FAKULTA MECHATRONIKY, INFORMATIKY A MEZIOBOROVÝCH STUDIÍ TUL

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FAILURE PREDICTION OF FIBER COMPOSITE MATERIALS

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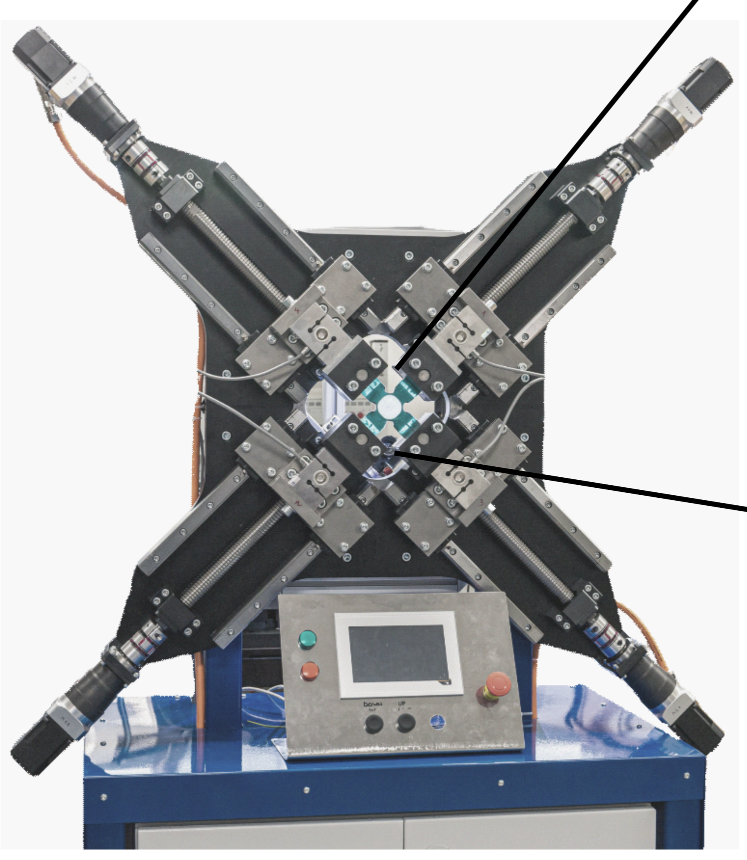
Biaxial cruciform test

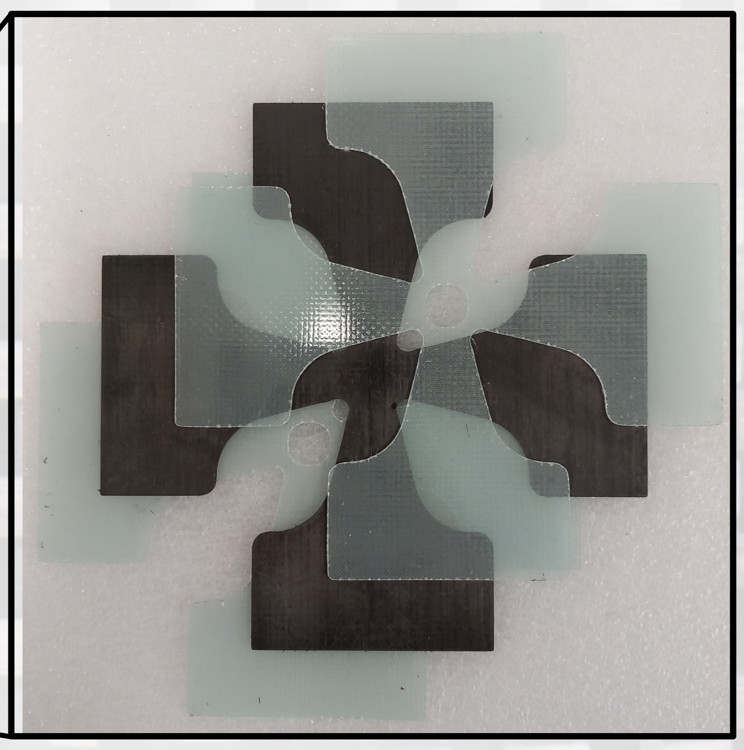
Different approaches can be employed to validate safety limits of parts from fiber composites obtained from numerical simulations. Traditionally, this involves proto-typing and conducting experiments to simulate real-world conditions. Alternatively, biaxial cruciform tests can be employed, following these steps:

1. Evaluate the critical stress state in the simulation.
2. Manufacture a cruciform specimen using desired material and layup.
3. Induce the critical stress state in the specimen by biaxial test machine.
4. Compare failure stresses and strains obtained from both the test and simulations

Advantages:

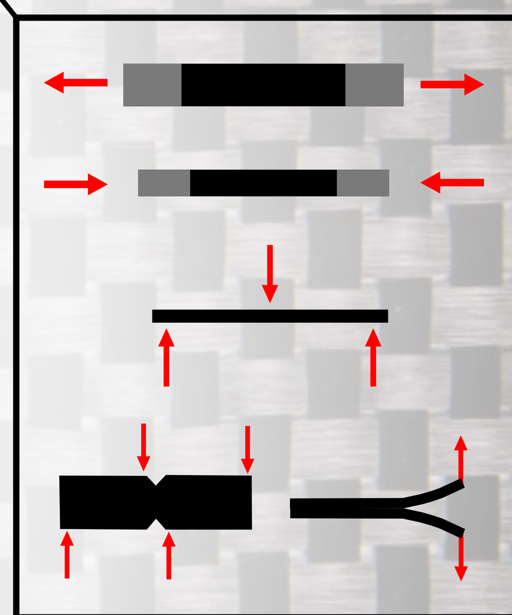
- Specimens made from flat laminates
- Relatively fast specimen preparation, measurement and evaluation.

