Integration for installation Upper Body of the European Semi-bonnet Truck

JiYong. Song, WookJin. Na

Abstract: *The semi-bonnet Truck consists of Chassis Cab composed of Cabin (CAB) and chassis frame and Upper Body (UB) such as Deck etc. The motor company has to offer manual about connection part of Chassis cab and Upper body to body builder company for manufacturing specially equipped vehicle of European Semi-bonnet truck. This is called BBM (Body Builder Manual). In this study, the simulations are carried out under several loading conditions (Normal loads, Abuse loads, Special loads) in various specially equipped vehicles (Tail-Lift Box, Side-wards of Tipper, Backwards of Tipper vehicle etc.) for ensuring robustness of connection part of Chassis cab and UB. It was able to secure stiffness and strength of connection part of Chassis cab and UB through this process, and optimize the position and number of the chassis bracket.*

Keywords: *Semi-bonnet, Chassis Cab, Upper Body(UB), Tipper*

1. Introduction

SOLATI (H350) is a European multipurpose LCV (Light Commercial Vehicle) which is developed first in Hyundai motor company and is being produced in three variant of BUS/VAN/TRUCK. It is unfamiliar vehicle in KOREA, but generalized model produced as cargo and VAN type in the European market. Among these, the truck type is composed by mounting upper body in chassis cab (cabin & main frame). The chassis cab is designed and manufactured by vehicle manufacturer and Upper Body is manufactured for type of BOX, Tipper in body builder company. Especially, Vehicle manufacturer has to offer various conditions of design and manufacturing conditions when body builder company attaches upper body to chassis cab in Europe unlike domestic. This is called BBM(Body Builder Manual). In this study, the simulations of various specially equipped vehicles are carried out to ensure robustness of connection part between chassis cab and upper body in BBM manufacturing stage.

In the simulations, it was able to ensure the stiffness, strength performance of connection console between chassis cab and upper body, and the position and number of chassis brackets can be optimized. Also, we could predict the bolt fracture as calculating bolt looseness.

2. Main Subjects

2.1 Configuration of connection console between chassis cab and upper body

The Semi-bonnet truck is consisted of Chassis Cab and Upper body. The vehicle company produces the chassis cab that is constituted cabin and chassis frame and body builder company manufactures upper body as Box and Tipper and attaches it to chassis frame. So, the vehicle company must check and design connection part of chassis cab and upper body for being able to satisfy durability and strength performance.

The chassis cab and upper body are configured as shown in Figure.1. Chassis brackets and upper body brackets are installed in each frame and connected using bolts for mounting upper body frame in chassis frame. Here, the mid-plate can be inserted between brackets in order to meet the durability and strength performance in some cases. Like this, after the upper body frame is mounted on chassis frame, special equipment (BOX, Tipper etc.) are installed by body builder company.

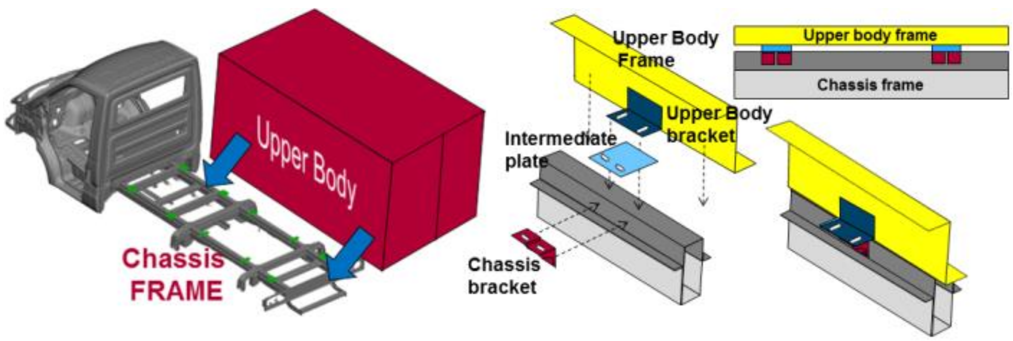

Figure 1. Schematic of chassis frame and upper body connection console.

