Development of Simple Connection Model for Plastic Parts in Low-Speed Crash Simulation

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***KEYWORDS** Low Speed Crash, Simple Connection Model, Plastic Clip, Catch, Beam Element.

1 Background

Collision performance is evaluated by CAE not only for metal parts such as steel and aluminum but also for plastic parts. As it takes time to create molds for a large part such as the bumper face, ensuring the performance by pre-calculation is important to shorten the development period. When mold production is started prior to the test to reduce the development time and if failures occur in the test, it will take time and cost to modify the mold. Therefore, high calculation accuracy is desired, but the test reproducibility is not satisfactory in some areas. Out of those areas undergoing enhancement efforts, this document introduces our efforts for plastic parts connection coming-off.

The clips used to join plastic parts have various functional constraints. They should be easy to install, should not be loose, and should not come off. Also, it should be inconspicuous from the appearance perspective. If the assembly load is increased too much for fear of coming-off, it may end up in not only the assemble difficulty but also a risk of design surface damage. In addition, there are cases where the height of the catch is limited during the course of the mold production, and the assembly load cannot be sufficiently secured. Furthermore, plastic has many factors affecting the product tolerance such as fluidity and shrinkage inside the mold, so we found it important to reduce the risk of missing the prediction by quantitatively understanding the load variability of existing clips.

2 Objective

The objective of this work was to predict the risk of plastic parts falling-off due to clip coming-off by the simulation prior to the low speed collision test, and to visualize the result of the input on the connection area in order to facilitate the risk check. At the same time, we also tried to keep the model creation time and calculation time suppressed and not to increase the development time period.

3 Plastic Clip Types and Coming-Off Load

Fig.1 shows the shape and the names of each part of the plastic clips used here. Plastic parts involved in low speed collisions use several types of clips, and each has its own characteristics. Fig.2 shows different types of clips. The characteristics of TYPE A are low insertion force and high removal force. The size of the male part tends to be big. Although TYPE B can be smaller in size than A, its maintainability is inferior to that of A. TYPE D has a simple catch spring so the removal force is not much affected by design. TYPE E is relatively difficult to secure removal force.

Firstly, the removal load was measured multiple times for all types. The load measurement was performed in a simple tensile direction, not by considering the vertical and horizontal components. This was because the simple tension had the smallest removal load, and was suitable for estimating as much risk of coming-off as possible.

Fig.3 indicates the results of each measurement. The bars represent the mean value of the measurement data, and the thin lines the standard deviation (3σ). Every clip had measurement variability, which was likely due to the manufacturing variability. Then, we discussed how to incorporate this variability of the measurement value into the calculation model as input information.

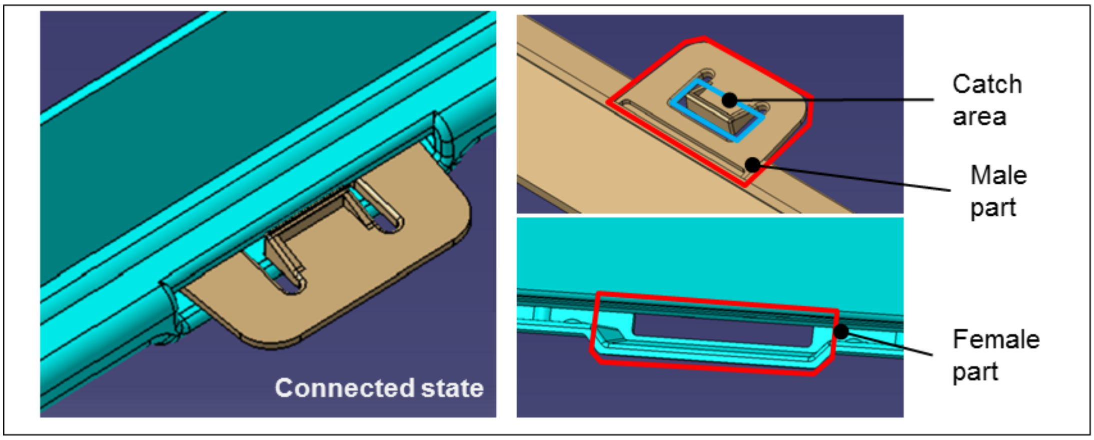

Fig.1: Part names of plastic part.

