Material Data Determination and Crash Simulation of Fiber Reinforced Plastic Components

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Summary

The quality of the mechanical simulation of reinforced thermoplastics depends on very complex input parameters regarding the complex material behaviour. At the beginning of the simulation chain the material data has to be determined in different mechanical tests (tension, compression and shear, different fibre orientation to load direction, etc.). After the injection moulding simulation the calculated fibre orientation has to be mapped to the structural FE mesh. For the structural simulation a combination of the material model MAT108 and MAT54 was used to simulate the orthotropic, load case sensitive material behaviour.

Keywords

anisotropic material properties, input data for material models, part_composite

Introduction

Short fibre reinforced thermoplastics are used in a wide range of industrial applications. Especially in the car industry the material has to fulfil high requirements on the mechanical loads and durability. For using these reinforced materials in highly stressed parts the mechanical properties has to be known. The components in automotive structures are focus of special interest, in particular for problems in passive safety at a car crash.

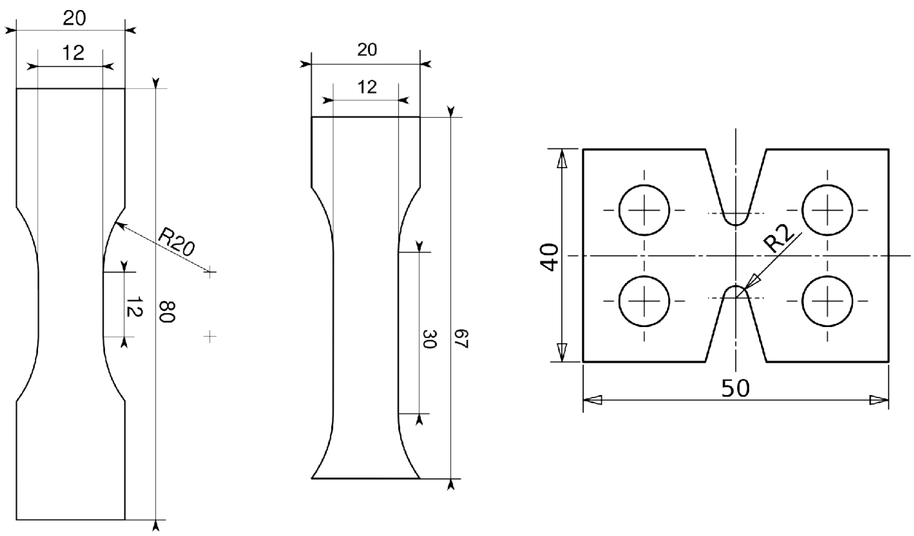


Fig. 1 Specimen geometries for tension, compression and shear tests (left to right).

Experimental Methodolgy

To determine the mechanical properties of this material class tests at different stress states, specimen orientations to the flow direction and loading velocities (strain rates) are performed. All quasistatic tests are performed on a uniaxial testing machine (Zwick Z020). For the tests at higher strain rates ($\dot{\varepsilon} > 1 \cdot 10 - 3\, s^{-1}$) a servohydraulic high speed testing machine was used (Zwick HTM 5020). To determine the influence of the fibre orientation plates with an dimension of 80 x 80 x 2.5 mm were manufactured by injection moulding. Out of these plates the different specimens were milled out longitudinal and lateral to the flow direction. The different specimen geometries for the stress states are shown in Fig. 1.

