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Utilizing a Validated Laminated Glass Model to Simulate Pedestrian Head Impact on a Windshield

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Introduction

Agenda

- Laminated safety glass (LSG) and its components
- Testing requirements
- Material model build-up and inputs
- Windshield set-up
- Results
- Conclusions

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Introduction

Laminated Safety Glass

- Composite material
- Durable and visually permeable properties of glass
- Benefits of a ductile viscoelastic polymer

Introduction

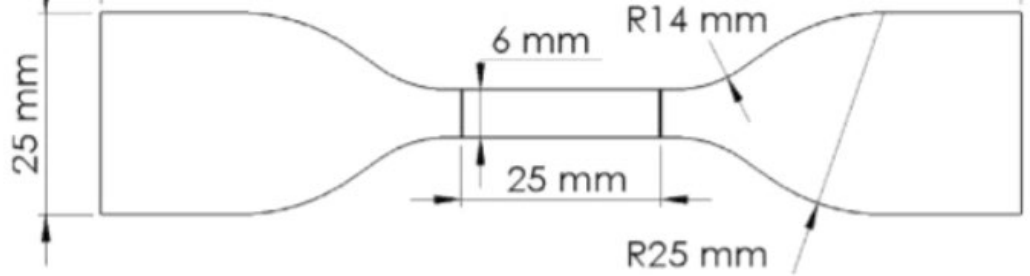
Laminated Glass

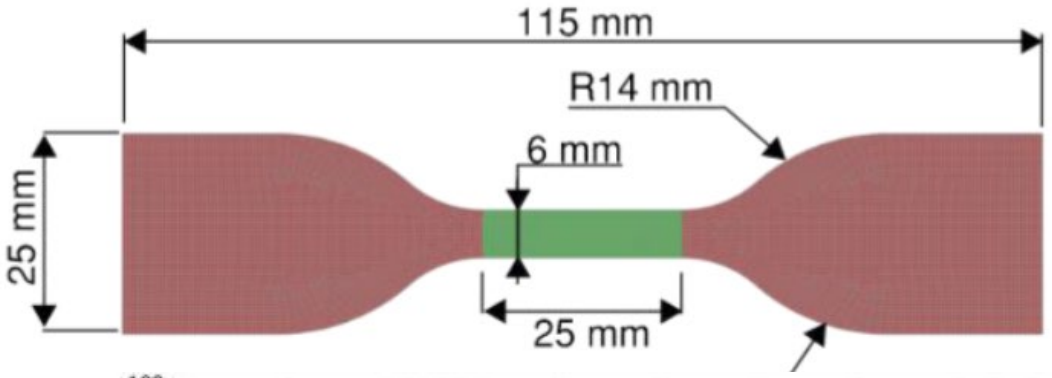
- The two primary components of LSG, glass and PVB, possess complex mechanical characteristics.
- When combined to form a composite material, such as LSG, these characteristics result in a non-linear material.

