Efficient Characteristic Identification of Plastic Materials for Crash Analysis with 3-Point Bending Machine

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1 Introduction

According to WHO's report, there are over 270,000 people who are involved in traffic fatal accidents [1]. Based on this accident data, the third-party assessment organization performs pedestrian protection test to evaluate a vehicle safety performance [2]. The pedestrian protection tests are evaluated for the protective performance of a head and legs of pedestrian. In particular, plastic parts such as a bumper face, a grille and head lights are evaluated by the leg pedestrian test. On the other hand, low speed crash test regulated by the United Nations evaluates a bumper protection performance (ECE42). In general, the pedestrian and bumper protection performances are in a trade-off relationship. Therefore, it has become important to balance these performances because the country which does the pedestrian protection test is increasing in recent years.

In order to design these performances, it is essential to use the plastic CAE model with high accuracy. However, there are many types of characteristics for the plastic parts compared to the steel parts. It is an issue to collect the material properties for the many plastic parts in author's development environment. Investigating the past literature to solve this issue, we found that Reithofer et al.[3] developed the machine and method to create the material property for CAE in a short time. So this study is to validate that the machine can be used efficiently to identify the material property for the pedestrian protection and low speed crash.

***KEYWORDS Pedestrian protection, Low speed crash, Plastic parts, Optimization.**

2 Methodology

2.1 Work flow

Fig.1 shows the conventional work flow to identify the material property for CAE. Since the test for getting the material property was outsourced, it is not efficient for adjustment work in this work flow. It also took a lot of time to identify the material property such that the CAE result could match with the test result manually. Then in this study, the work flow is improved as shown in Fig.2. This study tried to short the work time by setting the test machine in-house and automating for the identification work of the material property.

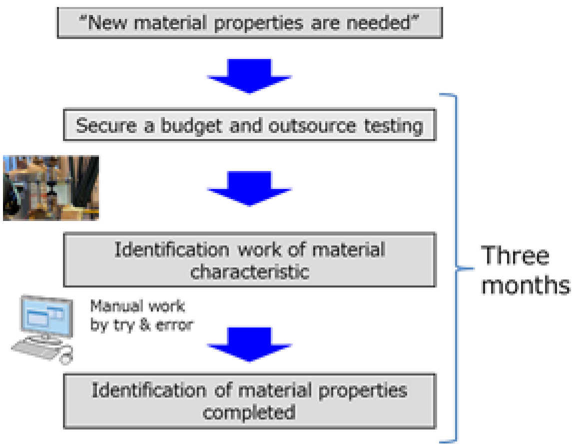

Fig.1: Conventional work flow for material property identification.

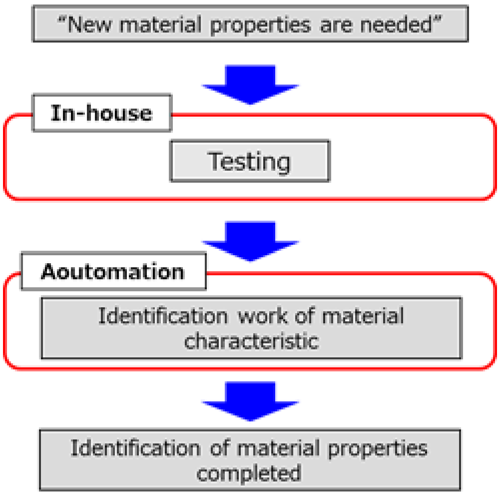

Fig.2: Improvement work flow for material property identification.

2.2 Test equipment

IMPETUS^{TM} and VALIMAT^{TM} [3] were used for in-house testing and automation of material property identification, respectively. Fig.3 shows the schematic diagram of the equipment. IMPETUS^{TM} has a impactor by the pendulum and perform the 3-point bending for a test piece. The impact velocity is changed by the first position and it is possible to test by different velocity in order to define the strain rate dependency. VALIMAT^{TM} identifies the material property by optimization CAE.