2.2 Loading Condition

The simulations of upper body connection parts were carried out by replacing the dynamic load applied to the actual vehicle by a simple static load like Figure.2. The replacement with a static load of the dynamic load was based on the DIN EN 12642, UPPER BODY TEST specification.

Figure 2. Replacement of a static in dynamic load

2.2.1 Normal Loads

The normal loads are general forces that apply in actual driving as follows.

1. Case 1: Standing Vehicle
2. Case 2: Vertical Impact(e.g. Pothole)
3. Case 3: Symmetrical brake
4. Case 4: Asymmetrical brake(e.g. Different road condition with 0.8μ,0.1μ)
5. Case 5: Shear loads axle(e.g. Wheel against kerb)
6. Case 6: Driving along curves(e.g. Skidding)
7. Case 7: Frame Torsion Front / Rear(e.g. One wheel has no road contact)
8. Case 8: Frame torsion diagonal(e.g. only two wheels have road contact

2.2.2 Abuse loads and special loads

The abuse(special) loads are forces that apply in worst driving cases as Figure. 3.4.5.

1. Case 9 : Overload condition of Box and Tipper vehicle → Case 1,3,4,5,6 of Normal Load Cases
2. Case 10/11 : When payload of Box and tipper vehicle is biased → Case 1,3,4,5,6 of Normal Load Cases

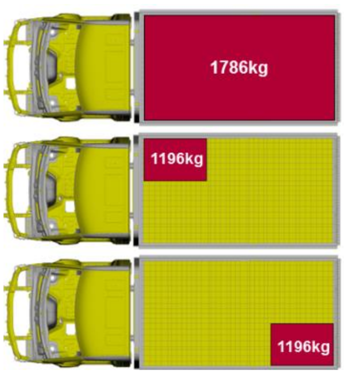

Figure 3. Overload and special-load of BOX vehicle

3. Case 12 : When payload of Box and tipper vehicle is biased → Case 1,3,4,5,6 of Normal Load Cases

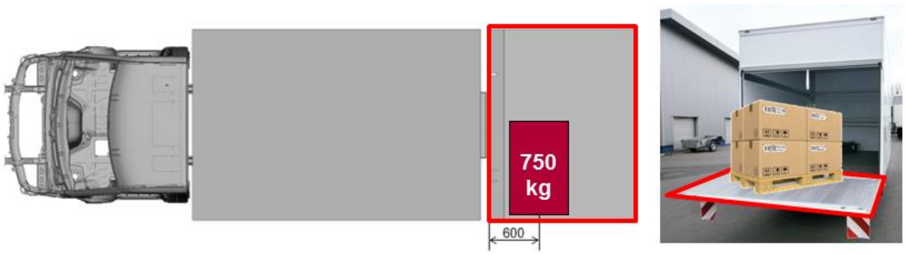

Figure 4. Special load of tail-lift vehicle with BOX

4. Case 13/14 : In case of Tipping condition(Tipping Angle 48°)→ Case 1 of Normal Load Cases

Figure 5. Tipping Condition of Tipper vehicle

2.2.3 Target for durability/strength verification

It is important to set up target of analysis result because we evaluate durability performance using static load. At first, it could make the following conclusions through result of datum in actual test of truck.

As we can see in Table.1, Body twist, Chuck hole and Pot hole are events that are not occurred frequently. And Belgian block , Cobble block and Curves L/R are events that are happened consistently.

Table 1. Probability of load-case occurrence in proving ground.

Event	Chance
Body Twist	7%
Chuck Hole	7%
Belgian Block	28%
Pot Hole	1%
Curves L/R	28%

Cobble Stones	28%

So, the strength performance verification was carried out in normal load case 2,7 and abuse(special) load and the durability performance verification was performed in other load cases in development of SOLATI chassis CAB. Also, the 90% of yield strength is used to critical point in strength performance verification and the 40% of Ultimate stress is used to critical point in durability performance verification.

