Capability of Simplified Folded Airbag Models in Gasflow Simulations

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ABSTRACT

With respect to out of position simulations it is considered necessary to model the airbag as detailed as possible and to take the gas flow behavior into account. Especially for folded bags the complexity and hence the computational costs increase enormously. This is mainly due to the time consuming contact algorithm and to very small gasflow grid size needed to resolve the fabric layers. Therefore a compromise must be found between a completely elaborated geometry with very small finite element grid cells and a computation time of several weeks, and a fast simplified model, where the relevant physical effects can no longer be described.

Beginning with a Leporello folded bag without considering any components (e. g. a metal sheet to channel the gasstreams), the model has been modified for its geometry around the inflator housing and the gas inflow specification. The goal was to find a configuration as simple as possible that models the real unfolding process in satisfying representation. Three variants were investigated: one with a radial inflow formulation, an other with a vertical inflow definition and the third was modeled most in detail as a two chamber bag. In addition the simulation of an airbag compression folding has been carried out. With the arising complexity the capabilities of building a model are limited and simplifications are unavoidable.

INTRODUCTION

The aim of this study was to advance the understanding in modeling folded airbags under consideration of the gas flow with regard to out of position simulations. For this purpose the airbag kinematics must be described exactly even during the unfolding process. The difficulties in calculating the common compression folding made it inevitable to start the investigations with a Leporello folded bag for that reproducible hardware tests can be obtained.

MAIN SECTION

LEPORELLO FOLDED AIRBAG

The first bag of interest is a Leporello folded one (see Figure 1). This type of folding is chosen, because it can easily be done by hand for some tests and the bag can be positioned on a flat plate without any surroundings like e. g. a box. The layers need only be fixed with one stripe of tape. So a comparison of test and simulation can be made, which is the condition for defining whether a model with its assumptions represents reality.

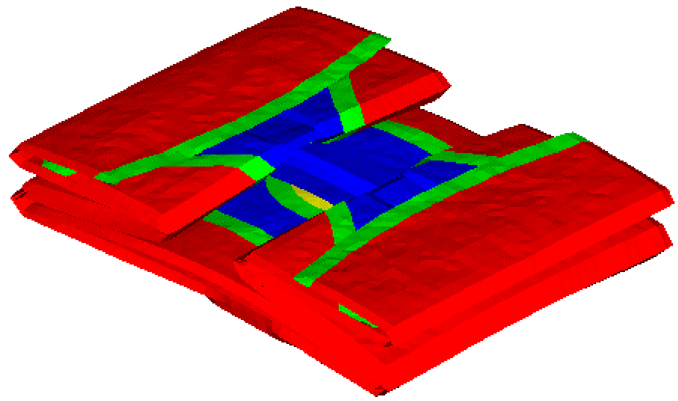


Figure 1 : Leporello folded airbag

The inflator is positioned inside the airbag volume surrounded by a metal sheet, that channels the gas stream. The thickness of the turning vane is very small, which is pictured in Figure 2.

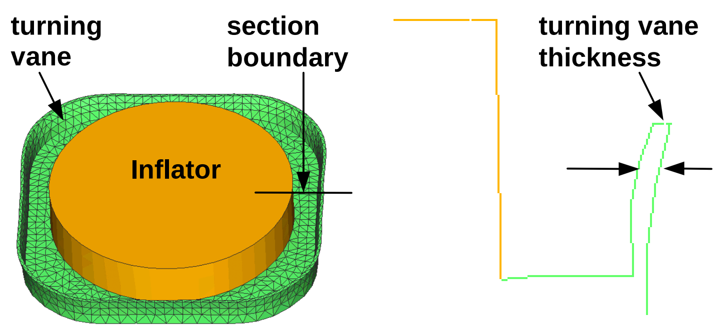


Figure 2 : Left : Geometrical proportion of inflator housing and turning vane. Right : Contours in the section boundary are drawn to a larger scale.

In uniform pressure simulations the metal sheet can be omitted, because of its negligible volume. If the gas velocity vectors must be considered, it is inevitable to make a simplification, because the Euler grid cells can not be defined that fine over the whole computation domain that at least one cell lies inside this thickness and can become inactive. A channeling of the gas streams along and not through the metal sheet parts can be achieved.

