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SOFTWARE ANALYSIS OF SIDE IMPACT DROPS IN A HATCHBACK VEHICLE USING D30 ELASTOMERIC POLYMER FOAM AS A COVERING MATERIAL FOR THE MAIN REINFORCEMENT OF THE DRIVER'S DOOR

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Abstract

The objective of this work was to develop the simulation of the side impact against a pole in a hatchback vehicle using LS DYNA covering the main reinforcement of the side impact system for which the materials that make up the driver's door and the elastomeric polymer to be used were analyzed. The mechanical properties of the materials were obtained by testing the specimens using the ISO 6892 standard. The accidents at the national level were studied, side crashes being the first cause with 27.42% which, through a non-probabilistic sampling and qualitative analysis, allows analyzing the range of vehicles circulating in the country, placing in the first place of units sold by the model in part of the year 2017 to the test vehicle 1, with 14.5%. Therefore, we analyzed the vehicle's geometry, being the door a structure with wide gaps minimally reinforced, lodging the main reinforcement inside the door, which limits deformation, increases rigidity and distributes the energy in the event of a lateral collision. For the analysis of the simulations, the results produced by simulating the side impact with the side impact system of the vehicle and implementing the elastomeric polymer coating to the main reinforcement are compared by evaluating the sections described in the Spanish UNECE Regulation No. 95 Revision 02; which aims to safeguard the life of the occupants in case of a side impact. It is concluded that the implementation of the elastomeric polymer in the primary reinforcement presents a reduction in

the deformation of the elements of the lateral structure of the vehicle, as well as a variation in the behavior of the dummies inside the passenger compartment in the two cases of study. Quality control of the meshing is recommended since the analysis and veracity of the results depend on it.
KEYWORDS: LS DYNA (SOFTWARE), LATERAL IMPACT, LATERAL IMPACT, LUXURY FLUID, SHEAR THICKENING, HABITACULUM, POLYMER ELASTOMER

1. Introduction

Improving vehicle safety is vital since the lives of the occupants and the occupants of other vehicles depend on it. Therefore, simulation is the computational tool that will allow to recreate, visualize and analyze the lateral impact of a vehicle.

The automobile, through time, has been evolving from its design to its sale, but it has been implementing the use of technology applied to the industry. CAD programs are used as a computer tool of great support for all areas of the automotive industry, with more emphasis on design.

The pioneers in implementing safety measures through regulations and standards have been the European countries since these measures will guarantee the life of the occupants in the event of a side impact by reducing physical contact with the deformed structure.

In order to study the behavior of vehicles in the event of a collision, the automotive industry has been working for some years on virtual accident simulation, which has led to more significant and faster progress in the field of safety, making it an essential means for its improvement (Novillo, 2005).

When performing a simulation, it does not replace a real impact test, through which the deformation of the car structure and, even more, the severity of injuries that the occupants can generate can be appreciated with greater precision. However, the simulation can be used practically to evaluate the structure's behavior and the safety it provides. Now, impact simulations are developed using models based on data obtained from real dummies; these tests are known as "crash test dummies," in which the results obtained allow to know the vehicle's behavior and the occupants to optimize the passive safety systems of automobiles.

A unique D30 elastomer polymer foam technology is used to provide anti-shock properties based on non-Newtonian principles: the molecules of the material flow freely and adapt to the structure of the body when the movement is normal, in case of impact, the molecules of the D3O material concentrate at the point of impact and absorb all the force of the blow. When the force of the blow stops, thanks to their elasticity, they quickly return to their original shape. This whole process can be repeated without the fabric breaking, thus reducing damage to the element it covers (D3O, 2019).

This project will simulate a side impact from a model that consists of a car, a pole and the D30 elastomer polymer foam of unique technology that will cover the main reinforcement of the driver's door since it is in this area where the impact will take place, based on the EURO NCAP Test Protocol for Side Impact against the pole that details the conditions that must be

met to carry out the impact in real life; as well as Regulation number 95 of the European Union, which establishes uniform prescriptions regarding the approval of vehicles for the protection of occupants in the event of a side impact (UNECE, 2015).
Advanced finite element calculation software has been used. The program used to process the simulation is Ls-Dyna and Ls-Prepost has been used to implement the model and visualize the results. Both programs are developed by the North American company Livermore Software Technology Corporation (LSTC) and are widely used in the automotive industry to analyze vehicle designs and, more specifically, to evaluate the safety they offer in impact situations (Corporation, 2009).

