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Title: Structural analysis of a lifting platform for autonomous vertical vehicular parking

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Introduction

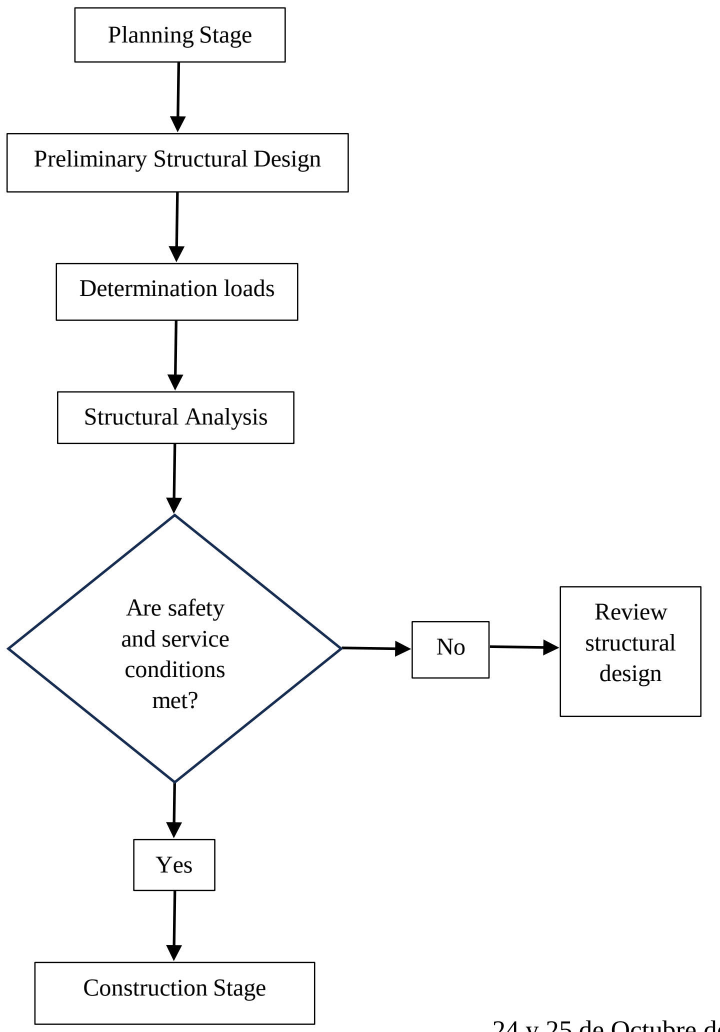
Since the middle of the last century, Latin American cities have experienced a rapid growth of their urban centers, which has resulted in a variety of problems such as traffic congestion, environmental pollution, infrastructure deterioration, among others (Rodríguez A. G. y Ramos J. L., 2009). Aiming to mitigate the limitations in the current parking infrastructure and address the global challenge of traffic congestion, propose a vehicle design scheme with vertical lift mechanisms and folding wings, which represents an innovative change for environmental protection, sustainable development and artificial intelligence (Yixu, Junying, & Kun, 2024).

Nowadays it is very important to know that urban space is becoming more and more limited, the need for innovative solutions to optimize land use is becoming more and more constant. In this context, conceptualizing vertical parking support structures, in this case, emerges as an efficient and practical response to the growing demand for parking spaces.

Methodology

Structural engineering is the science and art of safely and economically planning, designing and constructing structures to serve those purposes. Structural analysis is an integral part of any structural engineering project, whose function begins with the prediction of the behaviour of the structure.

A structural engineering study is described by various stages using a flow chart, this indicates that it is an iterative process, and generally consists of the following steps (Kassimali, 2015):



Methodology

Mathematical model FEM

Equilibrium equations in an elastic body in two dimensions:

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + F_x = 0 \qquad [1]$$

$$\frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + F_y = 0 \qquad [2]$$

Where σ_x and σ_y are normal forces in the x and y axes respectively, τ_{xy} and τ_{yx} are shear forces acting in the xy plane.

The strain-displacement relationships are:

$$\varepsilon_x = \frac{\partial u}{\partial x} \qquad [3]$$

$$\varepsilon_y = \frac{\partial v}{\partial y} \qquad [4]$$

$$\gamma_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \qquad [5]$$

Where $\varepsilon_x$and ε_y are the normal deformations in the *x*- and *y*-axis directions respectively, the engineering shear deformation in the *xy* plane is γ_{xy}; *u* and *v* are infinitesimal displacements in the *x*- and *y*-axis directions respectively.

