

CURTAIN AIRBAG GAS DELIVERY SYSTEM DEVELOPMENT USING CFD ANALYSIS

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ABSTRACT

This paper describes curtain airbag gas delivery system development work using CFD analysis. The objective of developing gas delivery system was to achieve uniform inflation and reasonable time to position for oblique pole test with 5th %ile female. CFD analysis has been conducted to design gas delivery system of 3 row curtain airbag. The gas delivery system consists of T-diffuser and flexible gas delivery tube. T-diffuser hole sizes and the hole sizes in flexible gas delivery tube system have been determined through CFD simulations. Confirmation static deployment test has been conducted to confirm the design specification from CFD analysis. In the static deployment test, pressure ports were installed to measure the pressure at several locations in the curtain airbag. It was found that the bag kinematics and pressures in the test were close to the simulation kinematics and results.

INTRODUCTION

In developing a curtain airbag system for head protection in side impact condition, gas delivery system development work is very important to achieve uniform inflation and reasonable time to position. In this paper, a 3 row curtain airbag is considered to design a gas delivery system which consists of T-diffuser and two flexible gas delivery tubes connected to the T-diffuser. Madymo CFD simulations are conducted to design a gas delivery system. Through Madymo CFD simulations, T-diffuser hole size and hole size in flexible gas delivery tube are determined, which achieve uniform inflation and reasonable bag positioning time. Then, static deployment test is conducted to confirm the design specification from CFD simulations. In the static deployment test, pressure ports are installed to measure the pressures at three locations in the curtain airbag. The curtain airbag kinematics and pressure curves from the static deployment test are compared to the ones from the CFD simulation which produced the design specification.

Curtain Airbag System

Figure 1 shows the 3 row curtain airbag system which has been considered here.

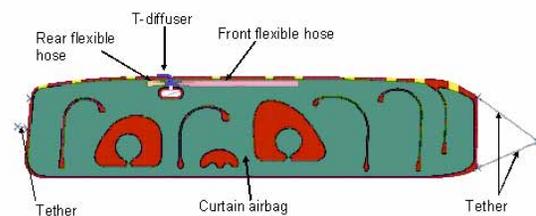


Figure 1. A 3 row curtain airbag system.

The 3 row curtain airbag system considered here consists of T-diffuser, front flexible hose, rear flexible hose, curtain airbag and external tethers. The right side is the vehicle front. An inflator is connected to the T-diffuser inlet. The front and rear flexible hoses are connected to the T-diffuser inside the curtain airbag as shown in Figure 1. Gas flows into T-diffuser from the inflator and is distributed into front and rear flexible hoses. The right end of front flexible hose has a hole and three holes can be made on the front flexible hose. Gas flows through holes into curtain airbag. The left end of rear flexible hose has a hole through which gas flows into curtain airbag. The front and rear flexible hoses have some permeability. Therefore, some gas flows into curtain airbag through hose walls.

MADYMO CFD Simulations for a 3 Row Curtain Airbag System Design

Madymo CFD code has been used to design T-diffuser hole size for rear flexible hose and 3 hole sizes on front flexible hose. Other design factors such as hose lengths, hole locations on front flexible hose and T-diffuser hole size for front flexible hose have already been decided, based on the experiences. For Madymo CFD analysis, inflator modeling and DOE simulations have been conducted.

Inflator Modeling - In order to obtain the mass flow rate and inflator exit temperature data which are Madymo inputs for CFD simulations, Madymo MTA analysis has been conducted. Figure 2 shows the inflator mass flow rate and Figure 3 shows the tank pressure simulation which justifies the mass flow rate and inflator exit temperature which generate the same tank pressure curve as in the tank test.

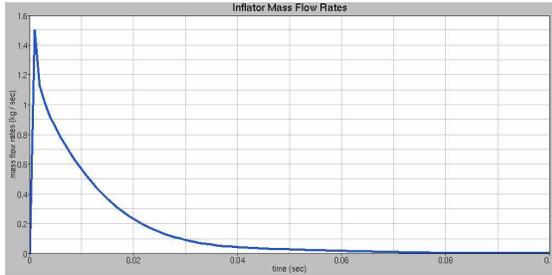


Figure 2. Inflator mass flow rate.

