Numerical Simulations in Mechanical Engineering

Topic 4: Dynamic behavior of laminated windshield upon head impact

By

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Abstract

Automotive accidents have been increasing sharply in recent years and have become one of the major causes of death worldwide, particularly among vulnerable road users (VRUs). In VRU–vehicle accidents, the contact of the head of a VRU with the windshield is statistically regarded as the leading cause of fatal head injury or death. Therefore, improving the head impact safety of windshields is a pressing need.

Our task is to develop a finite element model for laminated windshield which can accurately predict the dynamic response of laminated windshield upon pedestrian head impact.

Introduction

Since the windshield is not only a part of a vehicle that saves the passengers but also the pedestrian in case of an unfortunate event. The study and development of a better windshield probably leading to safety is needed. The simulation carried out in this project work ahead deals with a crash impact study of a head onto a laminated windshield. Having the safety in consideration the laminated windshield is used with 1 layer of PVB polymer and 2 layers of glass which sandwiches the layer of PVB. The laminated glass is tested by having the head impact on 5 different position and getting the data from the simulation. The finite element modeling is done with the data for windshield provided from the research paper and the head model provided for the impact. The Finite Element Analysis study will help in validating the experiment carried out in the windshield of the vehicle and hence leading for a development of a better model for the windshield that can be used in the vehicles.

Finite Element Modelling procedure

The windshield needed to work on had the dimensions and the geometry provided so that the experimental and simulation model are having the same structure to work on. The head structure that was used for impact was also provided but since the head structure is the property of the company the dimensions were not disclosed but we had a model to work on. The following figures show the dimensions and the assembly of the head structure and the windshield.

Important things to be taken into consideration are the positions and the angle of impact. These factors are can lead to a better simulation and plot later. The velocity of impact is also affected with this parameters. As the position changes, the influence of the impact is also changes.