2. Objectives

2.1 General Objective

Simulate using the LS-DYNA finite element program the side impact against a pole in a hatchback vehicle by coating the main driver's door reinforcement with D30 elastomeric polymer foam.

2.2 Specific objectives

- Identify the mechanical properties of the D30 elastomer polymer using tests under ISO 6892 standard
- Simulate by CAE software the side impact on the driver's door of a hatchback vehicle.
- Coat the main reinforcement of the driver's door with D30 elastomer polymer.
- Perform a CAE software comparison of the side impact on a hatchback vehicle with and without the D30 elastomeric polymer coating.

Methodology

3.1 Methodological design

3.1.1 Type of research

Bibliography.

The use of relevant information, such as scientific articles, technical journals, and books, will allow the development of the present work, which is why it emphasizes the bibliographic field.

Experimental.

Through the behavior of the simulations intended to be performed on the vehicle, we analyze what will happen when the vehicle impacts laterally against a pole, allowing the information obtained to be experimental.

3.1.2 Population and sample

3.1.2.1 Population

The population generated in this research is in the subcategory of M1 vehicles, according to NTE INEN 2656, which are four-wheeled motor vehicles designed and built for transporting people.

3.1.2.2 Sample
The study included the analysis of traffic accidents and statistics of the automotive sector, being important to select test vehicle 1 in which the lateral impact test against a pole in the driver's area will be simulated based on what is indicated in the Unece N 95 R2 regulation.

3.1.2.3 Sampling unit
The sampling unit consists of vehicles in the M1 subcategory marketed in the country.

3.2 Data collection method
3.2.1 Observation
Using this technique, the investigators make notes that will be of great importance for the analysis of the statistics of the Ecuadorian vehicle fleet, traffic accidents, considerations for the simulation, behavior of the structure, speed, time, materials used and other data that will allow obtaining a variety of results that are the fundamental basis for the simulation.

3.2.2 Documentary
The technique is used to collect important information from documented statistics, books, scientific articles, manuals, national and international standards, and data obtained from the simulation of lateral impact against a pole.

4. Results
4.1 Simulation of post-processing of side impact against a pole.
This simulation is performed with a speed of 32 km/h, and the time considered for the analysis is 150 milliseconds with a computational calculation time of 12 hours. The results of the simulation are very important since they will allow comparing the existing changes between the lateral protection system with and without the elastomeric polymer inside the door of test vehicle 1, for which there are existing deformations, the energies that are carried out within the simulation and the accelerations that occur in the dummy.

4.1.1 Vehicle Speed and Acceleration.
Figures 1 and 2 show the velocity and acceleration of the vehicle, respectively, in the direction of impact with the pole.