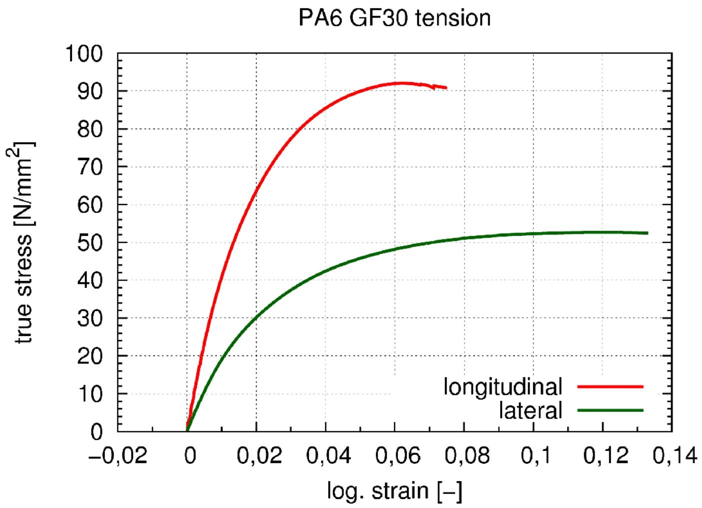


Fig. 2 Quasistatic stress-strain behaviour of a PA6-GF30 at tension load lateral and longitudinal to the flow direction of the injection moulding process

At all tests the strains were measured by an optical measuring system. This system is based upon the principle of the grey scale correlation (Vic2D, Limess GmbH) and permits the determination of a 2D strain field on the surface of the specimen. Out of the strain data the calculation of the Poisson's ratio is possible.

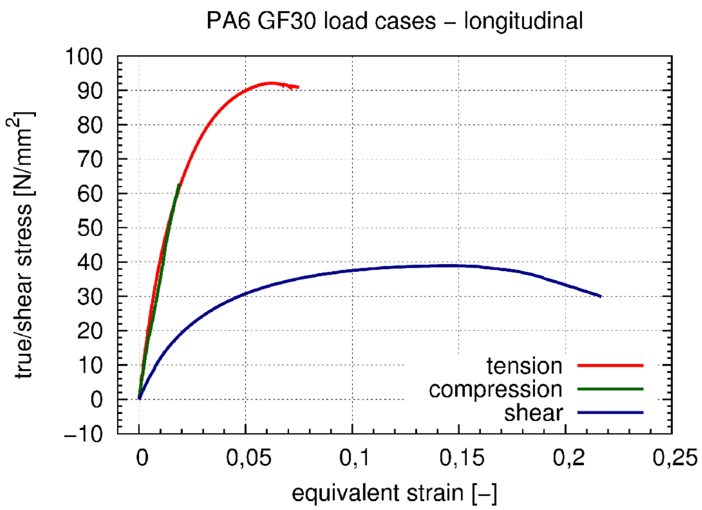


Fig. 3 Stress-strain behaviour of a PA6-GF30 at different load cases longitudinal to the flow direction of the injection moulding process

Comparing to non reinforced plastics the investigated reinforced material shows a highly complex mechanical behaviour. Due to the fibre orientation the properties depend among other things on the moulding process (Fig. 2) and the load case (Fig. 3). So, besides the structural simulation, the simulation of the moulding process to determine the fibre orientation has to be performed. For the structural simulation all mechanical properties of the anisotropic material have to be determined. Specially for the crash simulation theses properties have to be researched for different strain rates – from quasi-static up to high dynamic tests (Fig. 4). For the determination of the mechanical properties of reinforced thermoplastics new methods were developed to provide exact data for the FE simulation.

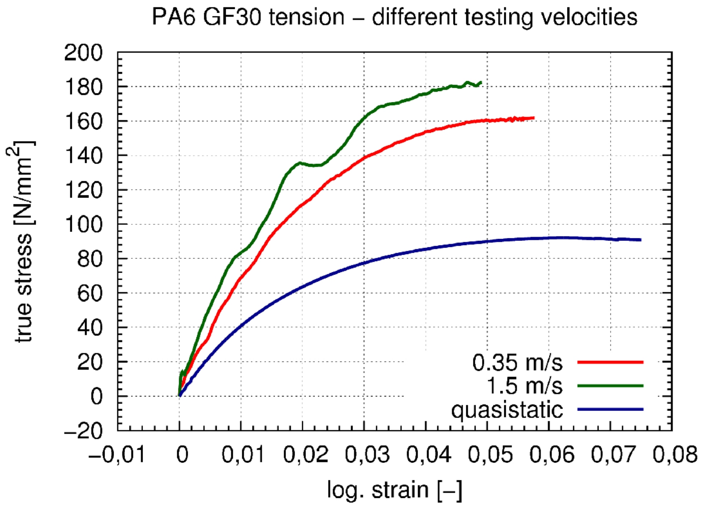


Fig. 4 Stress-strain behaviour of a PA6-GF30 at tension load longitudinal to the flow direction at different loading velocities

