Use Case: Crash

VALIDATING HIGH-STRAIN-RATE MODELS FOR CRASH/ IMPACT SIMULATION

Envalior

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SUMMARY

For accurate prediction of part strength and absorbed energy, Envalior has created Digimat material cards from high–strain–rate tensile experiments. Digimat material cards model anisotropic viscoelastic/viscoplastic material behavior. In addition, a failure indicator is included in the material card, which allows the user to identify critical locations quickly and easily by post–processing of the finite element analysis (FEA) results.

INTRODUCTION

Predictability is key when designing load–bearing components. Predictability reduces development time, enables first–time–right design and ensures part performance in service.

While most tensile bar experiments are performed at low–strain–rate and are used for static load cases, this Use Case focuses on modeling the high–strain–rate anisotropic stress–strain behavior of injection–molded glass fiber–reinforced plastics. These types of measurements are required for accurate evaluation of crash and drop–test performance.

USING RESULTS FROM MATERIAL *PROPERTY MODELING IN THE FEA SIMULATION & COMPARING SIMULATION RESULTS TO AN EXPERIMENTAL VALIDATION.*

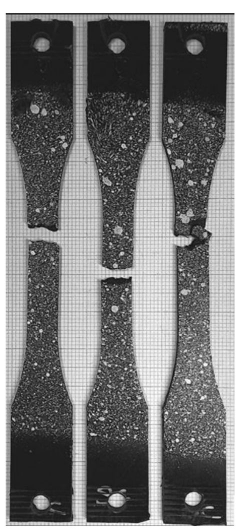
ELEMENTS
MATERIAL PROPERTY MODELING

Proper modeling allows for guided design while reducing the number of iterations. Fiber–reinforced plastics are often highly anisotropic, significantly affecting the properties. Therefore, local fiber orientation and the resulting properties need to be considered.

Advanced modelling tools allow successful prediction of:
- Fiber orientation
- Mechanical behavior of the material depending on fiber orientation
- Part performance: stiffness; strength; crash; noise, vibration, and harshness (NVH); dimensional stability; creep; and fatigue

Most tensile tests are conducted at a strain rate of approximately 0.001 s^{-1}. However, at higher strain rates the stress–strain behavior of thermoplastic materials changes significantly, showing an increase in stiffness and strength. Therefore, using tensile bars milled from injection–molded plaques at different orientations (0, 45, and 90°), stress–strain tests were conducted in the range of 0.001 to 100 s^{-1}.

Accurate strain evaluation in tests conducted at high strain rates is not trivial. The current state–of–the–art is to use the so–called digital image correlation method. This is a non–contacting image–based technique that requires the specimen surface deformation to be recorded with a high–resolution, high–frame–rate camera. Image analysis software is used to evaluate the strain field from these images. To attain accurate results, one needs a specimen surface with a pattern with unique features. This is created by spray painting, using layers of black and white paints (see Figure A below).



Based on the high–strain–rate experiments, we developed Digimat material cards, modelling the anisotropic viscoelastic/viscoplastic material behavior. Digimat is a multiscale material modelling platform using micromechanics and applied for accurate modelling of composite materials. The material cards can be shared with our customers and are compatible with all major FEA software tools.

Figure A

EXPERIMENTAL *RESULTS AND ANALYSIS*

To demonstrate the accuracy of our material cards in predicting the crash performance of injection-molded parts we have molded and tested our x-rib beam demonstrator part.

Various test samples are injection molded with Akulon® K224-PG6 and Akulon® K224-PG8 and tested in a dynamic three-point bending set-up.

Our x-rib beam demonstrator part was mounted on cylindrical supports. A hemispherical impactor was dropped onto the x-rib bead from a height of 0.5 m.

In Figure B, we show the failed beams of Akulon K224-PG8 after testing. Failure starts on the bottom flange which is loaded in tension. For specimen #4 and #6, failure occurs in the center, for specimen #5 it occurs a bit off-center.

Experimental Validation

Specimen #4

Specimen #6

Specimen #5

VISUAL COMPARISON
The tested parts show excellent agreement of the failure location: initiation is on bottom flange loaded in tension, as also the simulation predicts.

