Use Case: Stiffness & Strength

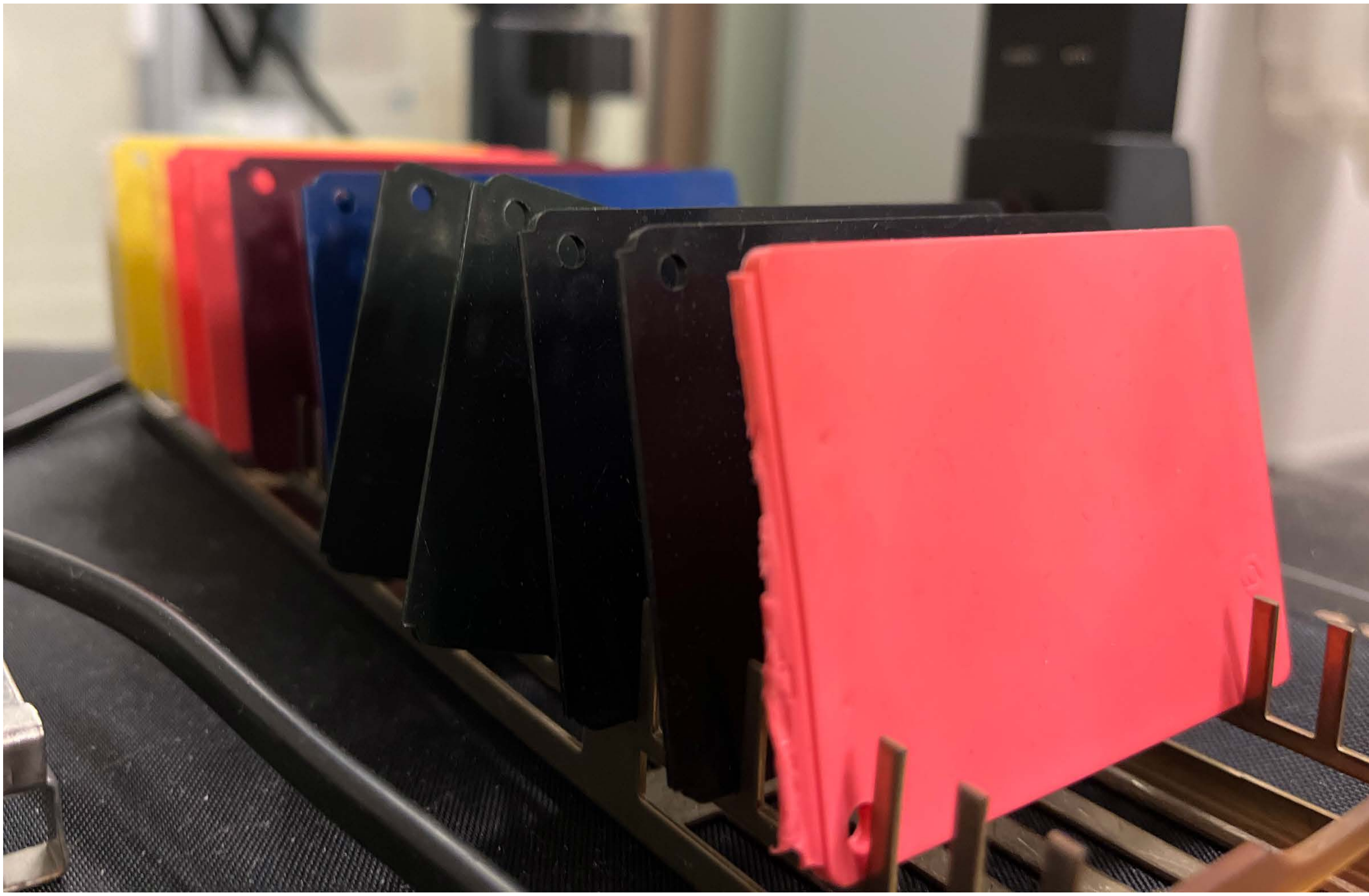
STIFFNESS & STRENGTH *PREDICTION OF INJECTION-MOLDED SHORT-GLASS-FIBER REINFORCED PARTS*

Envalior

Imagine the Future

SUMMARY

Based on stress–strain curves measured on tensile bars, we have developed a robust framework to define elasto–plastic material cards that capture the effects of fiber–orientation anisotropy. In this Use Case we are applying these material cards to predict the performance of two in–house demo applications: a load bracket made from Akulon® S223–HG6 (PA66–GF30) and an Electronic Power Steering (EPS) housing made from Xytron™ G4010T (PPS–GF40). The modeling results are within 5% accuracy while the prediction for the modulus is spot–on. This demonstrates the excellent quality of the material cards we have defined.