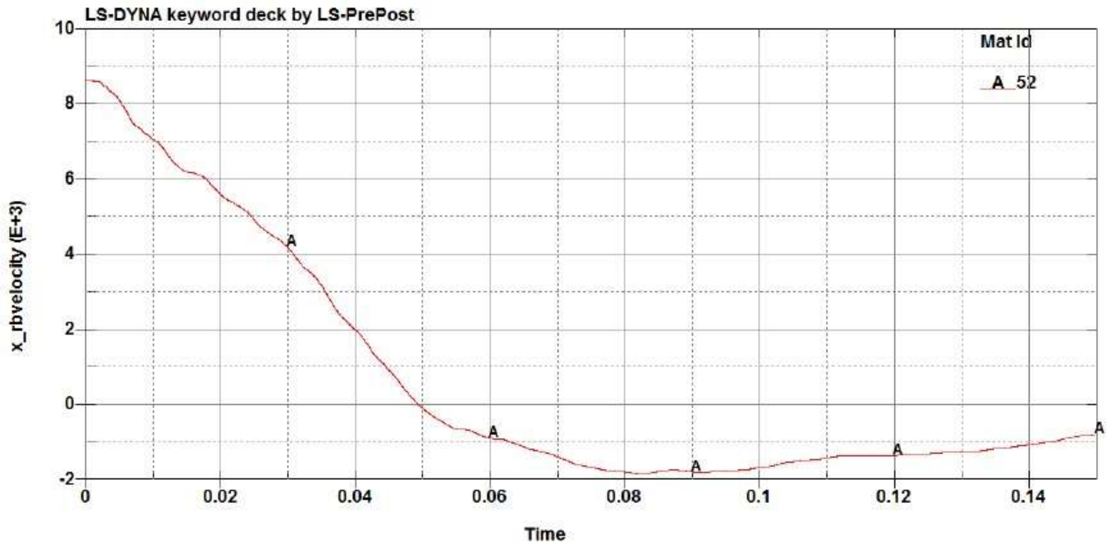

Figure 1. Vehicle speed measured on the X-axis.
Source: Omar Yupanqui (2019)

Figure 1 shows that the initial velocity is constant, i.e., 8945 mm/ms (32 km/h), up to the instant of the vehicle's collision against the pole. At t= 0.005 ms, it can be seen that there is already an impact against the metal sheet that forms the external part of the gate. As the simulation continues, it can be seen that the vehicle loses speed due to the pole's resistance.

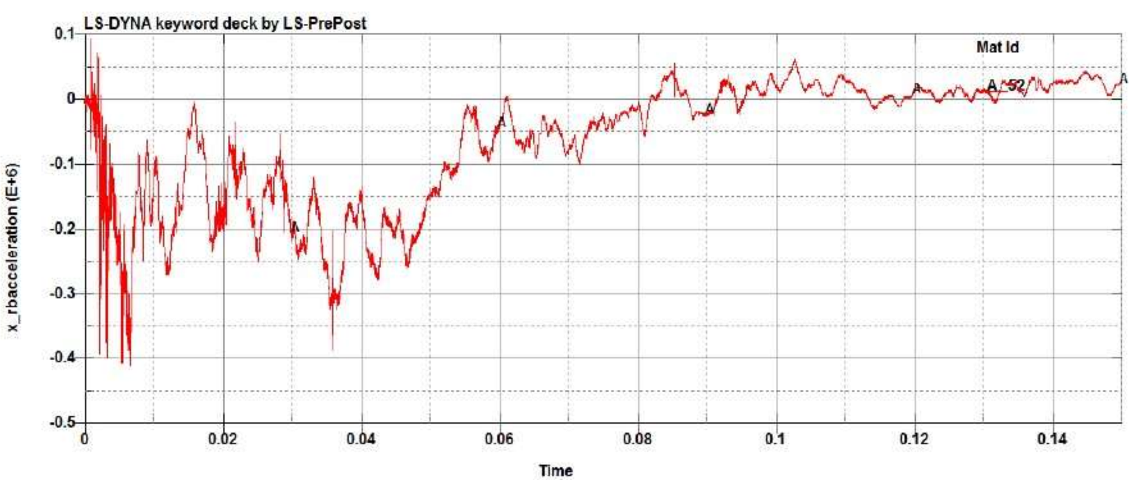

Figure 2: Vehicle acceleration measured on the x-axis
Source: Omar Yupanqui (2019)

Figure 2 shows that the acceleration of the vehicle at the beginning is zero because the imposed speed of 32 km/h is constant. When the first contact with the driver's door occurs, there is a deceleration, after which the resistance of the components of the side impact system is present, allowing visualization of a variation of decelerations and accelerations; therefore, the side impact is composed of multiple small impacts. This calculation is of great complexity because parameters such as speed, the impact resistance of the post, the vehicle's inertia, the center of gravity, materials, and dummies are involved.

4.1.3 Total deformation at the driver's door

The main structural element involved in the impact is the driver's door, so we start with this element without using the elastomeric polymer in the main reinforcement of the side impact system.