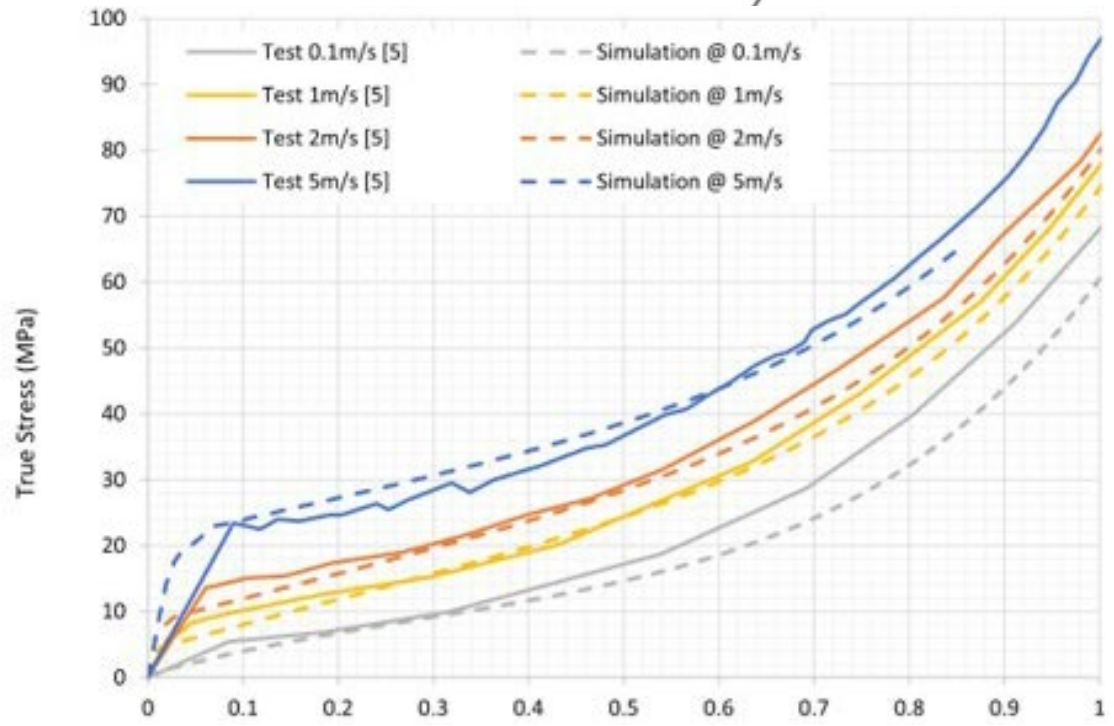
Introduction

Polyvinyl Butyral

- PVB is non-linear (hyperelastic) in material response and highly dependent on a range of factors including temperature, humidity, strain-rate, thickness, and ultraviolet light (UV) exposure.
- An appropriate material model must therefore accommodate a range of material factors in an attempt to capture the potential range of response







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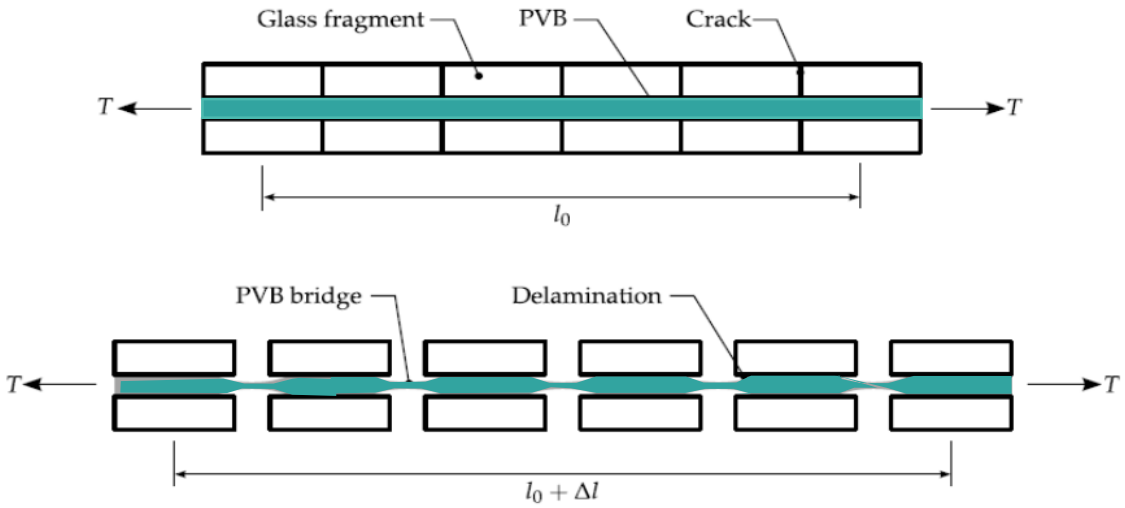
Adhesion

- Post-fracture response - larger deflections are the result of progressive delamination between glass and the interlayer.
- Owing to this, literature suggests adhesion could influence the properties of LSG