Figure 3 represents in section the most detailed Leporello bag that was considered in this study. A second chamber was introduced to obtain a high resolution in the part between the turning vane and the inflator with a fine Euler grid, where high flow velocities are expected. Beyond the outer part, mainly the moving fabric, a coarser grid is used to reduce the computational costs as far as possible.

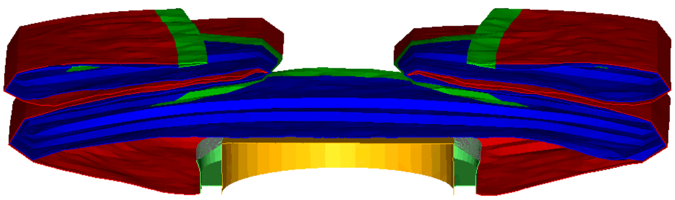


Figure 3 : Segment of the most detailed Leporello bag that is considered in this study.

Nevertheless the complexity of the model is high. Therefore some calculations without the above mentioned turning vane were done to investigate the effect of the defined flow direction.

<u>Exhaustion in Radial and Vertical Direction</u>

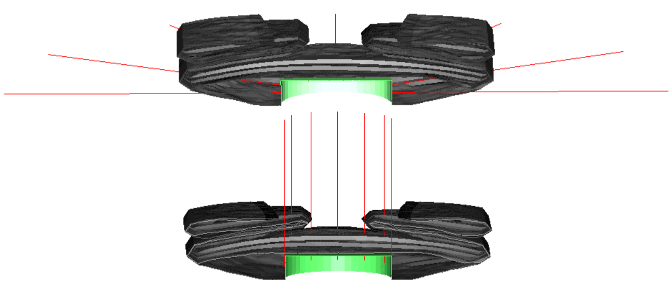
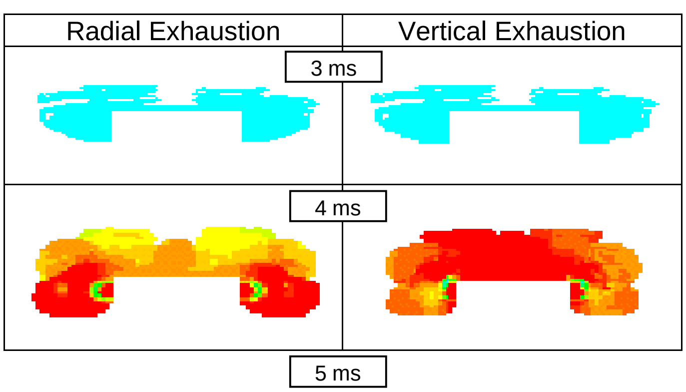


Figure 4 : Section through the Leporello bag with radial (top) and vertical (below) directed gas inflow.

Both models differ only in their definition of the gas inflow vectors. The red lines in Figure 4 visualize the directions. The vertical formulation is considered to take the gas direction change caused by the turning vane into account.



