Selecting a suspension system for a mini-baja vehicle

Selección de un sistema de suspensión para un vehículo de tipo mini-baja

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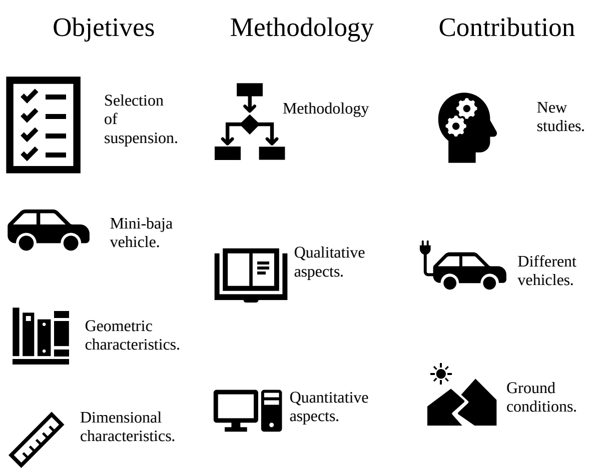
Abstract

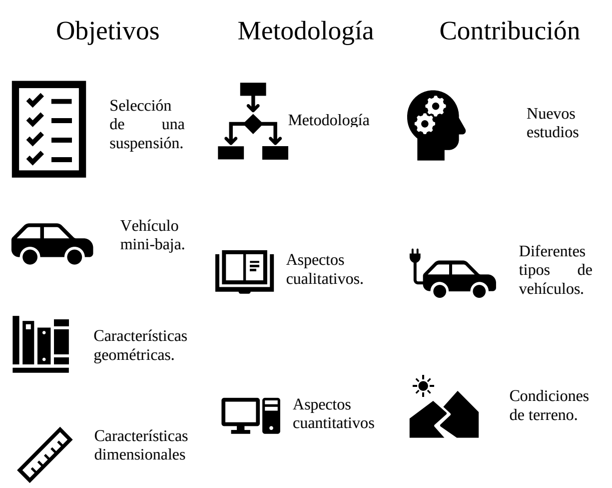
The general objective of this work is to select a suspension system for a mini-baja vehicle. Among the specific objectives is the development of an analysis of the geometric and dimensional characteristics of the semi-independent suspension system and McPherson suspension system. The type of methodology that was used had a quantitative and qualitative approach, since it was not only intended to select the suspension system based on mathematical data provided by the simulation, but also on certain physical characteristics that the suspension system possesses. This work contributes to the development of new prototypes in terms of suspension systems, since it opens the way for competitive vehicles to analyze the suspension system that best adapts to both the conditions of their vehicles and the of the land itself, considering the qualitative and quantitative analyses.



Suspension system, Geometric features, Finite elements

Resumen

El objetivo general del presente trabajo es seleccionar un sistema de suspensión para un vehículo tipo mini-baja. Dentro de los objetivos específicos se encuentra el desarrollo de un análisis de las características geométricas y dimensionales del sistema de suspensión semi-independiente y sistema de suspensión McPherson. El tipo de metodología que se utilizó tuvo un enfoque cuantitativo y cualitativo, ya que no sólo se pretendía seleccionar el sistema de suspensión en base a datos matemáticos que arrojara la simulación, sino también a ciertas características físicas que el sistema de suspensión poseé. Este trabajo contribuye al desarrollo de nuevos prototipos en lo que a sistemas de suspensión se refieren, ya que se abre el panorama para que los vehículos de competencia puedan analizar el sistema de suspensión que mejor se adapte tanto a las condiciones de sus vehículos como a las de los propios terrenos, considerando los análisis cualitativos y cuantitativos.



Sistema de suspensión, Características geométricas, Elementos finitos

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Introduction

Mini-low vehicles have become an important part of the educational sector, as it is here that students can demonstrate their knowledge and skills in the handling and design of mechanical elements.

