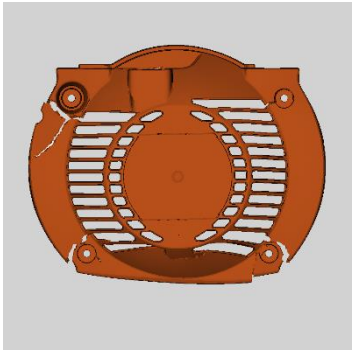
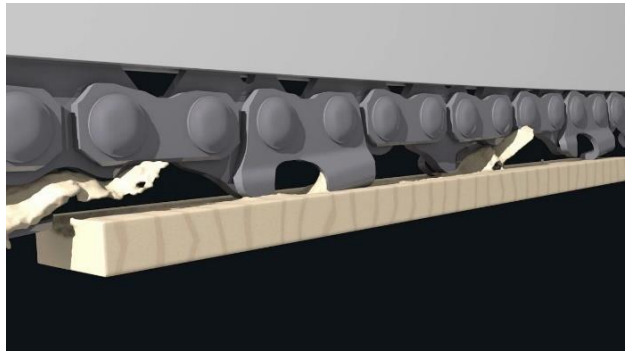
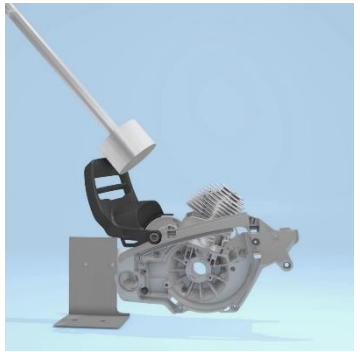
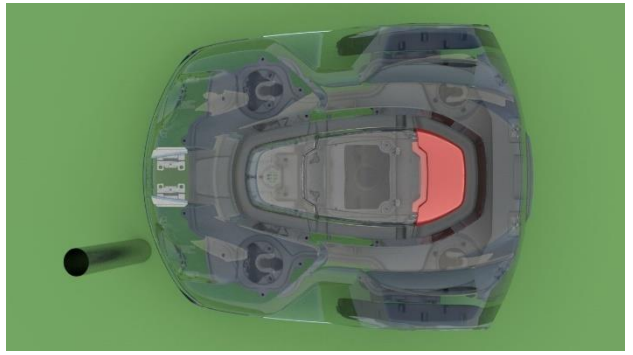
Husqvarna Group





Impact Simulations of Fiber Reinforced Plastics with LS-Dyna and Digimat

Mikael Palm, CAE team leader, Husqvarna Group

Content

- About Husqvarna Group
- Simulation work-flow for glass-fiber reinforced plastics
- DSM beam comparison in a three-point bending load-case
- Correlation of simulation method
- Example of complete impact simulation model

This is Husqvarna Group

- A global leading producer of outdoor power products including chainsaws, trimmers, robotic lawn mowers and ride-on mowers
- Net sales in 2018 amounted to EUR 4.1 billion
- Core brands: Husqvarna, Gardena
- Sales in more than 100 countries
- Leadership positions in products for forest, park & garden care, as well as construction
- Main distribution channels are dealers and retailers, and with growing on-line presence
- Approximately 13,000 employees in 40 countries
- The share is listed on Nasdaq Stockholm

330 years of innovation

1689

1872

1874

1903

1959

1974

1987

1995

2009

Auto Tune™

2009

2012

Battery products with petrol performance

2013

All-wheel-drive mower

2016

The Group's first chainsaw chain

Launched Gardena Smart System

2017

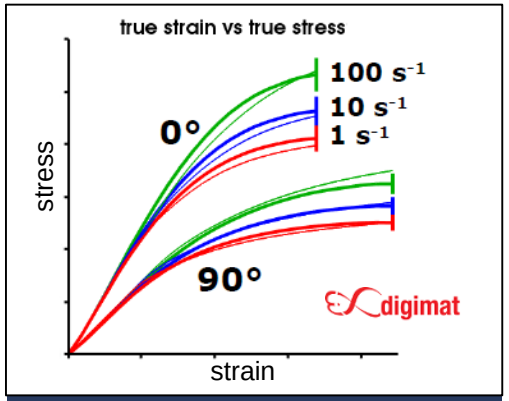
Acquisition of Pullman Ermator

2018

4-wheel drive robotic mower for professional segment

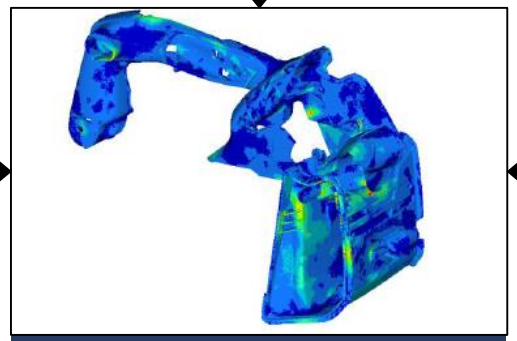
Simulation work-flow

Fiber orientation file from mold filling simulation in Moldex3D



Elasto-viscoplastic material model in Digimat

Finite element model

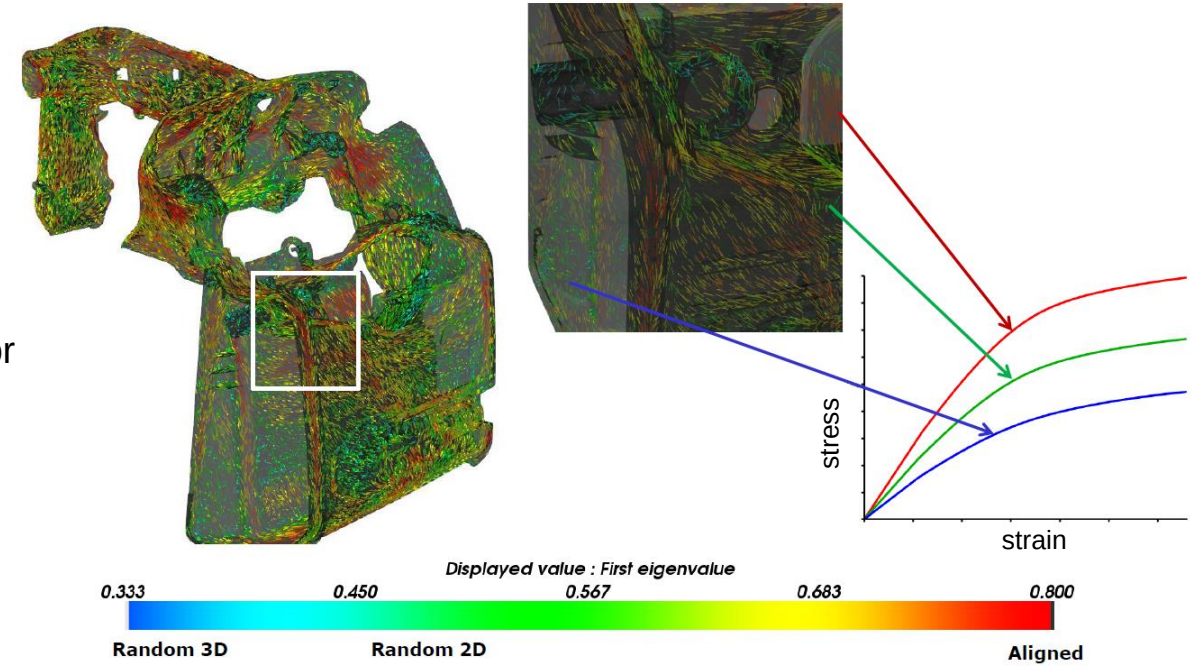


LS-Dyna impact model

Simulation work-flow

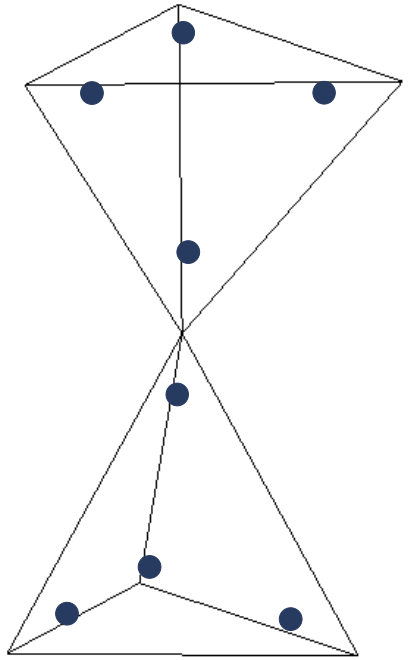
The information in the fiber orientation tensor is output from the FEA interface in Moldex3D

