Validation and model development for a laminated safety glass

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Content

Canoo's mission is to bring EVs to Everyone.

Canoo has teams in Arkansas, Oklahoma, Texas, Michigan & California

Canoo Delivers Crew Transportation Vehicles To Nasa For Artemis Missions

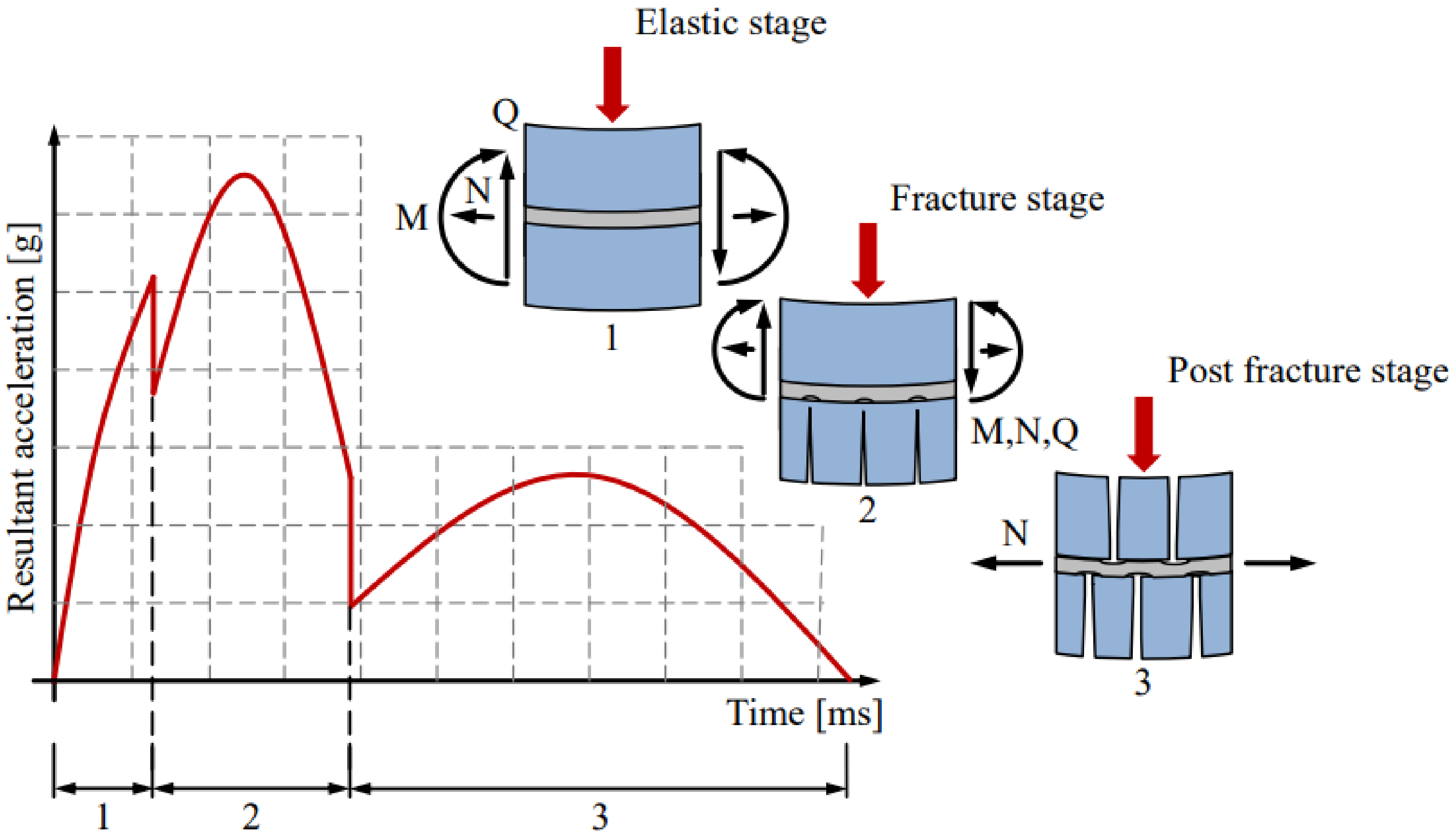
Introduction

- Head impact test on windshields area an inherent part of Euro NCAP, JNCAP KNCAO and potential further implementation for US NCAP.

- As Canoo vehicles shows an architecture with significant windshields is important to develop CAE material capabilities to assure safety related requirements even before physical test.