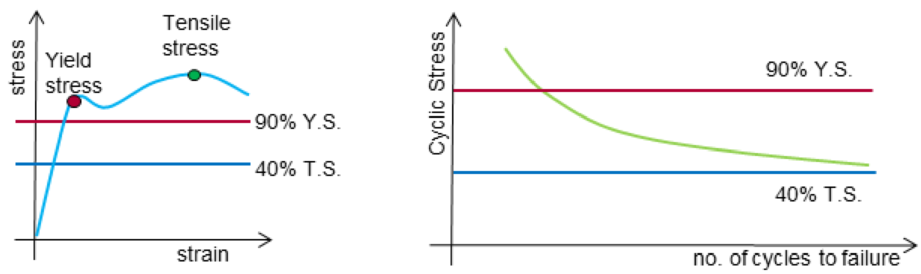

Figure 6. Set-up of target and S-N diagram

Here, we defined the strength index and Durability index for easy expression of simulation results. The definitions are as follows.

1) Strength Index = (90% of yield strength) / (stress)
2) Durability Index = (40% of ultimate stress) / (stress)

Therefore, when the strength / durability index is more than 1.0, we judged that the durability and strength performance is satisfied. The load cases and targets are shown in Table.2.

Table 2. Load cases and Target

<table>
<tr><th>Load Case</th><th>load</th><th>direction</th><th>Target</th></tr>
<tr><td>Case1</td><td>1G</td><td>-Z</td><td>Durability index over 1.0</td></tr>
<tr><td>Case2</td><td>3G</td><td>-Z</td><td>Strength index over 1.0</td></tr>
<tr><td>Case3</td><td>0.8G</td><td>-X</td><td rowspan="4">Durability index over 1.0</td></tr>
<tr><td>Case4</td><td>0.8G0.1G</td><td>-X</td></tr>
<tr><td>Case5</td><td>1G</td><td>Y</td></tr>
<tr><td>Case6</td><td>0.8G</td><td>Y</td></tr>
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Case7	1G	-Z	Strength index over 1.0
Case 8	1G	-Z	
Case 9~11	Same as Case 1/3/5/6		
Case 12~14	1G	-Z	

2.3 Simulation process and result

2.3.1 Loading and boundary condition

The load conditions were explained in 2.2, the boundary conditions for each load cases are all different. The Shock absorbers are constrained in front part of vehicle and the centers of leaf spring are fixed in rear part using different degree of freedom respectively.

And, The Abaqus/Standard 6.13-2 version is used for solver.

2.3.2 Structure adhesive modeling

The structure adhesives were used much in SOLATI truck. For implementing these adhesive, we used solid elements, and these are contacted with parent parts using tied contact method. Also, the material property adhesive was obtained by specimen tests.

The solid elements are consisted of HEX8 and PENTA6 elements, and the COH3D8 is used the type of HEX8 elements, and the COH3D6 is used the type of PENTA6 elements.

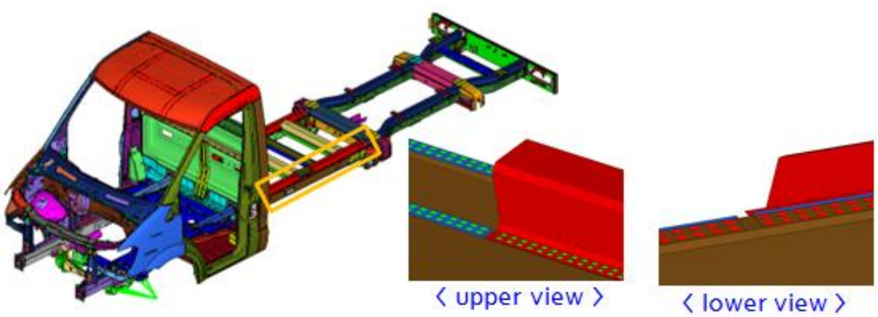

Figure 7. Structure adhesive modeling

2.3.3 Bolt looseness simulation

The bolt looseness simulations of connection consoles between chassis frame and upper body frame were carried out. The bolts are modeled using 1-D bar elements and we calculate axial and shear force of bar elements as shown in Figure.8. Through bolt tightening torque and these forces, we can know whether bolt is loosed or not. And the calculation procedure is as follows