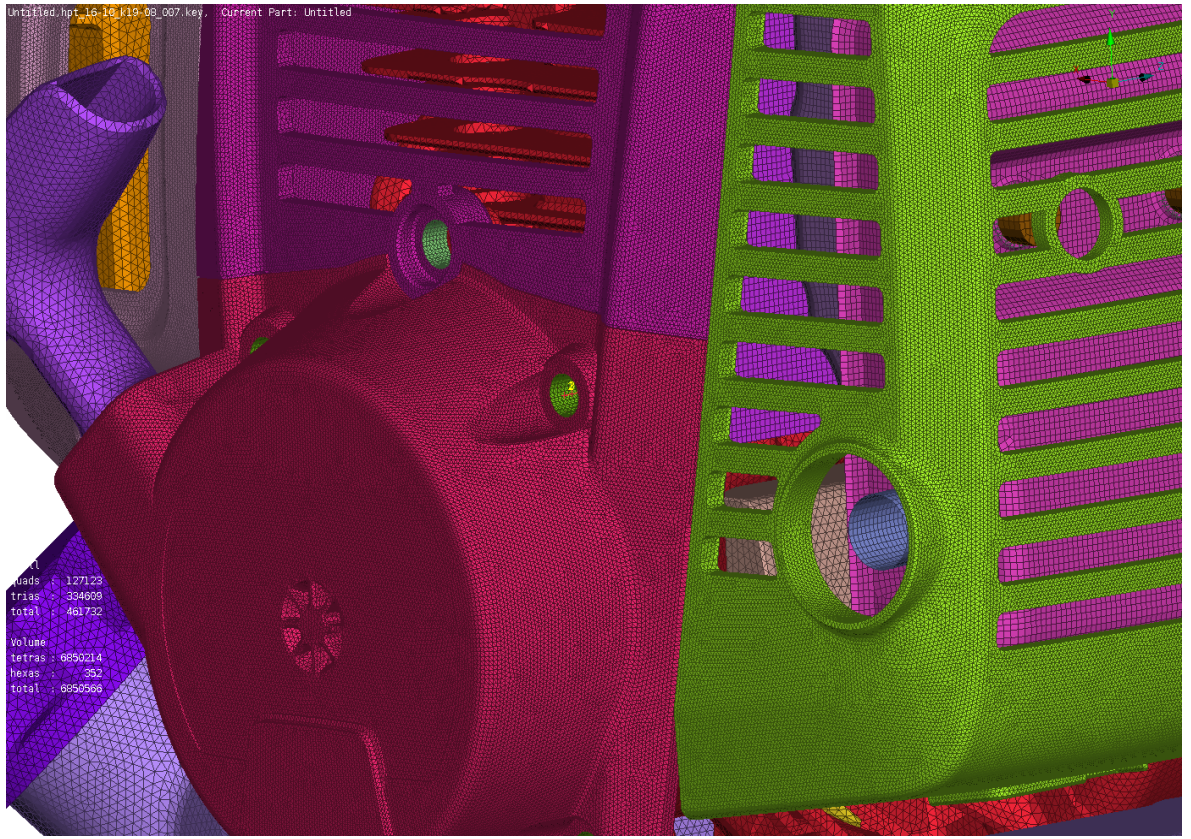
The direction of the vectors show the dominating fiber direction and the color represents the amount of alignment.



Digimat is used to map and simulate the non-linear material properties including failure. The structural mesh uses tetrahedral elements and the fiber orientation can vary within the element.

Simulation work-flow





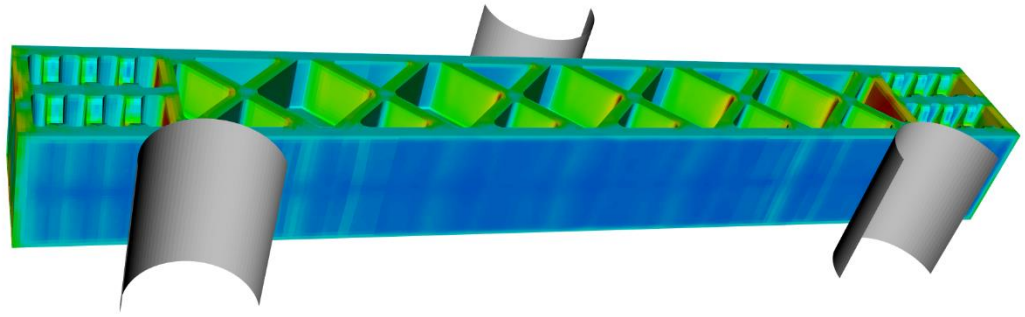
Linear tetrahedrons with 4 integration points (type 4 solids)
The element is deleted when 3 integration points have reached failure
Always at least two elements through the thickness. Element size ~0.7 mm.

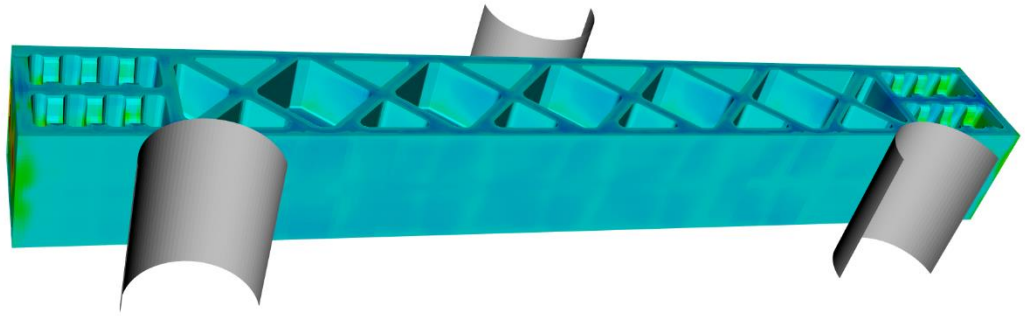
DSM beam comparison

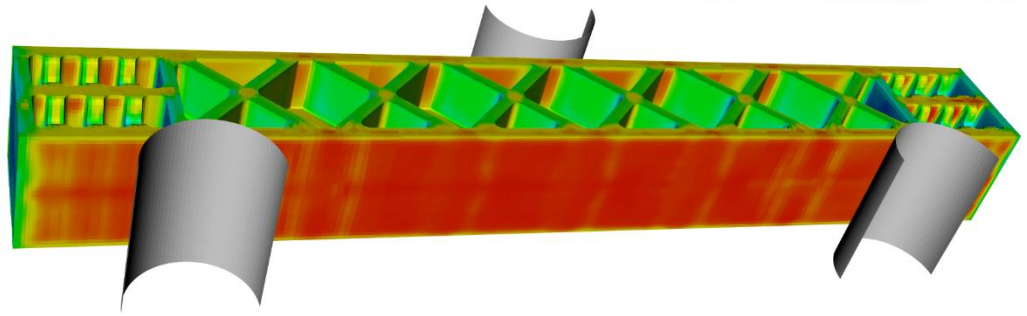
Material testing and characterization were done by our material supplier DSM at their material science centre.

The material models were validated by 3-point bending of an X-rib beam.

DSM beam comparison





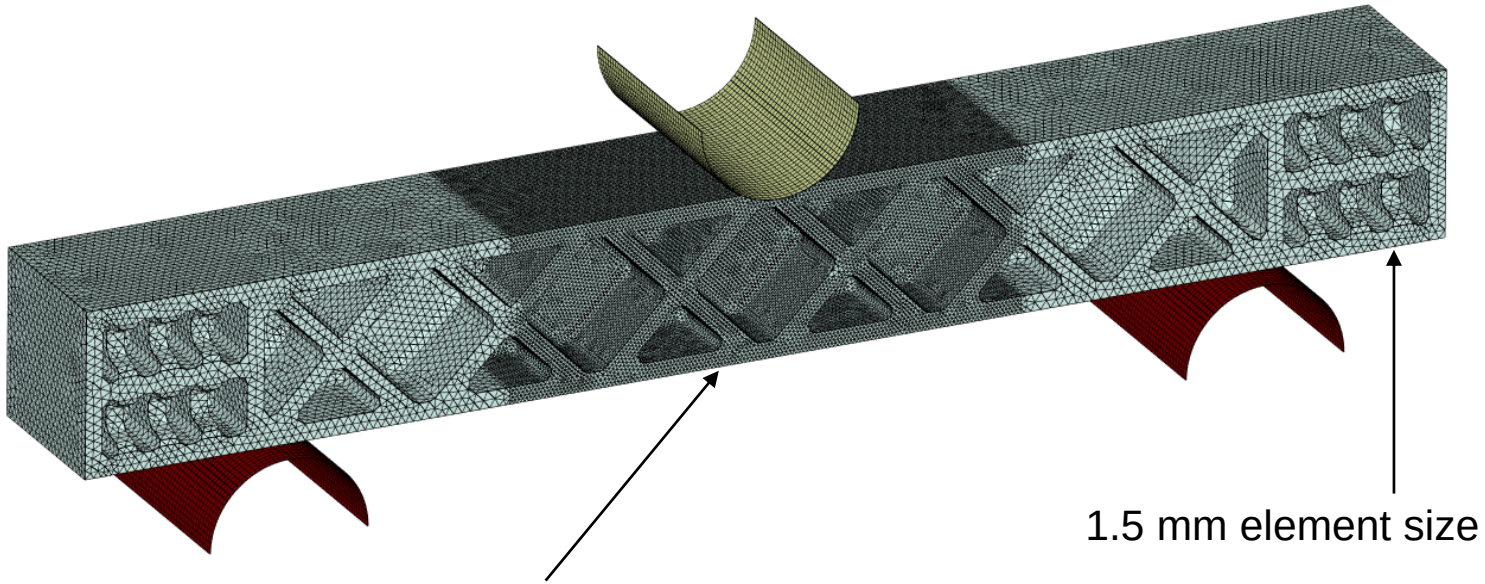


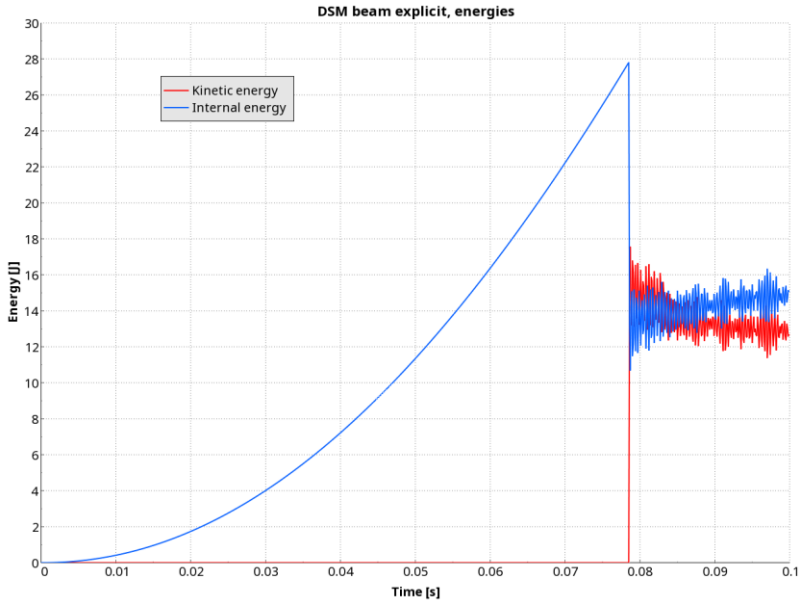
Mapping to LS-Dyna model were done in Digimat MAP.

