road holding means the ability of the machine, through its tires, to maintain contact with the road. It depends on frame stiffness, tire type and size, suspension characteristics and weight (and its distribution); and good handling is related with the ease, style and feels with which the motorcycle does rider's command. It depends on the same parameters as road holding but the requirements are sometimes contradictory so a compromise must be struck.

Frame bending and torsional stiffness is measured by means of experimental tests. These are non-destructive tests, so they run in the elastic range of the material

To get good chassis must be follow some testes.



4.2 TESTES

Instead, in this project they have been done only three testes. It has been taken into account bending and torsion testes.

4.2.1 TEST 1: FRAME LONGITUDINAL STIFFNESS TEST

On Picture 6.8 is shown a sketch of the test.

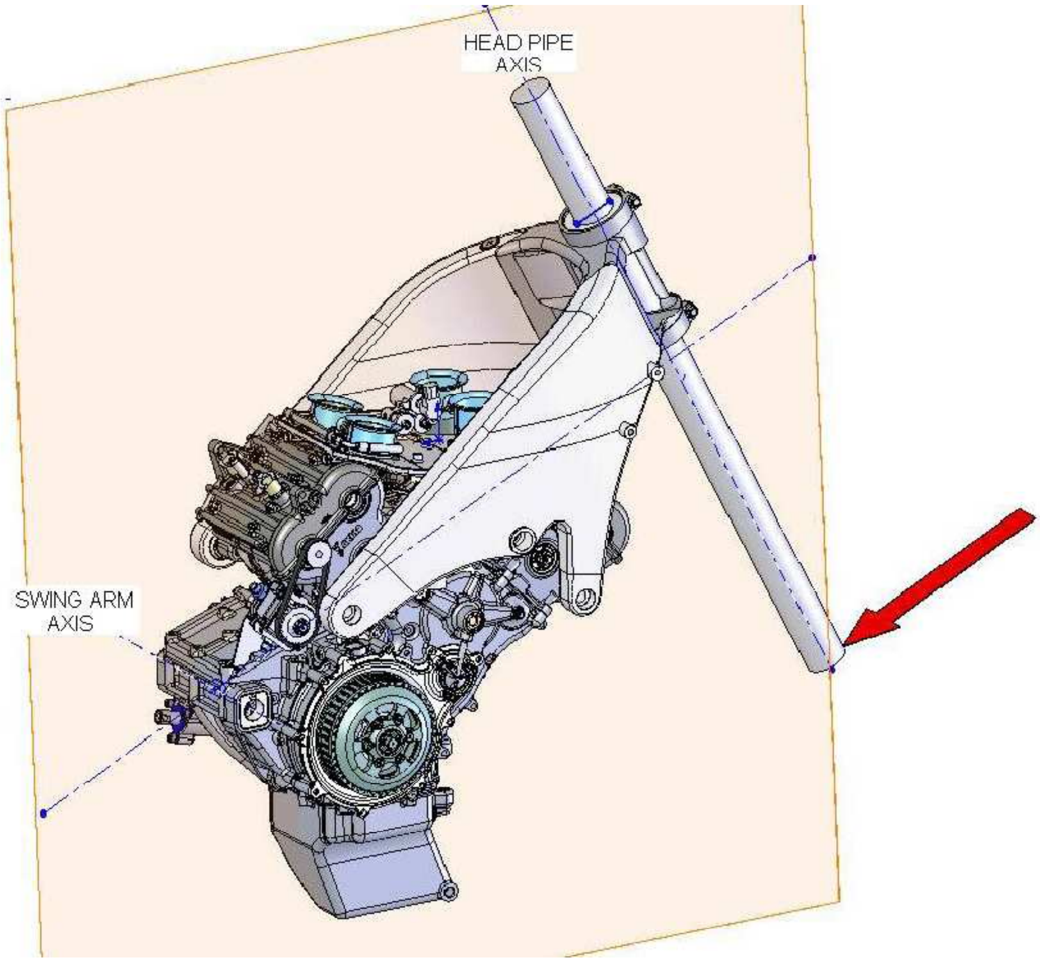


Figure 4.1: Longitudinal bending test

We can see that the head pipe collars (and bearings, not shown) are fixed on it. The body is fixed to the bench on the swing arm axis, which includes the swing arm bushes.

What we measure on the test is the displacement of the bar on the head pipe in which we apply the force. That measure will give us δ and, as we know F, we get k. The stiffness obtained from this test is the **Longitudinal Frame Stiffness, *kzf***.

We fix the frame from the swing arm axis to the rig and make sure it does not move (with the help, for example, of some extra structure on the frame). It comes with the bearings and head pipe collars on it. We also need a special swing arm axle to perform these stiffness tests (explained later).

The momentum will be introduced more or less the way you see on Picture 6.8: a bar introduced on the head pipe axis and a force applied on it to introduce a momentum on the head pipe. We will use the same instruments as on the torsional test, so we introduce directly the momentum and measure it on the dial.

In the elastic range of the material, the relation between the momentum applied (M) and the deflection (δ which we can convert to degrees, Θ) is linear. To check this, the test has to be done with several different momentums so we draw all the data obtained on a graph and we approximate it to a straight line. The slope of that straight line will tell us what the stiffness, *k*, is.

4.2.2 TEST 2: FRAME LATERAL STIFFNESS TEST

On Picture 6.2 is shown a sketch of the test.

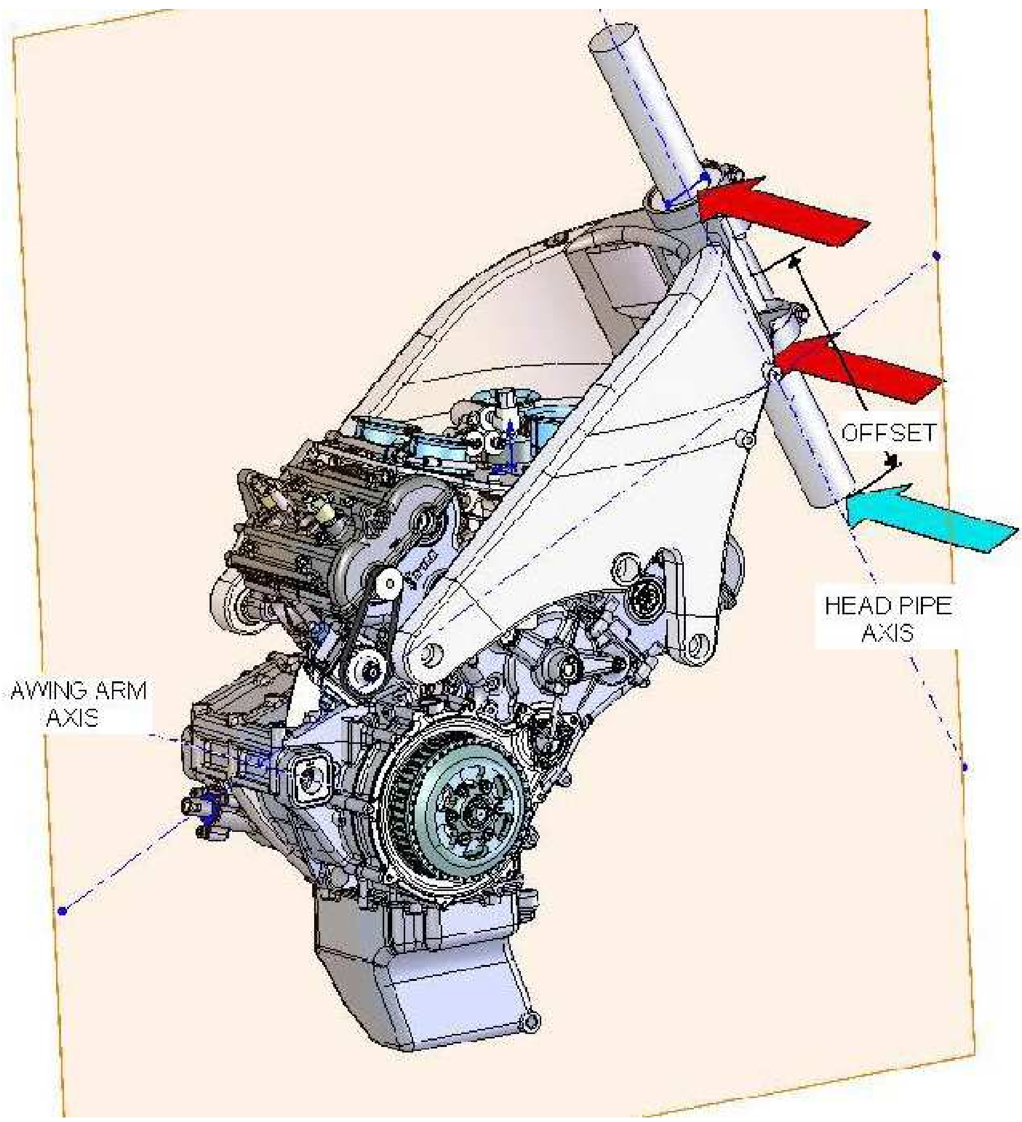


Figure 4.2: Lateral bending test

We can see that the head pipe collars (and bearings, not shown) are fixed on it. The body is fixed to the bench on the swing arm axis, which includes the swing arm bushes.

What we measure on the test is the displacement of the bar on the head pipe in which we apply the force. That measure will give us δ so, as we know F, we get *k*. The stiffness obtained from this test is the **Lateral Frame Stiffness, *kf***.

We fix the frame from the swing arm axis to the rig and make sure it does not move (with the help, for example, of some extra structure on the frame). It comes with the bearings and head pipe collars on it. We also need a special swing arm axle to perform these stiffness tests.

The testing bench:

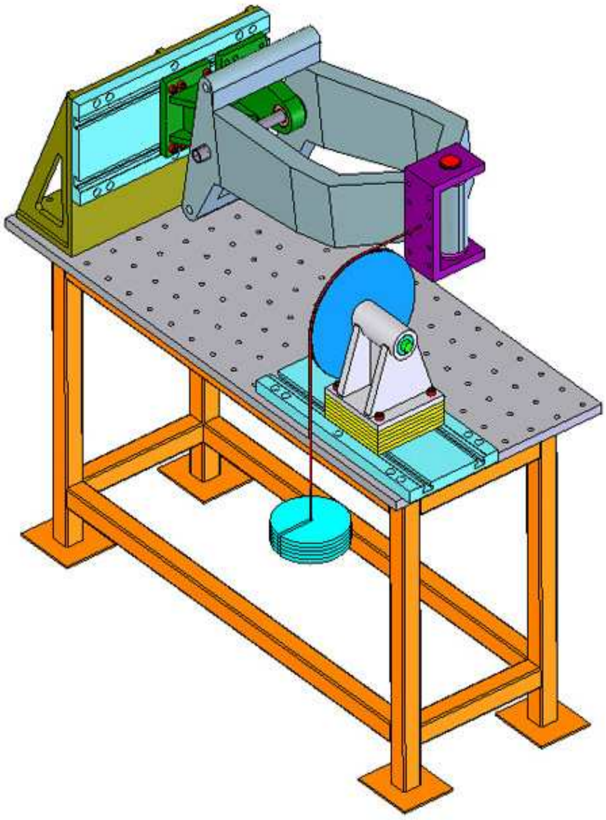


Figure 4.3: Flexion test

The weight makes a force on the chassis creating bending. The weight creates a force on the Y direction, that force is transmitted through the rope to the chassis analyzed. The force creates bending on the chassis.

4.2.3 TEST 3: FRAME TORSIONAL STIFFNESS TEST

On Picture 6.5 is shown a sketch of the test.

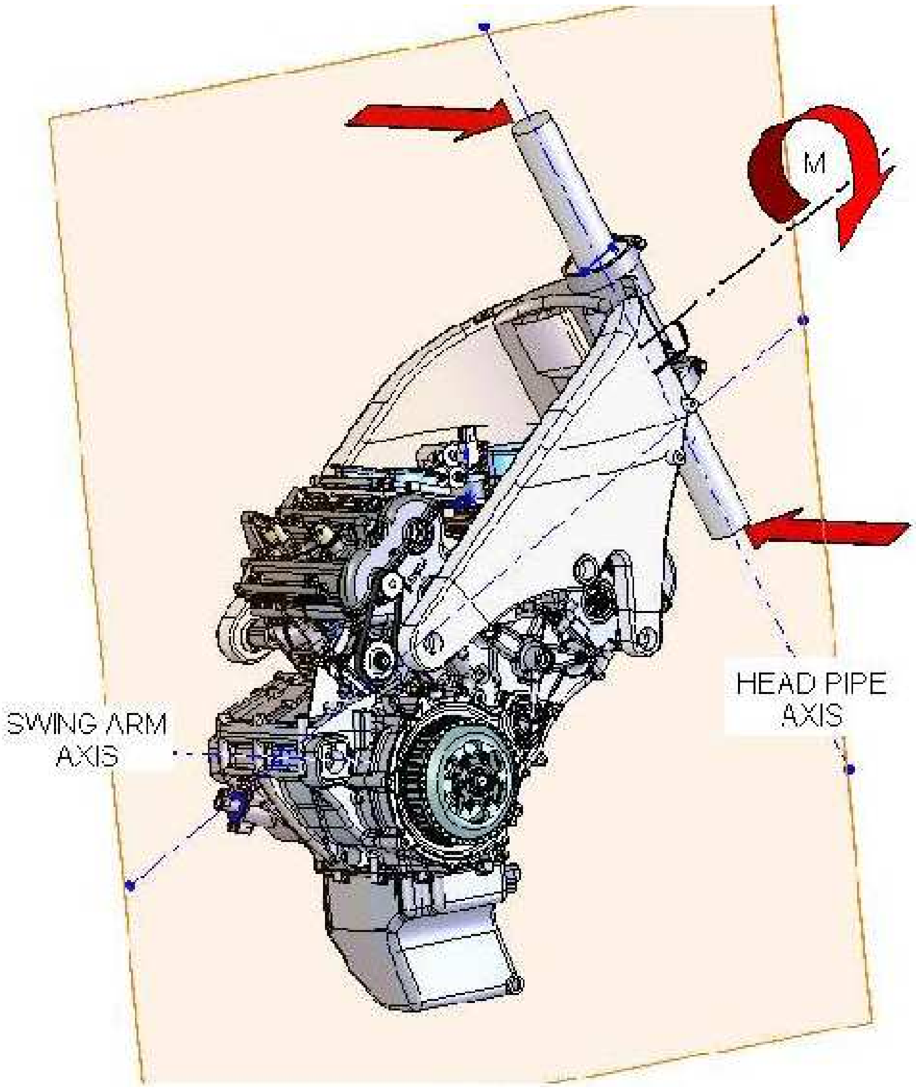


Figure 4.4: Torsional stiffness test

We can see that the head pipe collars (and bearings, not shown) are fixed on it. The body is fixed to the bench on the swing arm axis, which includes the swing arm bushes.

What we measure on the test is the displacement of the bar on the head pipe in which we apply the force. That measure will give us δ (that we can convert to degrees, ϴ) so, as we know M, we get *k*. The stiffness obtained from this test is the **Lateral Frame Stiffness, *ktf***.

We fix the frame from the swing arm axis to the rig and make sure it does not move (with the help, for example, of some extra structure on the frame). It comes with the bearings and head pipe collars on it. We also need a special swing arm axle to perform these stiffness tests (explained later).

The momentum will be introduced the same way you see on Pictures 6.5: a bar introduced on the head pipe axis and torque wrench introducing a momentum on it.

In the elastic range of the material, the relation between the momentum applied (M) and the deflection (δ which we can convert to degrees, ϴ) is linear. To check this, the test has to be done with several different momentums so we draw all the data obtained on a graph and we approximate it to a straight line. The slope of that straight line will tell us what the stiffness, *k*, is.

The testing bench:

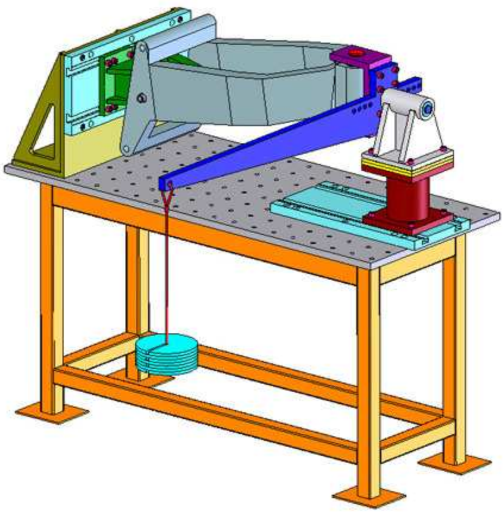


Figure 4.5: Torsion test

The weight makes a moment on the chassis creating torsion. The weight creates a moment on the X direction, that moment is transmitted by lever to the chassis analyzed. The moment creates torsion on the chassis.

4.3 THE CHOICE

The prototype chosen is the third, the reasons are:

- The tenses that this prototype suffers are almost always minors. They are always minors except in the third test (torsion test) that the prototype one suffers minor tenses
- If it is taken a look on the results obtained for the displacements, it can see that they are clearly better the results of the third prototype. Therefore, the best prototype is the third.

As already said the best prototype is the third, the reason of that is the tube was added. This tube gives more stability to the chassis doing it stronger and resistant for the vibrations.

5. MATERIALS

5.1 INTRODUCTION

Not infrequently in designing structures, the designer makes the mistake of ignoring the material that most suits from the beginning, and its possibilities to be modeling. The engineer must know the tools available to tinker, its costs and experience. He must know whether the material is made up in cold or hot, the behavior of welded joints varies. Also it is very important to know which are the mechanical properties of materials such as its elasticity modulus **E**, the shear modulus **G**, density **ρ** and its yield stress $\mathbf{f_y}$. In theory, the section of the tubes that are available can be circular or rectangular, and may be hollow or solid.

Taking everything into account, the material of choice is steel, because it has good properties.

5.2 KIND OF STEEL

The chassis could also be made of titanium, aluminum or carbon fiber, but I choose steel, why?

The truth is that chassis can be made of almost any material but it must also be taken into account cost, mechanical behavior and formability possibilities it has

The steel has the following advantages:

- Its price is relatively cheap
- Good weld ability
- Ductile material
- Its elasticity modulus is higher than many other materials such as titanium or aluminum.

As is mentioned in the introduction, the designer always needs to specify whether the material is cold-finished or warm-finished. The cold-finished tubular profiles are always welded, and the warm-finished tubular profiles, although most of them are also welded, may not have seam. In the case of the construction of a tubular chassis the most usual is to use cold-finished tubular profiles

The types of steel are specified by the International Organization for Standardization (ISO) in the following rules:

- **ISO 630**: Structural steels.
- **ISO 4951**: High yield strength steel bars and sections.

- **ISO 4952**: Structural steels with improved atmospheric corrosion resistance.

The chemical composition and mechanical properties of cold-finished tubular profiles comply with the recommendations of **ISO 630**. The mechanical properties of steels are generally characterized by the yield strength f_y, tensile ultimate strength f_u, and elongation δ_u. These properties are determined by tensile tests and can achieve diagrams **σ-ε**. The regulation **ENV 1993-1-1** prescribes the following minimum value for the relationship between ultimate strength f_u and tensile yield strength f_y:

$f_u / f_y = 1.2$ ***(based on the nominal values of*** f_u ***and*** f_y***)***

A structure made of tubular profiles filled with predominantly static loads should, in principle, be designed so as to provide a ductile behavior. This means that if the bars are critical, they should ensure capacity of rotation, or if the joints or connections are critical, they should also ensure sufficient rotation capacity. The ductility is measured in the Charpy V- test, in which a small steel piece with standard dimensions and a standard V-cut is subjected to a shock load in an environment with a given temperature. Charpy value represents the minimum breaking energy of the pieces in the trial that can withstand when they are set out to a given temperature, expressed in Joules. The values of the steels standardized by the ISO and by the CEN obey the minimum requirement of 27 Joules prescribed by the Eurocode 3.

Other aspect in the description of the mechanical properties is defined by the resistance and the ductility of the tubular profiles when they are loaded in the thickness direction. If during the test appear a crack (a lamellar tearing), it may be avoided by using steel with low sulfur content or adding sulfur with other elements such as, for example, calcium.

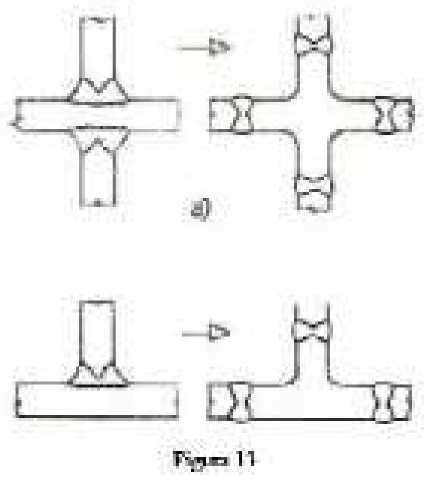


Figure 5.1: Lamellar tearing

5.2.1 Possible of steels

Among all the possible materials they have been chosen the followings

- AISI 304

AISI 304				
Chemical composition: C=0.08%max, Mn=2%max, Cr=19%, Ni=9.5%				
Property	**Value in metric unit**		**Value in US unit**	
Density	7.9 $*10^{3}$	kg/m^{3}	493	lb/ft^{3}
Modulus of elasticity	193	GPa	28000	ksi
Thermal expansion (20 ºC)	$17.2*10^{-6}$	ºC^{-1}	$9.5*10^{-6}$	in/(in* ºF)
Specific heat capacity	502	J/(kg*K)	0.12	BTU/(lb*ºF)
Thermal conductivity	16.2	W/(m*K)	112	BTU*in/(hr*ft^{2}*ºF)
Electric resistivity	$7.2*10^{-7}$	Ohm*m	$7.2*10^{-5}$	Ohm*cm
Tensile strength (annealed)	586	MPa	85000	psi
Yield strength (annealed)	241	MPa	35000	psi
Elongation (annealed)	55	%	55	%
Hardness (annealed)	80	RB	80	RB
Tensile strength (1/2 hard)	1100	MPa	160000	psi
Yield strength (1/2 hard)	760	MPa	110000	psi
Elongation (1/2 hard)	10	%	10	%
Hardness (1/2 hard)	35	RC	35	RC

Table 5.1: AISI 304

- AISI 1035

AISI 316				
Chemical composition: C=0.08%max, Mn=2%max, Cr=17%, Ni=12%, Mo=2.5%				
Property	**Value in metric unit**		**Value in US unit**	
Density	8.0 $*10^{3}$	kg/m^{3}	499	lb/ft^{3}
Modulus of elasticity	193	GPa	28000	ksi
Thermal expansion (20 ºC)	$15.9*10^{-6}$	ºC^{-1}	$8.8*10^{-6}$	in/(in* ºF)
Specific heat capacity	502	J/(kg*K)	0.12	BTU/(lb*ºF)
Thermal conductivity	16.2	W/(m*K)	112	BTU*in/(hr*ft^{2}*ºF)
Electric resistivity	$7.4*10^{-7}$	Ohm*m	$7.4*10^{-5}$	Ohm*cm
Tensile strength (annealed)	586	MPa	85000	psi
Yield strength (annealed)	241	MPa	35000	psi
Elongation (annealed)	55	%	55	%
Hardness (annealed)	80	RB	80	RB
Tensile strength (cold drawn)	620	MPa	89900	psi
Yield strength (cold drawn)	415	MPa	60200	psi
Elongation (cold drawn)	45	%	45	%
Hardness (cold drawn)	91	RB	91	RB

Table 5.2: AISI 316

- AISI 316

Propiedad	Valor	Unidades
Módulo elástico	2.049999984e+011	N/m^2
Coeficiente de Poisson	0.29	N/D
Módulo cortante	7.999999987e+010	N/m^2
Densidad de masa	7850	kg/m^3
Límite de tracción	585000003	N/m^2
Límite de compresión en X		N/m^2
Límite elástico	282685049	N/m^2
Coeficiente de expansión térmica	1.1e-005	/K
Conductividad térmica	52	W/(m·K)
Calor específico	486	J/(kg·K)
Cociente de amortiguamiento del material		N/D

Table 5.3: AISI 1035

5.2.2 Increase in the elastic limit caused by the cold deformation

That increase can be used only in RHS profiles in traction elements but not in flexion. For all, the best option is the CHS profiles so that increase does not matter in the elastic limit.

5.2.3 Consideration about the weld-ability of the materials

Essentially, the chemical composition of a type of steel is what determines your ability to solder. For welding, the ability of steel usually used for the construction of a chassis, the critical carbon content ($C \leq 0.22\%$) and purity of the steel indicated by sulfur ($S \leq 0.045\ \%$), phosphorus ($P \leq 0.045\%$) and nitrogen ($N2 \leq 0.009\%$). The weld-ability improvement, It is not only by the low percentage of carbon ($C \leq 0.20\%$), but also because of the fine-grained microstructure of the material, reducing the susceptibility to brittle fracture. The chemical composition, which influences susceptibility to fracture in the cold of the heat affected zone, often measured by the value of carbon equivalent CEV as follows.