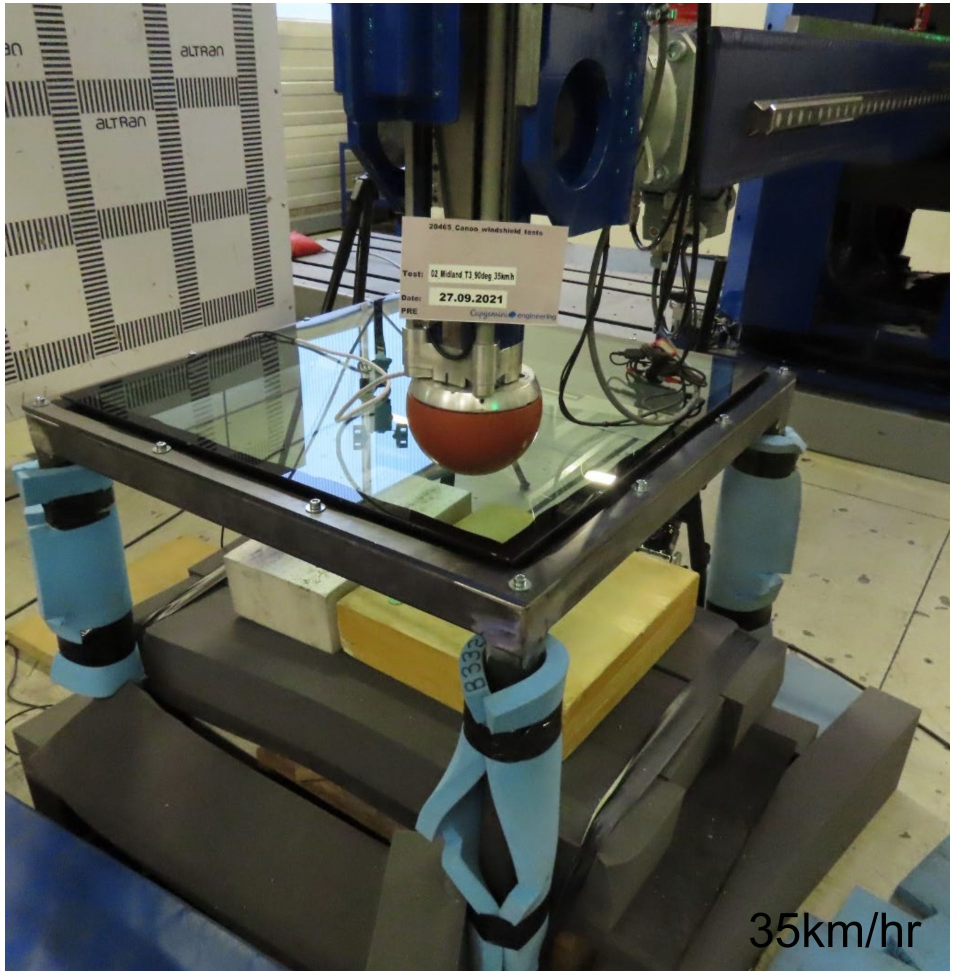
Challenge

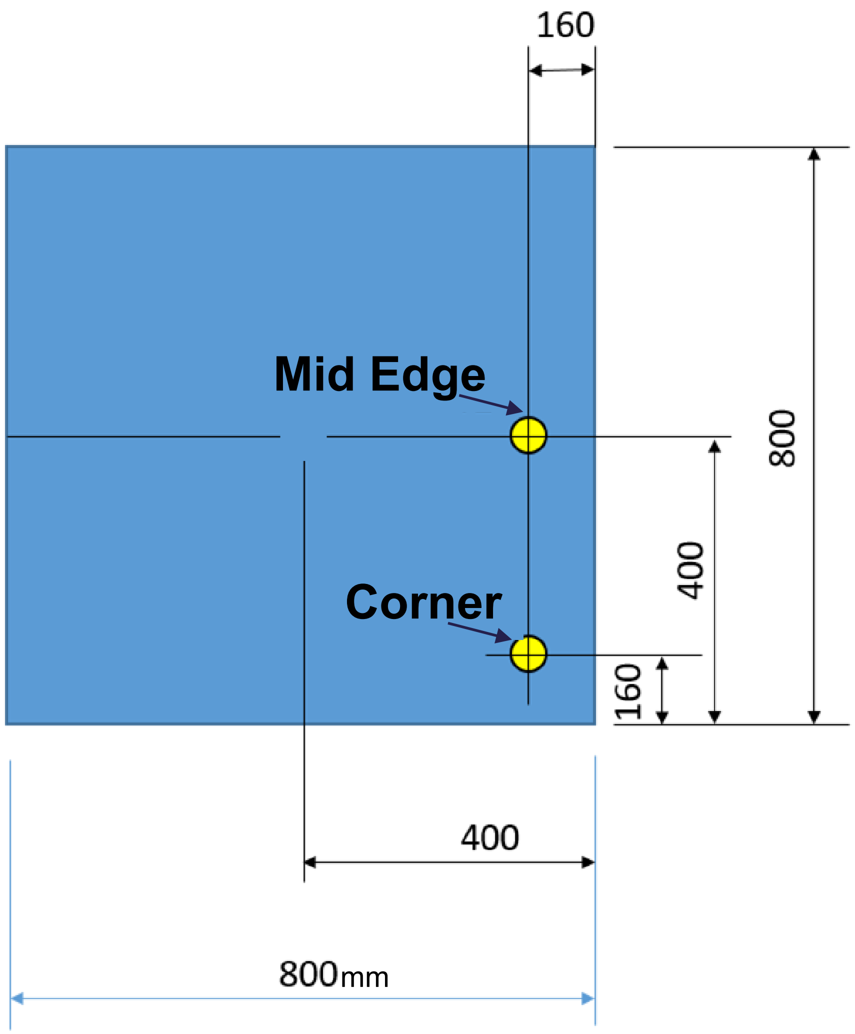
- The glass fracture process during the impact is very complex. The process of laminated glass at 35km/hr with pedestrian protection impactor may be divided into different stages, which can be summarized as follow:



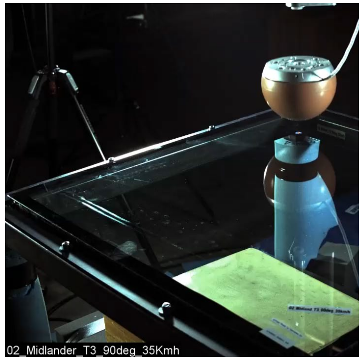
Physical test

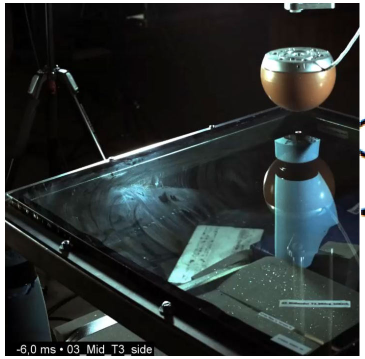
Validation, physical test setup:

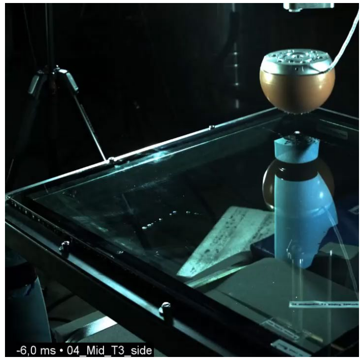


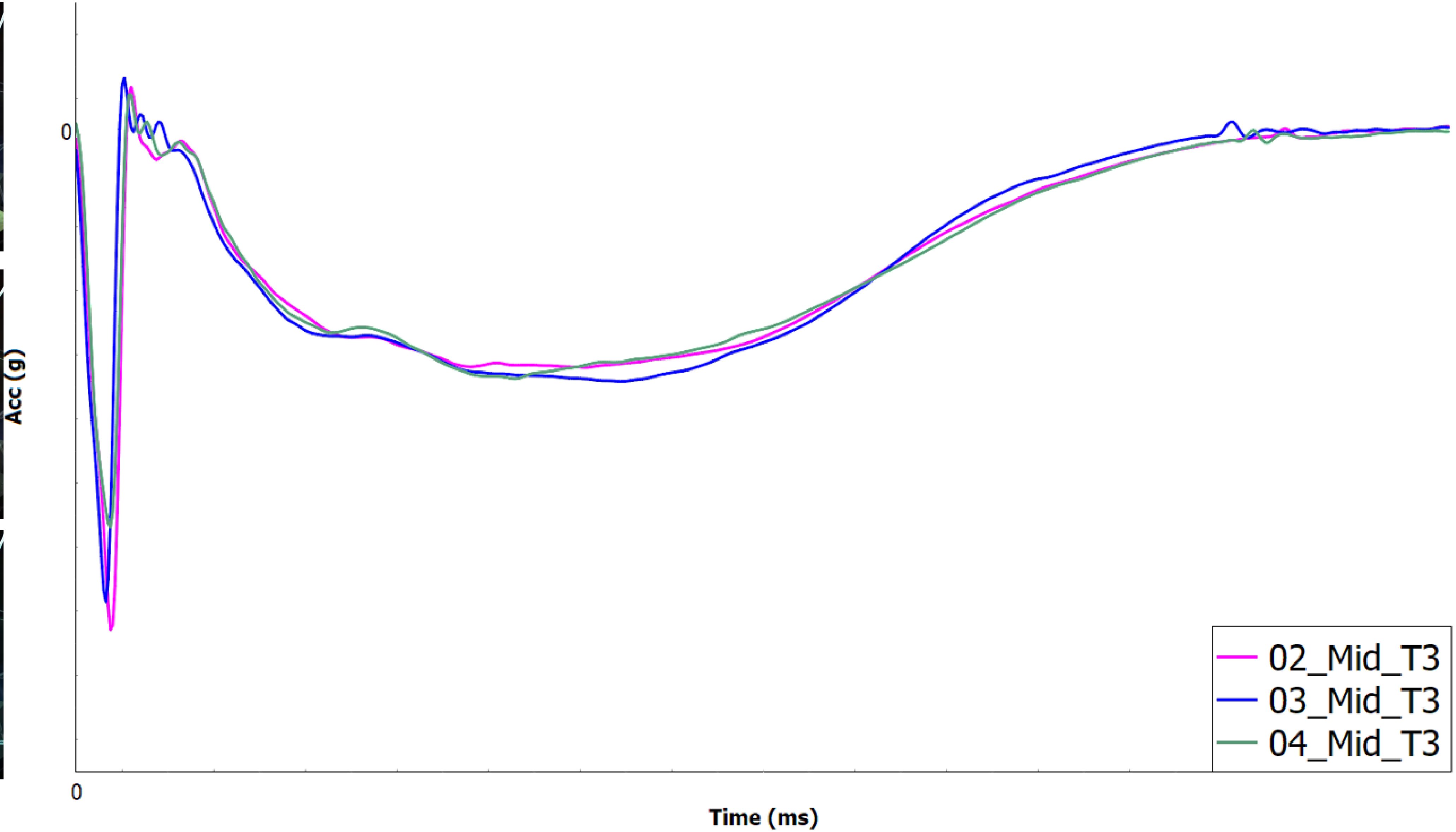


Acceleration curve – Corner Position

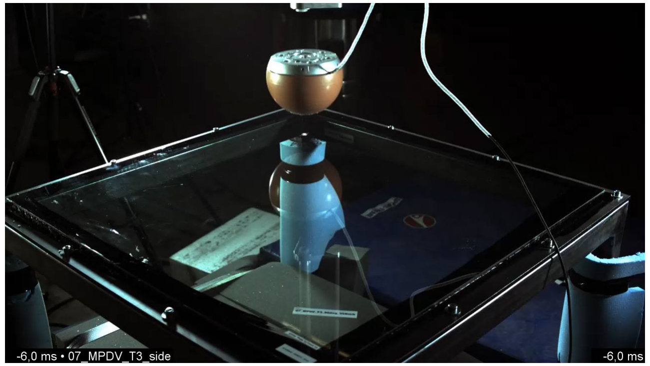


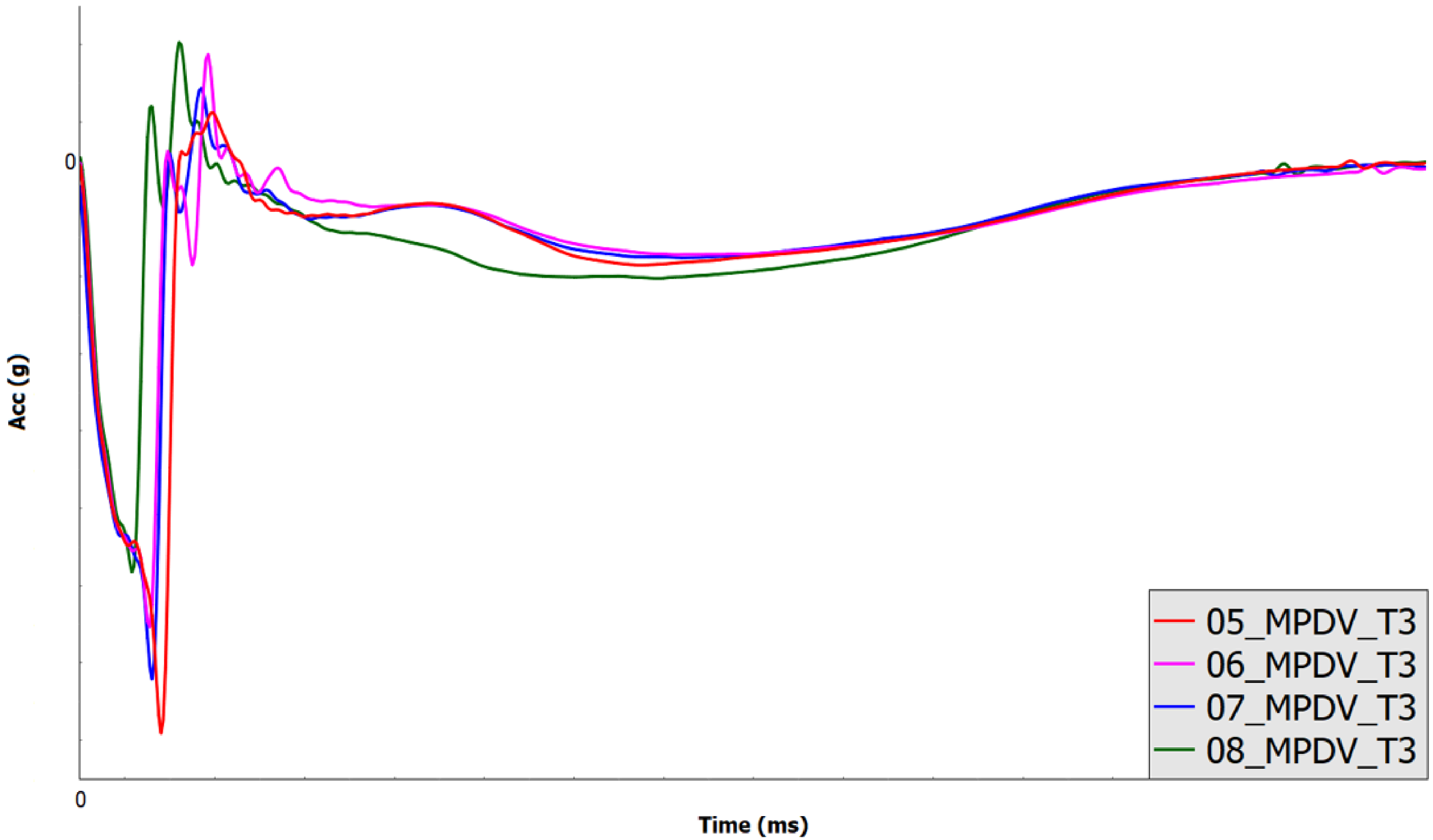






Acceleration curve – Mid Edge Position

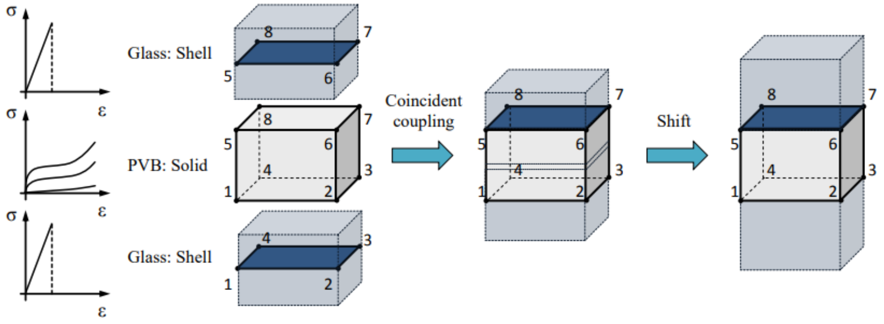


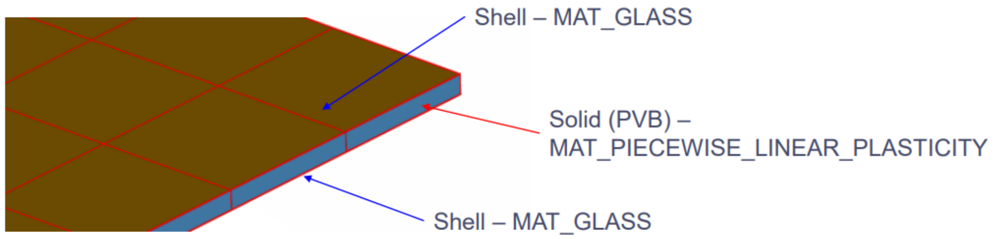


Simulation

FE – Model of windshield

- • The FE – model of windshield is modelled using 3 layers - SHELL – SOLID – SHELL (Outer glass – PVB – Inner glass)
- Target element length is 6mm (min 4mm, max 8mm)
- The mesh is combination of quads and trias, with priority on quads (trias below 0.1%)
- Final thickness of all layers is identical to CAD – 2.1, 0.76, 1.6 = 4.46mm
- NLOC Parameter is active to offset shell's thickness proper direction
- OPTT Parameter is active • The material cards were validated for LS-Dyna R11.1

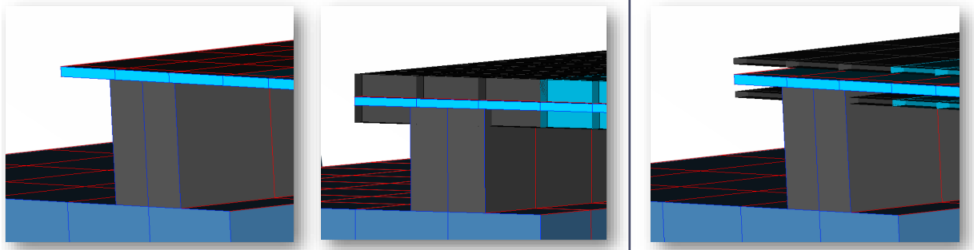




Default view

Draw shells as solid view, (for thickness calculation)

Draw shells as solid view, OPTT (for contact calculation)



FE – Model of windshield – Shell layers and solid elements:

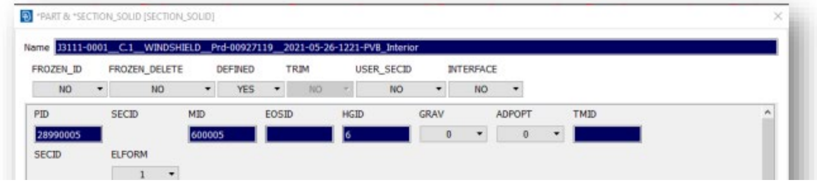
Outer shell

HGID: 8
T1: 2.1 (real thickness)
ELFORM: 2
SHRF: 0.8333
NIP: 1
NLOC 1
OPTT: 0.5

Inner shell

HGID: 8
T1: 1.6 (real thickness)
ELFORM: 2
SHRF: 0.8333
NIP: 1
NLOC -1
OPTT: 0.5

Solid bricks



HGID: 6
T1: -
ELFORM: 1
SHRF: -

Materials – Inner and outer glass layers

Validated for headform impacts close to edge of the glass

MAT_GLASS

1 Material card for both glass layers

Units - ton / mm / s

```
$================================================================================