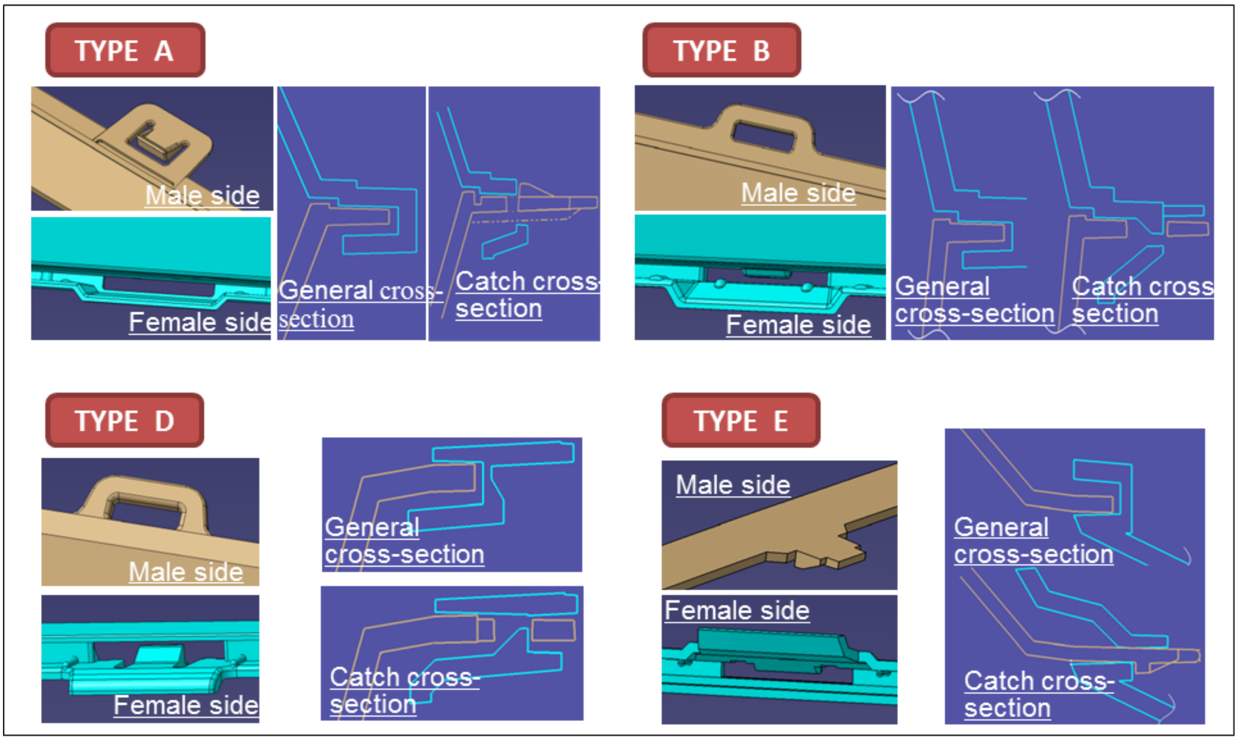

Fig.2: Plastic parts connection type

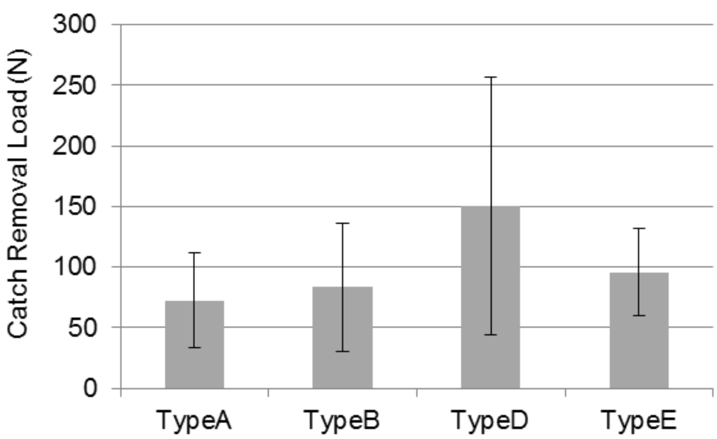

Fig.3: Catch removal load mean value and variability standard deviation

4 Simplified Connection Model

As for the conventional connection model, shape reproduction of the outer surface of the catch and the hole used to be done by the shell element. Fig.4 shows conventional connection models. The higher the shape reproducibility is, the smaller the mesh size is and the time-step is, so the shape reproduction will be limited. Also from the viewpoint of model interference, it is difficult to create a precise geometry in which the catch fits perfectly in the hole and exchanges contact reaction force like a real part. And because the behavior that the elastic deformation pushes down the catch cannot be reproduced, the catch does not fit in from the beginning.

