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Modeling and Simulation of an Aircraft Passenger Airbags

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Abstract

Aircraft's airbag is a concept in development due to its utility in case of a fatal accident. In order to increase the passive safety of passengers during take-off accidents, landing accidents and turbulence caused by critical weather, the integration of airbags seems necessary.

The approach in this study is based on modeling and simulation a new concept of airbag that will protect different sizes of passengers. A finite element model of airbag will be established respecting the properties of materials and bending. In order to validate our model, a digital crash-test simulation was conducted with analysis of the deformed results of manikins.

Keywords: *Passive safety, Aircraft airbag, Modeling, Crash-test, Simulation.*

1. Introduction

In aeronautical engineering, improving passive safety in aircraft remains one of the major challenges of designer. In this register, the passengers are in direct and constant interaction with highly complex equipment, which must meet strong operating constraints.

For the evaluation of protective devices of passivity, the aeronautical industry requires the crash-test simulation. It not only predicts accurately and in detail the characteristics of crash-test, but also ensures the development of aircraft equipment in a shorter term and at a lower cost [1].

This article aims to design and develop a finite element (FE) model of new airbag morphology to protect economy class passengers. This airbag will be folded and integrated on the seats and the galleys of the first row [2].

The digital crash-test simulation of the manikin-airbag will enable us to study the dynamic behavior of the model under specified conditions. It will also allow a detailed analysis of the test results and then optimize the airbag design to increase passengers' passive safety.

2. Airbag sizing and modeling

2.1 Airbag dimensioning

The dimensions of the airbag were chosen in order to protect the three sizes of the manikins on the one hand and, on the other hand, to respect the distance of comfort between the galley and the head of the dummy in economy class.

The anthropomorphic manikins Hybrid II exist for three different population categories [3]:

- 95th percentile: 1m90, 100Kg representative of 95% of the population and below.
- 50th percentile: 1m75, 80Kg representative of 50% of the population.
- 5th percentile: 1m45, 50Kg representative of 5% of the population and below.

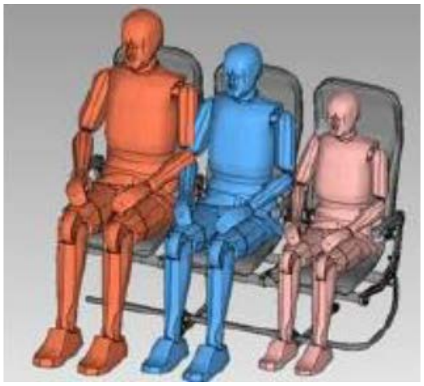

Fig. 1 Manikins Hybrid II with 3 sizes

Specialists in the field of biometrics have defined the anthropometric proportion that is 0.103 between the size of the body and the face of a human being.

Using information mentioned above with the margin of comfort and stability for the passenger, we were able to establish the dimensions presented in Table 1:

Table 1: Dimensions of the head and the contact surface models

Mannequin	***Head size***	**Diameter of the contact surface**
The big manikins	195.7mm	220 mm
The medium manikins	180.25mm	200 mm
The little manikins	149.35mm	175 mm

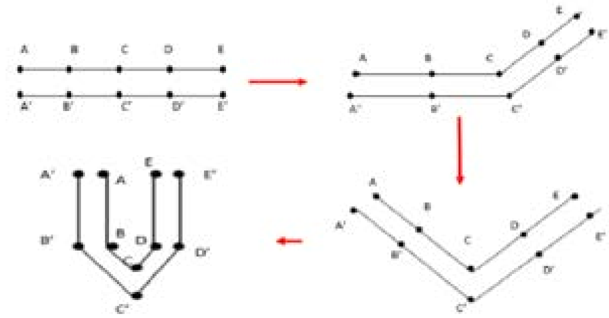

Fig. 3 Folding method

2.2 3D geometrical and FE models

The modeling steps of the airbag starts with the design of the 3D geometric model [4], then the extraction of the 2D neutral fiber, the assignment of physical properties, materials to the created surfaces and meshing surfaces with a size of 5 x 5 elements destined for the crash test. These steps are described in Figure 2.

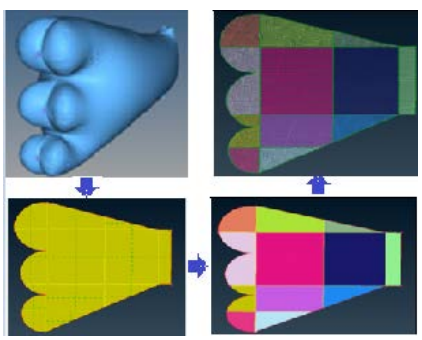

Fig. 2 the steps of the finite element model development

2.3 Folding the airbag

Folding is an important step in the design process of the airbag. Indeed, an easy and fast deployment of the airbag requires adequate folding. For our work, we used technical folding, with a method based on three axes of rotation. However, the fold of the two surfaces located on both sides of the rotation's axis is on the latter. The advantage of this method is that it is faster and does not generate intersections during folding.
In the case where we are obliged to fold a morphology which consists of several surfaces, we can resort to more than three axes.

