SIDE IMPACT SLED TEST METHOD FOR INVESTIGATION TO REDUCE INJURY INDEX

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ABSTRACT

This paper describes a very simple sled test method to simulate the thoracic behavior of dummy in the side impact test situation of SUV representative impacting a passenger car side. In this sled test, the door inner panel which was deformed in the full scale test was rigidly set on the sled, and impacted the dummy. Even if the sled moved in normal V-T profile used in HYGE sled facility, the dummy responses were correlated with full vehicle tests in order to study occupant protection practically. This test method could be applied for both SID2s and Eurosid dummies.
In addition to the real sled tests, FE simulation was also used to analyze the influences of various factors. In conclusion, it was found that the sled test with deformed door was a useful and efficient method to study for occupant protection. With this test method and FEM, it was found that one of the ways which has possibility to reduce injury index of SID2s is to disperse the impacting force by Side Airbag or door trim.

INTRODUCTION

Side impact occupant protection is one of the important issues in crash safety development. Mainly, there are two measures for side impact occupant protection, one is the body crashworthiness, and the other is characteristic of interior parts. Considering efficient process investigating interior or side airbag crush characteristics, it is beneficial to use the sled test. Key parameters to get good correlation between full scale side impact test and sled test are door intrusion velocity profile, crush characteristics of door, distance between door and occupant, etc. However reproducing these conditions on the sled isn't easy in side impact comparing to frontal impact, therefore many studies have been carried out in order to get good correlation of these key parameters and occupant injury indices, and many sophisticated sled test methods have been proposed. e.g. [1][2][3]
Although these efforts for good correlation are very important, considering simplification of test method with keeping reasonable correlation is also meaningful.
In this study, practical correlation of Eurosid rib deflection has been obtained using post test deformed door set on the sled. Simulated condition was similar to IIHS proposed new side impact test in which SUV representative is used. [4]

Test Method

Concept

In this test method, the door which was rigidly set on the sled and a new door trim on the door impacted the dummy sitting on seat. As the impacting device the door inner panel which was deformed in the full scale test was used to consider that the injury indices are determined during deformation of the door in full scale test. And to consider the difference of door impacting profile, final shape in the sled test and during deformation in the full scale test, the door fixture angle had to be adjustable to simulate the relative timing between contacts of thorax and pelvis regions in the full scale test. The seat could travel on the sled by the bearing and rail system located between the seat and the sled. (See Figure 1)

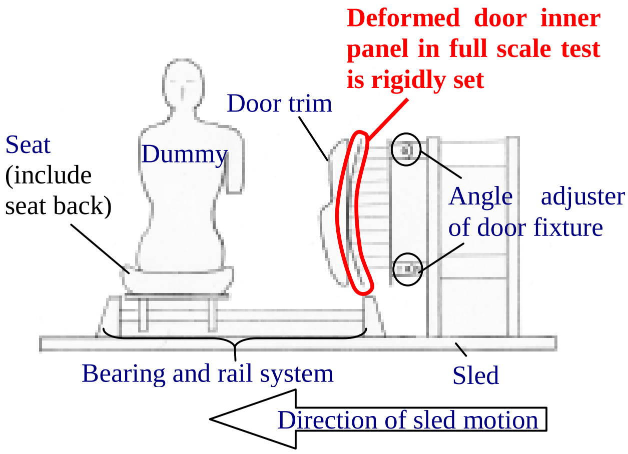


Figure 1. Schematic of sled test

Conditions

In the full vehicle test which was used as reference, the moving deformable barrier (MDB) with IIHS proposed barrier face impacted the sedan type car which had some modifications on a current production vehicle. This test condition was similar to IIHS newly proposed one, except Eurosid was used. The features of this test result were as follows. Because MDB contacted the comparatively high position of the impacted car and the mass of MDB was comparatively heavy, the body deformation tended to increase and MDB deceleration tended to decrease. In the sled test introduced in this paper, sled velocity profile was set at the same level of B-pillar intrusion velocity in full scale test (See Figure 2). This was one of the try of applying simple profile using HYGE facility without reproducing detailed velocity profile of B-pillar in full vehicle test.
The sled velocity profile and B-pillar intrusion velocity profile in the full vehicle test were

synchronized as shown in Figure 2. And the initial distance from the door trim to the dummy was set in order that the dummy contacted to the trim corresponding to the full scale test. The angle of the door fixture was adjusted in order that the relative contact timing of thoracic and pelvis regions to the door trim corresponded to the full scale test.

