AIRCRAFT DITCHING CERTIFICATION BY SIMULATION USING SMOOTHED PARTICLE HYDRODYNAMICS (SPH) FORMULATION IN MSC NASTRAN AND OTHERS

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Agenda

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Introduction

Analyze of an Aircraft dynamic loads and resultant structural response is a challenge, the goal of these studies is to investigate on aircraft emergency landings on water, generally called "Ditching"..

However, Physical testing is increasingly being replaced by numerical simulation models because it provides a more rapid implemented time and it is less expensive.

References-Background

1. *FAA Report AR-95/54 Transport Water Impact and Ditching Performance* (http://www.ntsb.gov/Dockets/Aviation/DCA09MA026/419887.pdf)

2. *Civil Aviation Safety Authority Australia CAAP253-1(0) – Ditching* (http://www.casa.gov.au/download/caaps/ops/253-1.pdf)

3. Stubbs, S. M. 1967, *Dynamic model investigation of water pressures and accelerations encountered during the landings of the Apollo spacecraft*, NASA, TN D - 3980, Washington DC, USA.

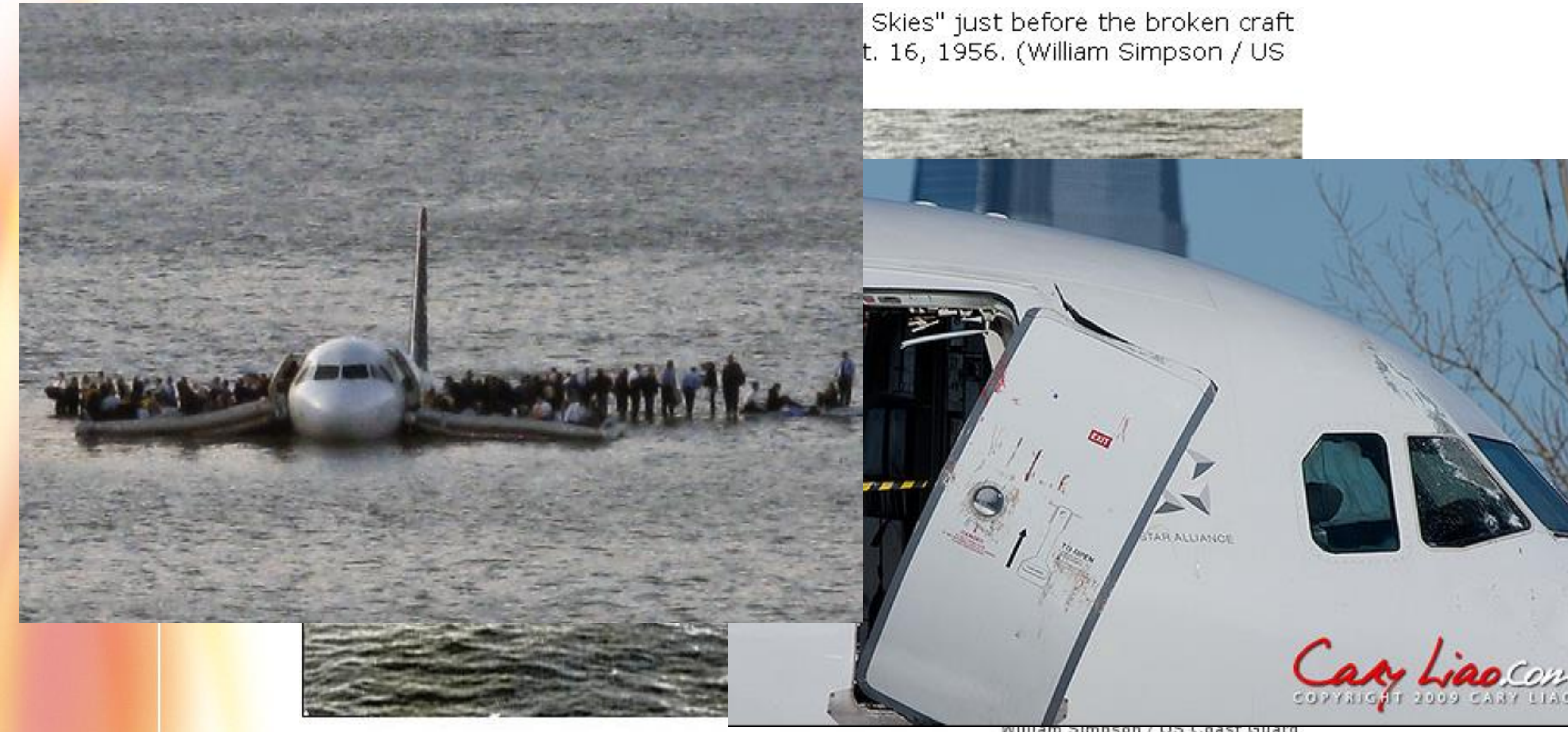
4. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 7-10 April, Schaumburg, IL, USA

5. Ubels, L. C. and Wiggenraad, J. F. M. 2002, *increasing the survivability of helicopter accidents over water*, National Aerospace Laboratory NLR, NLR-TP-2002-110

6. Vignjevic, R. 2004, *Review of development of the smooth particle hydrodynamics (SPH) method*, Cranfield University, UK.

7. Vignjevic, R. and Meo, M. 2001, 'Simulation of helicopter under-floor structure impact on water', *International Journal of Crashworthiness*, vol. 6, no. 3, pp. 425 - 443

Accuracy – ditching problem



Ditching– Regulation

Airframe design should assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable crash impact conditions.

- FAR *.562 Crush Requirements

Test I	PART 25	PART 23
Time to Peak (s)	0.08	0.05
Peak - Acceleration Pulse (g's)	14	19
Peak - Z Acceleration (g's)	12.1	16.4
Peak - Z Velocity (ft/s)	31.2	26.5
Peak - Z Displacement (inch)	30.3	16.2

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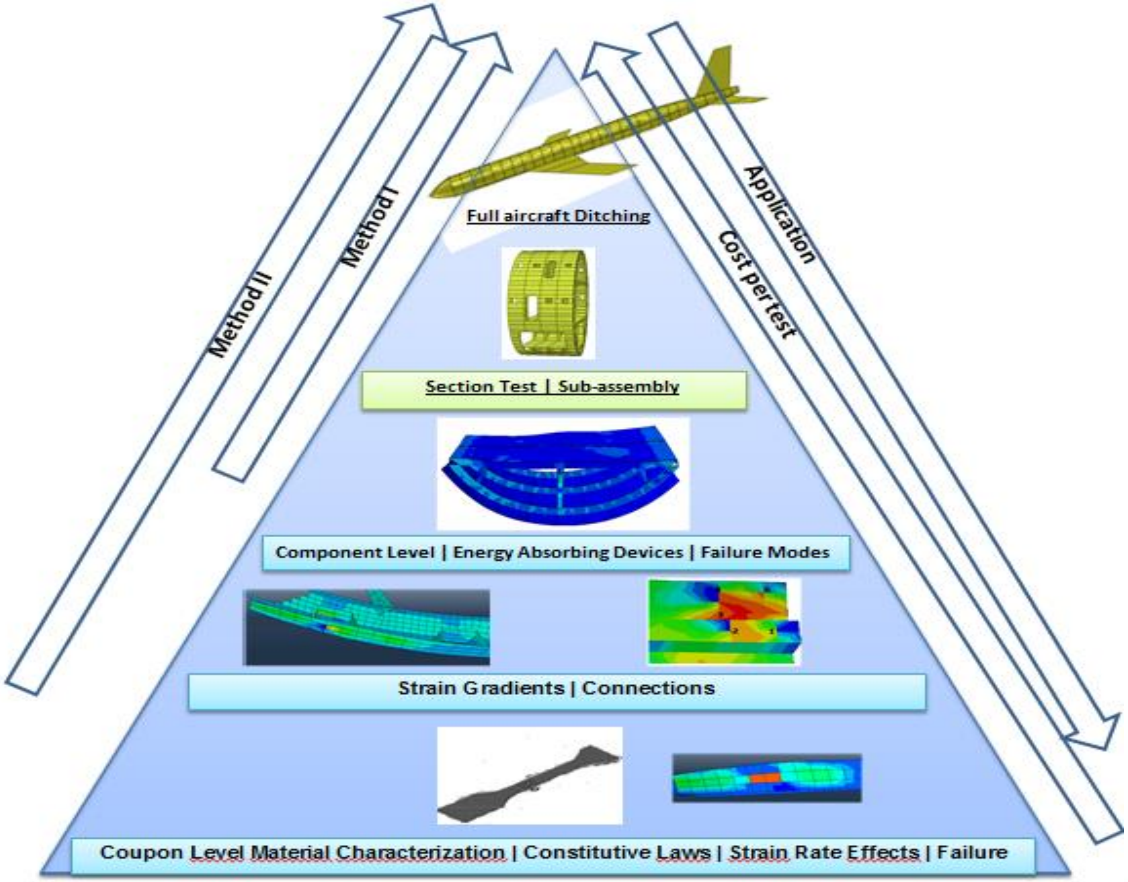
Building Block Approach-
Design Validation



