INFLUENCE OF SEATING POSITION ON OCCUPANT'S INJURY CRITERIA

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ABSTRACT

The number of fatalities in traffic accidents has been reduced continuously. One of the factors for such reduction may be improvement of safety devices. However, though total number of deaths has been reduced, many lives are still lost in traffic accidents. Nearly half of the deaths while driving automobile is in frontal crash. On the other hand, driver seating position is variable and the distance between the occupant and occupant restraint system becomes longer in rearmost position (RM) than mid position (MP) of seat slide, resulting in a delay of occupant restraint onset. Because of the delay of occupant restraint, pelvis restraint is also delayed and pelvis displacement increases. At that time, the motion of pelvis increases the tension of lap belt and it is transferred to the inboard shoulder belt through the thorough tongue. Tension in inboard shoulder belt increases the loading to the lower rib cage and may increase the risk of chest injury. This research examined the influence of seating in RM position to the occupant's lower thorax injury and the influence on lower thorax injury by controlling pelvis behaviors in RM position. In this study, finite element (FE) simulations of the sled test in flat56km/h were conducted in MP and RM seat positions. Firstly, it was confirmed that the tension of the lap belt caused by pelvis motion transferred to the inboard shoulder belt and it compressed lower rib cage. Especially it seemed to occur in RM. Secondly, simulation was conducted by changing constraint conditions on pelvis translation and lateral axis rotation to confirm the effect on injury criteria in RM. Since the distance between the instrument panel and the occupant became longer in RM, knees were not constrained by instrument panel(IN-PNE), therefore chest deflection increased. It is confirmed that the lap belt tension was increased with the pelvis forward motion caused by reduction of restraint force, and the tension transferred to the shoulder belt, and consequently the deflection of the lower rib cage was increased. By constraining pelvis translation or rotation, or both of them, the constraint of the pelvis was improved and the chest deflection decreased in each condition. In case of fixing translation and rotation, there was an increase in acceleration of the pelvis and acceleration of T12 also increased through the lumbar spine. Therefore, chest deflection was reduced. In terms of the effect to the tension of seat-belt, there was not transferring of the tension to the shoulder belt from the lap belt. Since the tension of the shoulder belt decreased after 80ms, it was seen that loading to the chest from shoulder belt decreased. It was found that in order to reduce chest deflection in lower right side, it is effective not only reducing the load from inboard shoulder belt but also increasing a degree of constraint on the lumbar spine. Loading to the chest from the inboard shoulder belt was able to be reduced by suppressing pelvis rotation and it was effective to reduce chest deflection further.

INTRODUCTION

Regulation or assessment for vehicle safety has been revised in each country or region and evaluation standard has become strict. OEMs or suppliers have continuously improved the safety performance of their products to adapt to such standards or to obtain good ratings in assessment, which has been resulting in a certain decrease of fatal accidents. National Police Agency [1] published the total number of deaths in traffic accident in 2018 was the least as far as the statistics in Japan, while they addressed further effort should be necessary to save more lives from significant accident. Traffic Statistics [2] showed nearly half of the deaths in car drivers is in frontal crash.

On the other hand, in many cases, the seats in the first row of automobile have a mechanism of seat-slide for adjusting the seat position from front-most (FM) to rearmost (RM). Since this mechanism allows occupants a wide range of seating position, car driver's seating position becomes variable. When the driver sits on the seat at the RM position, a driver airbag (DAB) and an instrument panel (IN-PNE) becomes farther than the mid- point (MP) of the seat-slide. According to the sled tests conducted by Yaguchi et al. [3] in FMVSS208 and UMTRI seating position, the femoral forces in the case of UMTRI position that was 49mm rearward from MP arose later. Moreover, since it affects the restraint to the pelvis to increases its forward displacement, it could be considered that the tension of the lap belt increases. Then the tension is transferred to the inboard shoulder belt and it compresses the lower rib cage. It was considered that this tendency appeared strongly in the case of RM. Kemper et al. [4] performed dynamic belt loading on PMHS thoraces and confirmed fractures occurred on the inboard side of lower rib cage where the shoulder belt passed first. Shimamura et al. [5] analyzed the detailed data on traffic accidents and reported that the locations of rib fracture were observed more in the lower parts of the thorax. Kent et al. [6] reported that the presence of rib fractures was associated with a significant increase fatality risk, and chest injury was a serious issue. This research examined the influence of seating in RM position to the occupant's lower thorax injury and the influence on lower thorax injury by controlling pelvis behaviors in RM seating position.