INTRODUCTION

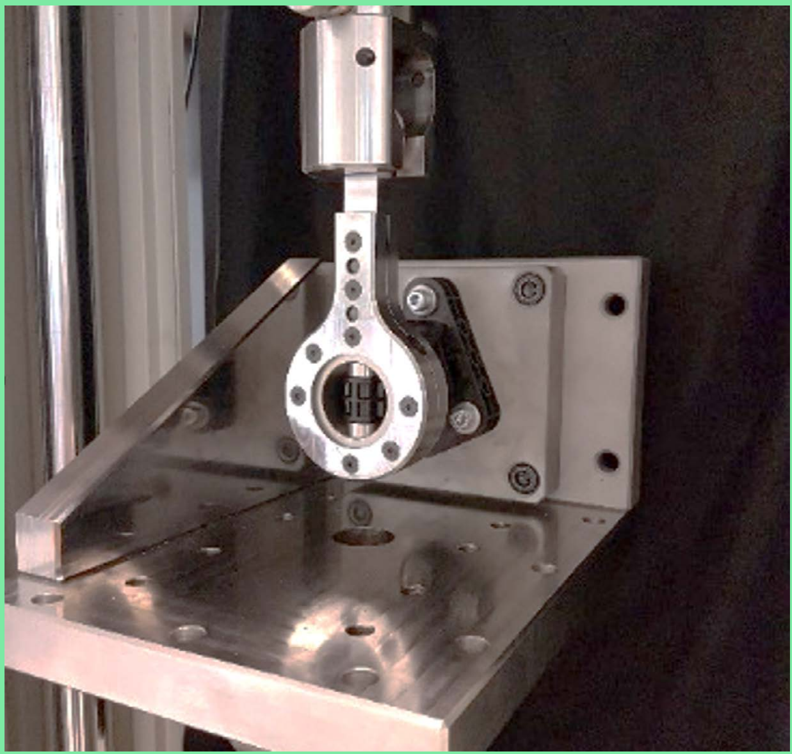
Predictability is key when designing load–bearing components—to reduce development time, design first–time–right and ensure part performance. Glass fibers take on varying orientations, causing anisotropy during injection molding. Anisotropy is when a part has different properties based on measurment direction. In this Use Case we focus on the modelling of stiffness and strength of injection–molded glass–fiber–reinforced plastics.

FIBER REINFORCED PLASTICS *ARE OFTEN HIGHLY ANISOTROPIC. THUS, LOCAL FIBER ORIENTATION AND THE RESULTING PROPERTIES NEED TO BE CONSIDERED.*