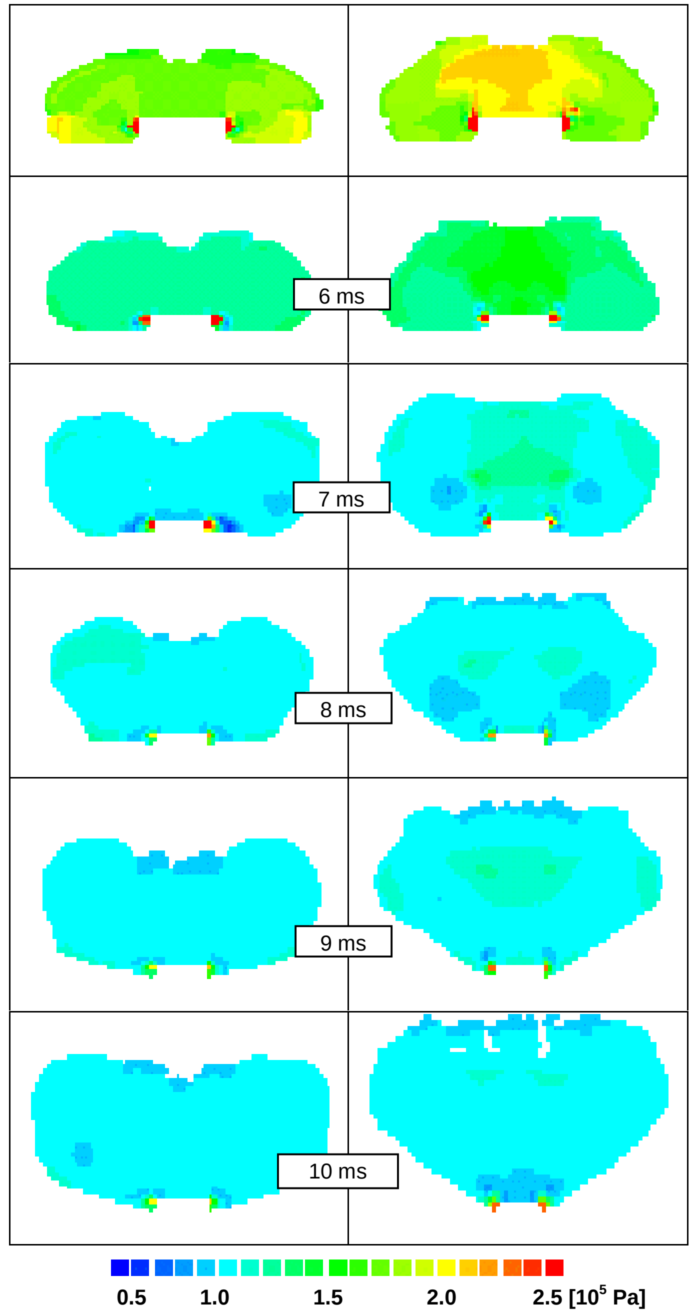


Table 1 : Pressure distribution in the section plane of both models which differ only in the exhaustion direction (time range : 3 – 10 ms, displayed each ms).

The first picture row in Table 1 shows the pressure in the active Euler cells in the models before the inflow starts. The different fabric layers can be identified. With each time step, that means in every table row, till 7 ms the figures are scaled when the bag is packed on small dimensions in order to recognise the details. This is done in the same way for each time step, so that the figures in one row can be compared with each other. The vertical amplitude is higher in the vertical exhaustion model as it was expected but the global volume values differ very little (about 1 % of the maximum volume).

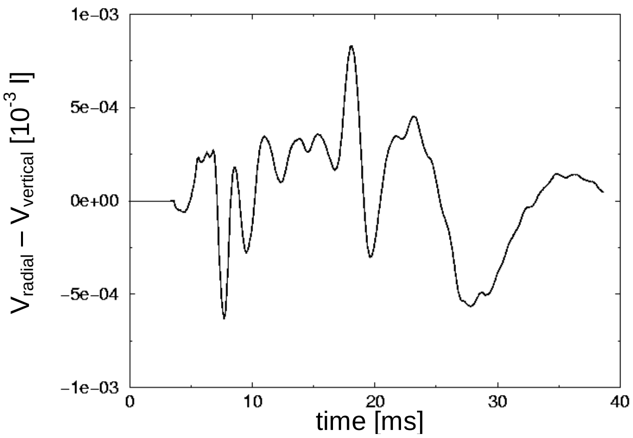


Figure 5 : Bag volume difference between radial and vertical exhaustion model.

In contrast the global pressure difference between the two models is about 7% (see Figure 6). The fact that during the simulations in a few time steps specifically in the beginning of inflation some of the inflators are partly blocked because of the fast moving fabric and the flexible Euler grid. In spite of that behavior the given massflow is exactly brought in both models.