METHODS

In this study, finite element (FE) simulations of sled test were conducted in order to confirm that the tension of the lap belt caused by the increase of pelvis displacement was transferred to the inboard shoulder belt and compressed the lower rib cage. Moreover, how the occupant changed by this effect was also investigated. THOR-Metric finite element (FE) Mode v1.4 developed by Humanetics Innovative Solutions, Inc were used on LS-DYNA R6.1.2 FE code. A collision pulse of a middle size sedan in flat barrier 56km/h test was used for a sled pulse. DAB, seat-belt, IN-PNE and other interior parts were also the same as that vehicle. Firstly, the dummy model was settled on MP or RM of the seat slide range and each calculated result was compared. The seat back angle was set to 22 deg. and the seat height was set to the lower-most position of the adjustable range. Figure 1. shows the seating postures of the dummy models in MP and RM. Accelerometers at the thoracic spine and pelvis, an angular velocity sensor was used to see occupant behaviors. These measurement locations in the dummy structure are shown in Figure 2. For polarity of pelvis angle, the posterior inclination side was defined as positive and the anterior inclination side was defined as negative as shown in Figure 3. Moreover, IR-TRACC in the lower right side thorax installed in THOR dummy was used for evaluating injury criteria of lower rib cage in case of MP and RM. In order to see the interaction between the lap and shoulder belts due to the pelvis behavior, the tensions of the lap and inboard shoulder belts were used.

Secondly, simulation was conducted by changing pelvis constraint conditions of translation and rotation around the lateral axis to see the tendency of injury criteria reduction due to pelvis constraint in RM seating position. Table.1 shows the simulation matrix. Three constraint conditions of the pelvis were defined. First the translational motion of the hip point (H.P) relative to the center of the seat back recliner was fixed, defined as ‘slide fixed’ (SF), and second, the rotation around the lateral axis at H.P. was fixed, defined as ‘rotation fixed’ (RF). Final, both of them were fixed, defined as ‘slide and rotation fixed’ (SRF).

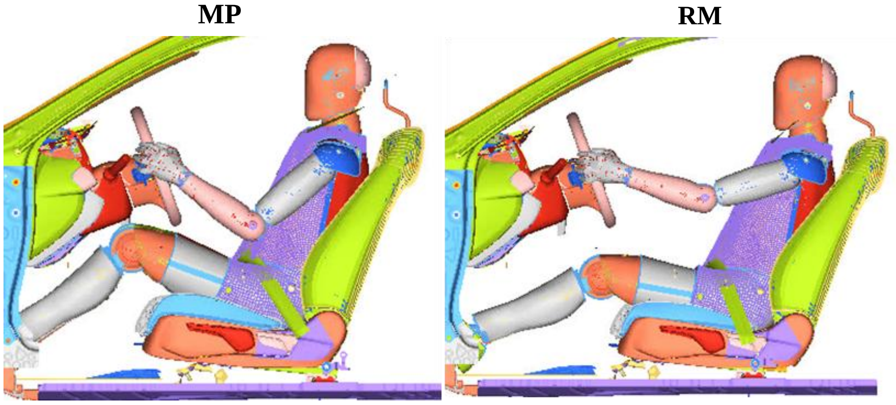

Figure 1. Setups of sled simulation in MP and RM seat positions

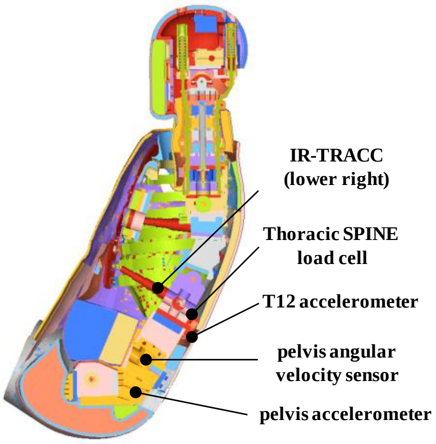

Figure 2. Measurement location in THOR dummy structure

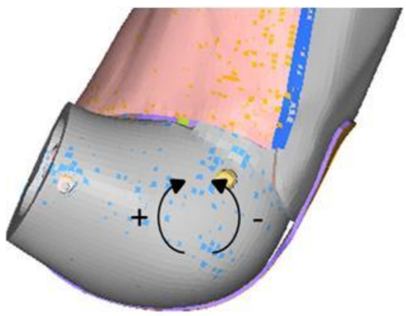

Figure 3. Polarity of pelvis angle

Table 1. Sled simulation condition

	Slide fixed	Rotation fixed
Base CAE (RM)	–	–
CAE No.1 slide fixed (SF)	○	–
CAE No.2 rotation fixed (RF)	–	○
CAE No.3 slide & rotation fixed SRF)	○	○

RESULT

Comparing of MP and RM

The restraint conditions at the time when the dummy was restrained by the DAB in MP and RM conditions are shown in Figure 4. Time histories of the acceleration of spine and pelvis, and pelvis angle, chest deflection, shoulder belt tension, and lap belt tension are shown in Figures 5–10. By increasing the distance between the IN-PNE and the occupant in RM seating position, the results show that knees were not constrained by the IN-PNE (Figure 4). In RM seating position, the tension of the lap belt rapidly increased from 60 ms (Figure 9), slightly later than the lap belt, the tension of shoulder belt also increased (Figure 10), the pelvis rotates to the posterior inclination from 40 ms (Figure 8) and acceleration of the pelvis increased greatly from 60 ms (Figure 6). With T12 as well, acceleration of T12 increased greatly from 60 ms (Figure 5), and chest deflection also increased (Figure 7).