Within the vehicles, various systems can be found, which require continuous study with the aim of improving them according to the needs that arise.

There are a variety of vehicles that are designed and structured to perform different tasks; these tasks will indicate the characteristics of the elements that make up a system.

Vehicles have different types of systems, which can be: steering system, braking system, transmission system, suspension system, among others.

This study will focus on studying the suspension system, which is an important point for the performance of any vehicle, as it is the one that gives stability to the whole system that integrates the car.

One of the objectives of this study will be to choose the suspension system option that best suits the needs of the mini baja type vehicle.

The suspension system to be analysed will be proposed for a competition vehicle; therefore, it is necessary to take into account certain parameters that the system must have, among which the weight allowed by the competition must be considered, as well as the size it must have. The above without losing sight of the safety that the system must have, as this is one of the priorities when studying its behaviour.

The BAJA SAE competition is an event that has as one of its objectives to design ‘all terrain’ type vehicles, which must meet and accredit certain static and dynamic tests. Within the design of the vehicle, the type of material to be used, the vehicle model, the dimensional characteristics, among others, must be considered, as well as its manufacture and costs. Therefore, this type of activity, such as the BAJA SAE competition, also seeks to develop collaborative work among students, as it is a group of students who develop the project in all its stages.

Methodology

The process that was carried out with the aim of achieving satisfactory results is shown in Figure 1. This methodology helped to structure the steps to be followed within the project, in such a way that it supported the clarification of the objectives and in this way to have reliable and valid results. The points shown in Figure 1 are points that were considered key when analysing the system and what it was intended to achieve. To guide the project, it was decided that the methodology to be followed should have a quantitative and qualitative approach, i.e. the analysis to determine the best option to consider for the system should be based on both numerical data and perceptions or experiences, the latter due to knowledge of the subject.

In the first instance, the vehicle was analysed as a complete system, so it was concluded that the elements to be analysed were those that make up the suspension.

Since there was some knowledge of the elements that make up the suspension system, it was considered that it was not enough, to such an extent that an investigation of these elements was carried out; among what was investigated, information was obtained such as the material of each of the elements of the suspension system, its operation, the response it has when subjected to forces, among others.

Based on the characteristics found in the elements that make up the suspension system and the conditions that were required, a couple of suggestions were proposed to analyse and thus be able to determine the one that best suits the vehicle.

A fundamental tool in the process of this work was the use of CAD software, which was a tool that simplified the work, giving satisfactory results without neglecting the improvement in the design processes.

