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Dynamic PIV Measurement of a High-Speed Flow Issuing from Vent-Holes of a Curtain-Type Airbag

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Abstract: A curtain-type airbag is a safety device designed to protect passengers from the side collisions of a car. The curtain-type airbag system consists of an inflator, a fill-hose, and a curtain-airbag. The fill-hose is a passageway and distributor of the exploded gases from the inflator to the airbag through vent-holes. Although the design of vent-holes is important for proper deployment of the airbag, it is very difficult to measure the exceedingly high speed flow issuing from the vent-holes by using conventional measurement methods. In this study, we employed a dynamic PIV technique to measure the temporal evolution of instantaneous velocity fields of the flow ejecting from the vent-holes. From the velocity field data measured at a frame rate of 2000 fps, the temporal variation of the volume flux from vent-holes was also evaluated for the diagnosis of airbag performance. The flows ejecting from the vent-holes showed high velocity fluctuations, and the maximum velocity was about 480 m/s. The instantaneous velocity fields in the initial stage showed a swaying motion of a high-speed jet. The accumulated volume flux from the vent-holes was also compared at each vent-hole region.

Keywords: Flow visualization, Fill-hose, Dynamic PIV, Curtain-type airbag.

1. Introduction

According to the USA statistics, 1.7 million airbags were deployed among the 257 million airbags on the road in 2003 (Evans, 2004). This number will increase as the number of installed airbags in vehicles increases. The effectiveness of airbags in reducing fatalities and severe injuries is well documented (Cummings et al., 2002; Zador and Ciccone, 1993). Besides the front airbag systems installed on most automobiles, a curtain-type airbag is increasingly being adapted in deluxe cars to protect passengers from the danger of side impact collisions. The curtain-type airbag system consists of an inflator, a fill-hose, and a curtain airbag. The inflator supplies high-pressure gases to deploy the airbag. Lee at al. (2006) measured velocity fields of the high-speed and high-pressure flows issuing from the exit nozzle of an airbag inflator. The flow ejected from the inflator showed very high velocity fluctuations with a maximum velocity of about 700 m/s. The duration time of the high-speed flow was very short and there was no perceptible flow after 100 ms from the ignition. The fill-hose is a long passageway of the charged gases ejected from the inflator nozzle toward the curtain-type airbags. A proper deployment of the airbag is directly related the flow issuing from vent-holes of a fill-hose. Unfortunately, there is very limited information on the exceedingly high-speed flow issuing from the vent-holes of a fill-hose. In this study, we focused on the high-speed flows ejected from the vent-holes
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of a fill-hose which would be used for deploying the curtain-type airbag. The whole processes occurred within less than 100 ms from the triggering of the airbag system due to impact. Because of its vigorous action, it is not easy to measure the flow ejected from vent-holes of a fill-hose using conventional flow measurement methods. Optical interferometers or LDV system can be applicable to these flows (Mizukaki, 2007). However, the flow information to be obtained would be qualitatively visualized flow images or point-wise data at several measurement locations. Recently, a dynamic PIV velocity field measurement technique was introduced with the advances of high-speed imaging devices and high-repetition pulse lasers. It is now possible for the dynamic PIV system to get instantaneous velocity field data at a very high time resolution (Etot et al., 2002). Therefore, the dynamic PIV system is very useful for investigating temporal evolution of turbulent flows, especially the unsteady transient high-speed flows (Hwang et al., 2005). In this study, we applied the dynamic PIV system to measure the temporal evolution of instantaneous velocity field of the high-speed flows ejecting from each vent-hole region of a curtain-type airbag fill-hose. Furthermore, based on the measured flow information, the performance of the tested curtain-type airbag was evaluated.

2. Experimental Apparatus and Methods

Figure 1 shows a photograph of the experimental set-up used in this study with a schematic diagram. A fill-hose assembled with an inflator was installed inside a transparent chamber having a physical size of 0.42 m(W) × 0.72 m(H) × 1.92 m(L). The chamber was made of reinforced transparent acryl and rigid aluminum profiles to endure the ignition shock of the inflator. In addition, the fill-hose model and an inflator were firmly fixed to the chamber with a holder, and heavy weights were put on the top side of the chamber to prevent structural vibration just after ignition. The chamber was designed in consideration of the size of a fully-inflated curtain airbag. A relay switch was used to synchronize the inflator ignition with the dynamic PIV system. When the relay switch receives a 5V DC TTL(transistor transistor logic) signal from the delay generator, it sends the triggering signal of 12V DC to the internal circuit of the inflator. The fill-hose model was made of steel pipe for a strong fixture. Its length and inner diameter were 900 mm and 38 mm, respectively. The diameter and location of each vent-hole are the same as those of the real standard fabric fill-hose. The 2-vent-hole, 1-vent-hole and 4-vent-hole regions correspond to the rear seat, B-pillar and front seat, respectively. The diameter of each hole in the 4-vent, 2-vent, and 1-vent-hole regions are 18, 15 and 12 mm, respectively.

Olive oil droplets generated by a Laskin nozzle were used as tracer particles. The transparent test chamber was filled with olive oil particles before the experiments. For high-speed flows, the lag velocity of tracer particles should be considered. The lag velocity \( U_l \) can be estimated as functions of

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Fig. 1. Experimental setup for dynamic PIV measurements and layout of vent-holes of a fill-hose with three sections of PIV measurement.