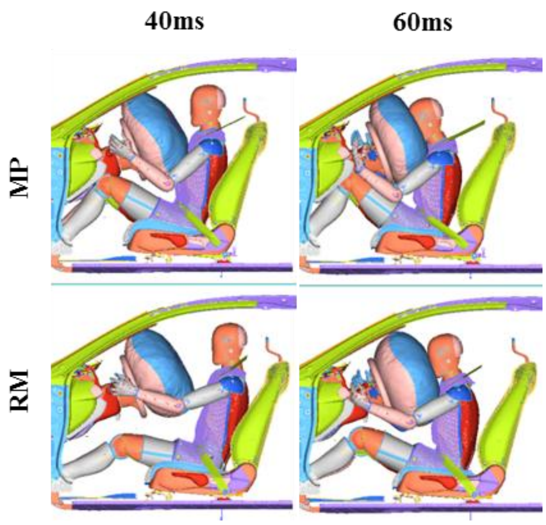

Figure 4. Restraint condition at the time when the dummy was restrained by the DAB in MP and RM

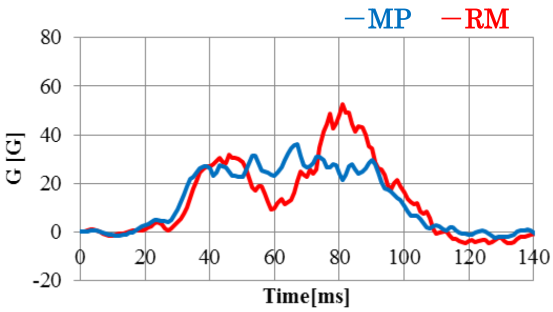

Figure 5. Time histories of T12 accelerometer (X direction) in MP and RM

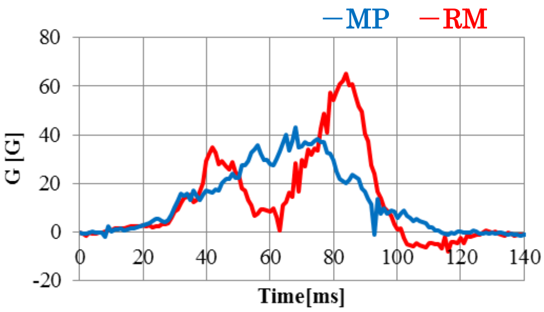

Figure 6. Time histories of pelvis accelerometer (X direction) in MP and RM

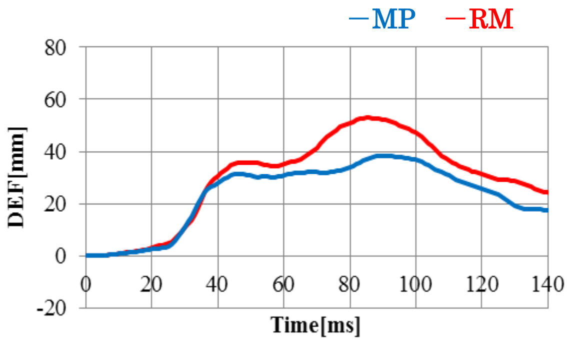

Figure 7. Time histories of chest deflection (lower right) in MP and RM

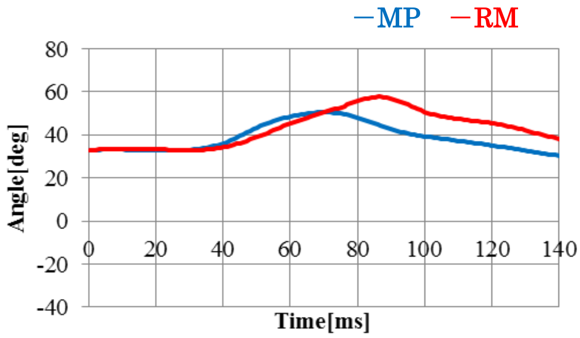

Figure 8. Time histories of pelvis angle in MP and RM

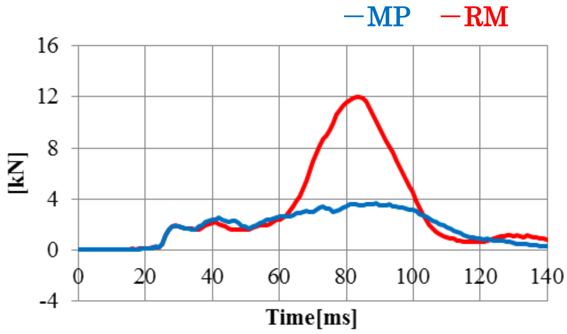

Figure 9. Time histories of the lap belt forces in MP and RM

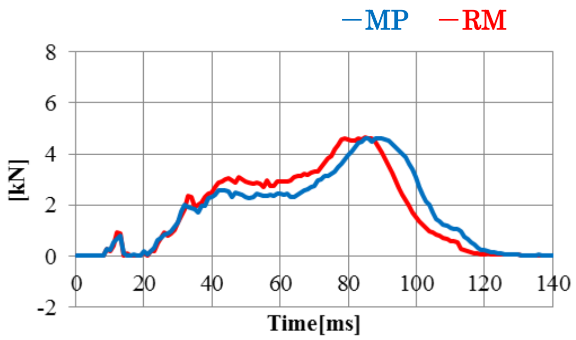

Figure 10. Time histories of the inboard shoulder belt forces in MP and RM

Investigation of the reduction effect on injury criteria by restraining the pelvis.

The effect on chest deflection by changing constraint conditions of the pelvis in RM seating position was investigated.

<u>CAE No.1 slide fixed (SF):</u> Figure 11 shows the restraint conditions at the time when the Pelvis started to rotate and at the time of maximum chest deflection value in RM and SF. Figures 12–15 show the time histories of the acceleration of spine and pelvis, the pelvis angle and chest deflection. Because the translation motion of the pelvis was fixed in SF, acceleration of pelvis increased at 10–30 ms and decreased at 80 ms compared to RM (Figure 13). In SF condition, the pelvis started to rotate to the anterior inclination from about 30 ms together with the seat deformation and got larger from 60 ms (Figure 15), it was confirmed that acceleration of T12 increased at 10–30 ms (Figure 12). Chest deflection greatly decreased at 40–60 ms and the peak value also decreased (Figure 14).

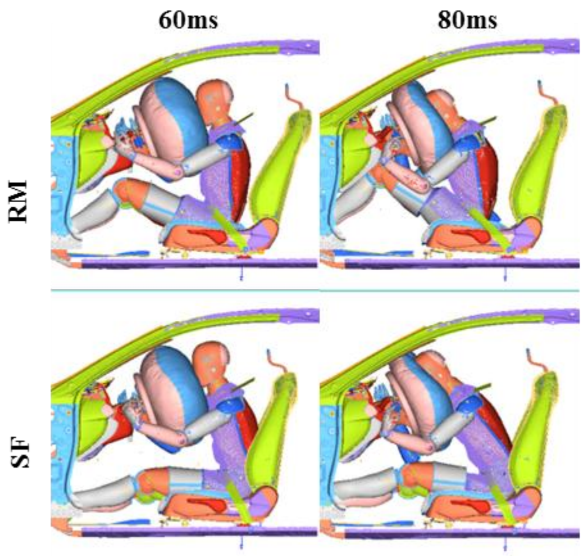

Figure 11. Restraint conditions at the time when the pelvis started to rotate and at the time of maximum chest deflection value in RM and SF.