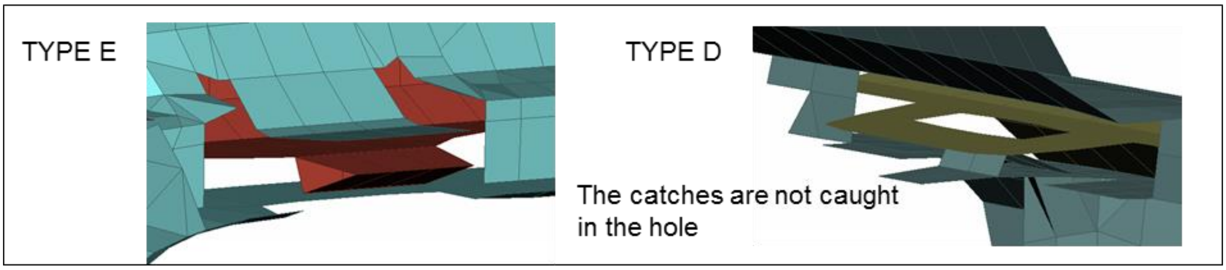

Fig.4: Conventional connection model

Due to such reasons, the calculation accuracy of the connection coming-off was unable to be enhanced for the conventional model. We ignored the shape of the catch and the hole for the new connection model. Instead, as shown in Fig.5, the exchange of the load due to the surface contact between parts was expressed by the shell element, and the connection coming-off due to the transferred load was expressed by eliminating the beam element. The male part and the female part were not directly connected by the beam element in this simple model. This way, the initial clearance of the catch could be reproduced by the clearance between the shell elements of female part and the shell element which represent the height of the catch as in Fig.5-A. Once the female part and the catch contacted the load transfer started (Fig.5-B), and finally the beam element which connected the male part and the catch fails at certain load to represent the coming-off of the connection (Fig.5-C).

