Hybrid Laminated Glass: Material Characterisation and CAE Modelling

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1 Introduction

Different from standard laminated glass which is made of two layers of soda-lime glass and PVB, hybrid laminated glass comprises layers of standard soda-lime glass, PVB and thin chemically toughened glass. Hybrid laminated glass has great advantage of weight saving, so it has drawn great attentions to the automotive industry recently. However, its application may have impacts not only on the performances of many attributes, such as safety, NVH, etc., but also on the CAE modelling method which we have adopted for the standard laminated glass for years.

This paper briefly discusses the research activity of understanding potential impact of hybrid laminated glass application, the method of material characterisations and CAE modelling development for hybrid laminated glass.

2 Review of CAE Method for Standard Laminated Glass

In automotive industry, it is important for CAE engineer to predict laminate glass behavior in windscreen application, which is associated with pedestrian head impact and passenger airbag deployment. For instance, able to model windscreen damage behavior will lead CAE engineer to have a good virtual toolset to optimise cowl and IP system to achieve good results for pedestrian head impact.

Over the past years, there are many papers and literatures on modelling fracture behaviours of standard laminated glass. The approaches vary from advanced material constitutive laws, to detailed layers and local fine meshes, etc.

However, from engineering application point of view, the windscreen is just one part of large vehicle model, such as pedestrian head impact model. Therefore, the criteria for a good glass model for engineering application are not only to be able to reasonably capture key glass behaviour but also simple and common in mesh size as other parts.

In a separate study, the windscreen model with standard vehicle model mesh size using simple MAT32 in LS-DYNA and optimised material properties through correlations to multiple head impact points and vehicles has been demonstrated as a good modelling practice, as shown in Figure 1 as an example. The method has given advantages of reasonably good glass behaviour and fast calculation time with vehicle common mesh size and time step.

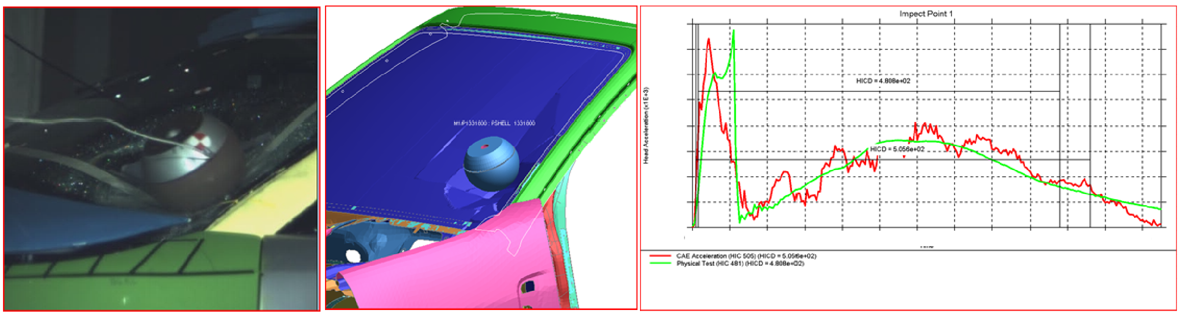

Fig. 1: Glass Model: MAT32, Common Mesh Size and Optimised Material Properties

3 Challenges of Hybrid Laminated Glass

Standard laminated glass behaviours under impact have been well understood. In normal bending test, for instance, the glass in tension side breaks first followed immediately by compression side glass. However, how hybrid laminated glass responses to pedestrian head impact and airbag deployment loading remains unclear as glass manufacturers are not able to provide such data.

On the other hand, hybrid laminated glass has inner glass which is chemically toughened. The toughened glass has different material properties and failure / fracture criterion. Therefore, current CAE practice for standard laminated glass is no long able to be used because the MAT32 can only allow one set of glass material input data. New CAE practice needs to be established to predict the thin toughened glass behaviour, but importantly it also needs to have common mesh size and time step within vehicle model.

Facing the new challenges, the research project has been established to investigate the safety attribute related behaviour of the hybrid laminated glass and to develop virtual CAE method of hybrid laminated glass to support vehicle programmes.

4 Material Characterisations of Hybrid Laminated Glass

To have basic understanding of hybrid laminated glass behaviour under the loading and also to support material characterisations, four-point bending tests are proposed and samples of hybrid laminated glass are sourced from two hybrid laminated glass suppliers. For the purpose of back-to-back study, samples of standard laminated glass, standard glass only and toughened glass only are also sourced. Table 1 shows the test matrix. Figure 2 shows the images of the physical tests.

Table 1: Four point bending test matrix

Standard Glass Only	Toughened Glass Only	Standard Laminated Glass	Hybrid Laminated Glass
v	v	thinner glass in tension	toughen glass in tension
		thinner glass in compression	toughen glass in compression

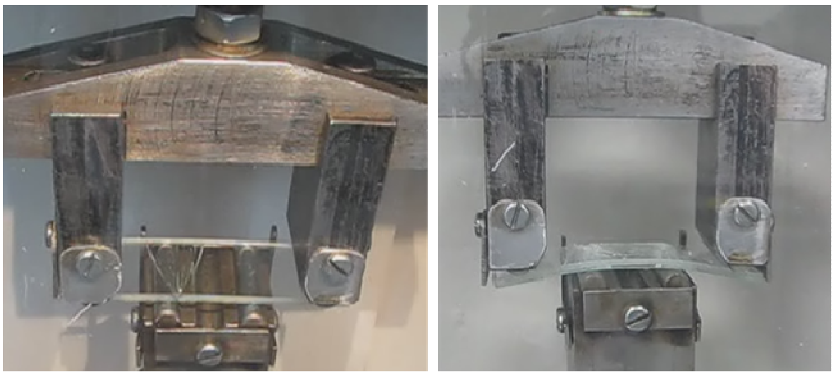

Fig. 2: Left - Standard Laminated Glass; Right - Hybrid Laminated Glass

5 CAE Methodology for Hybrid Laminated Glass

As mentioned above, simple single layer MAT32 material model is no long valid for hybrid laminated glass. Instead, three-layer model has been investigated. In this model, both standard glass layer and thin toughen glass layer are modelled as shell and PVB layer is modelled as solid.