Methodology

Constitutive equations (stress-strain relationships). These relationships describe the state of deformation, deformations induced by internal forces or stresses resisting against applied loads. These relationships depend on the material properties, they are determined experimentally. Hooke's law relates six components of the three-dimensional stress tensors to the strain tensors, as follows:

$$\sigma_x = \frac{\nu E}{(1+\nu)(1-2\nu)} e_\nu + 2G\varepsilon_x \quad [6]$$

$$\sigma_y = \frac{\nu E}{(1+\nu)(1-2\nu)} e_\nu + 2G\varepsilon_y \quad [7]$$

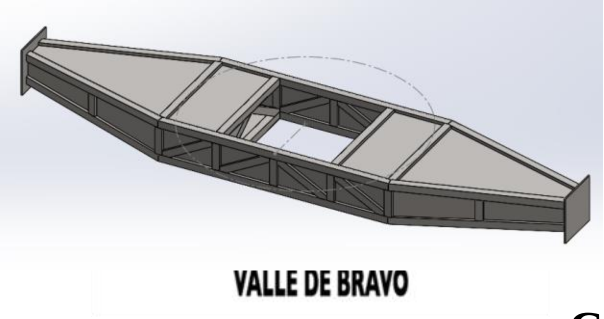
$$\sigma_z = \frac{\nu E}{(1+\nu)(1-2\nu)} e_\nu + 2G\varepsilon_z \quad [8]$$

$$\tau_{xy} = G\gamma_{xy} = \frac{E}{2(1+\nu)}\gamma_{xy} \quad [9]$$

$$\tau_{yz} = G\gamma_{yz} = \frac{E}{2(1+\nu)}\gamma_{yz} \quad [10]$$

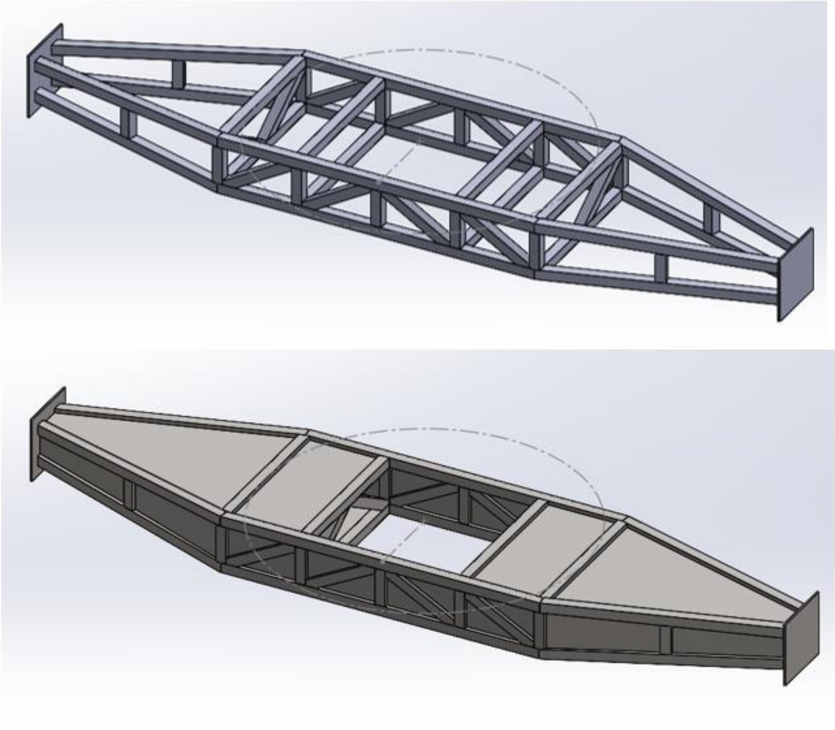
$$\tau_{xz} = G\gamma_{zx} = \frac{E}{2(1+\nu)}\gamma_{zx} \quad [11]$$

Where E is Young's modulus, ν is Poisson's ratio, G is the shear modulus and e_ν the volumetric strain expressed by the sum of the three normal strain components, $e_\nu = \varepsilon_x + \varepsilon_y + \varepsilon_z$.