VALIDATION *APPROACH*

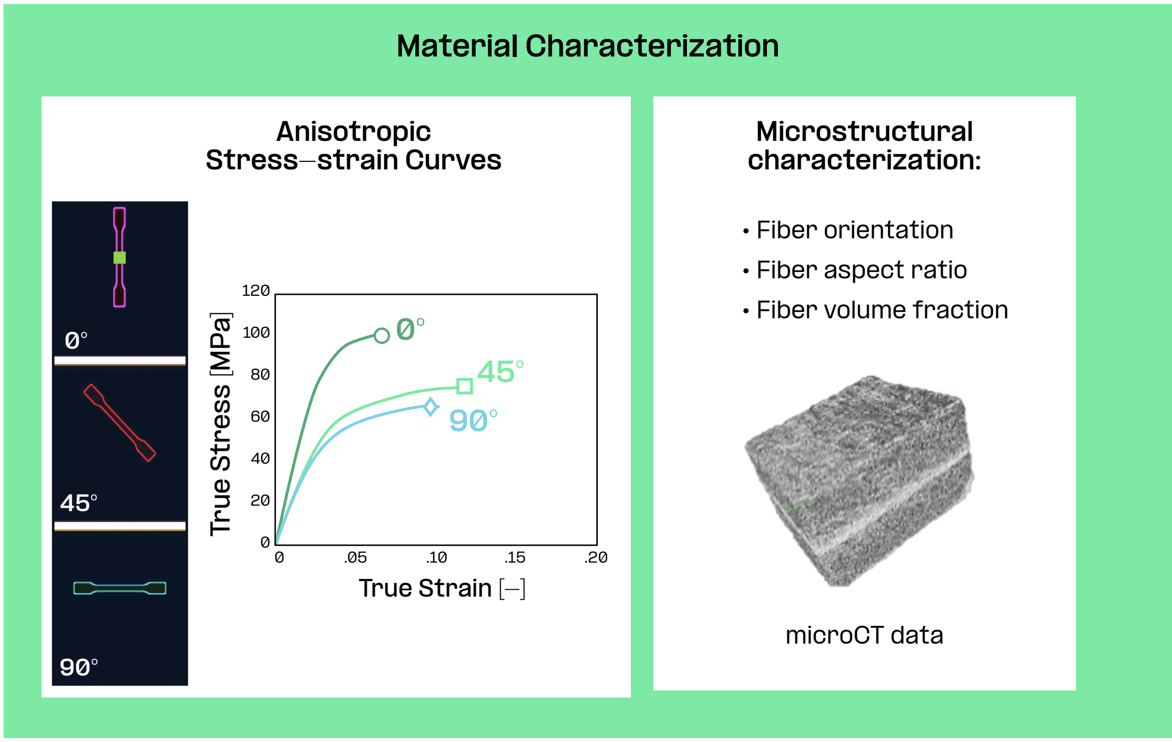
Proper modeling guides design while reducing the number of iterations. Fiber–reinforced plastics are often highly anisotropic, significantly affecting their properties. Thus, local fiber orientation and the resulting properties need to be considered. Our state–of–the–art injection molding simulation tools allow us to successfully predict fiber orientation in injection molded parts. As a result, we can accurately predict their stiffness and strength, crash performance, dimensional stability, creep and fatigue.

Validation on Application



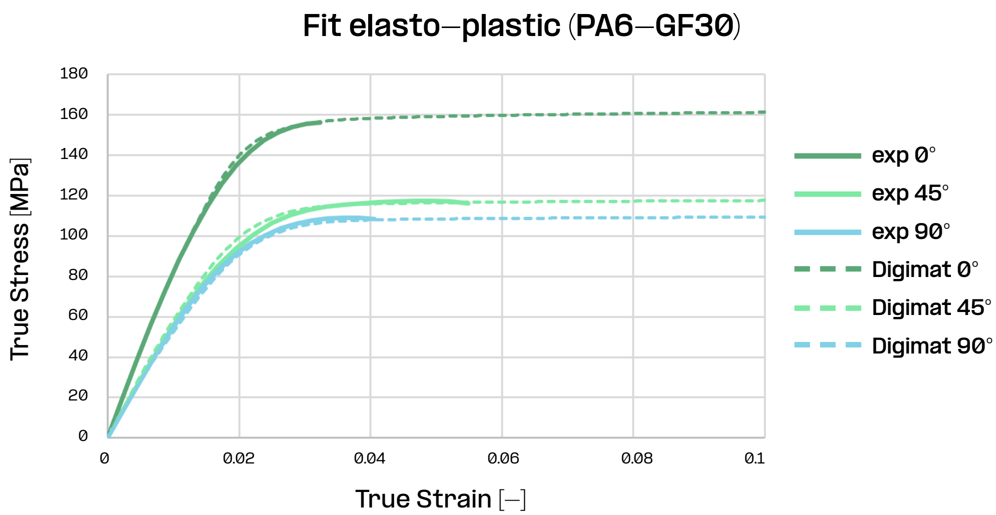
MATERIAL
CHARACTERIZATION

Anisotropic stress–strain curves are measured at various temperatures. To take the fiber orientation into account, samples are milled at 0°, 45° and 90°, with respect to the flow direction, from injection–molded plaques. Using micro–CT images, the exact local fiber orientation, aspect ratio and volume fraction of the test specimen can be accurately determined.



Based on these inputs we calibrate anisotropic elasto–plastic material models.

The software we use for material modelling is Digimat. The Digimat material cards can be used with all major FEA solvers and are available to all Digimat users. To link the calibrated material to the part performance, the fiber orientation of that part is required which can be obtained by an injection–molding simulation. The predicted fiber orientation can then be mapped onto the FEA mesh.

