Computer Aided Design of Aircraft Seats

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Abstract

In the present work we studied the modeling and computer simulation of the structure of an airplane seat very similar to the structure used in the current economy class seats. The major objective of this study was to acquire sensitivity to the results of Static and Dynamic Simulation by certification specifications of European Aviation Legislation in use **(Amend.9 CS - 25)**, through the development and interpretation of computer simulations.

The revision in terms of existing legislation reveals great interest of itself, given the lack of organized information, serving those that wanting to develop a product or service in the aviation industry.

The procedures performed and subsequent results obtained in the context of this thesis serves to prepare the necessary basis for the future development of a new structure for aircraft seats through computational methods, as well as a preview of the results of the respective physical certification.

By the computer simulations performed could perceive the dynamics of a type crash test when applied to the structure in question, obtaining locate potential areas of weakness of the structure and discriminate those that entering in plastic deformation.

KEY - WORDS: Aeronautical Legislation, Simulation for Certification, CAD, Aircraft Seats

1. Introduction

Currently the industry is going through a phase of its most troubled history, with globalization have opened up new horizons for the development and sale of new products, but equally increased competition between companies around the world. Into account this fact with development centers should stand in mind that throughout the development of a new product the success factor is to reconcile the best possible way the trinomial time - cost - quality, by other words do well and quickly and be the first.

With this thought and making use of the potential of the software available today it is possible to develop an almost virtual prototyping. In parallel with the development process of the CAD model are held every computer simulations that are necessary to establish the future performance of the product in the real world.

Thus when developing the first physical prototype adjustments needed to launch in production the final product are very few, thus reducing the costs involved in the process and lead time .

The theme of this work enters in the aeronautic world, with the attempt to develop an aircraft seat. However, before developing a new seat concept is essential understand how the current works and its weaknesses. Over the CAD reproduction of the seat became clear the difficulty and delay modeling, also showed some difficulty in the acquisition of sensitivity in the simulation of the structure.

Through the cooperation between IST and TAP- SA, was possible to access a real model of an aircraft seat used in the past by the airline, to make the dismantling and play real scale their structural key components using CAD software. After playback, the assembly of the model was validated, and then developed several simulations with an finite element software, which aimed to test whether the model in question was in accordance with the requirements of Aeronautical Certification currently in effect **(CS-25 Amendt.9)**.

2. Introduction to Legislation

In all sectors of services and products, to let you know what is expected and feel safe, that niche needs to respond to standards and follow certain protocols. With the globalization the aviation has become a key for the carriage of goods or passengers. The world has become smaller and in recent years has been towards an escalation in air traffic and is expected to increase the capacity air available. Although it was stated as a means of transport safer, but taking into account the inherent dangers associated with this mode of transportation was expected introducing legislation that serves as a ruler and square of the principles governing the design and use of aircraft.

At the level of European airspace the entity responsible for aviation is the European Agency for Aviation Safety Agency (EASA). Its mission is to promote the highest common standards of safety and environmental protection in civil aviation sector, along with the Federal Aviation Administration are responsible for the certification of the two largest makers of passenger aircraft in the world, Airbus and Boeing.

Given the difficulty felt in the perception of all these concepts we chose to create a flowchart, which are outlined in the needs that an entity need to possess or to obtain certification in a particular article and approval to proceed to the installation an aircraft.

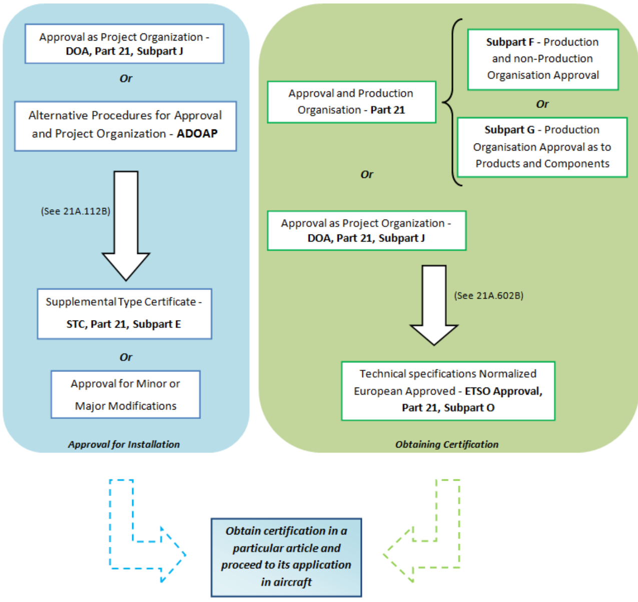


Figure 2-1 Flowchart of the Certification Process

In the European Certification Specifications (CS - Certification Specification) published by the Agency match the technical standards are not binding, which however, compliance with these is a necessary condition for obtaining certification. [1]

