

Benefits of Simulation Process Automation for Automotive Applications

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Abstract: The use of iSight to automate Inergy's simulations related to automotive plastic fuel tank development is highlighted by three examples:

- 1. the static venting simulation, where the low added value part (finding the position of valves on the tank so that the customer's specifications are fulfilled) is automated. This allows the expert to focus on higher added value tasks.*
- 2. the tank aging simulation, which consists in computing the permanent deformation of the fuel tank caused by the plastic creep. iSight permits to easily investigate different tank architectures at early stage of development.*
- 3. the blow molding simulation is simplified so that non-simulation specialists are able to run it. This eases the access to simulation for technical experts.*

Keywords: Plastic fuel tank, task automation, optimization, fuel tank aging, blow molding, fuel tank venting.

1. Introduction

In the last years, the use of numerical simulation has spread within INERGY Automotive Systems and is now a mandatory part of the Development process of a plastic fuel tank. A step further is now made by automating the simulation processes with two objectives: reducing the cost and duration of simulation to make it even easier to integrate in the Development process, and facilitating the access to simulation to allow more persons in the organization to take advantage of these tools.

Three concrete examples of benefits taken from the use of simulation process automation are presented.

2. Support technical experts

One of the most obvious tasks that are expected from simulation results is an efficient support to the technical experts. This implies a few constraints:

1. Technical experts are not necessarily familiar with simulation tools, nor comfortable with simulation results. The output of the simulation must be expressed in terms that are familiar to the field expert.

2. The expert remains responsible for the technical solution he proposes, and simulation must provide useful data without impairing the expert's analysis.
3. The simulation result must be provided on time, to be used when needed.
4. Of course the expert must be convinced by the accuracy and the reliability of the simulation result.

This approach will be highlighted through a concrete example: the static venting simulation.

2.1 Venting a fuel tank

A fuel tank must be vented to avoid excessive pressure variations inside the tank shell. These pressure variations are mainly caused by:

1. Variations of temperature (night/day cycle for instance)
2. Variations of pressure (hill climbing)
3. The evaporation of gasoline

Valves are welded on the tank shell to allow the pressure inside the tank to remain within boundaries, which prevents an excessive deformation of the fuel tank.

Finding the position and number of these valves is a real challenge. The venting architecture must be defined at a very early stage of the development, often before receiving the award from the customer. In fact, the cost induced by the venting architecture and the resulting usable volume that can be put into the tank at gas station are key figures that must be known to provide a competitive quotation.

The numerical simulation is of course a mandatory step in the definition of this venting architecture, at a time where no physical prototype exists.

2.2 The static venting simulation

Of course a CAD software like Catia can do the job (Figure 1); drawing planes on the tank at various slopes and computing the maximum volume of fuel that can be vented by a set of valves (at least one must be above the fuel level) is feasible, but this is quickly not convenient:

1. The venting function must be fulfilled not only when the vehicle is nicely parked on a horizontal ground, but also at various slopes. There are commonly around 250 vehicle positions to check.
2. Several valves positions must be tested to find the best one (which implies 250 computations each time)
3. The optimization of the valves position has also to be done with several numbers of valves, typically between 1 and 5.
4. The venting study has to be done several times, since the design of the tank shell is continuously evolving