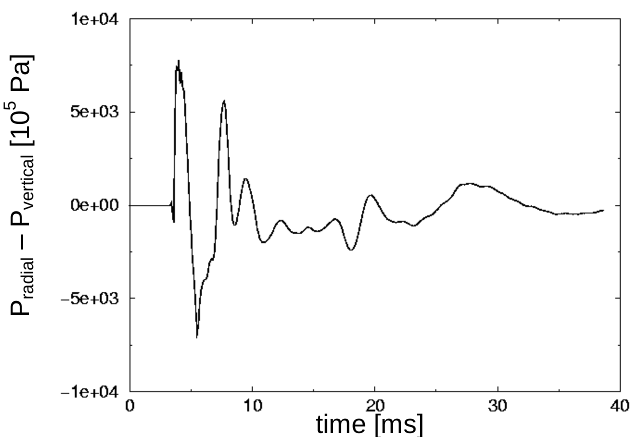


Figure 6 : Average pressure difference between radial and vertical exhaustion model.

In order to get more insight in the gas flow behavior a more detailed model is used.

<u>Two Chamber Model</u>

The most complex model (see Figure 3) with two chambers and therefore two gas flow grids is used. Figure 7 depicts the inner chamber, which is limited by the inflator outline, the inner contour of the turning vane and the hole elements. With it the gas is forced to change its flow direction from radial at the inflator definition points to an oblique one to reach the outer flexible volume.

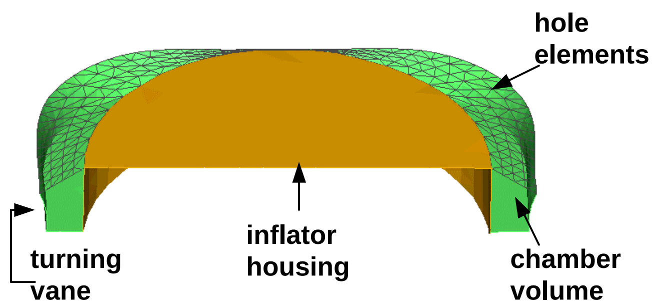


Figure 7 : Inner chamber with hole elements which emit the inflator gas to the second chamber.

The active Euler cells that result from the two chamber modeling are depicted in Figure 8.

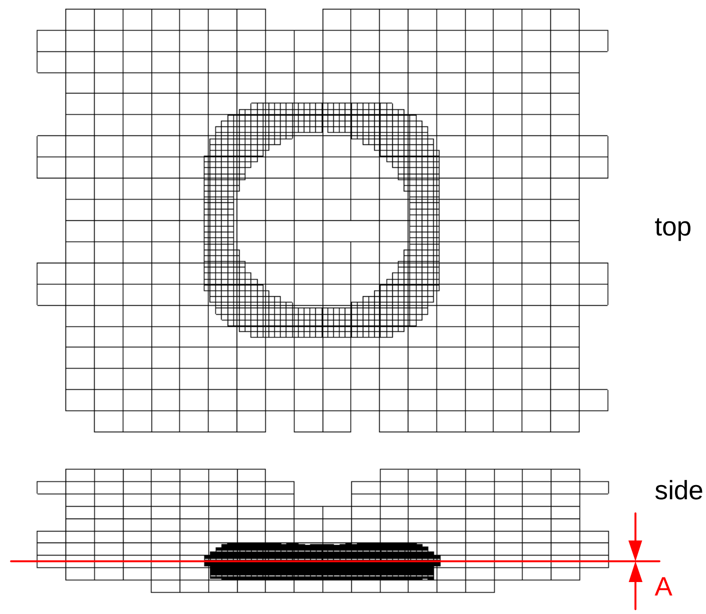


Figure 8 : Fine grid of the inner chamber volume (top view) and a coarse cell size in the outer, flexible chamber (side view).

The inner grid consists of 40x40x40 cells. This is necessary to resolve the pressure distribution in the cavity as exactly as possible. Figure 9 shows pressure and temperature distributions in the section A of Figure 8 through the gas inflow locations at the time of maximum inflator massflow.