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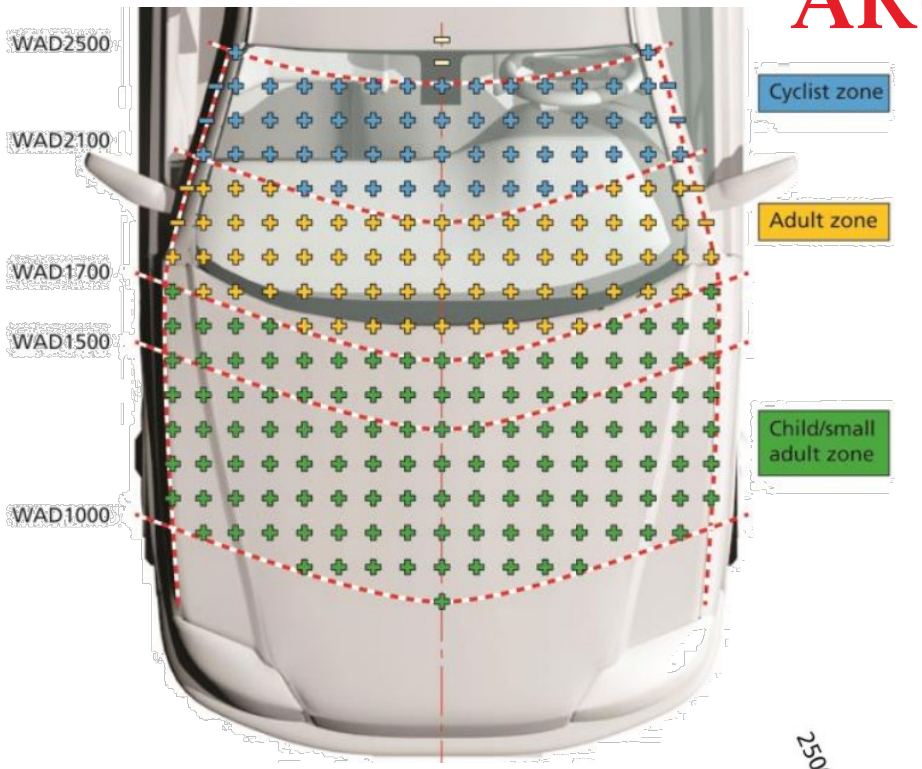
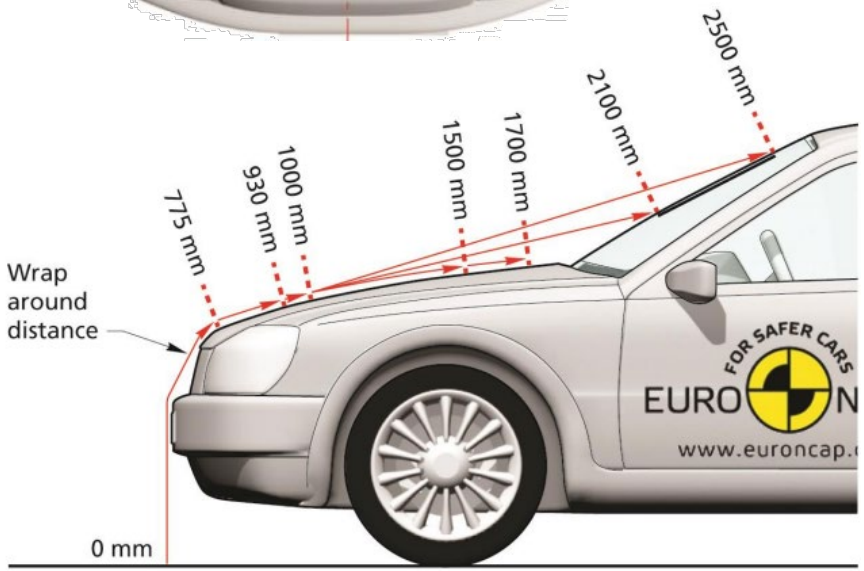
Testing Requirements

- Historically, pedestrian head impact primarily concerned with body panels.
- R127 has adopted a new windshield test zone
- Euro NCAP requires full analysis/testing
- Growing need for robust and accurate glass models, capable of reproducing physical testing.





Euro NCAP Vulnerable Road User Testing Protocol v 9.1

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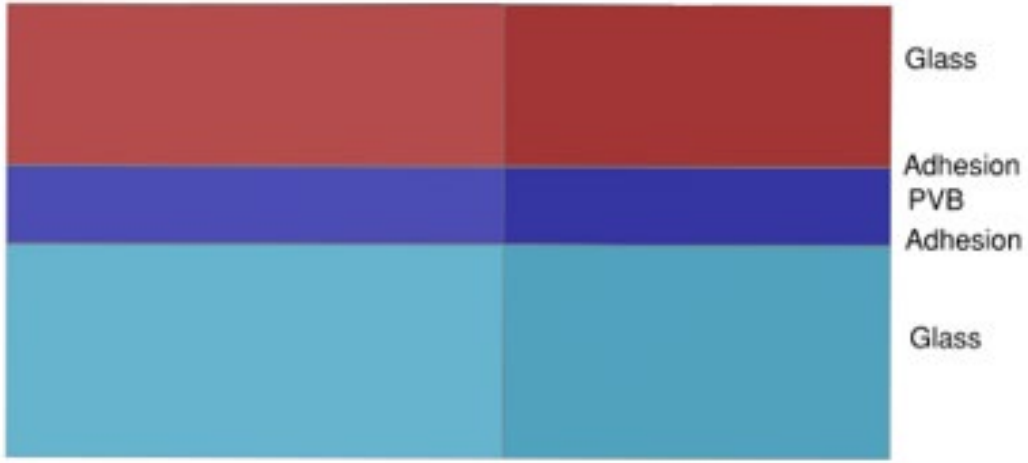
Material Model

