New Method to Characterize Airbag Inflators On the Way to OoP Simulation

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Summary:

An accurate Out-of-Position (OoP) simulation will be a mile stone for the development of restraint systems, as this would save hundreds of expensive hardware tests. OoP load cases are currently required by the US legislation and as in-house specification by many car manufactures for other markets. But simulating OoP is a difficult issue, as several challenges have to be addressed, for example: An improved dummy model validated against new component tests and an accurate modeling of the folding/unfolding of an airbag including an appropriate gas model. One of the missing pieces for this simulation is the accurate representation of the inflator mass flow.

The current method to characterize gas inflators is the tank test. This method has big advantages, being cheap, reproducible and independent of the inflator geometry. The tank test shows, however, some important drawbacks: The lack of similarity of the bag inflation regarding volumetric work of the gases and initial conditions, a uniform and immediate pressure distribution must be assumed, the measurement –tank pressure– must be derived to obtain the inflator gas mass flow resulting in a higher measurement error and heat losses are high and not uniform during the process.

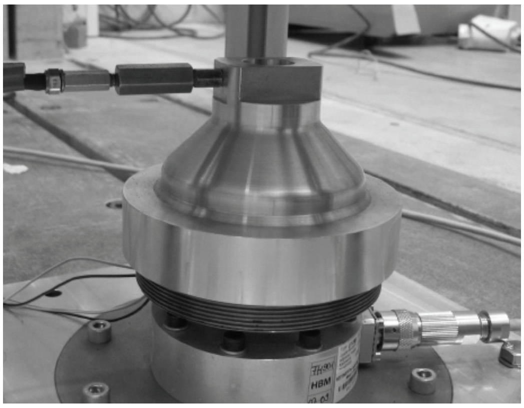

Figure 1: Thrust Measurement Test Setup. A disc inflator is inside the nozzle. Measurement equipment includes an underlying force sensor and a static pressure sensor at the nozzle end.

Alternative methods like the dynamic tank test have not succeeded as they are not practical enough for every day's use. A new method is proposed based on a thrust measurement (Fig. 1), which has been validated at TAKATA-PETRI with excellent test results. This method uses a minimalist test setup, allows a direct measurement of the mass flow and implies lower thermal losses, thus, providing a more practical and reliable characterization of the inflator for simulation.
The nozzle of the thrust measurement setup was designed by computational fluid dynamics simulation to produce a choked flow at the nozzle end. In this condition, the gas reaches Mach 1 and following relation is valid:

$$\sqrt{\frac{2R(\kappa+1)}{\kappa}}\sqrt{T_i}\,\dot{m}_i = F \qquad (1)$$

being R the gas constant, κ the heat capacity ratio for the inflator gas, T_i the exit gas temperature of the inflator gas, m_i the inflator gas mass and F the thrust force.

Thus, the thrust force is proportional to the mass flow, assuming a constant exit gas temperature. This assumption is valid at least for pure pyrotechnical inflators. A constant exit gas temperature can be calculated by integrating equation 1 over the time, or alternatively, by a complementary tank test, from which only the exit gas temperature is taken over.

Also the static pressure at the nozzle end is proportional to the mass flow because of the sonic flow at the nozzle and can be seen as a redundant measurement to the thrust force.

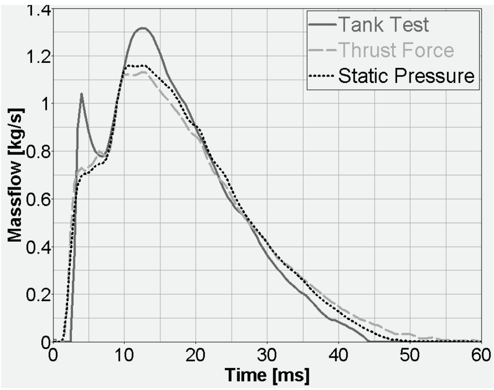

Figure 2: Dual-stage driver inflator's mass flow calculated from the test results after the average temperature method. Inflator was triggered with 5 ms delay between both stages.

In figure 2, the results of the tank test and the thrust measurement are compared. For the tank test, the mass flow was calculated after the average temperature method, assuming zero heat losses. In the other cases, just a scaling of the measured data is needed, as the mass flow is proportional to the force and static pressure, as seen in the equation 1. The tank test has a higher measurement delay, due to the lack of sensitivity of the pressure sensor and the pressure wave delay until the sensor is reached. Also the curve stops at aprox. 45ms –due to the heat losses–, although the inflator actually delivers gas during 50ms. This results in high peak values, as the integral of the curve is constant and equals the gas mass which is produced by the inflator. The result of the thrust/static pressure measurement is more plausible than the tank test.