5.3 MATERIAL CHOICE

The chassis has been analysis by SolidWorks with different material, exactly the materials before mentioned. The objective, choose good material for this material for this structure.

The material chosen is AISI 304. It has been chosen this material because taking into account the results, these materials are very similar. So, it has been chosen AISI 304 because is often used for this kind of structure.

Then, it is showed the physical properties from the material chosen, AISI 304:

- Elastic modulus **E = 190,000 N/mm^2 (MPa)**
- Shear modulus **$G = \frac{E}{2(1+\nu)}$ = 75,000 N/mm^2 (MPa)**
- Creep limit **fy = 207 N/mm^2 (MPa)**
- Poisson ratio **ν = 0.29**
- Linear expansion coefficient **α = 17.2 x 10^{-6} /°C**
- Density **ρ = 8000 Kg/m^3**

6. ANALYSIS OF THE CHASSIS

6.1 INTRODUCTION

The final design has been analyzed with SolidWorks. It is a program of computer-aided design for modelling mechanical currently developed by SolidWorks Corp.

The program allows modelling of parts and assemblies and to extract both flat and other information necessary for production. It is a program that works using new modelling techniques with CAD systems. The process is to transfer the mental idea of the designer to the CAD system, "virtual build" the piece or whole. Later, all withdrawals (drawings and swap files) are made fairly automated.

The chassis has been analyzed statically and dynamically, when the motorbike is stopped, when the motorbike is accelerating, when it is braking and when it is cornering.

6.2 STATIC ANALYSIS

In this case the motorbike has been studied when the motorbike is stopped. The motorbike has a weight that makes a force focused on the center of gravity.

The total weight of the chassis is equal to the sum of reactions at the supports, in our case, the axles of the wheels. The module sum of **F1** and **F2** is equal to **P**.

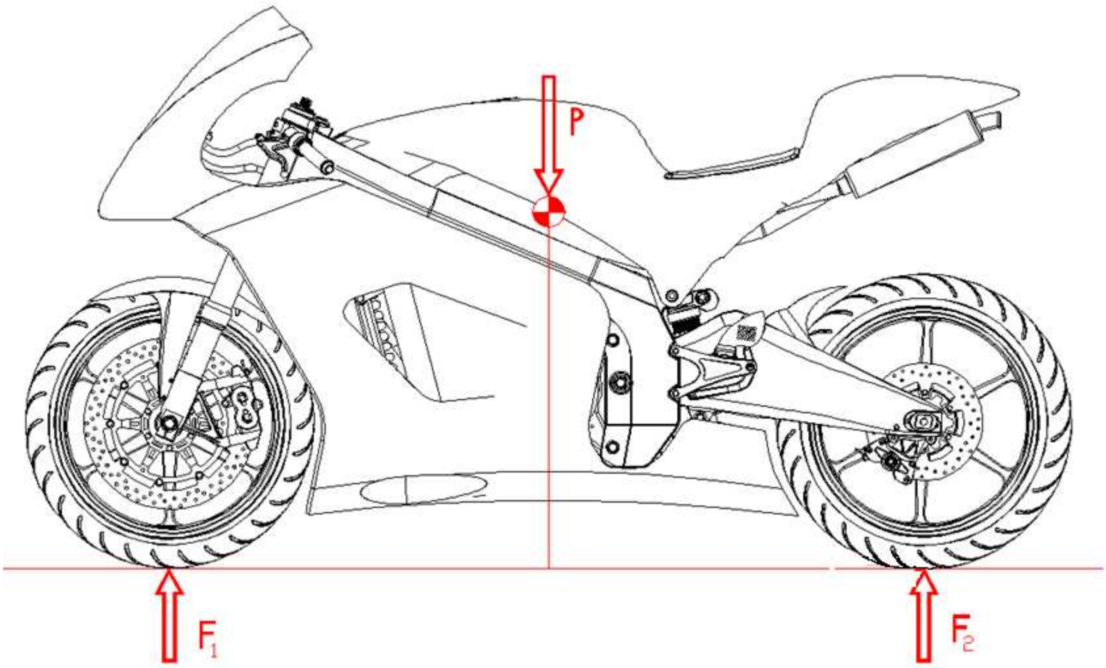


Figure 6.1: Static study

P=m x g= 190 kg x 9.8 m/s2 =1864 N

So, taking into account the center of gravity is in the middle, **F1** and **F2** are equal and their value is 932 N.

These forces have been applied dividing equally on four different points of the chassis and calculated with SolidWorks. The values depend with the distance they have to the center of gravity.

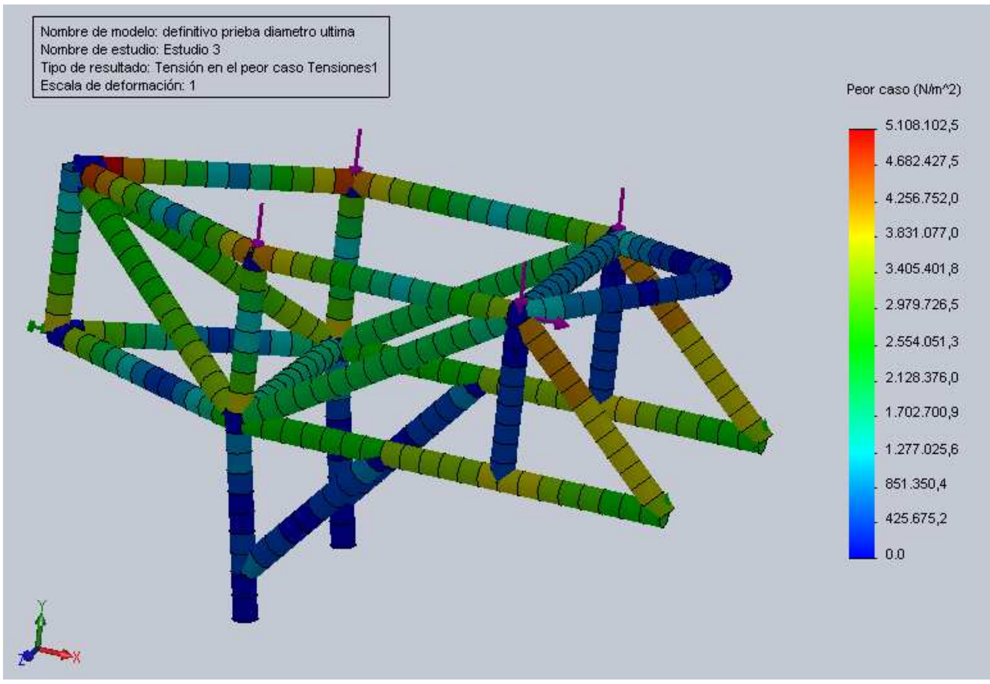


Figure 6.2: Static analysis, Von Mises

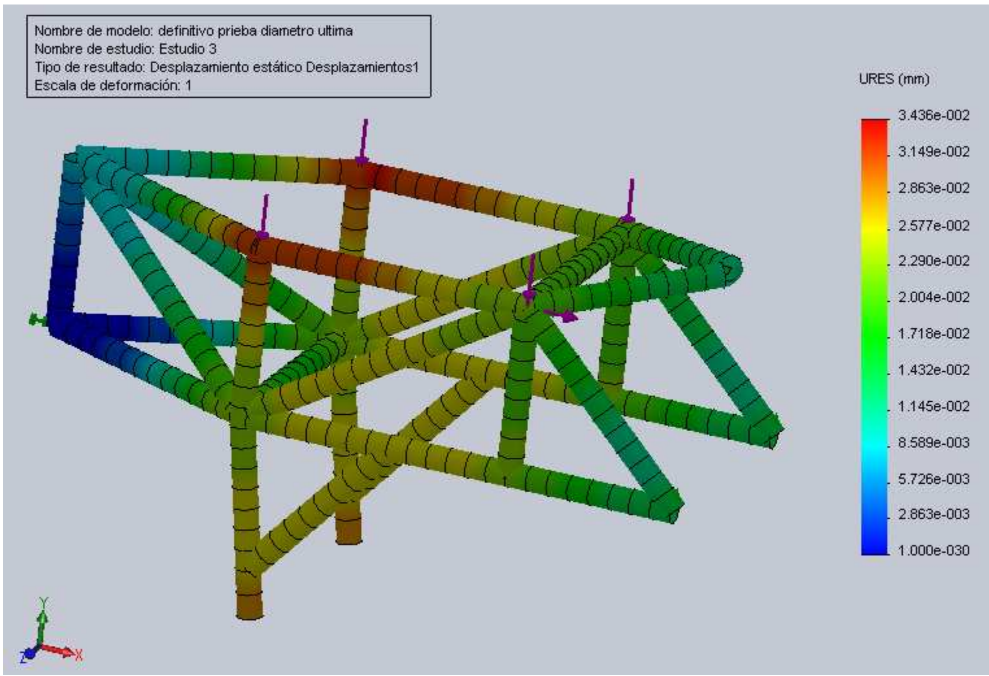


Figure 6.3: Static analysis, Displacements

The highest tense is found near the direction axis and the value is about 5 MPa.

The highest displacements are found where on red places and their value is about 3.436e10-2 mm.

The chassis will hold the weight without problems.

6.3 DYNAMICS ANALYSIS

6.3.1 IN MAX ACCELERATION

In this case they will be studied the forces that motorbike support when it is in its maximum acceleration possible. The acceleration creates a force (**Fa**), so if I take into account Newton’s laws, I’ll have another force to equal this (**Fi**). **Fa** is located at the point of contact between the rear tire and asphalt, having the same direction as the direction of acceleration. **F1** and **F2** represent the vertical force due to the weight, being downstream at the point of application (CG) and opposite reaction at the point once again at the point of contact between the rear tire and asphalt.

When we are in max acceleration, it will be nil the force on the front wheel. So, geometrically we can see that the product of two vectors, the vector sum of **P** and **Fi** on the one hand, and **Fa** and **F2** on the other, must be aligned (dotted red line in the drawing).

It is considered that the coefficient of friction between asphalt and rear tire 1.2, thus avoiding the tire slip. In addition, the CG position will not be the same that when the motorbike is in rest, the pilot's forward tilt will also move forward so that the two vectors of force resulting in the CDG and rear wheel are respectively aligned.

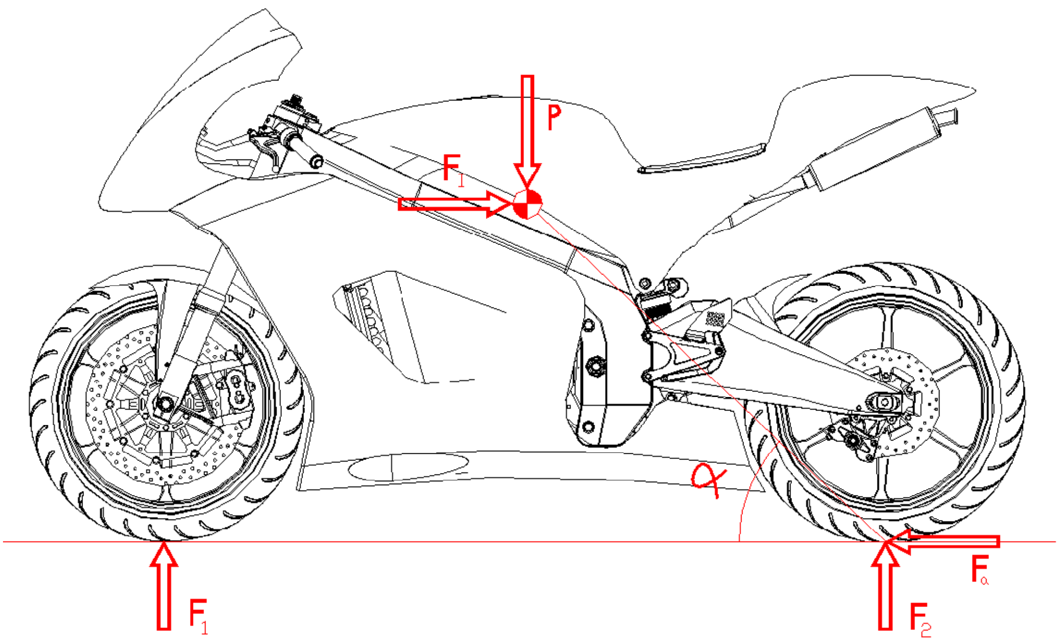


Figure 6.4: Max acceleration study

So, **F1**=0 and then **F2**= **P**
P=m x g= 190 kg x 9.8 m/s2 =1864 N
Doing ∑MCG , I will obtain **Fa**
∑MCG = 0
Fa x 650 = **F2** x 705
Fa = 1864 x 705/650 =2021.72 N
Fa = **Fi** = 2021.72
α= arctg (F2/Fa) = arctg (1864/2021.72) = 42.67º

The motorbike suffers a moment respect of the chassis of the gravity center. It is **M**=1314.118 Nm. This moment is applied like a force in one or some points on the chassis but must be taking into account the distance to the center of gravity.

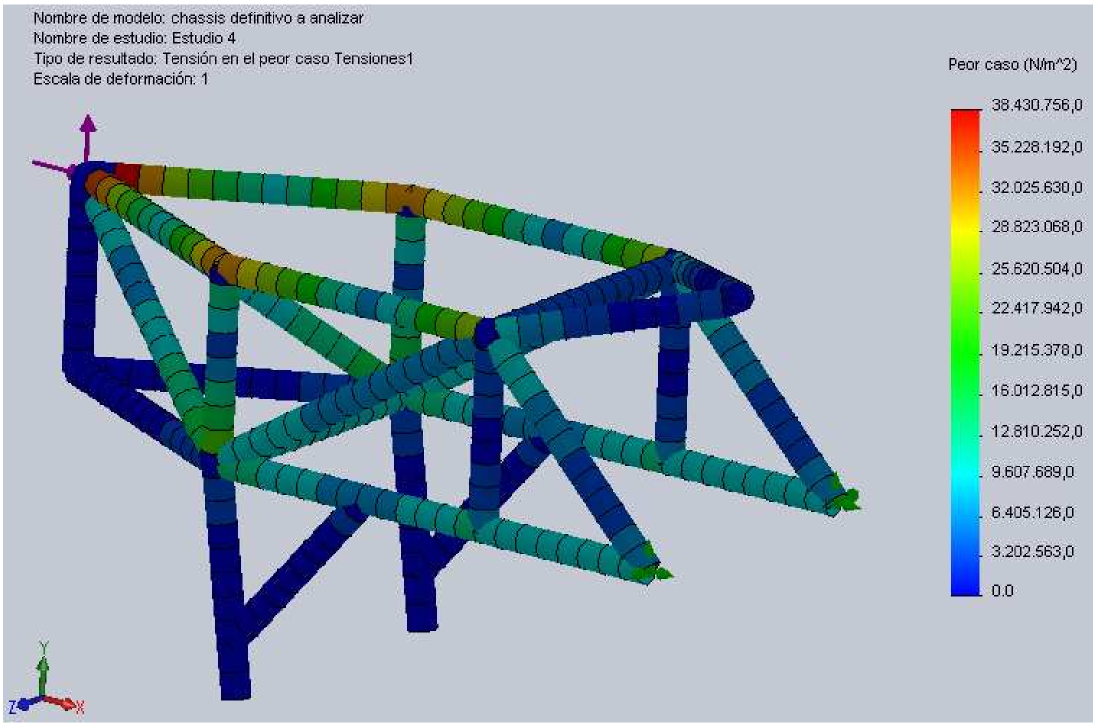


Figure 6.5: in max acceleration, Von Mises

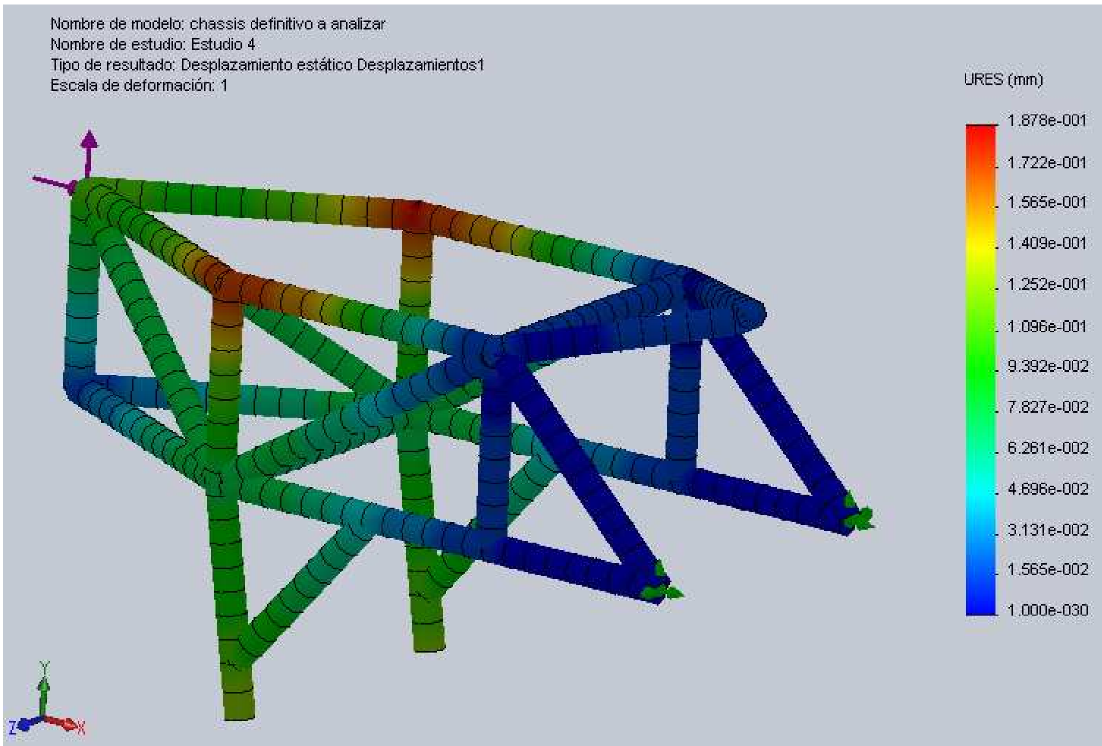


Figure 6.6: in max acceleration, Displacements

The highest is found near the top of the direction axis and the value is about 38.43 MPa. The highest displacements are found in the red places. And their value is about 1.87e-1 mm.

6.3.2 IN MAX BRAKING

6.3.2.1 On the front wheel

In this case, consider that only stop with the forward brake with the maximum efficiency. The brake creates a force (**Fb**). So, if I take into account Newton's laws, I will another force (**Fi**) equal to this.

When we are in maximum braking, it will be nil the force on the rear wheel. The vector sum of **P** and **Fi** will be a vector applied to the CG that must be aligned, in the limiting case, with the resulting vector of the vector sum of **Ff** and **F1**, located at the contact point between the front and the asphalt.

It should be noted that braking causes the collapse of the fork, a phenomenon that lowers the motorbike's CG and reduce the vertical distance between **Fi** and **Ff**, but not be considered because the consideration of this situation causes a solicitation rigid higher, so it will be a design case even more critical.

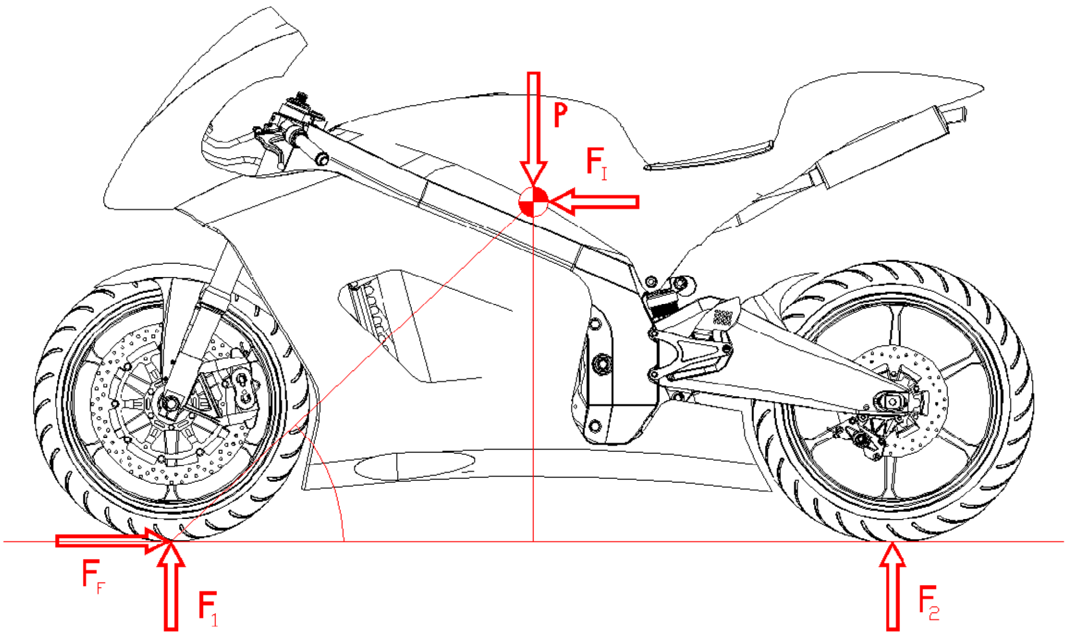


Figure 6.7: max braking with front wheel study

So, **F2** = 0 and then **F1** = **P** =1864 N
Doing ∑MCG , I will get **Ff**
∑MCG = 0
Ff =2021.72 N
α=arctg (F1/Ff) = 42.67º

The motorbike suffers a moment respect of the chassis of the gravity center. It is **M**=1314.118 Nm. This moment is applied like a force in one or some points on the chassis but must be taking into account the distance to the center of gravity.

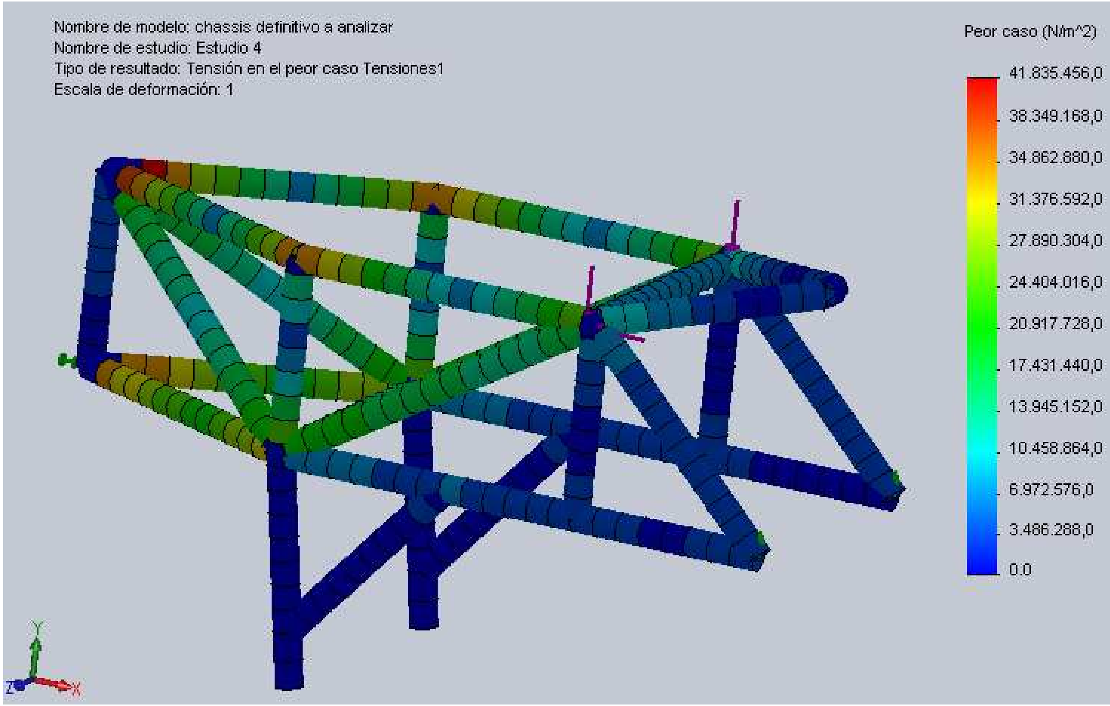


Figure 6.8: in max braking with front wheel, Von Mises

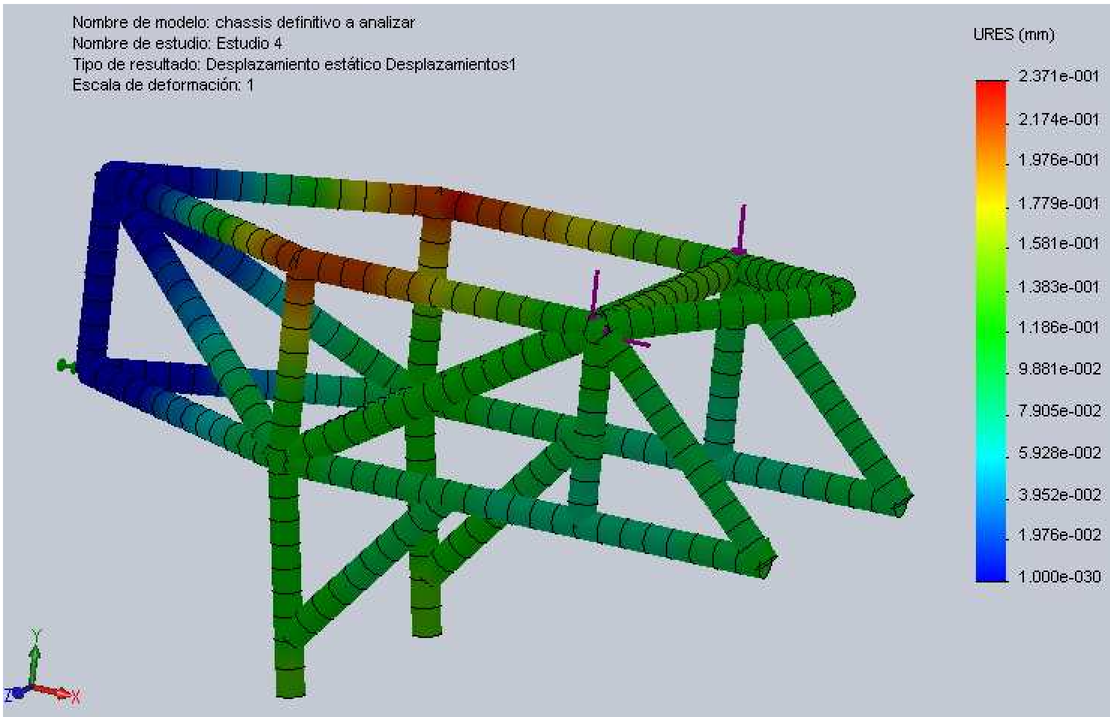


Figure 6.9: in max braking with front wheel, Displacements

The highest tense is found near of the direction axis and the value is about 41.83 Mpa, higher than in max acceleration. The highest displacements are found in red places and their value is about 2.37e-1 mm, higher than in max acceleration.