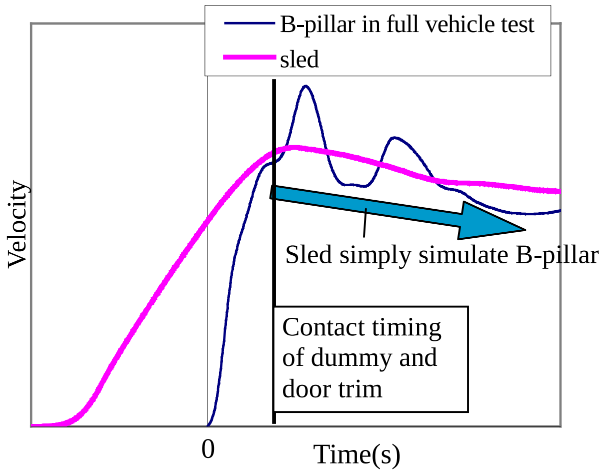


Figure 2. Sled and B-pillar velocity.

Correlation With Test

The movement of the pelvis and spine of the dummy in sled test were correlated with those in full scale test at a reasonable level (See Figure 3). The tendency of injury indices in sled test was also correlated with those in full vehicle test. The indices tended to be increased relatively in abdominal and thorax part (See Figure 4). But, as concerns the tendency of rib deflection, upper rib deflection was larger in full vehicle test, lower rib was larger in sled test meanwhile (See Figure 5). It was guessed that this difference was caused by the difference of door shape, final shape in the sled test and during deformation in the full scale test. This matter is also discussed in the FEM section below.
Furthermore, the influence of equipping side airbag was studied (See Figure 6). With respect to input force characteristics to abdomen, the tendency of earlier input and reducing peak force were simulated in both sled test and full scale test with side airbag. The difference of peak force value between sled test and full scale test was caused by a slight difference of timing when side airbag begin to effect. Then it could be considered that influence of Side Airbag was correlated practically.

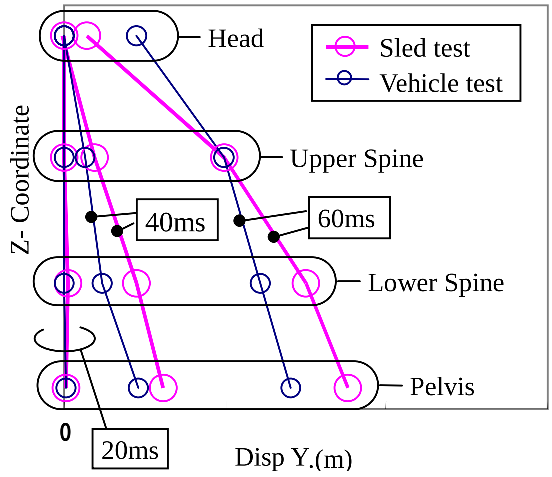


Figure 3. Dummy movement (Displacement).

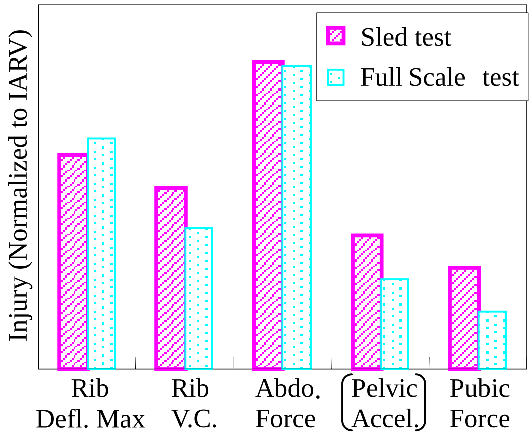


Figure 4. Tendency of injury.