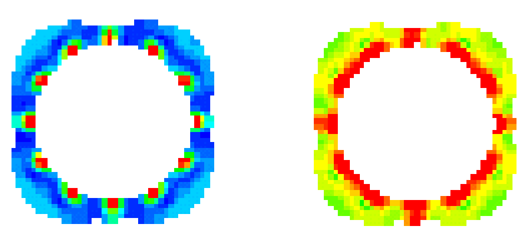


Figure 9 : Pressure (left) and temperature (right) distribution in section A, the height of the inflator definition (red : high value, blue : low value).

The red colored cells in the pressure section correspond to the spots of inflator mass inflow. It is expected that the inflator gas enters the Euler cells with high velocity (approximately sound speed) which decreases, when approaching the turning vane. Near the metal sheet opposite to the inflator inflow holes dynamic pressure points develop. Such regions of higher pressure can be observed in Figure 9, but with an intensity that is much lower than in the vicinity of the inflator housing. Assuming that the above pictured pressure distribution corresponds to its static portion, then it seems that the inflator gas mass per time step is concentrated in the appropriate Euler cell and is therefore brought into the computational domain without any initial velocity. From this, it follows that a more finer grid is required to reach a fully developed flow field in the cavity. Because of the big quantity of elements in the Leporello bag model it is not possible to enlarge the number of euler cells without increasing the CPU time. Therefore a reduced model is considered that consists only of the turning vane, inflator housing and hole elements. During the first 20 ms the values of the pressure fraction between outer and inner chamber are lower than 0.5 (see Figure 10), which means the Euler cell average pressure in the inner chamber is considerably higher than twice the outer chamber (average) value. With that, the condition of critical flow criterion through the artificial vent hole is satisfied and the two volumes are in a first approximation regarded as being independent. Thus, the omission of the fabric should not have a significant influence on the flow field inside the cavity.

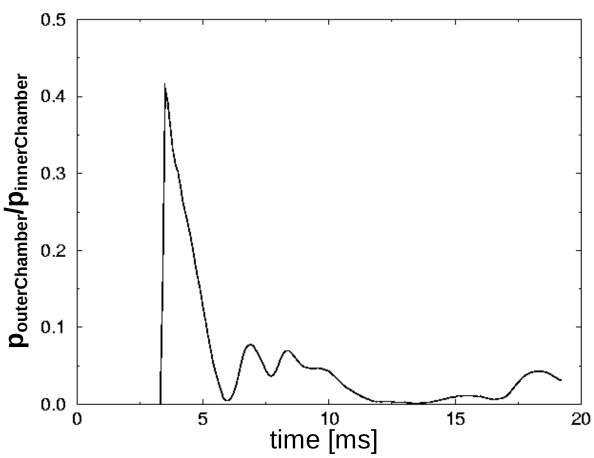


Figure 10 : Fraction between outer and inner average chamber pressure in the Leporello bag calculation.

<u>Model reduced to the inner chamber</u>

If the number of Euler grid cells is increased from 40x40x40 to 80x80x40 elements the pressure rises at the inflator definition points in less than one ms of gas inflow to 6.5 MPa. The average pressure in the cavity amounts after ten ms about 65 MPa. These high values are never reached in the two chamber model not even locally in the inflow cells.

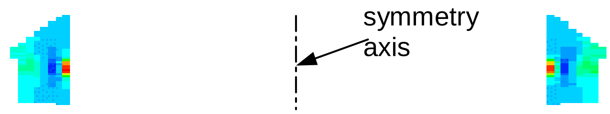


Figure 11 : Pressure distribution (red : 65·105 Pa, blue : 45·105 Pa) in the section through the cavity (time step 4 ms).

One might assume that there is a mistake and the venthole has no permeability. However Figure 12 shows the supplied and exhausted gas masses during the first ten ms which are almost the same. This means that the inflowing gas does not remain very long or cumulate in the chamber and the outflow is working. On one hand it was expected, that the mean pressure in the reduced model is unchanging or decreases a little compared to the two chamber calculation, because the gas escapes against the lower ambient pressure. On the other hand in the finer grid, the cells in the vicinity of the inflator holes, which are filled with the predetermined massflow, are smaller. Due to that, higher pressure values in these cells are generated, which is responsible for an increased pressure over the whole domain.