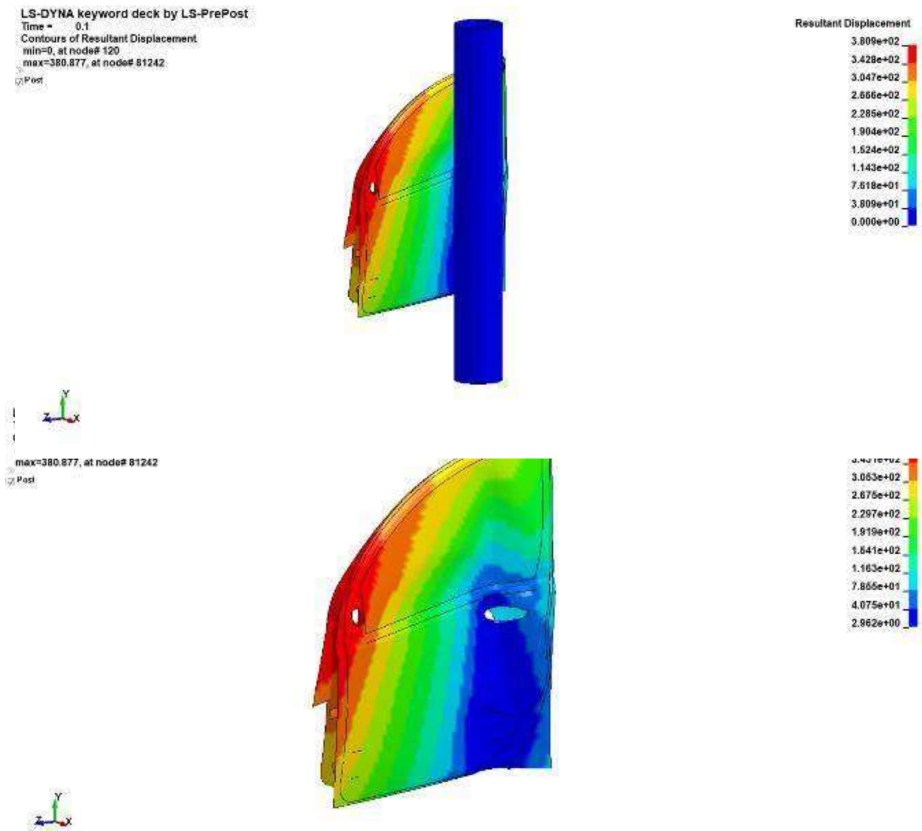

Figure 1: Deformations in mm produced without polymer elastomer
Source: Omar Yupanqui (2019)

Figure 1 shows two images where (a) shows the door impacting against the post in a time of 0.1 seconds, while (b) shows only the door at the same time allowing to appreciate how the impact affects the contact area with the post. The deformation produced has a value of 380.87 mm. This is because the vehicle, while impacting, begins to generate the collapse of the door due to the impact; it can be seen that the greatest deformation occurs in the front of the door, where the red tone shows the greatest deformation and the least deformation of blue color.

4.1.4 Von Misses stress produced in lateral impact

In order to know the existing elastic limit, the study will have to know the von Mises stress and the maximum admissible stress of the material. Figure 2 shows the Von Mises stress produced in the door upon impact.