The folded airbag model obtained according to the folding method is shown in Figure 4.

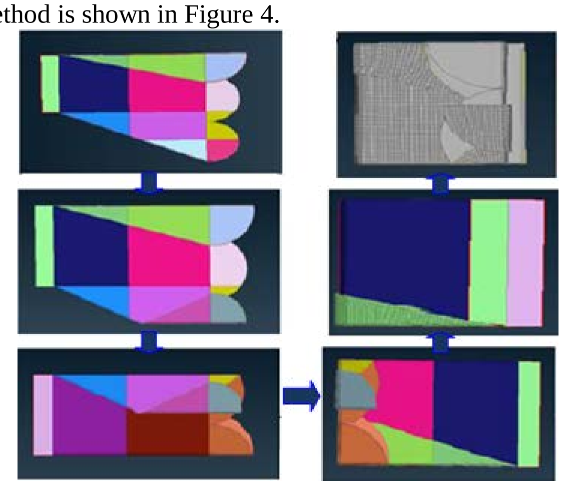

Fig. 4 Airbag model folded

2.4 Materials and Property Settings

The most used material in the airbag industry is Nylon 6.6, which represents the most important characteristics for an airbag fabric [5]:

-High tensile strength.
- High resistance to tearing.
- Low air permeability.
- Good heat capacity.
- Good folding behavior.
- Better absorption of energy.
- Good coating adhesion.
- Functionality under extremely hot and cold conditions.
- Reduced abrasion of the skin (softness).
- Good thermal stability.

2.5 Airbag injection gas properties

In order to ensure the deployment of the airbag during the crash test [6], we apply the load "Monitored volumes" to the airbag. This load is used to model gas tanks, fuel tanks and airbags.

This tool allows defining the properties of the gas that we will use for the airbag deployment as well as the injection surface and the injection rate in the aeronautical conditions.

The deployment of airbag is provided by a cold gas injector based on Helium 66MPa. The injection curve represents the variation of the injected in the airbag as a function of time.

The curve below represents the flow of gas injected for our model of airbag.

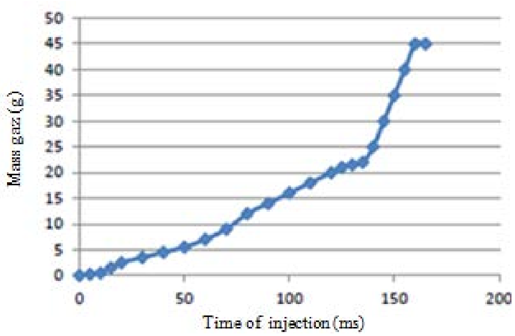

Fig. 5 Curve of the gas flow injected into the airbag

This curve was defined based on the moment of first contact between the manikin and the airbag.

The behavior of the gas temperature during injections constant at a value of 293 K.

3. Simulation and analysis results

3.1 Full simulation model

In order to validate airbag model, it must be defining the full simulation model. This model includes seats, the three manikins, wall and FE model airbags fixed and centered relative to the faces of the manikins, Figure 6.

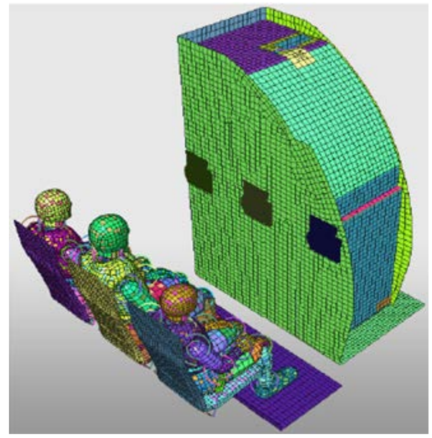

Fig. 6 Full model (airbags, Galley, Seats, manikins)

3.2 Loads applied on the crash model

3.2.1Imposed acceleration

To model the conditions of use of the airbag in the aircraft (during a bad take-off or landing or during turbulence), an acceleration imposed with gravity will be applied to the on the assembly including galley, seat and manikin.

The modeling of the aircraft deceleration generating the deployment of airbag in reality is based on the curve of Figure 6 made from the results of several real crash tests.

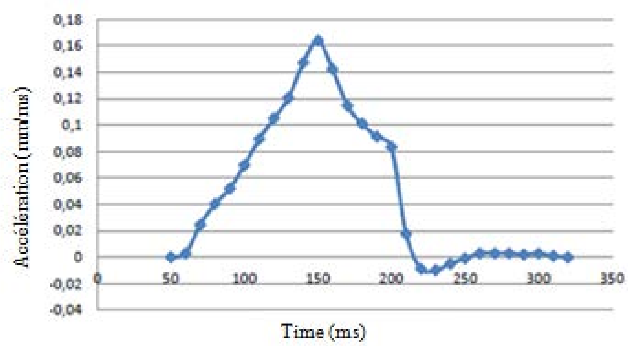

Fig .7 Deceleration evolution

3.2.2 Gravity evolution

In this part, we model the effect of gravity on the whole model, then on the behavior of the manikin alone. For the manikin, we define two gravities load, one along the Z-axis and the other along the X-axis. Gravity along the X axis is used just for the first 25 milliseconds. it enables to position the dummy and stabilize the front seat that will be impacted by the deceleration effect. For the positioning of the manikin along the X axis, we used the gravity evolution, Figure 8.