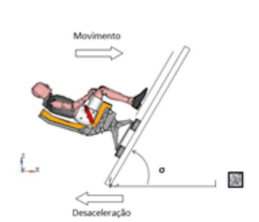
As regulations change over time, sometimes due to the detection of problems or suggestions for improvements, it should be noted that not all aircraft are in service comply with the design regulations for the year due. The regulations are revised and released as an Amendment (**Amendment Number**).

In paragraph **25.561 of EASA CS-25** are stipulated instructions of static loading tests. They argue that the respective chairs and fittings shall not deform significantly before the application of the following inertial forces acting independently of the surrounding structure: [2]

i. Up, 3.0 G;
ii. Forward, 9.0 G;
iii. Lateral, 4.0 G;
iv. Down 6.0 G;

v. Backward, 1.5 G.

Paragraph **25,562** develops the following requirements in the development of the two dynamic tests, comprising positioning the chair should be described in relation to the movement, the speed during the collision and deceleration forces to achieve minimum. In the first test the dynamic forces are applied mainly in the vertical direction and in the second test downward forces predominate in the longitudinal forward.



Scheme of the 1st Dynamic Test

Scheme of the 2nd Dynamic Test

Requirements for Dynamic Testing	1º Test	2º Test
Minimum speed at impact (m / s)	10.7	13.4
Peak deceleration, Gmin (G)	14	16
Instant Time to Peak, tmax (s)	0.08	0.09
Initial Conditions		
Fixing angle, σ (°)	60	0
Horizontal misalignment angle, θ (°)	0	10
Tilt Angle Vertical, α (°)	0	10
Bearing angle, β (°)	0	10
Compliance Criteria		
Deformation Limit	Negligible, while not compromising structural integrity, remaining attached to all anchorages	

Figure 2-2 Certification Test Requirements

3. Scope of the Concept Model Study

3.1. Historical Review

In the aeronautical world exists a varied range of models of chairs, ranging in size, shape, comfort, totally dependent on the context in which they operate. Throughout this chapter we present the main distinguishing factors between various concepts in an attempt to locate the chair model that is addressed in this paper. Develops an historical review as way to show the evolution of the chairs over the time as well as the current state of the art.

At the end of the chapter expounds on all the procedures that have been developed since the initial contact with the physical structure of the chair by plane to the development of a CAD model that allows the reliable performance of a whole set of computer simulations.

The first scheduled air service came to January 1, 1914, with the invention and use of the seaplane carrying a single passenger over the Tampa Bay, St. Petersburg, Florida. The world's first airplane passenger appeared in 1919 with 26 seats Lawson Airliner, was composed of two rows of seats designed based wicker woven arranged throughout the cabin together with its huge windows celluloid, see Figure 3-4. [3]

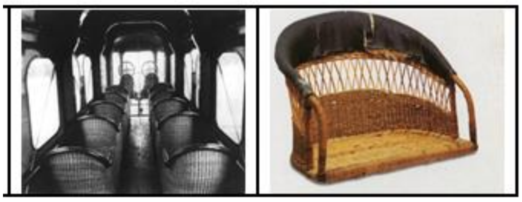


Figure 3-1The oldest aircraft seat

In 1930 with the softening of prices of pure aluminium, the Aluminium Company of American (Alcoa) introduced the world's first seat constructed from aluminium, eliminating the problems of warping, combustibility and infestations associated with wood models. For example, three years equipped its Boeing 247 with two rows of such seats.