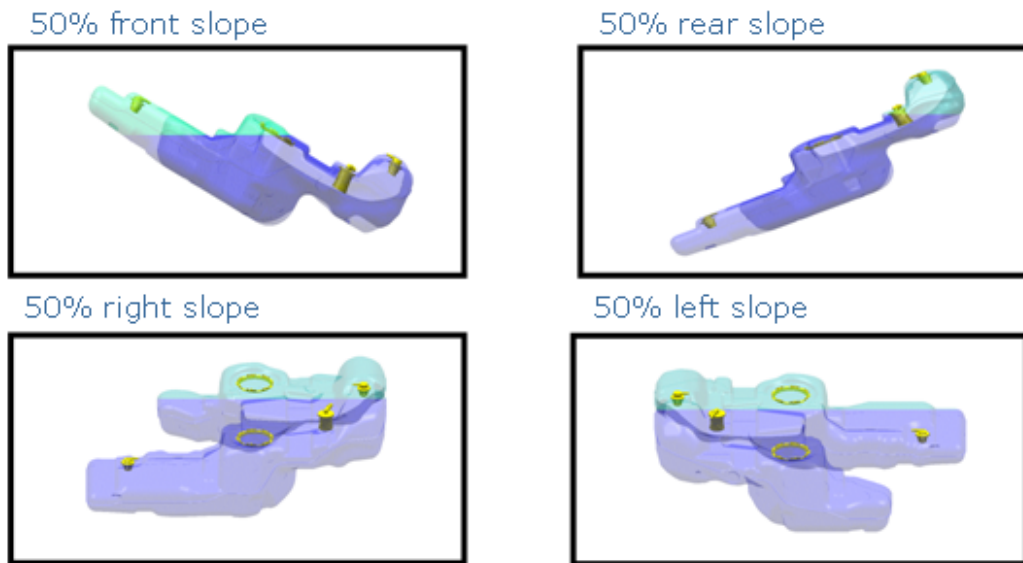


Figure 1. Static venting study with Catia.

Inergy has developed an internal software called VEGA (VEnting & GAuging) that permits to run easily static venting computations, taking also into account the air entrapment in the tank, a variable thickness of the shell coming from a process (blow molding) simulation and much more. Basically the input data of a standard venting simulation is tank geometry, a set of valves positions and a set of vehicle slopes to be tested. The output is the minimum volume that can be vented in all slopes, to be compared with the customer's specification.

This task is done by the CAD designer, who performs several computations and proposes a few valves configurations to the venting expert. Then a venting architecture is defined, taking into account other constraints (manufacturing, design ...)

2.3 Automation of the venting simulation

Looking at the process depicted above, it appears that defining the position of valves on a tank is split in two parts:

1. A lower added value phase, consisting in finding a set of valves locations that pass the customer's specifications.
2. A higher added value phase, where other constraints are taken into account to find the optimal location.

We are using iSight to explore the design space of possible valves locations. The goal is not to find an optimum, since not all constraints are taken into account by the simulation, but to find a set of solutions that pass the minimal vented volume constraint that is imposed by the customer. This

optimization study is automatically performed for 1 to 5 valves. This provides a full coverage of the options that remain available to the venting expert.

A part of the simflow used for the venting computation is shown in Figure 2.

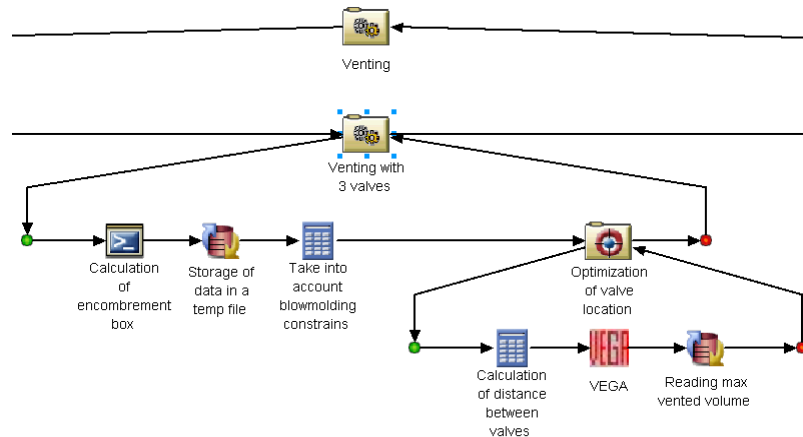


Figure 2. Simflow for calculation of venting (three valves).

The results are then put in an exploitable way, i.e. a picture of the upper tank shell with dots on it representing the admissible valves positions.

2.4 Benefits

A CAD designer usually performs computations on a few dozens of valves positions, depending on the tank complexity. The automated process performs about 500 computations and provides usually between 10 and 20 good configurations.