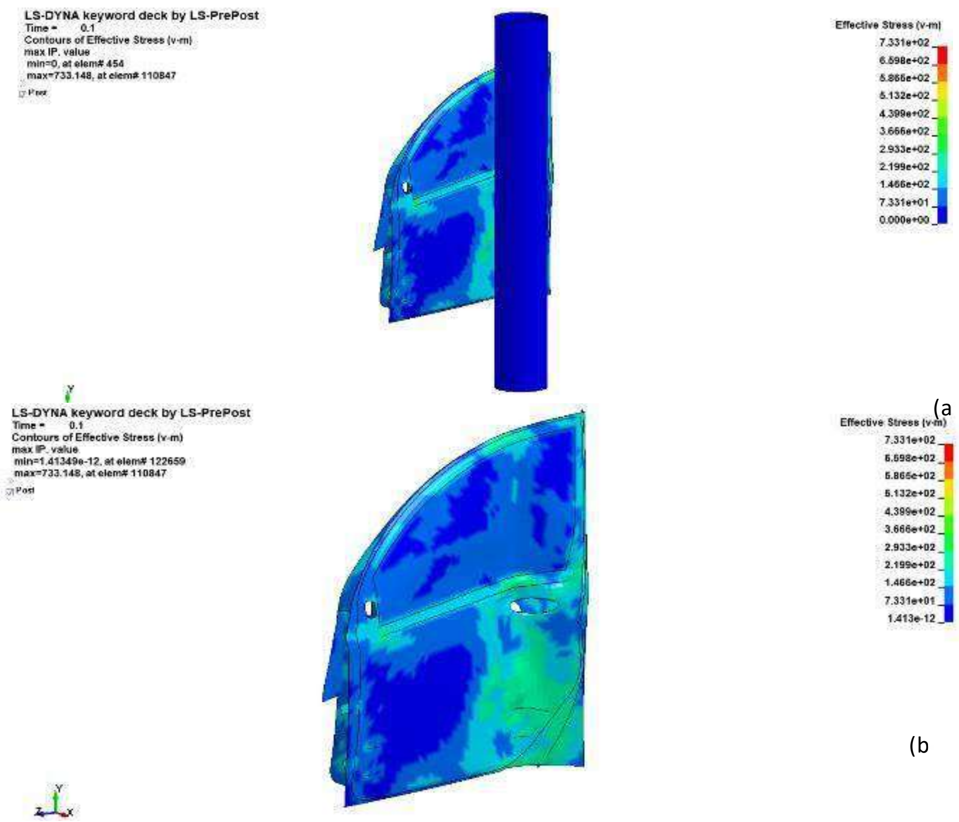

Figure 2: Von Mises stresses in MPa produced without polymer.
Source: Omar Yupanqui (2019)

In this case, the highest stress is concentrated at the point of contact between the driver's door and the post, having a maximum stress of 733.14 MPa. As in the previous case, the time taken is 0.1 seconds.

4.2 Simulation of post-processing the lateral impact against a pole by coating the main reinforcement with an elastomeric polymer.

This simulation is performed with a speed of 32 km/h, and the time considered for the analysis is 150 milliseconds with a computational calculation time of 15 hours. The simulation results are very important because they allow us to compare the changes that exist when using the elastomer polymer and the lateral protection system inside the vehicle door.

4.2.1 Vehicle Speed and Acceleration

Figures 3 and 4 show the velocity and acceleration of the vehicle, respectively, in the direction of impact with the pole.

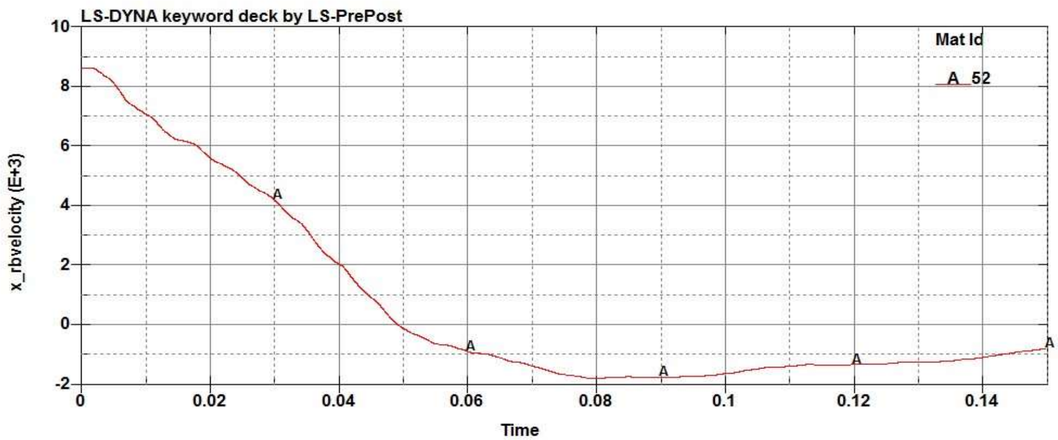

Figure 3: Vehicle speed measured on x-axis
Source: Omar Yupanqui (2018)

Figure 3 shows that the initial velocity is constant, i.e., 8945 mm/ms (32 km/h), up to the instant of the vehicle's collision against the pole. At t= 0.005 ms, it can be seen that there is already an impact against the metal sheet that forms the external part of the gate. As the simulation continues, it can be seen that the vehicle loses speed due to the pole's resistance.