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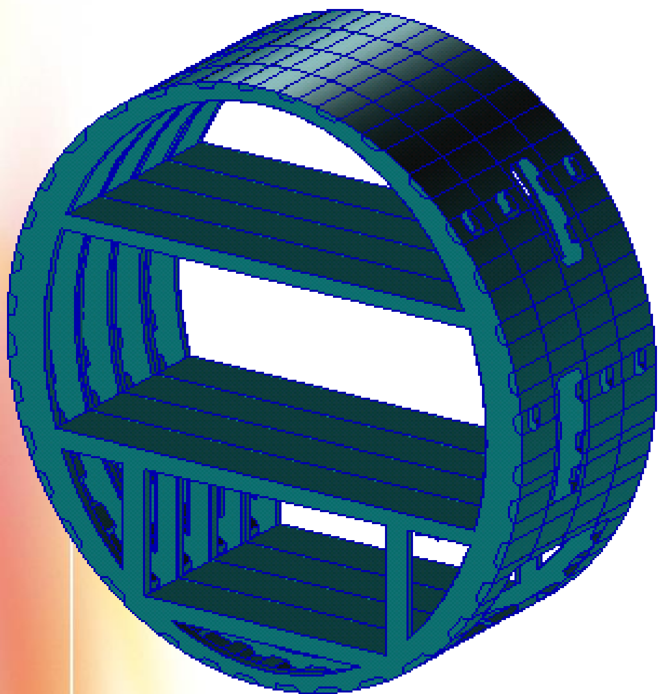
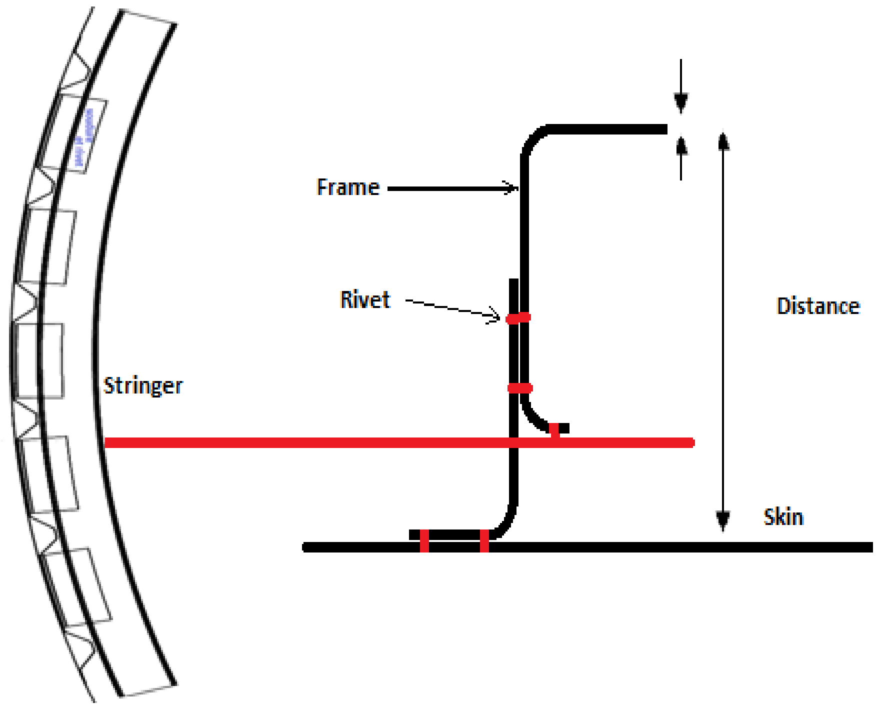
Design – Procedures and Requirements (Patran model)

Design of the different Structures





- ✓Skin, airframe, tie shear, stringers etc..

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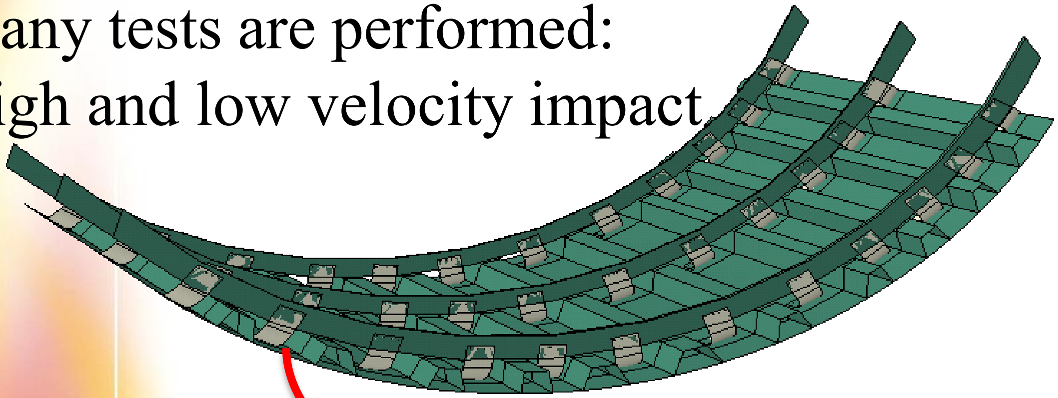
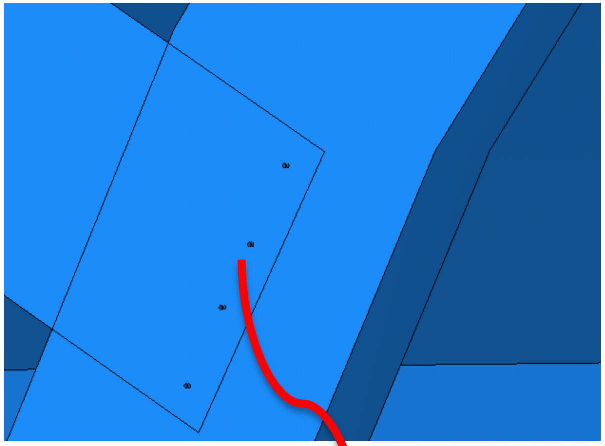
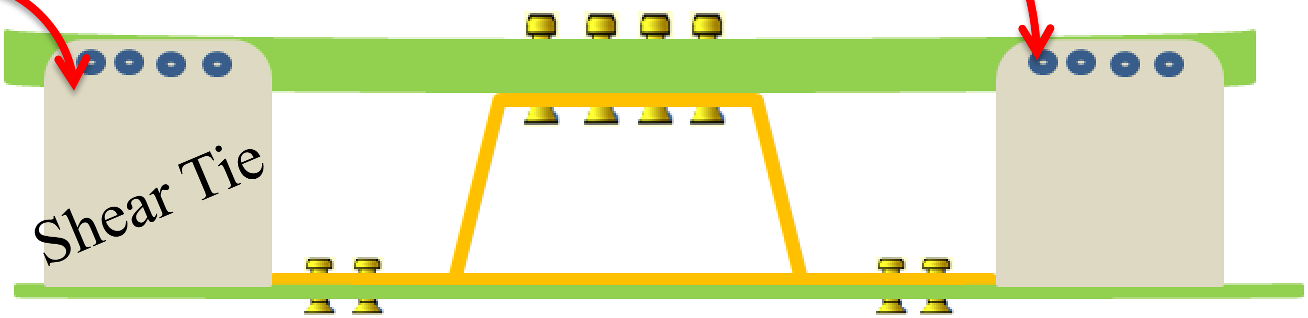
Design – Procedures and Requirements

For the validation of the structure
Many tests are performed:
High and low velocity impact

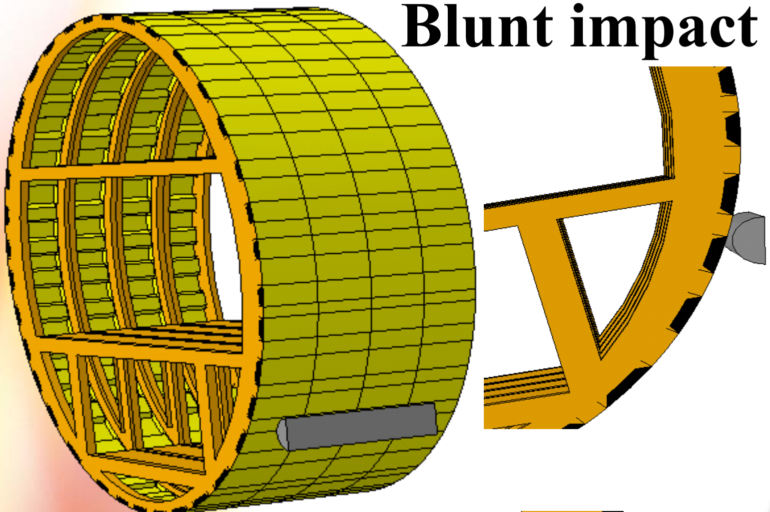


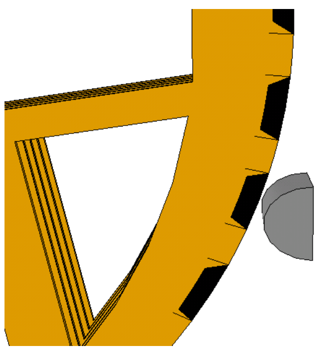




Structure Performances and validations - Abaqus (Low and high V impact)

