Use Case: Gears

ACCURATELY PREDICT *STRENGTH AND LIFETIME OF INJECTION-MOLDED STANYL® GEARS*

Envalior

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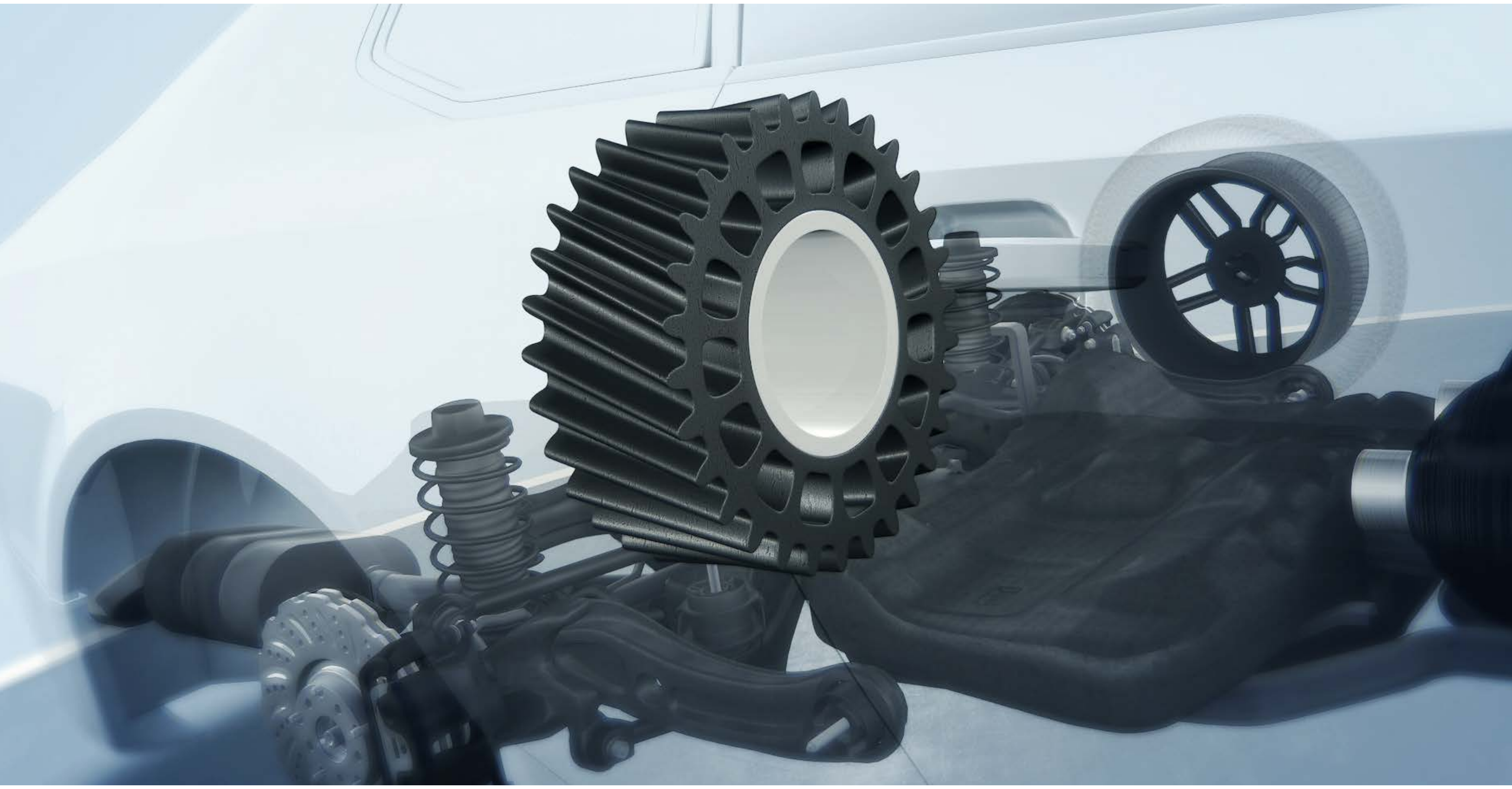
SUMMARY

Predictability is key when designing load–bearing components. Predictability reduces development time, enables first–time–right design and ensures part performance in service. In this use case we focus on the prediction of the most important failure modes of plastic gears—static overload, root stress fatigue and wear.