$
$ Windshield GLASS - For headform impacts close to edge of the glass
$
$================================================================================
*MAT_GLASS_TITLE
Windshield_Glass
$      mid        ro         e        pr                                imod      ilaw
 100010027 2.5000E-9     70000      0.22                                           1.0
$     FMOD        FT        FC        AT        BT        AC        BC     FTSCL
       1.0      30.0     240.0                                                   5
$    SFSTI     SFSTR      CRIN     ECRCL     NCYCR      NIPF
     0.001     0.010       0.0     0.002         1         1
$    EPSCR    ENGCRT    RADCRT    RATENL    RFILTF
$EDGE

$
```

Materials – Edges of inner and outer glass layers – without rupture

Validated for headform impacts close to edge of the glass

MAT_GLASS

1 Material card for both glass layers

For the area 20mm from the free edge of the glass – **w/o rupture**

Units - ton / mm / s

```
$================================================================================
$
$ Windshield GLASS - WITHOUT RUPTURE
$
$================================================================================
*MAT_GLASS_TITLE
Windshield_Glass - without rupture
$      mid        ro         e        pr                            imod      ilaw
 100010028 2.5000E-9   70000.0      0.22
$     FMOD        FT        FC        AT        BT        AC        BC     FTSCL

$    SFSTI     SFSTR      CRIN     ECRCL     NCYCR      NIPF

$    EPSCR    ENGCRT    RADCRT    RATENL    RFILTF
$

$
```