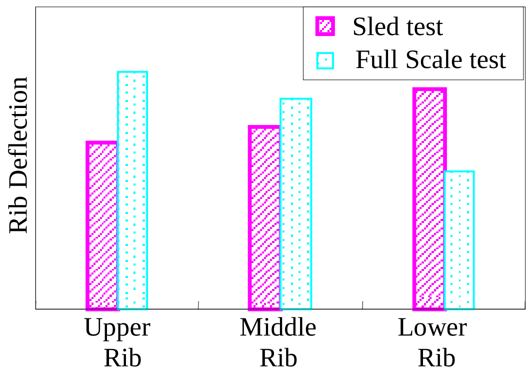
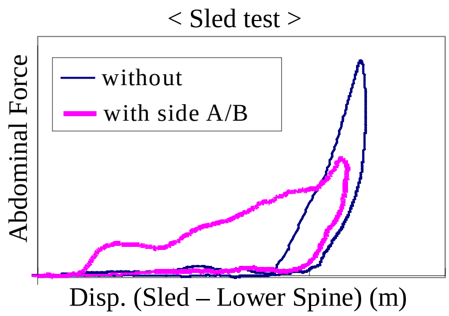


Figure 5. Tendency of Rib Deflection.



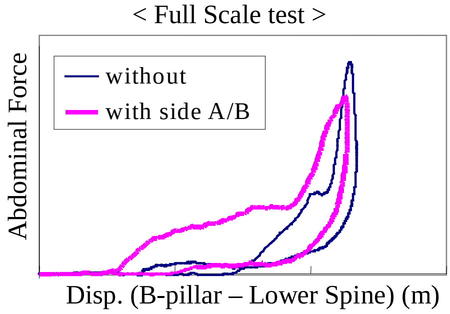


Figure 6. Abdominal force characteristics.

FEM Modeling

Modeling and Correlation

The FE model was developed with a view to analyze the effect of factors which had influence on the correlation of this test method and factors which had influence on injury indices.

The conditions of this FE model are mentioned below;

- The model contains door inner panel, trim, B-pillar inner panel and trim, seat frame, dummy, and side airbag. (See Figure 7)
- The models of Eurosid and SID2s are used. (See Figure 8)
- The deformed door panel shape is obtained from the full vehicle calculation. The angle of the panel replicates the condition considered in the real test.
- Door panel and seat anchor parts have boundary conditions of displacement time history curve obtained from real test. (See Figure 9)
- In respect of side airbag, folding is not modeled and it is simply deploys with increase of inner pressure.

With some modifications, good correlation to sled test was obtained as described below.

In the condition with and without side airbag, the level of injury value is correlated enough for both EuroSID and SID2s. Figure 10 shows the result of SID2s. It can be said that this model is considered to be applicable to a variety of the analysis.

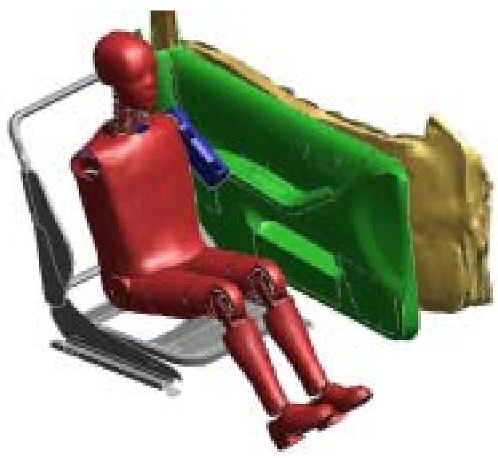


Figure 7. FE model of sled test.