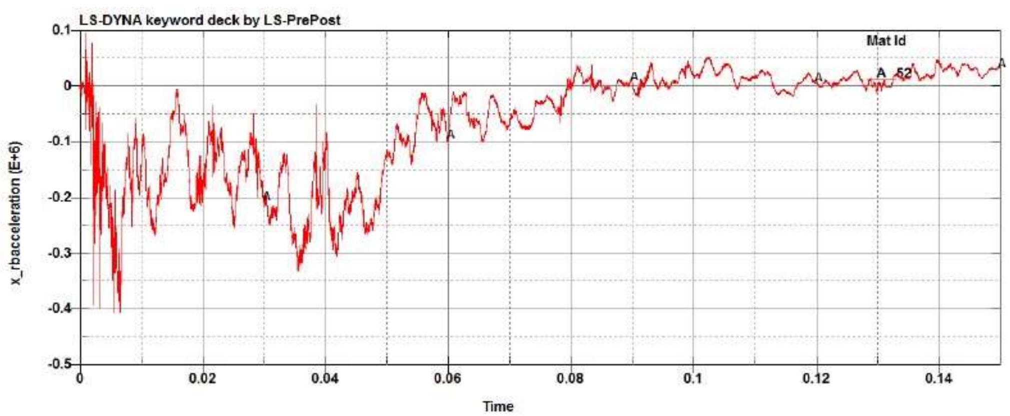

Figure 4: Vehicle acceleration measured on X-axis
Source: Omar Yupanqui (2019)

Figure 4 shows that the acceleration of the vehicle at the beginning is zero because the imposed speed of 32 km/h is constant. When the first contact with the driver's door occurs, there is a deceleration, after which the resistance of the components of the side impact system is present, allowing to visualize a variation of decelerations and accelerations; therefore, the side impact is made up of multiple small impacts. This calculation is of great complexity because parameters such as speed, the impact resistance of the post, the vehicle's inertia, the center of gravity, materials, dummies and the elastomer polymer are involved as the main aspect.

4.2.2 Total deformation at the driver's door using the elastomeric polymer.

The main structural element involved in the impact is the driver's door, so it starts with this element by using the elastomer polymer in the main reinforcement of the side impact system.

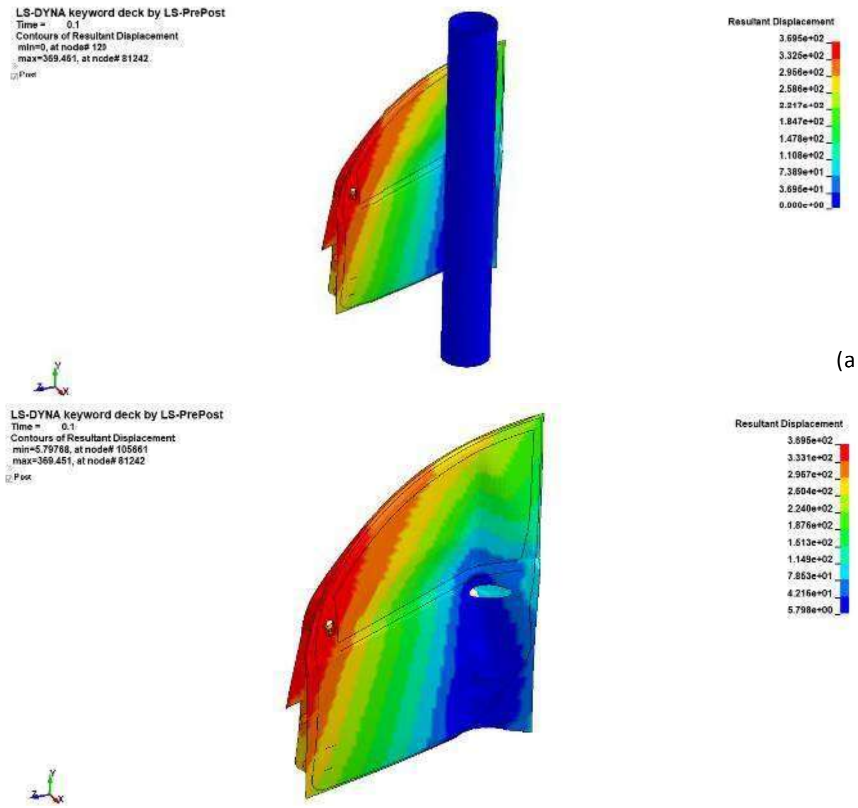

Figure 3: Deformation at the gate using the elastomeric polymer
Source: Omar Yupanqui (2019)