Stanyl® is a PA46 based polymer which, due to its chemical composition, is intrinsically very suitable for high load (strength and tribological) and high temperature gear applications. We have developed insights based on in–house dedicated test setups in combination with fundamental polymer mechanics and finite element simulations. These insights enable us to apply our expertise and, based on the outcome of simulations, recommend design improvement proposals.



INTRODUCTION

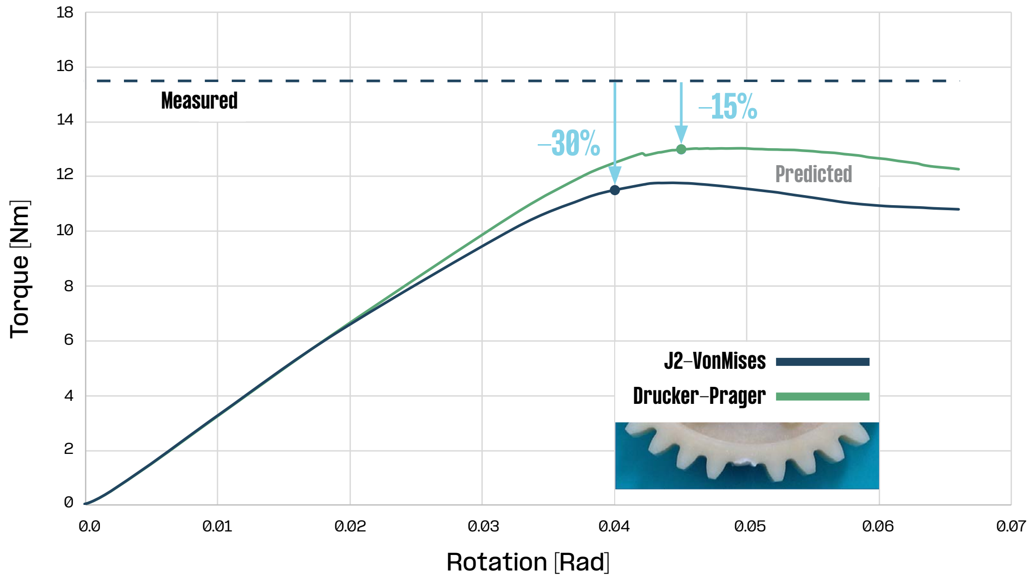
Depending on the application and gear type, a thermoplastic gear can potentially suffer from several failure modes if employed or designed incorrectly. By performing simulations, one can evaluate a design proposal and modify it if needed. This showcase addresses static overload, dynamic root stress fatigue and wear.

Stanyl offers excellent fatigue resistance and long–wearing performance across a large temperature range. However, all the failure modes will accelerate at higher temperatures. Therefore, a fundamental understanding of these processes is crucial.

PERFORMING EXPERIMENTS, *CREATING FINITE ELEMENT ANALYSIS MODELS, AND COMPARISON BETWEEN BOTH*

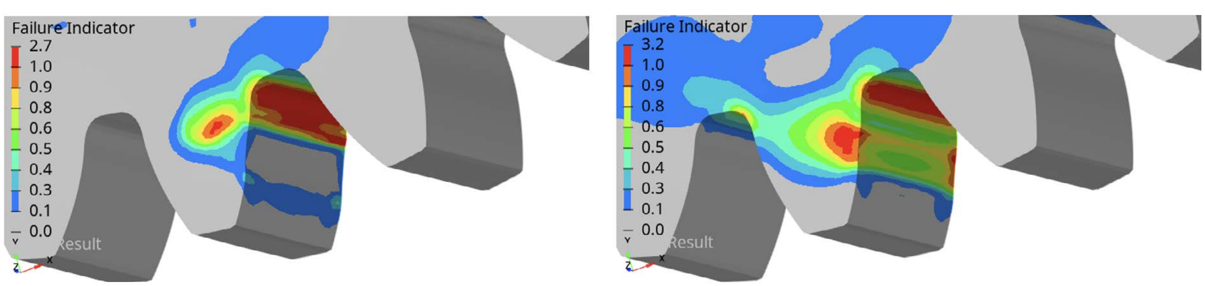
STATIC OVERLOAD

Experimental method: We determined the critical static torque of a gear by increasing the static load until the gear broke. This is represented by the blue dotted horizontal line in the below graph.



