Development and Research of EMU Honeycomb Floor Structure Mechanic Simulation Modular

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Abstract. Basing on PYTHON coding, honeycomb floor static and dynamic strength simulation modular had been developed. Modular automatic analysing, database parallel saving and parametric modelling technique were introduced. By means of the modular, component-level actual loading test was simulated and results of test and simulation were compared. It was presented that result deviation between test and simulation was small and accuracy of the modular could be verified. References of related honeycomb floor design and simulation could be provided.

1. Introduction
As one of the most important components of EMU train interior system, honeycomb floor consists of low-density hexagon honeycomb core and two thin aluminium plates which would be cementing or welding with each other. This type of floor structure, which is the most appropriate choice of high speed EMU train[1-3], has multiple advantages such as high stiffness/mass ratio, excellent stability, enough stiffness & strength and good performance of heat isolation[4-6]. However, the honeycomb inner structure is much complex and need loads of time to execute pre-treatment work during the simulation process then cause relatively low efficiency of computation.

In this paper, honeycomb floor structure mechanic simulation modular has been developed basing on ABAQUS platform. This modular has formalized the honeycomb mechanic simulation procedures at both specimen and component levels according to standard requirements and actual load cases. Meanwhile, it can achieve parametric setup and engineering application of the honeycomb floor design by means of adding boundary models to simulate the actual floor component assembly conditions. Then regular designer could finish the complete process of floor structure static and dynamic mechanic simulations automatically.

2. Modular development and application

2.1 Analytical strategy establishment
When developing new mechanical component, “Bottom-Top” strategy, which is shown in Figure 1, has usually been applied considering that each type of boundary conditions are still unknown. First, specimen tests should be engaged to acquire mechanical performance of the structure. Then component test results could be used to verify if the whole structure could meet the requirements of stiffness and strength under the actual load cases.

On the contrary, if improved and modification designs were conducted basing on the existed product, “Top-Bottom” strategy, which is shown in Figure 2, has usually been applied considering that each type of boundary conditions have already been known. First, component test results should be
used to verify if the modified structure could meet the relevant requirements under the actual load cases. Then “Bottom-Top” strategy could be used to obtain those needed mechanical indices.

![Figure 1. “Bottom-Top” strategy](image1.png)

![Figure 2. “Top-Bottom” strategy](image2.png)

The object of the modular is the regular designer group and provide convenient simulation tool to them. So both the two strategies above could be realized. When developing new-designed EMU honeycomb floor, designers could choose “Bottom-Top” strategy. When modifying and optimizing EMU honeycomb floor, “Top-Bottom” strategy will be the appropriate choice.

### 2.2 Analytical process and parameter setup

![Figure 3. modular analysis procedure](image3.png)

![Figure 4. Parameter setup home interface](image4.png)
To this modular, no matter which strategy being used, the core parts of the operation process are the same. Firstly, the designer inputs the size and material parameters into the specimen level simulation modular and initiate the computation. At the meantime, permissible value analysis modular will be activated to compute the related values and automatically deliver them into the component level simulation modular for equivalent model solutions.

Finally, component simulation results, which have been computed under the actual vehicle assembly conditions, would be outputted through verification result display modular and simulation reports or other deliverables would also be created by computer. There is no need to deliver each parameter data manually during the whole procedure as is presented in Figure 3 and it can realize total simulation analysis automation. Take component level simulation modular of chute mounting type of floor as an example, the parameter setup home interface has been presented in Figure 4.

2.3 Standard models establishment
When managing the pre-treatment work of simulation, the modular contains two types of models, which are specimen models and component models. Those models have all been established according to national standards and sealed in the modular already. Specimen models are mainly used to engage four kinds of computations, which are bending, side compressing, even compressing and even tension. When all four computations finished, nine elastic constants, which are needed by honeycomb core orthotropic equivalent, could be confirmed. Figure 5 shows the bending test specimen model as an example.

![Figure 5. Bending test specimen FE model](image1)

![Figure 6. Chute mounting type of floor FE model](image2)

According to the actual floor component assembly conditions, component models could be divided into two types: chute mounting and screw thread mounting. Boundary conditions of those two types of model keep the same with the actual ones. By inputting or changing parameters of size, material and assembly, the related models would be established along with different design drawings. Figure 6 shows the chute mounting type of floor component model as an example.

2.4 Load cases setup
Load cases of those four specimen models have been provided in national GB standards and fixed in our modular. As for component models, their load cases have been summarized and presented in Table 1 basing on the loading characteristics of EMU operation on lines.

| Num. | Load case                     | Load magnitude and distribution                      |
|------|-------------------------------|------------------------------------------------------|
| 1    | Full load + Corridor load     | Single person 80kg, 6 persons/m²                     |
| 2    | Full load                     | Single person 80kg                                  |
| 3    | Deviate load(Triple seat)     | Single person 80kg                                  |
| 4    | Deviate load(Double seat)     | Single person 80kg                                  |
| 5    | Full load braking             | Single person 80kg, braking acceleration speed 0.3g  |
| 6    | Unlade shock                  | IEC61373: 1999 standard requirements                 |

2.5 Contact and constraint setup
Different computational model in the modular has different actual load cases and standards which should be followed. In order to be convenient for users, all contact and constraint setups, which are
presented in Table 2, have already been fixed and sealed in the modular and they have no need to input the parameters manually.