Figure B

FEA MODEL
SET–UP AND RESULTS

We have created an FEA model of the test setup. A detailed FEA geometry was constructed based on mold dimensions. The Digimat anisotropic material cards with high–strain data are essential to correctly describe the material's properties.

The simulation reveals the highest tension at the bottom of the geometry. Its magnitude becomes so high that part breakage occurs. As can be seen in the failure indicator contour plot (Figure C, below), the critical areas (values higher than 1.0) on the bottom of the flange correspond well to the observed failure locations in the tested parts.

FEA Model Set–Up & Results

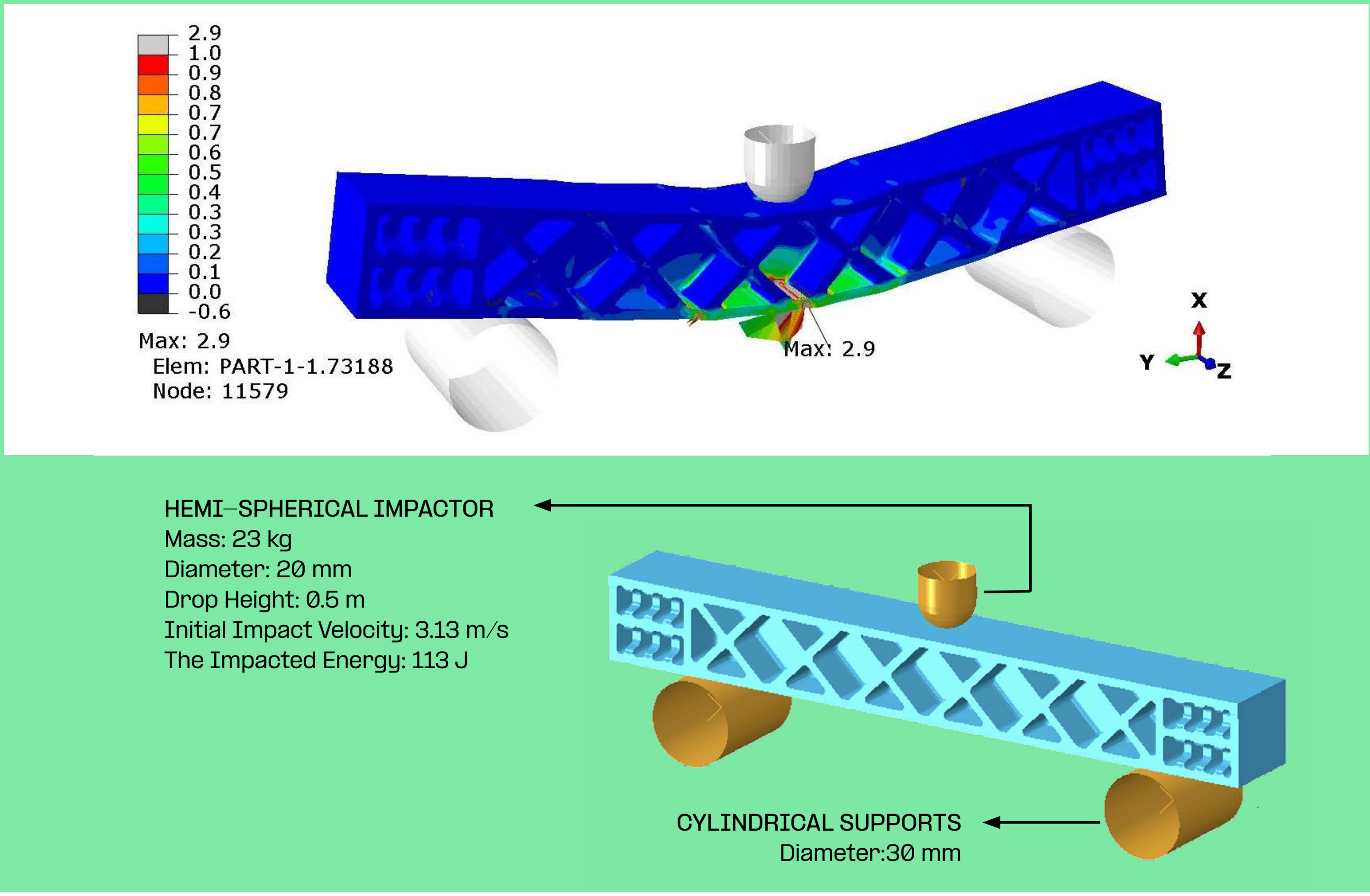
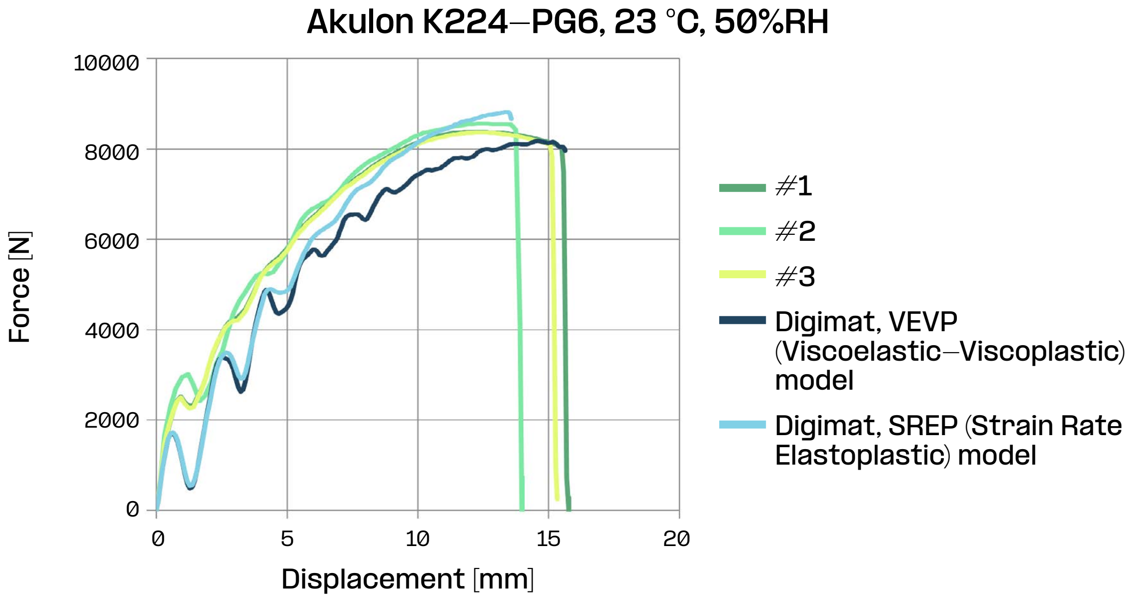