Finite Element Simulation

Also the simulation methods (Fig. 5) starting from the simulation of the moulding process, mapping the fibre orientation to structural simulation and simulating the plastic part at different load cases were researched. The anisotropic character of these materials demands the usage of more complex material models. So, the quality of the simulation results using different material models are researched by comparing the models MAT24, MAT184 (SAMP) and MAT108/54. The most interesting model is the last one using the part composite approach in LS-Dyna to merge the models MAT108 (orthotopic behaviour) with MAT54 (load case sensitive failure). The principle schema of this combination can be seen in Fig. 6.

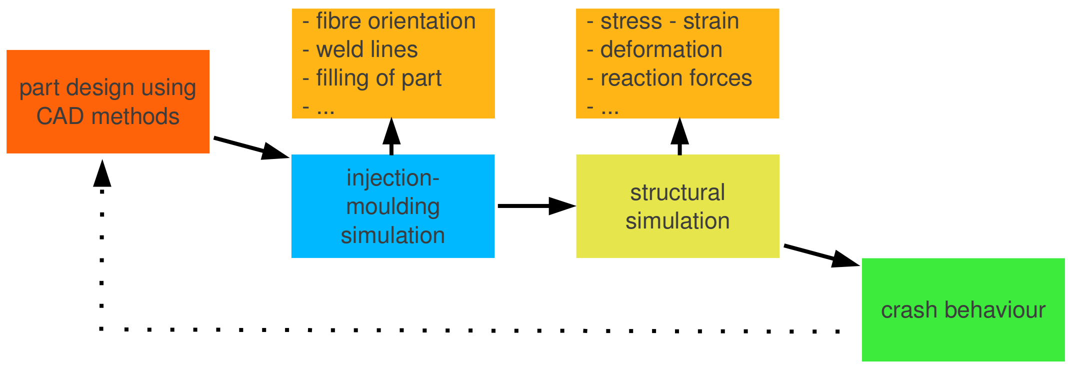


Fig. 5 Simulation chain from first design to final part

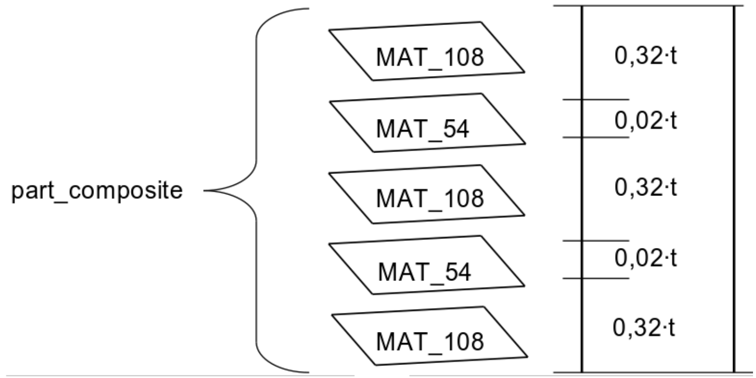


Fig. 6 Principle schema of the combination of the models MAT108 and MAT54 in LS-Dyna using part_composite

At the end the developed simulation method and the material input data from mechanical tests were approved by the simulation and testing of a real moulded part (Fig. 7) in bending load. Comparing the deformations of experiment and simulation the combinational model MAT108 /MAT54 shows the best results (Fig. 8).