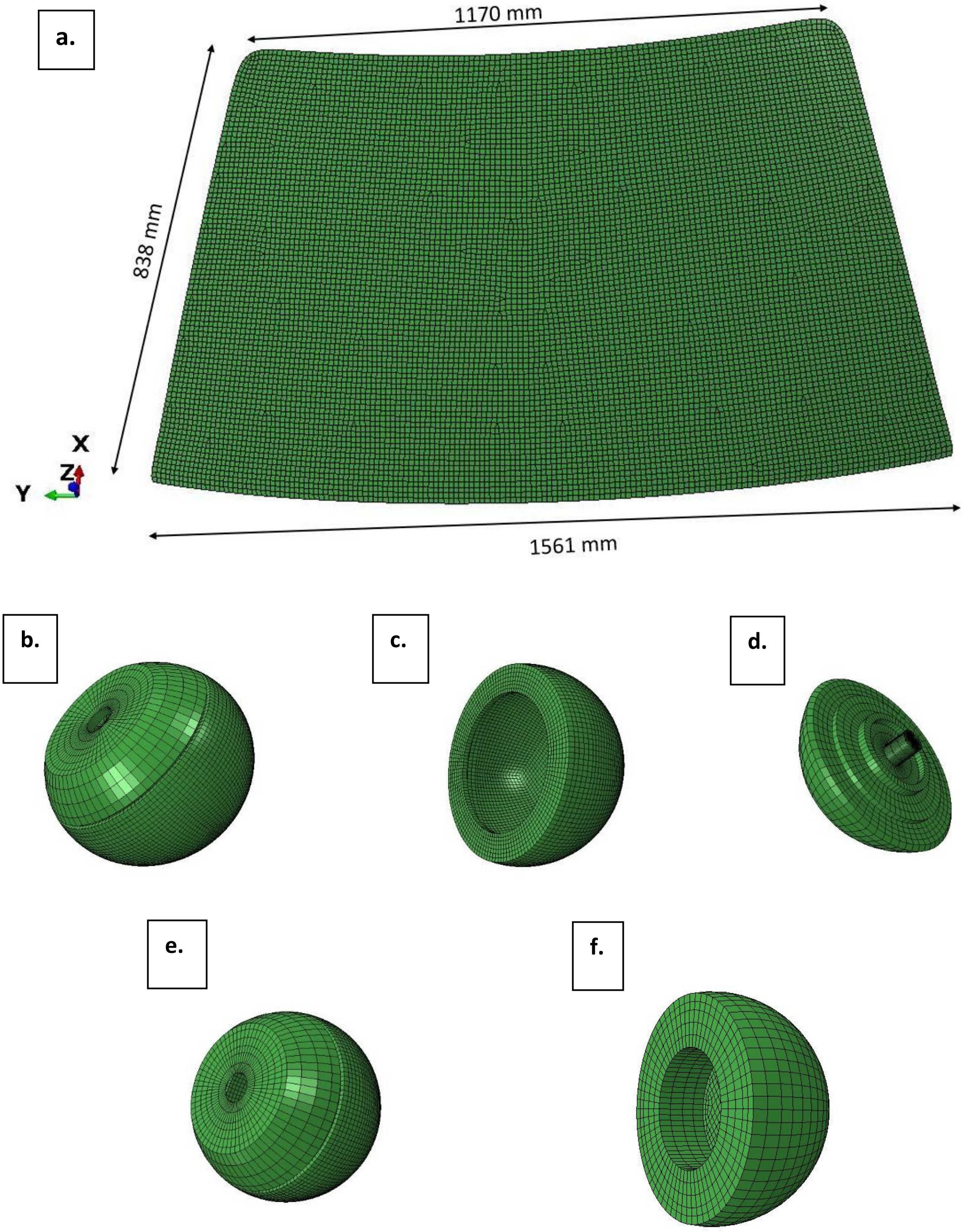


Fig.1. (a) Windshield with the dimensions, (b) Complete head structure used for impact, (c) Skin part of the head, (d) Base part of the head, (e) Skin null part of the head, (f) Sphere part of the head.

Element meshing

Each part of the head and the windshield had the meshing predefined. The mesh used to is 5mm as it is pretty fine and can help us in getting really good simulation results. The head part was split and meshed properly since the contact of the head and the windshield is a crucial part of the FEA modelling.

Materials of the components

The laminated glass is made of 3 ply layers like mentioned earlier. The PVB sandwiched in between the layers of glass. The head has a little different material property. The following table gives the properties of the materials.

Table.1. Material properties

Material	Density (kg/m^3)	Youngs Modulus (MPa)	Poisson's Ratio	Yield Stress (MPa)	Tangential Modulus (MPa)	Plastic Strain	Thickness (mm)
Upper Glass	2500	10000	0.23	110	50000	0.0004	2.55
Lowe Glass	2500	10000	0.23	110	50000	0.0004	2.1
PVB	-	280	0.495	10	20	-	0.76
Base plate and Sphere	2559	70000	0.33	-	-	-	-
Skin null shell	1000	10000	0.3	-	-	-	-

The properties of the skin on the head are a little different than other parts as it is the viscoelastic material.

Density = 1600 kg/m^3, Bulk modulus = 10000 MPa, Shear modulus for short time = 5 MPa,, Shear modulus for long time = 2MPa, Maxwell's decay constant = 0.75.

Section properties

A homogenous material selection was chosen for all the materials. The glass part used a composite conventional layer up was used to get the ply layers in the laminated glass.

Contact conditions

Contact condition through out the model was generalized but as mentioned in the reference paper the friction coefficient for the laminated structure and its layer used was 0.3 for surface to surface contact. The general contact condition was chosen the same as 0.3.

Boundary conditions

As per the requirement like in the experiment the windshield is stationary and the head is projected with a certain velocity on the windshield. Referencing the same the borders of the windshield edges were made fixed and depending the position of the impact the velocities of the head are different. Each velocity is needed to have components in X and Z direction as the direction of impact is 35 degrees from positive X axis. The velocities and the components are summarized in the following table:

Table.2. Velocity at impact with components.