1. At first, the shear force 1,2 are obtained by simulation and the shear direction force can be calculated.
2. The axial force is obtained by simulation
3. The allowable shear force is calculated using friction coefficient, scale factor and bolt clamping force being decided by bolt size.(using equation that is set up in Hyundai)
4. Bolt looseness index= $\dfrac{\text{the allowable shear force obtained in 3}}{\text{shear direction force obtained in 1}}$

If the bolt looseness index is more than 1.0, we can judge that the bolt is safe. The bolt looseness index of 1,2,3,4 and 5 position in Figure. 8 were calculated in load case 10-1,2,3,4,5, and the result is shown in Table.3. Because the bolt looseness index of 2nd row bracket in LH is 0.99, we had to reinforce it.

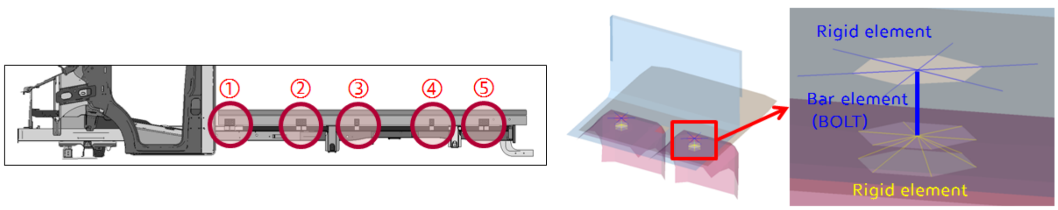

Figure 8. Modeling for bolt looseness simulation

Table 3. Result of bolt looseness index

ROW	1		2		3	4	5	
LH	21.0	22.4	1.06	0.99	4.52	6.54	8.08	7.18
RH	21.7	22.9	1.2	1.11	2.36	2.3	4.4	4.44

2.3.4 Elastic connection simulation of chassis cab and upper body

The problems are sometimes happened behind back panel of cabin because of the discontinuity of stiffness. We compared rigid with elastic consoles in 1st and 2nd rows of chassis cab in this study. The rigid console means the bolt connection and elastic console means the connection which inserts flexible element as shown in Figure.9. Also, the material properties of flexible element are obtained from tensile test for simulation.

Figure 9. Rigid and flexible consoles and pre-tension model

When the FE-model of elastic connection is composed, the bar elements are used. Then the *pre-tension section keyword is used, and forces are loaded in the pretension nodes on the section. And the force is obtained from the bolt tightening torque. The model configuration is shown in Figure 9.

The simulation is carried out in load case 12(when the payload is biased in tail-lift box vehicle), and the stress of elastic console was lower than it of rigid console as shown in Figure.10.

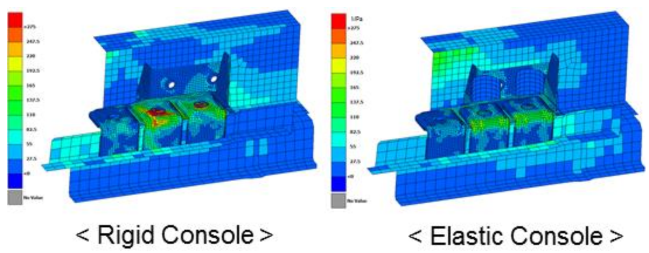

Figure 10. Simulation result of rigid and elastic consoles

2.3.5 The connection part simulation of Tipper vehicle

The connection console of last row is highly stressed in case of backward tipping. So, the case studies are performed for improving last row connection console. The simulations are carried out in 4 cases in load case 13, the results are as shown in Figure.11.