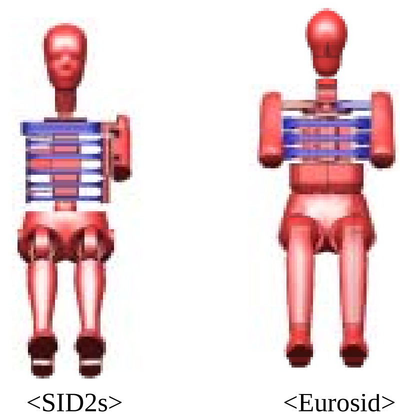


Figure 8. FE dummy models.

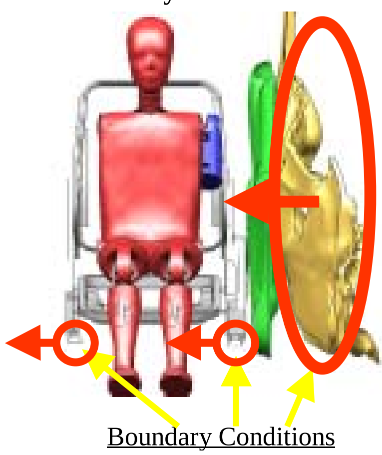


Figure 9. Boundary conditions.

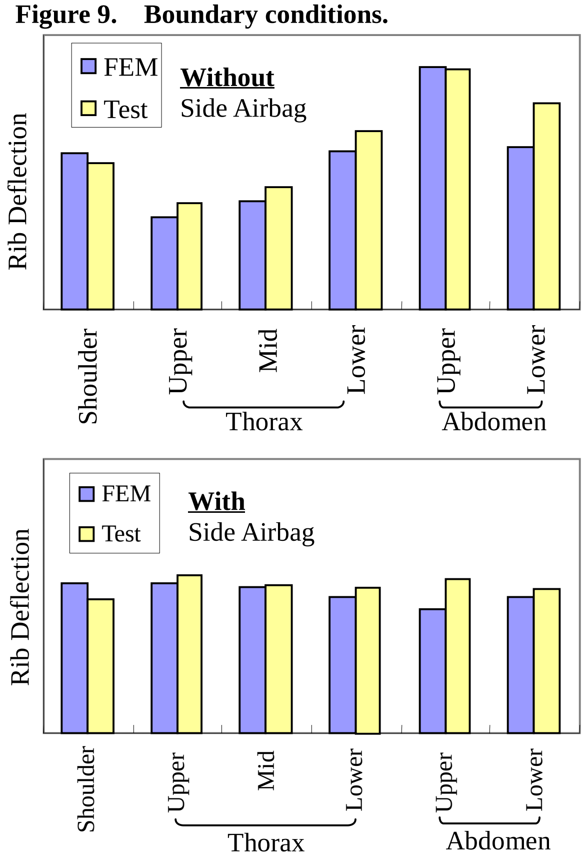


Figure 10. Comparison of Rib deflections of SID2s between FEM and test

Study on the test condition

Concerning about the difference of rib deflection tendency between the SLED test and Full vehicle side impact test mentioned above, FEM is good tool to investigate the effect of door shapes in the different phases of deformation on the dummy response. Four phases, initial, 20ms, 34ms, and 50ms as final, of deformed door are used as the impacting door to investigate the effect on Eurosid response in the FE model. Each door shape is picked up from the Full vehicle FE calculation and applied as an initial shape in the FE SLED calculation. (See Figure 11)

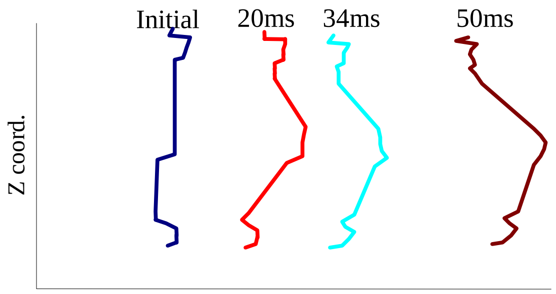


Figure 11. Deformation shape of door inner panel in each phase

Figure 12 and 13 show the difference of Eurosid response for each deformation shape of door. The results show, when the deformed doors are applied, abdominal forces tend to increase than the case when the initial shape are applied. (See Figure 12) And there is no big difference in maximum rib deflections. Among the tests with application of deformed doors, there is a tendency that the more deformed door is used, the larger the lower rib deflection be. (See Figure 13)
This should be one of the reasons why the lower rib deflection tended to increase in SLED test in which final shape of door was used, comparing to full scale test in which the injury indices are determined during the deformation of door.