Blunt impact

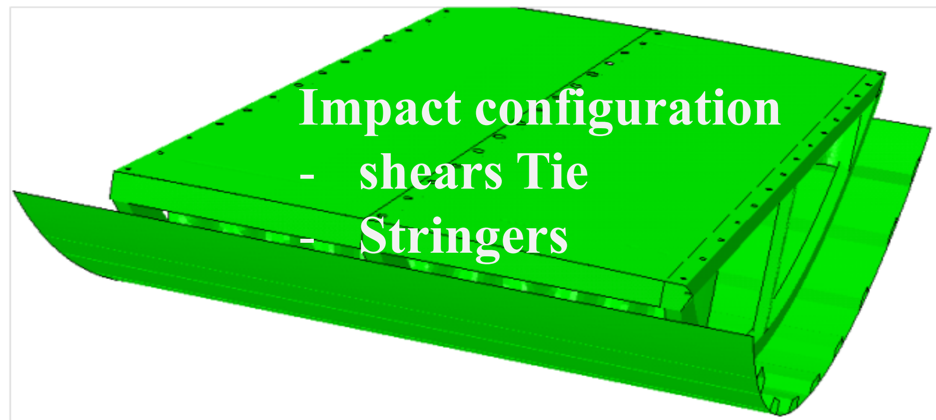




Vx: 2m/s
Impactor: 200kg

CRASH TEST /High velocity Impact

Vx: 30m/s
Vz:15m/s



A survival crash: Structure must be able to Resist during an impact of 3ft /s.

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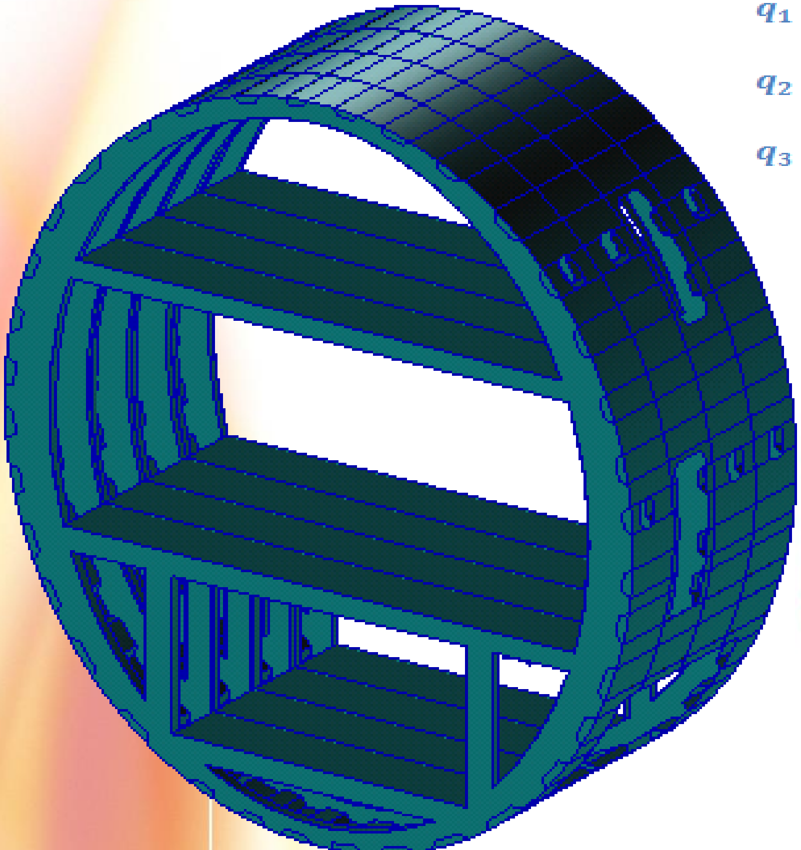
Cargo Doors and Windows – Configuration Methods

