Isight Automatic Process in the Virtual Drop Test Simulation for Innovative Packaging Design

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***Abstract**: This paper will illustrate a SIMULIA SEE process involving Abaqus/Explicit in order to perform an automatic complex sequence of virtual drop test on the packaging of gas hobs. The virtual drop process is intended to be used by the designers without specific knowledge of the explicit dynamic simulations and it involves automatic mesh of the packaging CAD geometries. The Isight virtual drop process enables the design of innovative packaging, it supports the introduction of new materials in the packaging technologies reducing the time to market within the usual try&fix of the physical testing. The process has been designed flexible enough to address the meaningful library of the gas hob product line shapes and material. Some numerical versus physical test validation will be shown.*

***Keywords**: Foam, Food Processing, Impact, Packaging Appliance*

1. Introduction

The delivery of products with the highest quality is one of the most important goals for Electrolux starting from the transportation outside the factories where products are built. In order to fully guarantee the integrity of the product, the packaging design is one of the key points.

Some domestic appliances, like built-in hobs, need a customized packaging for each model. This means to develop several codes and test them, with a wide use of time and resources.

Another point is the sustainability and the environmental impact of some components like EPS and plastic materials used. Electrolux is fully involved in reducing the carbon footprint globally, by doing better and greener products, operations and solutions. For this goal the reducing of the wastes and the use of recyclable or bio materials is extremely important and considered as a priority.

Introducing virtual prototyping and testing in all the aspects of the development and the production is a way to achieve these goals.

Actually the intensive usage of drop test simulation for several design validations required an automation of the mesh and run processes and the creation of a dedicated tool for packaging designers: a typical hob package is shown in Figure 1.

The hob packaging drop validation is based on a cumulative sequence of six drops from a specific height and with a specific angle of impact based on the Electrolux quality requirements for this kind of products.

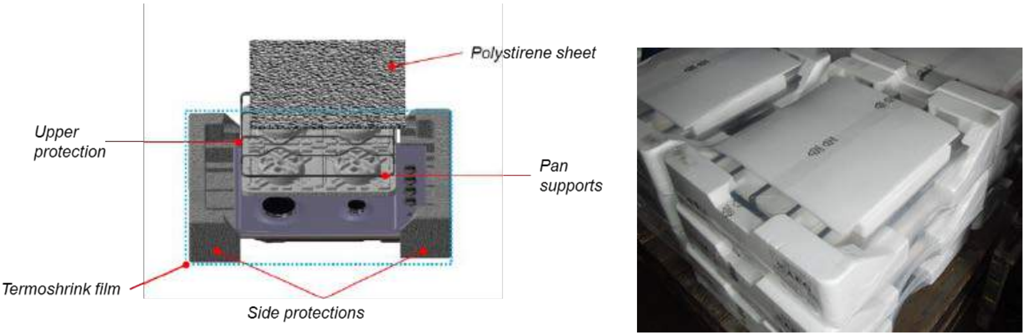

Figure 1 - a typical hob with its protection package

2. SEE process description

The aim of the project is to provide to the packaging designer of the hobs, a simulation tool tailored for the Electrolux requirement for the drop test validation. The starting input information of the whole process is the assembly archive (CATProducts and CATParts) of the hobs with packaging prepared by the designer.

The process is based on four main tasks: the FEM model assembly generation (1), the thermal shrink film application (2), the six cumulative DROP sequences (3) and finally the reporting (4).

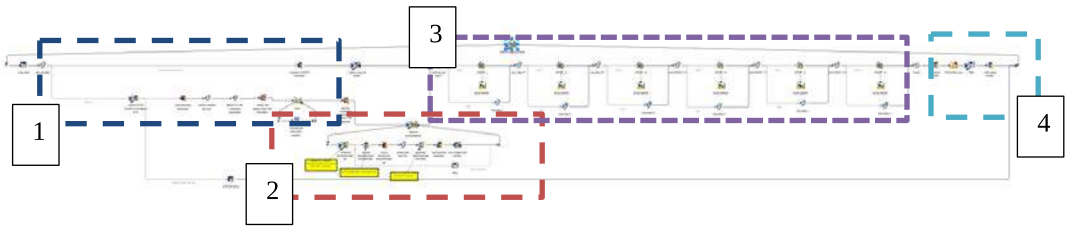

Figure 2 - the virtual drop process defined using Isight

2.1 The FEM model generation

The FEM model generation for an explicit simulation is a challenging task, due to the high sensitivity of the solver to the mesh size and quality: extraordinary care should be used during the mesh generation in order to control the element edge length and the quality of the element.