Build-Up

- PVB represented by MAT_HYPERELASTIC_RUBBER solid elements.
- Cohesive elements represented by zero length solid elements using MAT_COHESIVE_GENERAL.
- Glass modelled with thick shells using MAT_GLASS.



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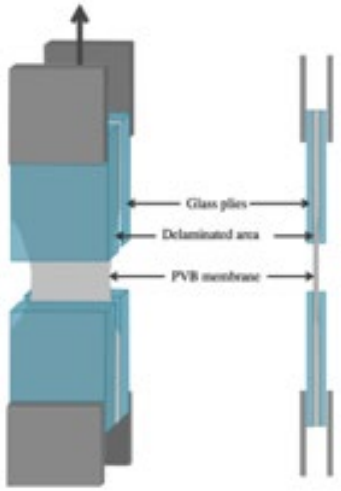
Material Model

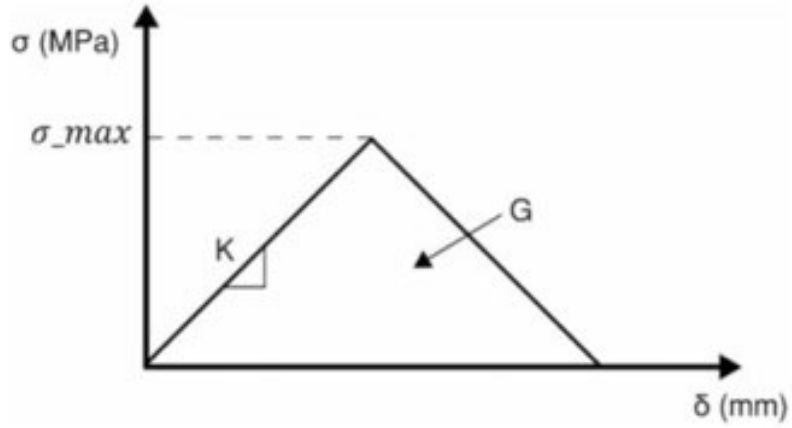
Input Parameters

- The PVB uses six-term polynomial to fit the hyper-elastic part of material
- The cohesive elements are represented with a traction separation curve
- Adhesion and behaviour validated using through cracked tensile test

Summary of the materials employed in FEA models for the Through Cracked Tensile Test.

Material	Model Type	Material model
Glass	Linear Elastic	MAT_1 ELASTIC
PVB	Hyperelastic with Viscoelastic Constants with a 6 term Prony series	MAT_77H HYPERELASTIC RUBBER
Cohesive Elements	Bi-Linear Traction Separation	MAT_186 COHESIVE_GENERAL