Figure 3-2 First seat developed in aluminium and its commercial application at Boeing

3.2. State-of-the-art: Economy Class

Before make a comprehensive presentation of some of the most innovative concepts of seats in use or under development, will show up certain keywords that should be in mind on the development of new conceptions. As a note of differentiation, the blocks at green are features to take into account the perspective of the airline, while others are related to the perspective of the user.

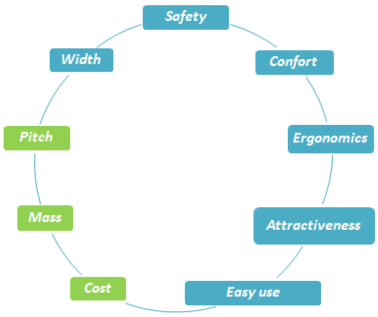


Figure 3-3 Relevant keywords in the evaluation of new concepts

3.2.1. Recaro - BL3520

Figure 3-4 Presentation of the Recaro BL3520 [4]

It takes only four keywords for a simple way to describe this new set of Recaro seats: Habitability Maximized, Improved Comfort, Cost Reduction and Design Catchy.

3.2.2. Aereas Seat Project

Figure 3-5 Presentation of the Aereas Seat Project [42,43]

This new idea is collaboration between Geiner Aerospace, the Kobleder Knittec and Lukedesign. Encompassing design, development and construction of a new seat that sets new standards in terms of comfort, weight, design and materials costs using latest and innovative.

3.3. Presentation of the Model

Some parts of the original structure in the present work was based as a starting point for the development of a new concept are exemplified in the figure 3-6. The approach consisted in dismantling one piece at all the main components of the structure which could influence absorption and the driving efforts, while important physical testing for certification.

Figure 3-6 Photos to Model Study, obtained in TAP®

3.3.1. CAD Modeling

In general, in geometric terms can split the universe of structural components into two groups, one with respect to components with defined geometric shapes and other geometric shapes not defined. We understand that the components defined geometric shapes that can be defined geometrically by points, lines and circles, geometric shapes are not defined as those in which it is impossible to extract any tangible measure for later playback CAD.

Figure 3-7 A component of the real model

For the construction of most the components on the assembly of the three-dimensional model was used CAD software Autodesk Inventor Professional 2013®. In the figures below shows the method explained above for the construction of component 20 using several benchmarks for the preparation of sketch of the outside and cavity of the component.

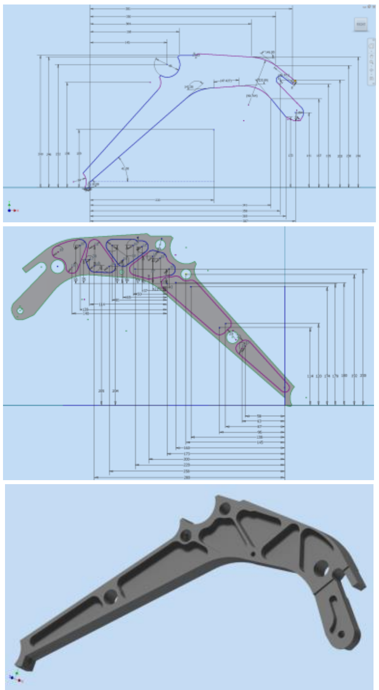


Figure 3-8 The construction of one component

There were, however, other components that are presented as a challenge, due to the non-specificity of their contour shapes. Unlike the previous component and the other examined, there were two requiring the use of another surface modeling software Alias Automotive 2013 Autodesk®.

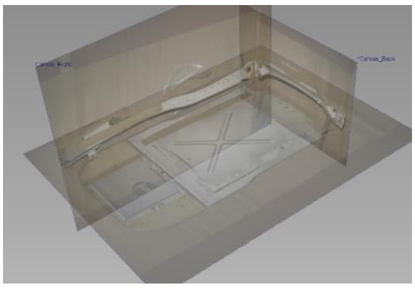


Figure 3-9 Reference Plans

A key point lies in the dimensional adjustment of views used. Given that the shooting distance may vary, we used a reference volume to ensure that the three views were synchronized with each other, and represent the original dimensions of the physical model.