The desired process should have an automatic robust meshing tool to handle the meshing of all the components in the hob assemblies, but at the moment the mesh algorithm robustness is still far from providing an automatic software that can efficiently mesh all the different kinds of components that are needed for a hob drop explicit analysis.

The hob assembly luckily is based on a not so wide library of geometry parts that are extensively combined to create new fashion hob design: a new design hob drop analysis usually required to perform a manual mesh of 3-4 new components: the other parts benefit from previous simulations.

For these reasons, the automatic FEM mesh model generation in the virtual drop process has been focused only on the foam parts and the thermal shrink film at the moment, that are the parts that mainly change during the design and optimization of a new packaging system.

Figure 3 - the hob FEM model assembly is based on pre-meshed components db, the automatic mesh of the foam packaging and the automatic application of the thermal shrink film.

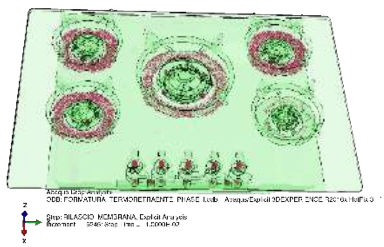

Figure 4 - The red lines in the FEM hob represent the tie connection used to bond the different parts in the model: they are used for the screw or for the bonding

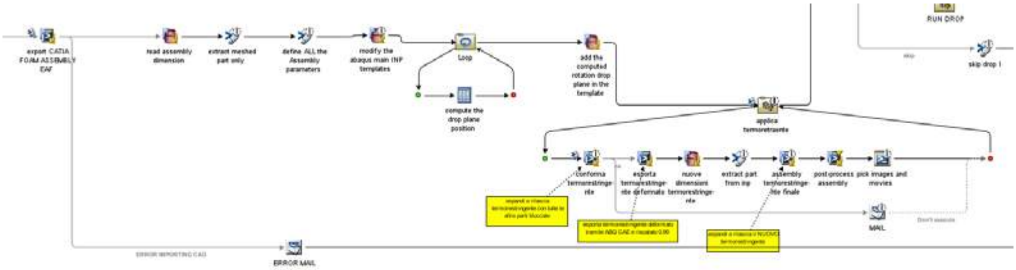

Figure 5 - the FEM model generation and the thermal shrink film application in the Isight process

Before the execution of the iSight virtual drop process, the user must checks in the mesh DB (see Figure 6) which are the components that missing a mesh representation. The components not present in the mesh DB are manually meshed by the user, he performs all the quality mesh check for the explicit solver and then finally he will upload the mesh part file in the DB through a specific iSight process.

The bone of the FEM model automatic assembly of the virtual drop process is based on the Catia V5 interface for Abaqus/CAE. This interface imports the hob CATIA assembly data structure (instance name, part name, hide or shown status, positioning, material name, publication surfaces and publication edge) inside the Abaqus/CAE database: all this information is then used by a python procedure to setup the Abaqus assembly model.
The automatic mesh strategy of the foam package is developed using a Abaqus/CAE python scripting. A second order reduced tetrahedral elements mesh is used for these components.
The connection between the different parts in the hob assembly model is performed with the Abaqus tie constrain; they are paired based on the set name of node set (see Figure 4).