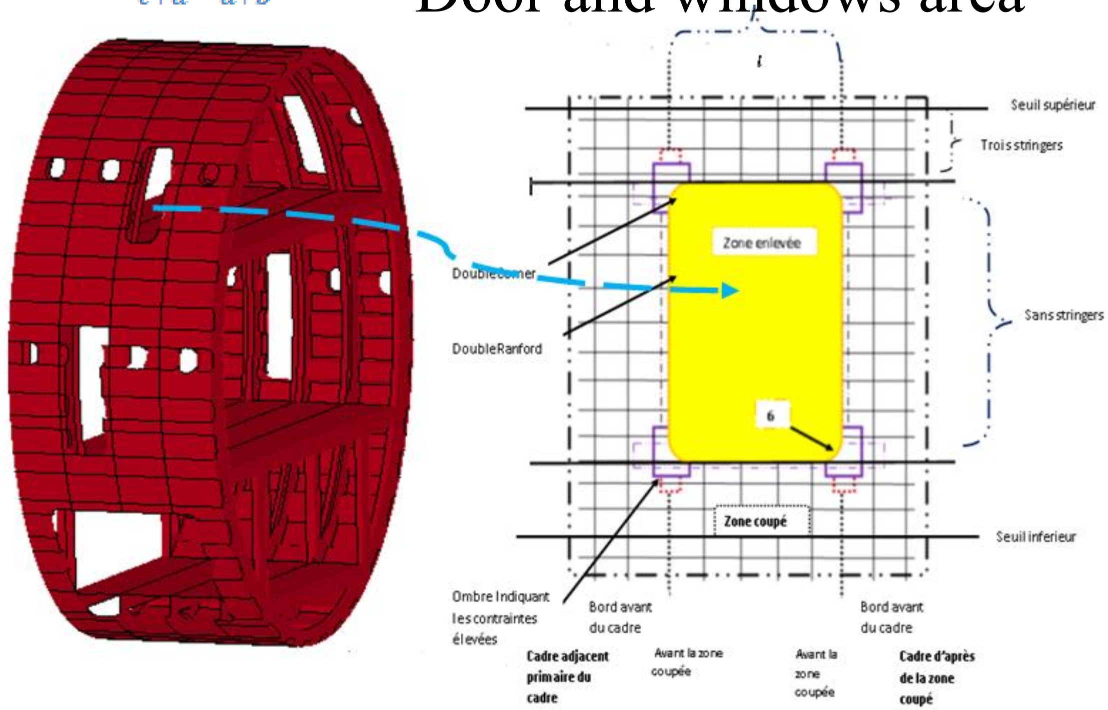


$$q_1 = (1 + \frac{h}{a+b})q_0$$

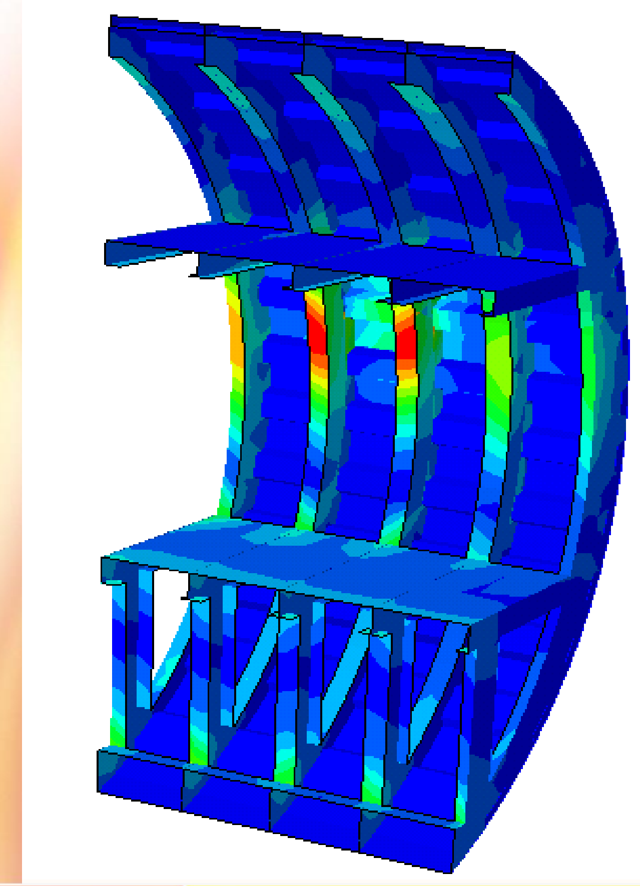
$$q_2 = (1 + \frac{l}{c+d})q_0$$

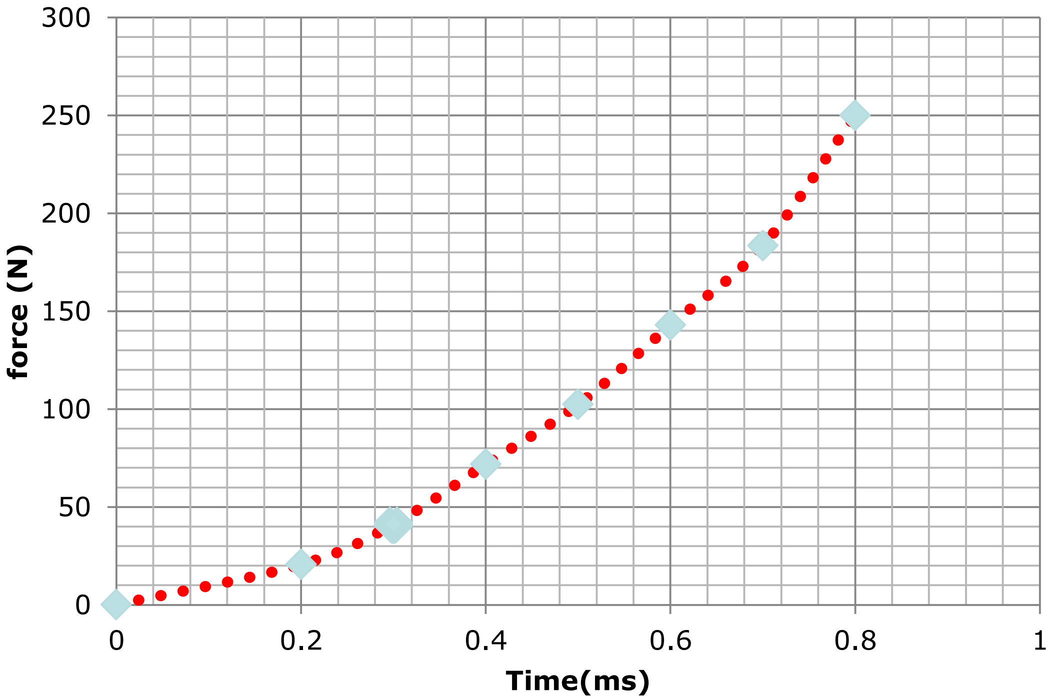
$$q_3 = [1 - (\frac{l}{c+d})(\frac{h}{a+b}) - 1]q_0$$

A specialized materials
Are applied for to assign
Door and windows area



Force after impct- Blunt impact





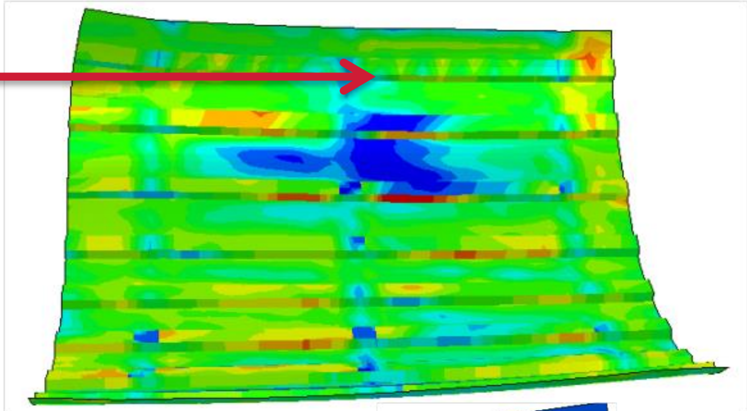
In Abaqus

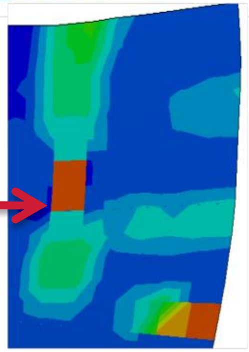
Crash test-
High velocity Impact with ABAQUS

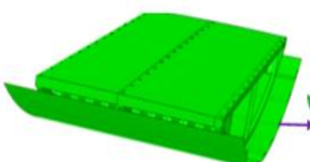
<u>Increased usage of analytical tools:</u>

- Airframe crash behaviour
- Dynamic skin testing
- Impact pressure loads

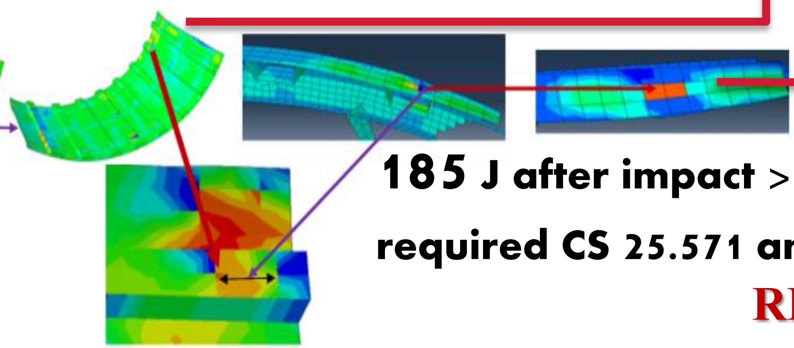
"Equivalency" with past successful designs







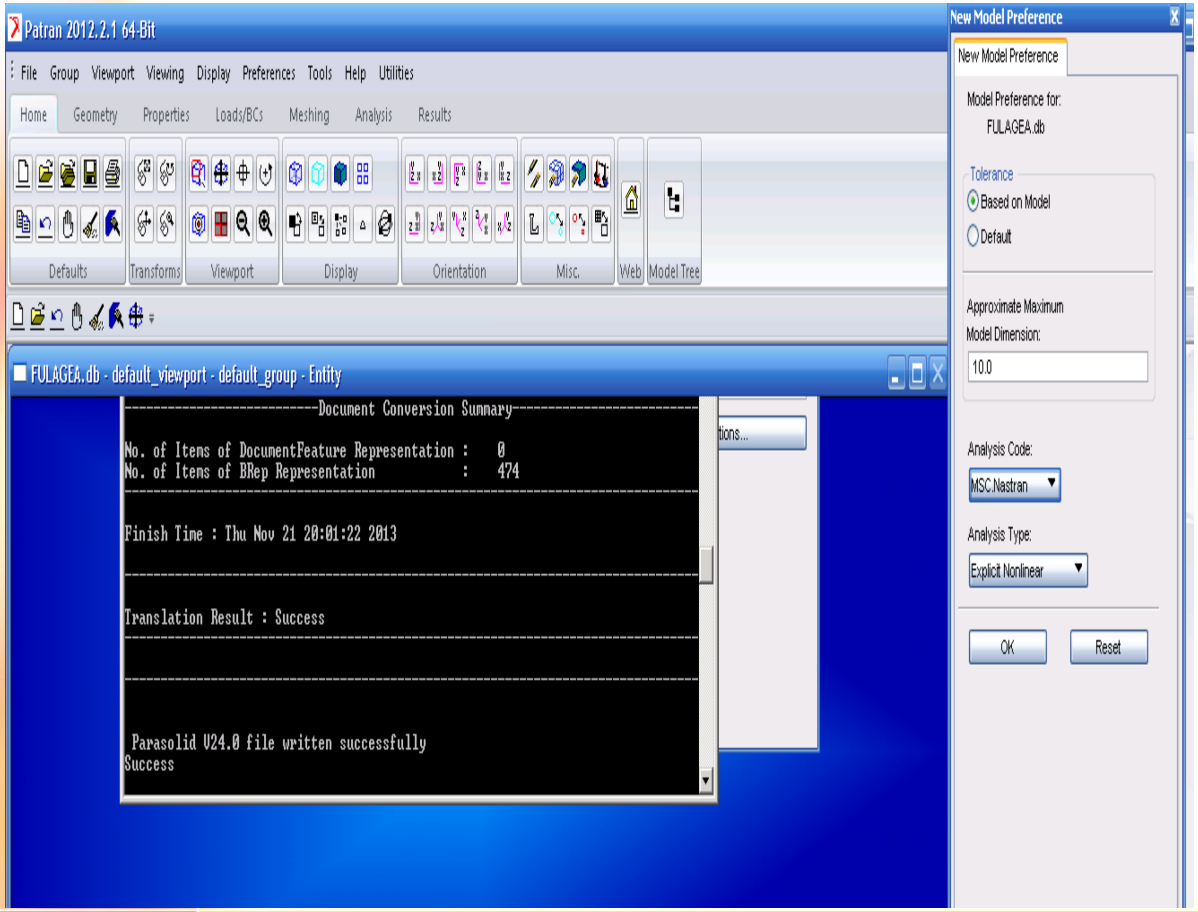
CRASH TEST



185 J after impact > Certification required CS 25.571 and CS 25.963 (e)

RIVET DAMAGE / rivet phenomena of compression/tension

The Patran and Nastran Mondel



Model and solver

- Call the model in Patran
- Non-linear explicit
- NASTRAN

Modeling of the ditching and simulation in-(MD Nastran-Ls dyna)

Aerospace companies perform ditching simulation to predict the impact-resistance properties of the aircraft structure.