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Box 1

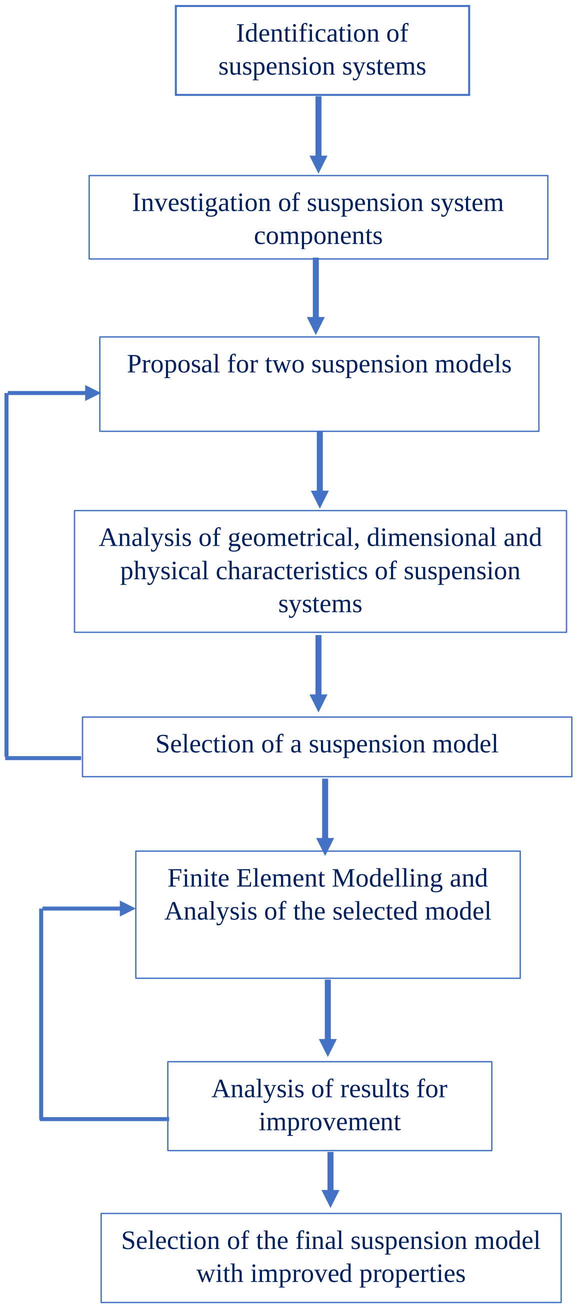

Figure 1
Methodology for the selection of the suspension system
Source: Own elaboration

Like the CAD software, the CAE tool was important in the complete study of the system, as it helped to give a numerical and reliable response to the parameters indicated according to the behaviour of the elements that make up the suspension system, i.e. it helped to solve the complete system subjected to various loads or physical phenomena, in such a way that it allowed various adjustments to be made and thus obtain the expected results.

Development

Generalities of modelling of suspension systems

The suspension model to be considered had to be capable of adapting to the circumstances of the vehicle of interest, i.e. to absorb impacts, as well as to guarantee user comfort, without neglecting the stability and safety of the vehicle. In order to define the characteristics of the suspension system, it was necessary to know the type of vehicle on which the system would be assembled, i.e., it was specifically necessary to know the chassis on which the suspension system would be mounted, in order to know the geometric characteristics on which it would work. Figure 2 shows the chassis on which the system would be assembled.

Box 2

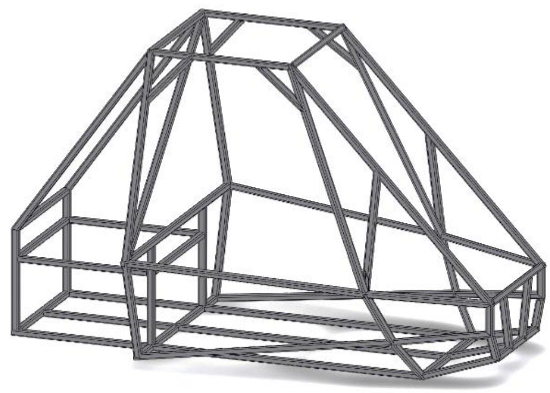

Figure 2
Model chassis for suspension mounting.
Retrieved from: Huerta, H., et al., 2020.

The chassis shown corresponds to a single-seater competition vehicle, which has the characteristic that the elements that form it are tubular; likewise, it has a weight of around 187 kg, which makes it an extremely light vehicle, which helps to have a better performance in competitions due to the low weight and thus a reduction in fuel consumption without losing the necessary power. In addition, the chassis has a wheelbase of 150 cm.

It is worth mentioning that, in order to make the right choice, 2 types of suspension systems were considered: semi-independent suspension system and McPherson suspension system. The suspension system used inside the vehicle must be sufficiently robust, as the conditions to which the vehicle is subjected tend to be extreme.

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The importance of selecting a suitable suspension system for the vehicle lies in the fact that it must be capable of absorbing certain irregularities that may occur on the roads where the vehicle travels and thus have an adequate level of comfort, as well as excellent stability.