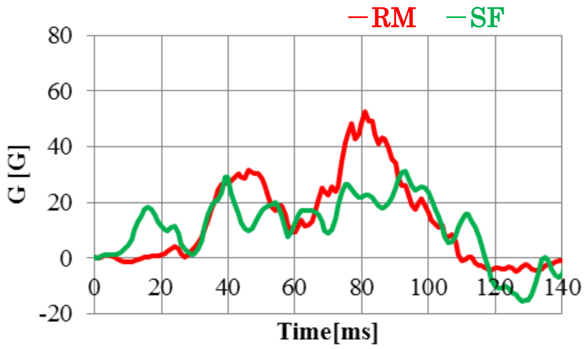

Figure 12. Time histories of T12 accelerometer (X direction) in RM and SF

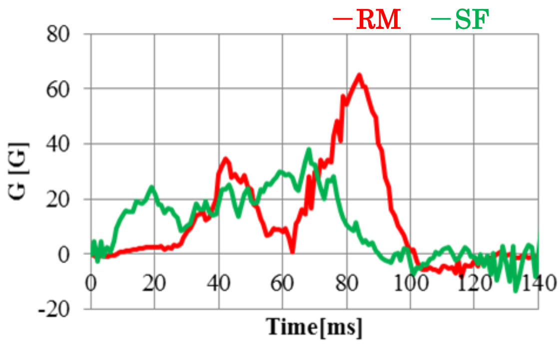

Figure 13. Time histories of pelvis accelerometer (X direction) in RM and SF

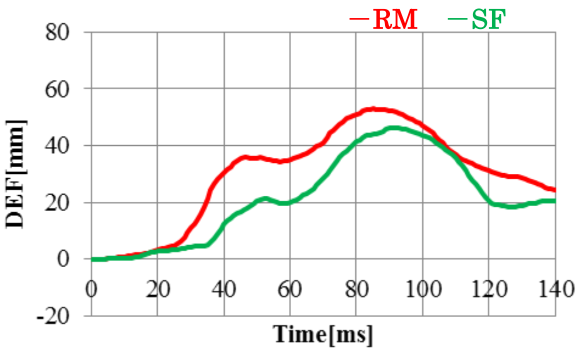

Figure 14. Time histories of chest deflection (lower right) in RM and SF

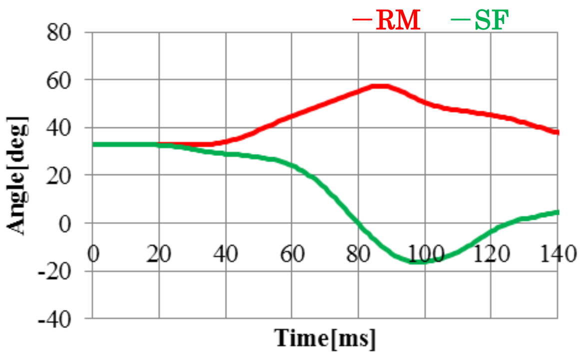

Figure 15. Time histories of pelvis angle in RM and SF

CAE No.2 rotation fixed(RF): Figure 16 shows the restraint conditions at the time when the pelvis started to rotate and at the time of maximum chest deflection in RM and RF. Figures 17-20 show time histories of spine and pelvis acceleration, the pelvis angle and chest deflection. Because the rotation motion of the pelvis was fixed in RF, acceleration of pelvis increased at 50ms (Figure 18). The pelvis rotated to the anterior side in RF relative to RM (Figure 20). In RF condition, acceleration of T12 decreased at around 40ms (Figure 17) and chest deflection slightly increased at around 40ms (Figure 19) compared to RM.

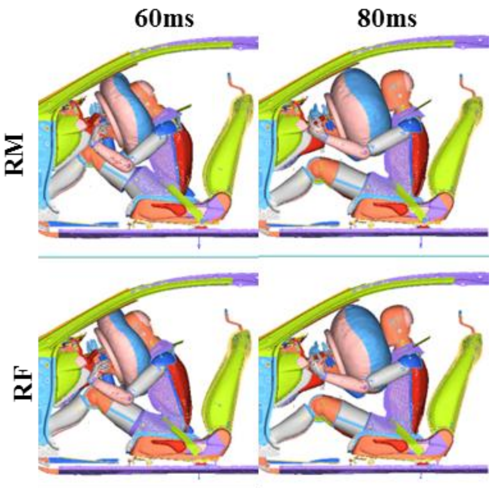

Figure 16. Restraint conditions at the time when the pelvis started to rotate and at the time of maximum chest deflection value in RM and RF.