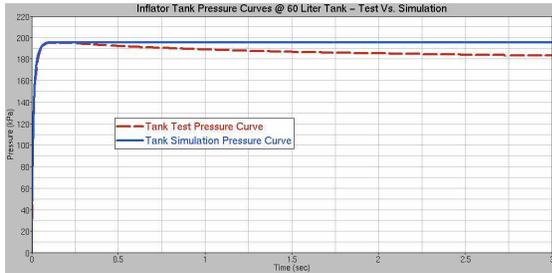


Figure 3. Tank pressure curves @ 60 liter tank – Test vs Simulation.

Madymo CFD Curtain Airbag System Model - Madymo CFD curtain airbag system model has been built, which is close to the real curtain airbag system. Figure 4 shows the Madymo CFD curtain airbag system model.



Figure 4. Madymo CFD curtain airbag system model.

The model in Figure 4 consists of 4 chambers which are the T-diffuser chamber, front hose chamber, rear hose chamber and curtain airbag chamber. Inflator is fired at the inflator inlet of the T-diffuser using a jet. Therefore the inflator gas flows into the T-diffuser and then from T-diffuser into both front and rear hose

chamber and then from front and rear hose chamber into curtain airbag chamber. The front hose chamber can have 3 downward holes on the hose surface. Therefore, gas can flow through 3 holes from front hose chamber into curtain airbag chamber. Both the front and rear hose chambers have the permeability which allow gas to flow into the curtain airbag chamber. The curtain airbag chamber is roll-folded to simulate the real situation as close as possible. The MADYMO CFD solver is used, which does not provide uniform pressure inside chambers. Therefore, the pressures can be different at different locations inside one chamber.

CFD Simulation Matrix - Running time of a Madymo CFD model is usually very long. In this work, running time is around 11 hours. Therefore, the number of design parameters should be reduced. The design parameters considered here are the rear diffuser hole size and the vent hole size on the front flexible hose. The rear diffuser hole connects the diffuser to the rear flexible hose. The rear diffuser hole size affects the bag kinematics and pressure in the rear part of curtain airbag. The vent hole size of three holes on the front flexible hose affects the kinematics and pressure in the front part of curtain airbag. Table 1 show the CFD simulation matrix.

Table 1. CFD Simulation Matrix

No.	Rear Diffuser Hole Size	Hose Size On Front Hose
1	6 mm	0 mm
2	6 mm	9 mm
3	6 mm	12 mm
4	6 mm	15 mm
5	8 mm	0 mm
6	8 mm	9 mm
7	8 mm	12 mm
8	8 mm	15 mm
9	10 mm	0 mm
10	10 mm	9 mm
11	10 mm	12 mm
12	10 mm	15 mm

Madymo CFD Simulation - From the previous experiences, it has been noticed that the permeability of the flexible hose plays an important role. Therefore, the permeability of flexible hose fabric has been obtained through tests in the lab. The obtained data was the permeability function which is dependent on pressure. The pressure vs permeability function data have been introduced in the front and rear flexible hose models.

Curtain Airbag Kinematics And Data Analysis

- The goal of this CFD simulation work was to obtain a curtain airbag gas delivery system specification with which the bag can deploy fully within 25 msec after firing, considering the 20mph-5th %ile oblique pole test condition. Therefore, the bag kinematics comparison is the most important one in this work. The figures below show the bag kinematics at 25msec after firing.

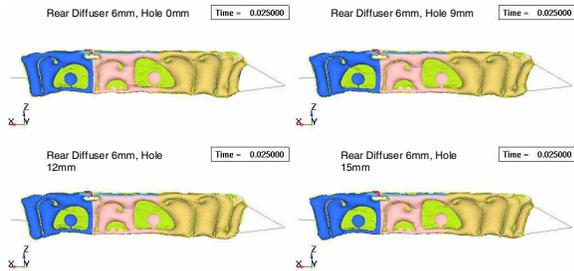


Figure 5. Curtain airbag kinematics at 25msec – 6mm rear diffuser hole – 0, 9, 12, 15mm holes on front hose.