This is an example of a cylinder, impacting against water.

The Impact configuration is given in the next page and it has an initial velocities of 15 m/s(z) and 30 m/s (x).

In this example we'll learn the following:

1. How to prestress a model in MD Nastran SOL 700
2. How to perform a transient run in MD Nastran SOL 700 using prestressed results

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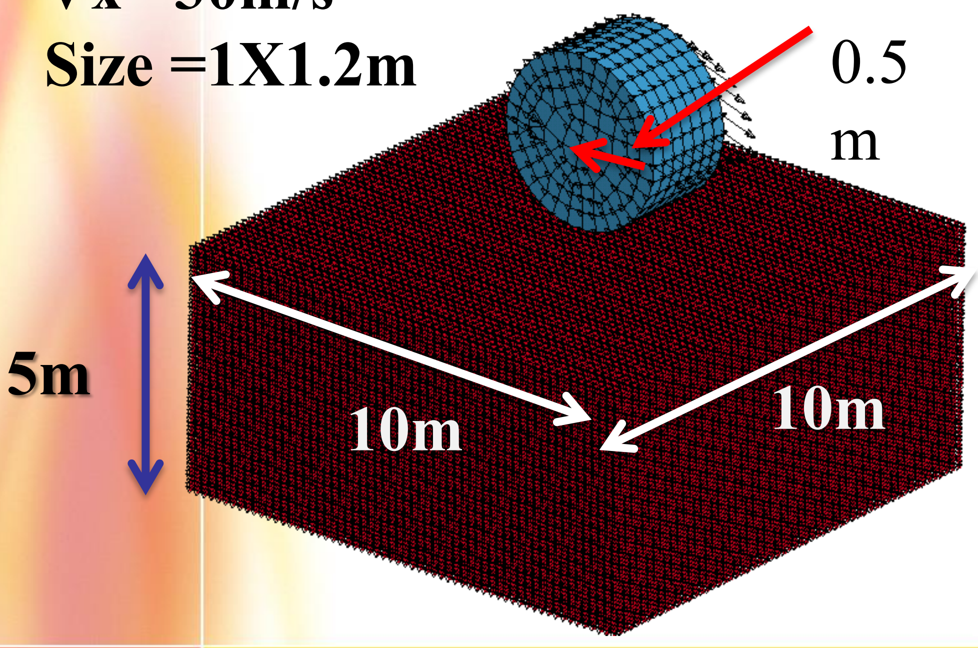
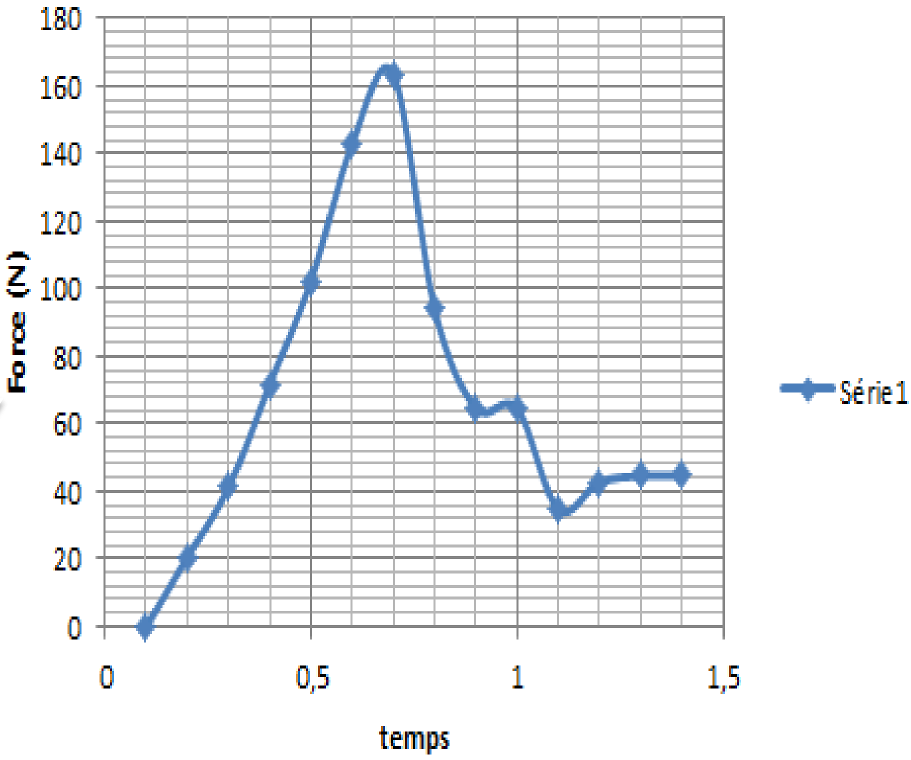
Modeling of the ditching and simulation in- (MD Nastran- Use LS Post to post process the results.)

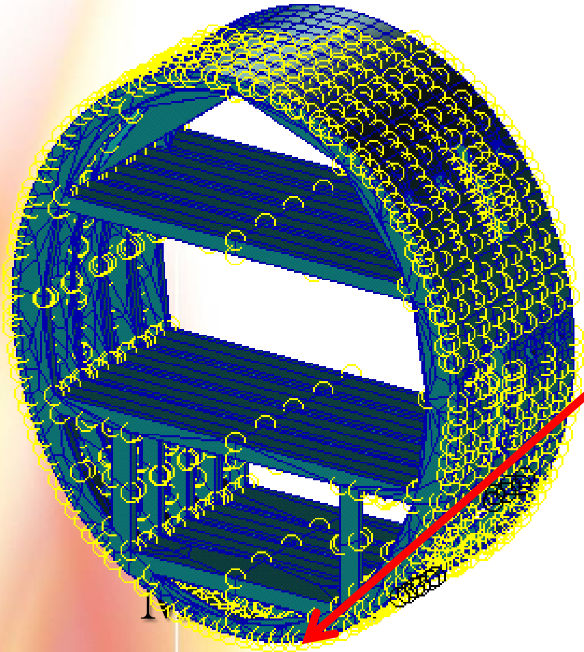
First Assumption/ Simulation of a Cylinder

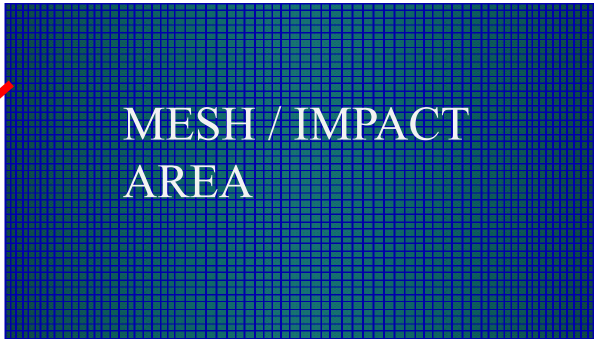
VZ=15m/s
Vx= 30m/s
Size =1X1.2m

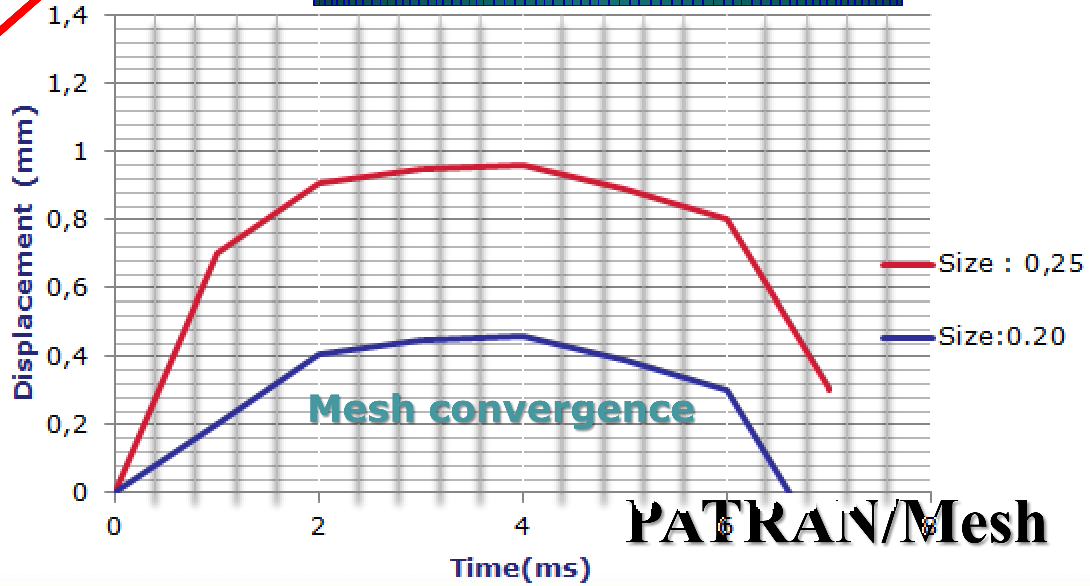




Mesh Qualities-
Patran







PATRAN/Mesh

- Node 51936
- Shell Elements 47469
- Solid 250
- Rivet 3743

Materials-
Modeling

Materials

- The water is treated as a nearly incompressible, nearly in viscid Newtonian fluid
- The fuselage is modeled with a Damage and element removal for ductile metals (**MATD024)**
- The Hydro **(MAT10)** are use for water and air pressure characterization

- **EQUATION OF STAT**

- The Mie-Grüneisen equations are both appliqued in Abaqus and Ls dyna for the water surface

- An equivalent of The linear polynomial equation are modeled for the characterization of the air pressure (between water –fuselage)

Equation of state- Definition with Nastran

Enter a Material Name,

Click Input Properties.