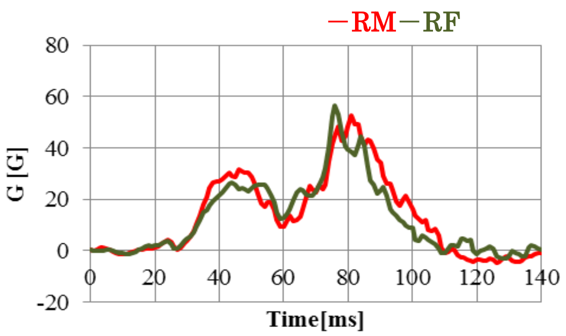

Figure 17. Time histories of T12 accelerometer (X direction) in RM and RF

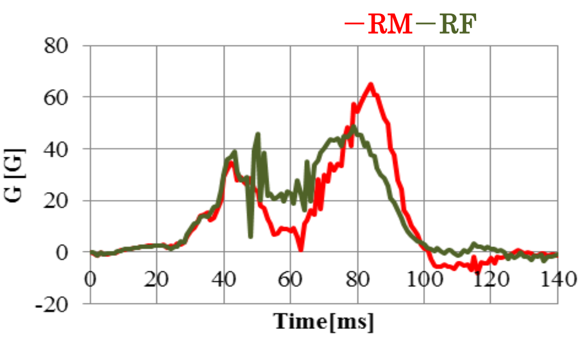

Figure 18. Time histories of pelvis accelerometer (X direction) in RM and RF

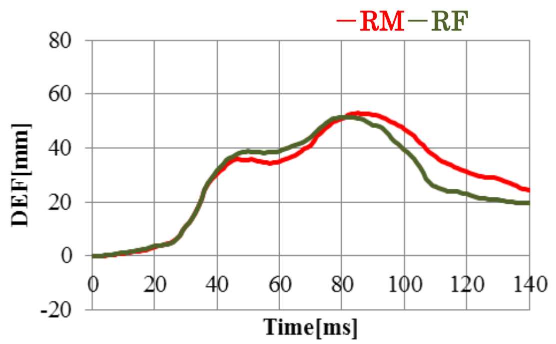

Figure 19. Time histories of chest deflection (lower right) in RM and RF

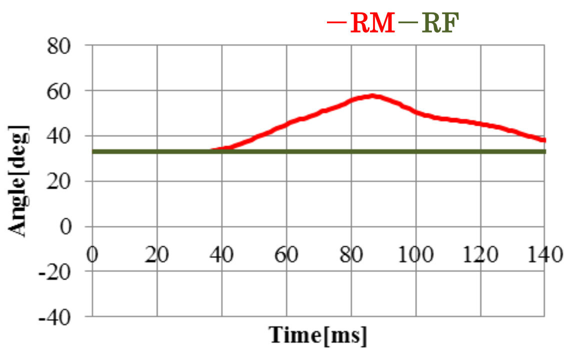

Figure 20. Time histories of pelvis angle in RM and RF

CAE No.3 slide and rotation fixed (SRF): Figure 21 shows the restraint conditions at the time when pelvis started to rotate and at the time of maximum chest deflection in RM and SRF. Figures 22- 25 show time histories of spine and pelvis acceleration, the pelvis angle and chest deflection. Because the translation and rotation motion of pelvis were fixed in SRF, acceleration of pelvis increased at 10-30ms and decreased at 80ms compared to RM (Figure 23). In SRF condition, the pelvis started to rotate to the anterior inclination from about 20 ms together with the seat deformation (Figure 25), acceleration of T12 increased at 10–30 ms (Figure 22). Increase of chest deflection from 60ms did not appear in RSF while it appeared in RM (Figure 24).

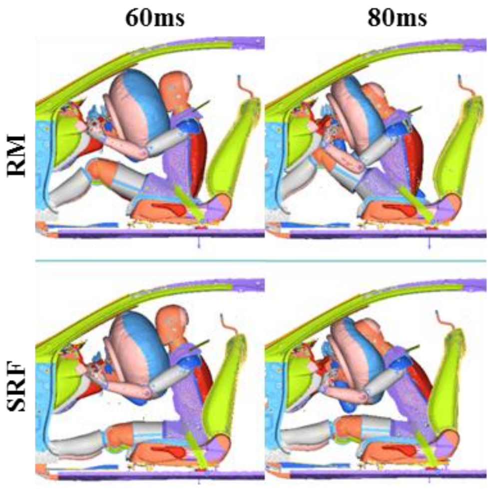

Figure 21. Restraint conditions at the time when pelvis started to rotate and at the time of maximum chest deflection in RM and SRF