Suspension systems are basically composed of two elements: elastic elements and damping elements. Therefore, suspension systems are governed by Equation [1] (Beer, F. et al., 2021):

The above can be explained as follows: a mass vehicle has a suspension system which is made up of a spring with an elastic coefficient, damper with a damping coefficient, which will cause the body to be exposed to forced vibrations with damping when the vehicle travels over uneven areas.

Due to the nature of the damper systems, the spring will absorb the unevenness of the terrain, while the damper dissipates the energy so that prolonged oscillations are precisely avoided.

Main characteristics of semi-independent and independent suspension systems

An important point to consider in the selection of the appropriate suspension system was the review of the main characteristics of each of the two suspension systems under consideration. The semi-independent suspension system is a system that is mechanically simple and has a good dynamic performance, in addition to being inexpensive in relation to other types of suspensions on the market, it is also light, which would complement the vehicle very well, since the vehicle is intended to be light.

One of the disadvantages that can be observed in this type of suspension system is that it lacks precision when cornering, as well as the same comfort on uneven roads. This does not help much in terms of control and dynamic response. On the other hand, there is the independent suspension system which, due to its characteristics, offers better performance, stability and comfort.

This type of system has the characteristic that, on uneven roads, only the wheel (together with the suspension system) that is affected by the terrain situation acts; this helps each wheel to adapt to the terrain, thus improving the traction of the wheel with the ground. Among the disadvantages of this system is the cost, which is higher, as well as the weight, which is higher than the semi-independent suspension system.

Modelling of parts of the semi-independent suspension system

The semi-independent suspension system was one of the proposals that were put forward, because it is a mechanism that supports high loads, as well as having the appropriate conditions to adapt it to the vehicle chassis. On the other hand, the McPherson suspension system is a system that can be adapted to different types of vehicles, as well as being cost-effective, since it requires a low maintenance cost, and also has a low degree of difficulty to assemble and disassemble from the vehicle. The McPherson system tends to be used in light vehicles, which is one of the reasons why it was decided to analyse this option, as the vehicle we worked with is light in weight.

In the first part of the development of the work, the parts that make up the suspension system were created with the help of CAD software. The most important parts (of the semi-independent damping system) are the spring and the outer cylinder.

The spring and inner axle system together perform the function of compression, rebound and stabilisation of the system, which helps to absorb and release energy, while keeping the wheels on the ground and maintaining control of the vehicle. The integrated shock absorber and spring assembly makes it possible to reduce the space required for a small vehicle size. Figure 3 shows the spring together with its inner axle, on which much of the force is applied when the vehicle passes over an uneven surface.

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Box 3

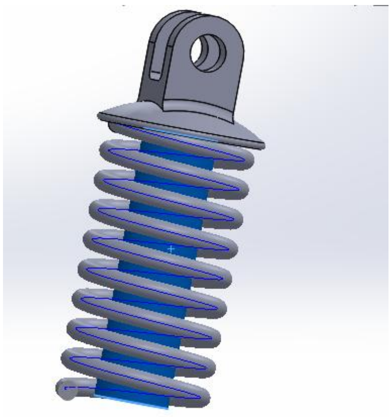

Figure 3
Spring and inner axle of the semi-independent suspension system
Source: Own elaboration

Figure 4 shows the outer cylinder of the shock absorber, which has among its objectives to maintain spring stability, together with the inner shaft; in the same way, the cylinder maintains the working fluid at a constant pressure and volume. Another of the functions of the outer cylinder is to give a certain rigidity and support to the shock absorber, as well as helping to dissipate the heat that is generated during the action of compression and expansion of the internal fluid.

Box 4

Figure 4
Outer shock absorber cylinder of the semi-independent suspension system
Source: Own elaboration

Subsequently, the assembly of the complete semi-independent suspension system was carried out, which is shown in Figure 5. In this assembly, all the parts that make up the suspension system are found, including the rim and tyre.