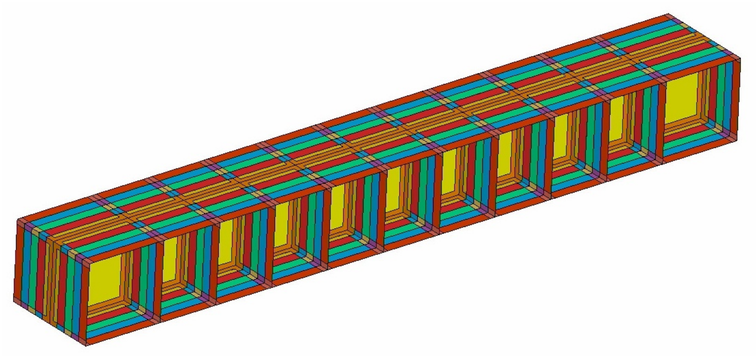
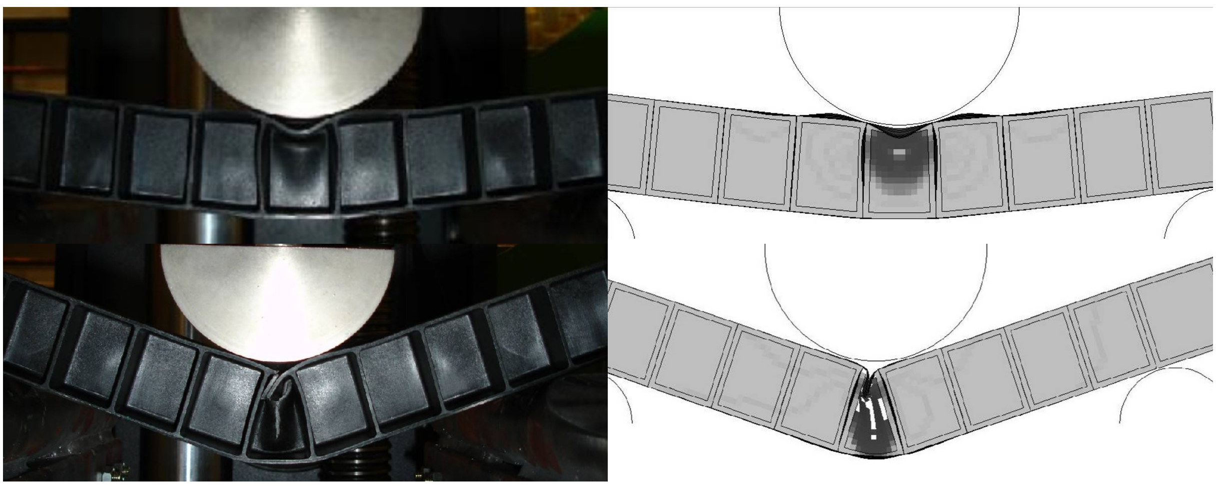


Fig. 7 Real plastic part (FE mesh) for validation of the simulation at bending load



Experiment Simulation

Fig. 8 Comparison of experiment and simulation for the material model MAT108/Mat54 (cross head displacement: top 15 mm, bottom 40 mm)

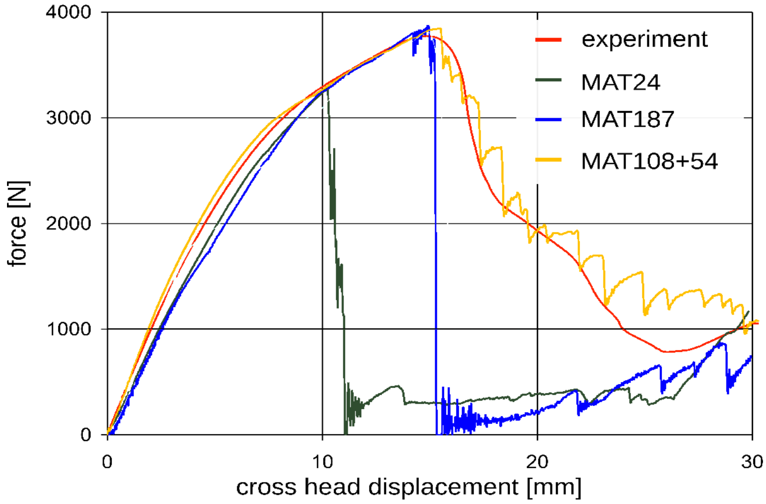


Fig. 9 Load curve of the bending test and the simulations using different material models

Comparing the load curves of all investigated models (Fig. 9) the MAT108/MAT54 shows the best fit to the experimental data during the loading of the structure and at the failure of the material.