For Constitutive Model, select Equation of State.

For Constant C, enter 0.5428.

For Constant S1, enter 1.450.

For Constant S2, enter 0.

For Constant S3, enter 0.

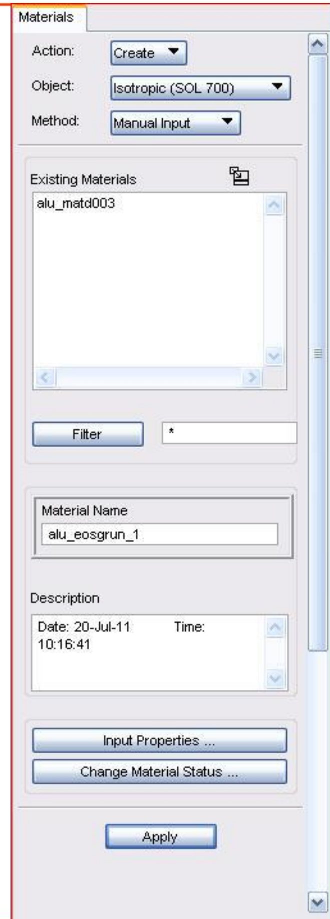
For Gruneisan Gamma, enter 2.

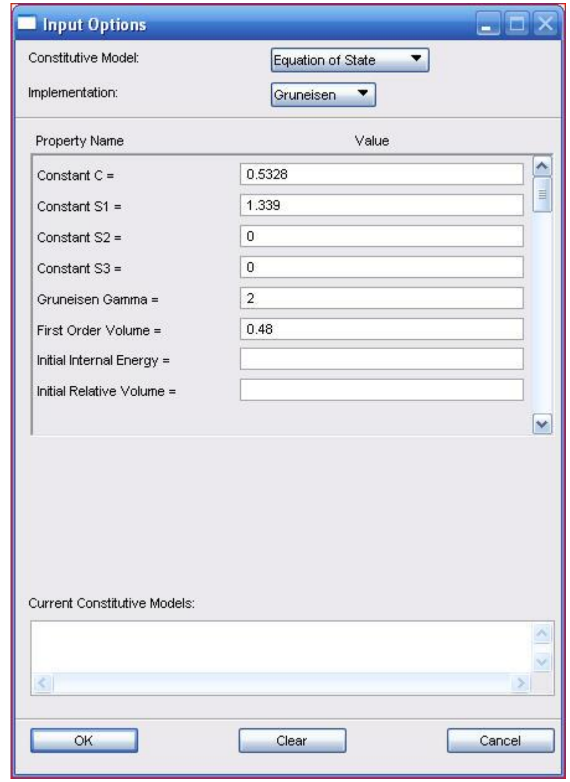
For First Order Volume, enter 0.48

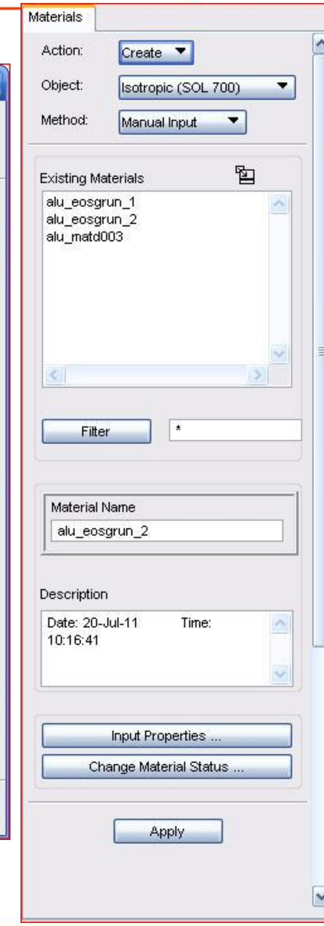
Click OK.

Click Apply.

Repeat steps c. through l., with Material Name and the same input properties.







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Contacts-
Modeling

Three different contacts are applied in the modeled :

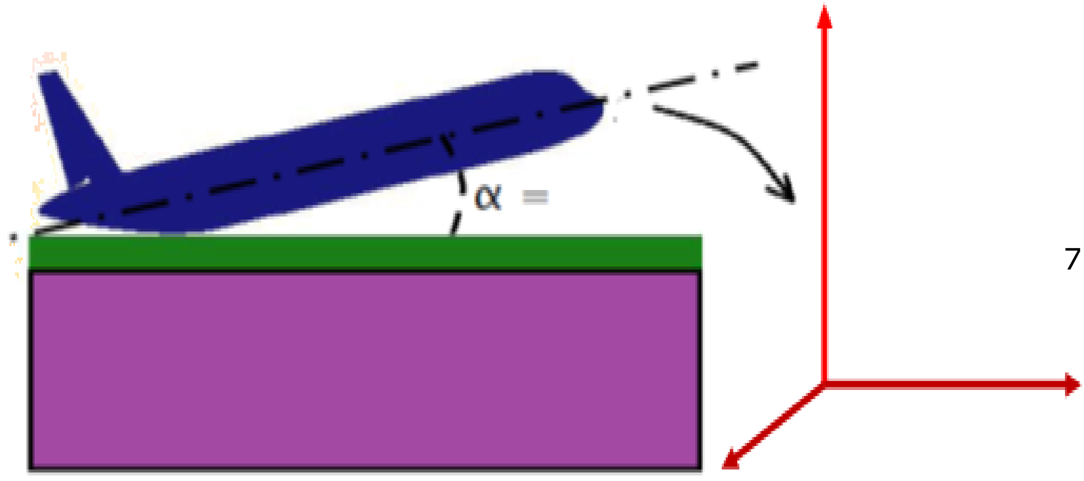
A personal subroutines is implemented for the contact modeling

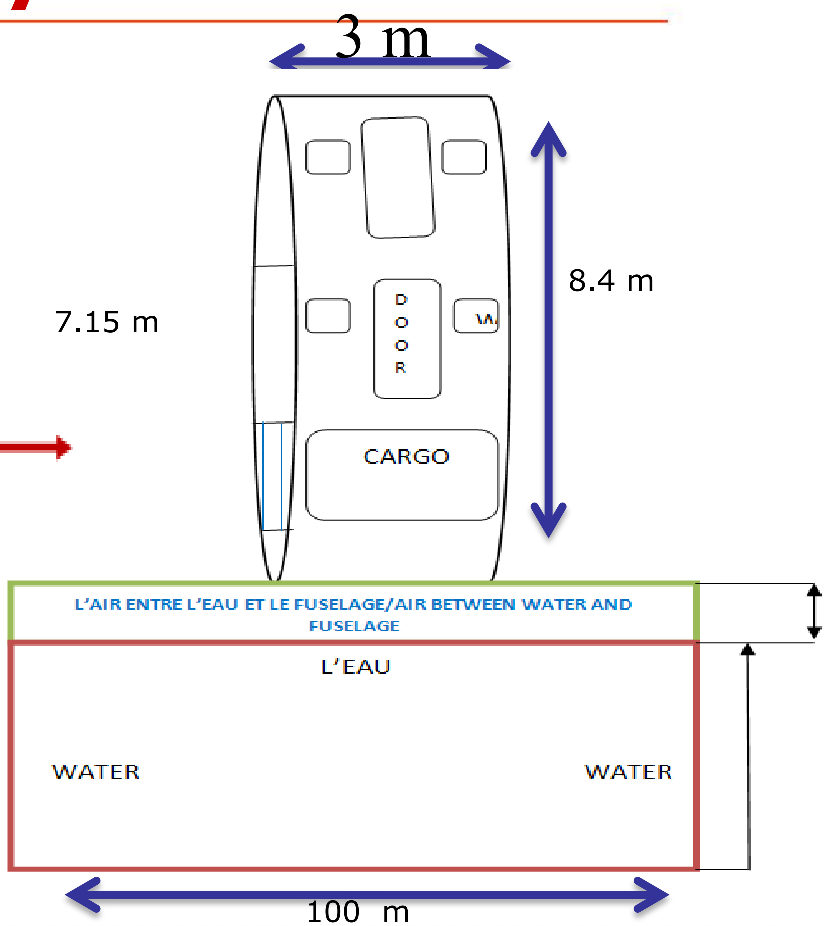
- **Tie contact for the modeling of the rivets component**
- **Faster contact is applied for the characterisation of the rigid rivets**
- **General contact are also applied between the fuselage and the water**