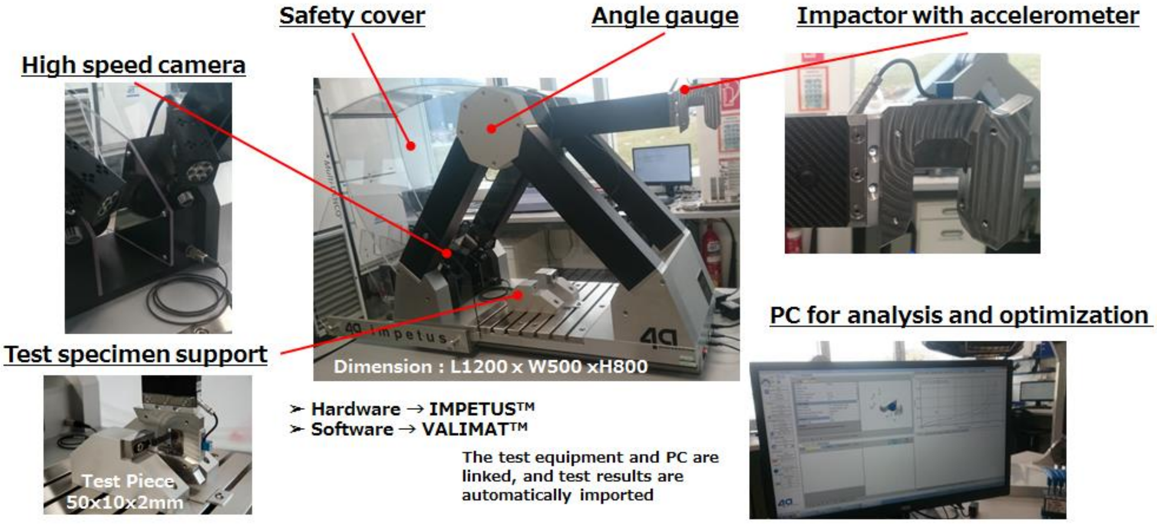

Fig.3: Schematic diagram of testing machine.

2.3 MAT_24 identification

MAT_24 was used for the material type in this study. Firstly, the test pieces were impacted by the pendulum and the history of acceleration and angle were measured. Secondly, the force was converted from the acceleration and the displacement was also converted from the angle. Then the Force-Displacement curve was obtained. However, the quasi-static velocity was tested by AGS-X manufactured by SHIMAZU because IMPETUS^{TM} does not support the quasi-static mode. After that the optimized CAE was performed on these Force-Displacement curves so that the simulated force-displacement curve can match the experimentally obtained response. Each setting of optimization CAE was followed by the method of Reithofer et al. [3]. In general, bumper face has often a lot of strain energy when the pedestrian protection CAE is performed (Fig.4). Therefore, we decided to identify the material property of the bumper face in this study.

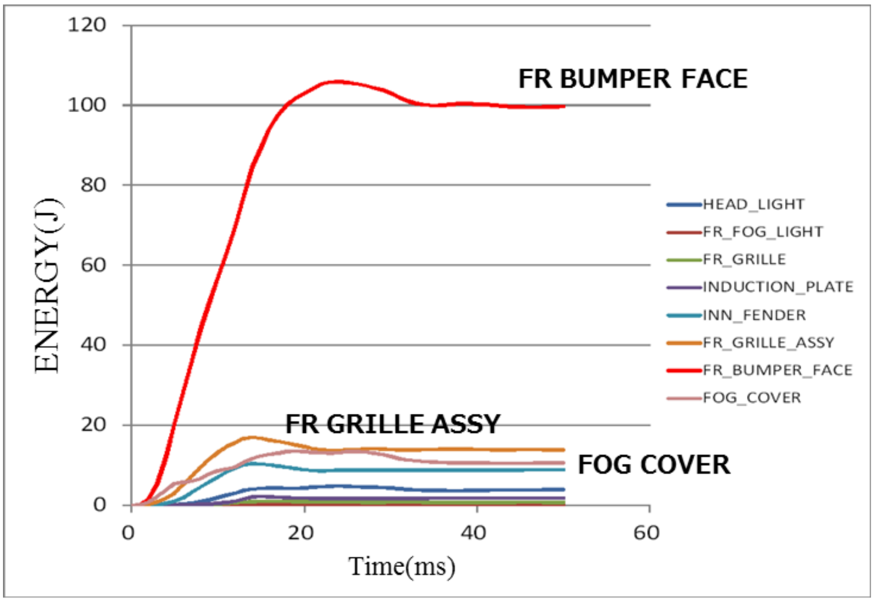

Fig.4: Time history of absorbed energy by pedestrian CAE.