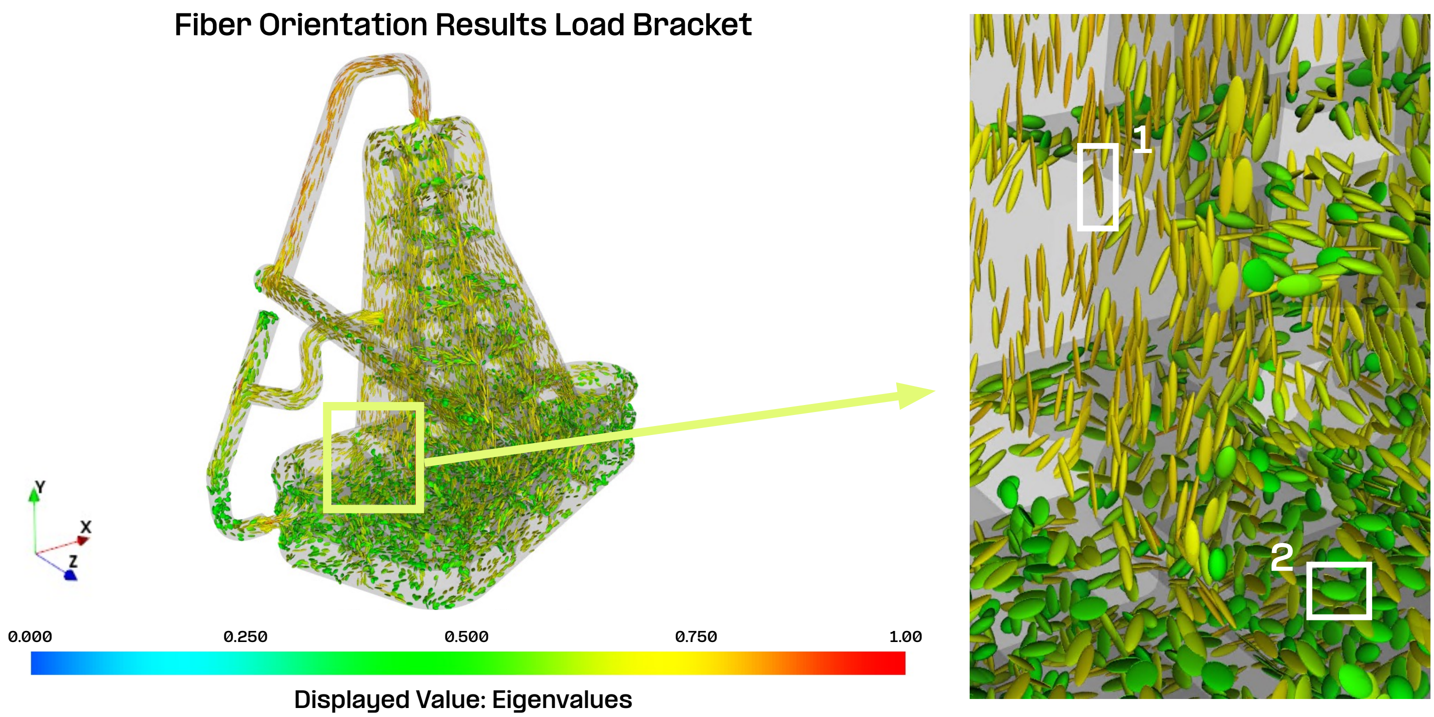


To validate the quality of our material cards we have injection molded in–house demonstration parts and tested them in our laboratories, considering different materials, load cases and temperatures.

We will show a couple of results of our extensive campaigns, comparing finite element analysis (FEA) results with experimental results on our load bracket and EPS housing, where we evaluate the stiffness and strength of these parts.