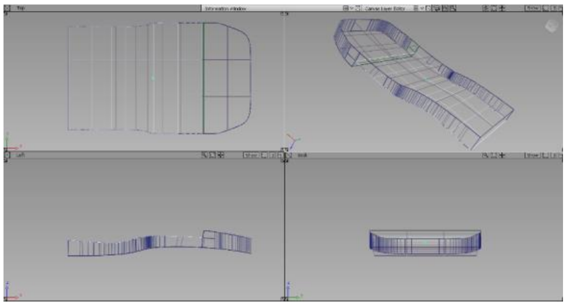


Figure 3-10 Final Model of Sheet Support Coasts

Figure 3-11 The Final Model

4. Materials used in the structure

Like all equipment used in the aircraft industry, the criteria for selection of materials for the structure of the seating system mainly consists of six assumptions: high mechanical strength, significant extensions to avoid brittle fracture, good corrosion resistance, low density to reduce weight, machinability and formability, and last but not least the question of price.

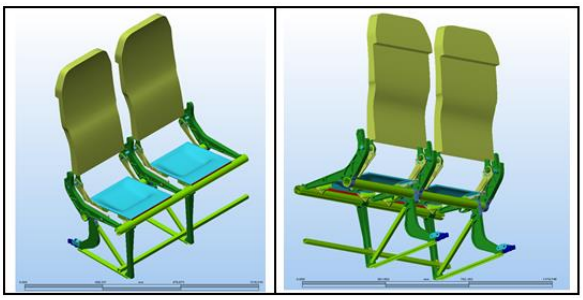


Figure 4-1 Mounting Assembly Seat Frame for Static Testing

Brass	Red Brass
Polymeric	*ABS*
Stainless-Steel	*AISI 302, cold-rolled*
High Strength Steel	*AISI 4130*
Spring Steel	*AISI 1080, rolled*
Machined aluminum	*Al 2024-T351*
Extruded Aluminum	*Al 7075-T651*
Embossed Aluminum	*Al 6061-T651*
Shock simulator	*Al 7075-T651*

Figure4-2 Correspondence Table Material Type vs Color

The majority of the components present in the structure are composed by aluminium alloys. With respect to the set of machined components, it is noted that a large part of the material 'raw' is waste, it is then preferable to select an alloy of lower cost, but at the same time guaranteeing all the requirements of resistance, appearance and maintenance. The choice fell to the alloy 2024-T6, so it was decided initially by one whose thermal treatment gave him added strength.

For the set of stampings preference for the choice of alloy 6061-T651 is due to the suitability for these shows the manufacturing process of stamping. As in the previous case it was decided to heat treatment as to confer improved mechanical properties.

We grouped in the subset of all components extruded components that are possible to obtain by aluminium profile (extruded), although they can be subsequently subjected to light machining operations. For this type of components was chosen choice of alloy 7075-T651.

The method of selecting the type of spring steel to fit for this type of component was up due almost exclusively to the options that are available simulation software. The only steel of this type available was 1080. The choice fell on the laminate 1080 in the state as it was this that possessed better mechanical properties in terms of strength.

Then the approach is high-strength steels used in aerospace components obtained through the forging process. The criterion of separation between this type of steel and the other relates to the value assigned to the yield stress, which is the first about 1200 MPa.

For the components of high-tensile steel present in the structure methodology of choice was then also based on the availability BOM simulation software adopted. Thus we used the 4130 steel with a temper heat treatment at 425 ° C, leaving a yield of approximately 1190 MPa.

Finally with regard to ferrous metals, there is set the type of material used for example in the design of the print seat, or the type of stainless steel used. Unlike the vast majority of the other materials used in the seat, this component is not made from aluminium alloys, requiring strength, fatigue resistance and conformation requirements that are only achievable with the application of ferrous metals. For the same reasons that the earlier the choice fell on 302 cold rolled steel.

For choose of polymeric material the first highlight that we need to have is some properties and specifications that the material must possess in order to play a full role in the environment in which it operates:

- Mechanical Resistance to Impact (dimensional stability under tension, compression)
- Fracture Toughness
- Vibration and Shock Absorption
- Low Coefficient of Friction

  In terms of wear resistance and flammability properties ABS displays good, hence the choice.