Box 5

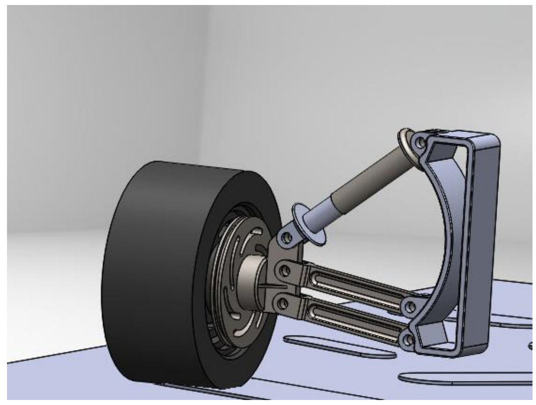

Figure 5
Semi-independent suspension system assembly
Source: Own elaboration

Modelling of parts of the McPherson strut system

On the other hand, the McPherson suspension system falls into the category of independent suspension systems. Among the elements that make up the system are: springs, stabiliser bar, ball joints, among others.

To this work, the elements that are part of the McPherson suspension system were modelled. Figure 6 shows the external axle.

One of the functions of the external axle is that it helps the stability and alignment of the vehicle, which allows a better adherence of the tyres to the ground in a curve; within this element, an internal axle is introduced, which is the one that performs a displacement when the suspension system is subjected to a load, whether constant or variable.

Box 6

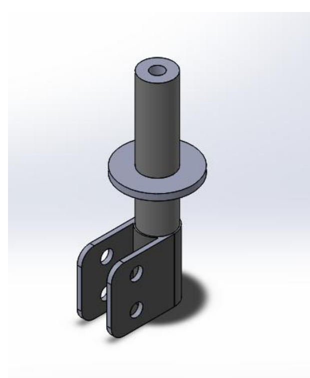

Figure 6
McPherson strut outer axle
Source: Own elaboration

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Figure 7 shows the stub axle, which plays an important role in the suspension system, because it is where several elements are connected, such as: the wheel with the steering linkage, in other words, it is at the stub axle where the suspension and steering are connected, so that the wheels can perform their function properly even on uneven roads.

This element has the task within the suspension system of acting as a central point connecting the suspension to the rim. Due to its geometrical characteristics the design is easily adapted to the McPherson suspension system. On the other hand, due to its mechanical properties, the stub axle is designed to withstand significant mechanical loads, which makes it a versatile element with a long service life.

In summary, this element is important within the McPherson strut suspension system because it adds value to the user's comfort and the care of the vehicle itself.

Box 7

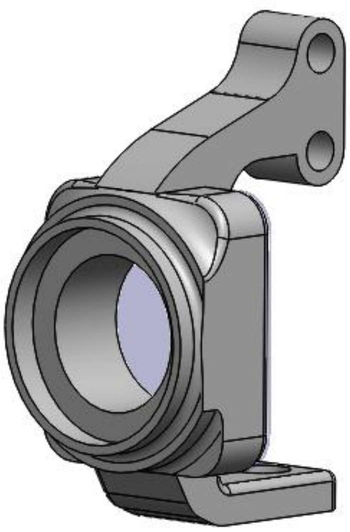

Figure 7
McPherson strut suspension system
Source: Own elaboration

The simulation of a physical phenomenon makes sense when most of the possible circumstances are considered, so that the analysis approaches a real situation; therefore, the model of the track on which the suspension system model would move was developed in order to carry out the virtual tests.

The material of which the track is made was analysed, and it was concluded that the material best suited to the conditions sought was concrete. It is worth mentioning that the surface of the track has some "imperfections", due to the fact that the aim was to bring the model closer to a real environment and thus obtain the expected results. The track was considered to be bumpy and uneven, which would give more accurate parameters on the behaviour of the vehicle under extreme dynamic loads that the vehicle can face. Under these conditions the dynamic stability of the mini baja can be thoroughly analysed.