DSM beam comparison

Explicit tet-mesh model

Simulated time: 0.1 s, time-step: 1.1e-7, added mass: 0.012 kg

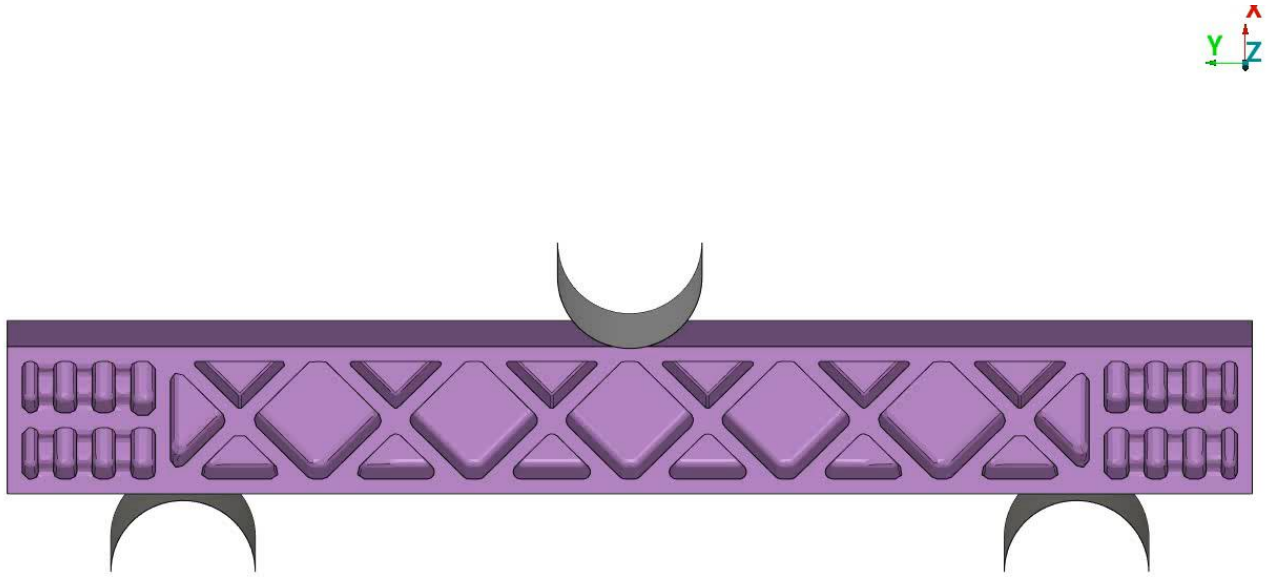


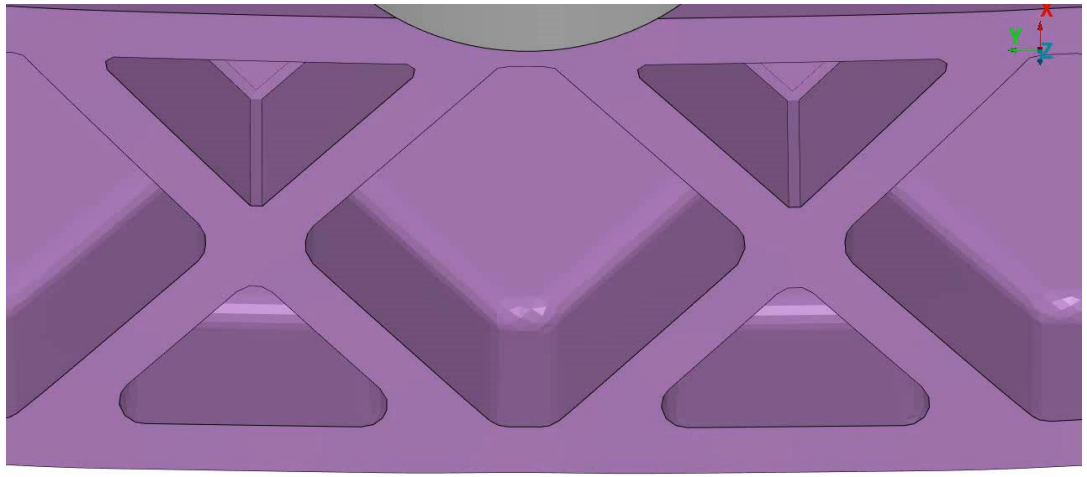


DSM did a quasi-static implicit analysis in Abaqus with hexa elements in combination with Digimat, but the simulation was successfully re-created with an explicit simulation and tetrahedral elements in LS-Dyna at Husqvarna.

DSM beam comparison

Results with element erosion

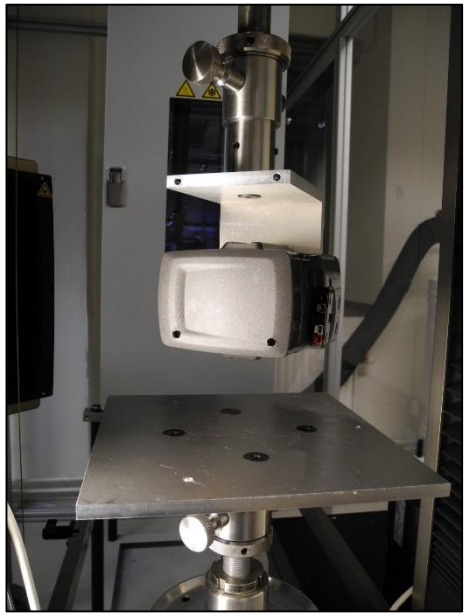


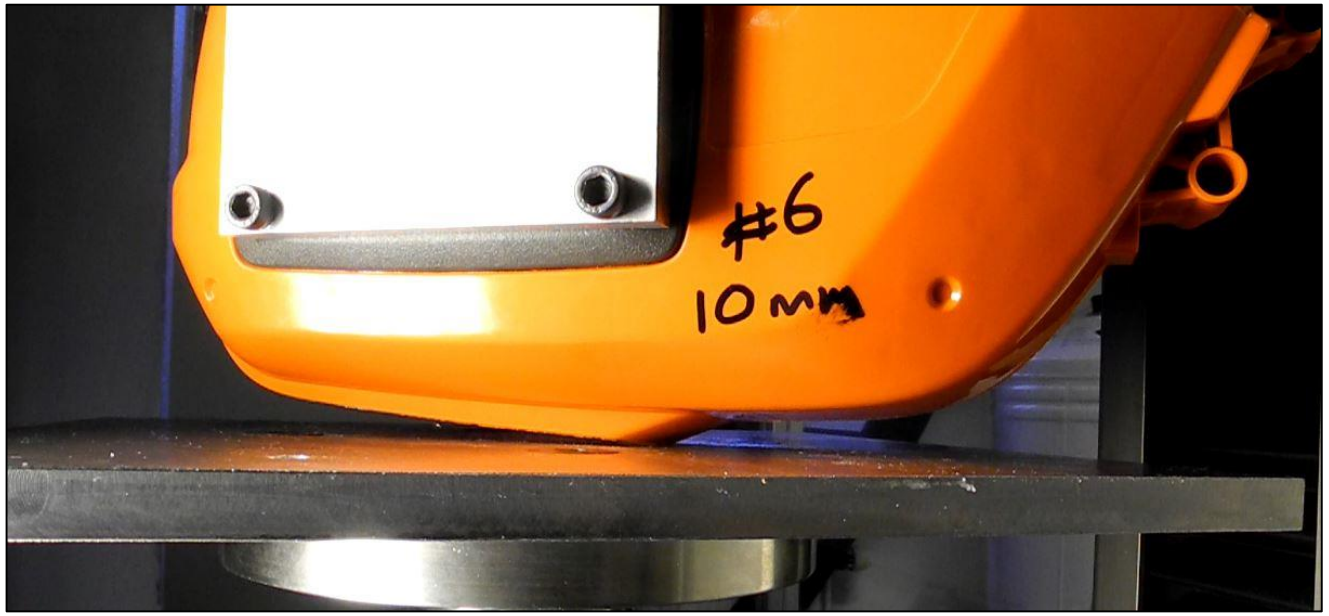


Both the stiffness and crack initiation point were close to the original Abaqus results.

Correlation

Test setup for correlating the simulation method by crushing a battery housing





A stiff battery dummy was used.