6.3.2.2 On the rear wheel

In this case, the motorbike only brakes with the rear wheel. Immediately activated rear brake, the weight distribution will vary. **F2** will be less than **F1**. Due to that, I will apply a coefficient of 0.7 to **F2** force.

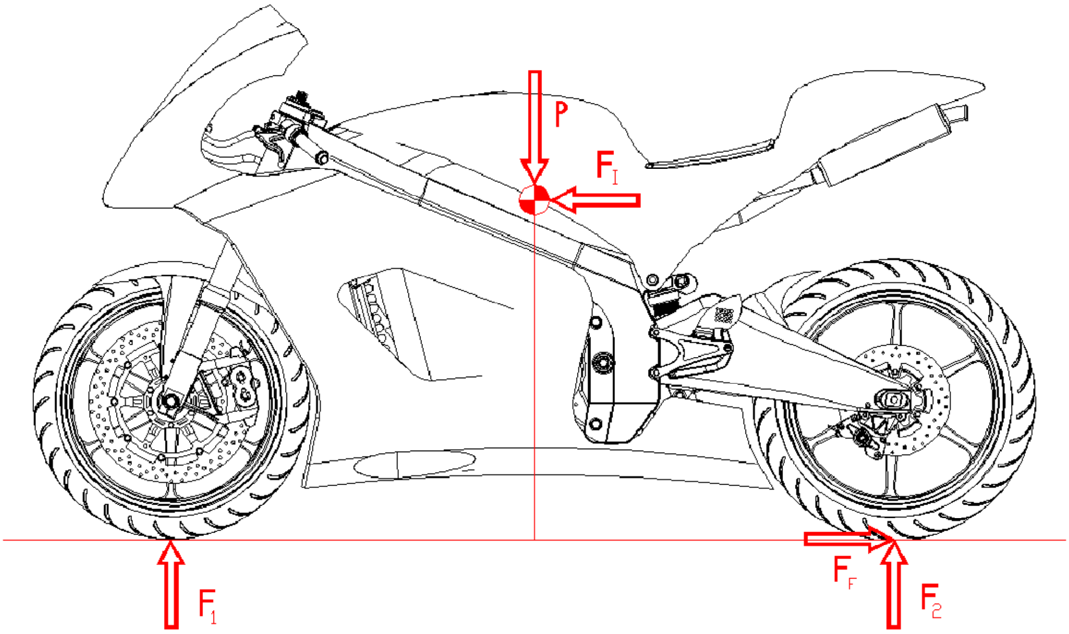


Figure 6.10: Max braking with rear wheel study

If **P** = 1864 N , so **F2** = 0.7 x (**P**/2) = 0.7 x (1864/2) = 652.4 N
And **F1** = **P – F2** =1211.6 N
Doing ∑MCG, I will get **Ff'**
∑MCG = 0
1211.6 x 705 – 652.4 x 705 – **Ff'** x 650 = 0
Ff' = 635.8 N

The motorbike suffers a moment respect of the chassis of the gravity center. It is **M**=413.27 Nm. This moment is applied like a force in one or some points on the chassis but must be taking into account the distance to the center of gravity.

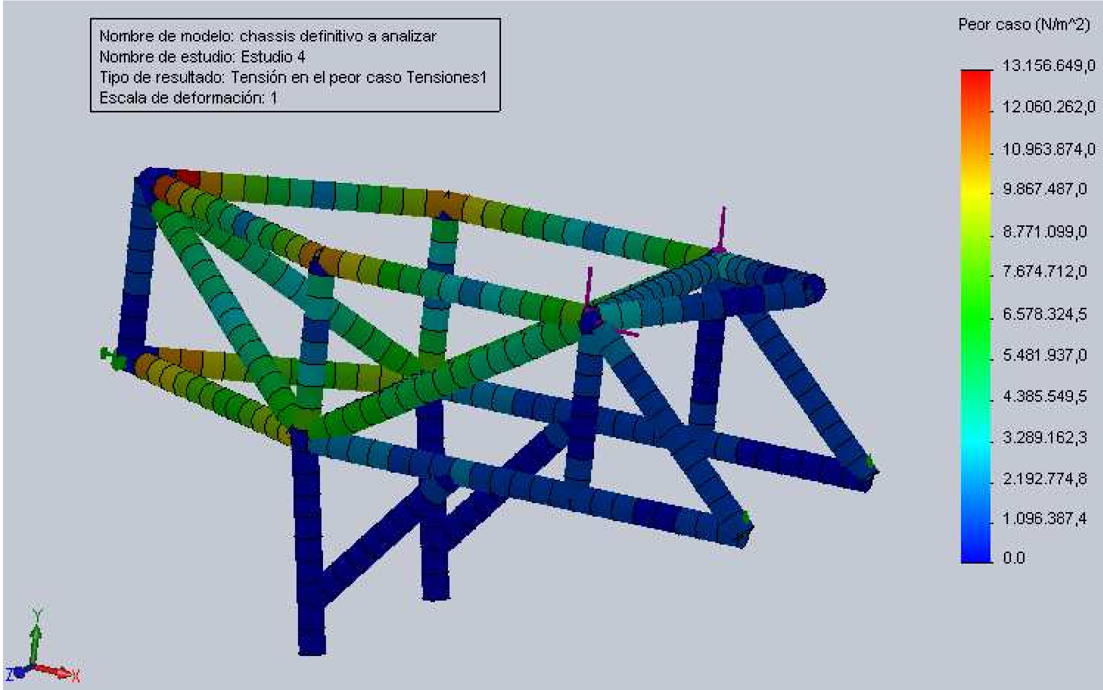


Figure 6.11: in max braking with rear wheel, Von Mises

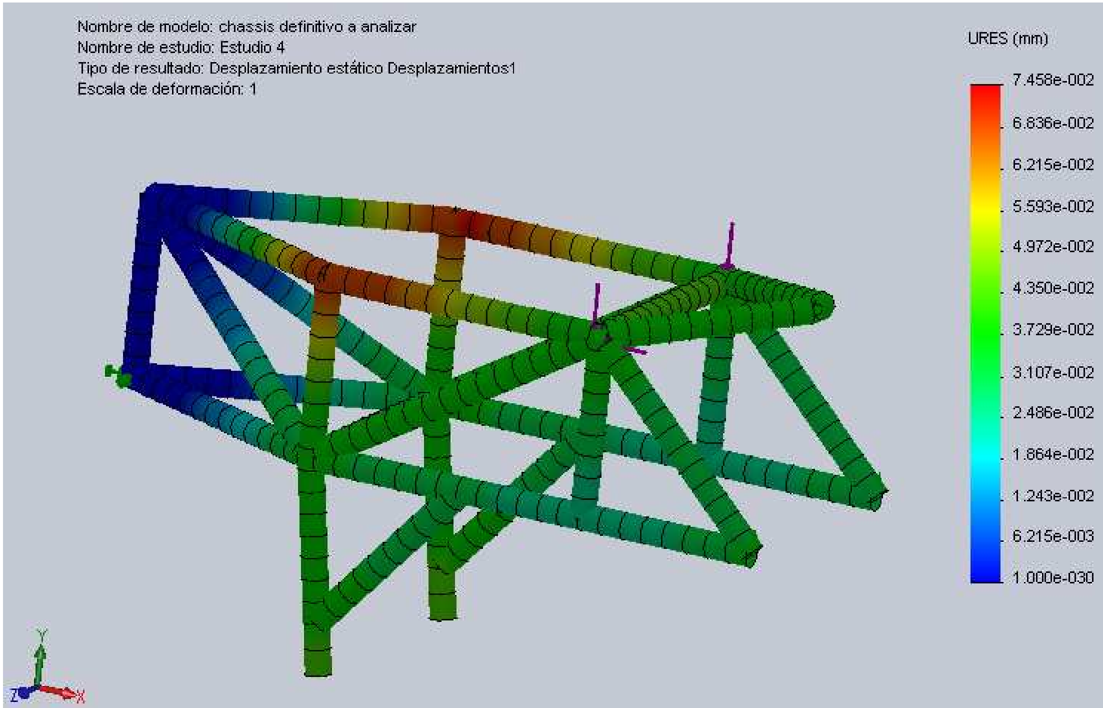


Figure 6.12: in max braking with rear wheel, Displacements

The highest tense is found near of the direction axis and it is really smaller than tense obtained with braking on front wheel. The value is just 13.16 MPa. The highest displacements are found in the same place and also they are smaller. Their value is about 7.46e-2 mm.

6.3.3 IN CORNERING

This study has been done considering the maximum inclination possible of the motorbike, taking in account that not exist acceleration force and braking force. Around the tire's grip is intended to overcome the force centrifuge due to cornering.

The vector sum of **F1** and **N** is collinear to the vector sum of **P** and **Fc**. The fulcrum of the motorbike is moved, but also the center of gravity because the driver goes off it.

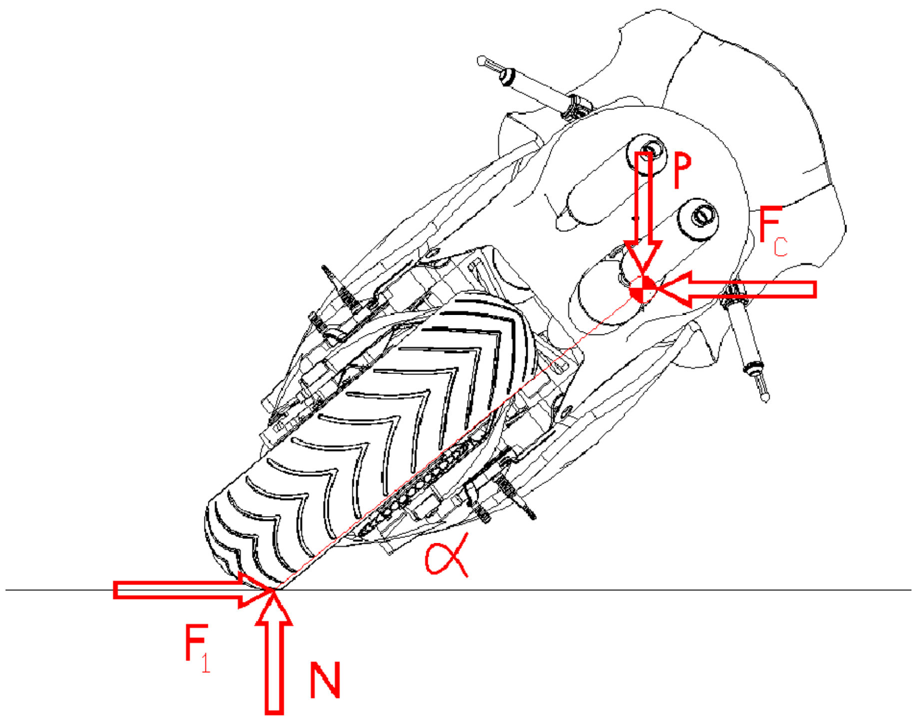


Figure 6.13: Cornering study

P = **N** = 1864 N

α = 42.67º

tg**α** = **N/F1** → **F1** = 1864/tg42.67 =2022.12 N

F1 + **N** = 2750 N

Fc + **P** =2750 N

The motorbike suffers a moment respect of the chassis of the gravity center. It is **M**=890.84 Nm. This moment is applied like a force divided equally in four points on the chassis but must be taking into account the distance to the center of gravity and the direction.

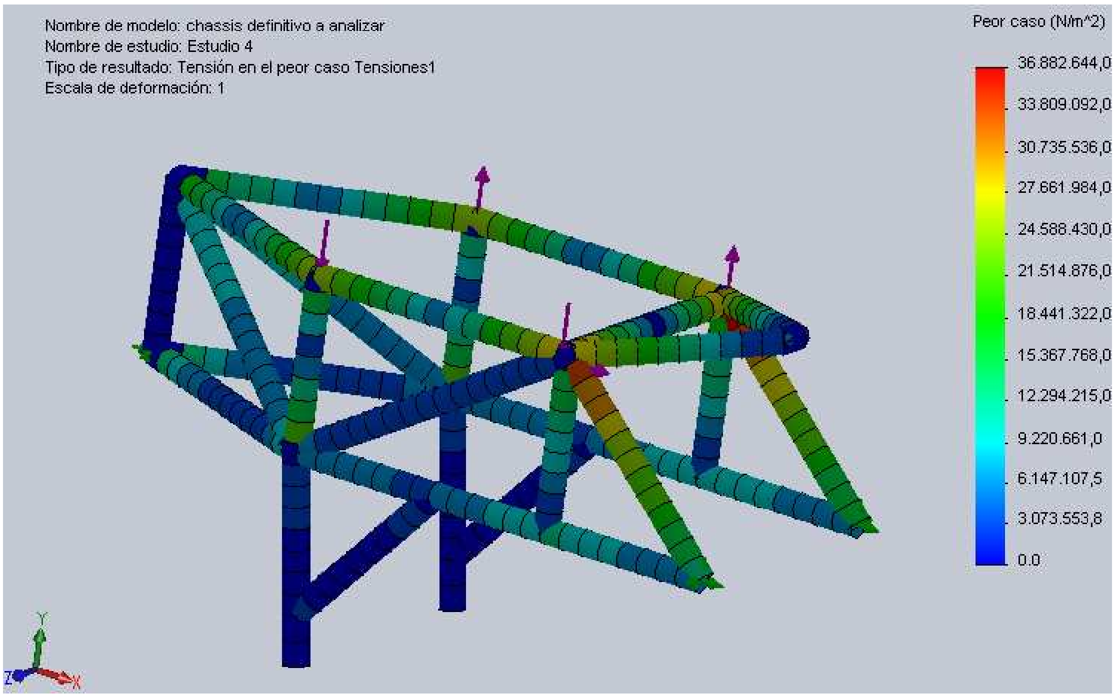


Figure 6.14: in cornering, Von Mises

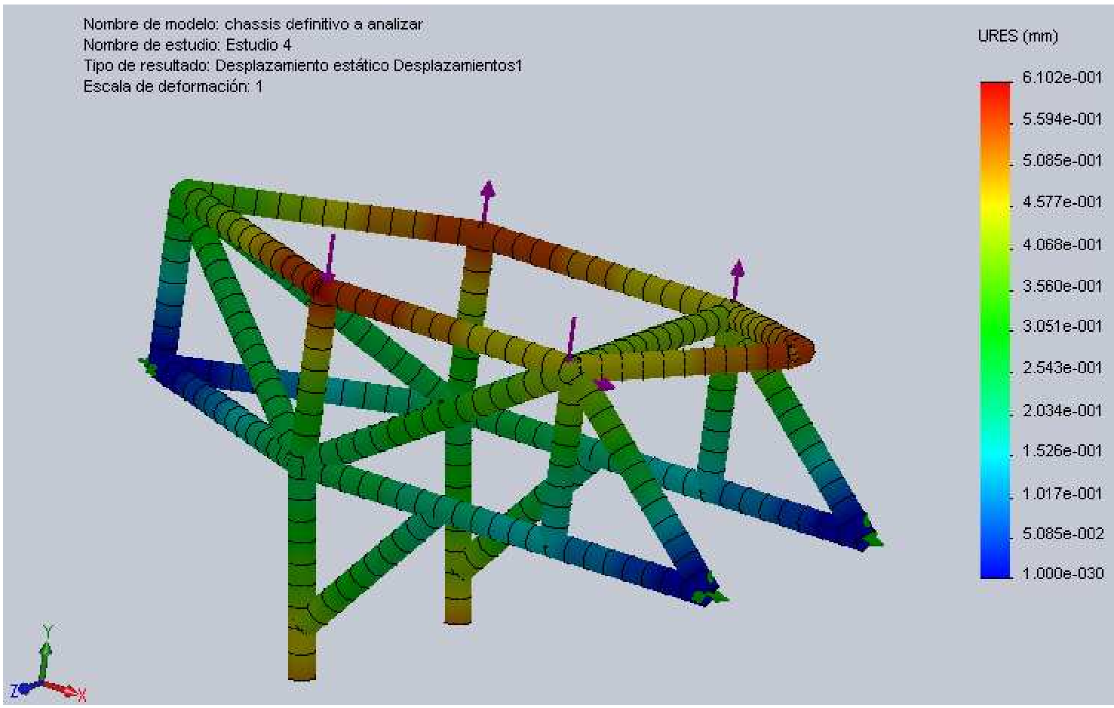


Figure 6.15: in cornering, Displacements

The highest tenses are found on the back of the chassis where they are red placed. And the value is about 36.88 MPa. Therefore, the tense in curve is smaller than the tense in max acceleration and the tense in max braking with the front wheel. The highest displacements are found in red places and the value is about 6.1e-1. It is higher than in max acceleration and in max braking with the front wheel.

6.3.4 COMPARISON

It has been done the contrasting between max acceleration, max braking with the front wheel and in draft. It can be seen that the worst situation for tense is when the motorbike is braking then when it is accelerating and then when it is in draft. Also it can be seen that the worst situation for displacements is when the motorbike is braking and then when the motorbike is accelerating.

6.4 CREEP LIMIT CHECKING

To perform the checking of the creep limit in the chassis will be needed the obtaining of the stress distribution in each case, or, which are the bars that are withstanding more stress. This Von Misses stress is compared with the maximum stress that can withstand material (**f_y= 207 MPa)** and, thereby, it is obtained the use of each section in the form of percentage. Then it is analyzed the results of each scenario:

$$\sigma_{VM} = \sqrt{\left(\frac{N}{A} + \frac{M \cdot \frac{D}{2}}{I}\right)^2 + 3\left(\frac{T\frac{D}{2}}{I_P}\right)^2}$$

6.4.1 Static analysis

In static analysis, the points that suffer the most are near the direction axis. The chassis will only support 2.4 % respect its total capability.

6.4.2 Dynamic analysis

In maximum acceleration, the points that suffer the most are near the direction axis. The chassis will support 18.56 % respect its total capability.

In maximum braking, the points that suffer the most are near the direction axis. The chassis will support 20.21 % respect its total capability.

In cornering, the points that suffer the most are on the back of the chassis. The chassis will support 17.81 % respect its total capability.

As a general conclusion, from the study of bars for the three scenarios, it has been found that the working sections are far below of the creep limit. As it has already been mentioned several times throughout the project, that is because, the chassis is designed to be rigid and not only to hold the maximum stress.

7. CONCLUSIONS

The first and most important conclusion is that there is no method completely automatable to design and calculate a chassis. Is needed a creative mind to make decisions regarding changes in geometry that it can give up to get the final design.

As can be seen in this report, designing this chassis, following this method, is long and tedious. Depending on the initial design, must be done a high number of iterations to achieve a satisfactory result. It is therefore very important to follow the design criteria defined in the report from the beginning.

I can say that the objectives of the project have been achieved and the results are available because the percentages are low. The working sections are far below of the creep limit. So, the chassis will resist in max acceleration, max braking and in cornering without many problems.

Therefore, removing some material, could be got lighter chassis and the results would continue being available. Other option could be change some bars for other with lower diameters and thickness.

As a final conclusion, it must be said that this project is a method which can lead to tubular chassis engineering, although not the ideal method. The ideal is not feasible now because CAD technology has not reached the point where it can be drawn the tubular structures with the interested flexibility.

8. RECOMMENDATION

The chassis has been designed taking into account only the considered static loads. When driving, it is obvious that, in the vehicle, appear vibrations due to the efforts from the field have different distribution. This will make that the chassis can fail to fatigue.

The design of the chassis has been done taking into account only the weight of the pilot and the weight of the motorbike. A complete would be the one which takes into account the suspensions, transmission, steering, etc… Moreover, a motorbike is exposed to collisions that are more common than we would like to, and usually, they have serious consequences. According to the motorsport magazines, the chassis should absorb these efforts. To absorb these efforts, the chassis should be deformed. This requires that certain areas of the chassis should have relatively small stiffness. At this point, it is reached a contradiction with what has been seen in this project, so, a balance between rigidity and flexibility on the different areas of the chassis should be done. Another point that should have been studied is the determination of the applicable load assumptions due to aerodynamic forces.

It is an iterative method, and depending on how close is the initial design and the final solution, sooner or later will be finished. It is advisable to make a good initial estimate. But there are no tricks to it; the more experience the better projecting the initial design.

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APPENDIX A: TECHNICAL REGULATION SPEED CHAMPIONSHIP OF SPAIN

APPENDIX A: TECHNICAL REGULATION SPEED CHAMPIONSHIP OF SPAIN

12. INTRODUCTION

With the only condition of which the Regulation of the Championship of Spain of Speed is respected, the Builders can be innovators regarding the conception, the materials and the set of the construction of the motorcycle. Only will be admitted the check of an alone motorcycle by pilot and class. In case a motorcycle, after fall in the course of the official trainings, was suffering hurts of difficult repair in the circuit, the Commissioner Technician might admit the check of the second motorcycle. Once begun the official trainings, only it will be able to remain in the stall the checked motorcycle.

2. CLASS 125 GP. SPECIFICATIONS.

• 125 GP. Superiors to 80 cc. And up to 125 cc., an alone cylinder.

3. ENGINES

3.1 The engines can work only under the beginning of two.

3.2 The engines must be of type aspiration.

3.3 The cylinder capacity will be defined:

Displacement = (D2 x 3.1416 x C)/4

- D = Diameter.
- C = Stroke.

3.4 No tolerance will be authorized in the cylinder capacities.

3.5 The cylinder capacity of the engine will have to measure up to temperature set.

4. GEARBOX

There will be a maximum of six gears.

5. WEIGHTS

5.1 The following minimal weight is authorized:

125 GP: 136 Kg motorcycle + I pilot

5.2 To come to the minimal weight, one can use ballast. The checked weight will be the total of the pilot with the whole kit and protections mass the weight of the motorcycle, including warehouse of fuel, water and other liquids, besides any complementary element fixed to the motorcycle, such as the issuer of timing, chamber, equipment telemetric, etc. During the trainings random controls of weight will be able to be effected in the zone designated by the Chief of the Commissioners Technician, as well as at the end of the career.

6. WAREHOUSES OF FUEL

6.1 The stoppers of fuel must be monopolies and have an effective system of closing.

6.2.1 The chimneys of aeration of the warehouse of fuel must take a valve of retention. The exit of the chimneys of aeration must come out inside an appropriate recuperate, one for motorcycle with a minimal capacity of 200 cc. And a maximum of 250 cc.