These contacts consider:

- **The thickness**
- **Normal and tangential behavior**
- **The stiffness**
- **The friction**
- **Penalty**

Load applied- Boundary Condition



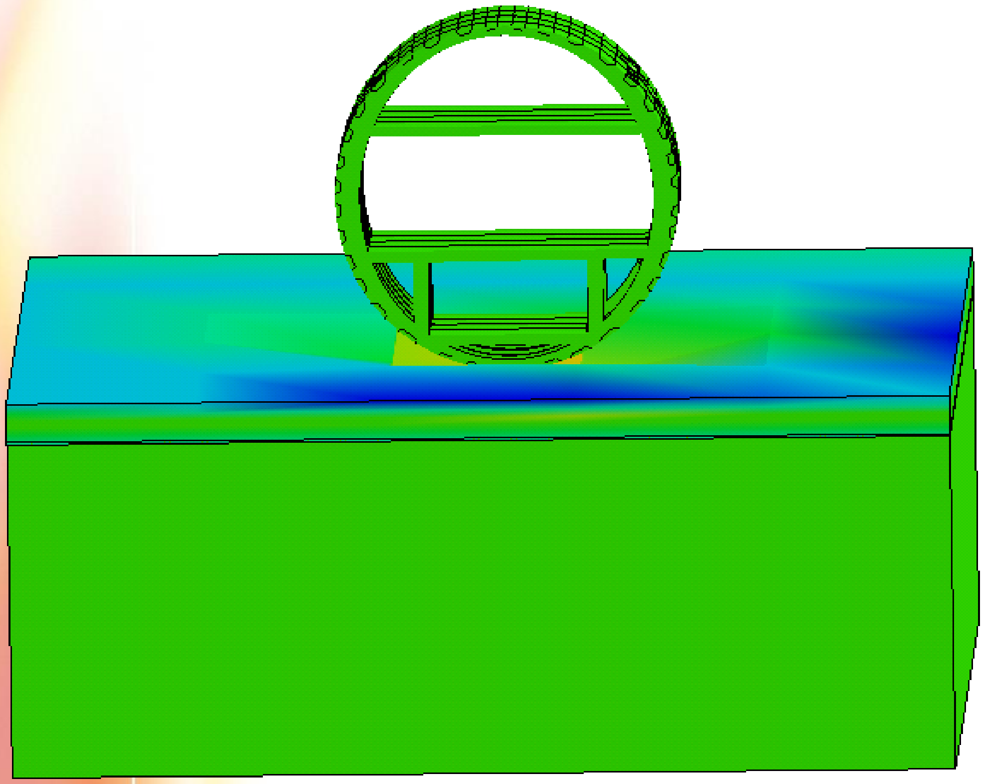


Model configuration

- Angle of Impact
- Impact's velocities
- load and passengers mass
- contact pressure (hydrostatic)
- impact acceleration
- water behavior and level

Results

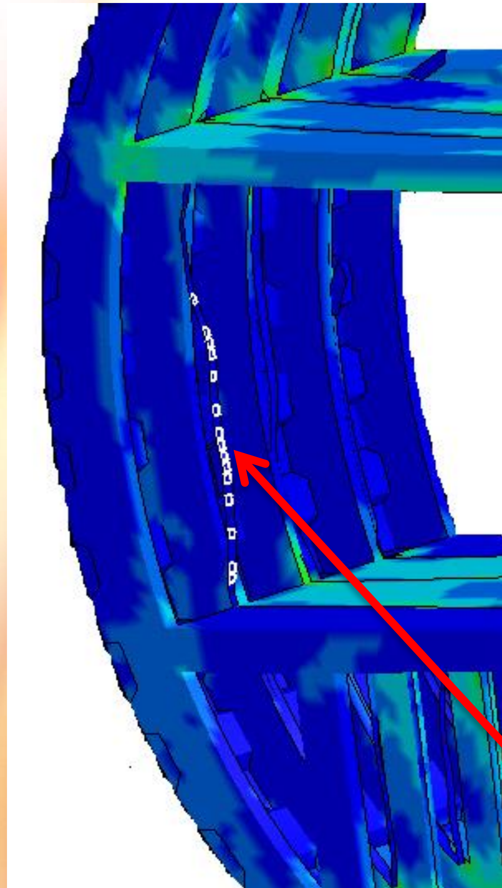
(use LS Post to post process the results.)