The venting expert can then choose between all the possible good configurations.

3. Investigate more design options

3.1 Prediction the aging deformation of a plastic fuel tank

A plastic fuel tank, made of HDPE, might be subjected to creep during its life. The fuel tank is usually placed in the car underbody; therefore caution must be taken to keep enough clearance between the bottom of the tank and the ground.

Several countermeasures are available (brackets, straps ...) to maintain the tank in place and keep its creep deformation to an acceptable level. The challenge is optimize them early in the design process to permit a competitive quotation.

3.2 The aging simulation

The accurate prediction of the creep deformation of a plastic fuel tank needs to take several parameters into account:

1. An accurate design of the fuel tank is needed, with its brackets and straps
2. The variable thickness of the tank shell coming from a process (blow molding) simulation
3. The local effect of tank components (pump, heat shield, ...)
4. The behavior of HDPE in fuel at various temperatures
5. The type of fuel (gasoline, diesel, Bio-fuels)
6. The barrier type to reduce hydrocarbon emissions (multilayer wall, fluorination, ...)

The simulation is performed using Abaqus and a user defined function to account for the degradation of mechanical properties with fuel soaking inside the HDPE.

3.3 Automation of the fuel tank aging simulation

The fuel tank aging simulation studies are characterized by the large number of simulations to be run on the same tank design (several straps positions, several fuel types).

The simulation process has been automated using iSight. The different simulations are also put in a loop, which permits to run all the countermeasures ideas in an automatic sequence.

In addition to that, a gauging simulation on the aged tank is performed, and a set of pictures is created (using a python script) to be used in the report.

The simflow used for the aging computation is shown in Figure 3.

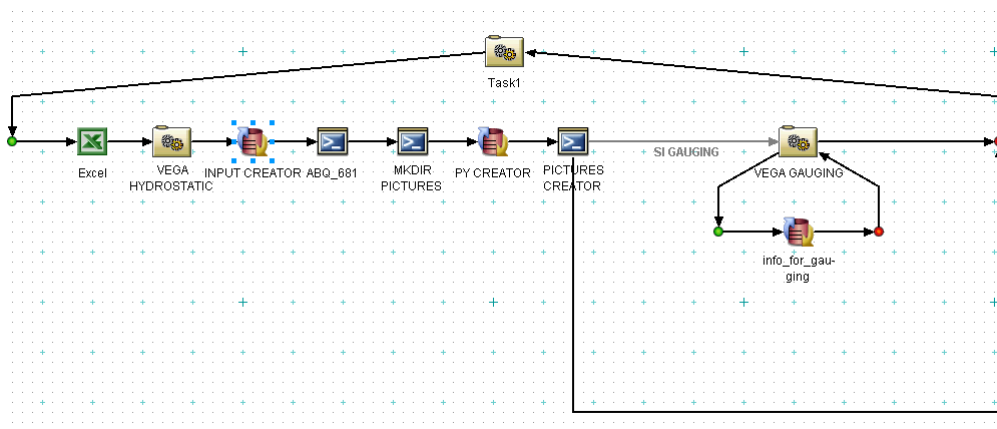


Figure 3. Simflow for Aging computation

3.4 Benefits

The first benefit comes from the automatic management of straps and fuels; the user only has to make a choice in an excel file instead of using the Abaqus interface. This saves model preparation time, and reduces the risk of confusion between almost identical configurations. The simulations are then run automatically, taking advantage of nights and weekends.

The second benefit is a direct consequence of the gain in efficiency of this simulation. Since the cost and the duration of this simulation have been dramatically reduced, more innovative ideas are tested by simulation which increases the chance of finding an efficient solution (Figure 4).