6.3.1 The warehouses of fuel must have a protection system against the fire or be provided with a bladder of fuel.

6.3.2 Except in case a warehouse of fuel is screwed to the chassis, all the conduits of fuel between the warehouse and the carburettor or the system of injection must have a system of fittings monopolies. This fitting must separate when there is exercised a force lower than 50 % of the necessary load capable of conquering a resistance of any part of the conduit of the fitting or of starting it of the warehouse.

7. SAFETY AND CRITERIA OF CONSTRUCTION

7.1 Gyratory fist of gas.

7.1.1 The gyratory fist of gas must be closed automatically in all that him release.

7.2 Direction.

The handle must have a minimal width of 450 mm. And his ends must be solid or covered of rubber. The width of the handle is that measure between the exteriors of the fists of the handle or of the gyratory fists of gas.

7.2.2 There will have to be a minimum of 15 º from movement of the direction to every side of the axis.

7.2.3 A few ceilings will have to be fixed to assure a space of a minimum of 30 mm. Between the handle and the petrol tank and / or the fairing, when the angle of draft is in his maximum point.

7.2.4 The motorcycles must be provided with a button of he gives birth in operative condition.

7.3 Brakes.

The motorcycles will have to be equipped with at least a brake in every wheel, which works separately.

7.3.2 There remains totally prohibited the utilization of brake discs of carbon.

7.4 Leak.

7.4.1 The exit of the leak cannot exceed the tangent vertical one of the edge of the back tire.

7.4.2 The last 30 mm. Of the pipe must they be horizontal and parallel in relation to the average line of the motorcycle.

7.4.3 For safety reasons, the exposed radius of the exit of leak must become wealthy not to have sharp tops.

7.5 Footrest.

The footrests must have extremities rounded with a minimal spherical full radius of 8 mm.

7.6 Handles of the handle.

The length of the handles cannot be superior to 200 mm, measured from the pivot and finished in a sphere with a diameter not lower than 18 mm.

7.7 Fairing.

7.7.1 The edge of the dome and the edges of the rest of the exposed parts of the fairing must be rounded.

7.7.2 The maximum width of the fairing cannot overcome 600 mm. The width of the saddle or of any another element later to this one cannot overcome 450 mm. (With the exception of the pipes of leak).

7.7.3 The fairing cannot happen from a line planned vertically in front of the axis of the front wheel and a line planned vertically in the edge of the back tire. The suspension must be completely extended in the moment of the measure.

7.7.4 When it looks laterally, one must be able to see:

a) 180 º at least of the rim of the back wheel.

b) The totality of the rim of the front wheel, with the exception of the part covered by the mudguard or the pitchforks.

c) The pilot sat in normal position, exempting the forearms.

Note: No transparent material can be in use in order the rules to skip before mentioned.

7.7.4 No part of the motorcycle can be behind a line planned vertically at the edge of the back tire.

7.7.5 There will be a maximum difference of 150 mm. Between the base of the saddle and the highest point of the saddle.

7.7.7 The mudguards are not obligatory. The front mudguard, if he establishes himself, will not have to exceed:

a) A line planned up and towards in front of 45 º of a horizontal line that happens for the axis of the front wheel.

b) Below a line planned horizontally and behind the front wheel.

7.7.8 Ailerons can fix, always and when they are an integral part of the fairing or of the saddle, and that do not overcome the width of the fairing or of the saddle or the height of the handle. Any edge in top will have to become wealthy. The mobile aerodynamic devices are prohibited.

7.8 Free movement / space.

The motorcycle, not loaded, has to be able to incline up to an angle of 50 º from the vertical one without touching the soil, with no other element that is not the tire. There must stay a free space of a minimum of 15 mm. About the circumference of the tire in all the positions of the suspension of the motorcycle and all the positions of adjustment of the back wheel.

7.9 Pipes of aspiration.

Any pipe of aspiration from the engine or from the gearbox will have to come out into a warehouse adapted with a minimal capacity of 250 cc. There will have to be a warehouse separated for every pipe of aspiration.

7.10 Titanium and light alloy.

The utilization of the titanium in the manufacture of the chassis (I) (fit), of the front pitchfork, of the handle, of the axes of the oscillating arms and of the axes of the wheels it is prohibited. For the axes of the wheels there is equally prohibited the utilization of light alloys.

7.11 Protector of chain.

A protector of chain must notice so that it prevents that the leg / the foot of the pilot gets between the tour of the low chain and the later crown of the later wheel.

12. TIRES AND RIMS

The maximum widths of the rims are the following ones:

125 GP

- **Front:** 2,5 inch
- **Rear:** 3.5 inch

9. NUMBERS AND FUNDS

9.1 The numbers of career must be fixed in the front part and in both sides of the motorcycle, in order which they are clearly visible for the timing, the spectators and the Officials. The front number must be placed in the center of the altar frontal of the fairing or in the side where the official timing is placed. The lateral plates must be placed in the later right and left part of the 50odelli. The numbers will have to be visible for the spectators and officials from any side of the track.

9.2 The measures of the numbers will be: 140mm x 25mm minimum. The numbers of the 1 to 9 will be able to be broader. Only they will be able to use the dorsal ones of the 1 to 99.

9.3 The minimal measures of the funds will be:

· Width: 275 mm.

· Height: 200 mm.

9.4 The funds of the plates it carries numbers they must not have an inclination of any more than 30 º with regard to the vertical one.

9.5 There will have to be left a free space of at least 25 mm. About the numbers.

9.6 In case of conflict as for the reading of the numbers, the final decision belongs to the Commissioner Technician.

10. FUELS AND LUBRICANTS

The fuels will have to be unleaded and with the characteristics that are specified in the Regulation of Fuels (Article 01.63).

11. CONTROLS OF SONOROUS LEVEL

11.1 The controls of sonorous level must be affected in a zone opened with a space of 10 m. At least between the motorcycle that is controlled and any wall or another type of obstacle. It is necessary that the sonorous level sets in the zone are minor of 90 dB in a radius of 10 meters.

11.2 The equipment of measure must be calibrated before the control and be recalibrated regularly.

11.3 The equipment of measure must place to 50 cm. Of the end of the pipe of leak and with an angle of 45 º of the pipe of leak, already be of side or for below.

11.4 Sonorous level.

• **The sonorous maximum level for the whole event is of 113 dB/A.**

• For major comfort, made possible by the similarity of the career of the piston for configuration of the engine according to the cylinder capacity of every class, the control can be affected to a maximum number of R.P.M. 7000.

12. DANGEROUS MOTORCYCLES

If during the trainings or the career, a Commissioner Technician states a fault to a motorcycle and that this fault might constitute a danger for the rest of pilots, it will inform the Juror. It is of his own responsibility to exclude the motorcycle of the trainings or of the career.

APPENDIX B:

CALCULATION WITH SOLIDWORKS

APPENDIX B: CALCULATIONS WITH SOLIDWORKS

INTRODUCTION

SolidWorks is a program of computer-aided design for 53modelling mechanical currently developed by SolidWorks Corp.

The program allows 53 modelling of parts and assemblies and to extract both flat and other information necessary for production. It is a program that works using new 53 modelling techniques with CAD systems. The process is to transfer the mental idea of the designer to the CAD system, “virtual build” the piece or whole. Later, all withdrawals (drawings and swap files) are made fairly automated.

Figure B.1: SolidWorks

TEST ANALYSIS FOR PROTOTYPE CHOICE

To do the choice of the best prototype, I had to do different testes for each prototype and compare the results.

TEST 1: FLEXION ON THE Y DIRECTION

For the first test I put a force on the axis of the direction creating flexion, the value of this force is 4000N. And the frame is fixed on the back of the chassis where is placed the swing arm.

Prototype 1

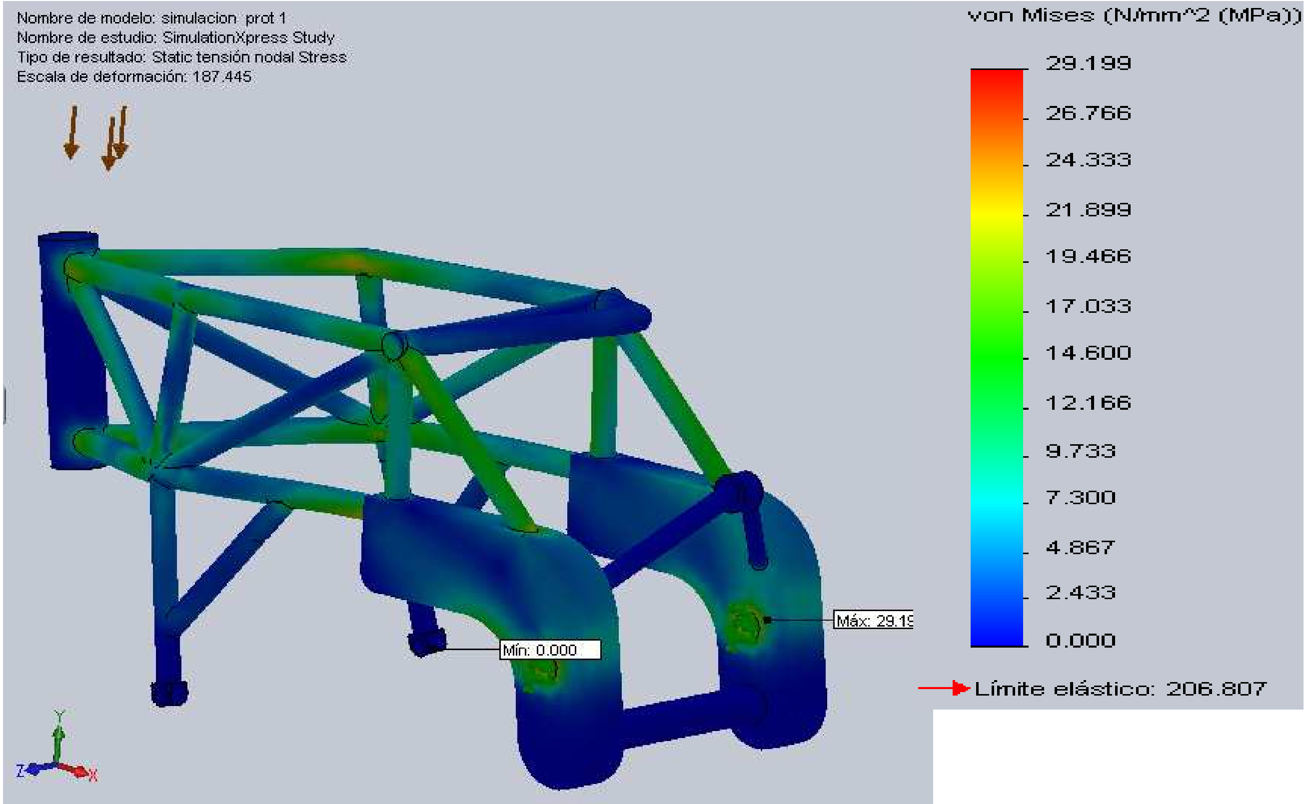

Figure B.2: Test 1, Prototype 1, AISI 304, Von Mises

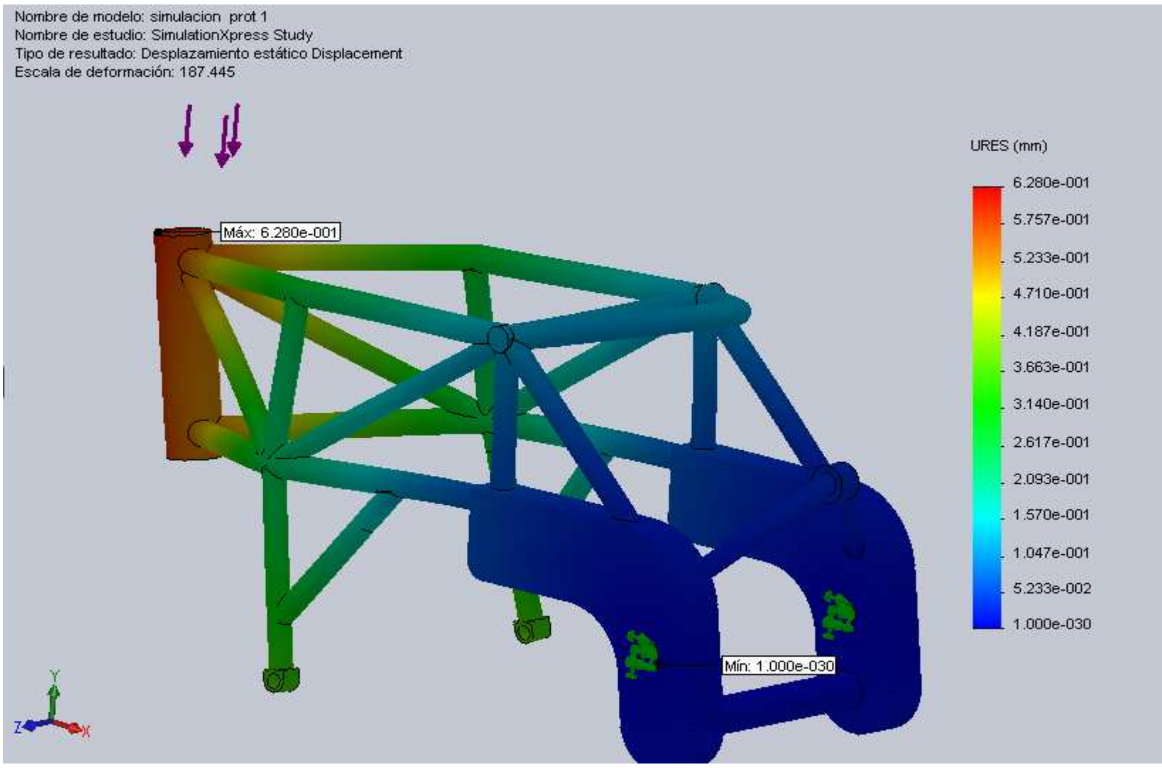

Figure B.3: Test 1, Prototype 1, AISI 304, Displacements

Prototype 2

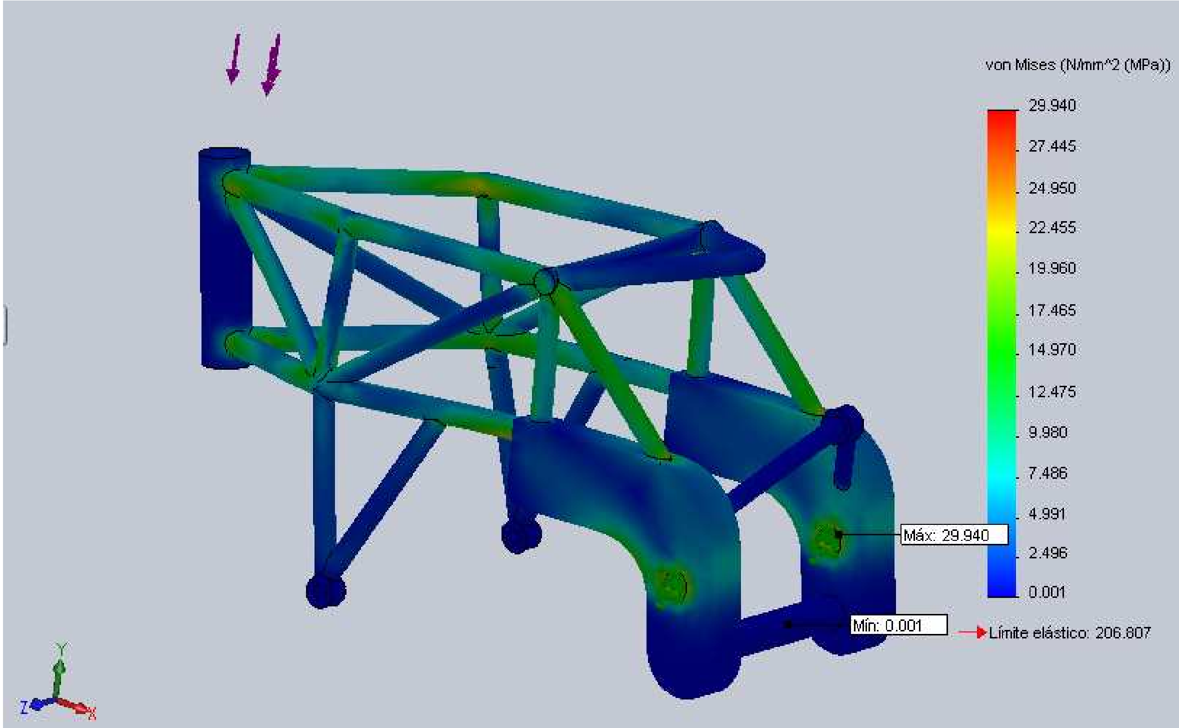

Figure B.4: Test 1, Prototype 2, AISI 304, Von Mises

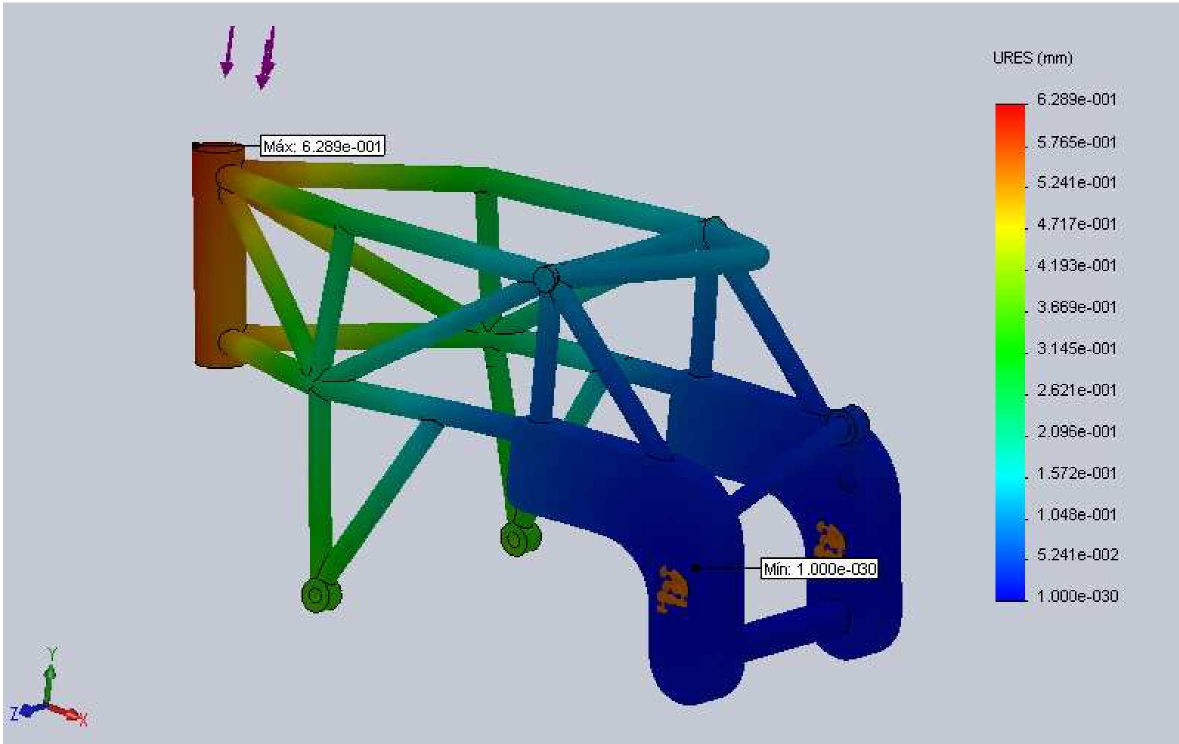

Figure B.5: Test 1, Prototype 2, AISI 304, Displacements

Prototype 3

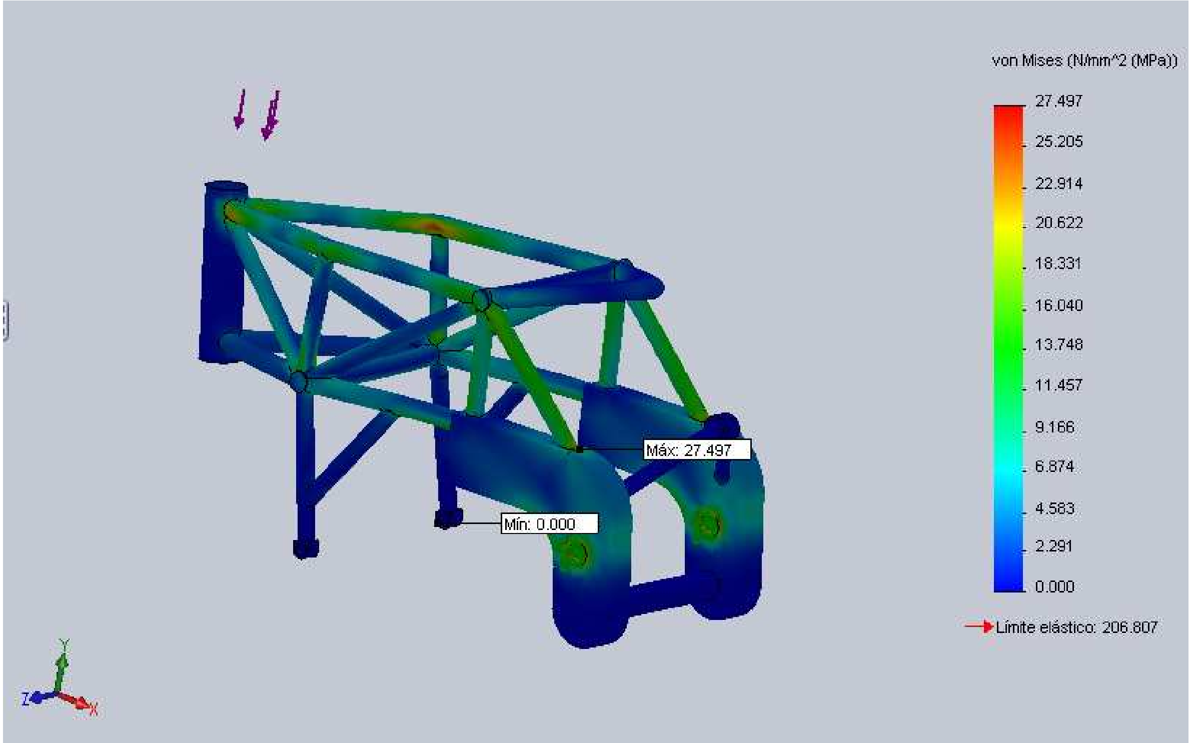

Figure B.6: Test 1, Prototype 3, AISI 304, Von Mises

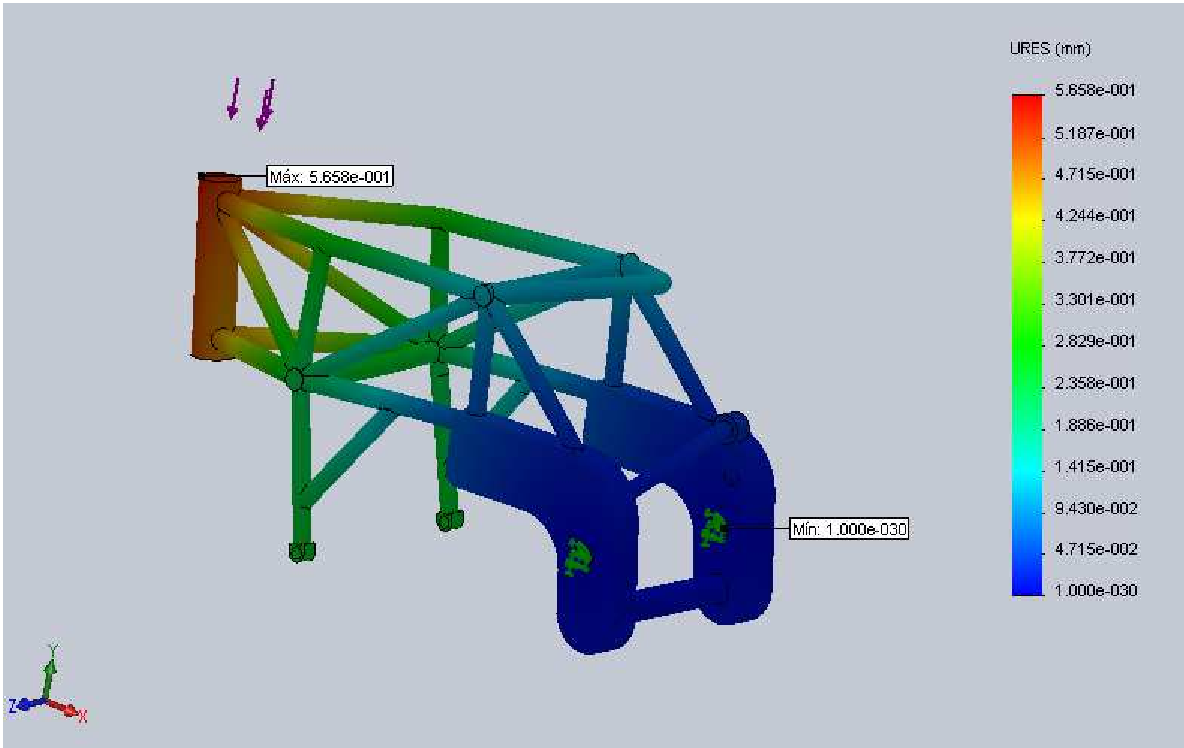

Figure B.7: Test 1, Prototype 3, AISI 304, Displacements

Like conclusion, it can see in this test that the prototype one and two are very similar. Also we can see that the efforts of the third prototype are minor.