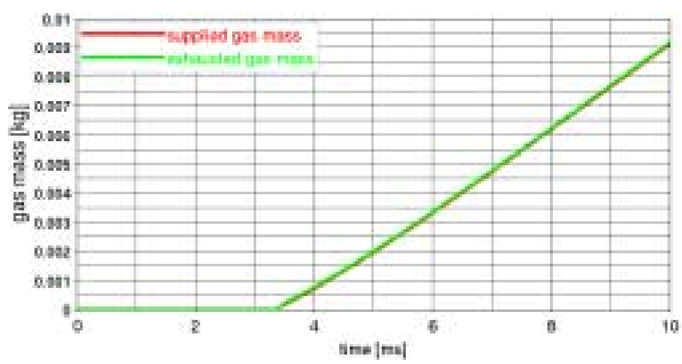


Figure 12 : Balance between supplied and exhausted gas mass in the cavity.

With this result, it seems that using a finer grid does not directly lead to a more apprehensible behavior. Only a comparison with hardware tests can show which model is closest to reality.

COMPARISON WITH HARDWARE TESTS

The comparison in Table 2 shows the differences between the simulations itself and between numerical and test results at the three time steps 5, 9 and 17 ms. In the radial and vertical exhaustion models (first two rows in the table below) the same initial Euler grid is used with 80x80x40 cells. Against it the two grids in the third model consists of 40x40x40 (inner chamber) and 20x20x10 (outer chamber) cells. With the radial inflow model the vertical spread can not be described accurately. This is done better with the vertical describtion, but it seems that after 9 ms there is not enough gas velocity left to accelerate the fabric in vertical direction. With the two chamber model (third row) the bag looks like a flame with the highest elongation in z-direction at 17 ms. The behavior in the beginning has a completely different characteristic compared to the other results in both test and simulations.

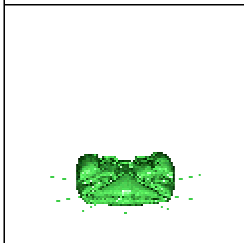
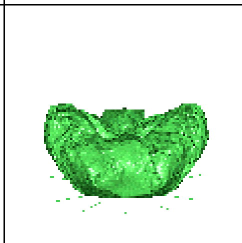
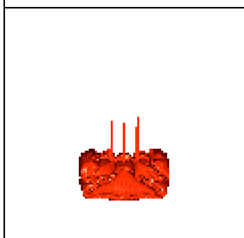
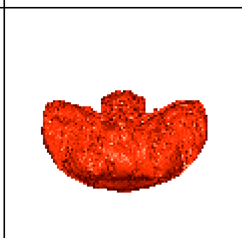
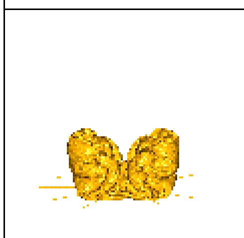
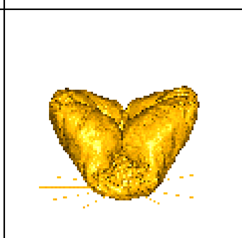
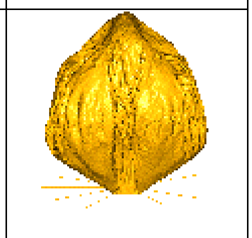
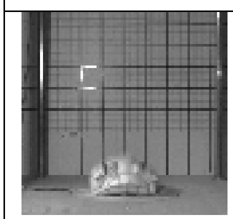
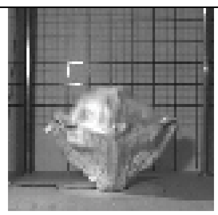
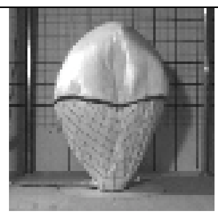
5 ms	9 ms	17 ms
		
		
		
		

Table 2 : Comparison between simulation and tests at 5, 9 and 17 ms (green : radial inflow, red : vertical inflow, yellow : two chamber model).

Table 2 shows that currently no model is able to depict the airbag unfolding kinematics accurately.