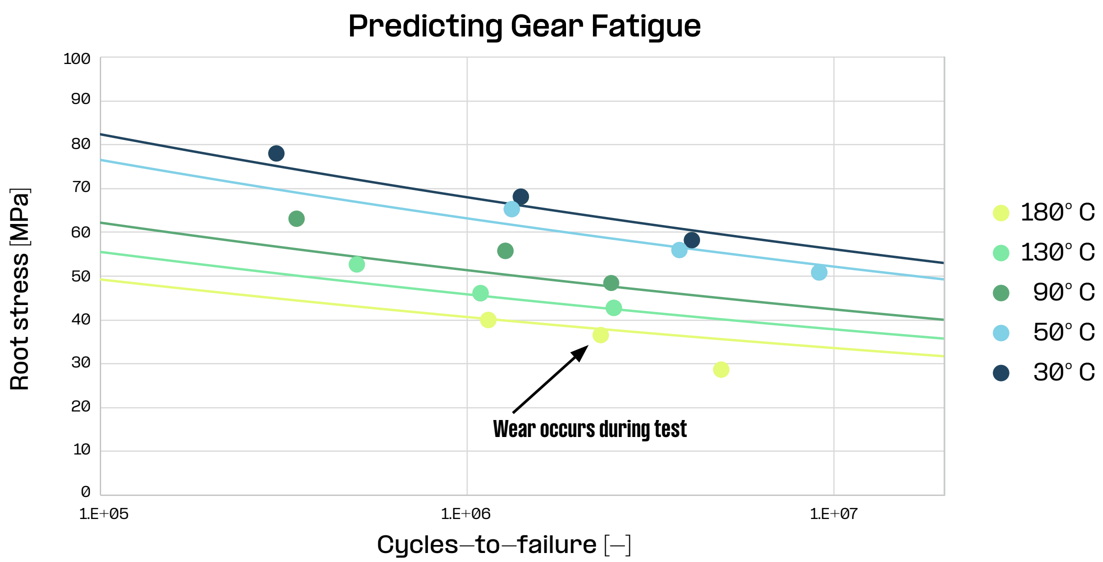
FEA model: Anisotropic material models, such as the standard J2–VonMises (blue line) or the more advanced pressure dependent Drucker–Prager (green line), are both combined with fiber–orientation predictions from injection molding simulations. Both are used to obtain highly accurate static failure load predictions. With these models, we were able to compare the CAE simulations to the experimental measurements.

Conclusion: Due to the pressure dependency, the Drucker–Prager model shows the best correlation with the measurements, which can be improved further with increasing pressure dependency.