Materials used

Within the finite element analysis, a situation that takes relevance is to identify and characterise correctly the materials that will be used, since these will give the guideline to obtain the expected results. For the analysis of the springs, a material commonly used in the manufacture of compression springs was used, which has the mechanical characteristics shown in Table 1; this material is considered to be a high carbon steel:

Box 8

Table 1
Mechanical characteristics of springs.

Common name	Alambre de piano
Specification	ASTM A228
modulus of elasticity (E), psi	30×10^6
Shear modulus of elasticity (G), psi.	11.5×10^6
Density (ρ), lbm/in3	0.283
Maximum Service Temperature °F	250
Main Characteristics	High strength, excellent fatigue life.

Data obtained: Nisbett, R., 2008

The mechanical properties of the materials used in the suspension system components are presented in Table 2:

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Box 9

Table 2

Mechanical properties of suspension system components.

Component	Modulus of Elasticity "E" (GPa)	Yield stress Sy (MPa))	Density (kg/m3)	Coeficiente de poisson
Outer shaft	210	370	7870	0.3
Inner axle	210	370	7870	0.3
Fork	210	370	7870	0.3
Sleeves	210	370	7870	0.3

"Amended: Rodriguez, F. D., et al., 2022"

Results

Due to the circumstances to which the vehicle would be subjected and based on the analysed benefits of each of the suspension types considered, it was decided to choose the McPherson strut suspension.

A parameter that was considered to be essential when carrying out the study was the safety factor, which would be the starting point for determining whether the choice of system was the right one, as well as whether the geometric characteristics would be appropriate.

Figure 8 shows the safety factor for the McPherson strut system, which was 1.4, indicating that the system is adequate.

Box 10

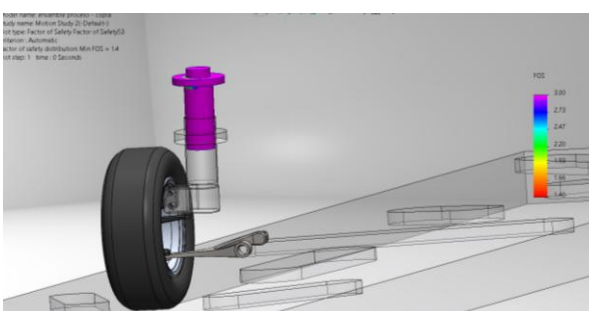

Figure 8

Safety factor of McPherson strut system

Source: Own elaboration

Conclusions

It was possible to determine the suspension system that would best adapt to the chassis of the vehicle under study.

This suspension will withstand the dynamic loads to which it will be subjected. The expected results were obtained, as the safety factor is above unity, so it can be considered that the system will have a useful life of a wide range, as the conditions to which the model was subjected are extreme situations.

One of the points considered for the choice of the suspension system were the geometrical characteristics of the chassis, the required clearances and the weight of the overall suspension system.

The McPherson suspension system is a system that can be adapted to various types of off-road vehicle chassis, due to the versatility it handles, as well as its flexibility and light weight.

Statements

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Contribution of each author

The authors working on this article worked together on all the points developed, however, due to their expertise they focused on a few points, which are mentioned below:

Sanchéz-Lerma, Josué: Contributed to the general idea of the project, as well as with the selection of materials.

Cerrito-Tovar, Iván De Jesús: Contributed to the analysis of the suspension systems.

Torres-Rico, Luis Armando: Contributed to the modelling of mechanical elements.

Huerta-Gámez, Héctor: Contributed to the development and analysis of the system in the CAE software, and also contributed to the writing of the article.

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Future work

Due to the projects that are being carried out within the Department of Automotive Systems Engineering of the Polytechnic University Juventino Rosas, the possibility of implementing the chosen suspension system in an electric vehicle has been considered, which is why the McPherson system was selected, because it is a system that adapts to various types of vehicles. It is also a flexible system, which can help the elements that make up the system to adjust to changes.

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