Analysis of Malaysian Pregnant Driver with Restraint System during Automotive Collision of a Multi-Purpose Vehicle

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Abstract - Placenta abruption is the most common injury sustained by pregnant driver in motor vehicle accident and the leading cause of foetal loss. Unrestraint pregnant women involved in crash are highly exposed to injury and foetal loss risks. The objective of this study is to investigate the efficiency of restraint system i.e. seat belt and airbag, for protecting pregnant drivers while driving. A 5th percentile female ATD with instrumented pregnant capsule was seated in driver position in a Multi-purpose vehicle (MPV). The MPV was then collided against ODB in frontal offset crash test at 64km/h. The result showed high pregnant lady’s peak pelvic acceleration (115.39g) and foetus head HIC value (398 HIC).

Keywords – Pregnant, driver, seat belts, crash test, restraint system.

I. INTRODUCTION

The most common injury sustained by pregnant woman involved in road crash is placenta abruption, which is also the leading cause of foetal loss. Unrestraint pregnant women involved in road crash are highly exposed to injury and foetal loss risks. Injuries sustained by pregnant women have also been identified in several crash-related studies. Placenta abruption (PA), is stated in previous related studies as the leading cause of foetal loss in motor-vehicle crashes if the pregnant victim survived [1,2].

Placenta abruption may occur due to improper wear of seat belt, where the seat belt crosses the pregnant woman’s abdomen; resulting in placenta separated from the uterus, and disrupting the flow of oxygen and nutrients to the foetus. A study carried out among pregnant occupants involved in road crashes in Michigan; found that the unbelted pregnant occupants suffered a higher severity of injuries [3]. 50% pregnant occupants in the study did not wear seat belt or any restraint system, and 70% of them suffered placenta injuries due to crash.

Besides that, the foetus can also be injured when the pregnant woman makes contact with the steering wheel or the dashboard, or when the pregnant woman’s abdomen is directly and abruptly hit by airbags. Most of the victims were drivers, and apparently most of the injuries were caused by the impact against the steering wheel during collision [4]. Another study found that unbelted pregnant drivers involved in frontal crashes during their last trimester experienced direct loading to the uterus by the steering wheel. This study reflects Klinich’s study [5] where he found that after the sixth month of pregnancy, the uterus lies below the steering wheel rim. Thus it is clear that the primary way to protect the foetus is to protect the mother, and the way to protect the mother in car crash or to minimize the injury is by properly buckling up the seatbelt.

II. METHOD

A. Real-World Pregnant Lady Anthropometry

To determine the seat adjustment position used by pregnant driver in an MPV, an anthropometric study of pregnant driver was conducted. A total of 10 pregnant women who regularly drive a car volunteered as respondents...
for this study. An MPV, similar model with the one being crashed was used for this purpose. The respondents were given full verbal explanations on the purpose of this study, method of adjusting the seat, seatbelt anchorage and steering wheel prior to the anthropometric measurement. After the explanation session, the respondents sat in the driver’s seat and adjusted the seat, seatbelt anchorage and steering wheel by themselves so that the sitting posture would be as close as their normal driving position. Then, anthropometric measurements were recorded.

B. MPV Driver Seat Setup

To determine the driver compartment adjustment positions of the dummy from the anthropometric measurement results, the mean values of four chosen subjects; whose anthropometry were similar to AF5 (Hybrid III 5th percentile female), were obtained.

C. AF5 Pregnancy Insert

Ballistic gel based pregnant insert was moulded using fake pregnant belly shape. The pregnant insert was then inserted using instrumented foetal transducer to measure the HIC of the foetus. The foetal weighed 3kg. The pregnant insert was then attached onto the AF5.

D. Test Setup

An MPV containing pregnant AF5 dummy at the driver seat and two child dummies (P3 and P1.5) seated in the child restraint system (CRS) was intentionally collided into an offset deformable barrier (ODB), at the speed of 64 km/h in frontal crash test. The ODB was positioned in such a way that the initial contact would be at 40% of the width of the front of the test car, on the driver’s side. The test speed of 64 km/h basically represents a car to car collision, with each car travelling at around 55 km/h and this addresses a significant proportion of serious and fatal casualties [6]. The crash test was performed at MIROS PC3; an official full-scale crash test laboratory established by MIROS, situated in Malacca, Malaysia.

E. Data Analysis

The assessment was based on the injury values obtained by the transducers installed in various body regions of the dummies e.g. head, neck, chest, femurs, knees, lower and upper legs. The worst injury results from each dummy were used for the calculation of the overall injury score. Pelvis peak acceleration in x-direction was then closely analysed as the value had a statistic significant contribution to the risk of foetal loss [7].