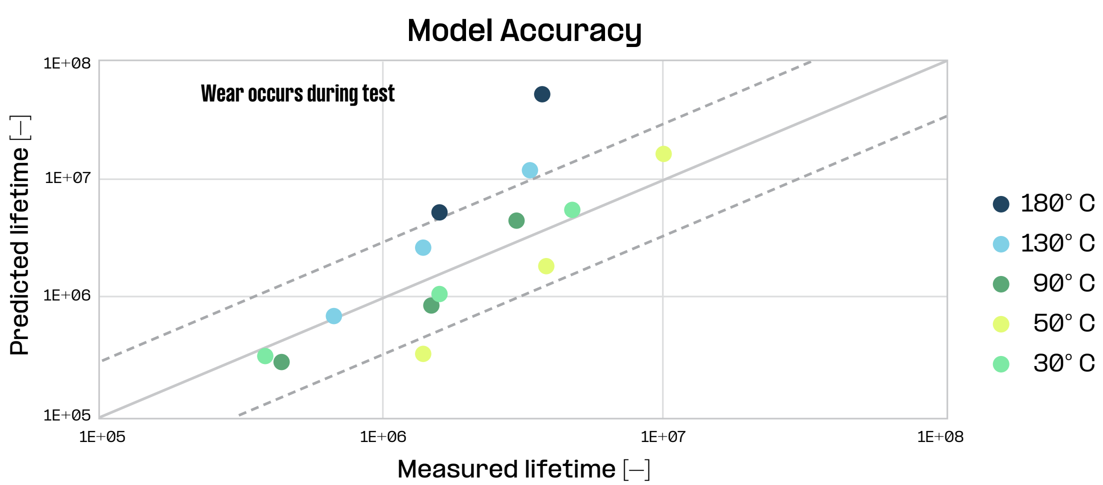
ROOT STRESS *FATIGUE*

Experimental method: Based on hundreds of tensile fatigue measurements at different loads and temperatures, a mechanistic model describing the dependence on stress (slope) and on temperature (vertical shift) of the lifetime of a gear can be predicted, based on a single gear fatigue measurement. See below graph.



FEA model: Subsequently we can use this model to predict, for any gear, failure for any temperature and any load. Combining detailed FEA simulations and measured results the measured–vs–predicted cycles are within an accuracy factor of 3, as displayed on the graph below.

Conclusion: The model can predict the lifetime well over a range of temperatures.

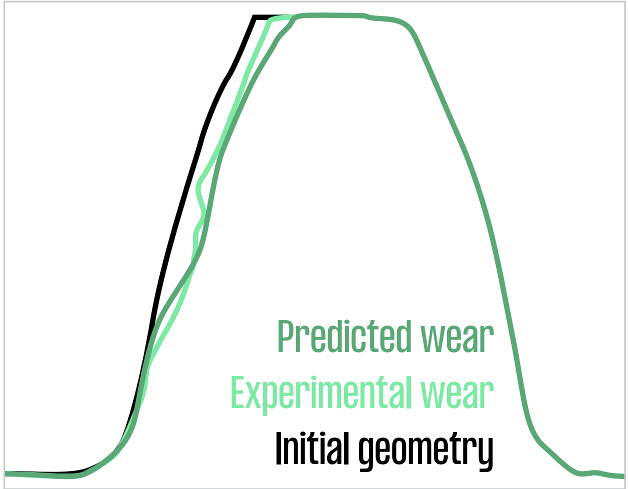


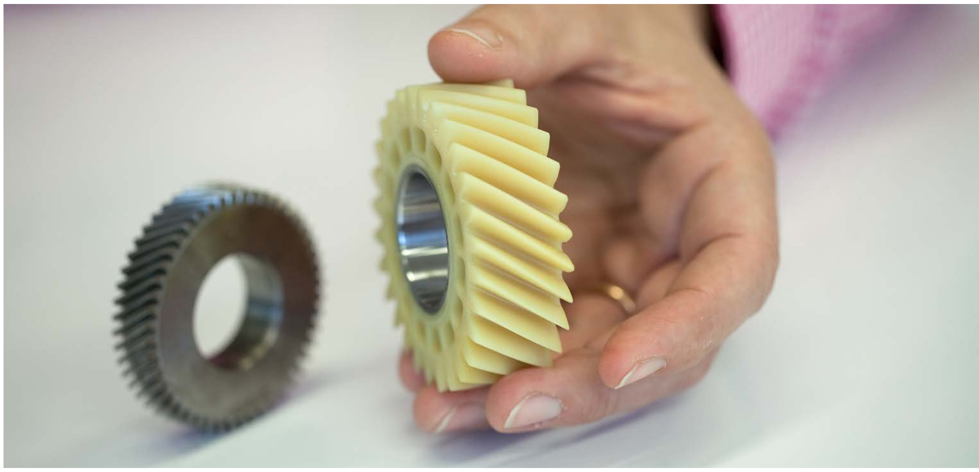
WEAR

Experimental method: In a dedicated experimental setup, the wear of two rolling discs over time has been studied for different contact pressures and rotation speeds, resulting in wear factor. Also, the wear of a gear was measured after a durability test. This was assessed in detail using a 3D microscope.