Figure 3 (a) shows the gate impacting the post at a time of 0.1 seconds, while Figure 3(b) shows only the gate allowing to appreciate how the impact affects the contact zone with the post.

The deformation produced has a value of 369.44 mm; due to the impact, the door begins to sag. This value will allow comparison with the result obtained in the previous case, where the lateral impact was analyzed without using the elastomeric polymer.

4.2.3 Von Misses stress produced in the side impact

In order to know the existing elastic limit, the study will have to know the von Mises stress and the maximum admissible stress of the material. Figure 4 shows the Von Mises stress produced in the door upon impact.

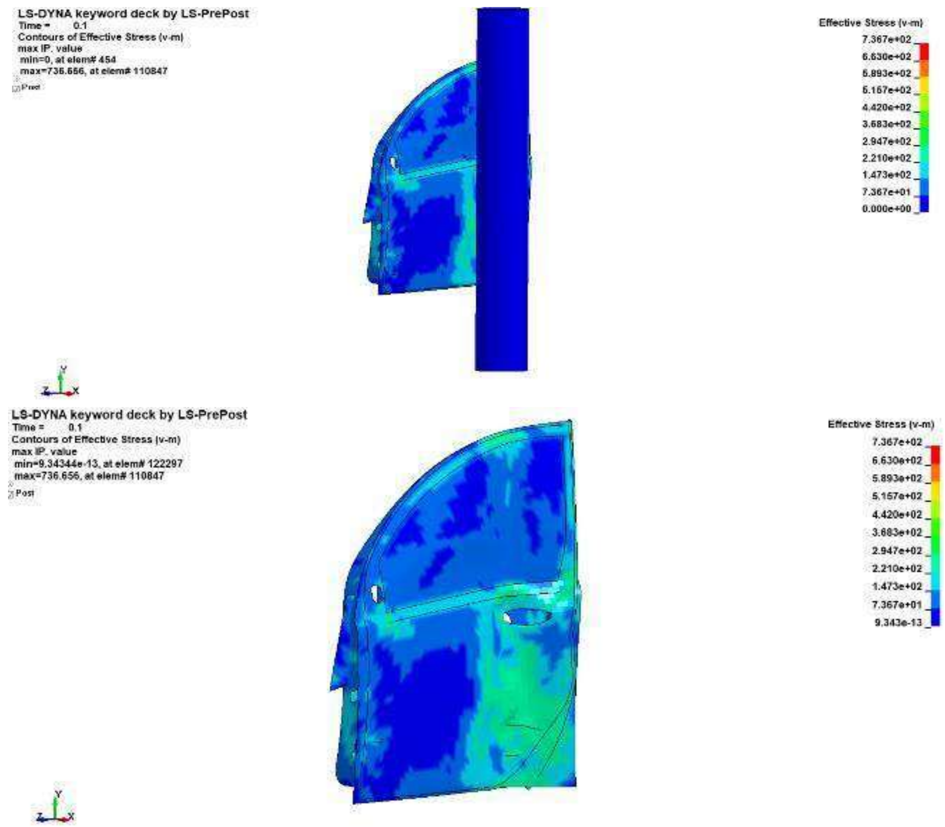

Figure 4: Von Misses stress in MPa produced in the door with polymer(b)
Source: Omar Yupanqui (2019)

In this case, the highest stress is concentrated at the point of contact between the driver's door and the post, having a maximum stress of 736.70 MPa. As in the previous case, the time taken is 0.1 seconds.