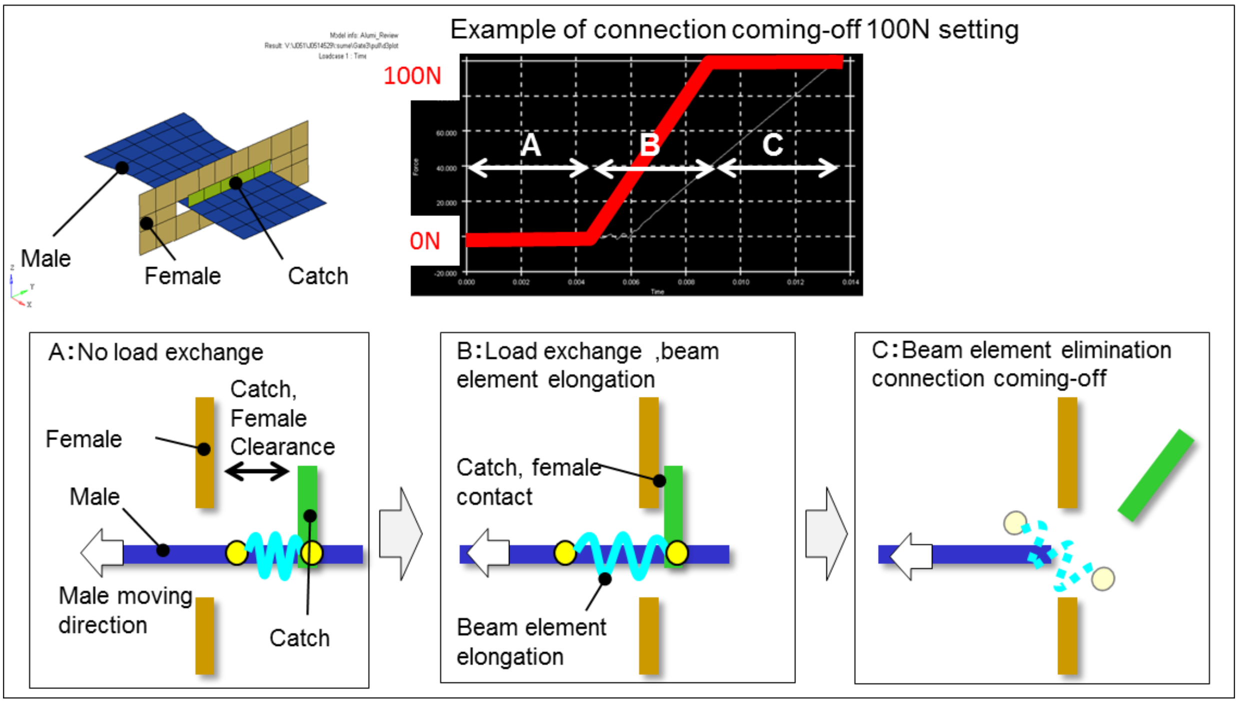

Fig.5: New simple connection model

Secondly, the selection of the critical load value for connection coming-off was investigated. The first step was to compare the phenomena of the low speed collision test and the calculation, and to confirm the level of measurement value which could reproduce the parts fall-off. As shown in Fig.6, the parts did not fall off when the critical load was set to the mean value, and only some of the connection came off. The input to the beam element of the connection which came off in the test was then checked. Fig.7 shows the time history of load input in the beam elements of several connections. It was found that the critical value was close to the minimum measurement value. When the load criterion of the beam element was set to the minimum value based on this result, the part fell off as shown in Fig.6.

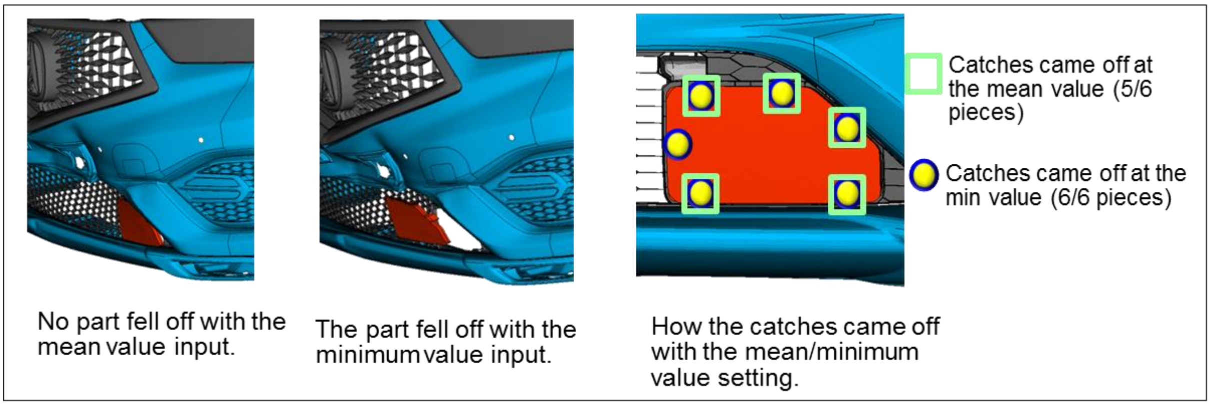

Fig.6: Calculation result difference of beam element input value

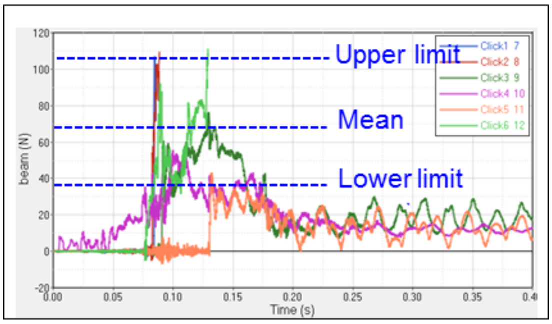

Fig.7: Input load on connection area

5 Calculation Result of Simplified Connection Model

Comparisons on the calculation results before and after the introduction of this model with the test result were made. As shown in Fig.8, the calculation with the conventional model was unable to reproduce the parts falling-off, but the calculation with the new model reproduced the connection coming-off and parts falling-off. Fig. 9 shows the connection breakage of the simple connection model in certain connection part. The light blue part (part A) was deformed and moved in a way to push the yellow part (part B) out of the hole. In the conventional model, the catch did not come off because it got caught around the hole even if it was pushed and it did not deform. For the new model, the red part which imitates the catch came off as the beam element was eliminated, and then the part B came off from the hole.