Parameter	*Input*
σmax	*1.8 MPa*
G	*3000 J/m²*
K	*5.4E+09*

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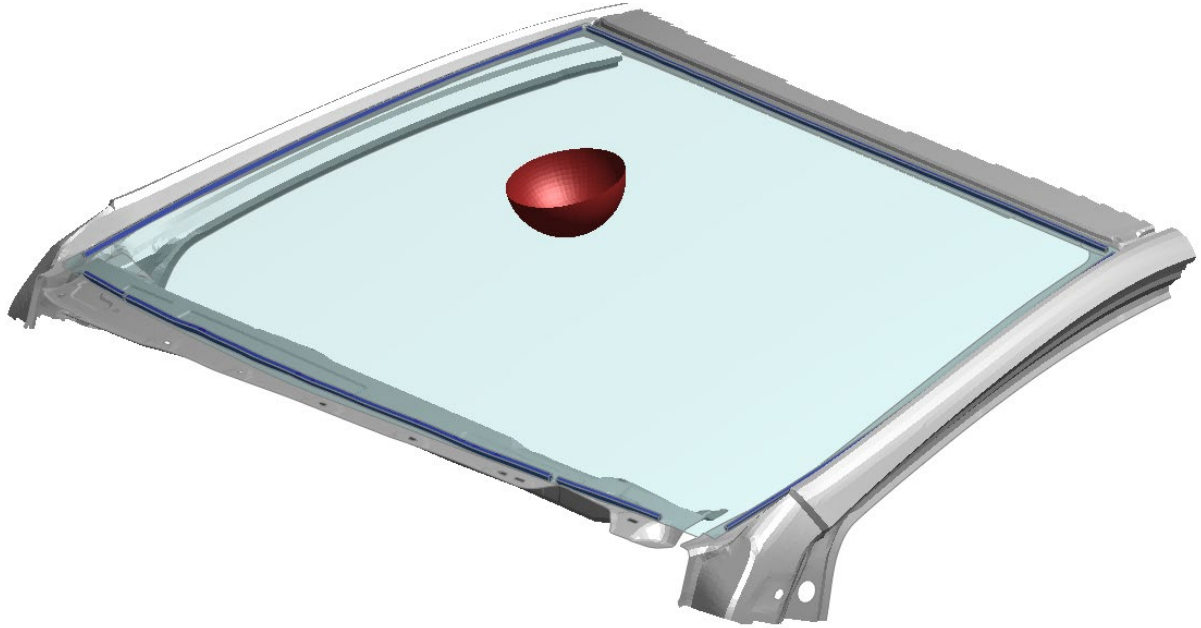
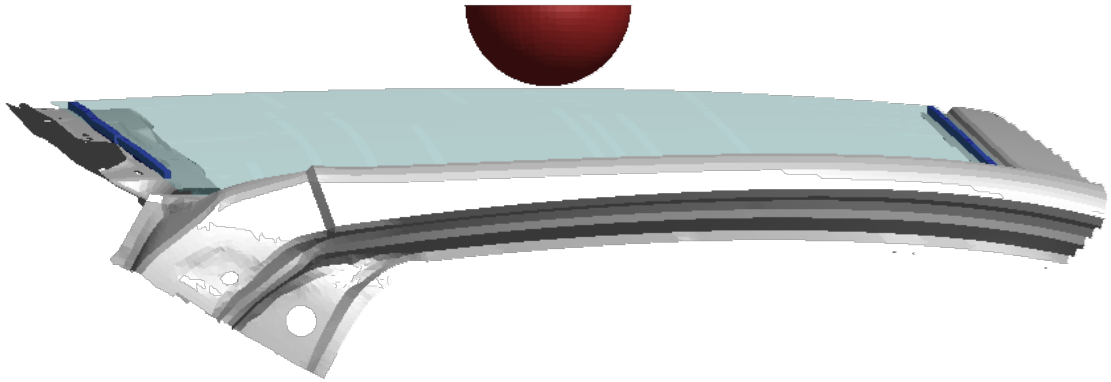
Windshield Set-Up

Model Overview

- Head form is modelled with MAT_RIGID shell elements
- Initial velocity and weight of the head form selected to meet required impact energy as per Euro NCAP
- The windshield is connected to the vehicle frame with an adhesive using MAT_PLASTIC_KINEMATIC