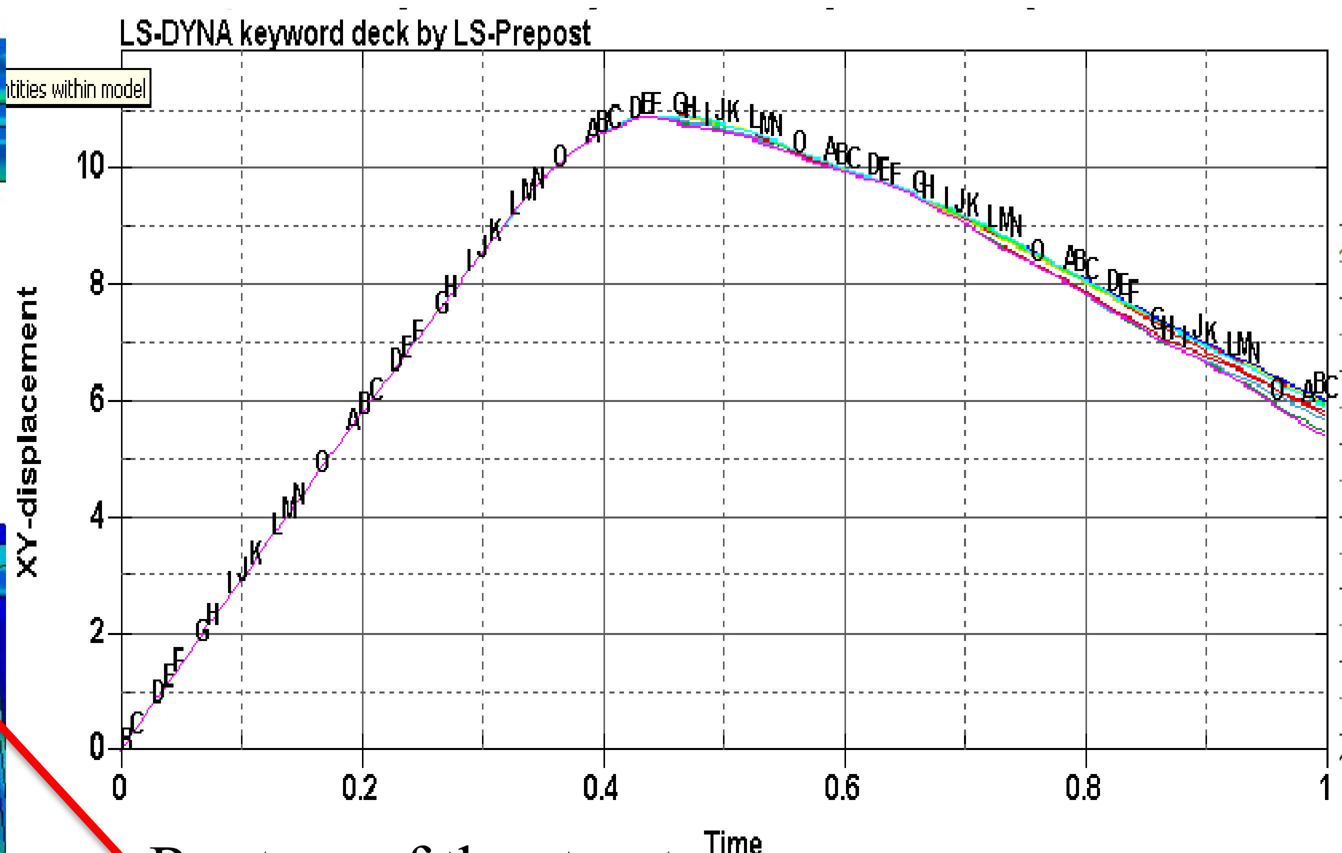


- Air compression
- Wave distribution
- Incompressible water

Pressure -Displacement

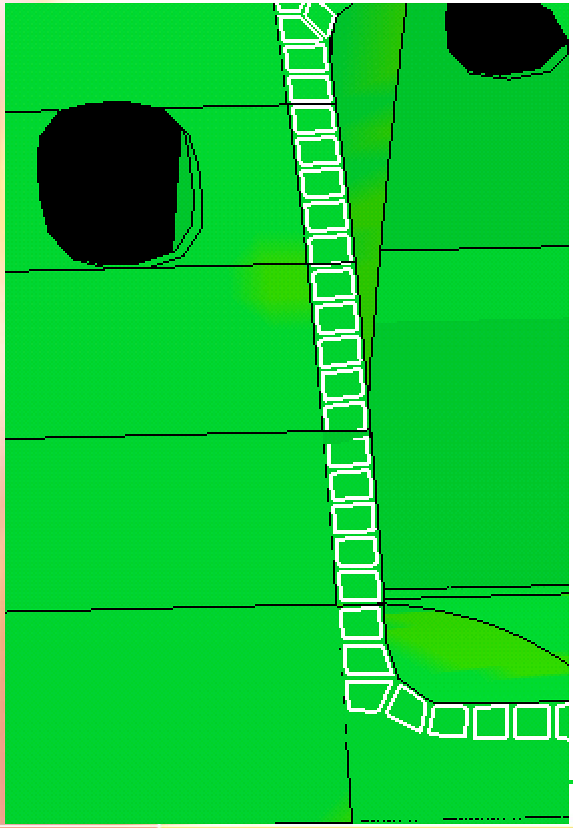
Use LS Post to post process the results.

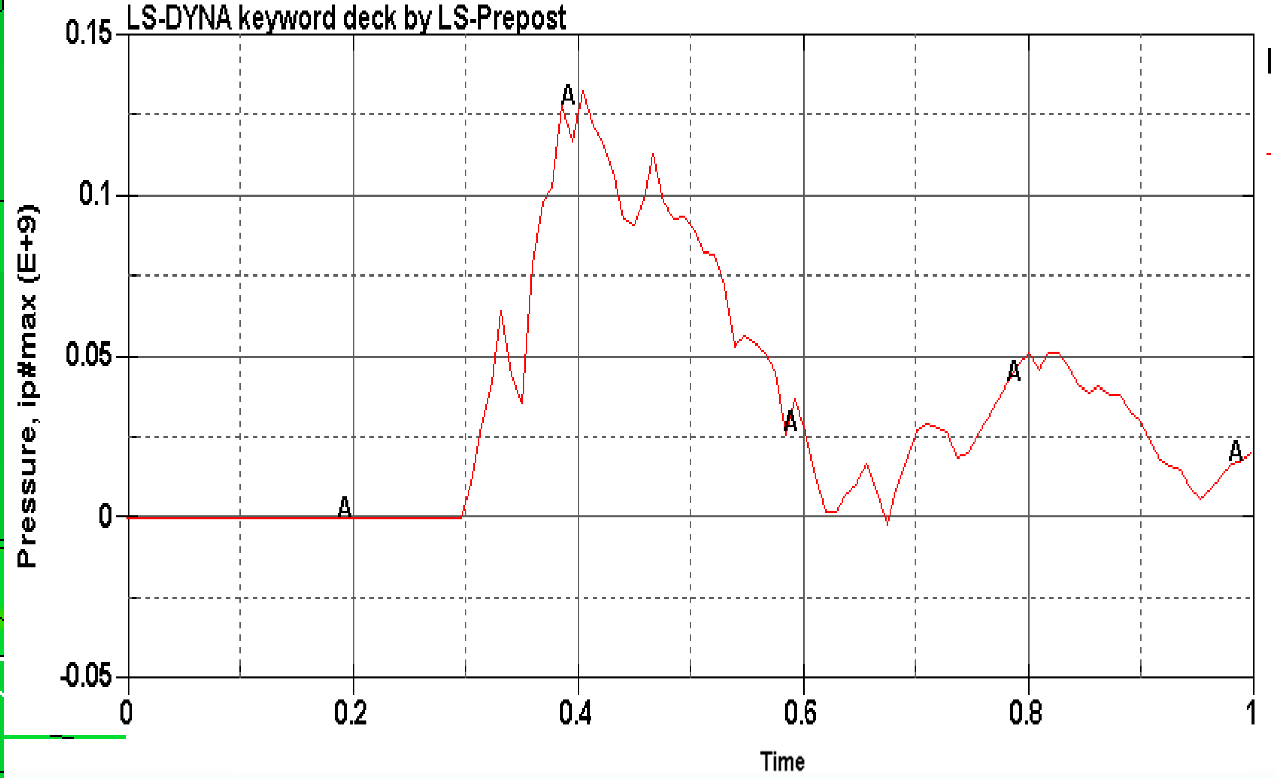




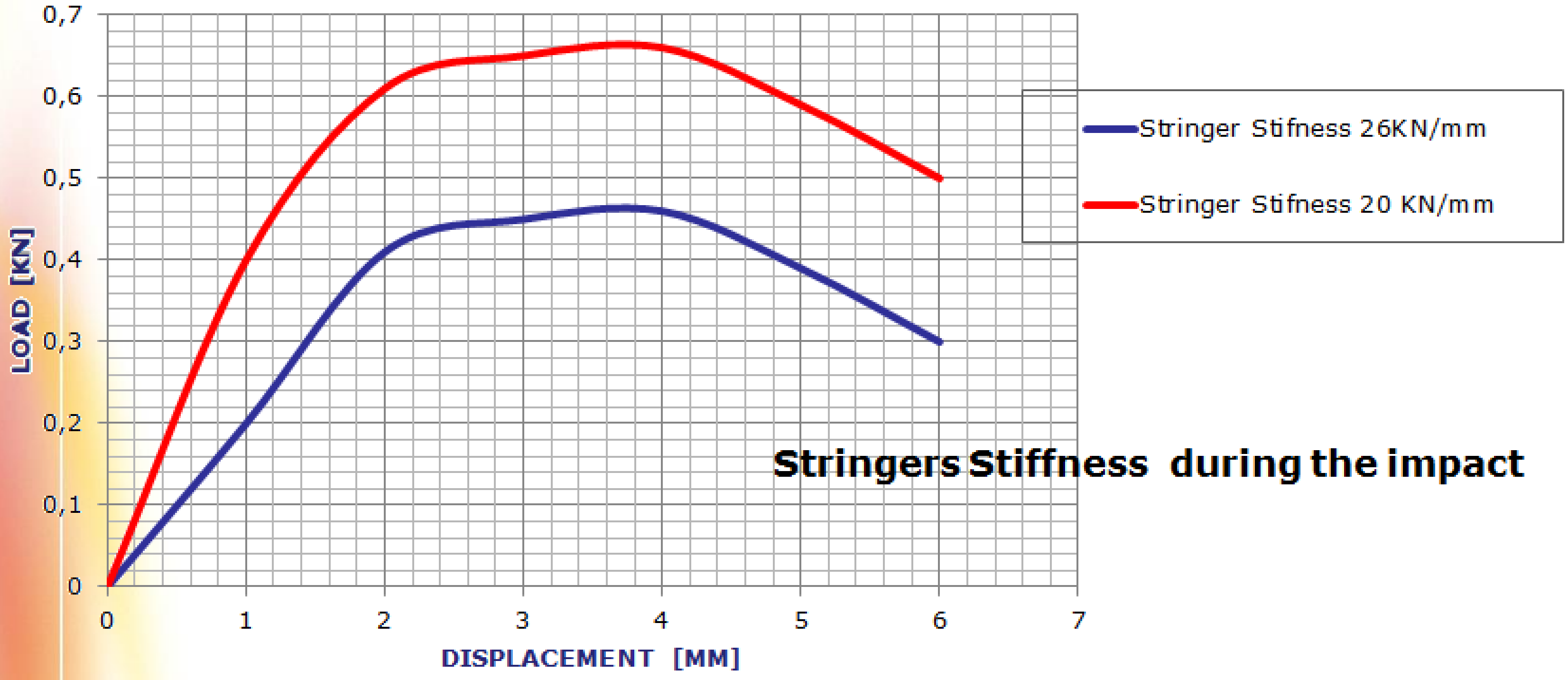
Rupture of the structure

Internal Damage and Pressure on the surface of the Door





Stringers Stiffness – After the Impact



Conclusion

In term of aircraft certification By analyses, company has to make more attention regarding numerical tools and implementing subroutines.

Regarding this simulation, we use 3 numerical tools MD NASTRAN, ABAQUS & LS DYNA, each one of these software has his role in the simulation, MD Nastran demonstrates a high capability in ditching and the computing of the impact result force.
Some knowledge in the different contacts applied are necessary for to represent the structure and soft surface behavior. However, in the future Different physicals tests will be required for the validation of this model.

Hydrodynamic and shock wave loads are the most important forces acting on aircraft during the impact phase because they may affect the airplane's structural integrity. .

THANK YOU