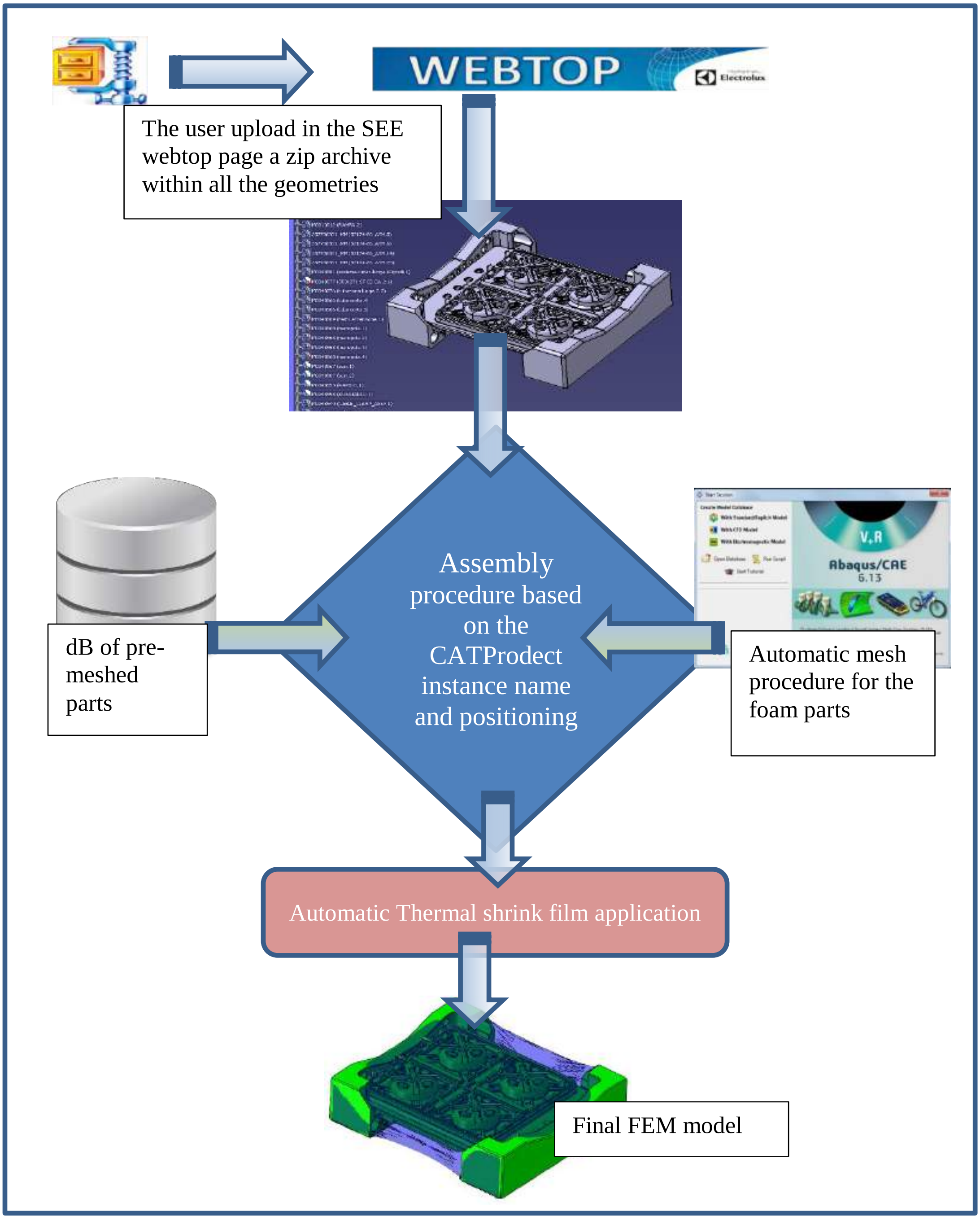

Figure 6 - the drop FEM model creation logical sequence

2.2 The virtual drop analysis

After the thermal shrink application simulation, the FEM model is ready for the cumulative drop sequences.

The model importing capabilities of ABAQUS/Explicit is intensively used during all the sequences of the drops; the hob and package position and their material status are imported from the previous to the next drop analysis in order to keep the material status (damage and degradation status) of the packaging and to completely remove the kinetic energy of the elements.