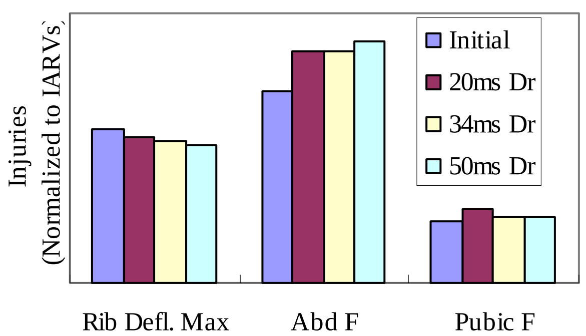


Figure 12. Comparison of Eurosid response for each door shape

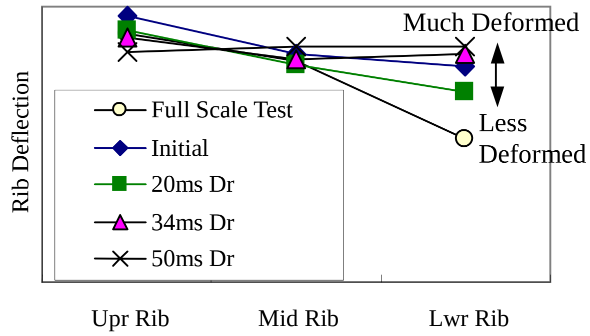


Figure 13. Rib deflection tendency of each door deformation shape.

Studies to Reduce Injury Index

From this SLED test and FEM, there are some results of investigation to reduce the injury index of SID2s. The test and FEM results mentioned below are mainly conducted with prototype Side Airbag covering shoulder and pelvis region of SID2s. These studies are carried out to find general tendency in limited conditions, and more research and development will be needed before applying to production vehicles.

Force Dispersion by Side Airbag

SLED test results using many kinds of SAB shows that there is a rough tendency, when the energy dispersion to shoulder area increases, the thoracic rib deflections reduce especially in the upper part. (See Figure 14) Here “energy to shoulder” is represented by the area of “Shoulder Force” vs. “Displacement of upper spine relative to Door” trace. Typical pattern to reduce rib deflection shows earlier input and smaller peak force. (See Figure 15) The same tendency is obtained from FEM calculations. (See Figure 14)

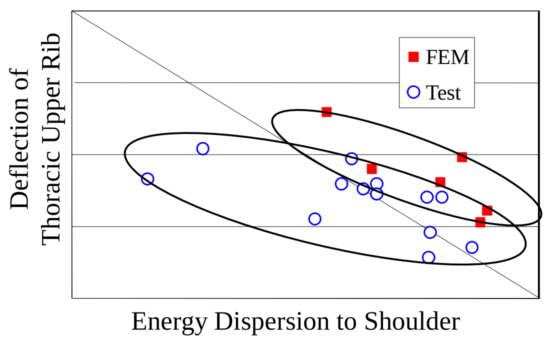


Figure 14. Input energy to shoulder vs. Upper rib deflection plot.

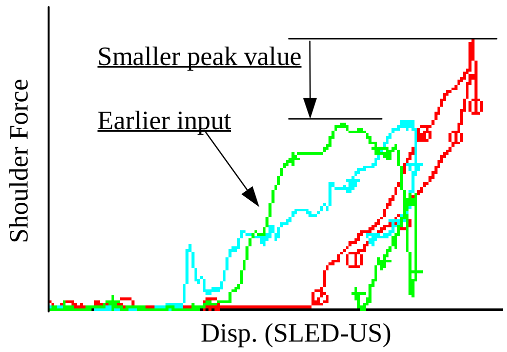


Figure 15. Typical curve of shoulder force.