In the Figure 5, it is noticed that there are no significant kinematics differences at 25msec between 0mm, 9mm, 12mm and 15mm holes at 25msec and all cases meet the bag kinematics requirement for the 5th %ile oblique pole test condition.

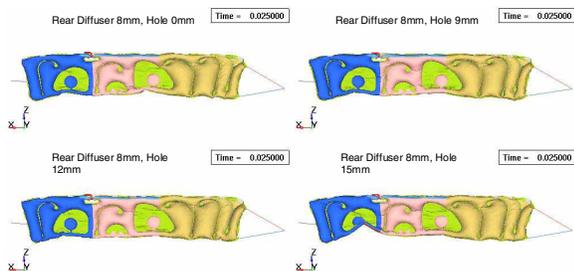


Figure 6. Curtain airbag kinematics at 25msec – 8 mm rear diffuser hole – 0, 9, 12, 15mm holes on front hose.

In the Figure 6, it is noticed that there are no significant kinematics at 25msec differences between 0mm, 9mm and 12mm holes, except the 15mm hole. However, it is considered that all cases meet the bag kinematics requirement for 5th %ile oblique pole test condition.

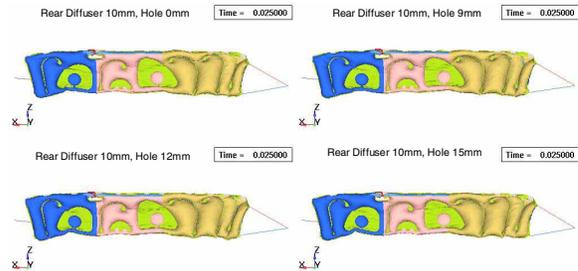


Figure 7. Curtain airbag kinematics at 25msec – 10mm rear diffuser hole – 0, 9, 12, 15mm holes on front hose.

In the Figure 7, it is noticed that there are no significant kinematics differences at 25msec between 0mm, 9mm, 12mm and 15mm holes and all cases meet the bag kinematics requirement for 5th %ile oblique pole test condition.

Considering that all cases in Figure 5, Figure 6 and Figure 7 meet the kinematics requirement for 5th %ile oblique pole, it is temporarily concluded that the holes do not necessarily be introduced on the front flexible hose. Therefore, only the cases of no holes on front hose are considered to determine the rear diffuser hole size. First, the gas mass flows in T-diffuser are compared between 6mm, 8mm and 10mm rear diffuser holes.

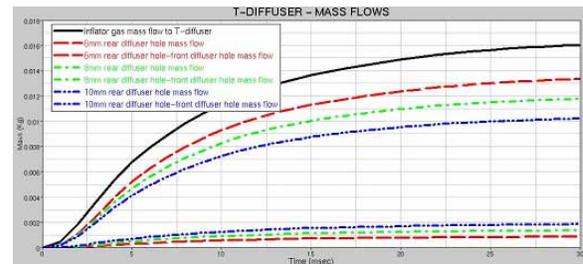


Figure 8. Mass flows in front and rear diffuser holes with 6mm, 8mm and 10mm rear diffuser hole sizes.

Figure 8 shows the mass flows in front and rear diffuser holes as expected. As the rear diffuser hole size increases, the mass flow in rear diffuser hole increases and the mass flow in front diffuser hole decreases. The next step is to investigate the pressures inside the curtain airbag. Three locations were chosen to investigate the pressures as seen in the Figure 9.

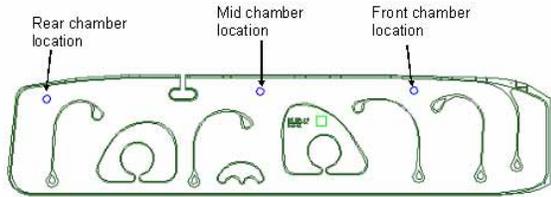


Figure 9. Three locations inside curtain airbag for pressure investigation.