Figure C

CORRELATION
OF FORCE

Excellent correlation of force–displacement curves for both Akulon K224–PG6, and Akulon K224–PG8 shown in Figure D.



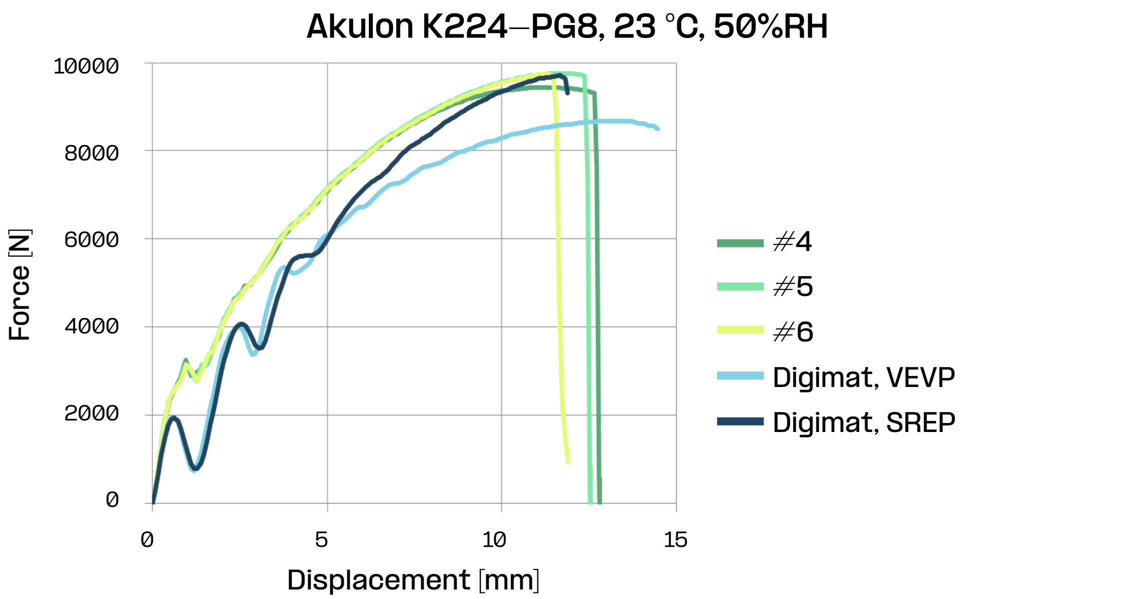
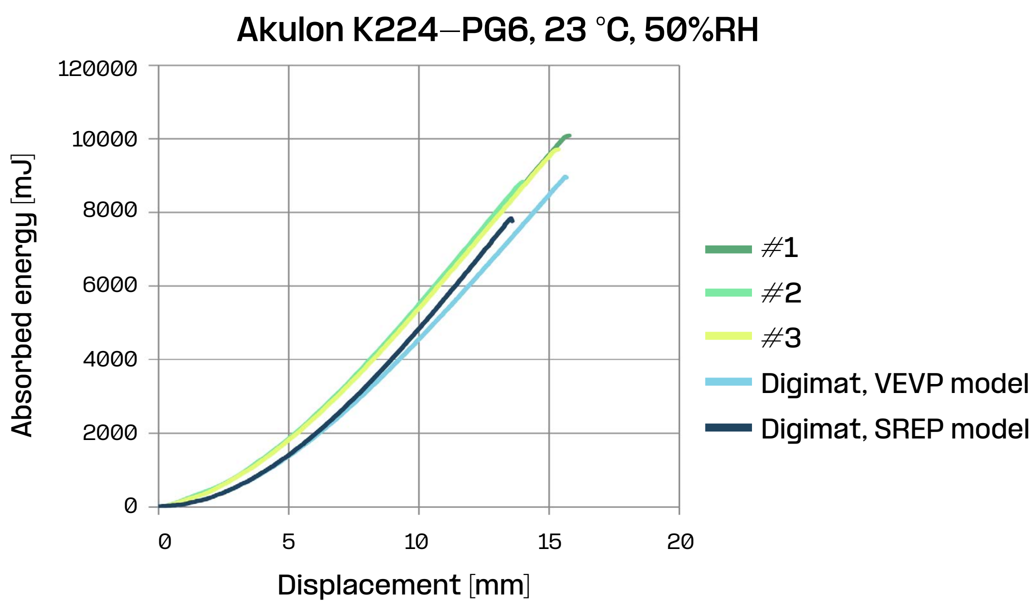


Figure D

CONCLUSION: Excellent correlation of forced–dispacement curves for both Akulon K224–PG6, and Akulon K224–PG8.

CORRELATION
OF ABOSRBED ENERGY

Excellent correlation of absorbed energy–displacement curves for both Akulon K224–PG6, and Akulon K224–PG8 shown in Figure E.