5. Study Models

Are developed one model to make the simulation of static certification and another to perform the simulation of the dynamic certification. In the first case it was decided to build a seat frame of two places, while remaining faithful to the original model, where the load was applied to the structure through a punctual distribution of forces. For the second case it was decided to simplify the model since the computational effort involved is indeed far superior when compared to the previous test, adopting a structure from one place only. In the second trial used a simplified model of a dummy for the application of efforts in the seat frame. The model was in a sitting position and their movements were constrained by the use of a safety belt fixed to the support structure.

5.1. Model Structure for Static Testing

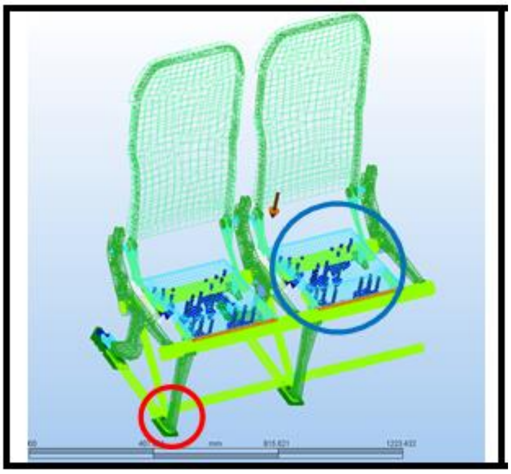


Figure 5.1 Loading and Constraints

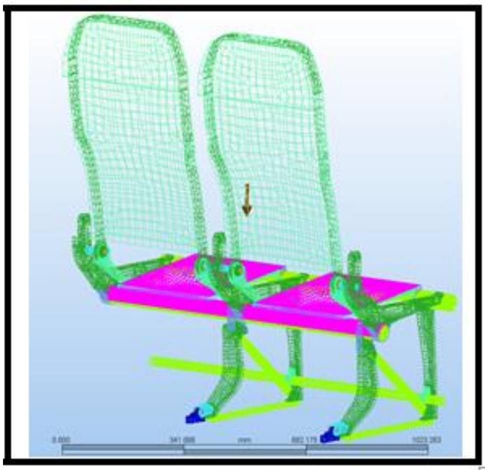


Figure 5-2 Zones of Contact between Surfaces

Figure 5-3 Test for Static Seat Certification [7]

On the Figure 5-2 to enhance the surface (rose), which is defined as possible contact surfaces between components, thus avoiding the interpenetration of meshes, since with this loading plate of the seat will tend to deform into contact with the tube support and forcing it to deform well. In the Figure 5-1 (green) shows the overall constraint applied at four points of the base of the structure simulating a fixation of the floor of the plane, and the pattern of distribution of the nodal load vectors (in blue). Figure 5-3 shows, by way of example, a static test in the upward direction.

5.2. Model Structure for Dynamic Testing

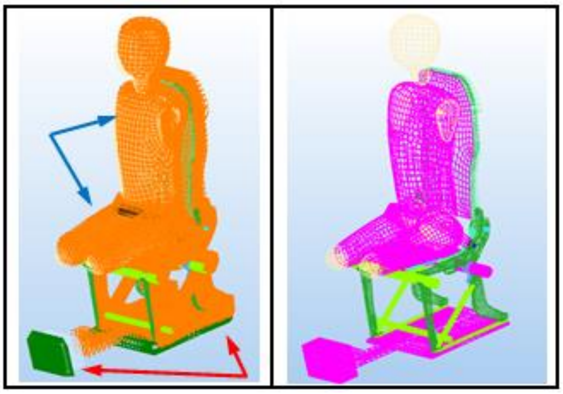


Figure 5-4 Representation of the Model Seat Frame with Dummy

Figure 5-5 Test for Dynamic Seat Certification [7]

In Figure 5-4, the right side (rose) to highlight the areas that have been defined as possible contact surfaces between components (Surface-to-Surface Contact) thereby interpenetration between meshes. All contact surfaces between the dummy and the structure of the chair have been customized (Frictionless Contact) as elements slip between the legs and trunk of the dummy (Frictionless Slide), and all surfaces of the chair support that will come into collision with the static block. In the left (green) shows the constraints applied to the chair structure allowing only the rectilinear movement towards and collision block (Orange) vectors representing the initial velocity imposed to the assembly.