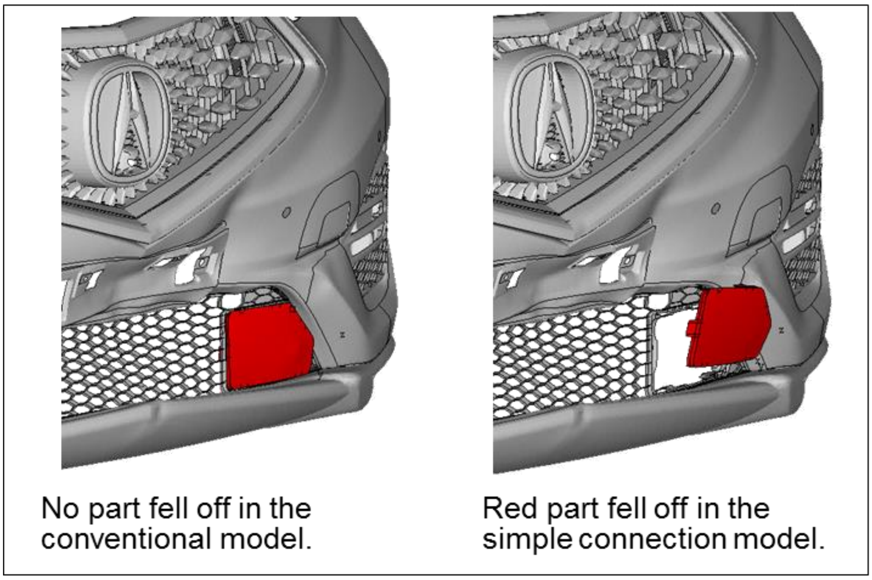

Fig.8: Result difference between old model and simple connection model

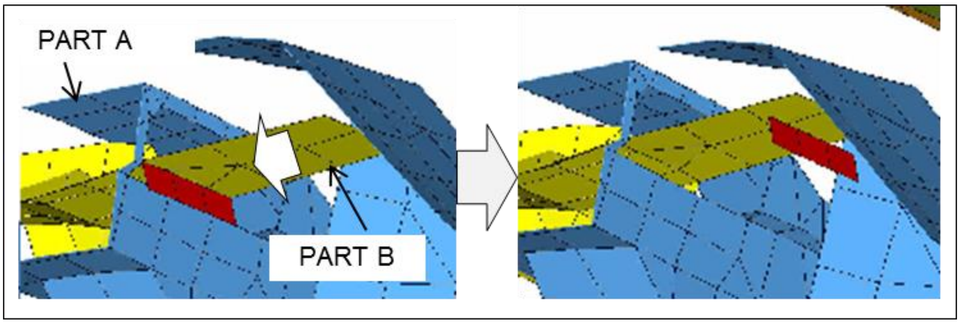

Fig.9: Connection breakage by beam element elimination of simple connection model

6 Automatic Creation of Simplified Connection Model

It is time-consuming to modify the geometry of original CAD model to the simple connection model. Therefore, using image recognition technology, we developed the program which automatically replace clip to simple connection model. Fig.10 shows the process flow. First, the operator manually read the CAD data and display connection parts. Next, the program automatically photographs it from many different angles. Then, it sorts out according to each connection type using image recognition. Finally, it creates meshes of a whole part with simple connection models attached.