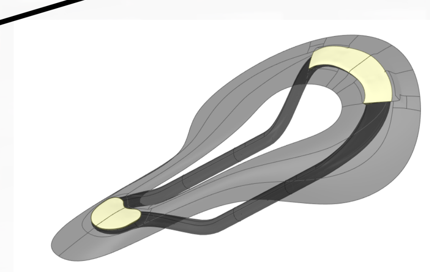




Material properties

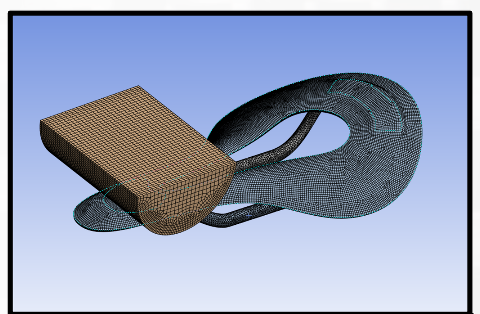
There are nine constants in total that are required to fully define the stiffness matrix for an orthotropic linearly elastic material. These constants consist of three Young's moduli, three shear moduli, and three Poisson's ratios. In addition to these material properties, the determination of strength is crucial for failure analysis. The process of obtaining these properties typically involves a combination of mechanical tests, micromechanical models and educated guesses.





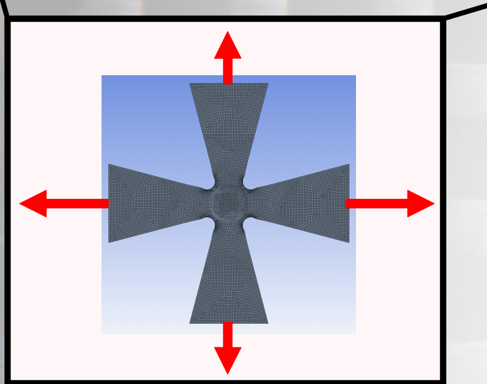
CAD (re)design

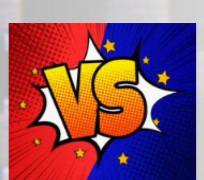
Numerical model



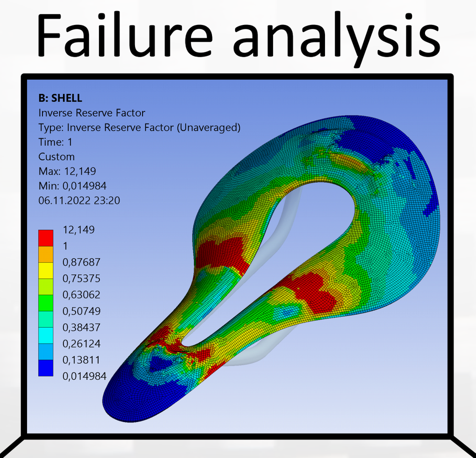
DESIGN LOOP OF COMPOSITE PART

Numerical model validation





Failure analysis

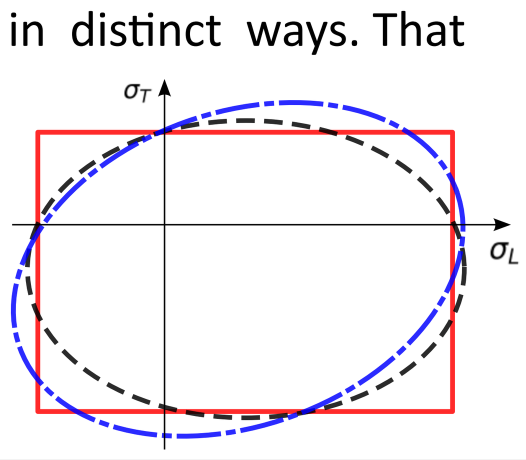


Prototype experiment

Prototype of the part has to be manufactured to be able perform experiment simulating conditions in real environment. In case of fiber composite part, this includes production of molds, which is usually the most expensive stage of manufacturing procces. Additionally, specialized test rigs with comprehensive measurement instrumentation are required. The significant advantage of this approach is the robust validation of simulations, leading to trustworthy results. However, it comes at the expense of high costs.

Falilure criteria

Various failure theories can be used to evaluate failure based on computed stresses and strains in simulations. Various failure criteria predict failure in distinct ways. That is the reason why failure prediction is not so straightforward as in the case of isotropic materials.



Numerical model

Realistic numerical model heavily depends on the accuracy of its input data. Numerous material parameters have to be determined and not all of them can be usually measured. This introduces the uncertainity into the outcomes of numerical models.

Fiber composite materials are usually analyzed using orthotropic linear elasticity. For simulating fracture behavior, a progressive damage model can be used. Additionally, in the case of thin laminates, the plane stress simplification is employed, reducing the number of independent material parameters to five.

$$\begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_x} & -\frac{\nu_{xy}}{E_y} & 0 \\ -\frac{\nu_{xy}}{E_x} & \frac{1}{E_y} & 0 \\ 0 & 0 & \frac{1}{G_{xy}} \end{bmatrix} \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix}$$

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