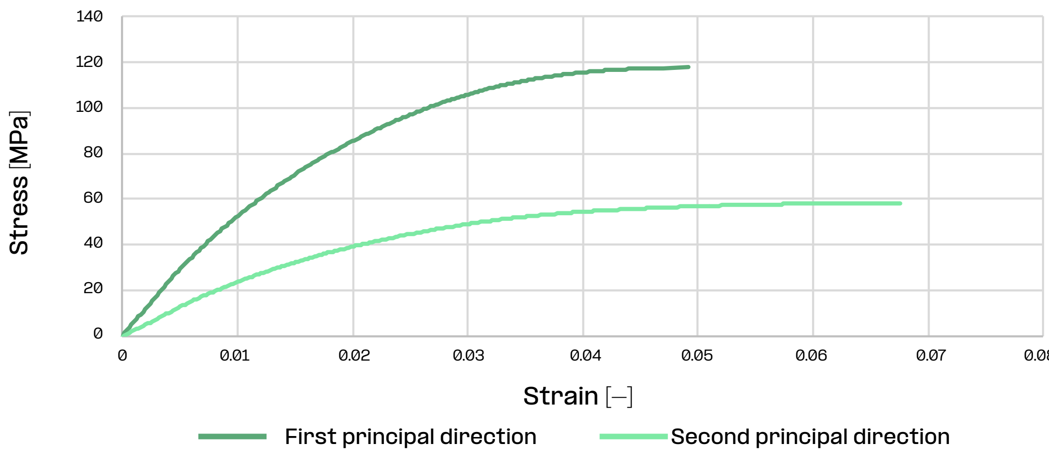
FIBER ORIENTATION *AND STRESS–STRAIN*

The image shows the local fiber orientation in the load bracket as calculated by injection–molding simulation software. The local fiber orientation is depicted as ellipsoids with different sizes and orientation. Location 1 shows a cigar–shaped ellipsoid, which indicates a high degree of orientation in the direction of the longest axis of the ellipsoid.



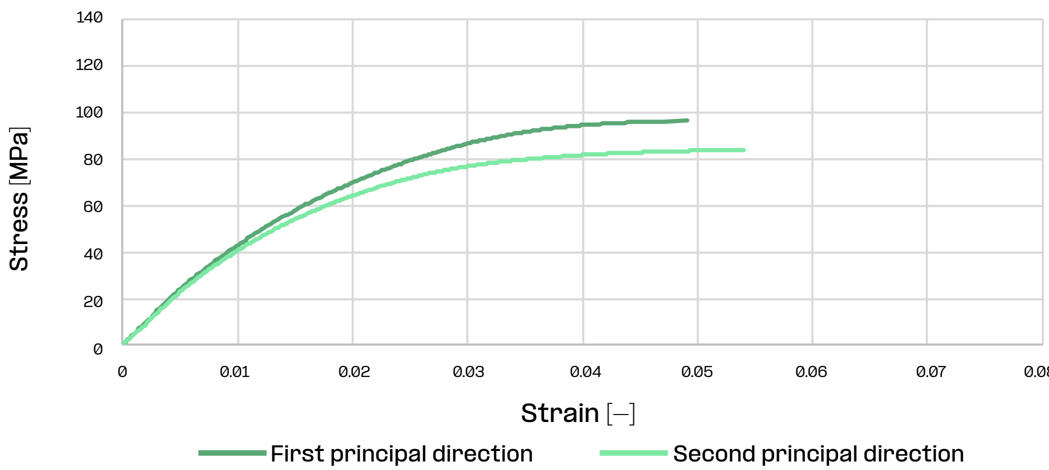
In the graph below, we show the stress–strain curve along the longest axis of the ellipsoid (dark green curve) as well as the stress–strain curve in the other two short axes of the ellipsoid (light green curve).