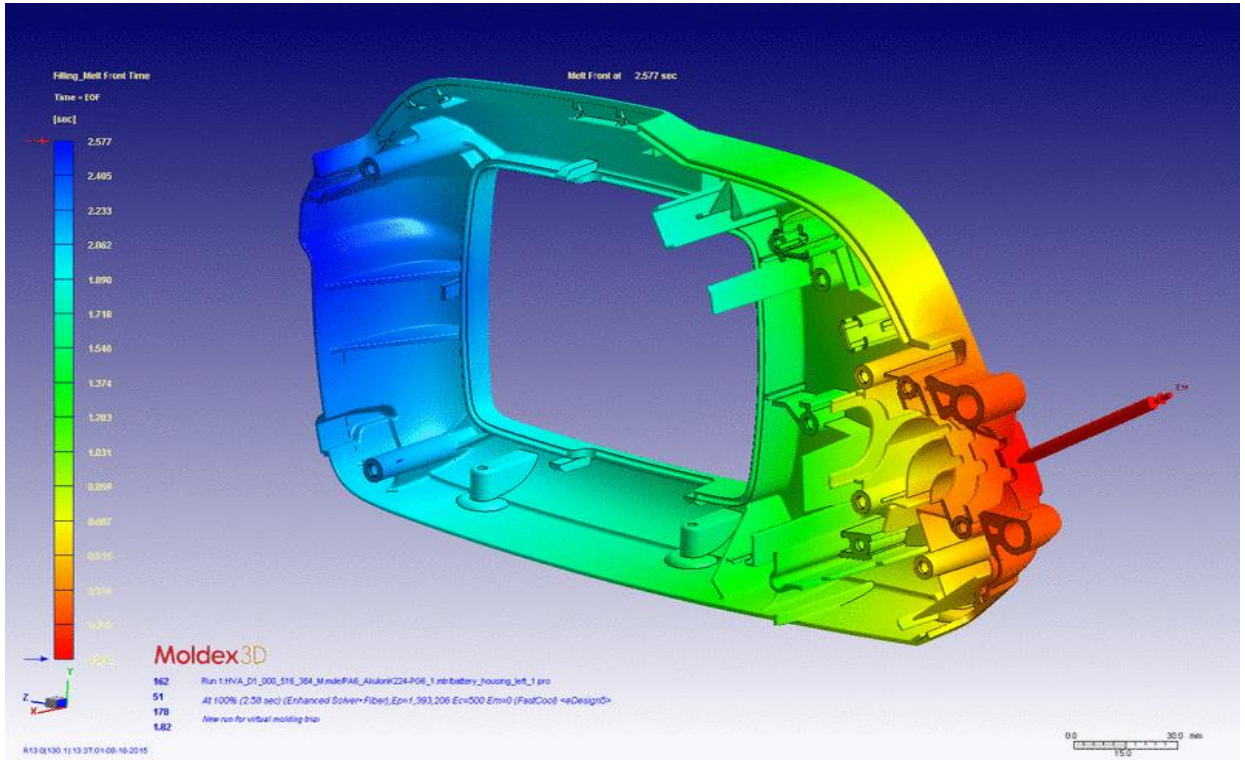
Deformation speed: 5 mm/min.

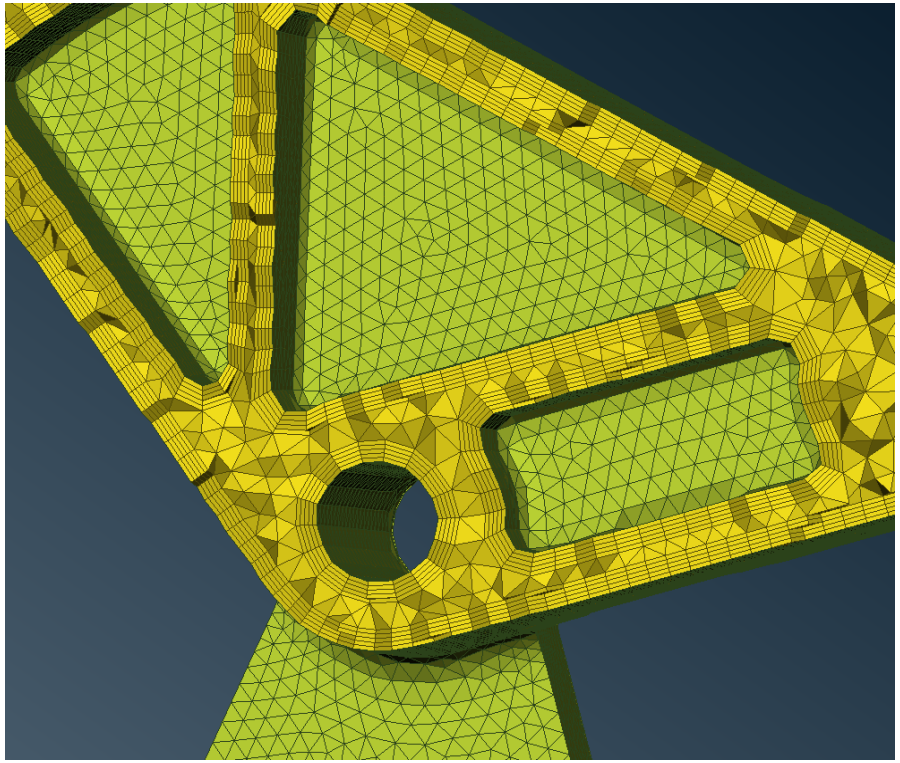
The flat surface was lubricated to avoid influence of friction.

Material: Dry Akulon K224-PG6 (PA6 30% GF)

Correlation

Moldex3D simulation to calculate fiber orientations in the battery housing

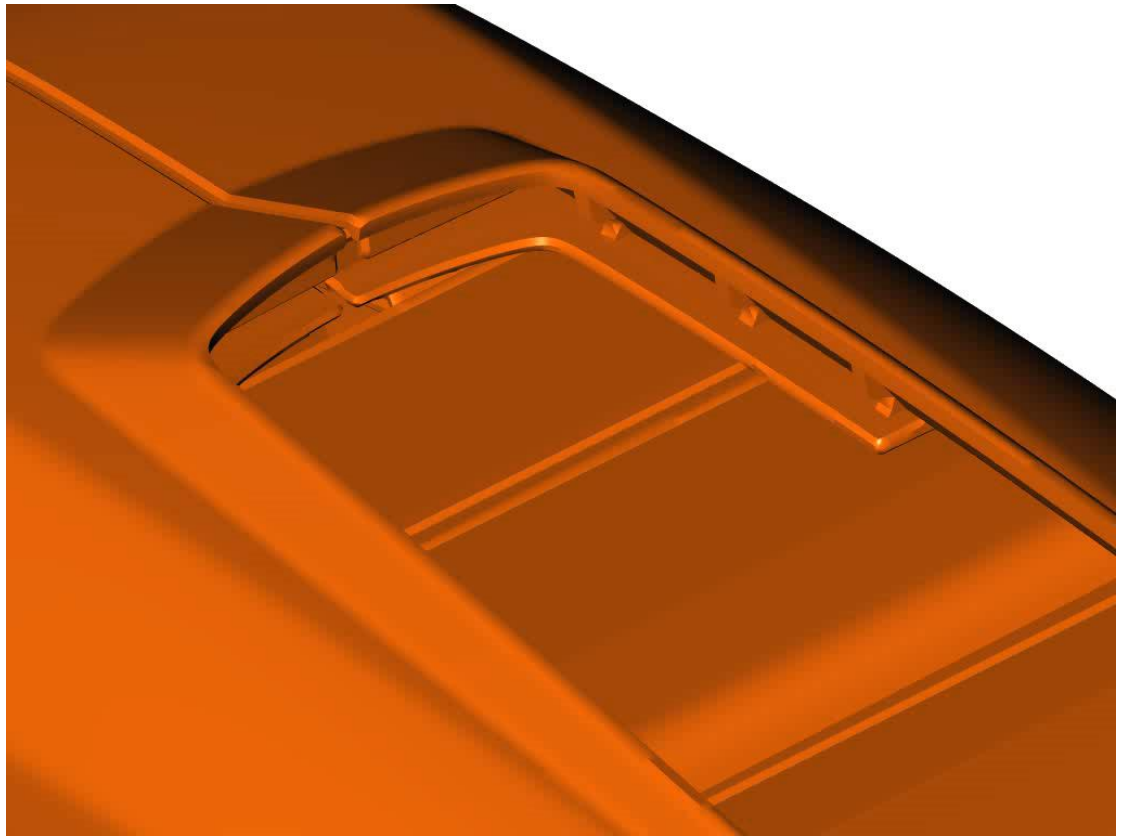




Boundary Layer Mesh (5 layers), meshed in Moldex3D designer (solid), 2.3e6 number of elements in cavity

Runs on 8 processors and only fill phase is necessary to calculate fiber orientations