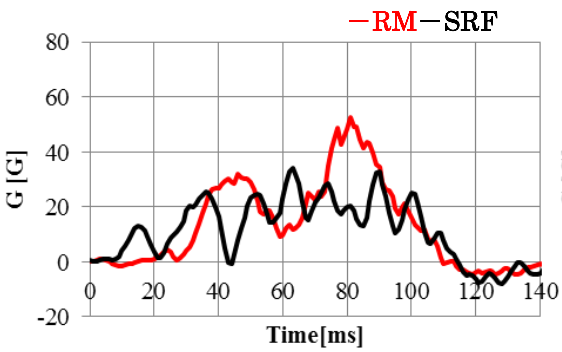

Figure 22. Time histories of T12 accelerometer(X direction) in RM and SRF

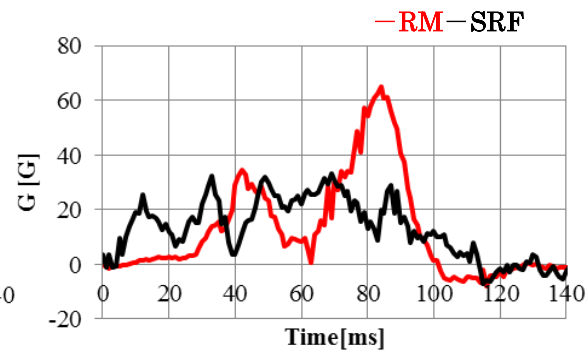

Figure 23. Time histories of pelvis accelerometer(X direction) in RM and SRF

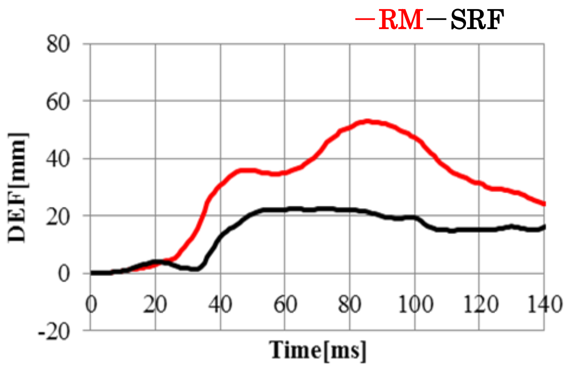

Figure 24. Time histories of chest deflection (lower right) in RM and SRF

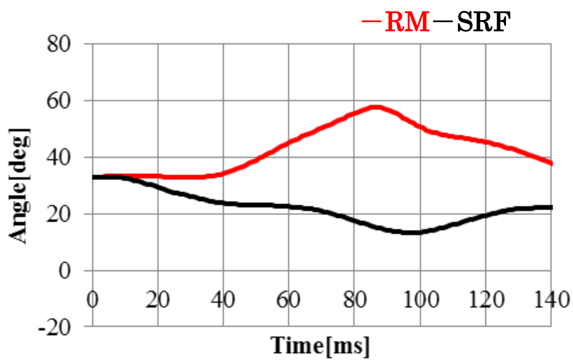

Figure 25. Time histories of pelvis angle in RM and SRF

DISCUSSION

It was discussed that how the difference of seating position and pelvis constrained condition effected to upper body. Comparing MP and RM, because the knees were not restrained by IN-PNE, the lap belt restrained the pelvis in RM (Figure 4, 9). As the RM results showed, it was confirmed that because the pelvis was not restrained and it started forward displacement at initial timing, the lap belt tension increased. Then the tension was transferred to the shoulder belt through the through tongue (Figure 9, 10), and as a result, chest deflection was increased. On the other hand, the increase in chest deflection before 60 ms was caused by decreasing acceleration of T12, which was result from the delay in restraining of the pelvis (Figure 5, 6). To check the effect of the pelvis rotation on the upper body, thoracic load cell shown in Figure 2 was used. The polarity is shown in Fig.26. Although the pelvis rotated to the posterior inclination, the force toward the back of the spine worked together with the rotation of the pelvis as shown in Figure 27, there appeared to be an effect of suppressing the displacement of the upper body. Particularly in RM, the knees were not restrained by the IN-PNE, so the pelvis rotated more to the posterior inclination than in the case of MP, and the effect of suppressing displacement of the upper body was also greater (Figure 8, 27). This made it clear that the delay in pelvis restraint and the behavior resulting from pelvis rotation had an effect on T12 and chest deflection through the lumbar spine.

Therefore the effect of controlling pelvis behavior to T12 and chest deflection thorough lumbar spine was focused on.