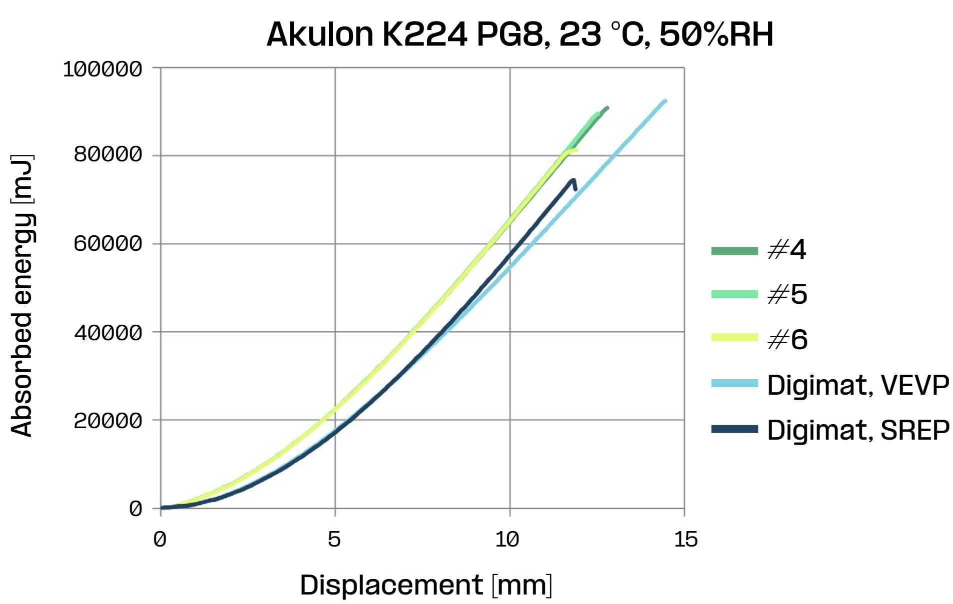


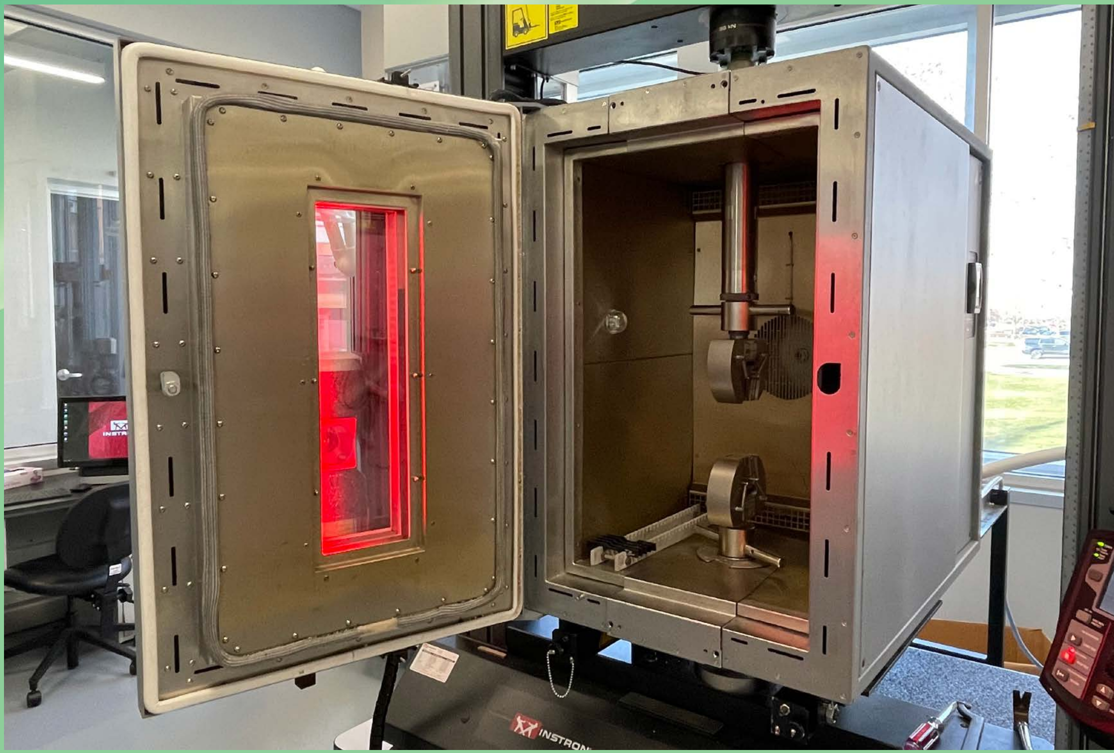
Figure E

CONCLUSION: Excellent correlation of absorbed energy–displacement curves for both Akulon K224–PG6, and Akulon K224–PG8.

CONCLUSION

Our validation study on our x–rib beam demonstrator part shows an excellent agreement between experiments and simulations, both for initial crack location as well as quantitively for force–displacement and absorbed energy. This proves that our material cards enable our customers to attain accurate simulation results.

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.



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