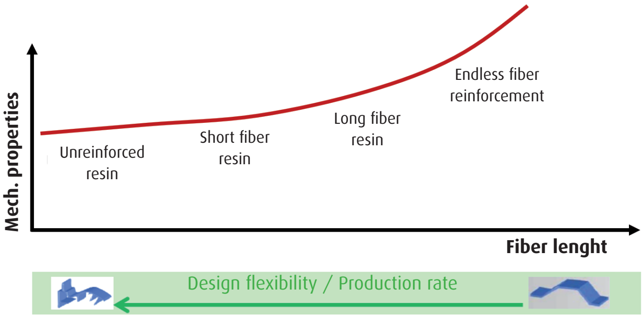
Predicting composite forming

Introduction

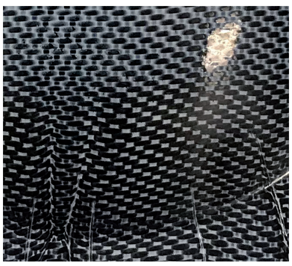
Design flexibility and production rate of applications with thermoplastic (TP) composites are directly related to the type of fiber reinforcement. From short fibers to endless fibers, design flexibility and production rate are decreasing. In combination with ever more complex geometries, the need for **predictive engineering** methods rises.



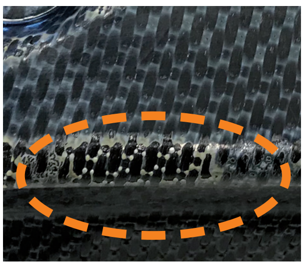
Challenges

An optimized composite forming process is generally more difficult to achieve for a more complex geometry, which includes features such as **double curvatures, deep drawing depth or small radius at corners**.
Two examples of problems occurring in a non-optimized process are shown below:

Wrinkling



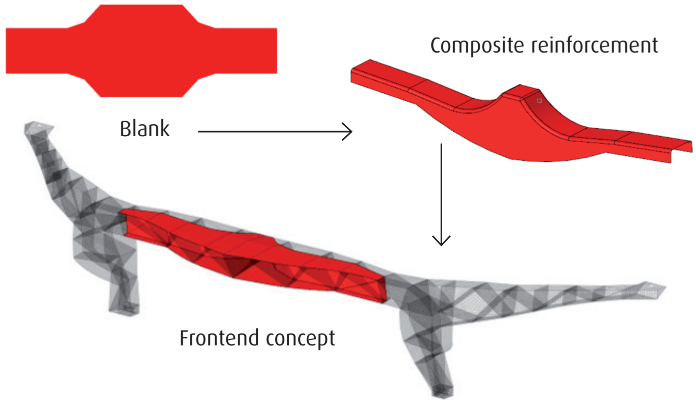
Resin squeeze out



An efficient manner to handle the optimization of more complex geometries, for fiber reinforced TP composites, is the use of predictive engineering methods, such as **computational simulations**.

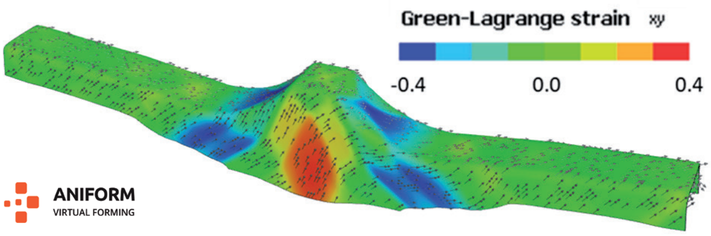
Application: Front-end module concept

The automotive front-end component shown below, serves as the subject for this case study. The TP glass fiber UD laminate (indicated in red) is an integral part of the total structure to achieve the required performance.
In this case, the composite forming of our design is simulated with the software AniForm.



Prediction: Shear angle and wrinkling

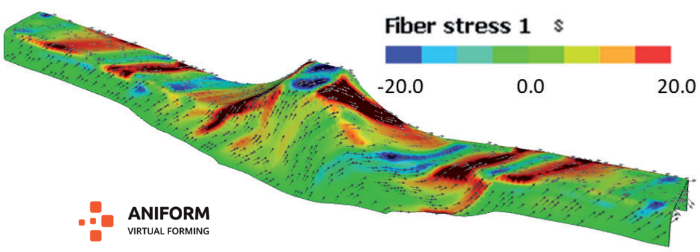
The material's shear deformation, resulting in a re-orientation of the fibers, can be regarded as one of the main drivers for wrinkle formation. Without going into detail here, the shown shear deformation result can be interpreted as probably no to only moderate wrinkling. With the help of simulations, fewer conservative steps are required to prevent severe wrinkling. The simulation tool thus



increases the design flexibility. Wrinkle formation depends upon the fine balance of the composite's resistance to shear, slip and bending deformations. Therefore, accurate modeling of these mechanisms is essential. (See section "How it works" for more background information.)