TEST 2: FLEXION ON THE Z DIRECTION

For the second test I put a force on the axis of the direction transversely creating flexion, the value of this force is 4000 N. And the frame is fixed on the back of the chassis where is placed the swing arm.

Prototype 1

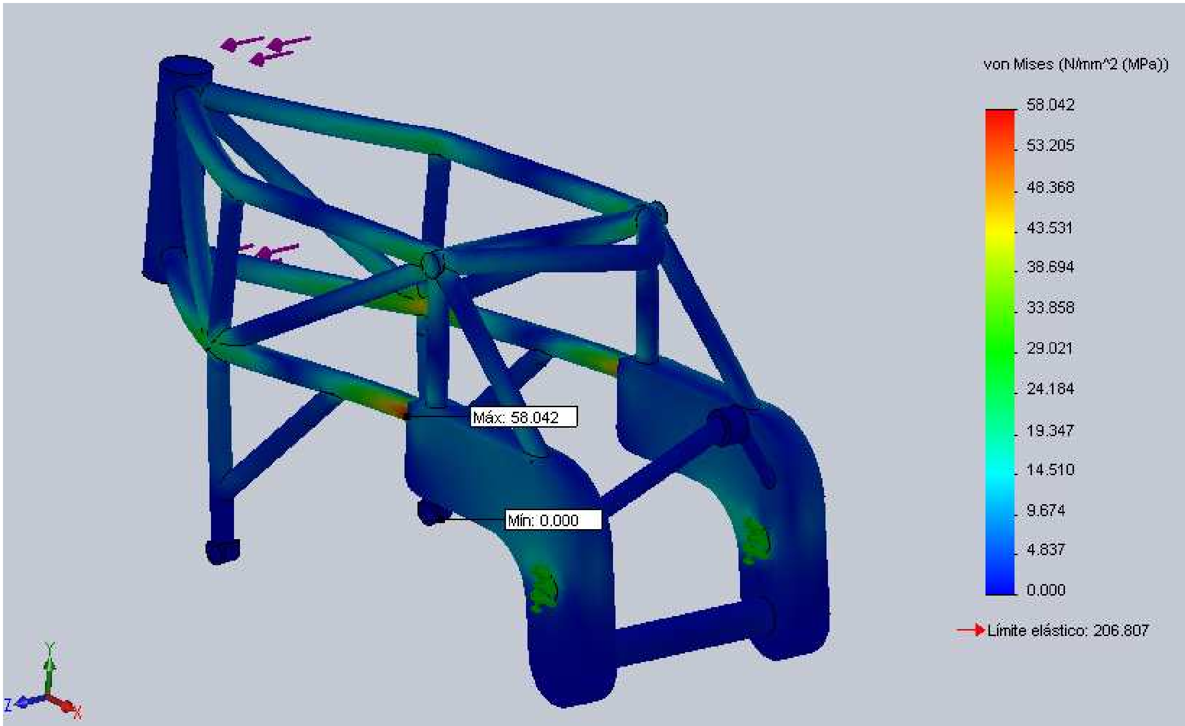

Figure B.8: Test 2, Prototype 1, AISI 304, Von Mises

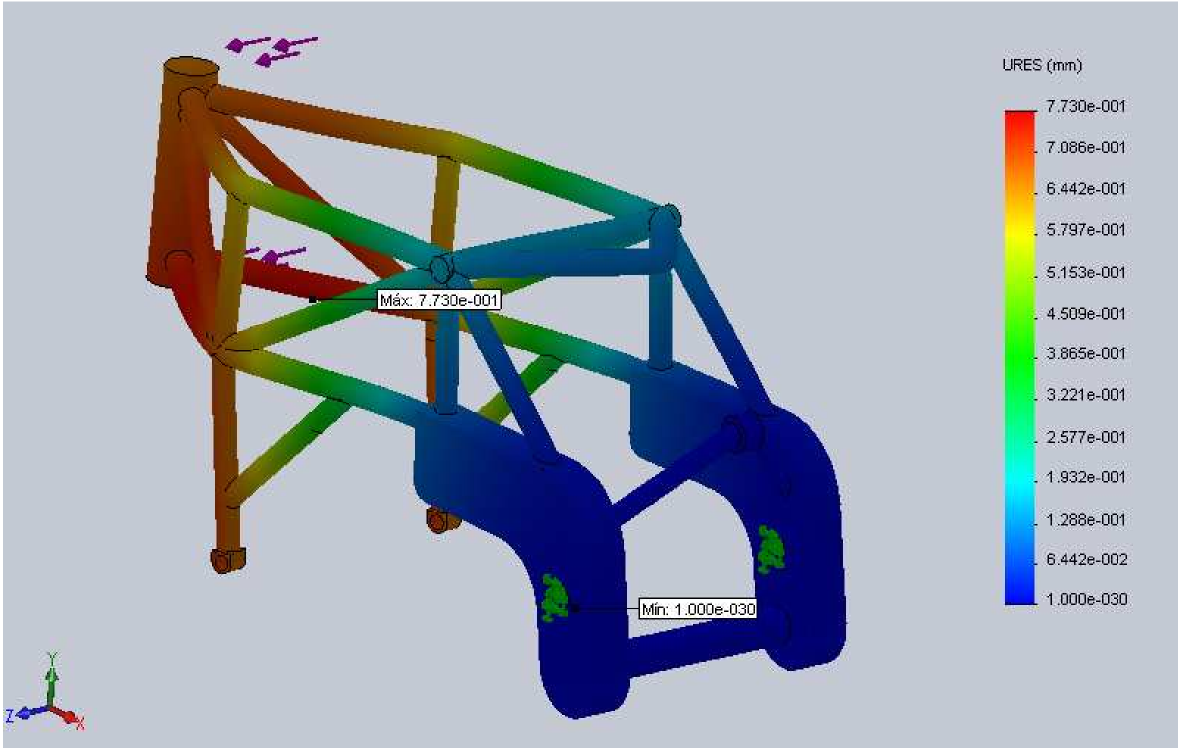

Figure B.9: Test 2, Prototype 1, AISI 304, Displacements

Prototype 2

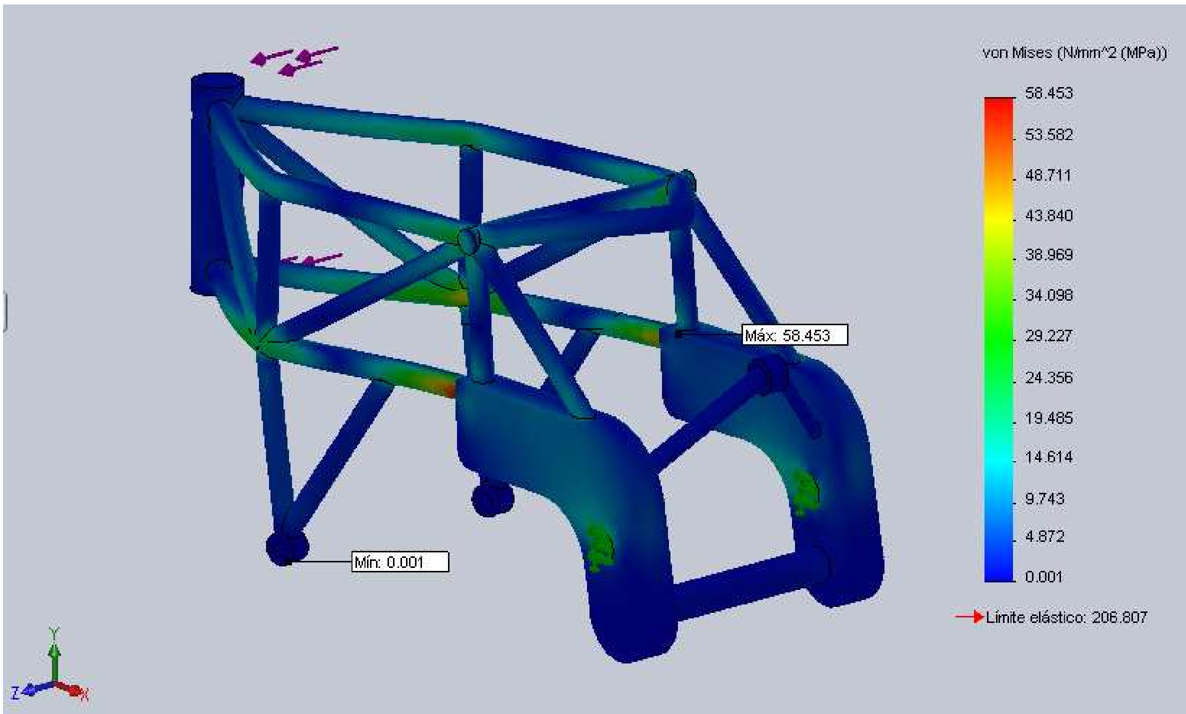

Figure B.10: Test 2, Prototype 2, AISI 304, Von Mises

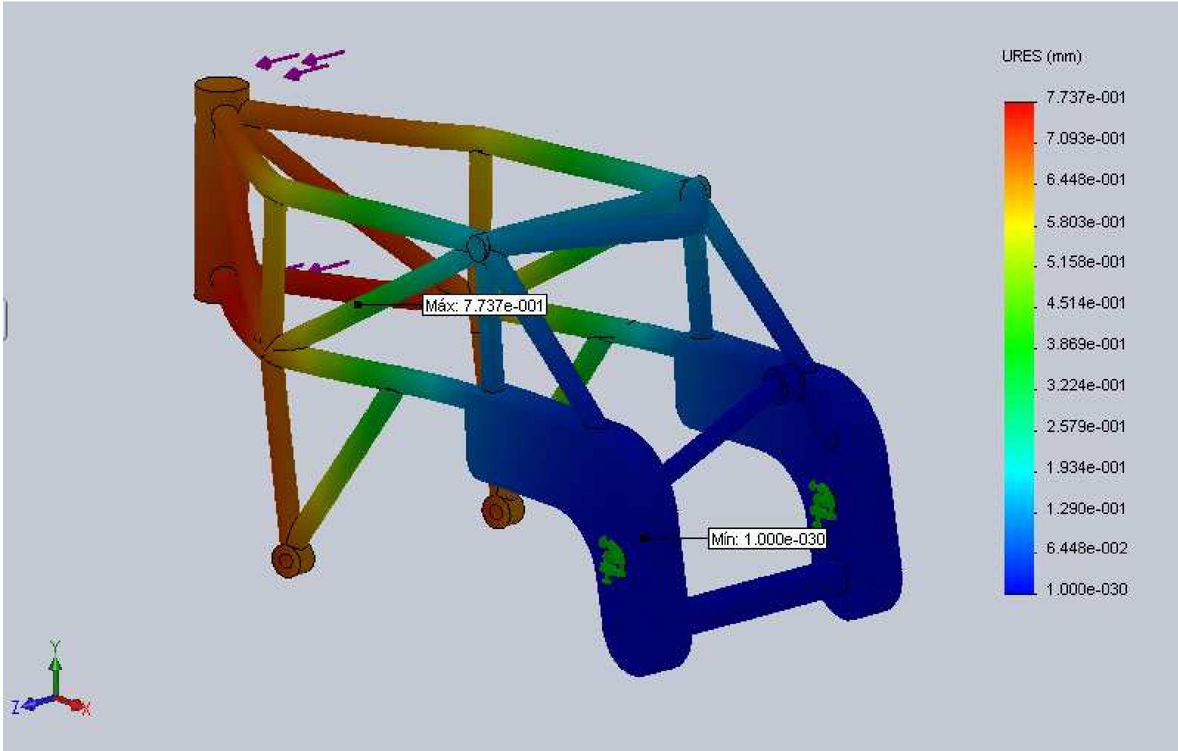

Figure B.11: Test 2, Prototype 2, AISI 304, Displacements

Prototype 3

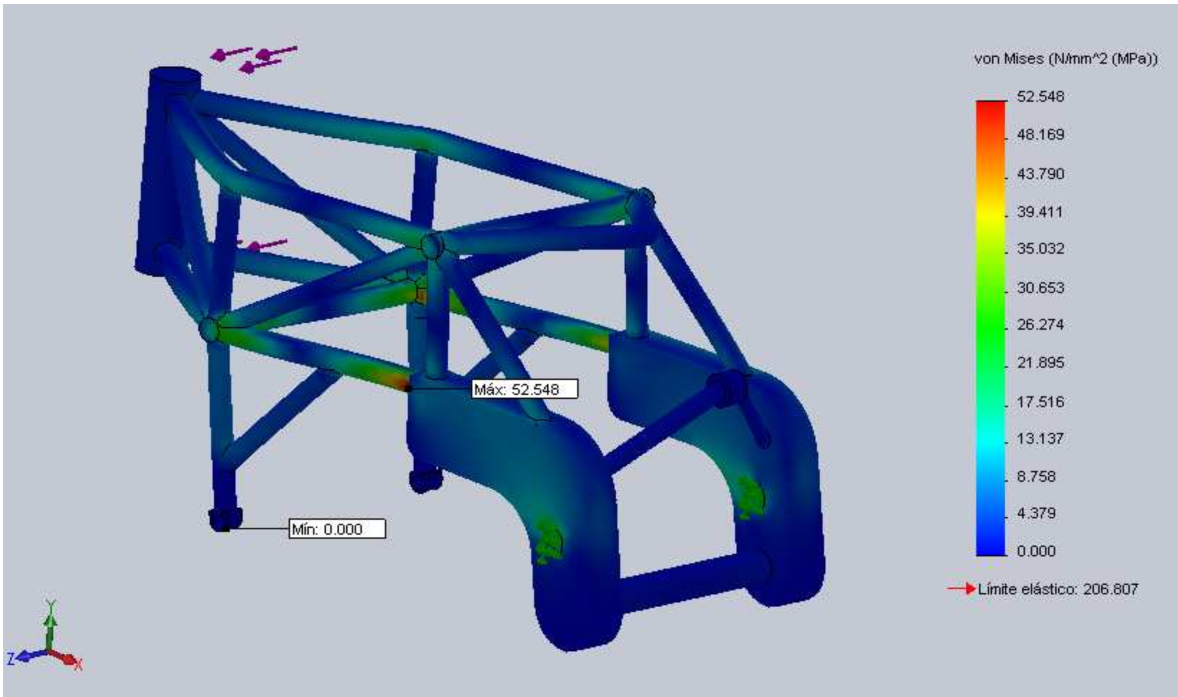

Figure B.12: Test 2, Prototype 3, AISI 304, Von Mises

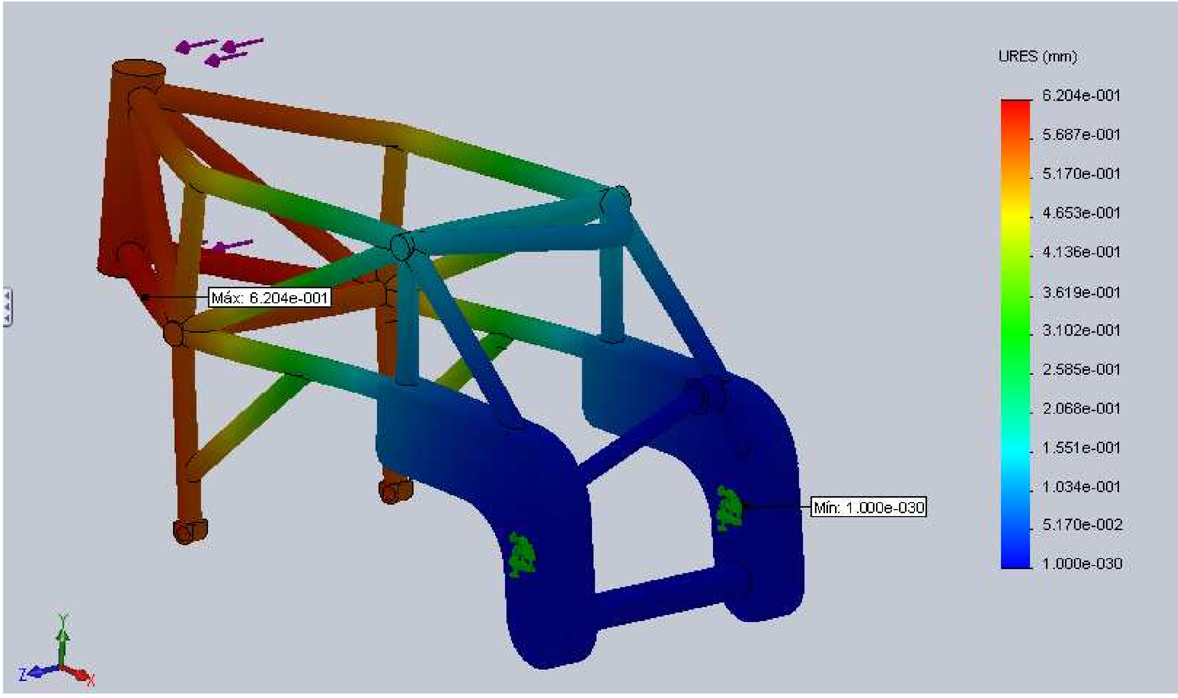

Figure B.13: Test 2, Prototype 3, AISI 304, Displacements

Like conclusion, it can see in this test again that the prototype one and two are very similar. Also we can see that the efforts of the third prototype are minor.

TEST 3: TORSION

For the third test I applied a moment on the X direction creating torsion, the value of this moment is 140 Nm. And the frame is fixed on the back where is placed the swing arm