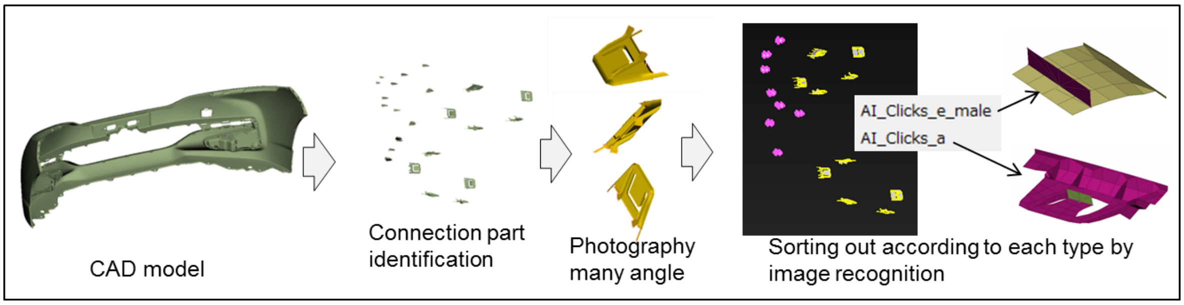

Fig.10: Process flow of automated simple connection model creation

7 Results of Vehicle Application

The simplified connection model was created using the automatic creation tool, and was applied to the low speed collision calculation as a practical example. As the load input of the beam elements in the simple connection model could be evaluated quantitatively, they were utilized to visualize the risk of part falling-off. Fig.11 shows the maximum load input to the beam element in each connection, visualized by different colors depending on its magnitude. The results of the actual vehicle tests are shown in Fig. 12. Comparisons on the calculation results with the actual vehicle tests showed that all the connections in parts such as headlight, fender, lower grille right, and lower grille left had the risk of falling-off, which was well correlated with the test results. Through this verification, the number of catches in the area with high load on the connections was increased, and the spaces between catches in the area with low load were widened, enabling us to make an appropriate spec proposal for the light collision performance.

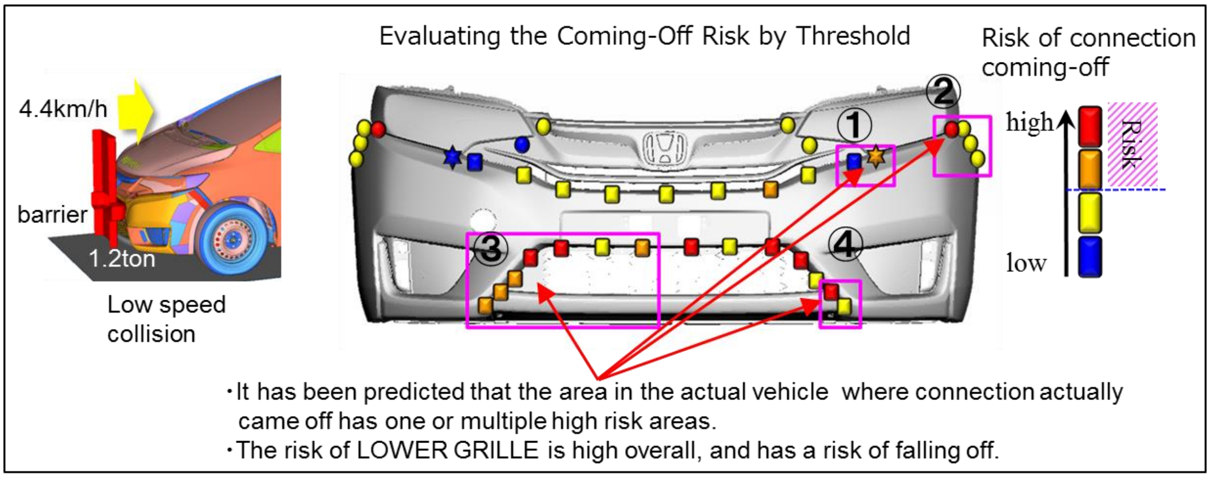

Fig.11: Calculation result of simple connection model

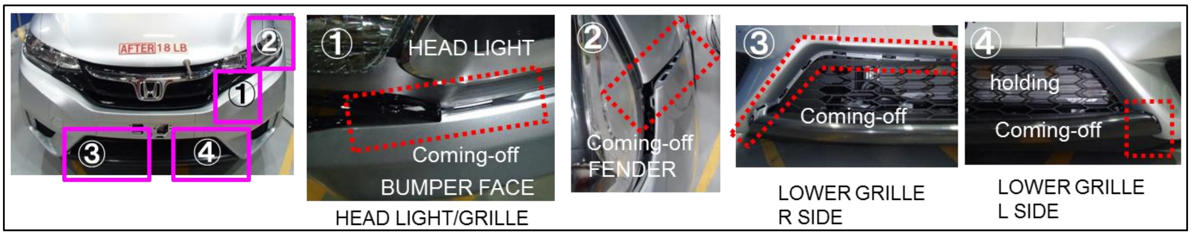

Fig.12: Car test result

8 Summary

Through our effort of enhancing the accuracy of plastic parts connection coming-off in low speed collisions, we succeeded in reproducing the coming-off phenomenon without increasing the calculation time, by replacing it with a simplified connection model instead of pursuing the clip shape reproducibility.