The user during the drop submission can focus the choice to perform the entire sequence or to focus on a more critical drop position in order to speed up the design of the packaging that reduces the simulation time. Within actual resources, the mesh and the thermos-shrink assembly phase use 0.5 hour, therefore each drop takes 3 hours within 8 CPUs: the whole simulation takes 19 hours. There is a plan to increase the resources in order to run a simulation by night.

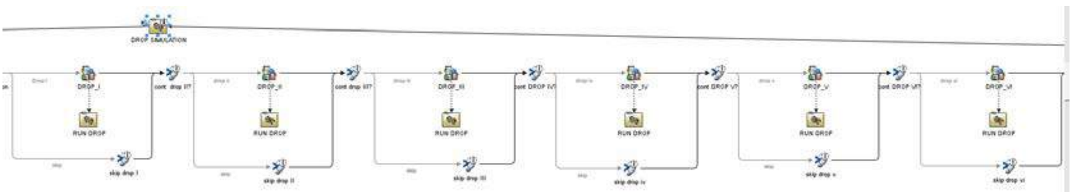

Figure 7 - The six cumulative virtual drop sequences in the Isight process: the user can skip some drop or continue from previous simulation if desired.

The user can continue a previous drop analysis to complete the sequence.

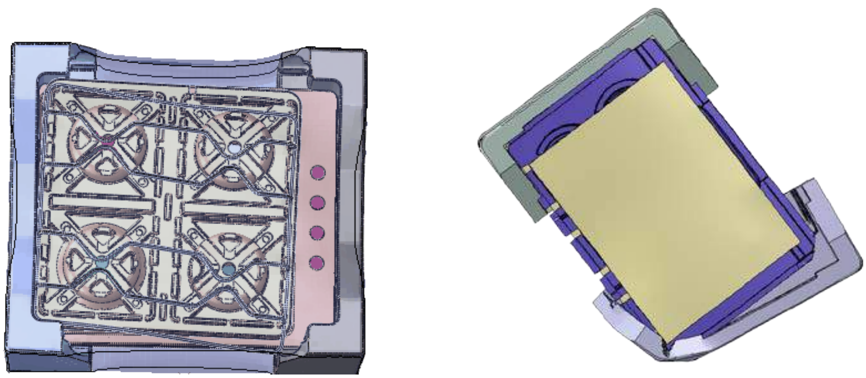

Figure 8 - The first and the second drop position of the sequence of six

3. Real vs Virtual drop

An experimental comparison campaign between the real drop and the virtual drop has been conducted in parallel scheduling within the development of the automatic virtual drop process.

Two different kinds of testing procedures have been setup for the virtual drop hob validation: a standard height energy controlled drop with accelerometer signal recording and an extremely high energy impact for the visual comparison of the damages in the foam package and in the hob component.

The impact behavior is characterized by short time period evolution with high energy exchange between the parts involved in the drop and a certain component of uncertainties in the temporal evolution of the phenomena. To mitigate the uncertain in the experimental test of the drops, the tests have been executed on three samples of the same kind of hob and packaging design.

3.1 The drop test with accelerometers

The scope of the accelerometer drop is to compare the energy dissipation rate and energy exchange rate during the impact of the hob parts against the low density foam parts.

The used accelerometers have different sensitivity in order to capture both the signal peak (the mono axial) and its lower decay (the triaxial accelerometer). Their position have been constrained by the accessibility of the hob part after the thermal shrink film application. In any case, a position on the hob close to the package has been preferred. In Figure 9 the real and the virtual hob are shown side by side: the accelerometer positioning and mass have been replicated in the virtual model with a mass element and a tie connection.