Prototype 1

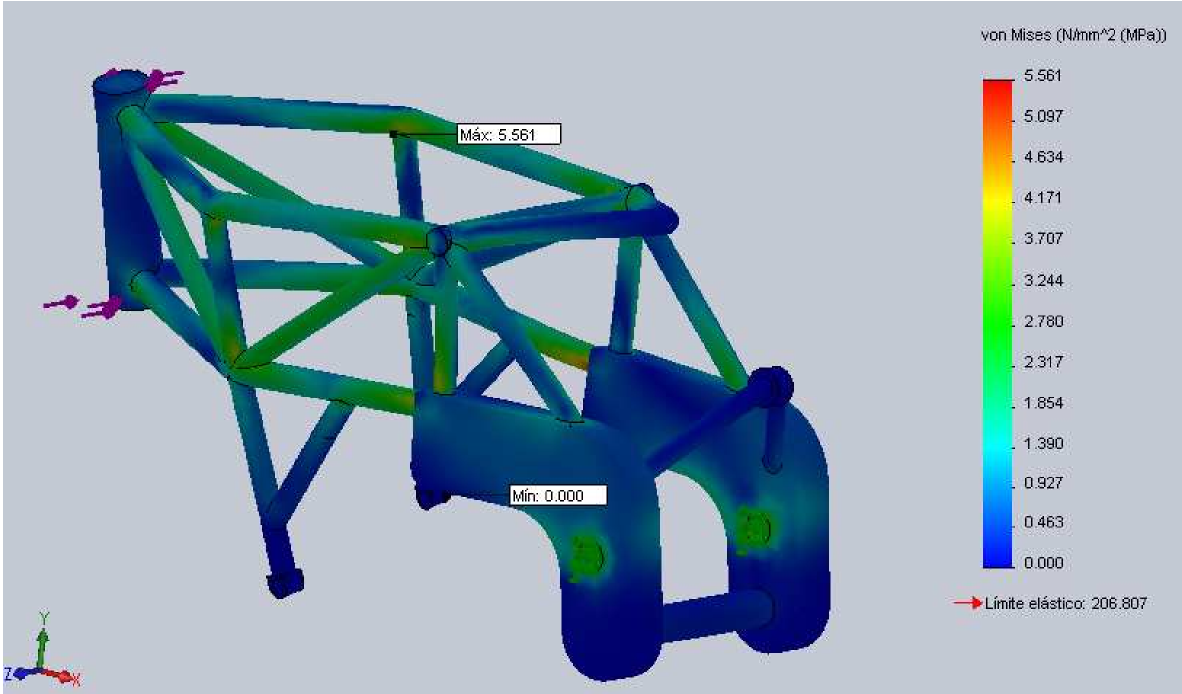

Figure B.14: Test 3, Prototype 1, AISI 304, Von Mises

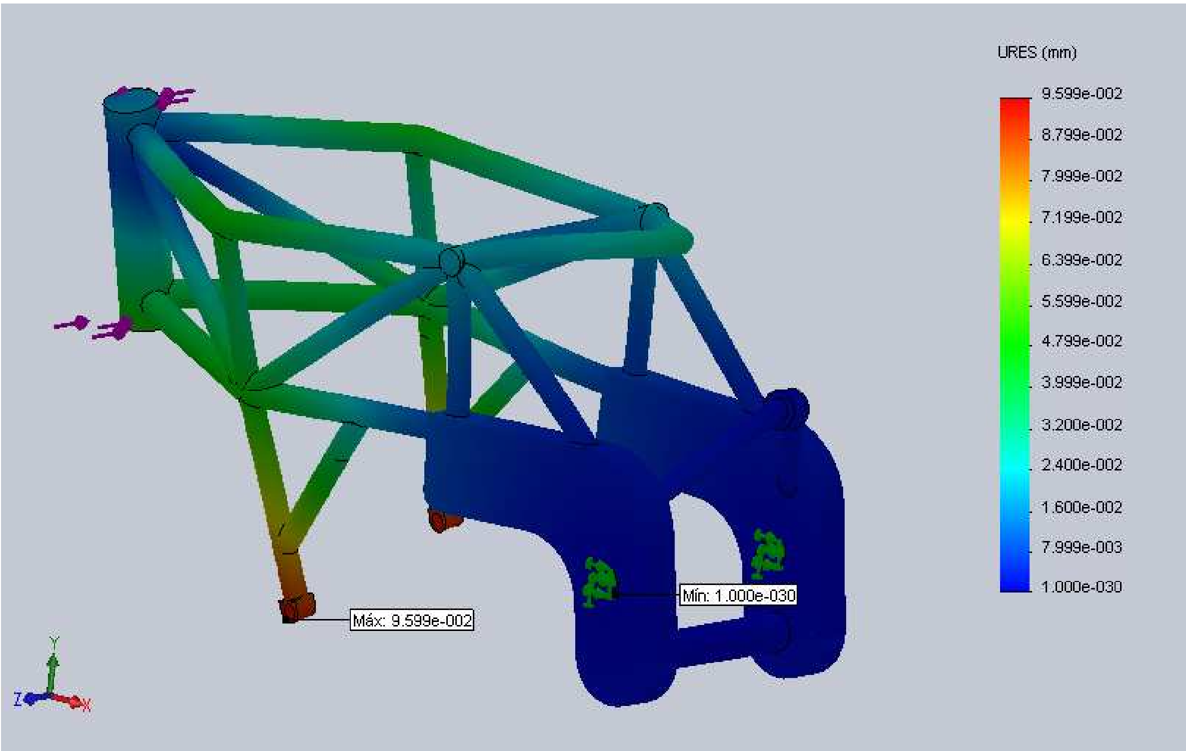

Figure B.15: Test 3, Prototype 1, AISI 304, Displacements

Prototype 2

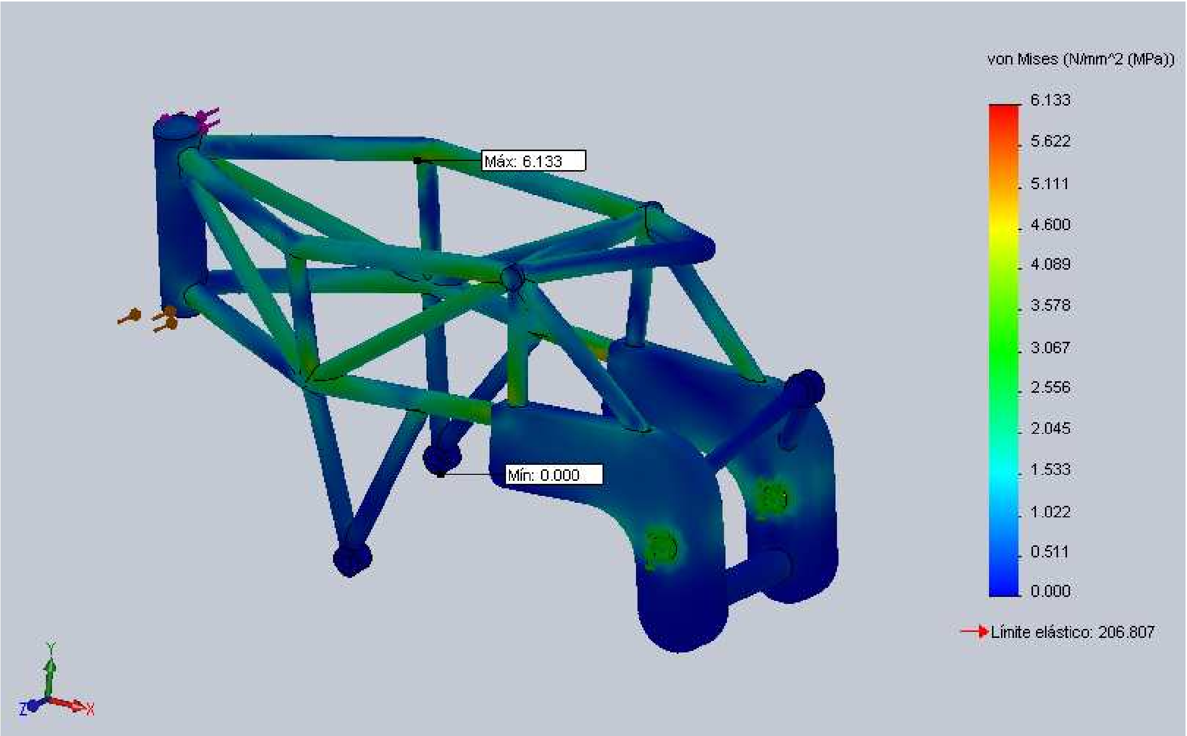

Figure B.16: Test 3, Prototype 2, AISI 304, Von Mises

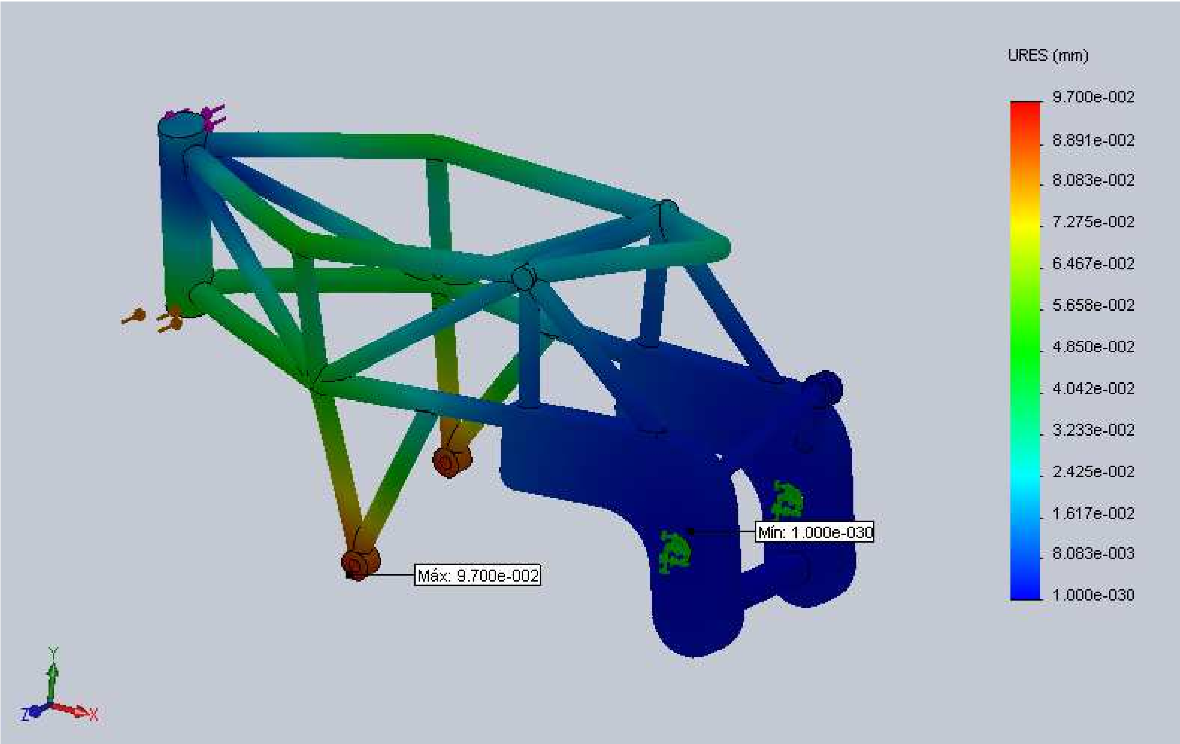

Figure B.17: Test 3, Prototype 2, AISI 304, Displacements

Prototype 3

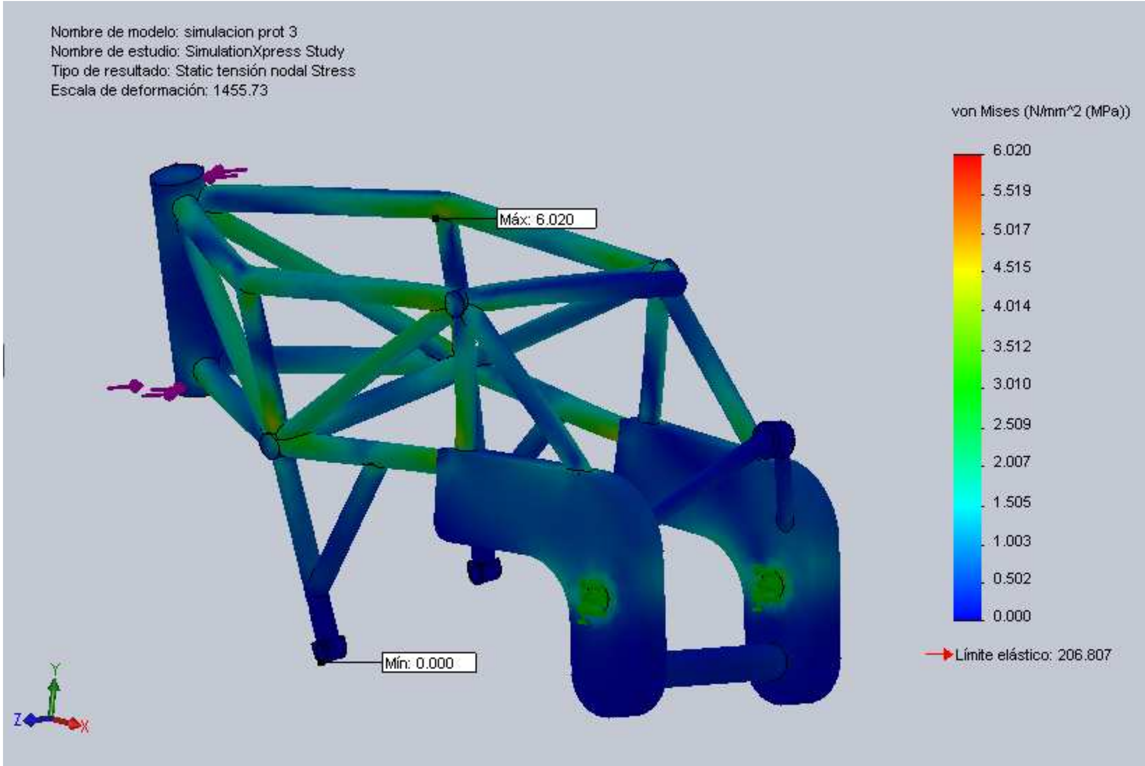

Figure B.18: Test 3, Prototype 3, AISI 304, Von Mises

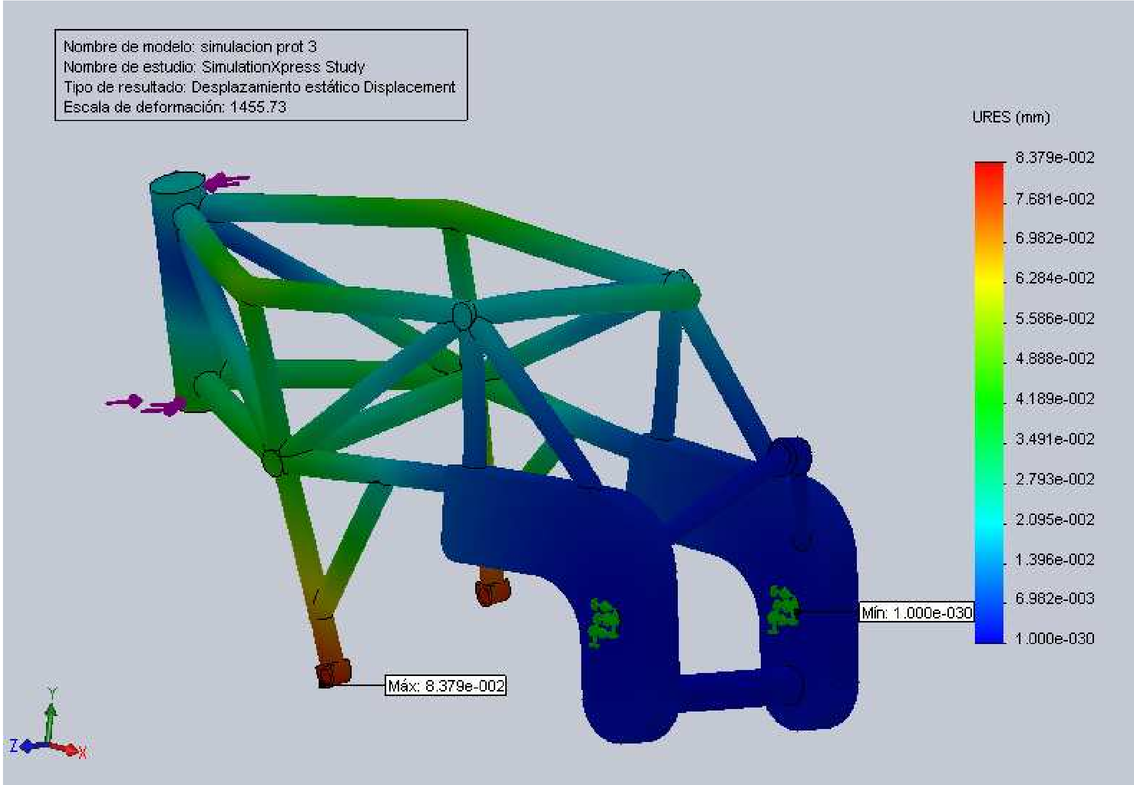

Figure B.19: Test 3, Prototype 3, AISI 304, Displacements

The prototype chosen is the third, the reasons are:

- The tenses that this prototype suffers are almost always minors. They are always minors except in the third test (torsion test) that the prototype one suffers minor tenses

- If it is taken a look on the results obtained for the displacements, it can see that they are clearly better the results of the third prototype. Therefore, the best prototype is the third.

As already said the best prototype is the third, the reason of that is the tube was added. This tube gives more stability to the chassis doing it stronger and resistant for the vibrations.

TEST ANALYSIS FOR MATERIAL CHOICE

Until now the simulation has been done with AISI 304 but it has been done also with other materials and then, chooses the best for this chassis.

Possible materials:

- AISI 304

- AISI 1035

- AISI 316

TEST 1 WITH AISI 1035

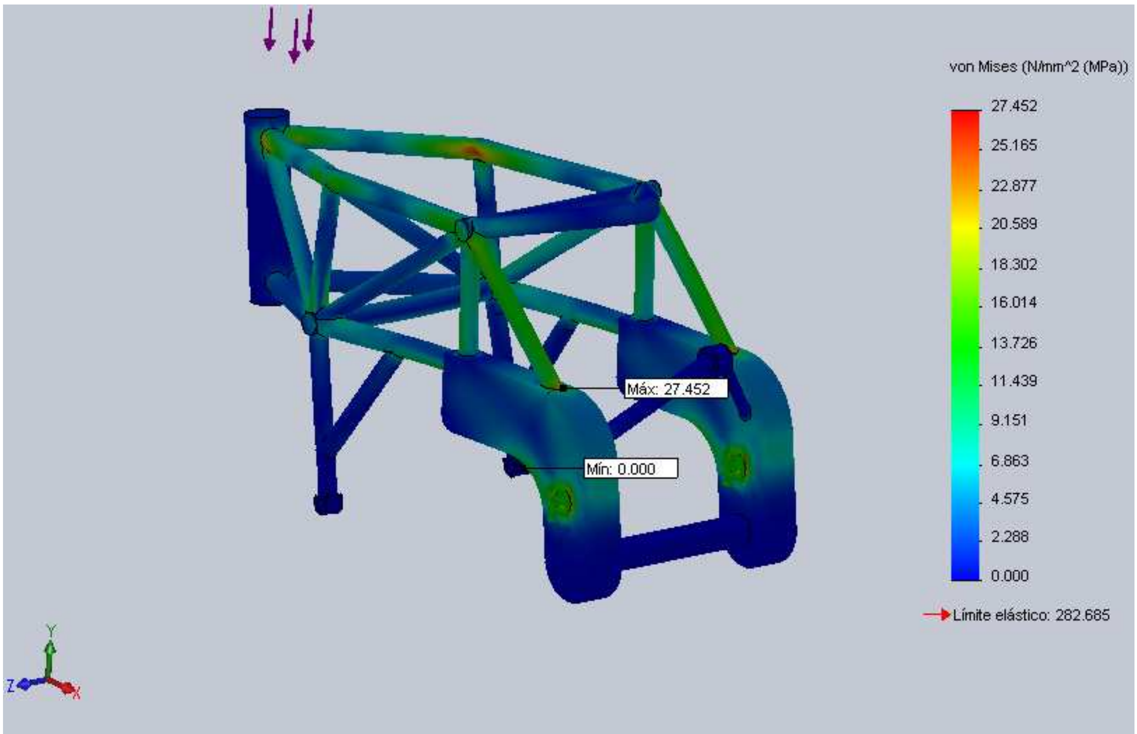

Figure B.20: Test 1, Prototype 3, AISI 1035, Von Mises

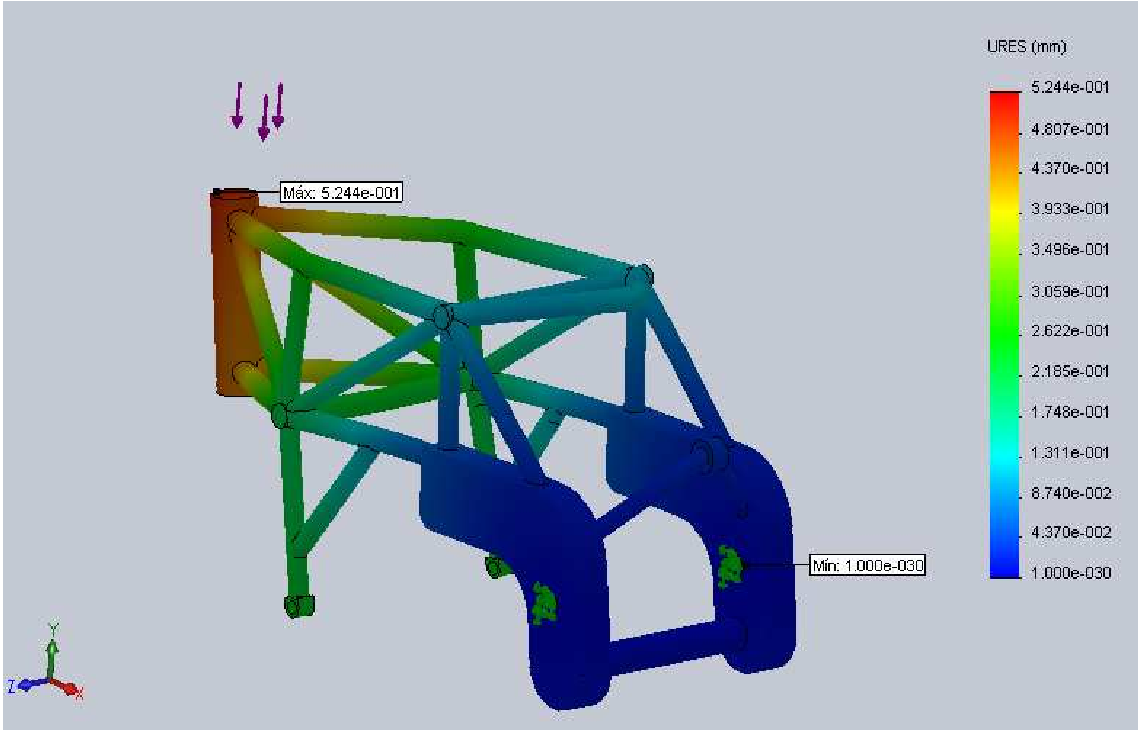

Figure B.21: Test 1, Prototype 3, AISI 1035, Displacements

TEST 1 WITH AISI 316

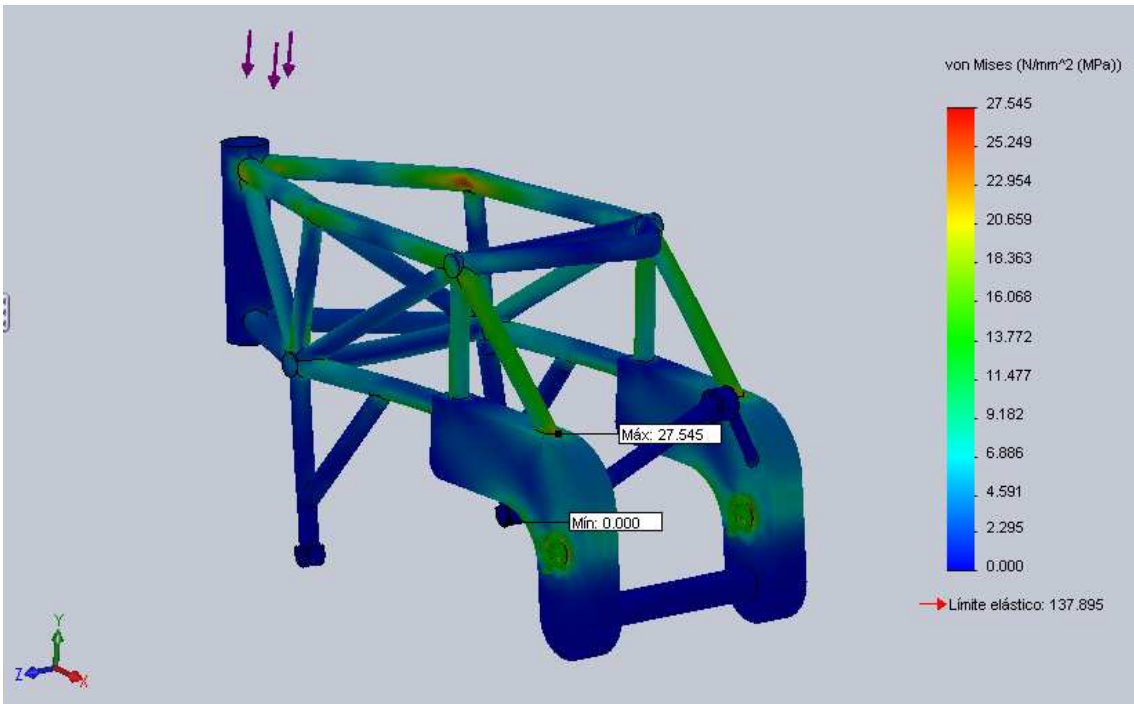

Figure B.22: Test 1, Prototype 3, AISI 316, Von Mise

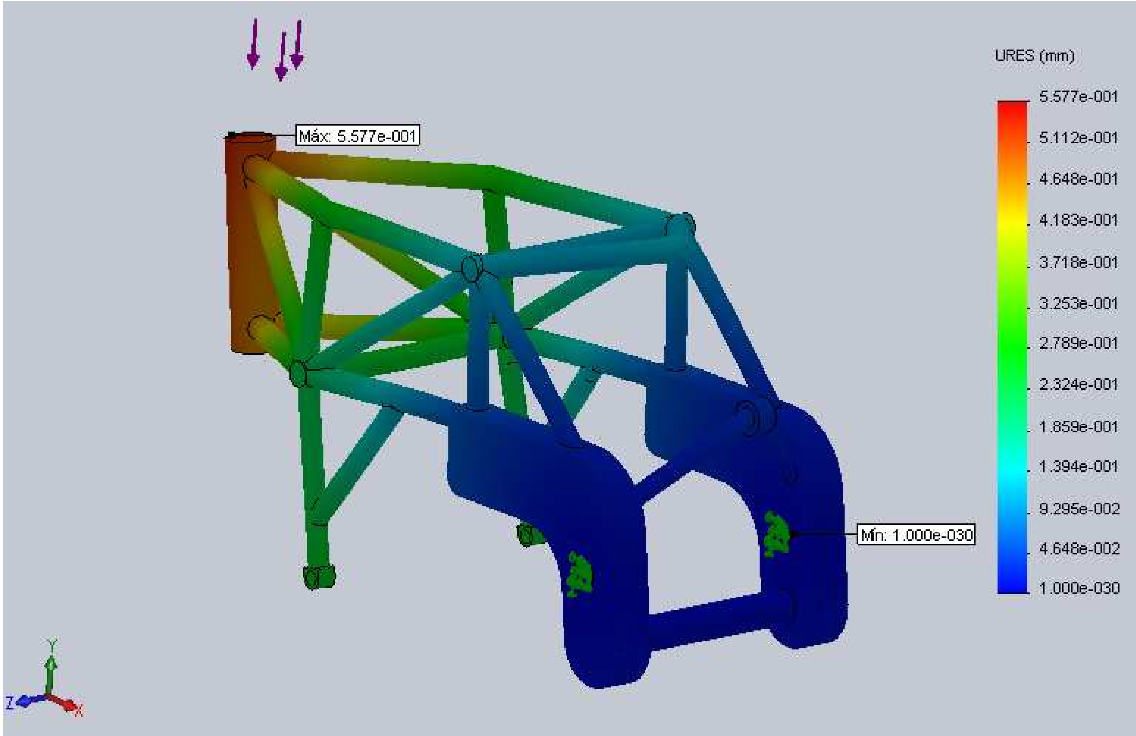

Figure B.23: Test 1, Prototype 3, AISI 316, Displacements

The highest tense can be found with AISI 316 then with AISI 304 and then with AISI 1035. The differences are very short.

The highest displacements can be found with AISI 316 then with AISI 304 and then with AISI 1035. The difference between AISI 316 and AISI 304 is short, a few higher between AISI 1035 and AISI 304.