The general logic flowchart of CAE methodology validation is illustrated in Figure 3. The CAE material model for hybrid laminated glass has been validated through the correlation to all the characterisation tests.

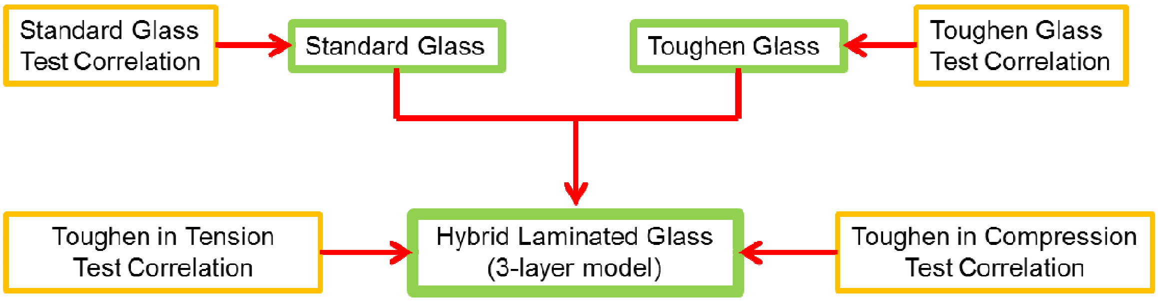

Fig. 3: Logic Flowchart for CAE methodology Development

6 Pedestrian Head Impact Predictions and Tests of Hybrid Laminated Glass

A series of pedestrian head impact tests with standard laminated glass and hybrid laminated glass have been conducted to understand the potential impact of the hybrid laminated glass application on head injury HIC. Figure 4 shows the images of the physical head impact tests for hybrid laminated glass.

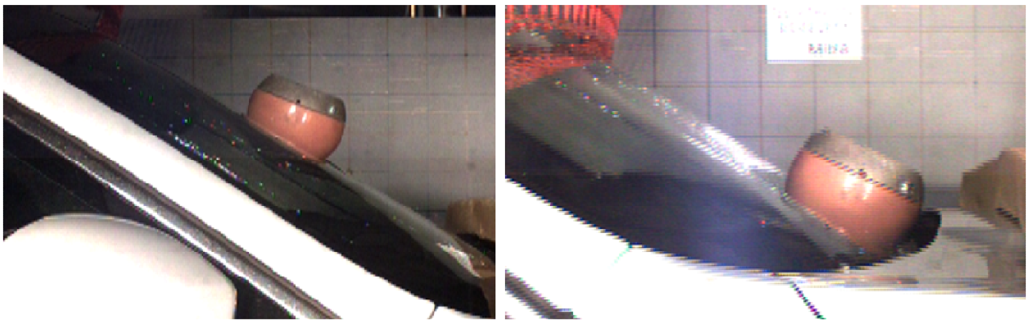

Fig. 4: Left – Centre Point; Right – Lower Centre Point

The tests also provide the validation points of the material model developed from the material characterisations. The hybrid laminated glass material model is assembled into the vehicle pedestrian head impact model. Figure 5 illustrates a snapshot of the CAE model with three-layer model to represent hybrid laminated glass. The CAE predictions are reasonably matched the physical tests in terms of HIC, curve features and head foam rotation.

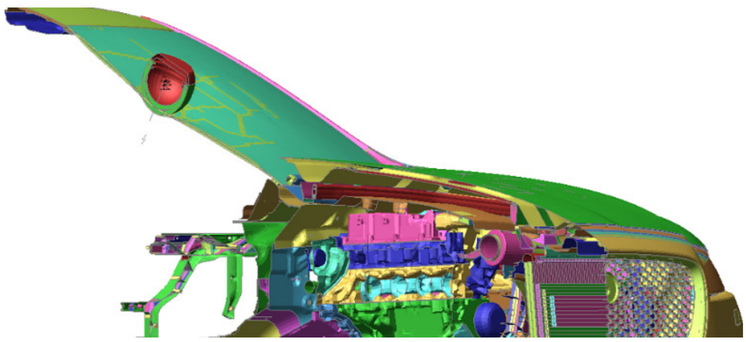

Fig. 5: Three-Layer Material Model to Represent Hybrid Laminated Glass

7 Conclusions

Through the project, the hybrid laminated glass behaviours under the impact loadings are understood. The virtual CAE toolset for hybrid laminated glass has been developed to support programme applications.

8 Literatures

[1] J. Xu, et al., Experimental and macroscopic investigation of dynamic crack patterns in PVB laminated glass sheets subject to light-weight impact, Engineering Failure Analysis 18, 2011

[2] J. Xu, et al., Characteristics of windshield cracking upon low-speed impact: numerical simulation based on the extended finite element method, Computational Materials Science, 48, 2010

[3] J. Xu, et al., Experimental study on mechanical behavior of PVB laminated glass under static and dynamic loadings, Composites: Part B, 42, 2011