2.4 Validation method

In order to validate the identified material property in this study, the validation test was performed. The bumper face was fixed as shown in Fig.5. Then the impact test was conducted by the head impactor and the acceleration was measured. In the same way, the CAE model was also created and applied for the identified material property in this study. After that the accuracy was confirmed by comparing the test and CAE results. Furthermore, the material property obtained in the tensile test was also applied on the CAE model and compared with the test. Then it was validated which is closer to the test result in the new property and the conventional property.

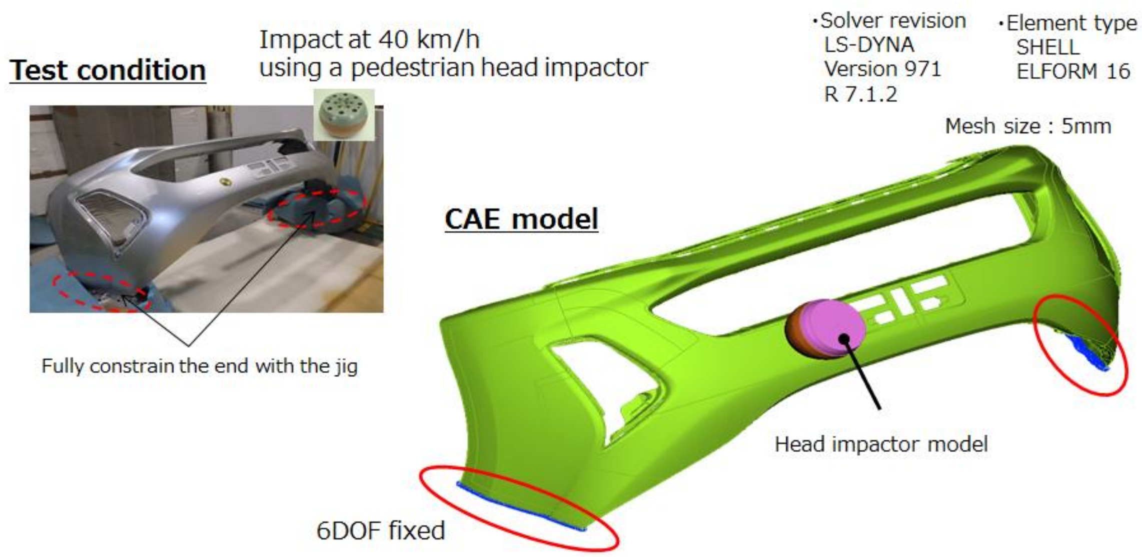

Fig.5: Validation test and CAE model.

3 Results

3.1 3pt bending test resluts

Table.1 shows the test conditions. Fig.6 shows the 3-poont bending reslut and identified result by VALIMAT^{TM}. We found that the CAE results approximately matched to the test resluts. Fig.7 shows the identified stress-strrain curves. The stres-strain curves which were identified by the tensile test is also shown in order to compare the both propertis. We found that there are differences in both obtainded curves. The work time taken for the testing and identification was 2 days. It was drasticaly shorten compared to the conventional method.

V_0(m/s)	Lw(mm)	M pendulum(g)	b(mm)	t(mm)	l(mm)
0.0001	39.98	0.0	10.04	2.03	50.02
0.001	39.98	0.0	10.01	2.02	50.01
0.6	39.99	10.01	10.01	2.01	50.00
1.0	39.99	10.05	10.05	2.01	50.01
2.5	39.99	10.02	10.02	2.01	50.01

Table 1: Test conditions for each velocity.