Position	Velocity (m/s)	X-component (m/s)	Z-component (m/s)
I	9.77	8.0031	5.6038
II	9.64	7.8966	5.5293
III	9.64	7.8966	5.5293
IV	9.69	7.9375	5.5579
V	9.66	7.9130	5.5407

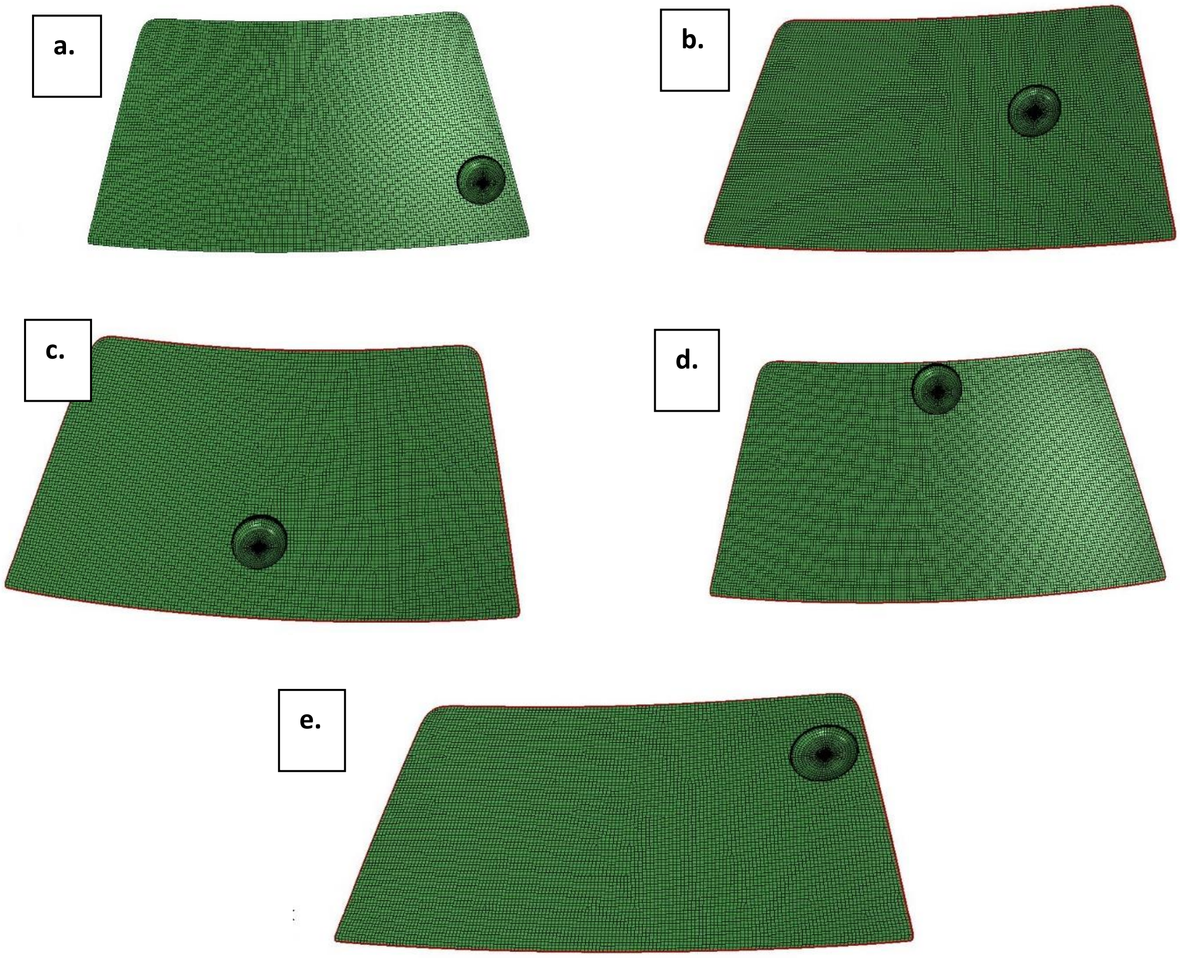
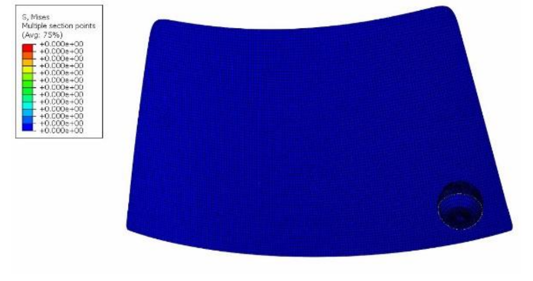
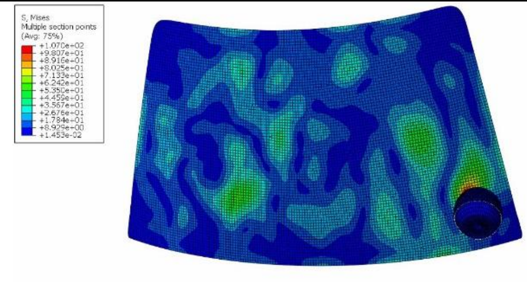