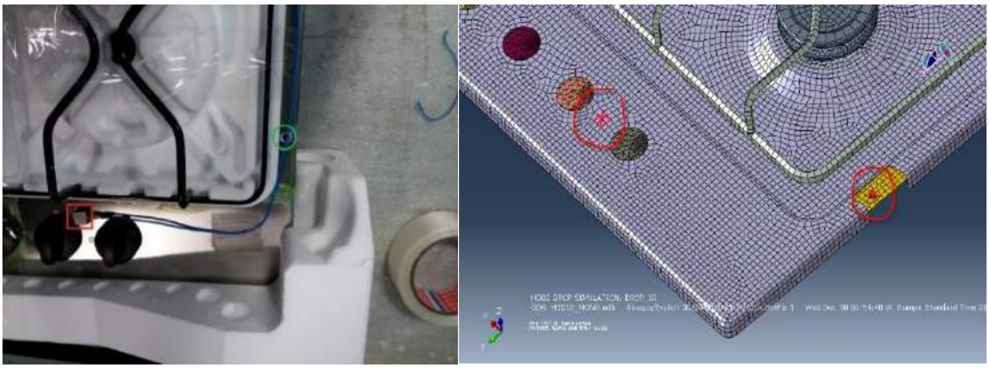

Figure 9 - one of the three tested hobs with the two accelerometers setup and the equivalent virtual hob setup: an equal mass element and a tie connetion has been used in the virtual model

Figure 10 shows an example of the real and virtual output signals from the accelerometers: all signals (real and virtual) have been equally pre-processed with a low-pass filter and mutually time shifted in order to maximize the coherence among them. The final coherence functions of the real and the virtual data are the same: this means that the acceleration loads of the virtual hob at standard energy drop are comparable to the real ones.

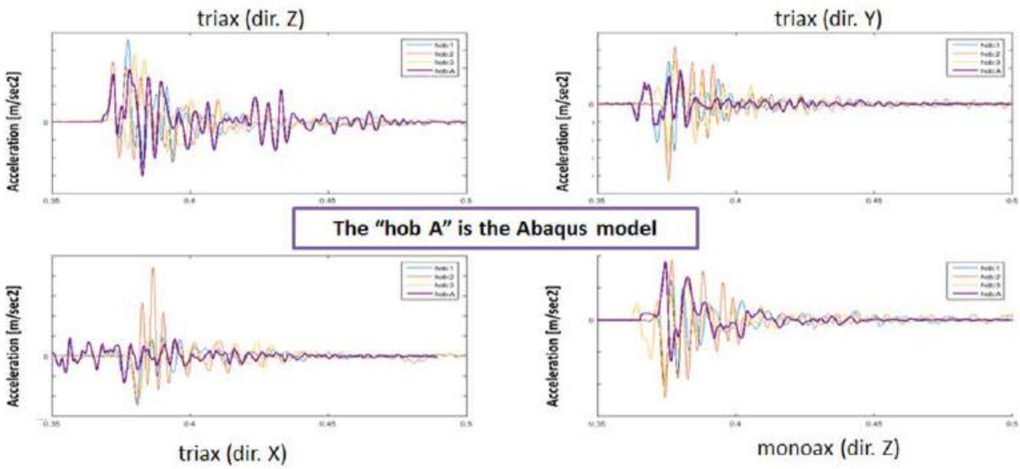

Figure 10 - the accelerometer signals comparison between the real and virtual drop from a height of 10inches

3.2 The high energy drop test

The scope of the high energy drop test is to compare the foam damage material model with the real behavior. Drops at increasing heights and different positions have been performed to reach the highest height of 1900mm. A total of 16 tests have been performed with three real hobs and the equivalent of virtual drop analyses have been performed.

A good coherence of the foam damage position and intensity in the three real package hobs has been found during the testing: the virtual hobs reproduce the real behavior with a very good correlation, too. In the Figure 11 and Figure 12 the real and the virtual packages are compared after the drop from 1900 mm height in the top-down position: the damage appears in the three hobs only on the right side of the package and not on the left side, analogically the virtual package shows the damage only on the right side.