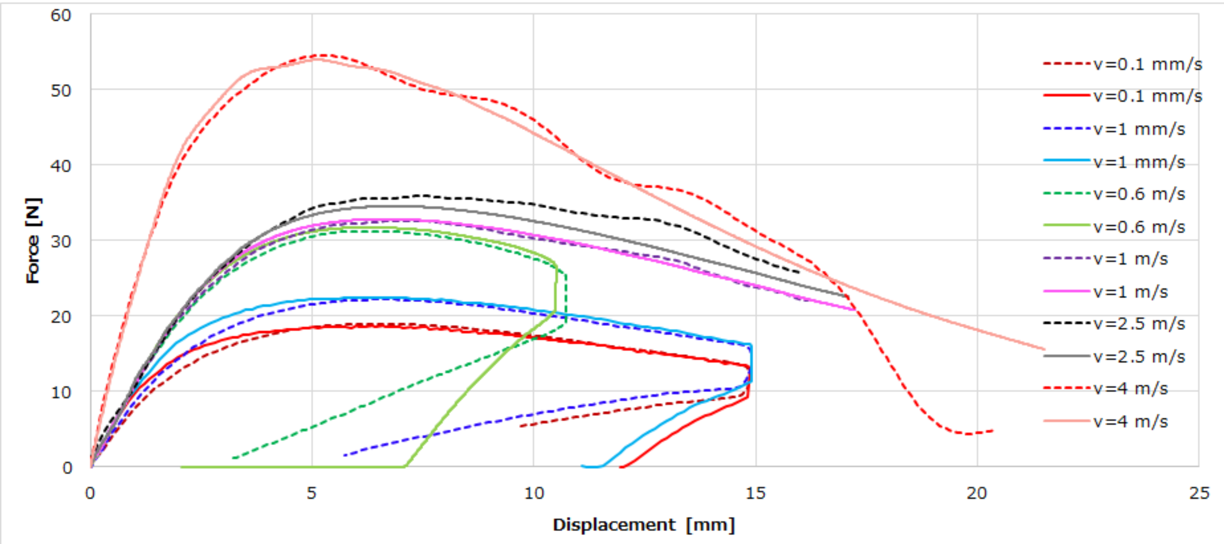

Fig.6: Comparison of Force-Displacement curves between CAE and test by 3pt bending. (dash line:test, solid line:CAE)

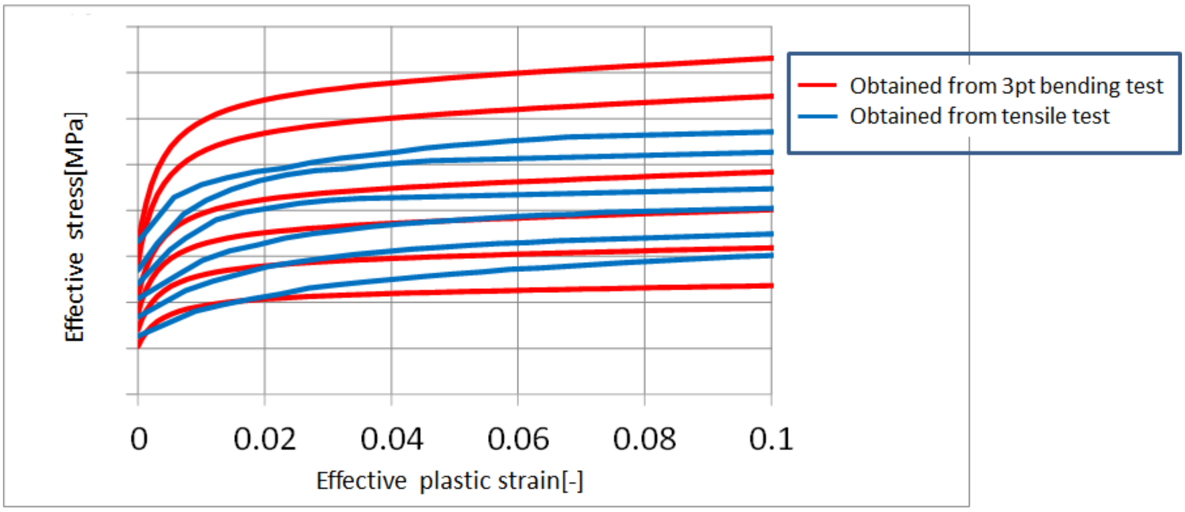

Fig.7: Comparison of effective Stress-Strain curves identified from tension and 3pt bending test.