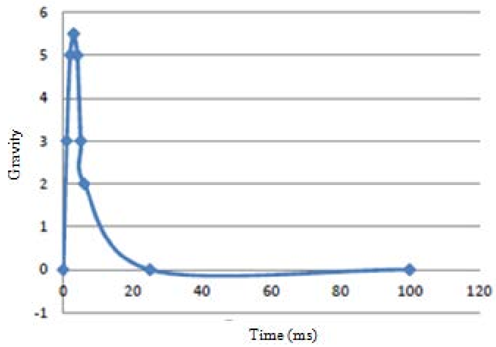

Fig. 8 Gravity evolution

3.3 Results of the crash-test scenario

The simulation of the crash-test validated the operating process of the complete model of the airbag by ensuring the protection of the three manikins, Figure 9. The results are analyzed based on the dummies reactions and displacements [7].

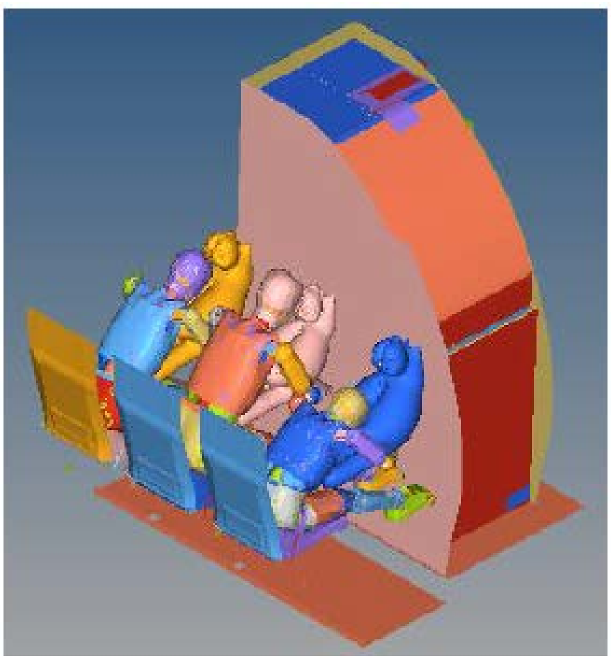

Fig .9 Crash-test scenario of the complete model

The figure 10 illustrates the analysis of the simulation results of an airbag deployment in front of a manikin. The airbag morphology designed for the protection of the head and thorax meets the criteria of contact and safety during compression.

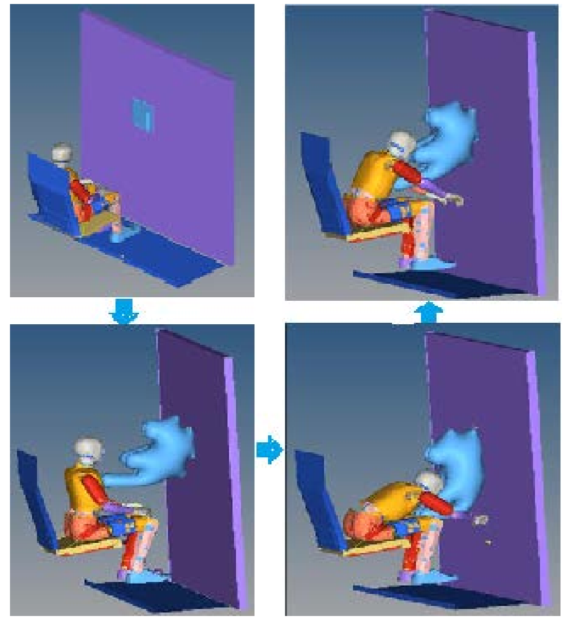

Fig 10 Analysis of the simulation results

Step 1: A t = 0 ms

The airbag is not yet deployed.

Step 2: A t = 156 ms

The airbag is fully extended. The moment of the first contact between the mannequin and the airbag is done with the neck.

Step 2: A t = 200 ms

The dummy moves to the galley, always keeping in touch with the airbag.

The contact is made between the face and the second surface of the airbag.

Step 2: A t = 250 ms

At the end of the simulation, the mannequin moves back to the seat to return to its initial position.

4. Conclusions

The process of developing an Aircraft passenger airbag concept is based on the design, the modeling and the crash-test simulation. The results confirm the protection of the passengers of different sizes in case of incidents or acceleration and deceleration during the flight critical phases.

Indeed, the design of the airbags took into account the parameters of ergonomics of the aircraft and the dimensions of the passengers. A FE model of the airbags was developed by characterizing the materials used and the folding method for reuse.

Finally, the analysis of simulation results of the model, the passenger reactions and displacements, allowed validating, by appropriate tests, the operating parameters of the airbag. The experimental tests could be envisaged in order to correlate and refine the model developed in advance an eventual industrial exploitation.

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