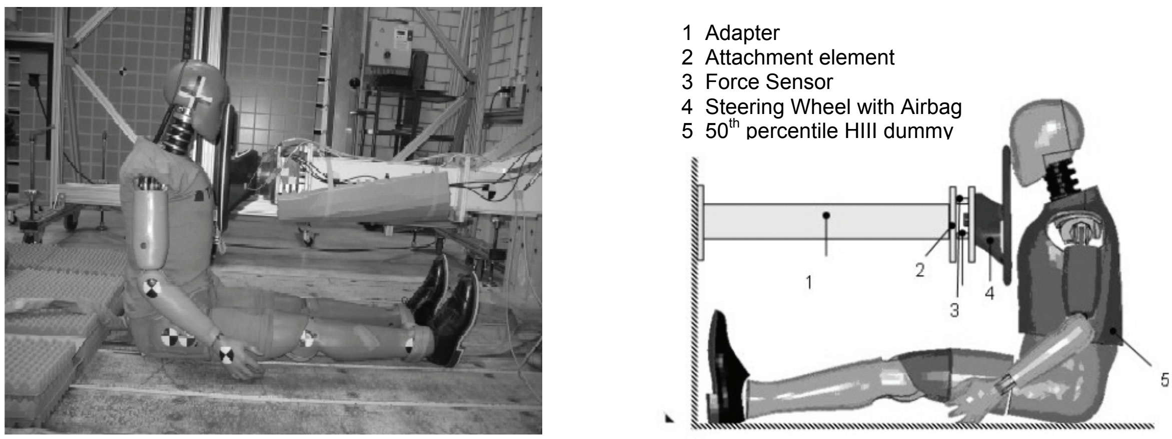

Figure 3: Simplified OoP Test setup [1].

For restraint system modeling, the mass flow obtained by a tank test is, however, accurate enough. No significant difference is seen by using one or the other method. The difference can only be observed in OoP modeling, using a gas representation with the corpuscular method (CPM).

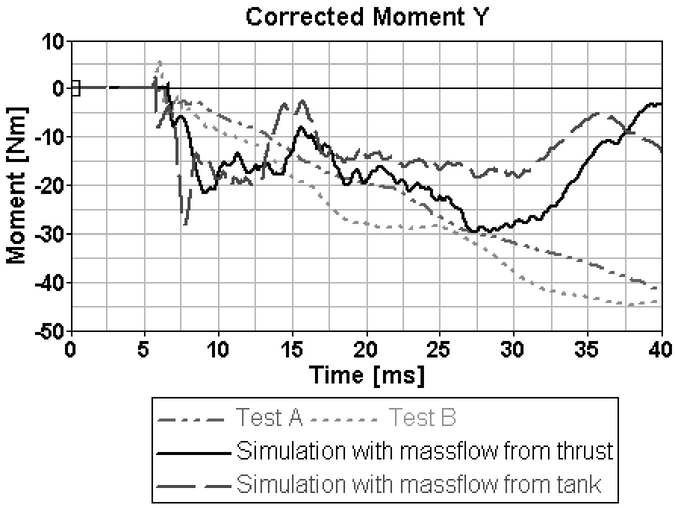

Figure 4: Out-of-position simulation results for the total neck moment. Acceptable results are achieved with the mass flow from thrust method until 30ms. After that, the whole dummy movement differs from the hardware test.

The application of these results to OoP models was done with a simplified setup [1] shown in the figure 3. The aim of this simplification was to reduce the complexity of the seating procedure and influences of components like seat and steering column. The steering wheel and airbag device are standard components in series application and the HIII 50th percentile dummy is used to obtain a robust behavior. The comparison between hardware testing and simulation can be observed in figure 4. The application of the mass flow achieved by the thrust method leads to better results, though far from the exactitude needed for an industrial standard method.

The tank test is further an important tool to characterize airbag inflators: It is cheap, reproducible and independent of the inflator geometry. But, when a simulation of OoP situations is needed, the mass flow curves delivered by the tank tests are not accurate enough. For this, a new method is proposed in addition, which measures the thrust force or the static pressure in a nozzle under choked flow conditions.

Keywords:

Inflator, Mass flow calculation, Thrust measurement, Out of position.

Literature

[1] Eschweiler, P.: "Simulation der Airbagentfaltung in OoP-Situationen bei verschiedenen Klappenteilungen", diploma thesis, 2008