3.2 Validation results

Fig. 8 shows the acceleration waveform. The CAE waveform showed 2 types both obtained from the 3 point bending test and the tensile test. It can be seen that the waveform obtained from the 3-point bending test has higher accuracy than the tensile test (Table.2).

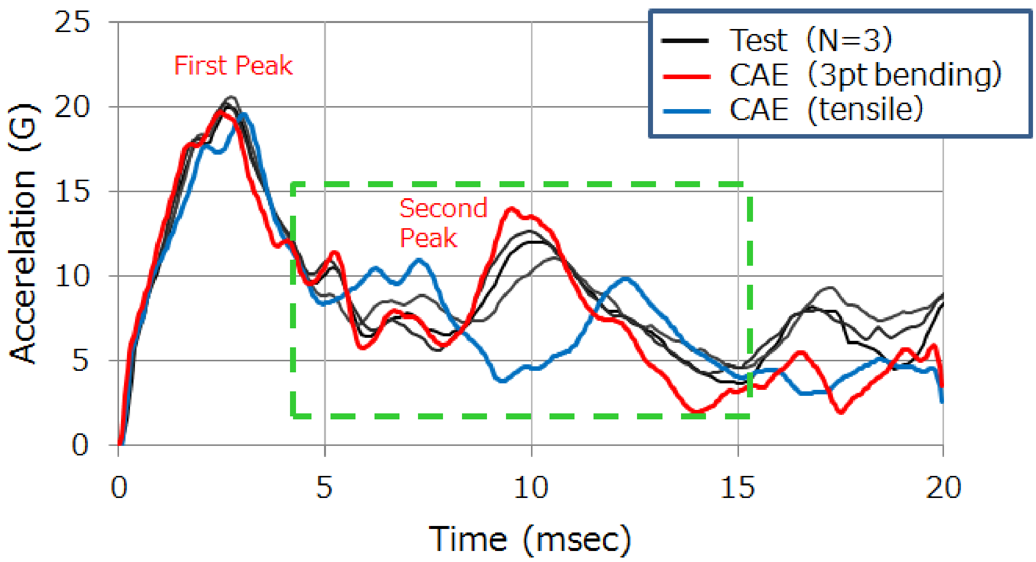

Fig.8: Test and CAE acceleration waveforms

Material property	Error of 1st peak		Error of 2nd peak	
3pt bending	-0.7G	-3.4%	-3G	-23%
Tensile	-0.5G	-2.6%	+1G	+8%

Table 2: Difference in error for each characteristic at each peak

4 Discussion

In Chapter 3, the results were different in the property obtained from 3-point bending and tensile tests. Because steels have generally same characteristic between the tensile and compression propety, only tensile tests are performed to identify the material property in the plastic materials. On the other hand, plastic material is not same charecteristic between the tensile and compression propety due to hydrostatic pressure dependency. Since the stress-strain curve was obtained by 3 point bending in this study, the curve was composed by both tension and compression characteristics. As a result, the stress value of the curve obtained by the bending test was higher than the curve obtained by the tensile test.

When the bumper face kinematics was observed at the impactor crash timing by replacing the element type from shell to solid, we can see both tension and compression mode (Fig.9). Therefore, it is considered that the characteristics identified by 3-point bending were in good agreement with the test results.