COMPRESSION FOLDED BAG

A very common kind of getting the airbag fabric packed is the compression folding. This can be done by a machine with several slides. They push the airbag material between two sheets. In the end, a stamp forces the fabric into a container, where the inflator has been brought in at the beginning (see Figure 13).

The result of the folding process can be seen in Figure 14. In this case, the geometry has been meshed with all its details, including the contour of the turning vane. With the sectional view, the difficulties in this model become clear: The available volume in the container is constructed very small, therefore some parts of the fabric are pressed in the gap between inflator and turning vane.

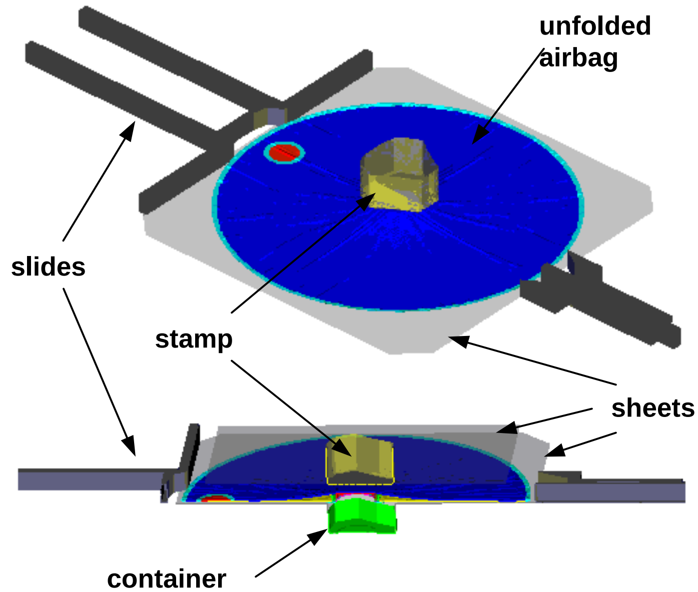


Figure 13 : Compression machine

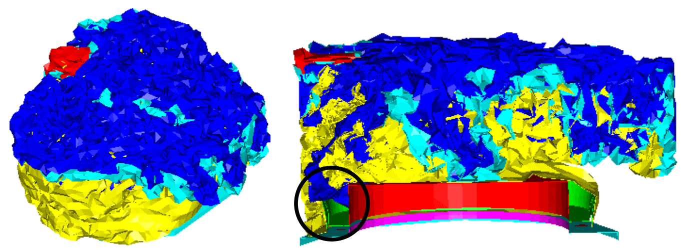


Figure 14 : Compression folded Bag – oblique and sectional view.

Some folding attempts have been made with a two chamber model that has an artificial venthole in the same manner as shown in Figure 7. Now the remaining volume for the fabric is even less, because the cavity is no longer accessible for the folds. The simulation terminates abnormally. One critical region is marked by the circle in the figure above. Of course, there are several possibilities to solve this: stronger contact definitions or reduced sliding velocities e. g. to get the folding simulation stable. With the knowledge of the flow behavior studied with the Leporello bag model and under consideration that the container (not shown in Figure 14) additionally prevents from a gas flow in radial direction no more effort has been spend to create a multi chamber compression bag. It is not possible to get some reproducible test results of the complex folded airbag alone that can be used to validate the model, because it can not be placed on a plate like the Leporello bag without being opened by itself.

CONCLUSION

The way in which gas flow is defined highly influences the simulation results. In this study a Leporello bag has been investigated. The flow direction has been varied before a more detailed and therefore a more CPU consuming two chamber model was created. A comparison with hardware tests shows no satisfying representation in the kinematic behavior during the airbag unfolding. The higher expense with the two chamber model does not lead to a better accuracy. Until the flow modeling is fully understood, it is advised to use the vertical inflow formulation, because this method seems closest to reality, at least regarding the airbag fabric kinematics. The investigation brought out that a finer grid does not directly lead to more realistic results automatically as long as there is no other possibility to specify the inflow conditions.

ACKNOWLEDGMENTS

The author likes to thank the members of the oop simulation working group for their good collaboration and the disposal of simulation models and test results.

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CONTACT

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