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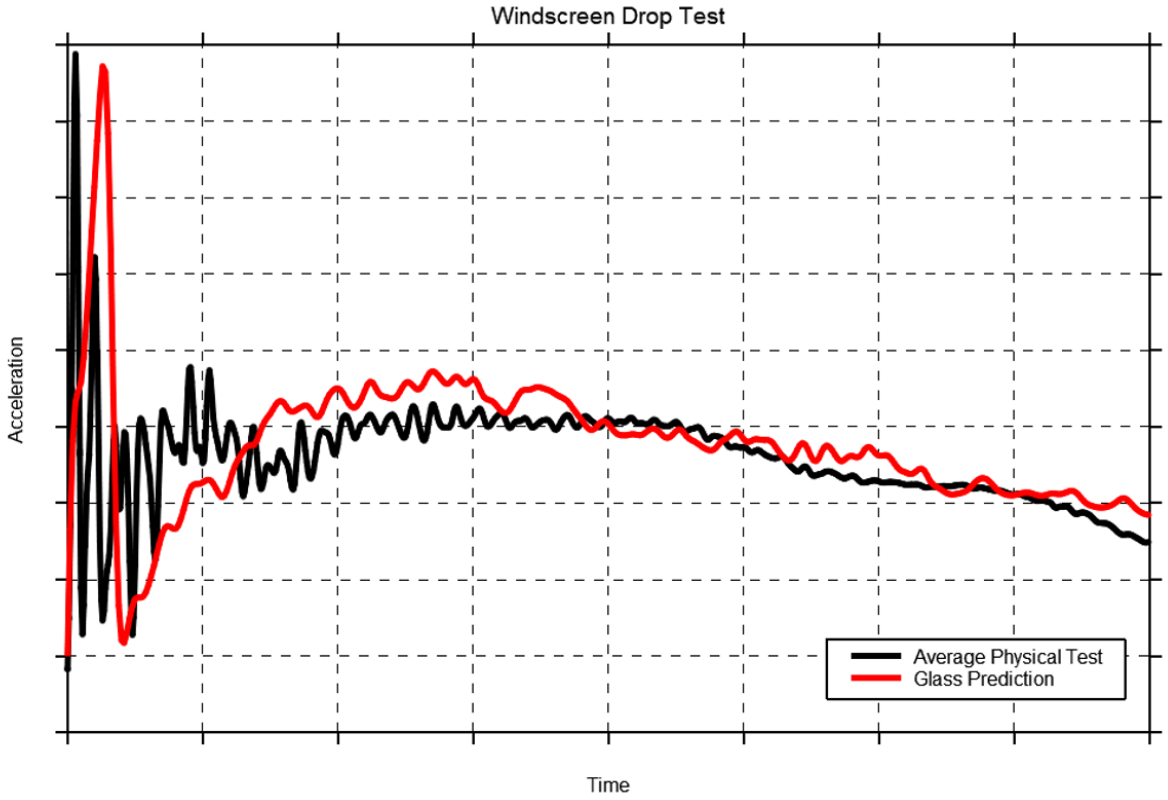
Results

Initial Correlation

- Correlation exercise to tailor inputs for windshield impact
- Initial results indicated less of a membrane effect
- Required reduction in stiffness in strength softness



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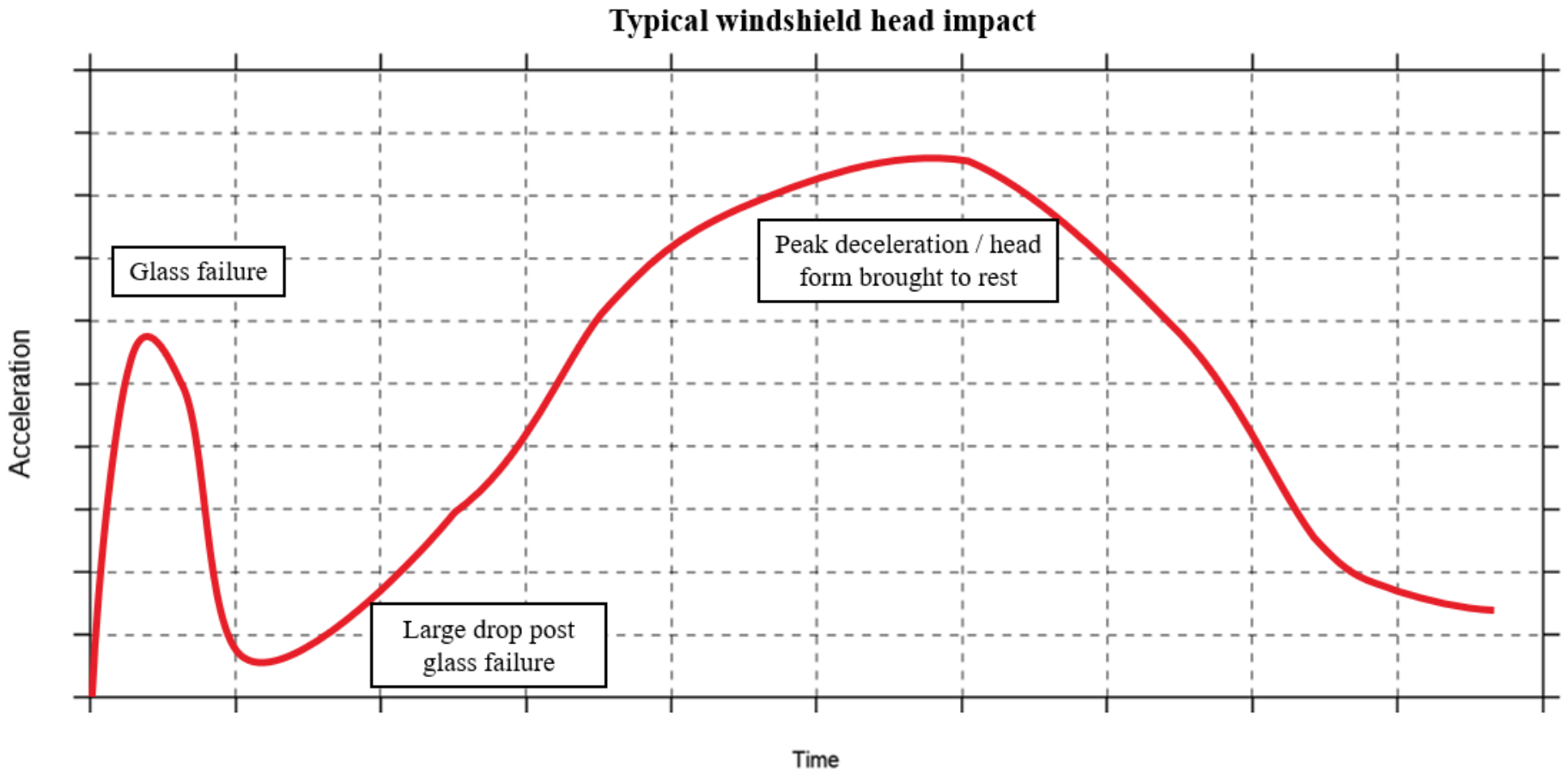
Results