Materials – PVB layer

- Validated for headform impacts close to edge of the glass

MAT_PIECEWISE_LINEAR_PLASTICITY

Units - ton / mm / s

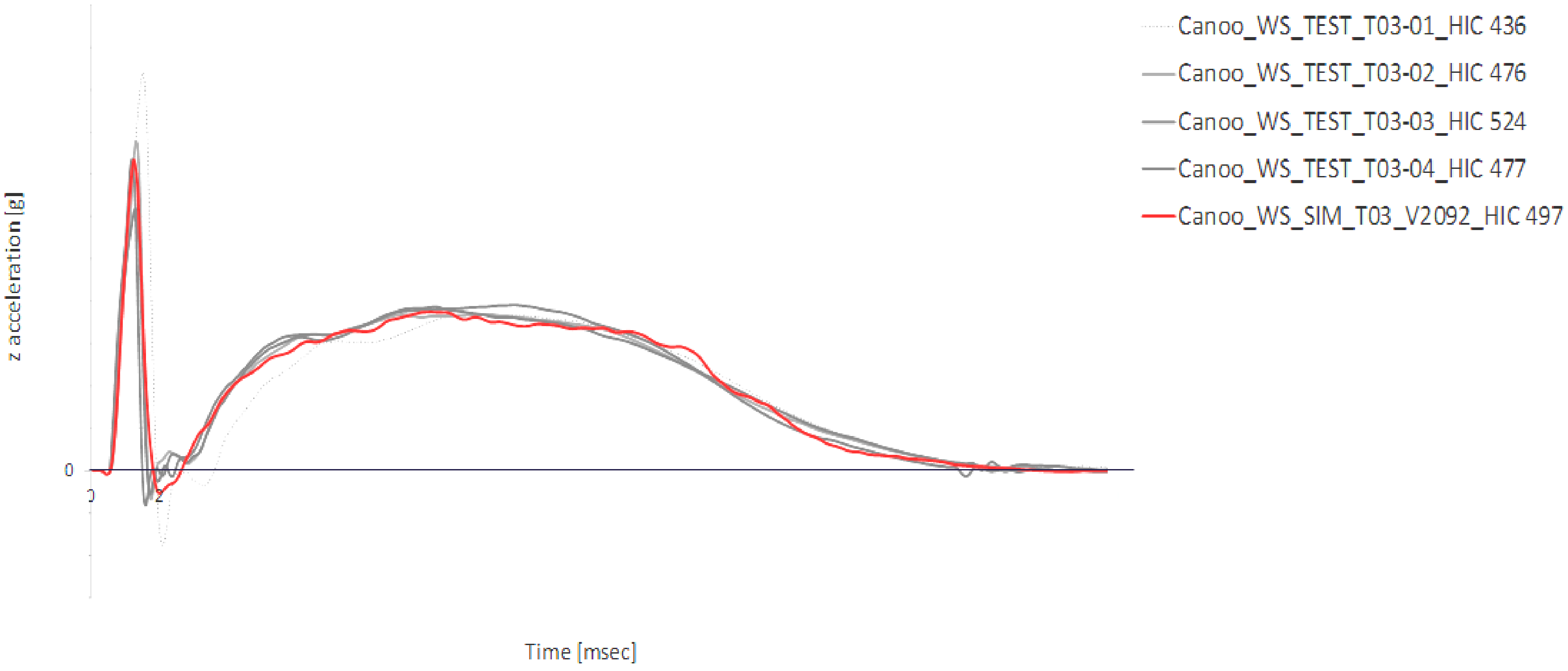
```
*MAT_PIECEWISE_LINEAR_PLASTICITY_TITLE
Windshield_PVB_Foil
$      MID        RO         E        PR      SIGY      ETAN      FAIL      TDEL
    600005  1.213E-9      2000      0.31        25        0.                  0.
$        C         P      LCSS      LCSR        VP
        0.        0.         0         0        0.
$     EPS1      EPS2      EPS3      EPS4      EPS5      EPS6      EPS7      EPS8

$      ES1       ES2       ES3       ES4       ES5       ES6       ES7       ES8

$
```