Fig.2. (a) Impact point I, (b) Impact point II, (c) Impact point III, (d) Impact point IV, (e) Impact point V.

Simulation Results

The following table shows the before and after images of the simulation when the head structure hits the windshield. The stress distribution throughout the shield can be clearly visible after impact and from Impact I it is observed how the stress is distributed. Figure.3. shows the Acceleration v/s time plot for the head structure from test results and simulation results.

Table.3. Before and after images on windshield for 5 impact positions.

<table>
<tr><th>Impact</th><th>Before Impact</th><th>After impact</th></tr>
<tr><td>I</td><td>
</td><td>
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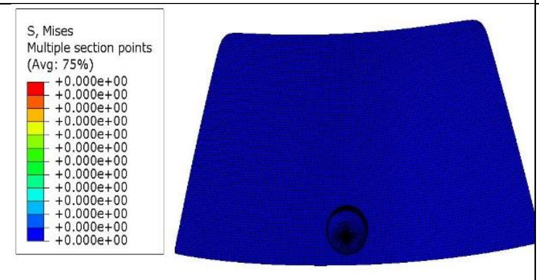
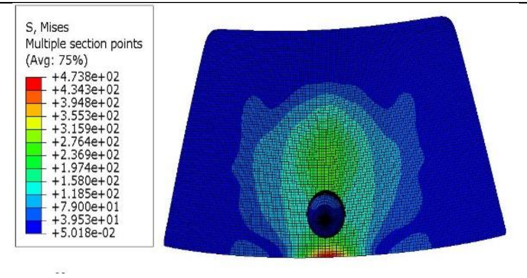
<tr><td>II</td><td>
</td><td>
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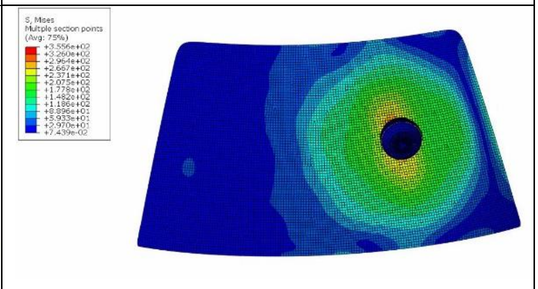
</td><td>
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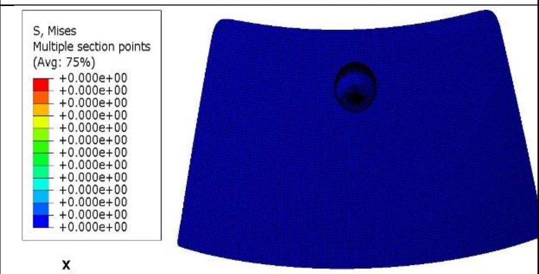
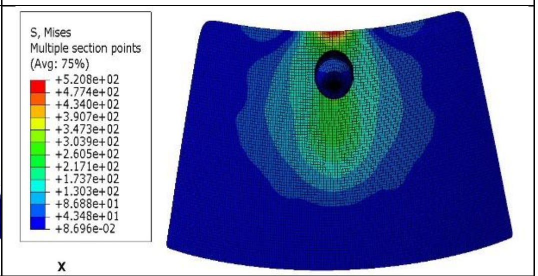
<tr><td>IV</td><td>
</td><td>
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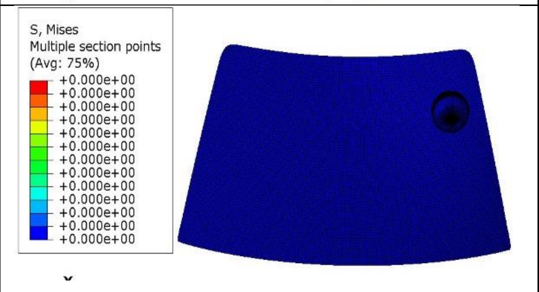
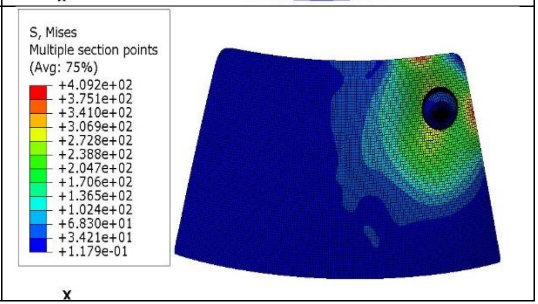
<tr><td>V</td><td>
</td><td>
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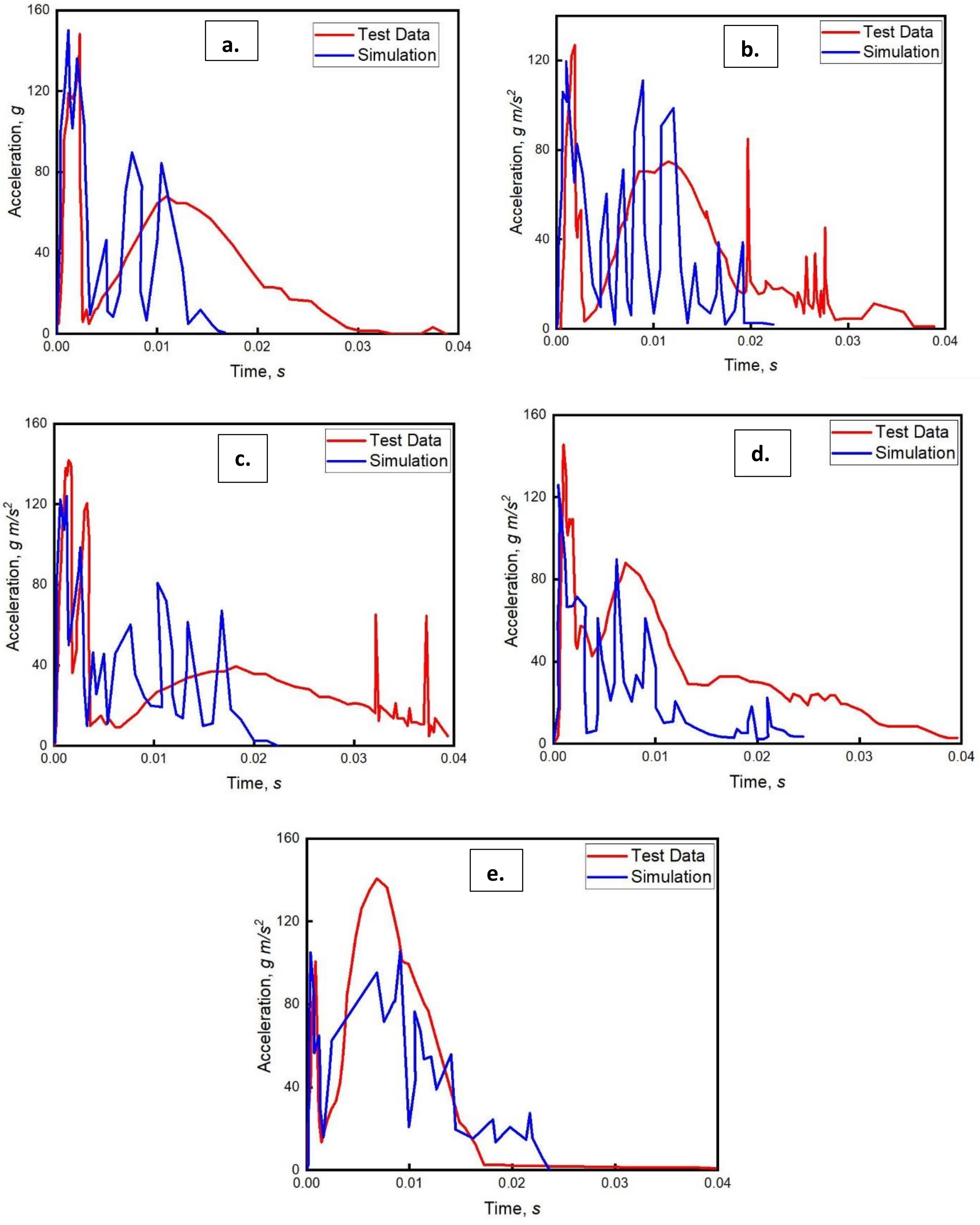