Correlation, component test

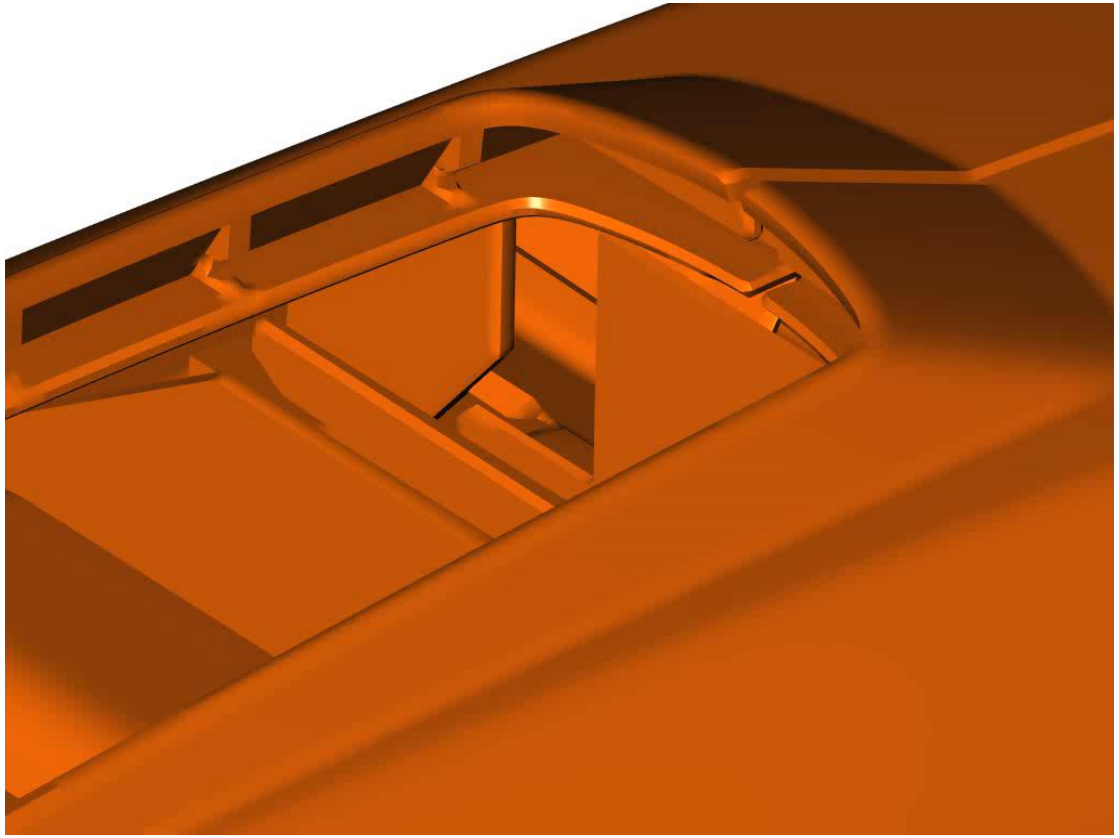


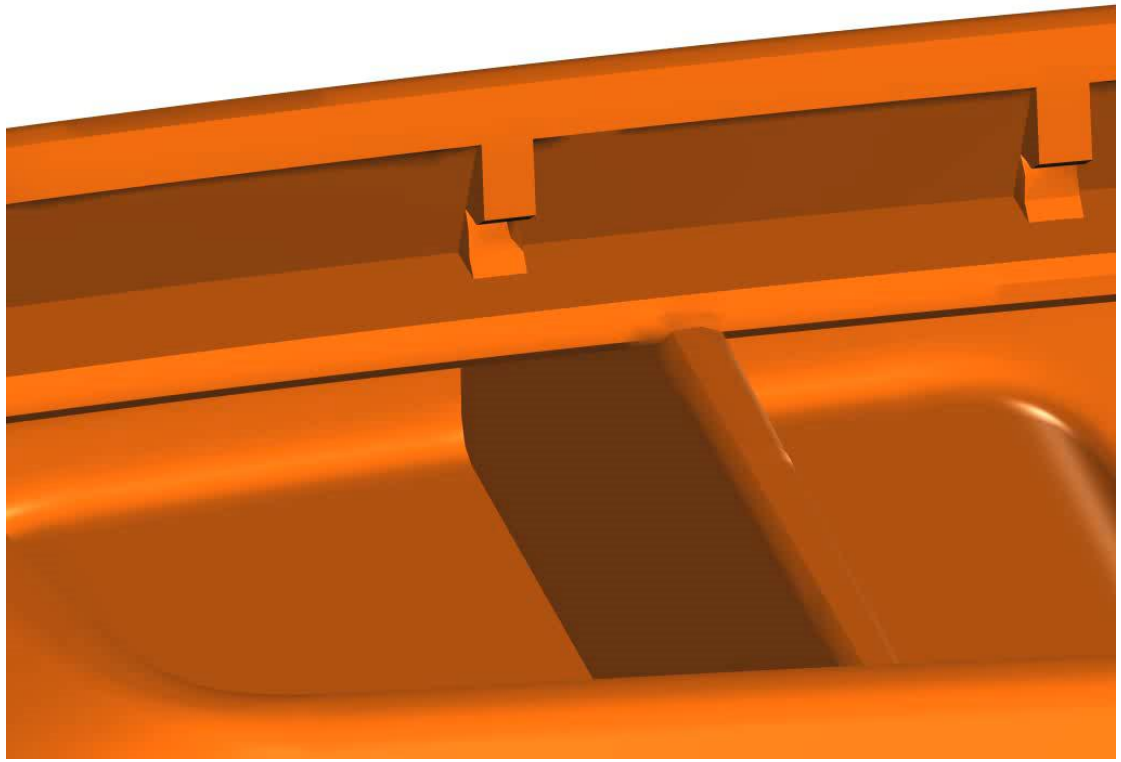
Simulation in LS-Dyna with contacts and Digimat anisotropic material model that included failure criteria.

The battery housing was compressed 10 mm.

Resembles a drop test where the heavy battery will apply a large force to the housing.

Correlation, component test

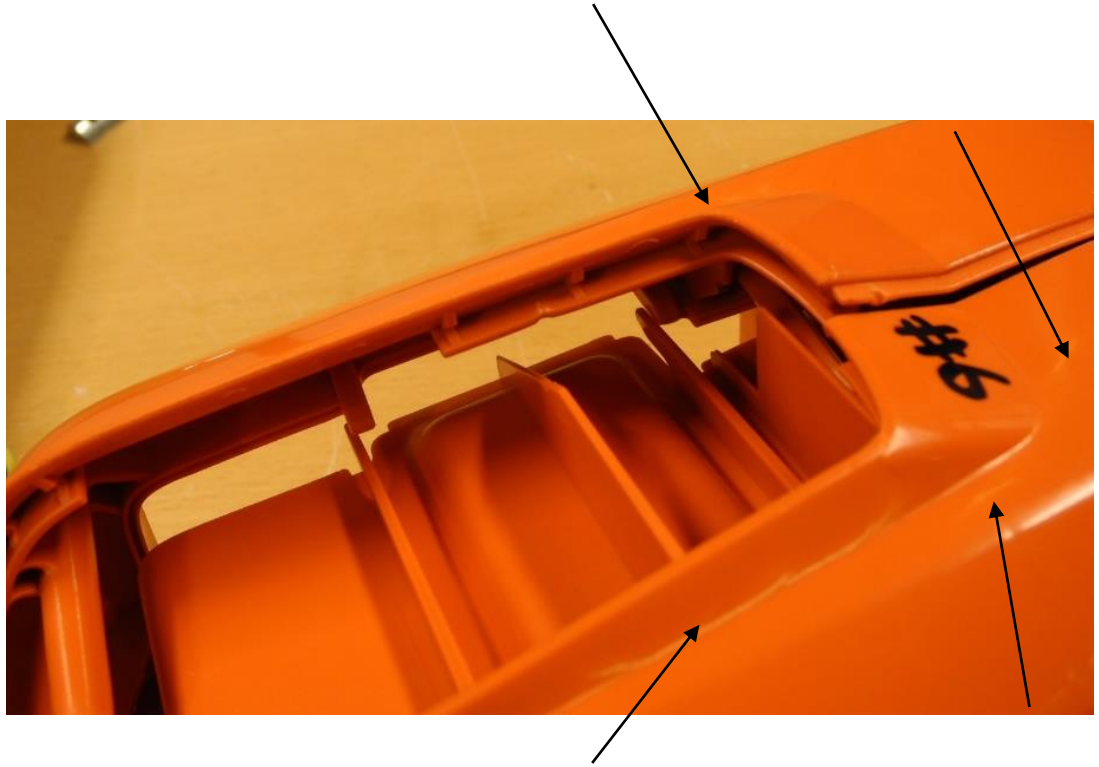


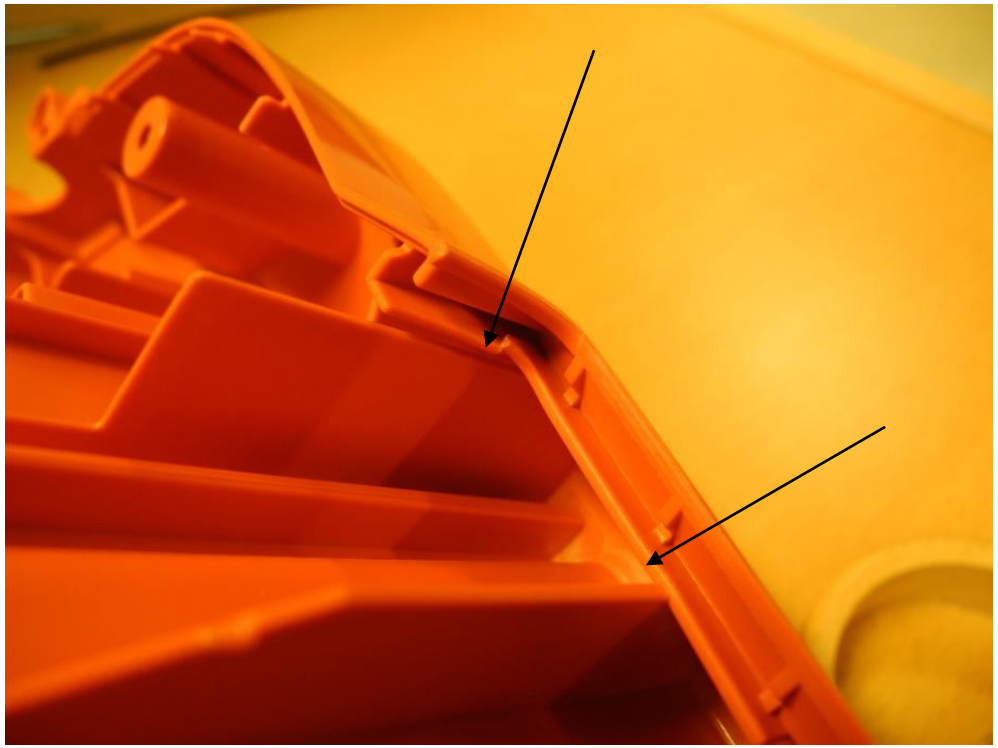


When failure is reached for a finite element it is deleted and a crack opens up.