2.6 Solving and post-treatment

When clicking the SUBMIT button, the solving process will be initiated automatically. Permissible value analysis modular will be connected to material database for new saving and delivering of elastic constants and stress data comparison. Then all results and contours will be displayed on verification result display modular and extracted to form the simulation reports.

| Model            | Contact                                                  | Constraint                                         |
|------------------|----------------------------------------------------------|----------------------------------------------------|
| Bending specimen | Section: press head to plate abutment to plate Normal property: hard contact Tangential property: penalty friction Friction coefficient: 0.24 | Rigid Body: press head abutment                    |
| Side compressing specimen | None | Rigid Body: press head Tie: press head to plate |
| Even compressing specimen | None | Rigid Body: press head abutment Tie: press head to plate abutment to plate |
| Even tension specimen | None | Rigid Body: press head abutment Tie: press head to plate abutment to plate |
| Screw thread mounting component | Section: vibration absorber to floor seat frame to floor Normal property: hard contact Tangential property: penalty friction Friction coefficient: 0.24 | Tie: honeycomb core to plate Floor to floor baffle vibration absorber to car body floor MPC Tie: all bolt connection |
| Chute mounting component | Section: vibration absorber to floor Normal property: hard contact Tangential property: penalty friction Friction coefficient: 0.24 | Tie: honeycomb core to plate vibration absorber to floor chute vibration absorber to car body floor MPC Tie: all bolt connection |
3. Engineering tests for simulation result verification

To verify the accuracy of simulation results, static load test under the floor mounting condition of screw thread, which is shown in Figure 7, combined with modular simulation had been engaged both. Distribution of strain gages sticking on the honeycomb floor during the test and simulation process are presented in Figure 8 and Figure 9 respectively. Dimension of the load area is 190 mm×190 mm. Take 0.4 t as the 100% load magnitude and incremental step is 10% until 2.4 t (600% load magnitude) to stop. Then, initiate unload step by step.

4. Engineering tests for simulation result verification

Taking records of the strain values from those eight strain gages and comparing the test results with simulation, the comparison data analysis is presented in Table 3. Comparison curves of No.107 and No.108 strain gages are shown in Figure 10 and Figure 11 respectively.

| Num. | 0.4 t | Test | Modular | DEV | 0.8 t | Test | Modular | DEV | 1.2 t | Test | Modular | DEV |
|------|-------|------|---------|-----|-------|------|---------|-----|-------|------|---------|-----|
| 101  | -165  | -128 | -0.22   | -353| -276  | -0.22| -543    | -432| -0.20 |
| 102  | -189  | -138 | -0.27   | -404| -288  | -0.29| -618    | -448| -0.28 |
| 103  | -143  | -139 | -0.03   | -305| -295  | -0.03| -460    | -466| 0.01  |
| 104  | -156  | -146 | -0.06   | -321| -302  | -0.06| -485    | -483| 0.00  |
| 105  | -166  | -138 | -0.17   | -346| -295  | -0.15| -531    | -458| -0.14 |
| 106  | -191  | -146 | -0.24   | -403| -304  | -0.25| -607    | -470| -0.23 |
| 107  | -127  | -138 | 0.09    | -268| -297  | 0.11 | -410    | -464| 0.13  |
| 108  | -144  | -146 | 0.01    | -300| -302  | 0.01 | -451    | -483| 0.07  |

| Num. | 1.6 t | Test | Modular | DEV | 2.0 t | Test | Modular | DEV | 2.4 t | Test | Modular | DEV |
|------|-------|------|---------|-----|-------|------|---------|-----|-------|------|---------|-----|
| 101  | -743  | -595 | -0.20   | -964| -762  | -0.21| -1708   | -929| -0.46 |
| 102  | -828  | -614 | 0.03    | -879| -813  | -0.08| -1404   | -990| -0.29 |
| 103  | -620  | -640 | -0.04   | -1030| -790  | -0.23| -1468   | -922| -0.37 |
| 104  | -691  | -663 | -0.16   | -983| -794  | -0.19| -1684   | -965| -0.43 |
| 105  | -744  | -625 | -0.22   | -1076| -792  | -0.26| -1607   | -956| -0.41 |
| 106  | -807  | -633 | 0.14    | -711| -819  | 0.15| -1012   | -996| -0.02 |
| 107  | -561  | -642 | 0.09    | -773| -793  | 0.03| -1124   | -933| -0.17 |
Figure 10. Comparison curves of No.107

Figure 11. Comparison curves of No.108

From the comparison of test and modular computed results, it could be verified that:

1. Before load reached to 510%, the strain results from the test keep linear increasing. It indicates that honeycomb floor structure was at the stage of elastic strain during that period. Slopes of the strain variation between test and simulation basically keep the same and it can prove that the accuracy of the honeycomb floor stiffness computation from modular simulation is satisfying.

2. When load reached to around 510%, slope of the strain from the test appeared to be sudden changed. It indicates that honeycomb floor structure has begun to lose efficacy. Because the honeycomb core was only given elastic properties, so the slope would no longer be changed. However, when checking the honeycomb core stresses in 600% load condition, it can be seen that the stress in the border of loading area had exceeded the permissible value that we computed. It indicates that honeycomb floor structure was destroyed now.

3. From the test and simulation strain value results comparison in Table 3, it can be proved that deviations in each location were all lower than 20%. Apart from the test error itself, deviation and changing conformity between test and simulation could be considered well. So, the accuracy of the modular computation could be guaranteed.

5. Conclusion

EMU honeycomb floor structure mechanic simulation modular, which had been developed by PYTHON code on ABAQUS platform, could realize all-steps automatic analysing process without any manual work from regular designers. Meanwhile, new material data could be saved and delivered simultaneously and computation results could be extracted to form simulation reports by using this modular. In general, it can greatly enhance the simulation efficiency and decrease the demand for finite element fundamental theory to users. By comparing the simulation results with the test, accuracy of the modular computation has been verified.

References

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