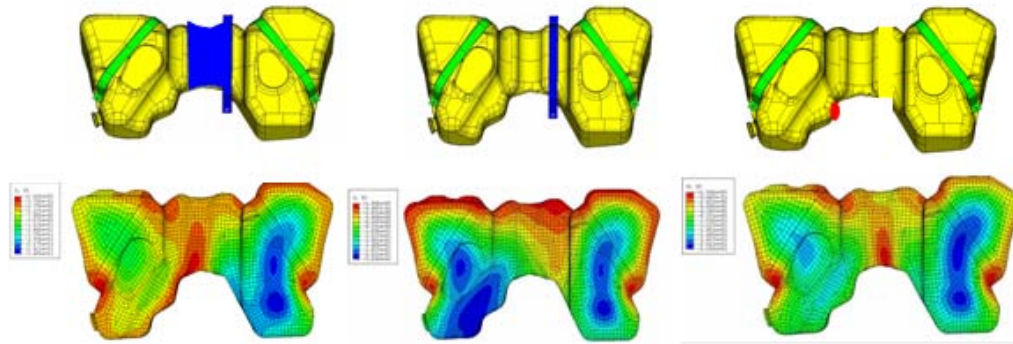


Figure 4. Proposals for tank fixations and the associated aging simulation results.

4. Ease access to simulation tools

4.1 Overview of the blow molding process

Plastic fuel tanks are usually manufactured using the blow molding process. It consists in extruding a hollow parison, pinching it between two molds, and injecting air through a needle that punctures the parison. The parison then inflates and takes the shape of the molds.

The blow molding machines are equipped with various means to adjust locally the thickness of the parison during the extrusion. This permits to target specific locations with appropriate thickness (to weld a component afterwards for instance) and to reduce the thinning effect that is observed when blowing the parison into “corners” of the tank.

The challenge consists in producing the lightest possible tank while maintaining a level of quality that permits to pass the safety tests (crash test and fire resistance test for instance).

4.2 The blow molding simulation

The full simulation of the blow molding process (from the flow of molten HDPE in the die to the cooling of the part when it comes out of the molds) is done by the BlowView software from the Industrial Materials Institute of the National Research Council Canada.

This simulation permits to explore the various set-up options and to anticipate the process or design issues before running into costly prototyping trials.

This software permits to simulate all the aspects of the process, with complex rheology materials, complex tools movements, pressure management, and of course all the techniques to adjust the parison thickness. This makes this software quite complex to master, and requires a good knowledge of the process for the person in charge of the simulation. This is quite a challenge in terms of organization, and iSight was used to overcome this issue.

4.3 Automation of the blow molding simulation

It is clear that the best decisions about the blow molding process can be taken by a field expert rather than a simulation engineer or a CAD designer. The goal of automating the blow molding simulation is to make the blow molding software easy-to-use enough so that the blow molding expert, who has no experience in numerical simulation, can take advantage of BlowView.

BlowView can be driven by text files, which make it possible for iSight to monitor the computation. A total of 27 elementary tasks were chained, which permits to run a computation from a simple excel sheet.

This simflow includes also the optimizer included in BlowView, which is able to adjust the settings of the blow molding machine to minimize the weight of the part while keeping the shell thickness above a given value.

4.4 Benefits

iSight does not replaces completely the need for manual actions on the software but it provides a good starting point for the field expert, who can focus on higher added value simulation tasks (optimizing the part thickness) rather than spending time on lower added value tasks (adjusting the parison length or setting the movements of molds for instance).

Moreover, a work has been done on automatically meshing the molds from the Catia files. This permits for the field expert to avoid all direct contact with meshing software. This saves time and reduces the simulation know-how needed to run this simulation.

5. Conclusion

The overall benefit of using iSight for the three automotive applications depicted in this paper can of course be seen as a gain in efficiency of the simulation tool itself (the duration of the blow molding simulation is cut by two for instance), but the intangible benefits are also very important and have an impact on the whole development process:

1. The static venting simulation, where the low added value part (finding the position of valves on the tank so that the customer's specifications are fulfilled) is automated. This allow expert to focus on higher added value tasks.
2. The tank aging simulation, which consists in computing the permanent deformation of the fuel tank caused by the plastic creep. iSight permits to easily investigate different tank architectures at early stage of development.
3. The blow molding simulation is simplified so that non-simulation specialists are able to run it. This eases the access to simulation for technical experts.