TEST 2 WITH AISI 1035

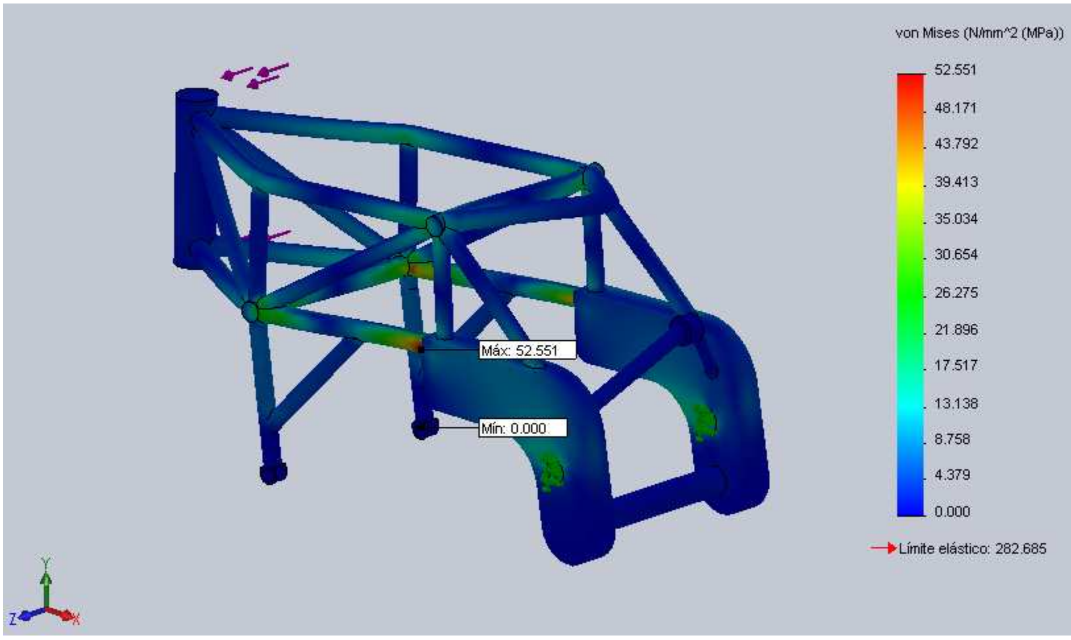

Figure B.24: Test 2, Prototype 3, AISI 1035, Von Mises

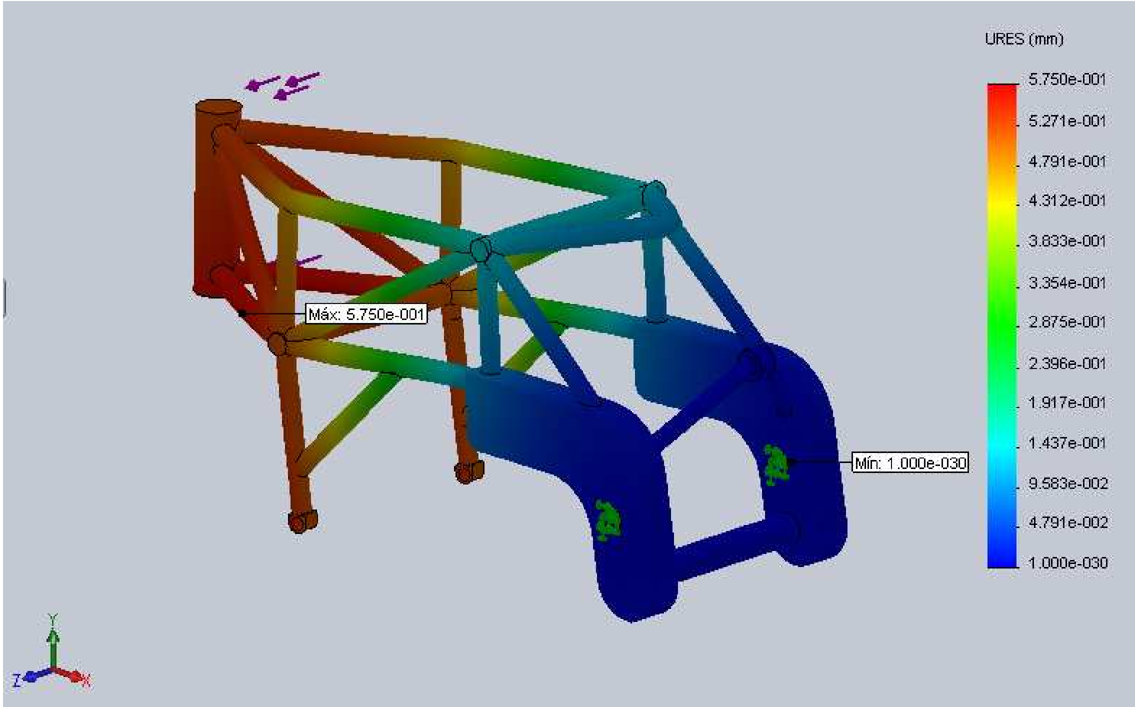

Figure B.25: Test 2, Prototype 3, AISI 1035, Displacements

TEST 2 WITH AISI 316

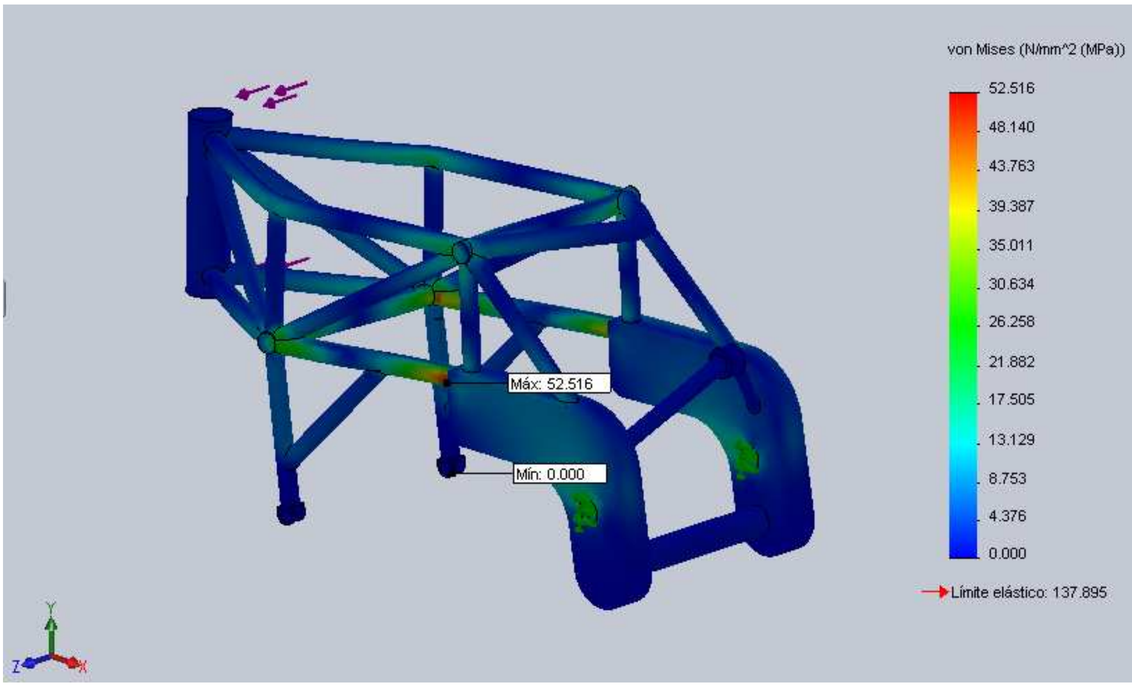

Figure B.26: Test 2, Prototype 3, AISI 316, Von Mises

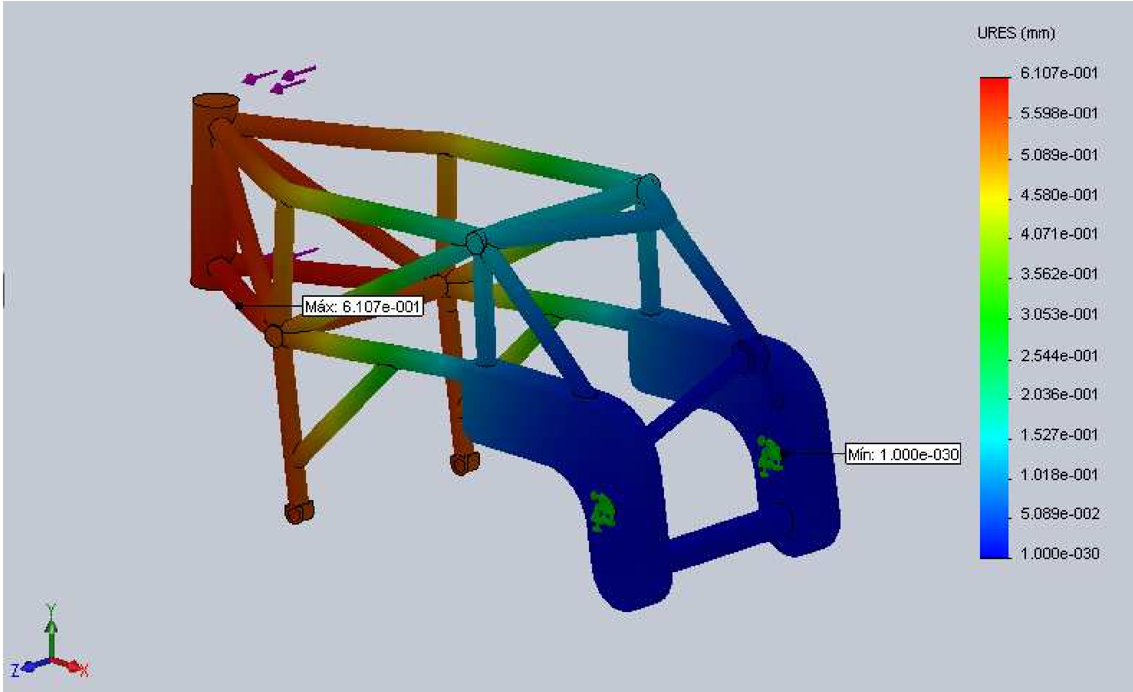

Figure B.27: Test 2, Prototype 3, AISI 316, Displacements

The highest tenses can be found with AISI 1035 then with AISI 304 and then with AISI 316. They are really similar tenses.

The highest displacements can be found with AISI 304 then with AISI316 and then with AISI 1035. The difference between AISI 316 and AISI 304 is short, a few higher between AISI 1035 and AISI 316.

TEST 3 WITH AISI 1035

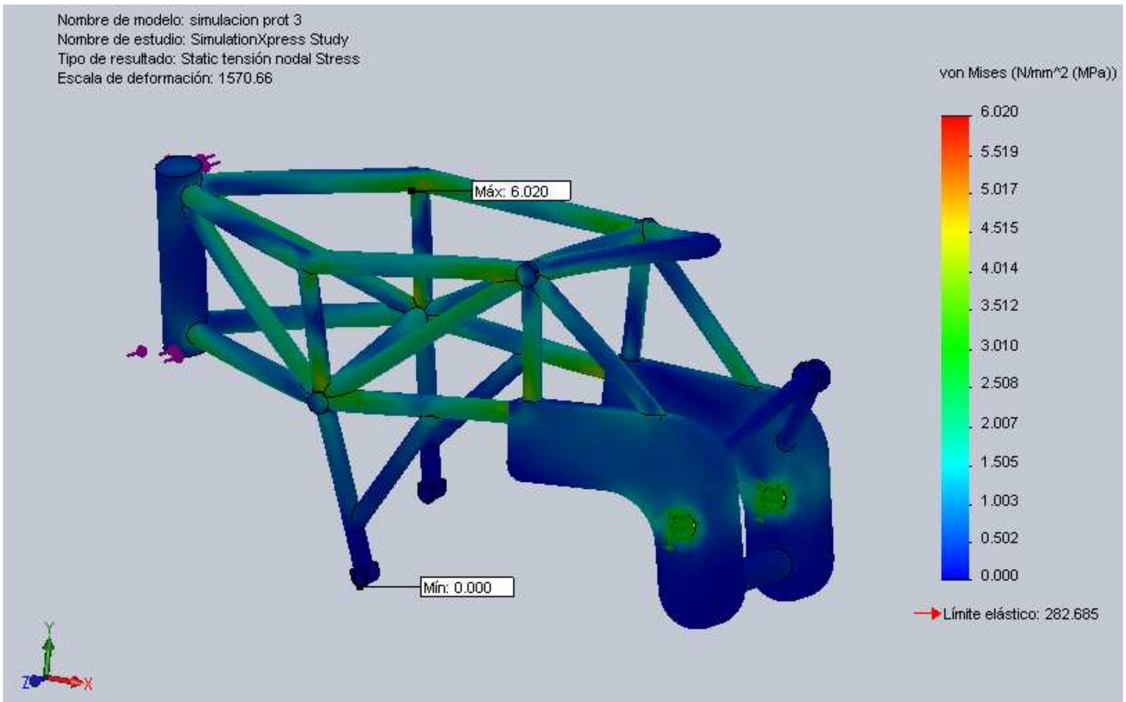

Figure B.28: Test 3, Prototype 3, AISI 1035, Von Mises

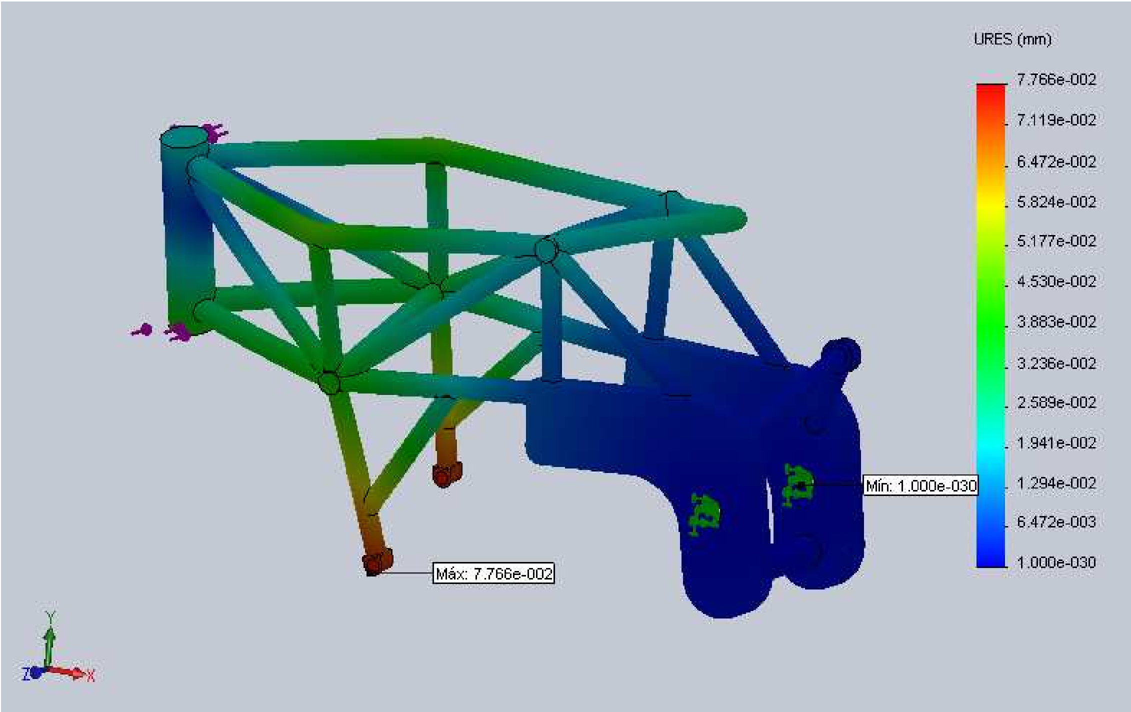

Figure B.29: Test 3, Prototype 3, AISI 1035, Displacements

TEST 3 WITH AISI 316

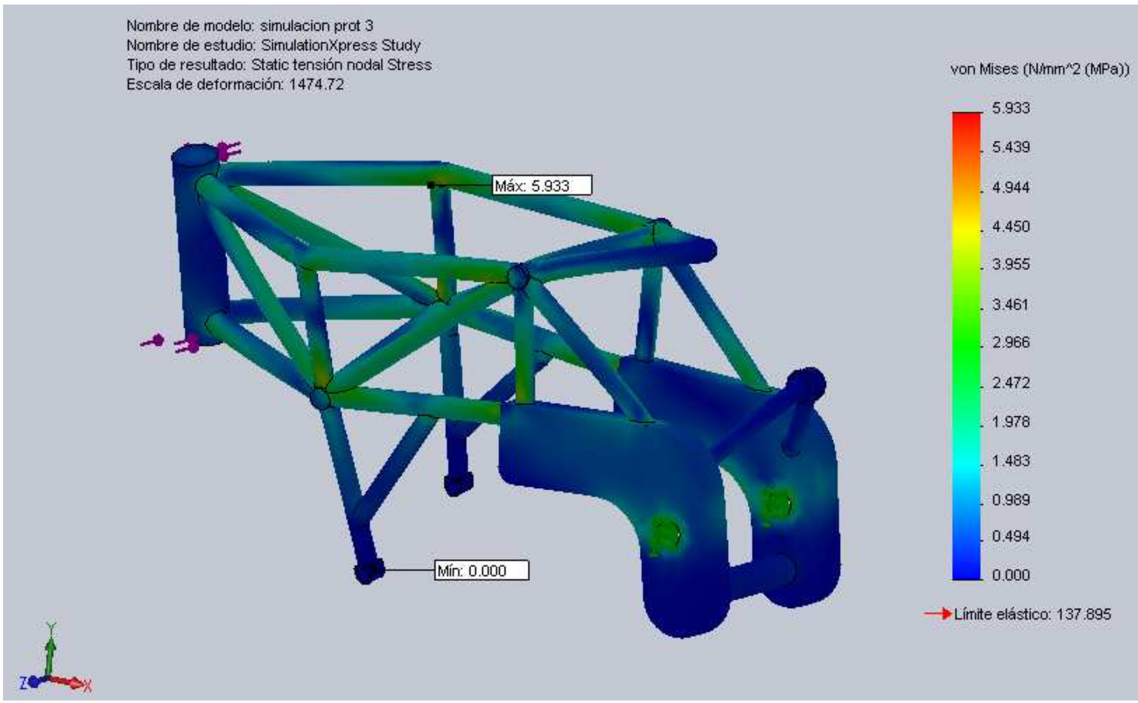

Figure B.30: Test 3, Prototype 3, AISI 316, Von Mises

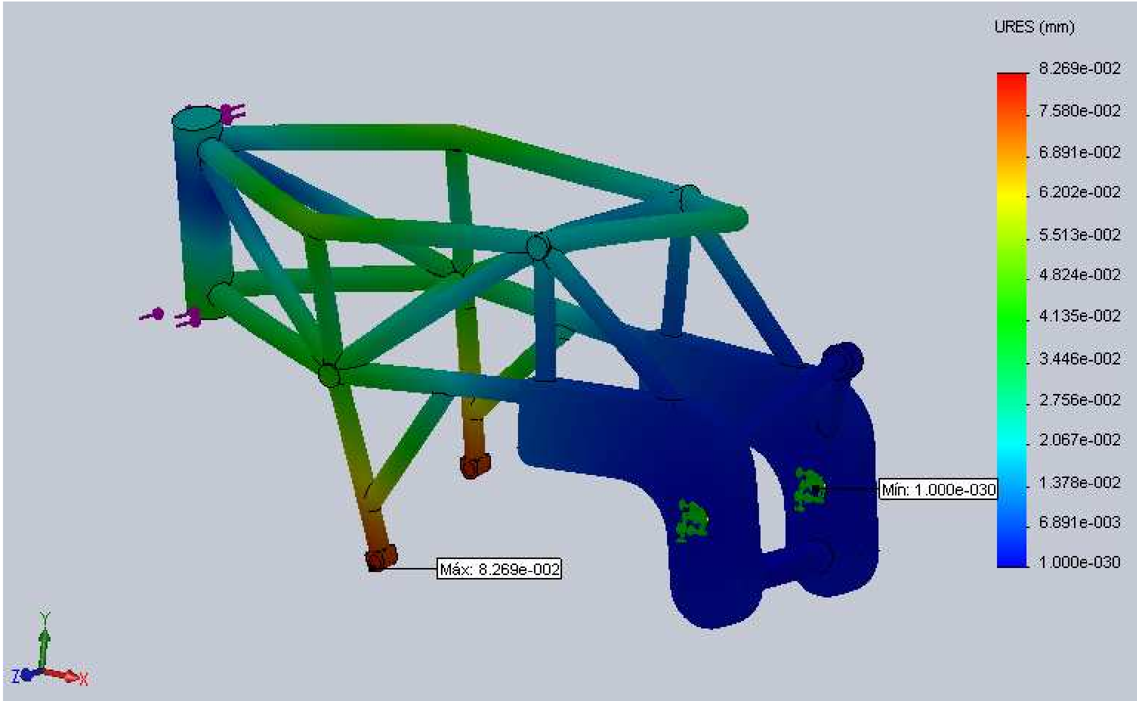

Figure B.31: Test 3, Prototype 3, AISI 316, Displacements

The highest tenses can be found with AISI 1035 and with AISI 304 and then with AISI 316. There is no difference between AISI 1035 and AISI 304. And it is really short the difference between AISI 316 and those.

The highest displacements can be found with AISI 304 then with AISI 316 and then with AISI 1035. The differences are very short.

The material chosen is AISI 304. It has been chosen this material because taking into account the results, these materials are very similar. So, it has been chosen AISI 304 because is often used for this kind of structure.

STATIC ANALYSIS

It was taken the force that it was calculated in static study (**F**=1864 N). This force it was applied dividing equally on four points different of the chassis and the values depend with the distance it has to the center of gravity.

These forces were calculated and they are the followings.

Fa => 1864 x 45.23 = Fb x 355.9 => Fa = 236.89 N

Fb => 1864 = 236.89 + Fb => Fb = 1627.11 N

Then these forces were divided by two because the distance to the center of gravity is the same and here is the result:

- **Fa’** = **Fa’’** = 813.55 N
- **Fb’** = **Fb’’ =** 118.445 N

It was coupled a fixed clamping in the front and clamping roll in the back

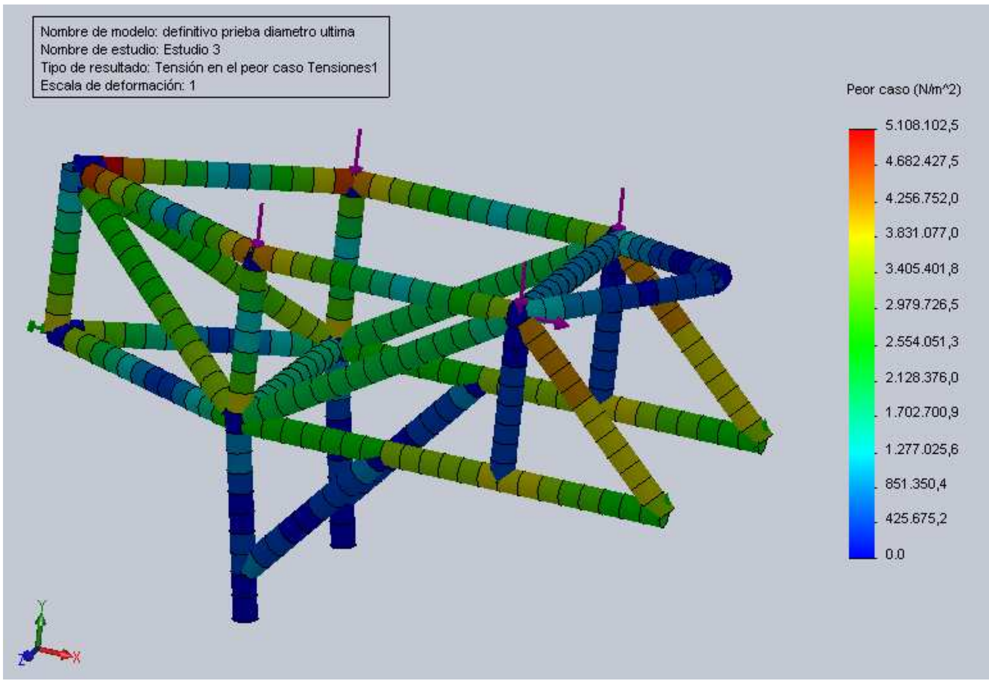

Figure B.32: Static analysis, Von Mises

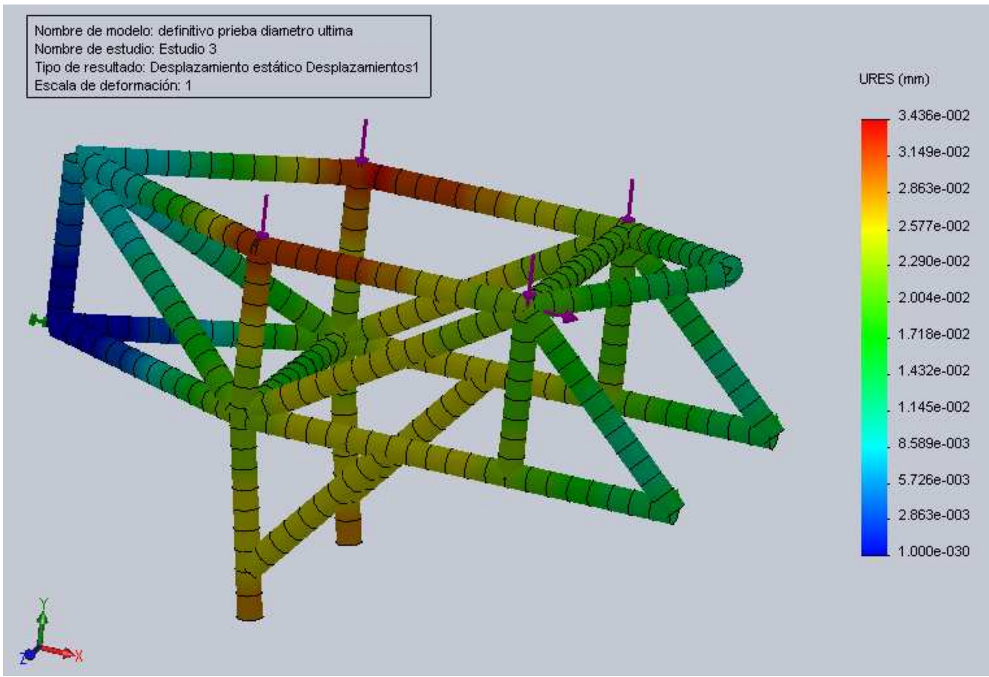

Figure B.33: Static analysis, Displacements

ANALYSIS IN MAX ACCELERATION

The force apply on the chassis was taken from study in max acceleration. This force create a moment respect center of gravity that is M=1314.118 Nm

This moment was applied on the chassis like a force. So it was applied in the top of the axis of the direction. For that, I needed know the distance from this point to the center of gravity.