4.2.4 Deformation produced on the primary reinforcement of the driver's door

Figure 5 shows only the primary reinforcement on which the elastomeric polymer is placed,

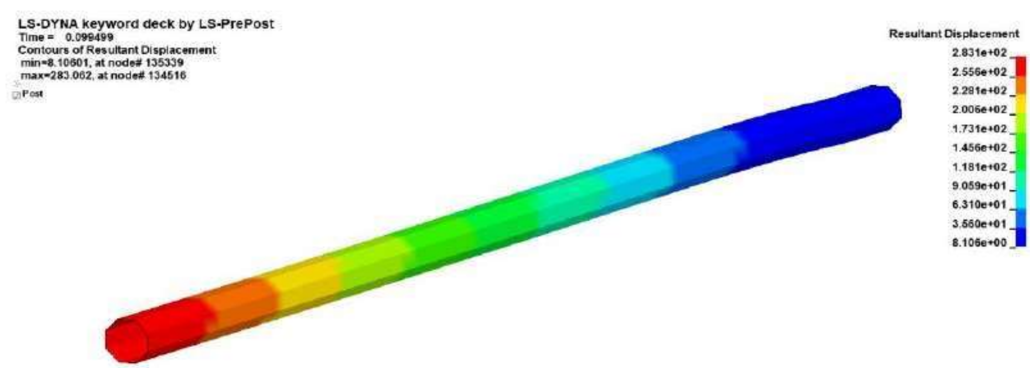

Figure 5: Deformation in the tube with the implementation of the polymer
Source: Omar Yupanqui (2019)

As can be seen, the greatest deformation is found in the front part of the main reinforcement with a value of 283 mm of deformation, and the simulation time in which these results are obtained 0.1 seconds. It can also be seen that the area where the impact with the post does not present an excessive deformation; as in the previous case, a greater deformation can be seen in the front part of the main reinforcement with a red color tone.

5. Conclusions

- LS DYNA allows performing nonlinear dynamic finite element analysis, allowing to establish boundary conditions, metallic and polymeric materials, which will produce large deformations and results as close to reality when analyzing the behavior of each element immersed in the impact, which is why this software is used in the simulation of collisions in the automotive field.

- Samples taken from the driver door components and the elastomeric polymer that will be used as a coating on the main reinforcement of the driver door allow tests to be performed to know the mechanical properties of the materials; data that are necessary to create the materials in the software.

- The impact simulation involves different parameters that must be known to develop it, such as boundary conditions, loads, velocity, contacts, simulation time, interactions, geometry, meshing, materials, accelerometers, units, Hourglass and other aspects that interact to develop the simulation, allowing to visualize this analysis through the database that generates results of the lateral impact against a pole that has been performed in this work.

- A previous analysis of the application of elastomeric polymer in the driver's door, specifically in the main reinforcement, was analyzed; analyzing several possibilities, such as filling the main reinforcement tube, coating, applying for polymer filler plates around the main reinforcement and implementing of impact absorption plates have been some of the ideas proposed to analyze the lateral impact.

- The simulations performed to give a clear idea of the critical points in the driver's door as well as in the dummy when it impacts against the post; the total deformation in the driver's door when simulating without elastomeric polymer has a value of 380.87 mm and when using the polymer in the main reinforcement of the driver's door is 369.44 mm; which allows understanding that there was a reduction in the total deformation of the door of 11.426 mm.

- The deformation produced in the main reinforcement, the main element of the side impact system without the use of the polymer, is 285.20 mm; when using the elastomeric polymer in the main reinforcement of the door, a deformation of 283.09 mm was obtained, which allows understanding that there was a reduction in the deformation of the main reinforcement of 2.11 mm.

- The resulting graphs of the accelerometers allow us to understand the behavior of the head, shoulder, thorax, abdomen and pelvis upon lateral impact in the two case studies; through the curves over position, one can understand the variation of the acceleration peaks existing in each one of the readings emitted by the accelerometers.

6. Recommendations

- The quality control of skewness meshing is important because the analysis and the veracity of the results obtained in the simulation of the lateral impact against a pole depend on it.

- The contacts, interactions and joints should be placed according to the conditions and analysis to be performed, as this will reduce the errors and interferences that may be generated during the simulation.

- The computational expense is of vital importance because the simulations, not having adequate core capacity, take too much time to develop the simulation.

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