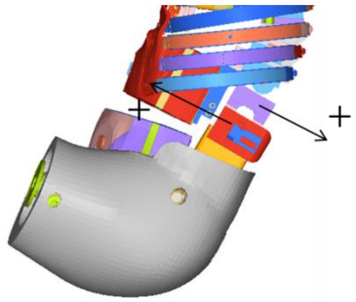

Figure 26. Polarity of spine Load Cell

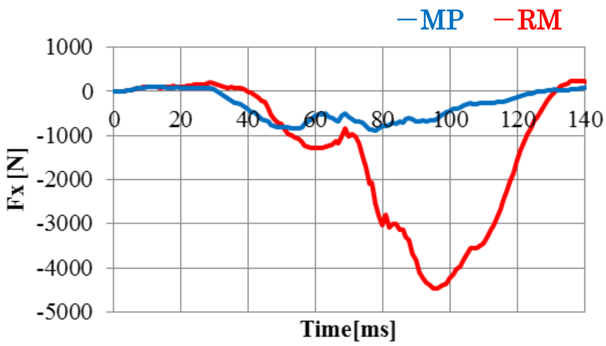

Figure 27. Time histories of spine load cell (X direction) in MP and RM

Comparing RM and SF, the effect by fixing the translation motion of the pelvis was confirmed. Because the translation motion of the pelvis was fixed, there was acceleration of the pelvis before 30 ms (Figure 13), and acceleration of T12 also increased through the lumbar spine (Figure 12), and chest deflection was reduced at 40-60ms by its effect (Figure 14). The pelvis started to rotate greatly to the anterior inclination from 60ms, and along with that, the effect of suppressing displacement of the upper body was decreased (Figure 28). The anterior inclination of the pelvis caused the decrease of T12 acceleration and it increased chest deflection, but early restraint of the pelvis was very effective and maximum chest deflection was reduced finally.

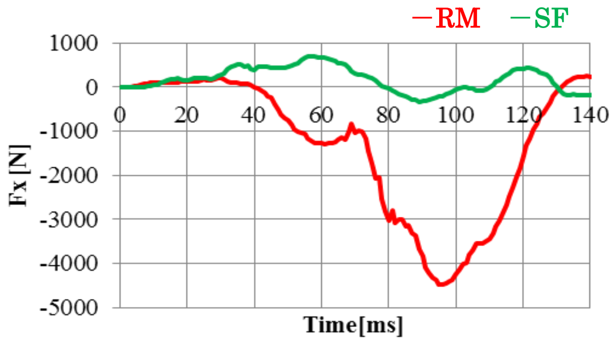

Figure 28. Time histories of spine load cell (X direction) in RM and SF

Comparing RM and RF, the effect by fixing the rotation motion of the pelvis was confirmed. Fixing the rotation of the pelvis means there was no rotational behavior of the pelvis, but in RF, the pelvis inclination was more anterior side relative to in RM (Figure 20). The difference in pelvis rotation started to occur from 40ms and the effect of suppressing displacement of the upper body before 60ms was decreased in RM (Figure 29). As a result, there was a decrease in T12 acceleration at 40–60 ms (Figure 17), therefore chest deflection increased (Figure 19). On the other hand, acceleration of the pelvis increased at close to 60–80 ms and it caused a slight increase in T12 acceleration through the lumbar spine (Figures17, 18). Initially, the relatively anterior inclination of the pelvis causes T12 acceleration to reduce and chest deflection to increase, however, after that, acceleration of the pelvis increased, thus the effect of increasing acceleration of T12 and suppressing upper body displacement was about the same as with RM, and maximum chest deflection was also about the same.