Inflator Characteristics

Study on the effect of inflator characteristics is conducted only by FEM because it is easy to set various characteristics in the FEM comparing to the real tests. The results with various characteristics show a tendency that when the amount of gas increased, rib deflection is reduced especially in the lower part. (See Figure 16) This should be the effect of dispersion of input force to pelvis area. The iliac force inputted earlier and peak value reduced. (See Figure 17)

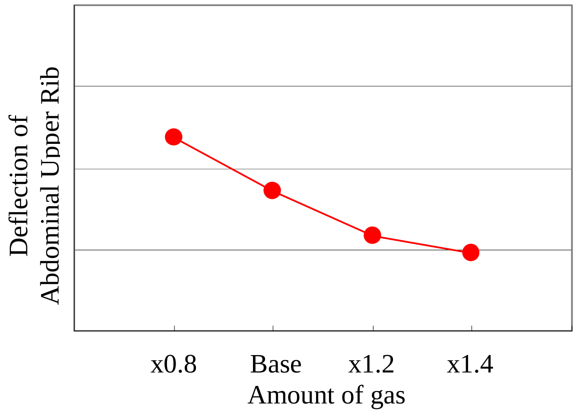


Figure 16. Amount of gas vs. Abdominal upper rib deflection plot.

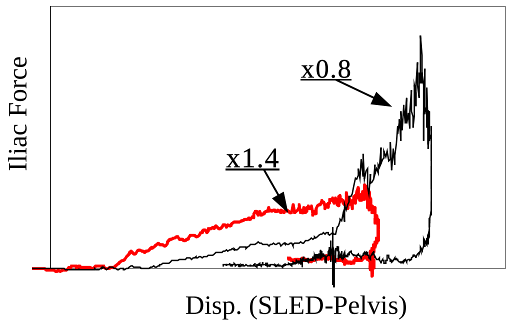


Figure 17. Typical curve of iliac force.

Timing of Deployment

Study on the effect of SAB deployment timing shows the tendency that early deployment reduces rib deflection, because SAB absorbs enough energy. On the other hand late deployment increase rib deflection, because SAB cannot absorb energy as intended. (See Figure 18)

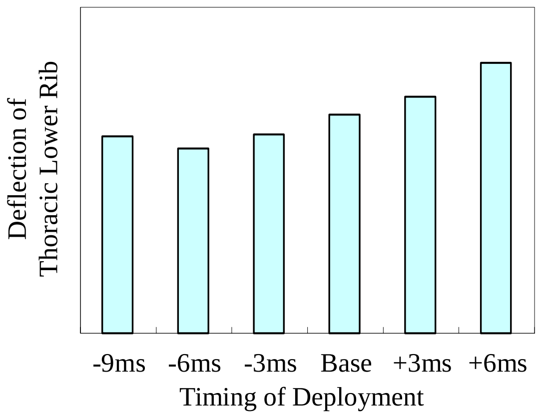


Figure 18. Effect of deployment timing

CONCLUSION

It is found that the simple HYGE sled test using deformed door panel could simulate the thoracic behavior of the dummy in the side impact situation which SUV representative impacts passenger car side in the practical level to study occupant protection. This test method might be an effective tool to tune Side Airbags or door trims. Using this SLED tests and FE calculations, general tendencies concerning with some parameters were found.
This test method has a weakness coming from the application of deformed door panel, that means it cannot be conducted in the very first phase of vehicle development before the first full scale test. On the other hand, FE models have enough level of correlation and have potential to overcome the weakness.
As an additional discussion about FEM, model of this SLED test is relatively smaller size than full vehicle model, and it is easy to apply the optimizing processes. And, there is one option that the deforming process of door panel in the full vehicle calculation can be used as a boundary condition in the sled type calculation.
More efficient process of side impact development will be continued to study in future.

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[2] Douglas J.Stein. 1997.“Apparatus and Method for Side Impact Testing” SAE97052

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[4] IIHS status reports. e.g. “Side Impact Crashworthiness Evaluation Development (October. 2001)”

[5] LS-DYNA Ver.960 User’s Manual