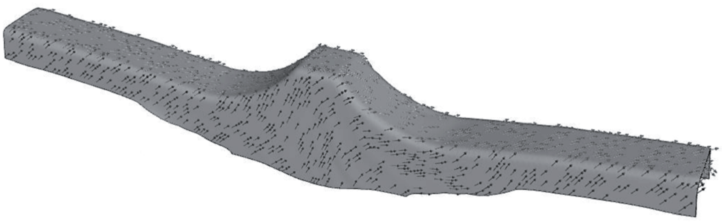
Prediction: Fiber stress and resin squeeze out

When pulled tightly over a corner, the fibers in the composite tend to be separated from the resin. High tensile fiber stress in a corner, predicted by a simulation, is a good indication of resin squeeze out. Further virtual optimization of geometry, lay-up and process conditions will reduce the likelihood of resin squeeze out before any real part has been produced.

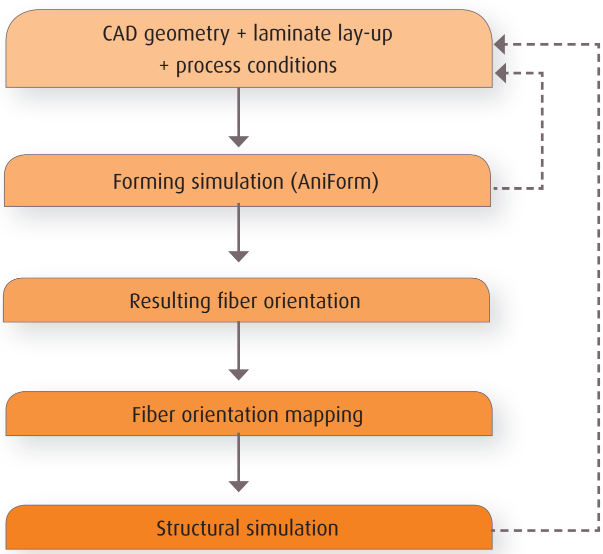


Integrative structural simulation

After forming, the fiber orientation shows significant local differences, which can influence the final mechanical performance of the part in the front-end module application.



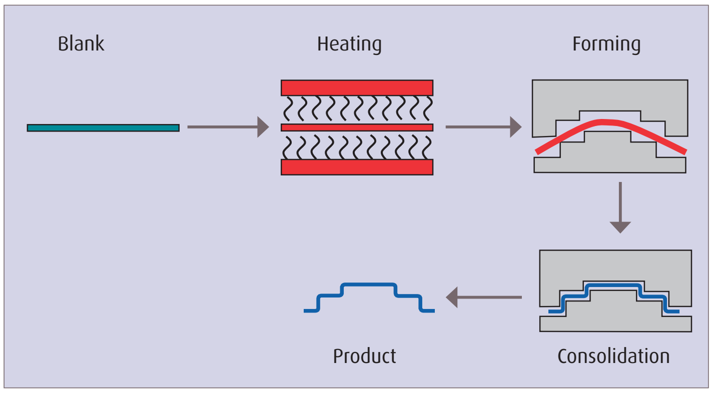
The performance of the composite component with imperfect fiber orientation can be optimized according to the following scheme. The small loop represents the iterations for the forming optimization, whereas the large loop represents the final optimized performance.



How it works

Composite forming process

The process starts with the laminate, which is first heated and then pressed into shape by the punch. As a result, the combined in-plane (intra-ply shear and inter-ply slip) and out-of-plane (bending) deformation modes allow the laminate to be formed into the desired shape.



Predictive engineering: Forming

Finite Element (FE) forming process simulations using the AniForm software, allows to model all relevant aspects:

Ply-modeling
- Constitutive ply material model at forming temperature.
- Individual plies modeled by shell elements.
- Ply-to-ply contact including adhesion.

Boundary conditions
- Initial sag of laminate due to gravity.
- Rigid tools, moving at defined speed.
- Evolving tool-to-blank contact surface which allows slip.
- Tensioned laminate due to gripping system.

Deformation mechanisms
- Intra-ply shear, leading to locally increased ply thickness.
- Inter-ply slip.
- Ply bending.

The isothermally modeled process neglects the heating and consolidation steps. However, the material characterization is done at the forming temperature.

Our achievements

- Maximising production quality and speed
- Efficient performance optimisation of complex geometries
- Prevention of wrinkling
- Avoidance of resin squeeze