Correlation, component test

Test results

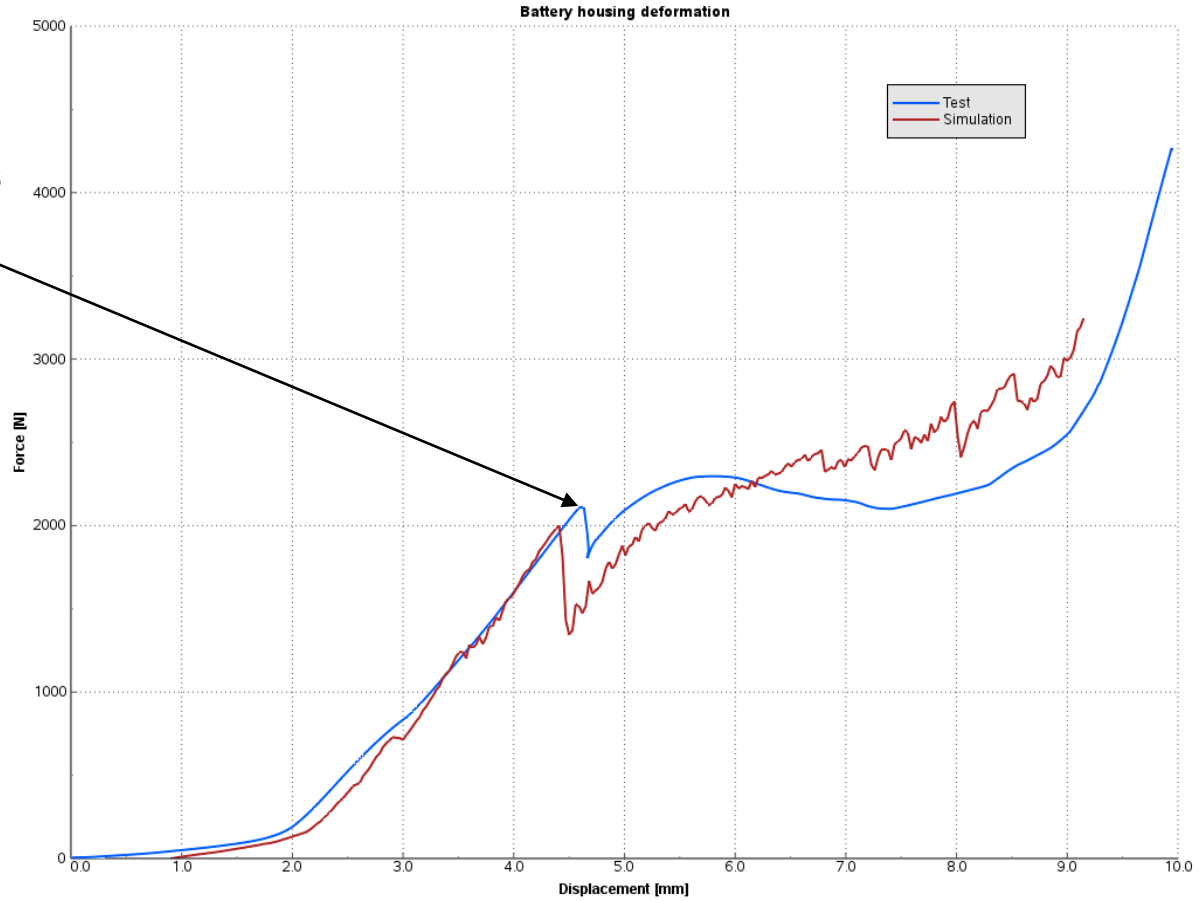




Cracks after 10 mm deformation correlate well with the simulated result

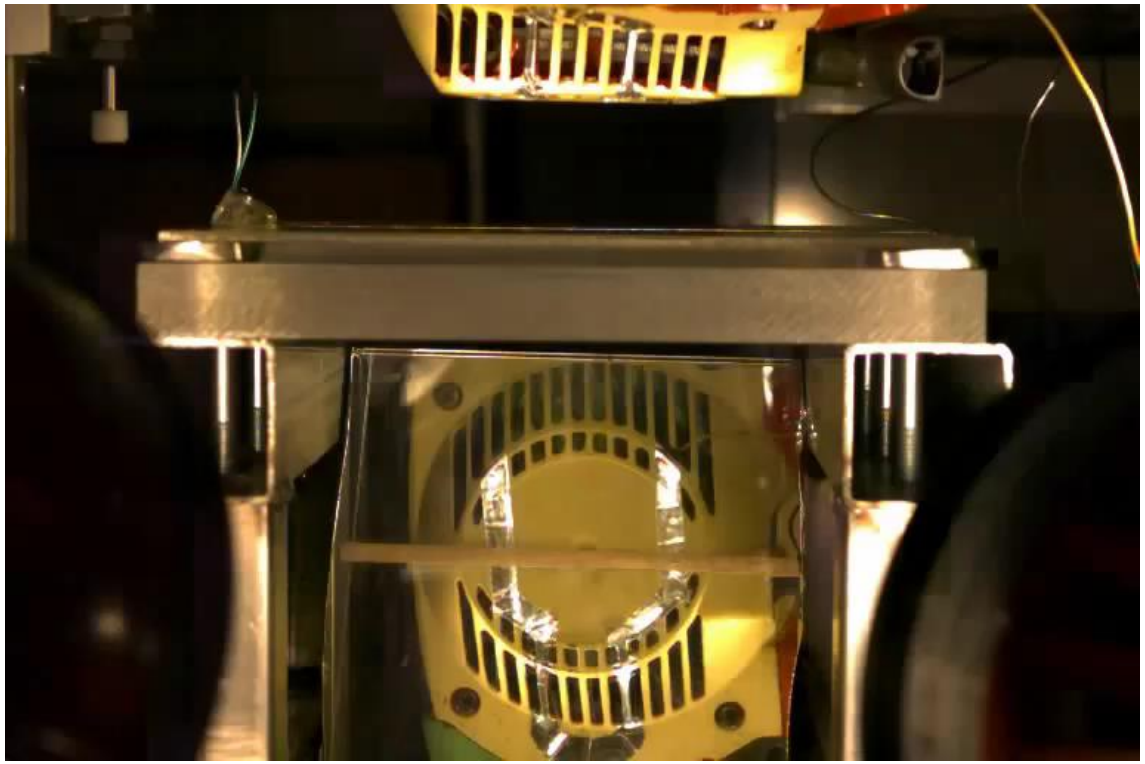
Correlation, component test

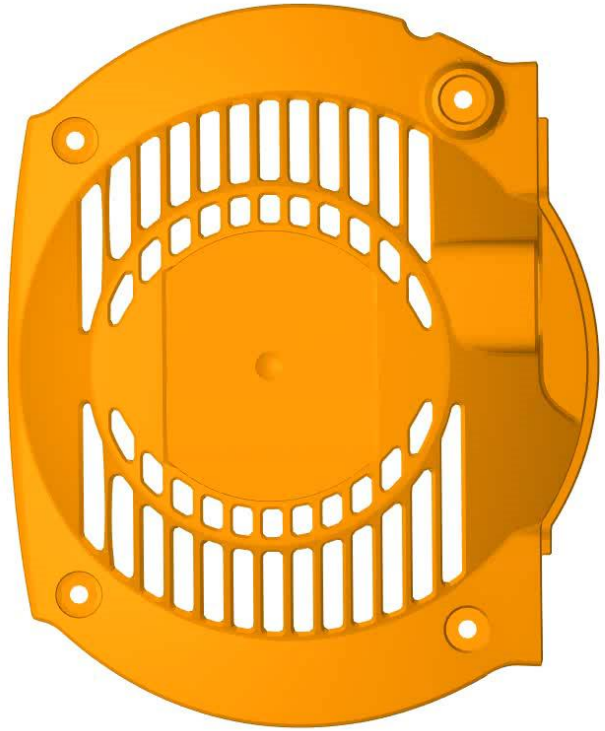
“Snap through” effect when accumulated internal stresses due to contacts are released