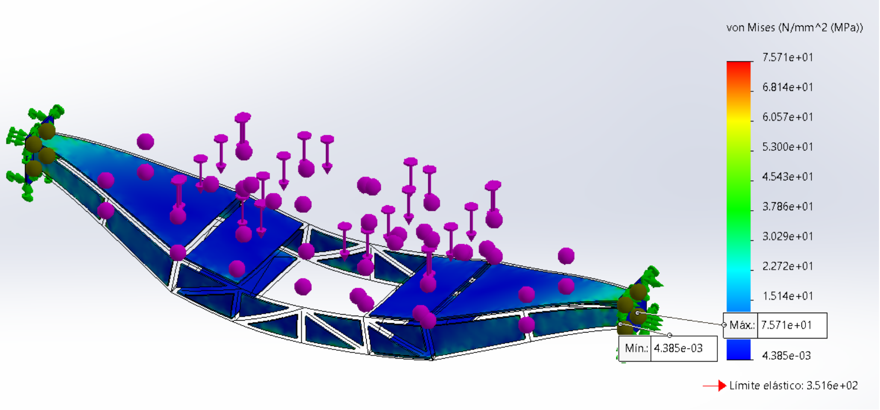


Results

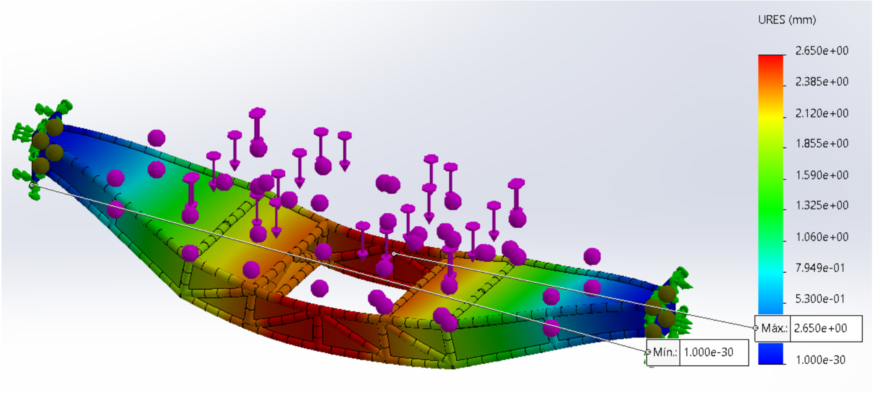
Computational Model



Computational model. *Source: Own elaboration*

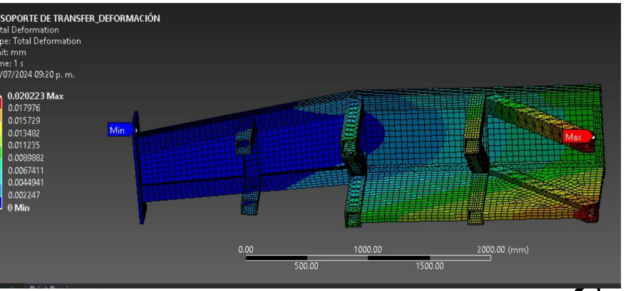


Von Mises forces. *Source: Own elaboration*

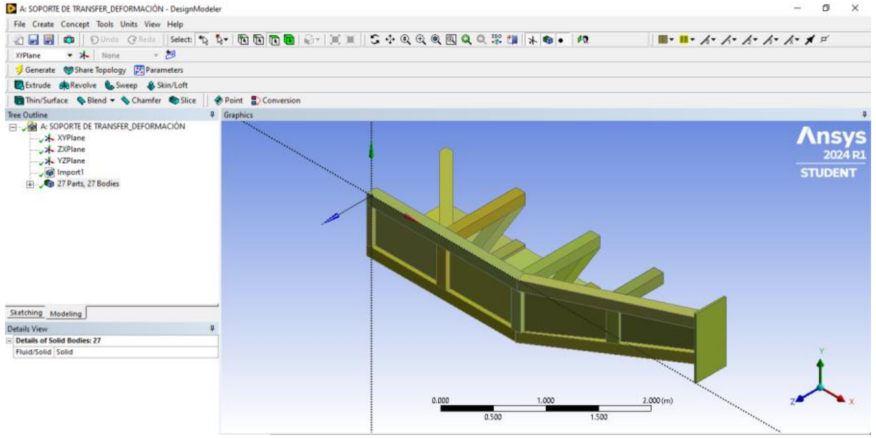


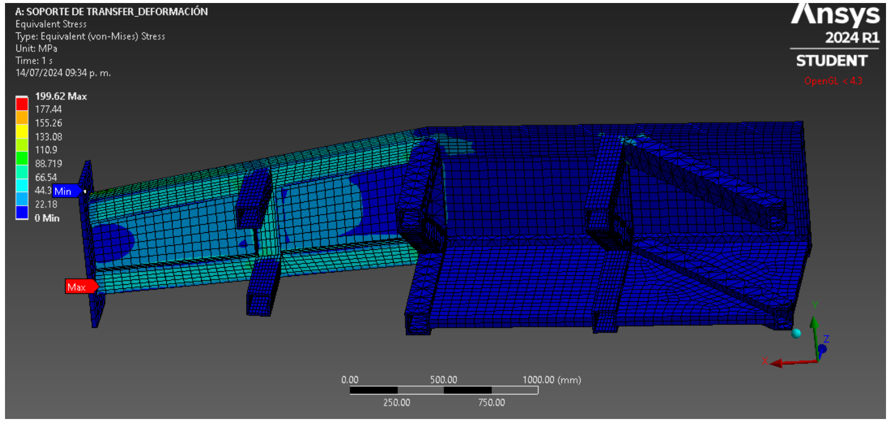
Total deformation. *Source: Own elaboration*