Stress VS. Strain at location 1



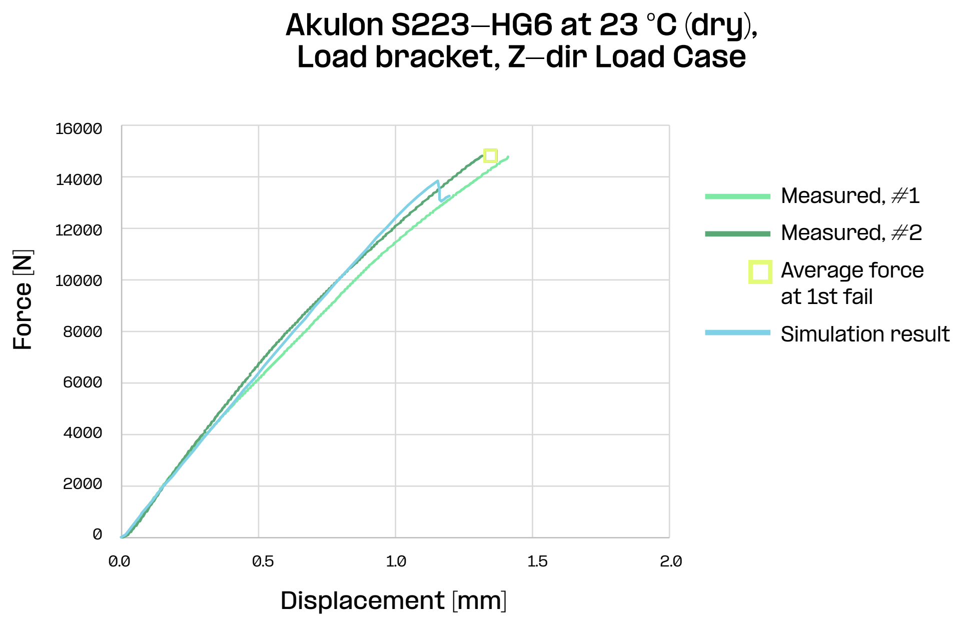
This indicates that a high degree of fiber orientation corresponds to a high degree of anisotropy in terms of stiffness and strength, as represented in the two stress–strain curves. Location 2 in the illustration shows a disc–shaped ellipsoid. For this case, the below graph shows about equal stiffness and strength in the two main axis directions of the disc.

Stress VS. Strain at location 2



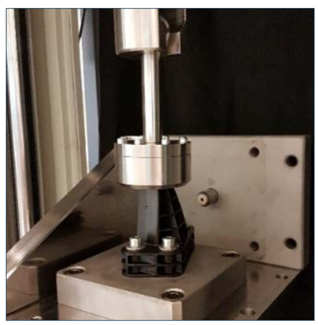
LOAD BRACKET *VALIDATION*

The load bracket is tested on a Zwick Universal Testing machine. We have built custom tools to fix and load the part in this machine. We record force and displacement, until the part breaks (see the green curves in the graph).

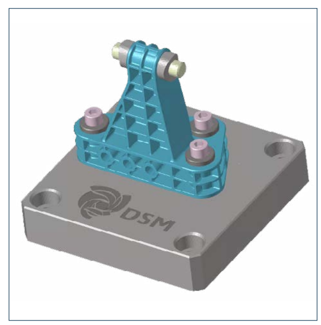


In our FEA model we apply the boundary conditions as applied in the actual test. We include the Digimat material cards in the FEA model in combination with the mapped fiber orientation results from the injection–molding simulation. The FEA result is shown as the blue curve in the graph.

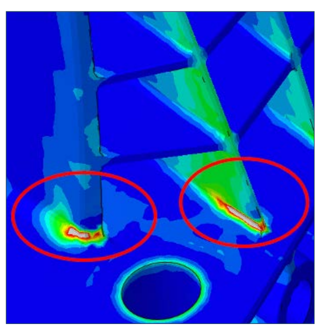
In this example we show results of the load in the vertical direction (note, we have adapted the tools such that we can load the part in different directions as well), for a PA66–GF30 material, loaded at 23°C. The predicted stiffness of the part (initial part of the force–displacement curve) matches very well with the measured stiffness. The force at failure is underpredicted by about 7%. Also, note that the FEA results (contour plots of the failure indicator) show critically loaded locations (red and light–grey zones in FEA results) that correspond with the location where the first cracks appear in the tested parts.