III. RESULTS

A. Real-world Pregnant Lady Anthropometry

To determine the seat adjustment positions used by pregnant female drivers, the measurements for pregnant volunteers were conducted using an MPV. The respondents were asked to adjust all the adjustable items, inclusive of the adjustment of the seat base, back rest, steering wheel and seatbelt anchorage point according to their usual driving posture. The average age of the pregnant respondents was around 30 years old. The mean gestational age was recorded around 26.7 weeks. The mean height and weight of the respondents were 1572mm and 68.2kg, respectively. Meanwhile, the waist circumference was 9768mm and the fundal average height was 3470mm.

<table>
<thead>
<tr>
<th>Driver compartment</th>
<th>Respondents</th>
<th>AF5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat Base (from forward most position)</td>
<td>5th or 6th</td>
<td>2nd</td>
</tr>
<tr>
<td>Back Rest (from forward most position)</td>
<td>2nd or 3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>Steering Wheel</td>
<td>Upper most</td>
<td>Upper most</td>
</tr>
<tr>
<td>Seatbelt Anchorage (from upper most position)</td>
<td>2nd</td>
<td>2nd</td>
</tr>
</tbody>
</table>

Table 1 shows the driver compartment adjustment setup for pregnant driver and the actual setup for crash test of AF5. As recommended by FMVSS, AF5 was positioned at forward most position, or the position at which the lower extremities of the dummy were
closest to the dashboard of the testing vehicle. However, the AF5 dummy could not sit this position due to interference of the protrusion of the abdomen with the lower rim of the steering wheel.

Due to the smaller stature of AF5 dummy as compared to pregnant respondents, the actual driver compartment test setup for seat base was adjusted so that the foot of the AF5 could touch the accelerator pedal.

The most comfortable sitting posture for the pregnant respondents and also the AF5 were then measured, as shown in Fig. 1. Table 2 shows the measurements of pregnant drivers’ and AF5 seating posture. With the adjustment of seat base, the gap of the dummy’s abdomen with steering wheel (LST) in crash test setup measured only 20mm.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Respondent Mean</th>
<th>SD</th>
<th>AF5</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>454</td>
<td>4.0</td>
<td>370</td>
</tr>
<tr>
<td>NH</td>
<td>475</td>
<td>4.0</td>
<td>395</td>
</tr>
<tr>
<td>CHH</td>
<td>350</td>
<td>3.9</td>
<td>310</td>
</tr>
<tr>
<td>LST</td>
<td>128</td>
<td>3.8</td>
<td>20</td>
</tr>
<tr>
<td>KDL</td>
<td>112</td>
<td>2.3</td>
<td>90</td>
</tr>
<tr>
<td>KDR</td>
<td>129</td>
<td>2.2</td>
<td>110</td>
</tr>
</tbody>
</table>

B. MPV Crash Test

The crash test speed recorded by using speed meter was 64.0 km/h, while the HIC of the pregnant driver was 534.85g. Contact switch was installed on the dummy’s abdomen and steering wheel. It was found that the dummy’s first contact with steering wheel was at 32ms with the duration of contact at 46ms.

The risk of placental abruption and peak pelvic acceleration in the x-direction had been reported having a significant relationship [7]. According to Manoogian [7], pregnant dummy with a peak pelvic acceleration above 67g had a 100% risk of foetal loss. This study recorded the peak pelvic x-acceleration 87.76g, as shown in Fig. 2. The final position of the dummy showed that the shoulder seatbelt was out of position during and post impact, as shown in Fig. 3.

Meanwhile, the peak foetal head acceleration was 115.39g with 398 HIC, as shown in Figure 4. Duma et al. [8] reported that in the 35 km/h crash simulation, the peak foetal head acceleration was estimated as a peak of
73.5g with a 118 HIC. In the 47 km/h crash simulation, the peak foetal head acceleration was 83.7g with a 215 HIC [8].

When examining direct foetal head accelerations, the peak accelerations and HIC values were found relatively high. The 398 HIC was higher than the tolerance level for the 1 year old infant dummy at 390 HIC [9].

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**IV. CONCLUSION**

The objective of the paper is to analyse the effect of restraint system, which includes seatbelt use and airbag on pregnant occupant. The result shows the high risk of foetal injury with the current setting of sitting posture. However, the finding from this experiment was an inconclusive finding as this test was only conducted once. In order to fully understand the effectiveness of restraint system as a whole, the behaviour of pregnant occupant in a crash test without restraint system needs to be examined in the future.

Further analysis also needs to be conducted to compare the reliability of the current pregnant AF5 with the established Maternal Anthropometric Measurement Apparatus, version 2B (MAMA-2B). The authors would also like to suggest pregnant lady to ensure that there is a significant gap between the mother’s abdomen and steering wheel. It is recommended that pregnant women should sit as far away as possible from the front airbag and the seat backward should be moved as much as possible.

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**ACKNOWLEDGMENT**

This research work is supported by the Vehicle Safety and Biomechanics’ research committee of Malaysian Institute of Road Safety Research (MIROS). This paper also benefits from the contribution of MIROS PC3, the official ASEAN NCAP crash test laboratory for their assistance in interpreting the test data.
REFERENCES