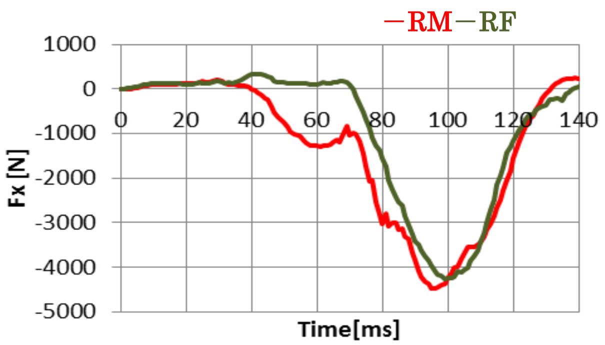

Figure 29. Time histories of spine load cell (X direction) in RM and RF

In preceding part, the influence in case of fixing either translation or rotation of pelvis individually was confirmed. The effect of fixing both translation and rotation of pelvis was confirmed. Because the translation of the pelvis was fixed, there was an increase in acceleration of the pelvis before 30 ms (Figure 23), the same as with SF, and acceleration of T12 also increased through the lumbar spine (Figure 22). This effect could be seen up to about 70ms compared to in RM.

As previously mentioned, the effect of pelvis behavior control on chest deflection was confirmed. Next, this section confirmed the effect on shoulder belt tension when both the translation and rotation of pelvis were fixed. The time histories of the shoulder belt and lap belt tensions in SRF are shown in Figure 30, 31. Fixing the translation and rotation of the pelvis increased pelvis acceleration, and for that reason, the lap belt tension did not increase (Figure 30). Therefore, there was not transferring of the tension to the shoulder belt from the lap belt, and the shoulder belt tension also could be reduced after 80 ms, (Figure 31), thus it was seen that the loading from the shoulder belt to chest was reduced.

This research confirmed that with sled test in flat 56 km/h, reducing the pelvis translation and rotation motion were effective for reducing chest injury criteria. Moreover, lateral behavior of the vehicle affects the occupantin case of angled collision, the extent of these benefits also needs to be determined for these cases to see if controlling pelvis behavior is effective in reducing chest injury criteria in these situations as well.

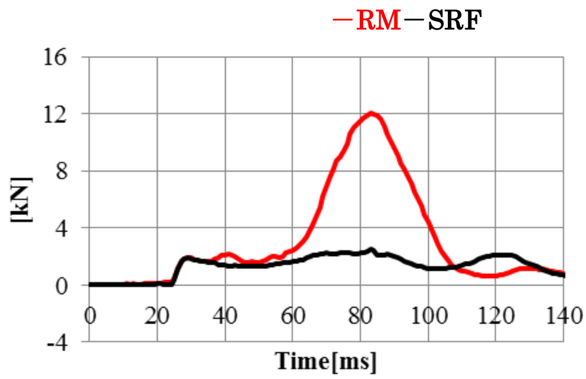

Figure 30. Time histories of the lap belt forces in RM and SRF

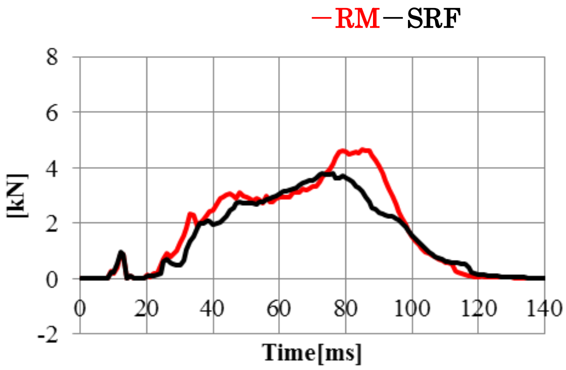

Figure 31. Time histories of the inboard shoulder belt forces in RM and SRF

CONCLUSION

Sled simulation for MP and RM occupant seating positions by using THOR FE model was conducted in this study. In addition, a parametric study which changed the pelvis constrained condition in RM seating position was conducted. As a result, the following were found

・In order to reduce chest deflection in lower right side, it is effective not only reducing the load from inboard shoulder belt but also increasing a degree of constraint on the lumbar spine.

・To improve the constraint on the spine, it is important to constrain the pelvis in early timing to reduce the translation of the pelvis.

・Loading to the chest from the inboard shoulder belt was able to be reduced by suppressing pelvis rotation and it was effective to reduce chest deflection further.

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