Correlation, drop test

Drop simulation of complete clearing saw model. Drop height: 600 mm

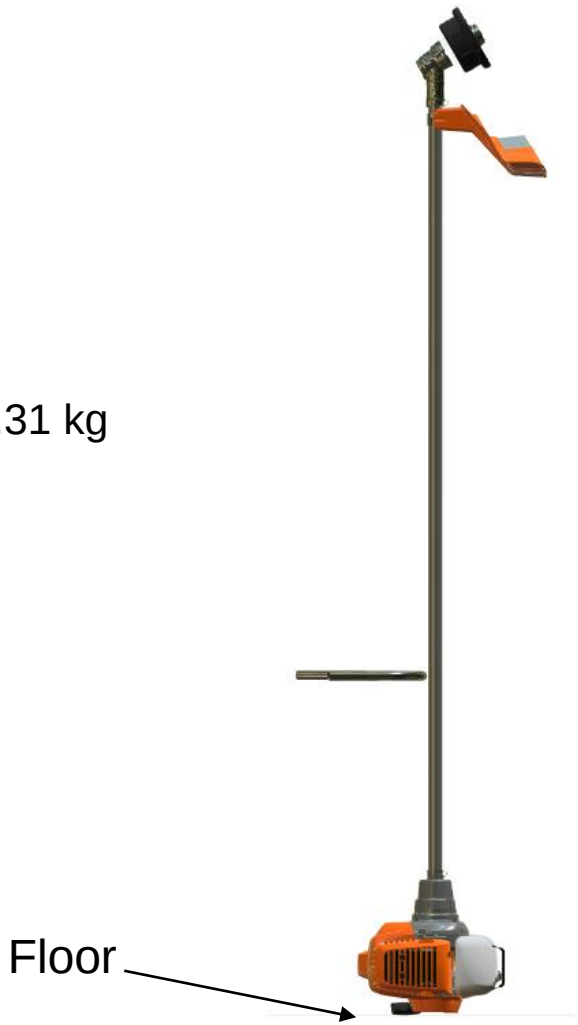





Example cases

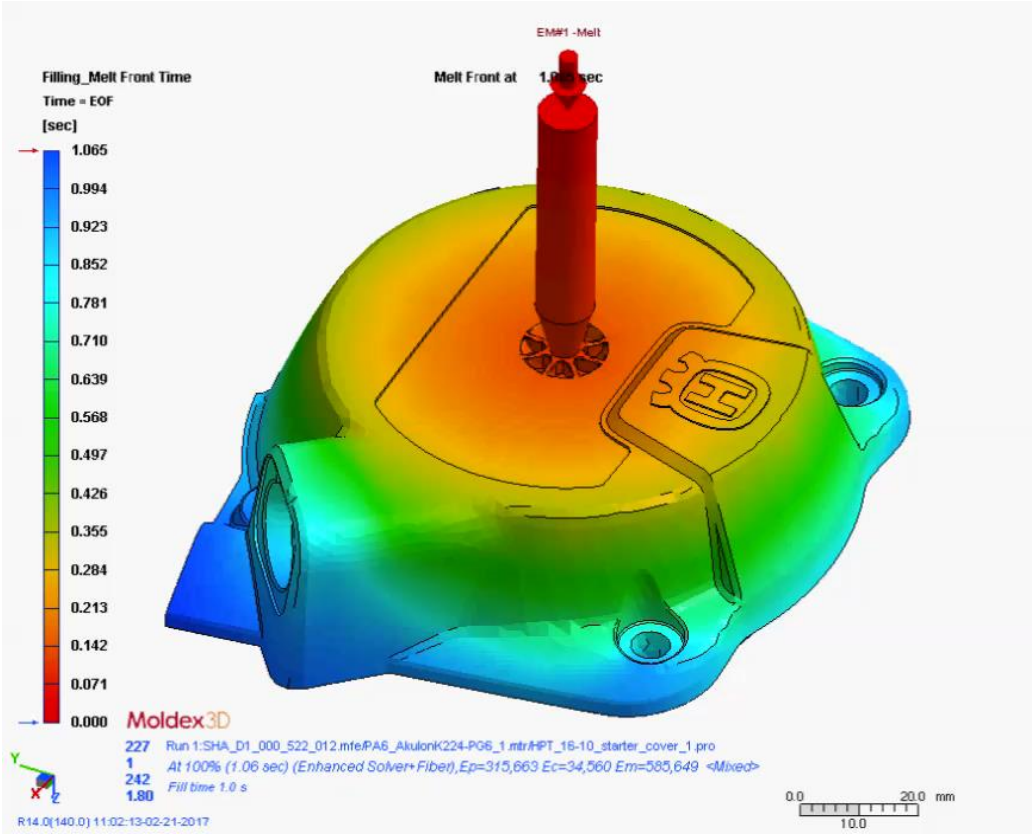
Impact on starter cover

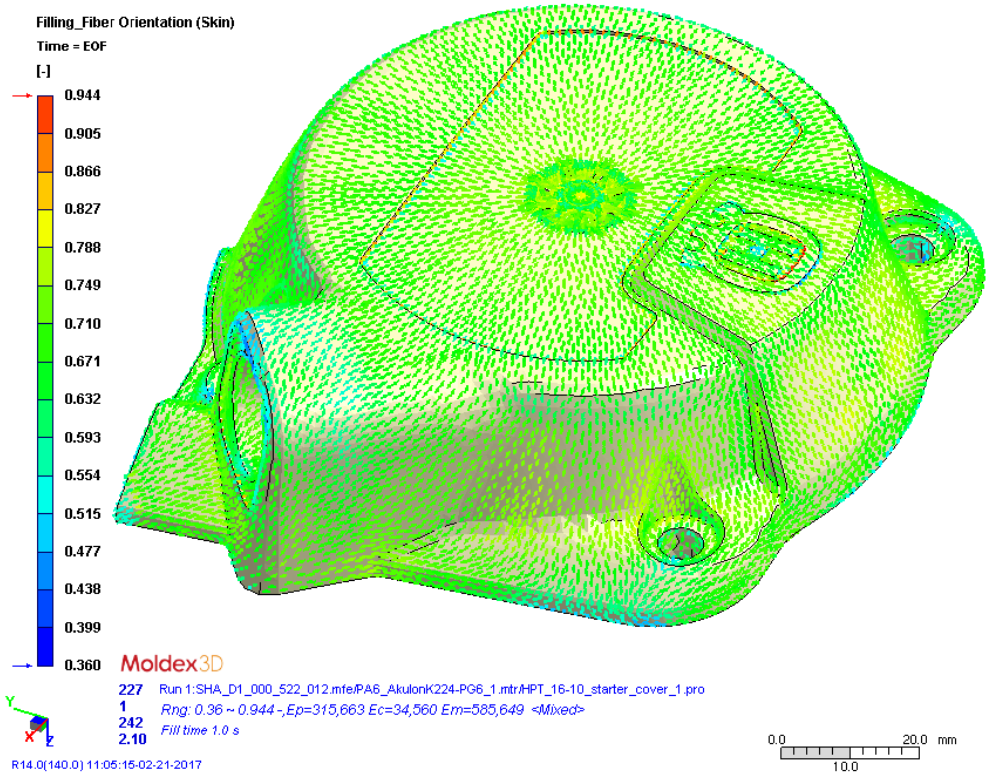
- Petrol trimmer drop simulation with Digimat material model in LS-Dyna
- Weight: 3.52 (engine) + 4.32 (shaft assembly) + 0.47 (fluid in tank) = 8.31 kg
- Drop height: 600 mm
- Impact energy: 48.9 J
- The drop test will be made with dry material at room temperature.



Impact on starter cover

Mold filling simulation of the starter cover. Material: Akulon K224-PG6 (PA6 30% GF)