6. Presentation and Discussion of Results

6.1. Results of Static Tests

An Static Certification Essay according to CS-25.561 6 G's vertically downwards uses as reference an occupant of 77 kg's: $\mathbf{182}\ \boldsymbol{N} \times \mathbf{25}\ \boldsymbol{vetores} = 4550\ N/por\ assento <=> 77\ Kg's \times 9.81\ m/s^2 \times \mathbf{6}\ \boldsymbol{G's} = 4532N$

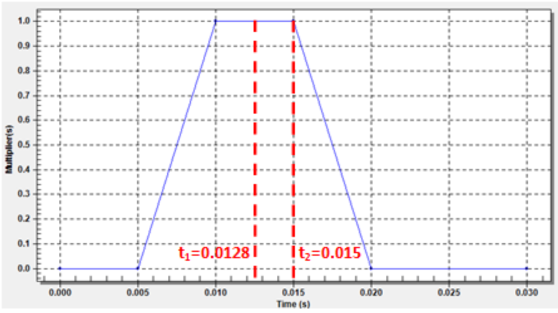


Figure 6-1 Graph Curve Applied Load

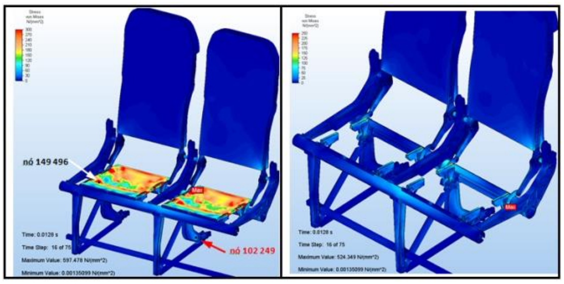


Figure 6-2 State of Stress in the structure at time 0.0128s

Figure 6-2 depicts the tension state of the entire structure, during the time of maximum force at time 0.0128 seconds differences between the two figures resides in the fact that in the left figure of the seat plates are not represented, and the range of graphical representation of the voltage is between 0-250 MPa. The structural material with lower yield stress this throughout the structure corresponds to the 6061-T651 with 262 MPa, thus observing the image on the right of Figure 7-2 it can be seen that the plastic deformation is virtually non-existent, except for some points where it is natural outweighs unrealistically.

In order to understand how efforts are transmitted along the leg structure, understood in this case as a critical component in terms of sustaining the passenger tried to make sweeping changes in the state of stress across multiple nodes, transversely and longitudinally respect to the direction of application of load.

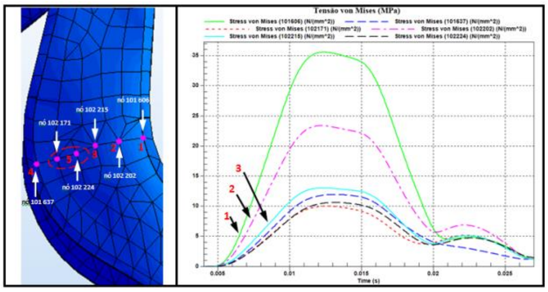


Figure 6-3 Sensitivity of the tension along the leg structure

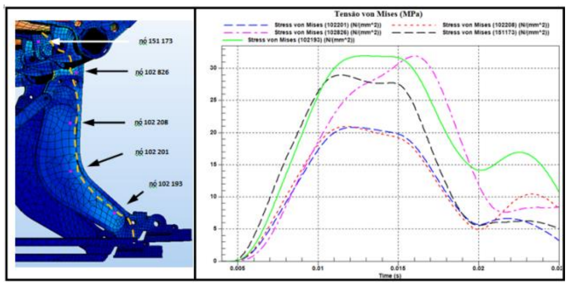


Figure 6-4 Sensitivity of the progression of tension in the structure

Analysing the graph of the evolution of the voltage set points marked along the seat frame (Figure 6-4), and also taking into account what is comprised in the previous paragraph in relation to the cross-state voltage component can be assume the critical path transmission efforts over the structure of the seat for the static test is one which is represented by the dashed line representation in the left side of Figure 6-4.

7. Dynamic Test Results

As the whole structure is mainly calculated based on several components of aluminium alloys, will be to limit the spectrum of stress distribution to the yield stress of the alloy with the highest yield point, the alloy Al 7075 with a voltage yield of 500 MPa.