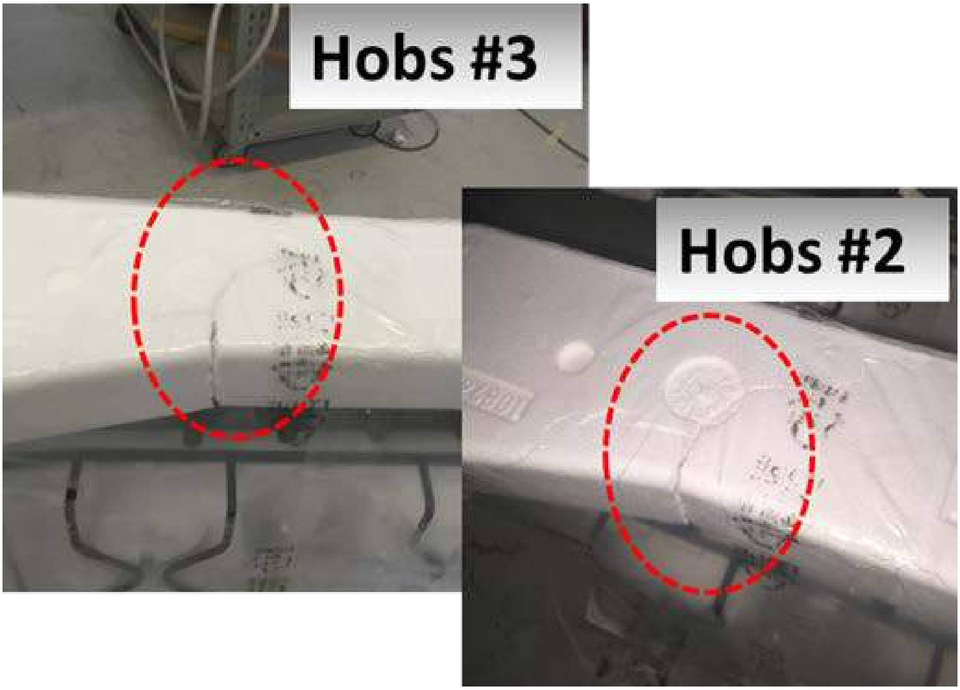

Figure 11 - the right side damage of the foam after a 1900mm drop at the top-down position

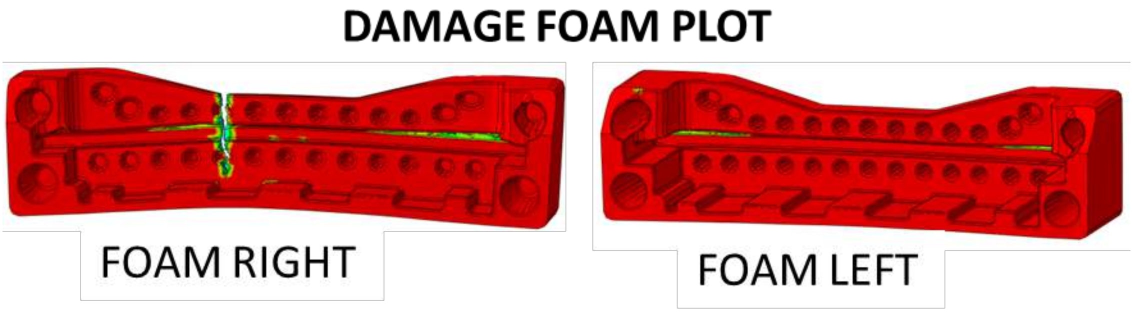

Figure 12 - the right and the left side of the foam package after 1900mm height drop at the top-down position

4. Conclusion

The automatic SEE process for the virtual drop simulations has shown a good result confidence compared to the real drop testing, this allows the designer to focus on the exploration of innovative package shapes and material usage. The virtual drop allows to better understand and visualize the mechanics behavior of the package during the impact in order avoid the try&fix testing based only on the final damage of the foam. The virtual drop process enables the designer to calibrate the usage of the foam in order to satisfy the quality requirement instead of oversizing the package.

The automatic process will be introduced in the mesh aspects in order to further reduce the manual mesh model time preparation required by the actual process before starting a new drop analysis campaign.

At the moment, no DOE or automatic optimization exploration for the packaging design has been taken into account due to the complex geometry parametrization constraints and the long time simulation required by the explicit analysis.

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