Full Vehicle & Deformable Head Testing – Typical



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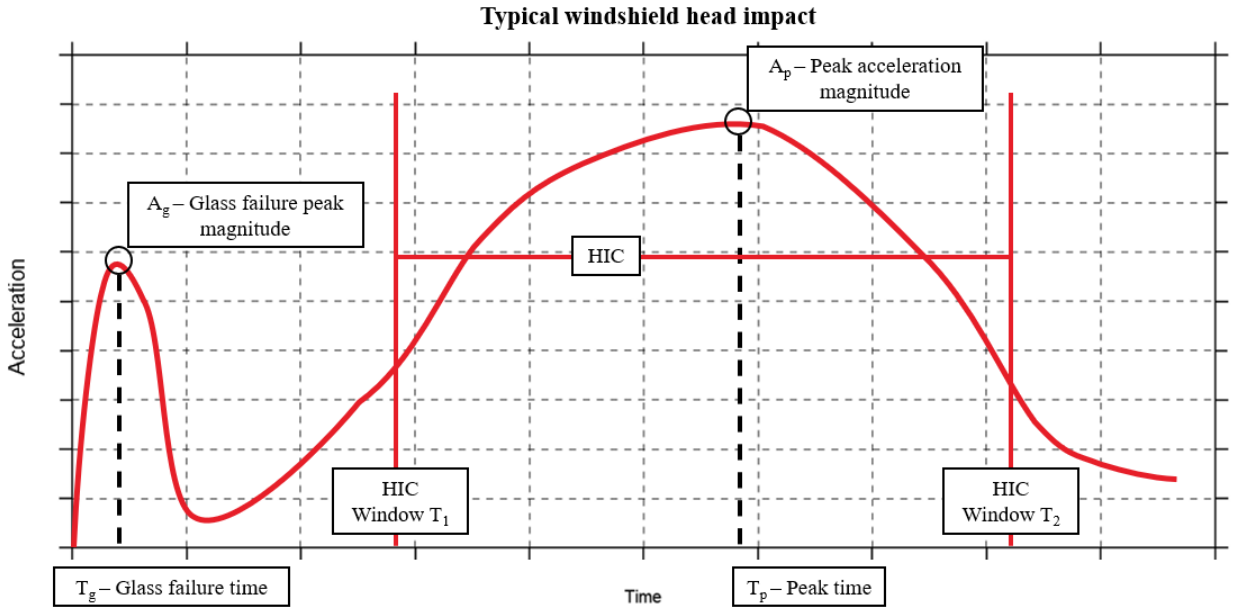
Results

Full Vehicle & Deformable Head Testing - Comparison

- Series of tests ran considering different windshield locations and test speeds
- Model predictions of HIC, HIC timing, peak acceleration and peak acceleration timing within 10% of tests



	Average % Difference	Standard Deviation
A_g	-2%	21%
A_p	-3%	1%
T_g	36%	45%
T_p	-1%	3%
HIC	1%	4%
T_1	-8%	6%
T_2	4%	2%