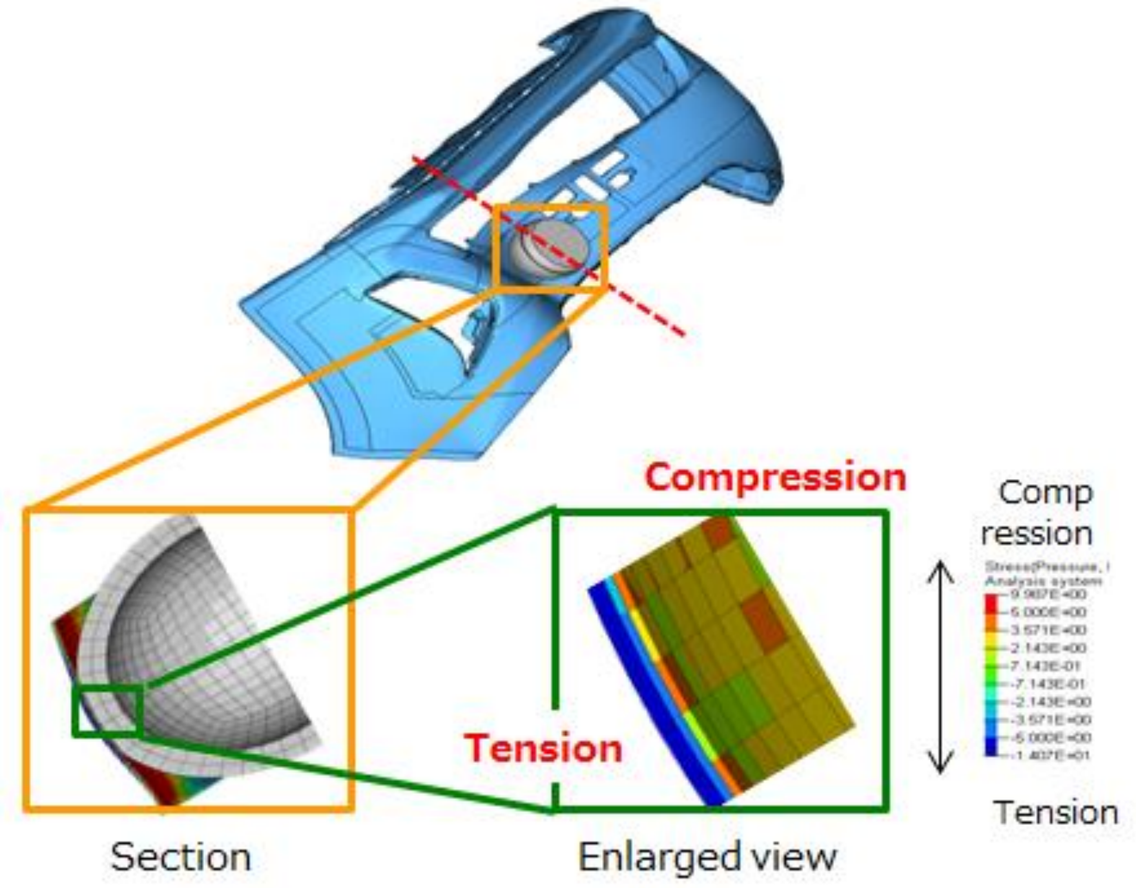

Fig.9: Distribution of tension and compression modes at impact.

5 Summary

- In this study, the efficiency of the material property identification work for CAE was examined using the 3-point bending test equipment (IMPETUS™).
- Three months of the identification work could be shortened to 2 days by introducing the 3-point bending test equipment (IMPETUS™).
- CAE accuracy was improved by using material properties identified with the 3-point bending test equipment (IMPETUS™) rather than the conventional method.
- Plastic materials differ in tensile and compressive properties from hydrostatic pressure dependency, but compressive properties could be taken into consideration by identification using the three-point bending equipment (IMPETUS™).

6 Literature

[1] World Health Organization: "Global Status Report on Road Safety 2013" ISBN 978 92 4 156456 4, 2013
[2] http://www.globalncap.org/
[3] P. Reithofer et_al.: "Dynamic material characterization using 4a impetus", PROCEEDINGS OF THE REGIONAL CONFERENCE GRAZ 2015- – POLYMER PROCESSING SOCIETY PPS, 2015