Test Set–up



FEA Model

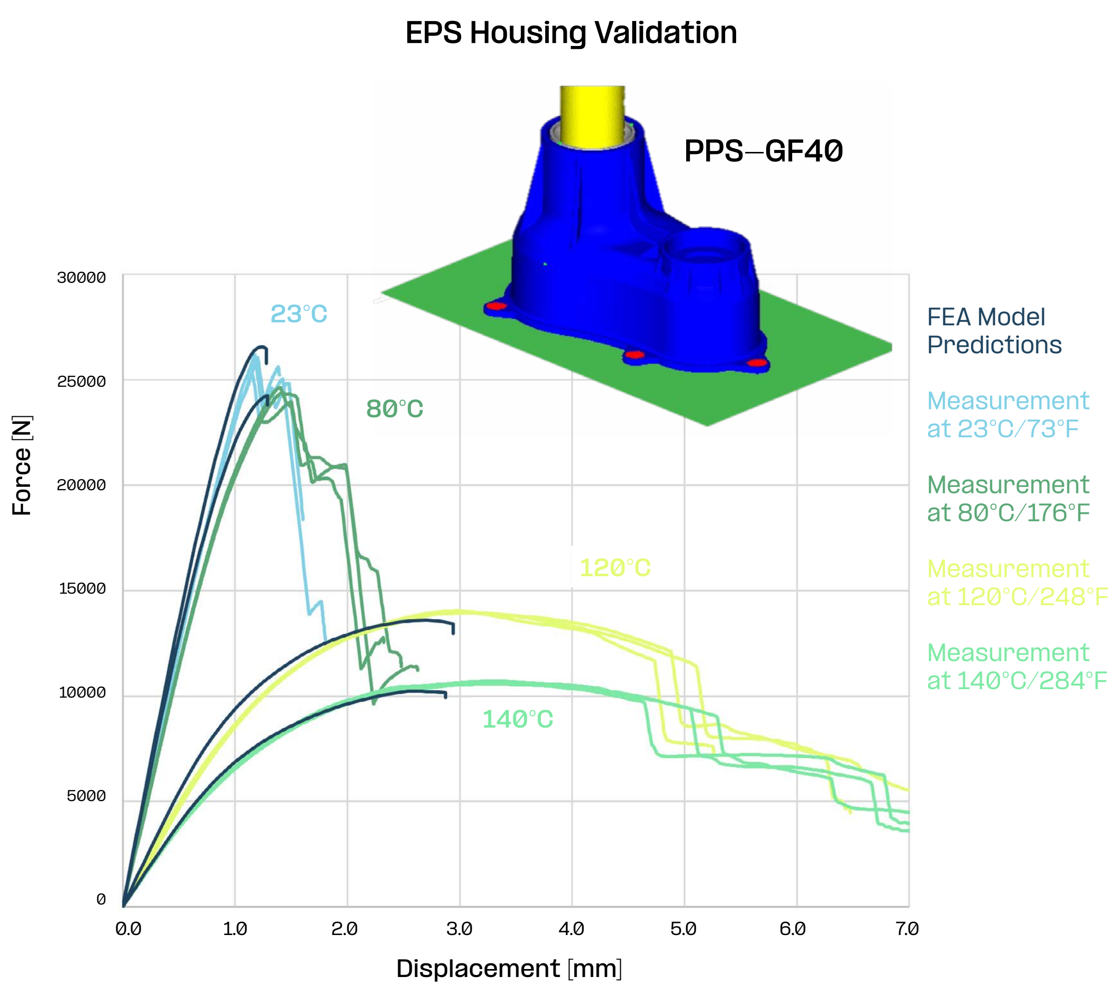


FEA Results

Test Results

EPS HOUSING *VALIDATION*

The EPS housing parts, injection molded from our PPS–GF40 material, are loaded in a Zwick Universal Testing Machine, at different temperatures. For all these temperatures we have conducted tensile tests at specimens with various fiber orientations and calibrated Digimat material cards, that we have used in the FEA simulation of these experiments.



In this test, the EPS housing (blue) is fixed to a base plate (dark green). When the test starts the indenter (yellow rod) pushes down on the EPS housing until it fails. Force and displacement on the rod are recorded and shown in the graph. Also, in this use case we observe excellent predictions for part stiffness and part strength, as well as identifying the critical locations where first cracks develop.

CONCLUSION

- Digimat material cards are available for major grades in our portfolio.
- Accurate predictions on a number of demonstrator parts have been shown for numerous material cards, for different grades, and many conditions.
- The material cards also include a strain–based failure indicator, which in practice enables easy and accurate prediction of critical loaded areas in the application.
- Our material cards are available to all users that have access to the Digimat software.

Envalior, a global leader in thermoplastic material science, offers a full portfolio of best–in–class thermoplastic material solutions and global application development support. Through innovation and market–leading sustainable products, we make ideas come to life. We drive progress for a better and more environmentally friendly world. This can only be achieved through deep collaboration with our customers and stakeholders who share the vision for a better future. Our products and innovative pipeline of new materials are sustainable, purposeful and circular and are designed to make the world a better place. Many challenges lie ahead to be tackled in an evolving environment, but we are confident our high performance, safe and lightweight solutions will shape the future in new mobility, advanced electrical and electronics, and many other industries