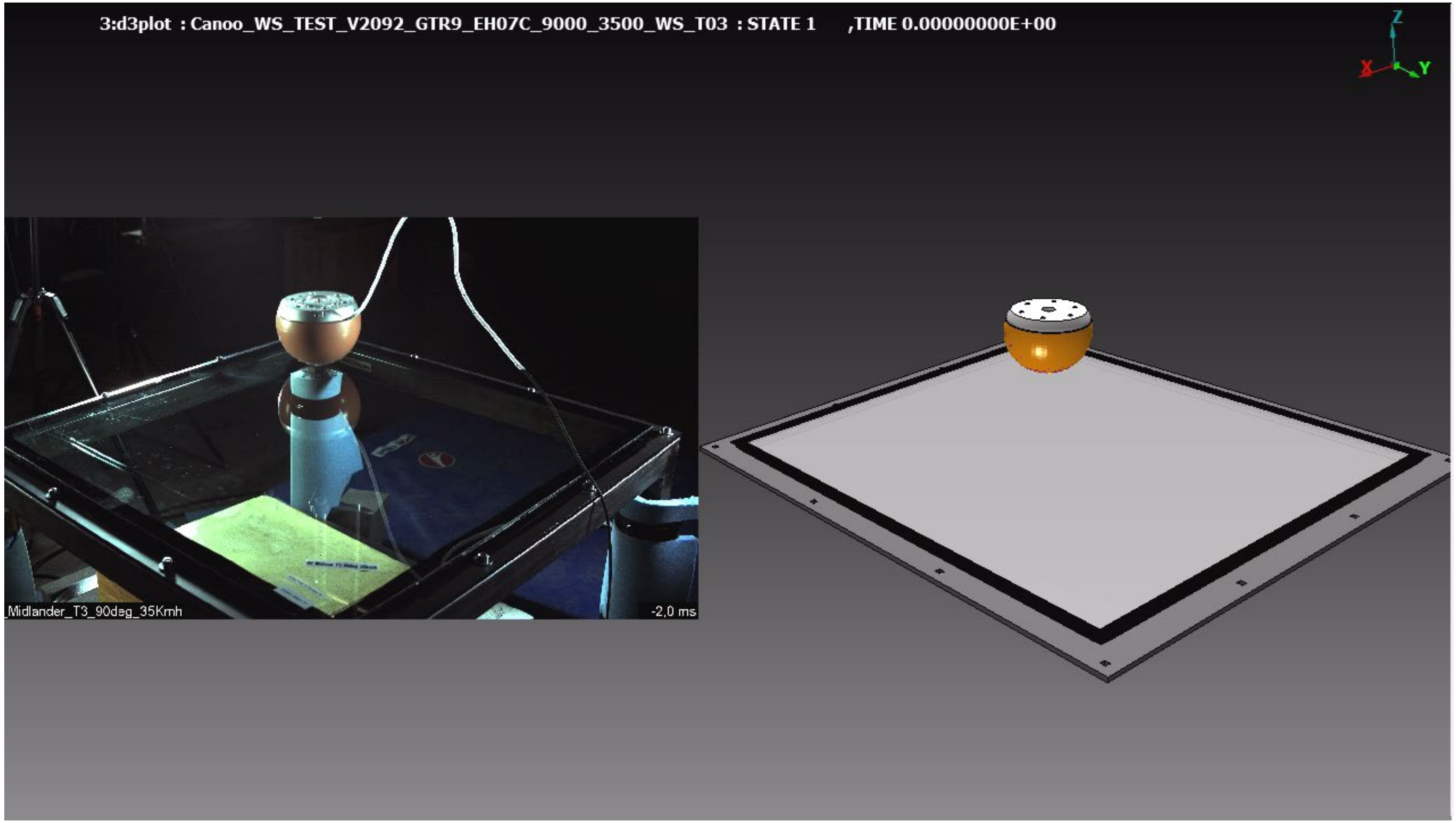
Correlation between test and CAE

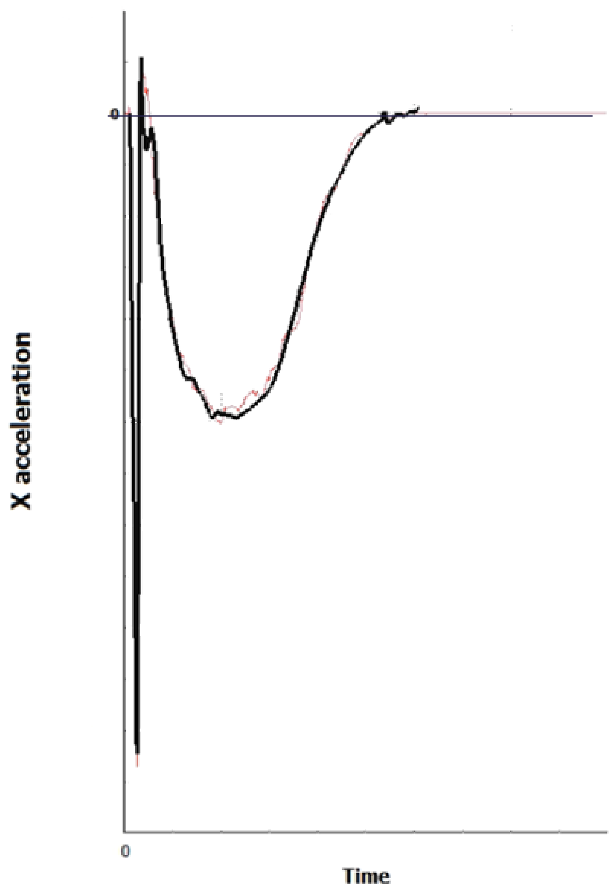
Acceleration correlation curve – Corner Position



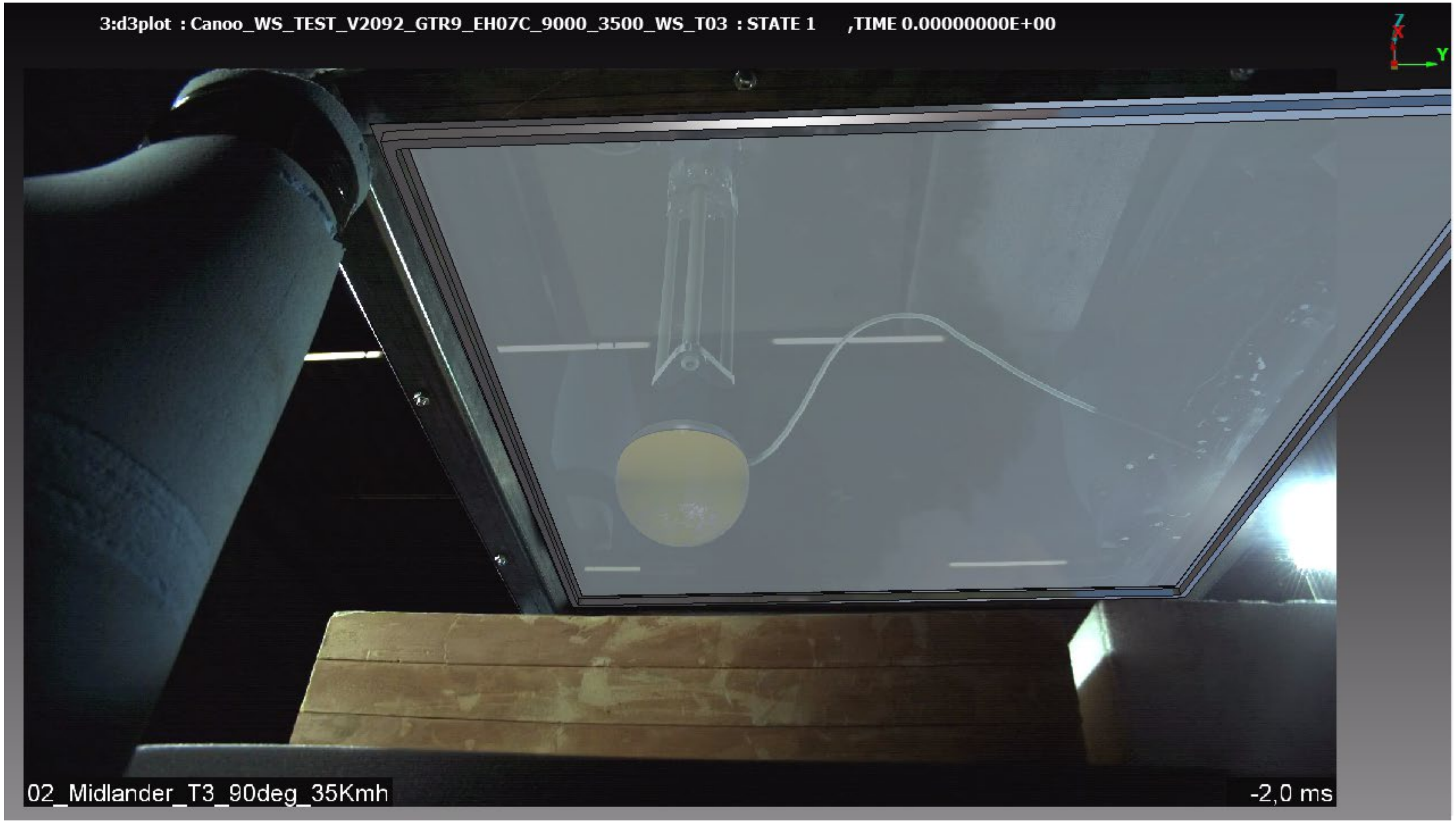
Simulation HIC	497	Simulation HIC-Interval	4.0 – 18.8
Test HIC (avg)	478	Test HIC-Interval (avg)	4.2 – 19.0
Test HIC (max)	524	Test HIC-Interval (max)	4.0 – 18.6
Test HIC (min)	436	Test HIC-Interval (min)	4.6 – 19.4