D = 600 mm + 290 mm – 650 mm = 240 mm

Therefore, **F** = 5475.5 N

- 818.78 N on axis Y
- 5413.93 N on axis X

It was coupled a fixed clamping in the back and clamping roll in the front

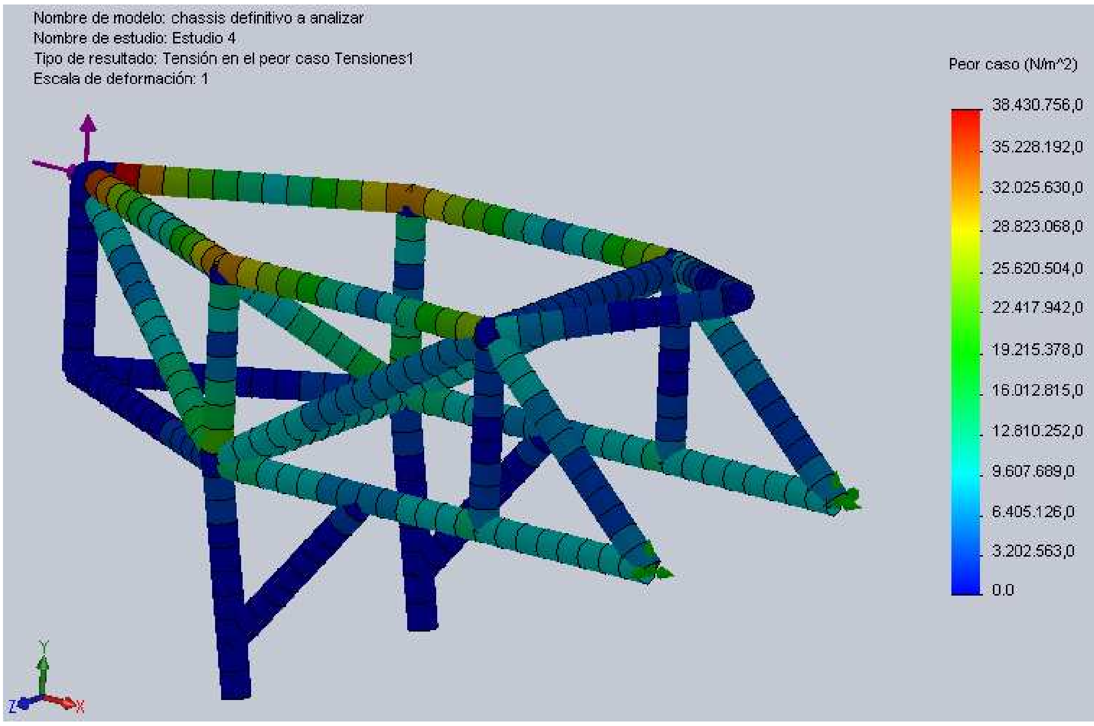

Figure B.34: in max acceleration, Von Mises

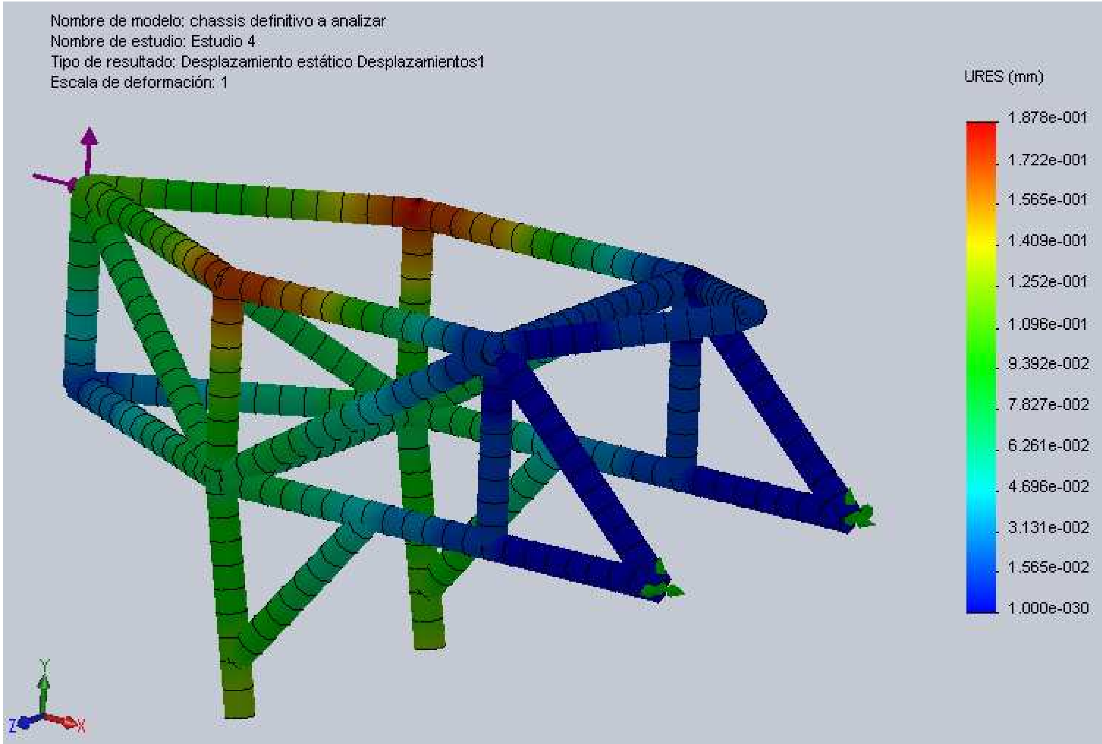

Figure B.35: in max acceleration, Displacements

ANALYSIS IN MAX BRAKING WITH FRON WHEEL

The force apply on the chassis was taken from study in max braking with the front wheel. This force create a moment respect center of gravity that is M=1314.118 Nm

This moment was applied on the chassis like a force. So it was applied in two points on the back of the motorbike. For that, I needed know the distance from this point to the center of gravity.

D = 600 mm + 240 mm **–** 101.04 mm = 138.96 mm

Therefore, F = 9456.81 N

This force is applied in two points. The distance is the same so the force is divided by two. **F'**= **F''**= 4728.4 N

- -707.065 N on axis Y
- -4675.25 N on axis X

It was coupled a fixed clamping in the front and roll clamping in the back.

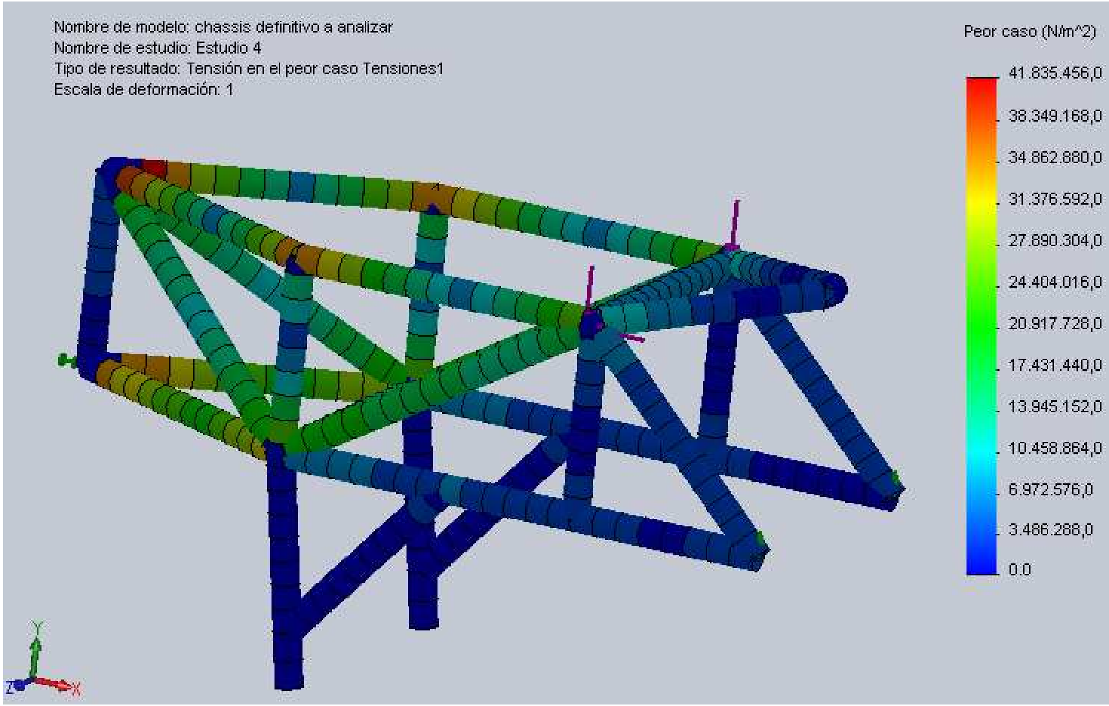

Figure B.36: in max braking with front wheel, Von Mises

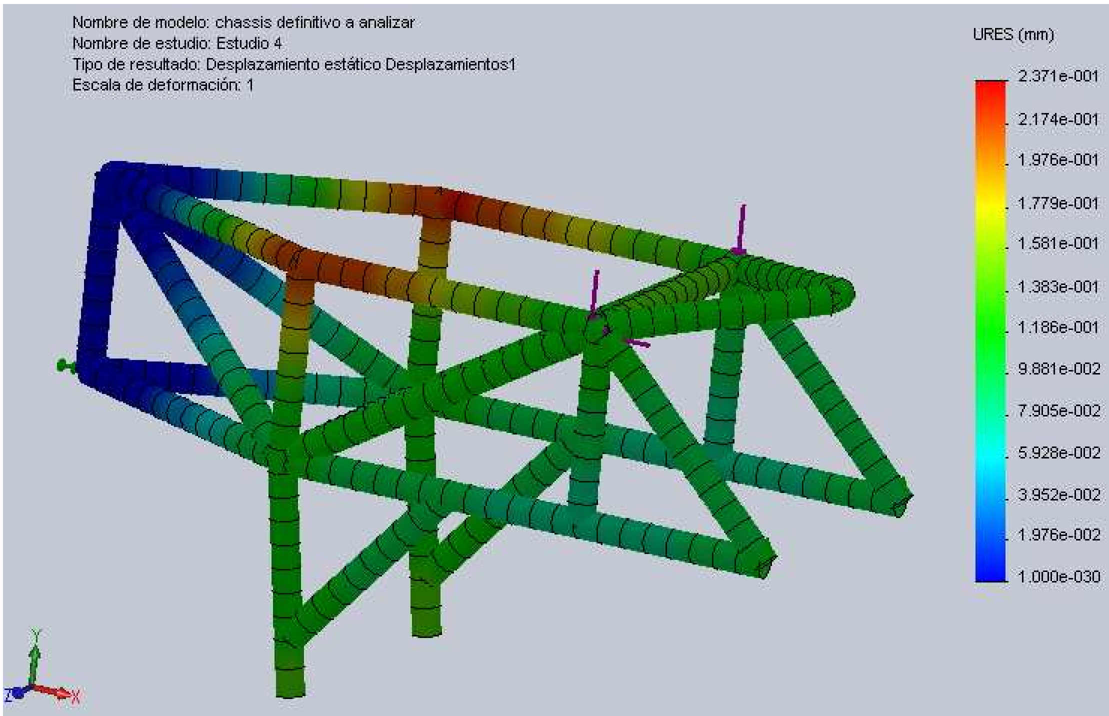

Figure B.37: in max braking with front wheel, Displacements

ANALYSIS IN MAX BRAKING WITH REAR WHEEL

The force apply on the chassis was taken from study in max braking with the front wheel. This force create a moment respect center of gravity that is M=413.27 Nm

It followed the same procedure. Therefore, F = 2974.02 N => **F'**= **F''**= 1487.01 N

- -222.36 N on axis Y and -1470.3 N on axis X

It was coupled a fixed clamping in the front and roll clamping in the back.

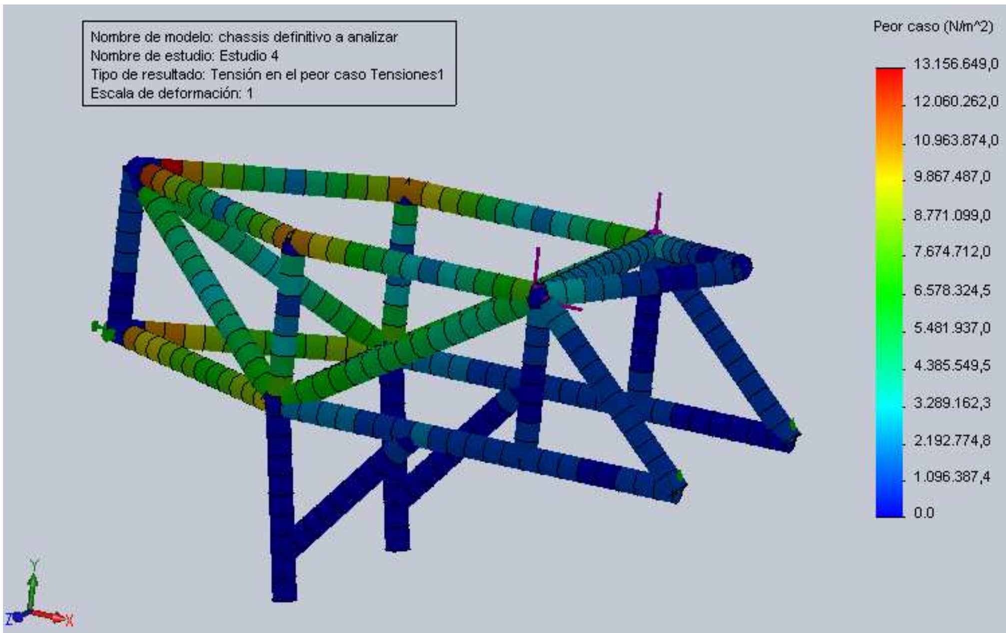

Figure B.38: in max braking with rear wheel, Von Mises

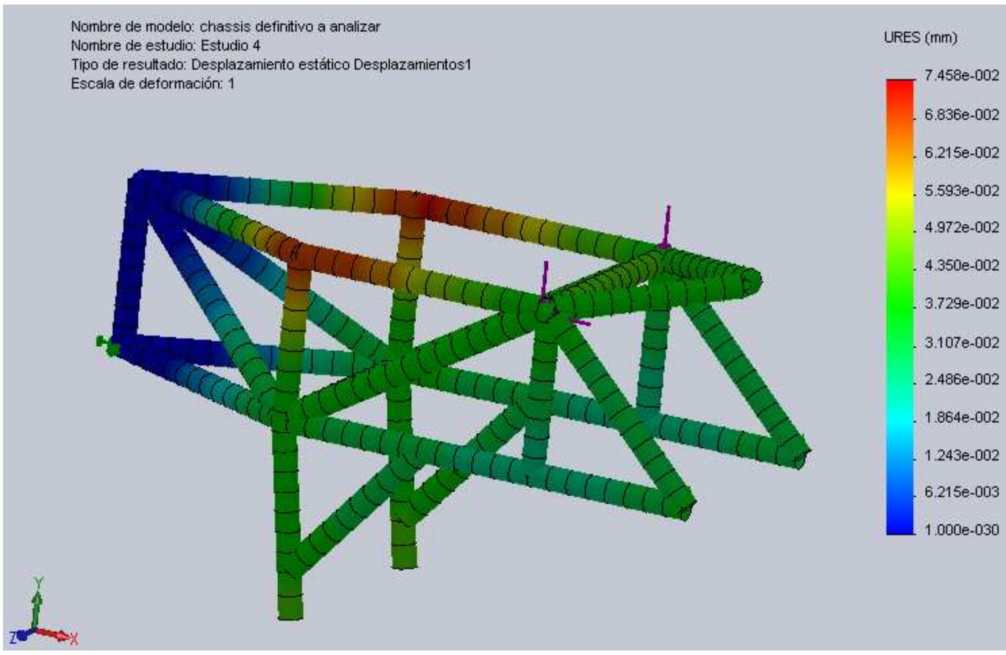

Figure B.39: in max braking with rear wheel, Displacements

ANALYSIS IN CORNERING

The force apply on the chassis was taken from study in max braking with the front wheel. This force create a moment respect center of gravity that is M=890.84 Nm

This moment was applied on the chassis like a force. So it was applied dividing equally in four points above the chassis. For that, I needed know the distance from these points to the center of gravity.

The value depends if it is in front or in back and also the direction depends if it is on the right or left. The distance between right and left is 350 mm and the center of gravity is in the middle of this.

F= 890.84 Nm/0.175 mm = 5090.51 N => Fr = Fl = 2545.26 N

Fr’ => 2545.26 x 45.23 = Fr’ x 355.9 => **Fr’** = 323.47 N

Fr’’ => 2545.26 x 310.67 = Fr’’ x 355.9 => **Fr’’** = 2221.79 N

Fl’ = -323.47 N and **Fl’’** = -2221.79 N

The chassis was fixed in the back and in the front not allowing the movement but it allows the rotation

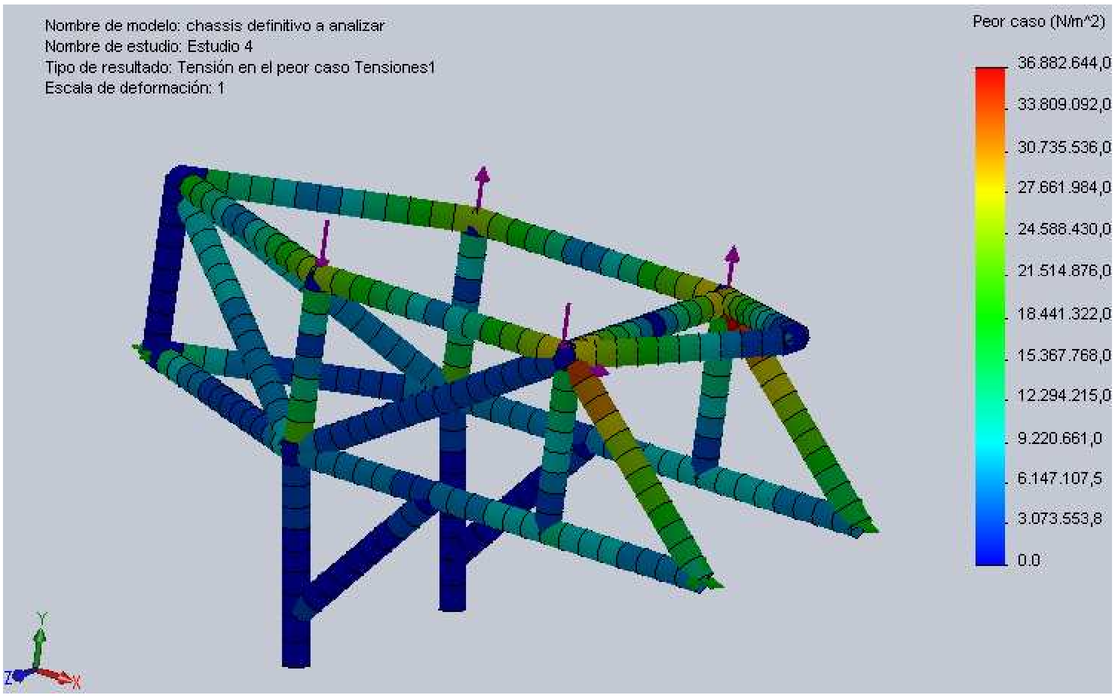

Figure B.40: in cornering, Von Mises

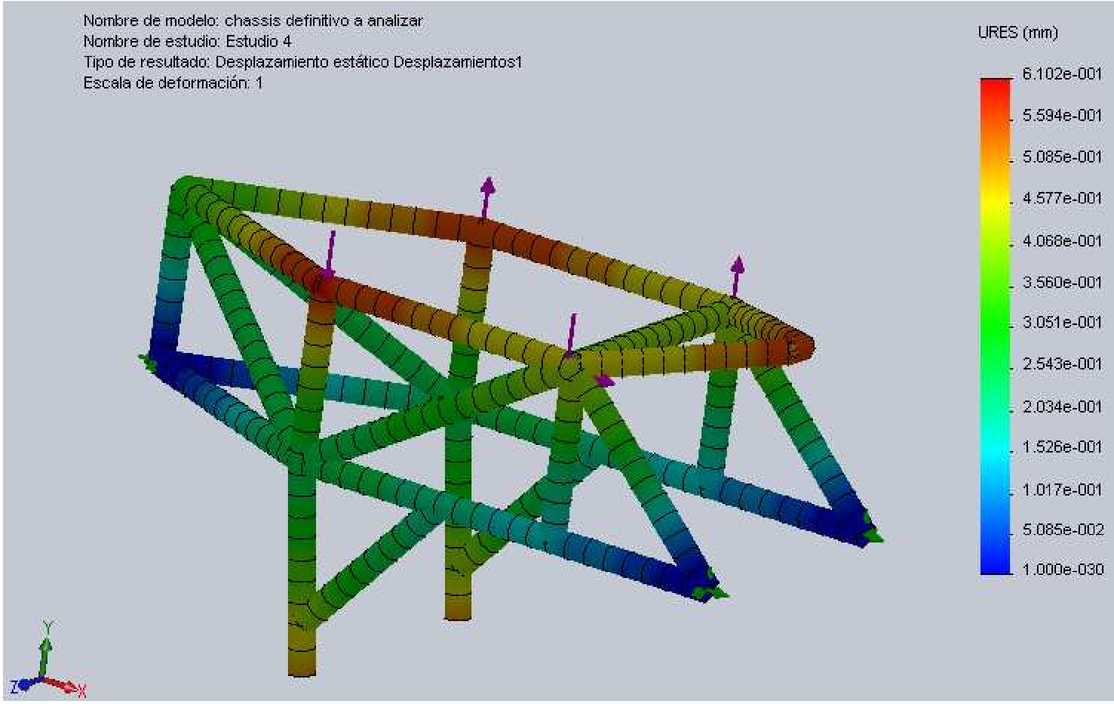

Figure B.41: in cornering, Displacements

APPENDIX C: TIMETABLE

APPENDIX C: PROJECT TIMETABLE.

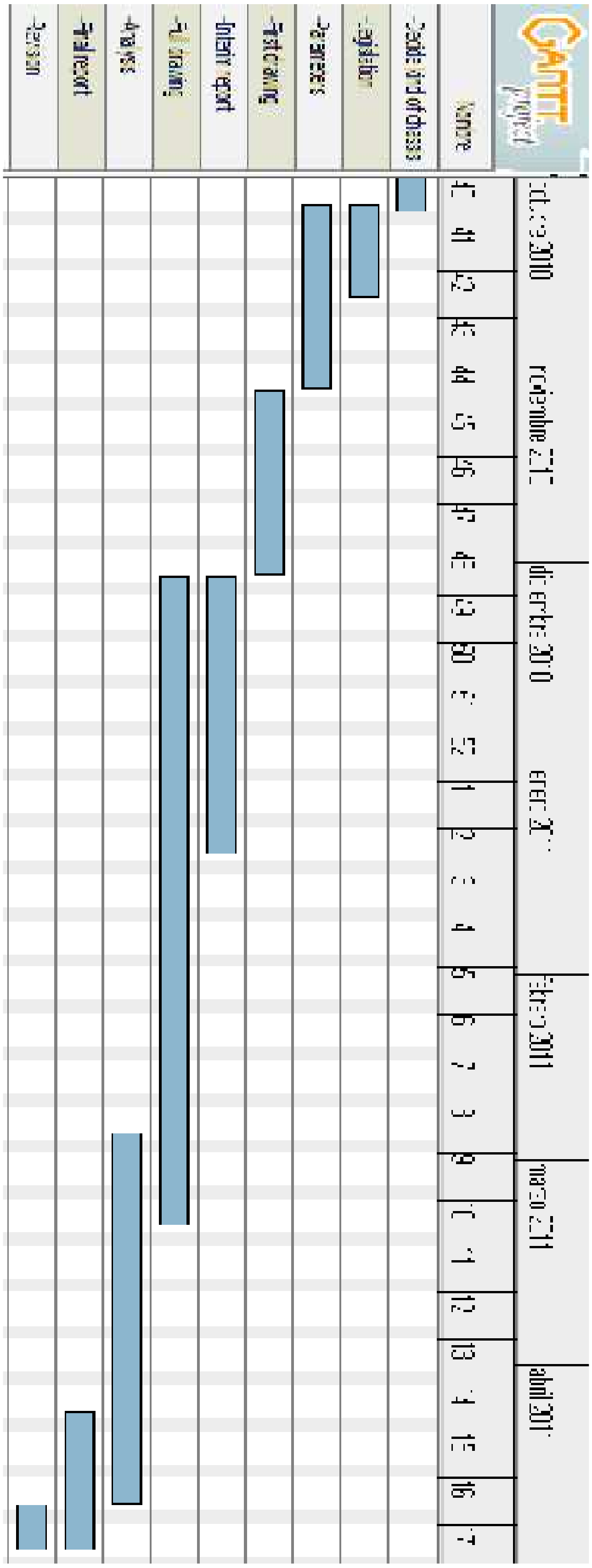

Figure C.1: Timetable