1. Version 1 : current design
2. Version2 : movement of 150mm backward
3. Version3 : movement of 150mm backward + Enlargement of mid-plate
4. Version4 : Addition of mid-plate in back of console

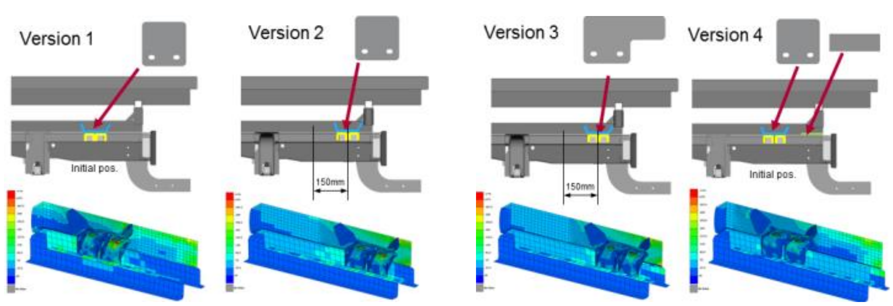

Figure 11. Simulation result of last row in case of backward tipping.

In conclusion, the strength index of version 3, 4 is higher than 1.0 among 4 cases. By the way, because version 3 is needed change of vehicle layout, version 4 is selected finally.

2.3.6 The selection of the number and position of chassis brackets

There are total 5 rows in connection consoles of SOLATI chassis cab. The number of chassis brackets is 3EA in 1st and 2nd row, 1EA in 3rd and 4th row, and 2EA in last row, respectively. Because the stress level of 1st and 2nd row is low in various load cases, we judged that the number of chassis brackets of 1st and 2nd row can be reduced.

The first chassis bracket in 1st row is removed because there is not enough space between cabin and upper body. And we considered removal of the first or third chassis bracket in 2nd row. The simulations were performed in load case 11 which stressed highly in 1st and 2nd row, and the stress results are as shown in Figure.12.

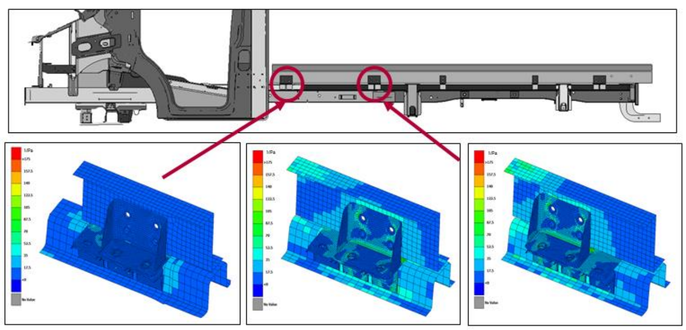

Figure 12. Case study about number of connection console bracket.

As a result, when the first chassis bracket in 1st row could be removed, the strength index was more than 1.0 around console. And when the first or third chassis bracket in 2nd row is removed, the stress level is equivalent, and strength index is higher than 1.0 in the both cases. So, we could remove total 4EA brackets including LH and RH.

3. Conclusion

We concluded throughout simulation of specially equipped vehicle (Tail-lift box and Tipper) in development process of European SOLATI (H350) truck using various loading conditions as follows

3.1 The durability and strength performance of connection part between chassis cab and upper body could be verified in Body Builder Manual (BBM) production process of SOLATI (H350).

3.2 The simulations of tail-lift box and tipper vehicle were carried out in various load cases representatively.

3.3 The structural adhesive simulation method is implemented using Abaqus/Standard, and it was used to verify durability and strength performance of SOLATI Chassis CAB.

3.4 It could contribute to weight reduction by reducing the number of chassis bracket.

3.5 By introducing bolt looseness index, we could know whether bolts are failed or not as calculating axial and shear force in Abaqus/Standard.

4. Reference

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