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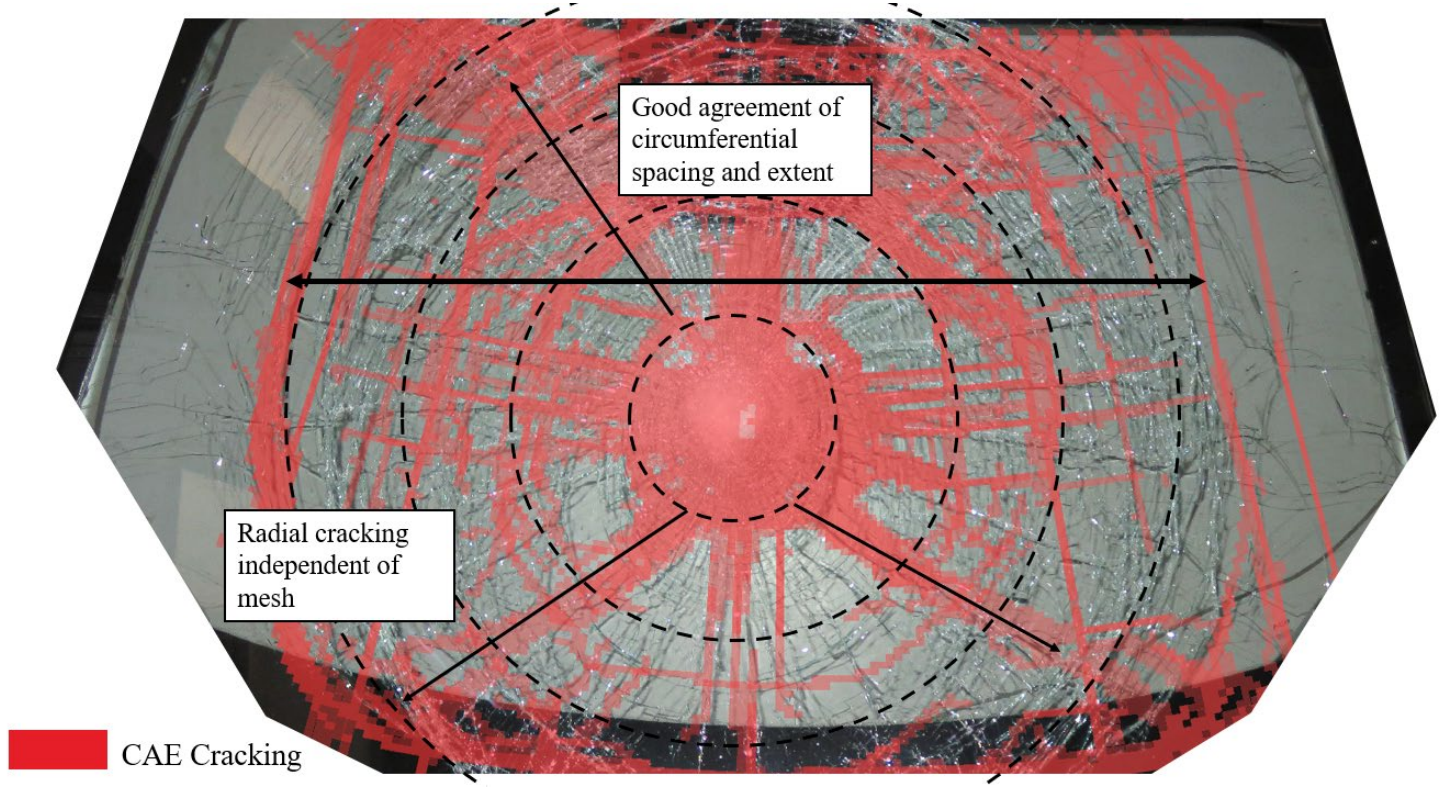
Results

Crack Pattern Comparison

- Good agreement in circumferential spacing and extent of cracking
- Radial cracking observed independent of mesh
- Crack pattern could be improved using a cobweb mesh



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Conclusions

Crack Pattern Comparison

- Validated laminated glass model to predict pedestrian head impact in accordance with R127 and Euro NCAP
- Good agreement with acceleration time history graphs and can predict HIC within 10%
- Model shows reasonable correlation with crack patterns observed in tests
- Further improvements can be made to improve cracking observed

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