In three locations, the pressures were investigated for the 6mm, 8mm and 10mm rear diffuser hole cases.

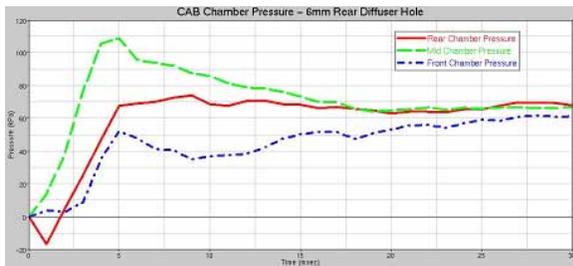


Figure 10. Pressure curves at three locations inside curtain airbag with 6mm rear diffuser hole.

From the Figure 10, it is noticed that the mid chamber pressure is the highest among three locations and three pressure curves tend to converge to equilibrium pressure.

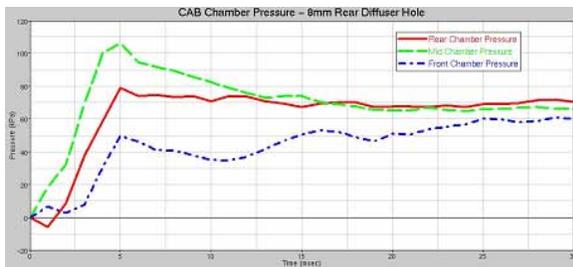


Figure 11. Pressure curves at three locations inside curtain airbag with 8mm rear diffuser hole.

Considering Figure 10 and 11, it is noticed that at 5msec, the rear chamber pressure with 8mm rear diffuser hole is higher than the one with 6mm rear diffuser hole and the mid chamber pressure with the 8mm rear diffuser hole is lower than the one with the 6mm rear diffuser hole. And the pressure converging to equilibrium with the 6mm diffuser hole is

observed to be faster than the one with the 8mm diffuser hole.

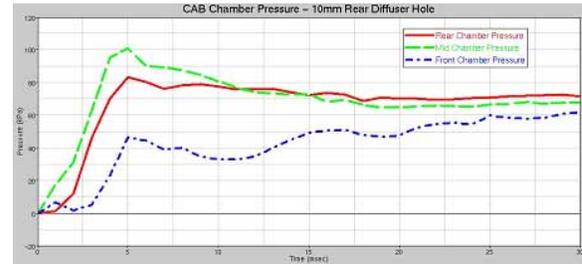


Figure 12. Pressure curves at three locations inside curtain airbag with 10mm rear diffuser hole.

Comparing Figure 10, 11 and 12, as the rear diffuser hole size increases, the mid chamber pressure decreases and rear chamber pressure increases. And with the increase of the rear diffuser hole size, the pressure converging to equilibrium becomes late. If the pressure converging to equilibrium is fast, it means quick and even unfolding of curtain airbag which is desirable. At 20msec, the pressure differences between mid and front chambers were 11.7 kPa for the 6mm, 14.2 kPa for the 8mm and 17.1 kPa for the 10mm rear diffuser hole. Therefore, the rear diffuser hole of 6mm was chosen for testing.

Curtain Airbag System Static Test

A curtain airbag system static test was conducted in a vehicle and the pressures were measured at the locations shown in Figure 9. Figure 13 shows the test environment at t=0 msec.



Figure 13. Curtain airbag system static test setup at t=0 msec.

Figure 14 shows the measured pressures at the location shown in Figure 9.

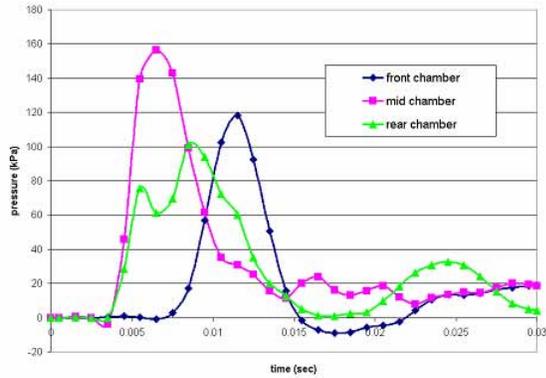


Figure 14. Pressure curves with the 6mm rear diffuser hole from system static test.