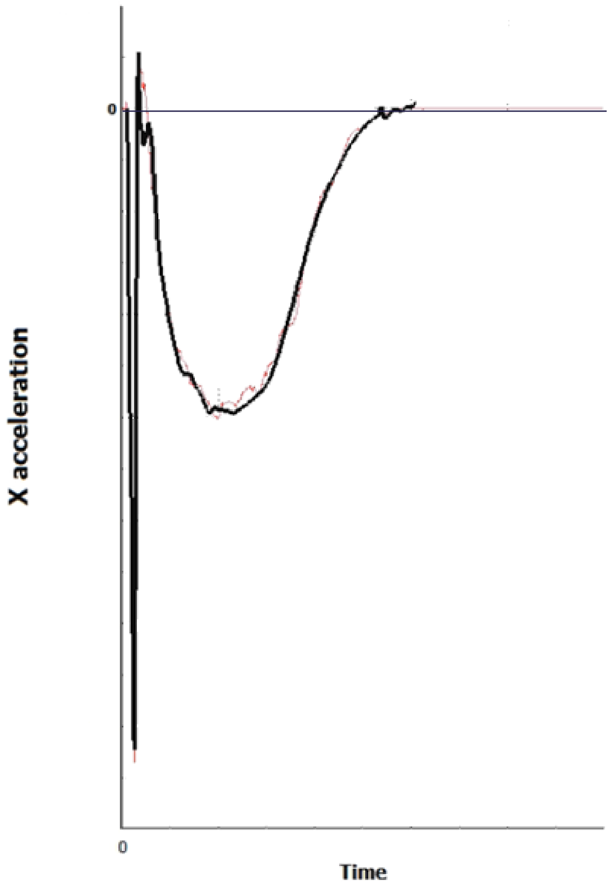
Visual comparison – Corner Position:





Visual comparison – Corner T3:



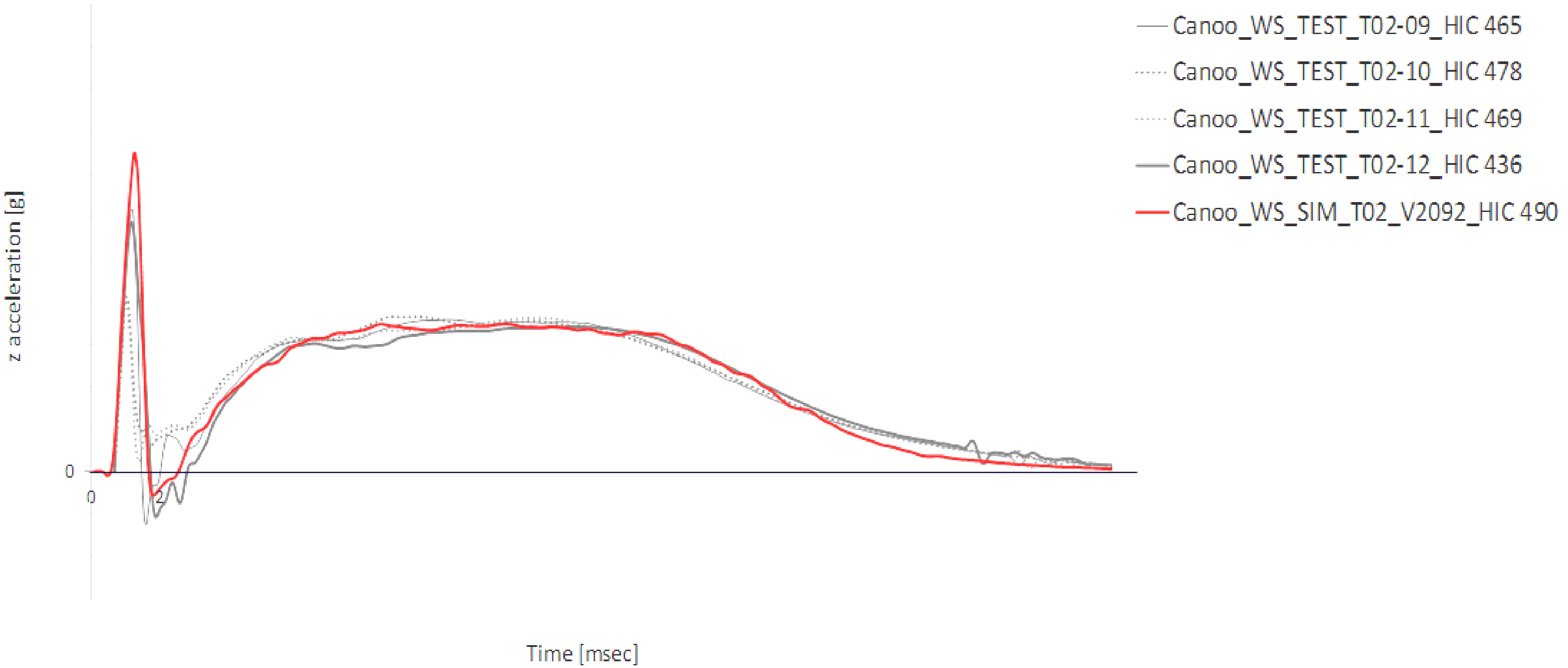


C A N O O

Fracture pattern. Corner Position

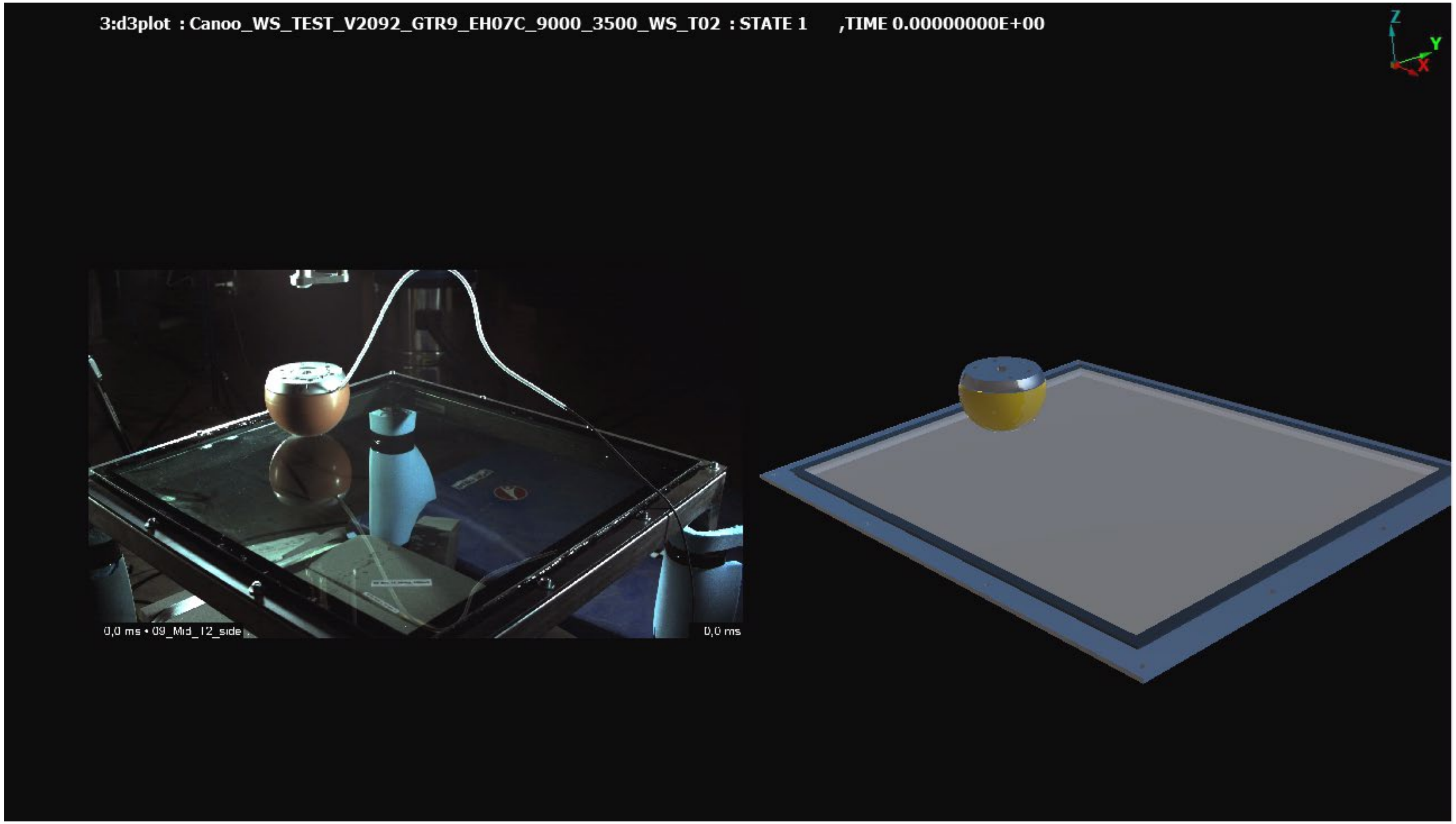
Simulation

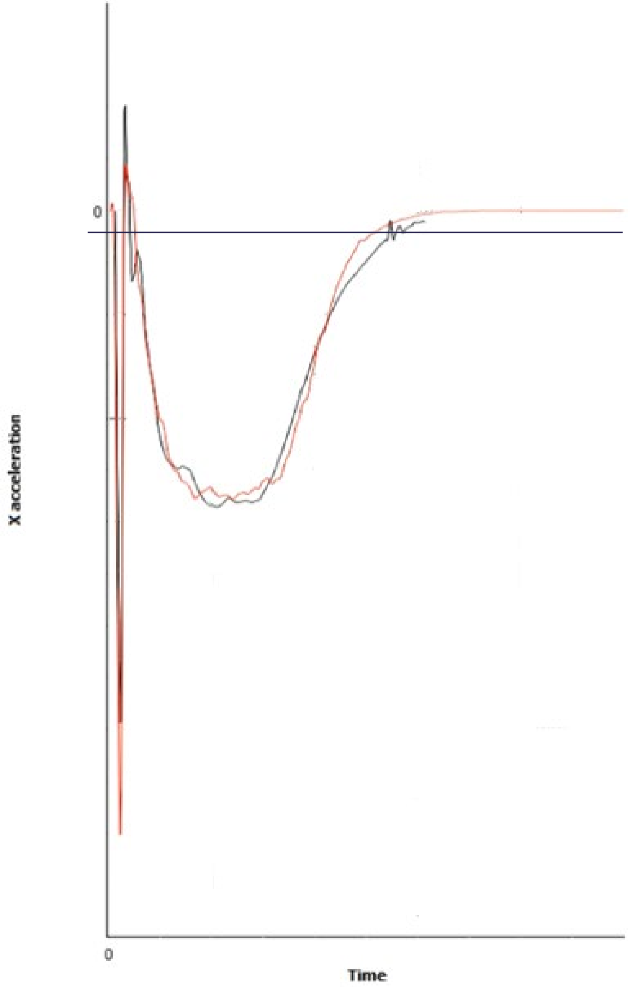
Acceleration correlation curve – Mid Edge position



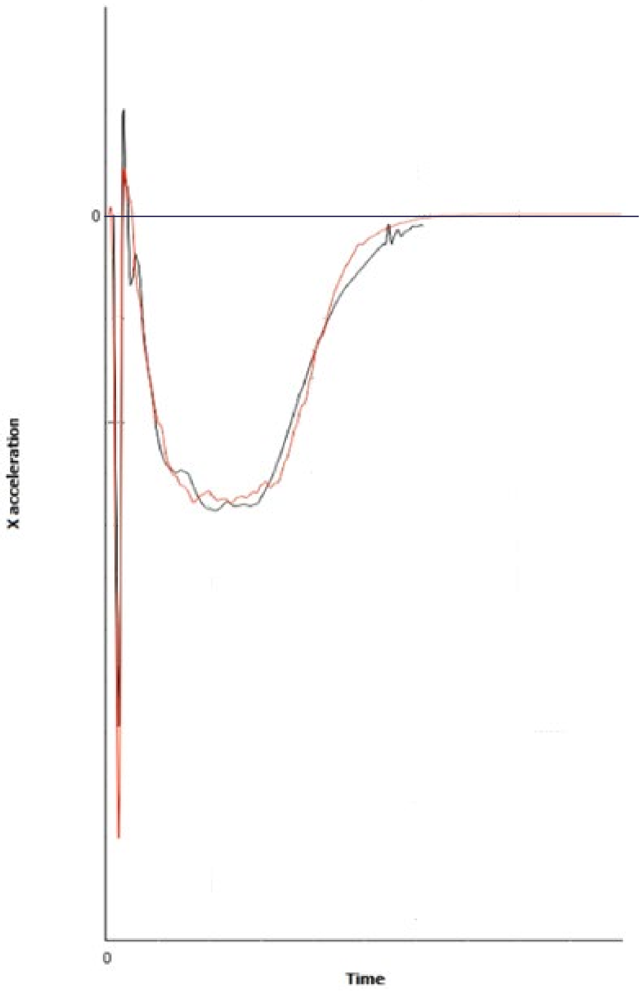
Simulation HIC	490	Simulation HIC-Interval	4.5 – 19.5
Test HIC (avg)	462	Test HIC-Interval (avg)	4.2 – 19.2
Test HIC (max)	478	Test HIC-Interval (max)	3.9 – 18.9
Test HIC (min)	436	Test HIC-Interval (min)	4.5 – 19.5

Visual comparison – Mid Edge Position





Visual comparison – Mid Edge Position



Fracture pattern – Mid Edge Position

Simulation

Conclusion

- As shown novel Ls Dyna materials cards such as *MAT_Glass shows an adequate correlation with physical test for component level.
- *MAT_GLASS has an approach easy to use, low computation times what yields a factible option in crash simulation.

THANK YOU

Discussion: Q & A