FEA model: By obtaining wear factors from a representative tribological setup in terms of fiber orientation, sliding speed, contact pressure and temperature as input, we can calculate the wear of a gear over its life–time, using contact pressures and sliding speeds obtained from detailed FEA models. See the below graph.

Conclusion: We can accurately predict the height loss at the flank of a gear as a function of the number of load cycles. Further improvements of the simulation could be obtained (e.g. by mesh refinement).



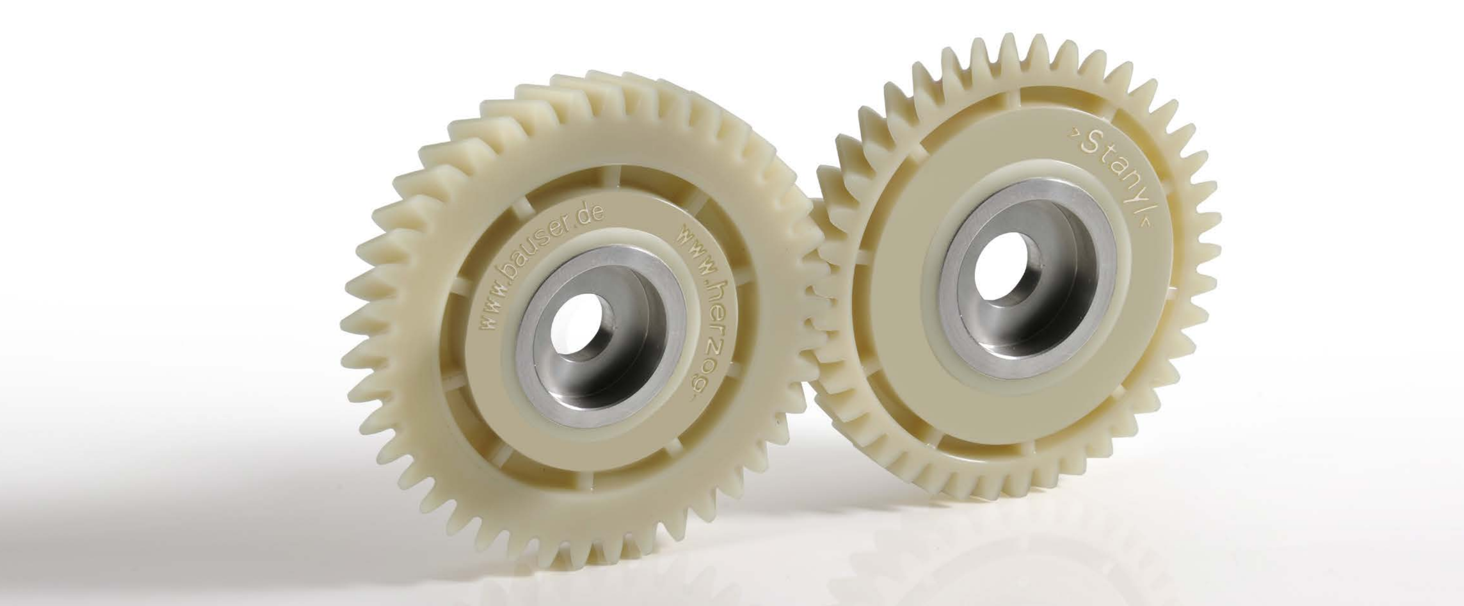


BOTTOM LINE

Stanyl combines intrinsically high strength and ductility at high temperatures with very high wear resistance and low friction behavior without adding additives. This combination makes it an excellent material of choice for high-demanding lightweight gear applications. In addition, Envalior's advanced predictive tools for static overload and durability lead to shorter development times and lower overall costs.

Envalior, a global leader in thermoplastic material science for automotive gears and actuation systems, offers a full portfolio of best-in-class thermoplastic material solutions and global application development support. Because of Envalior's commitment to quality and application development expertise, each year approximately 100 million Stanyl® gears are used in more than 40 million automotive actuators!

Besides gears for automotive applications, Envalior is also a leader in material solutions for appliance gears. As manufacturers increasingly replace metal gears with plastic ones, they are realizing the benefits of shorter and more cost-effective production cycles. as well as products that are more durable and that have better noise, vibration, and harshness (NVH) characteristics.



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