Considering Figure 14 and 10, it seems that the pressure curves from the test are different from the pressure curves from the simulation. The difference seems to come from the folding difference and the cover. The folding in simulation has more initial volume than the real, in order to avoid initial penetration which causes numerical instability. And the cover was not modeled in the simulation. However, as predicted in the simulation, in early time, the mid chamber pressure was the highest among three and the rear chamber pressure was higher than the front chamber pressure. Therefore, the curves characteristics in the test are the same as the one in the simulation. This fact made the chamber inflating order in test to be the same as in the simulation.

Deployment Kinematics Comparison

The figures below show the curtain airbag kinematics comparison between simulation and test.

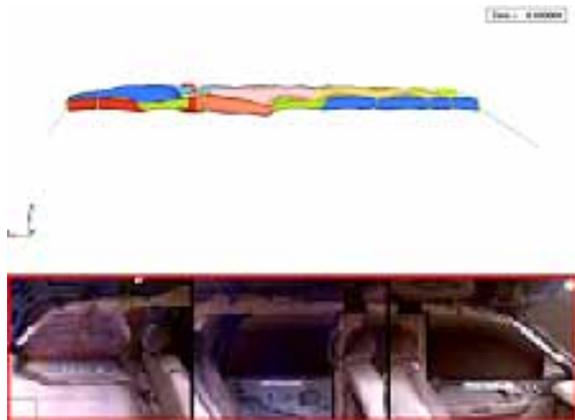


Figure 15. Curtain airbag kinematics at 5msec – simulation vs test.



Figure 16. Curtain airbag kinematics at 10msec – simulation vs test.

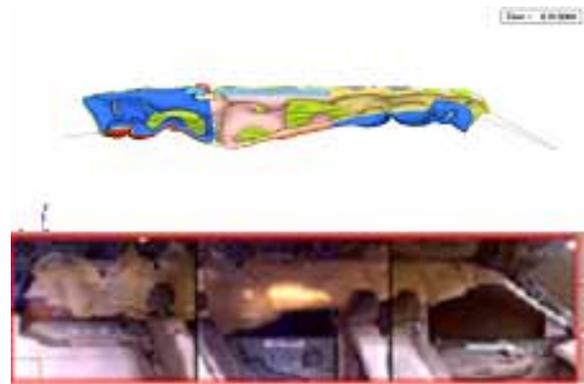


Figure 17. Curtain airbag kinematics at 15msec – simulation vs test.



Figure 18. Curtain airbag kinematics at 20msec – simulation vs test.



Figure 19. Curtain airbag kinematics at 25msec – simulation vs test.

From Figure 15 to Figure 19, the CAB deployment kinematics of simulation are seen to generally match the test. However, as seen in Figure 19, the right bottom corner of front chamber in the test did not be as fully unfolded as in the simulation. The reason is that the folding in test is tighter than in the simulation and the cover wraps the curtain airbag in the test. In the test, the right bottom corner of front chamber was unfolded fully at 40msec as seen in the Figure 20.



Figure 20. Front chamber kinematics at 40msec.

CONCLUSIONS

In this work, the following conclusions are made.

- Madymo CFD code can simulate gas flows in gas delivery system (T-diffuser, front flexible hose and resr flexible hose) plus curtain airbg.
- Madymo CFD code could be used to predict the curtain bag kinematics.
- Madymo CFD code could produce the pressure data inside curtain airbag which

show some difference from but the same trend as the test pressure data.

- To minimize differences in pressure data and kinematics, the bag folding close to the real and adding cover on the curtain are needed.
- Madymo CFD code could prove that the permeability function of flexible hose plays an important role.
- Madymo CFD code could be successfully used to design curtain airbag gas delivery system.

ACKNOWLEDGEMENTS

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REFERENCES

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