Results

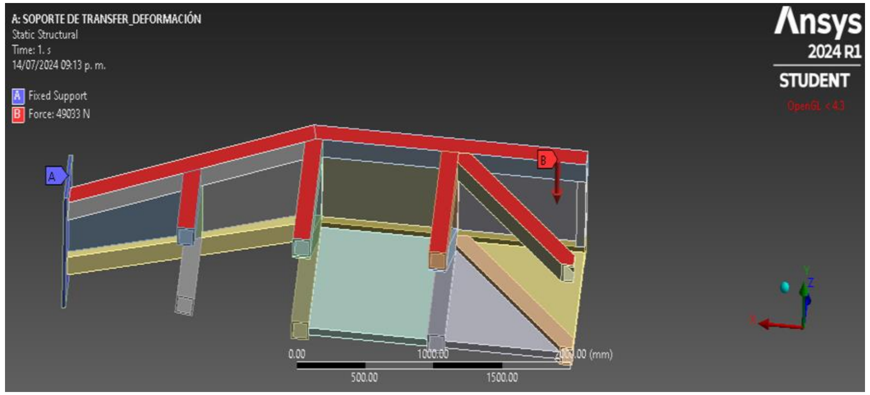


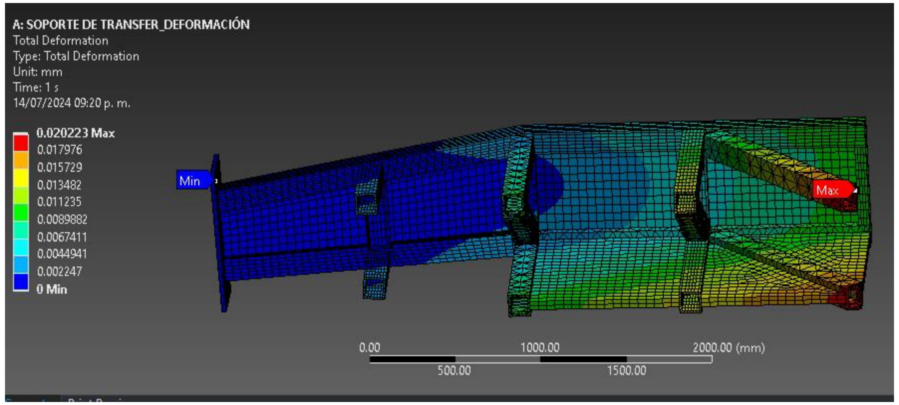
Computational Model





Equivalent (von-Mises) Stress. *Source: Own elaboration*





Minimum and maximum total deformation. *Source: Own elaboration*

Annexes

Discussion of results

The stress distribution and total deformation were determined numerically using the finite element technique, this type of analysis is very suitable for structural analysis, which allowed to determine the mechanical behaviour of a lifting platform that as a conceptual proposal will be used for an autonomous vertical parking with a vision towards Industry 4.0. In addition, this technique saves time and money in performing strength of materials calculations, as well as in the construction and prototyping of physical models.

The results of the present investigation indicate that it is feasible to use computational models with the help of CAD software, which allows with a certain relative ease to perform various simulations emulating with this the real physical conditions of this type of mechanical elements, as well as the comparison of the results obtained, so it is recommended to continue working on this line and take advantage of the benefits of these tools as support for research in the engineering area.

Conclusions

The present study demonstrated the potential of the finite element technique for similar physical phenomena in the area of strength of materials, since it allowed the numerical calculation of the total deformation and equivalent stresses (von Mises) by using two CAD software. This simulation will allow to extrapolate the results of real working considerations, since it is observed that both software have a greater potential, the results obtained are very similar, which undoubtedly will allow to analyze different scenarios of application.

Future work should be directed towards the study of new conceptual designs and make the comparison with theoretical calculations in order to optimize the results and resources. In this way, it will be possible to predict the behavior of the lifting platform in different materials subjected to different working conditions.

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