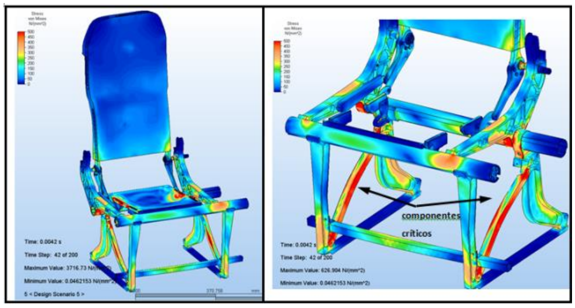


Figure 7-1 State of Tension in the Structure on last instant of time

In figure 7.1 we can see the state of tension of the whole structure to the last time point in which it was possible to get results. Just looking for structural components made from aluminium, it can be seen that there are two components (marked with two arrows) of greatest importance to maintain the integrity of the structure, being critical components to be analysed. Given that the yield strength of this material is 500 MPa, then these components are on the threshold of plastic deformation.

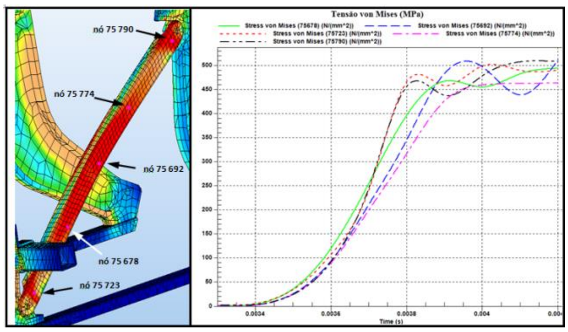


Figure 7-2 Sensitivity of the progression of the tension in critical component

Looking in more detail the evolution voltage to various nodes throughout the critical component, it appears that four of the nodes represented already reached the point of maximum tension and maintaining this uniform until the end of simulation. Thus it can be inferred that the time interval was sufficient to simulate the structure is subject to its maximum deflection.

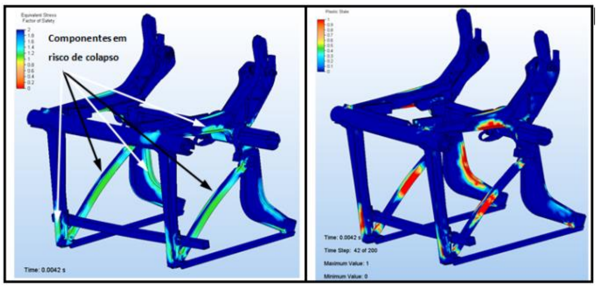


Figure 7-3 Representation of the Safety Factor, and Plastic Deformation Zones

Referring to Figure 7-3, the right image represents the various zones which have undergone plastic deformation, however, by analysing the distribution of the safety factor regarding the tensile strength of various materials can conclude that there are at least five components who are at risk of collapse, and surface tension very close to the tensile strength.

8. Conclusions

It was necessary to make some simplifications in three-dimensional models developed with CAD software, and models of finite element analysis in order to manage to obtain valid results in an attempt to develop the certification process of the structure through computational simulations. Based on the influence of these simplifications, the results do not allow the exclusion of physical tests for certification purposes. However, the model of work throughout the thesis allows to develop a preliminary analysis will approximate those expected results, anticipating possible weaknesses of the concept, and thus reducing the number of physical tests required until final certification.

Regarding computer simulations performed, we can conclude that the structure does not undergo plastic deformation modelled remarkable to compromise the physical integrity and safety of the passengers due to the collapse of same after an emergency landing, according to the requirements of Static Testing and Certification dynamic **(according to CS 25.561 and CS 25,562).**

After completion of this study looks a possible future work. To improve the current frame while maintaining the mechanical strength on the certification tests, reducing the number of components and optimizing the same, thereby reducing the weight of the structure. At the same time attention should revert to the user, trying to adjust the seat position of each user under the optimal conditions of temperature and humidity body. In short keywords and how guidelines for the project, should try to mount a concept that is simultaneously: lightweight, simple,customizable,attractive, environmentally friendly, comfortable, adjustable and finally relatively inexpensive.

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