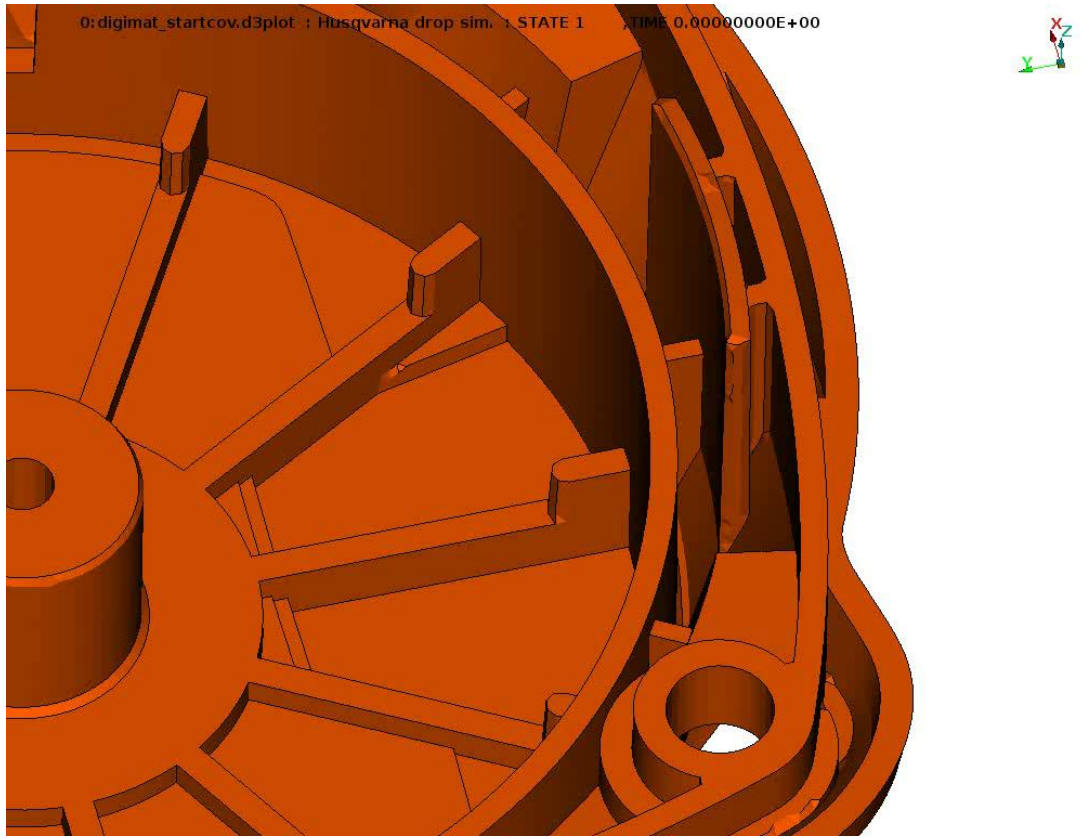


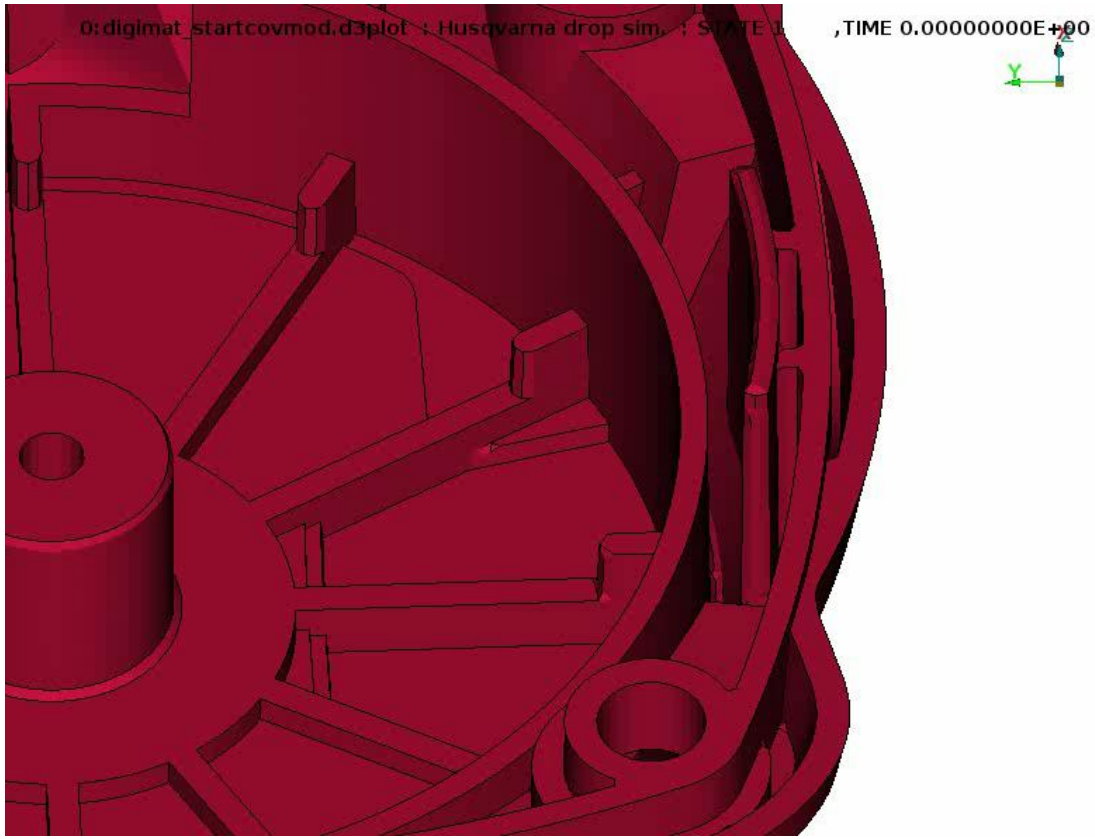
Impact on starter cover

Simulated time: 3 ms

Impact on starter cover

Animations of two variants of the starter cover



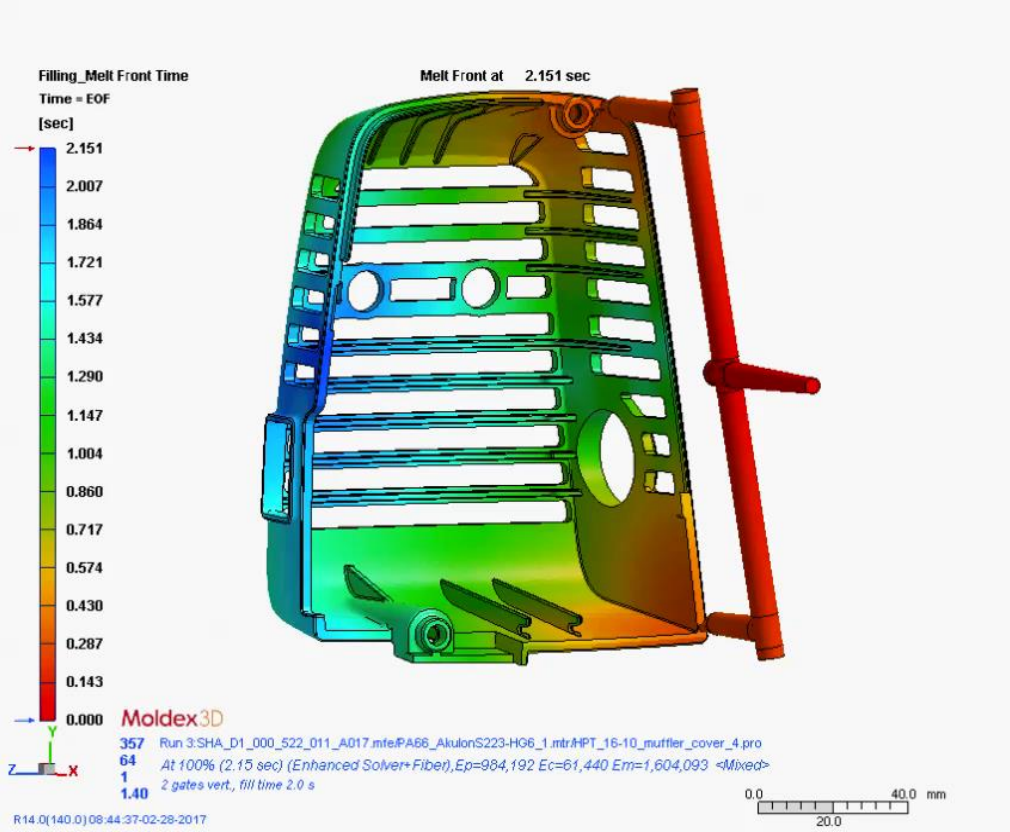


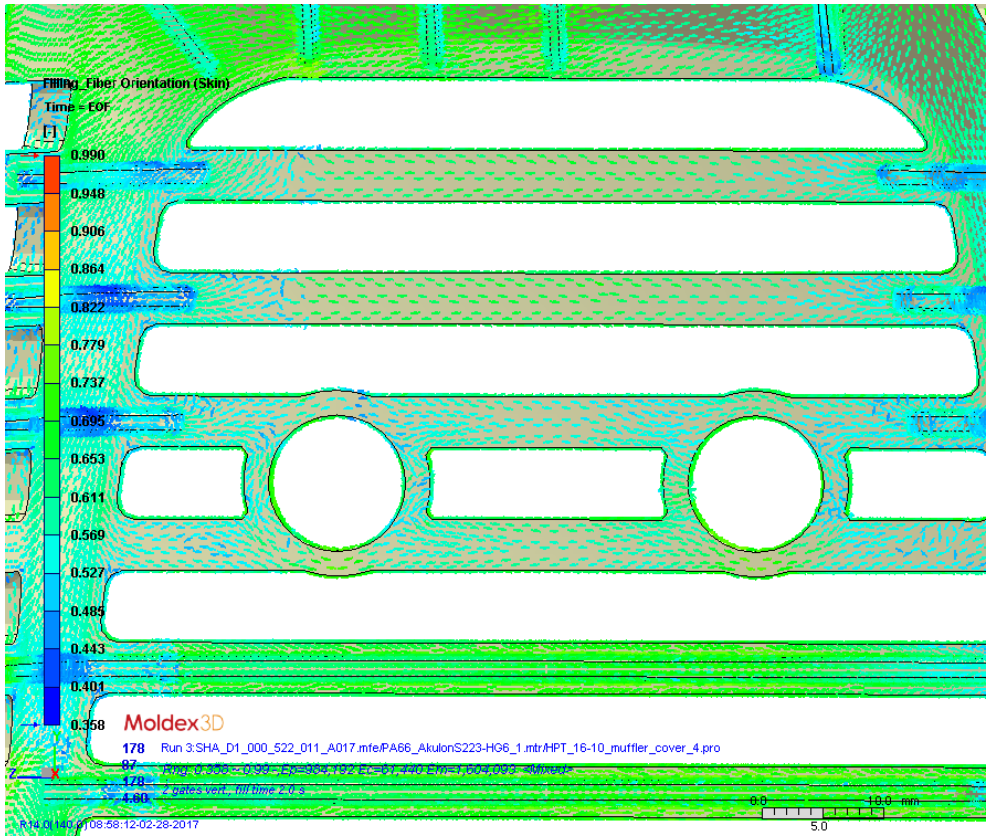
Removal of the connector that cracked solved a potential issue with the starter cover.

The material model included fiber orientations and failure for increased accuracy.

Impact on muffler cover

Mold filling simulation of the muffler cover. Material: Akulon S223-HG6 (PA66 30% GF)





Fiber orientation

Impact on muffler cover

Results example, not final version

Drop height of engine part: 600 mm

Impact energy: 30.1 J

Simulated time: 10 ms

Impact on muffler cover

Results example, not final version

Drop height of engine part: 600 mm

Impact energy: 30.1 J

Simulated time: 10 ms

Summary

- Implemented simulation loop containing mold filling simulations are now used mainly for impact simulations of Husqvarna battery products.
- Gives an increased accuracy and a possibility to predict the amount of damage after a drop test.
- Our material supplier (DSM) provides correlated material models in Digimat format.
- Design engineers can do the Moldex3D simulations that are used by the calculation group.

www.husqvarnagroup.com