Fig.3. Acceleration vs time comparison of head during impact for (a) Impact point I, (b) Impact point II, (c) Impact point III, (d) Impact point IV, (e) Impact point V.

Discussion

Looking at the Table.3. and Figure 3. we can observe the impact condition after impact is mostly affected neat the edges where the windshield is made fixed. After impact the most stressful area and the most dangerous zone which might lead to failure and shattering is the area at edges. Through out simulation it was observed that even though the head was impacted at particular places it has a significant stress distribution through out the windshield. I was seen that head impact sends a wave which leads to tension and compression of the windshield through out its surface.

Comparing the plots for acceleration vs time for test and simulation we can observe that initially the simulation plot the acceleration is very well aligned with the test plot, but later it shows very uneven curves and peaks and also the plot tends to ends pretty early in simulation than the test plot. All the simulation plots do end at around time of 0.02s. This implies the head structure is tracing the right path before it has the impact on the windshield and later it reduces as it tends to decelerate. Due to the laminated glass windshield, it bounces back the head structure hence gaining the peak again. The approximate distancing of the head and the windshield, along with the pinpoint positioning of the impact zone also play an important role in getting the desired output of the simulation. Also since comparison and modelling is mostly done in LS-Dyna in the reference papers, the transfer of the data from LS-Dyna to ABAQUS for simulation purposes may differ especially in the head properties region. These factors lead to variation in the plots of the simulation as they get compared with the plots from the test data.

The overall simulation shows even with the failure criteria in the model the glass of the windshield or the head structure did not get cracked or failed under the impact. This shows that the in case of an unfortunate impact accident pedestrian’s head is safe and the passengers are also safe from getting hurt as the glass does not shatter. Surely there can be a better results and experimental work done on each and all aspect of the impact test which may lead to a far more better manufacturing of the windshield to minimise the damage that is still occuring

References

[1] Yu, Guizhen, et al. "Computation modeling of laminated crack glass windshields subjected to headform impact." *Computers & Structures* 193 (2017): 139-154.

[2] Zhang, Xihong, et al. "The mechanical properties of Polyvinyl Butyral (PVB) at high strain rates." *Construction and building materials* 93 (2015): 404-415.