Design for composite wings with natural laminar flow

**Motivation**

Due to significant changes in society and economy, new concepts with increased economic and ecological efficiency for future aircrafts must be found. One approach is a wing with natural laminar flow, which provides up to 7% less fuel consumption due to reduced friction in the boundary layer. The material CFRP offers a high lightweight potential due to high specific weight and stiffness values and also possess highly directional stiffness's for an effective tailoring.

**Global, overall design in multidisciplinary context**

In the DLR-project LamAir, a transonic forward swept composite wing with NLF is developed. The main goal for the department of composite design is the dimensioning of the wing with coupled CFD-CSM calculations. With a CFD calculation, loads on the undeformed wing (jig shape) are calculated and structure response is calculated via FEM, and these deformations are given back for an additional CFD calculation. This iterative process leads to an aeroelastic equilibrium and a flight shape, where the aircraft will operate most time during operation. With aeroelastic tailoring, the structure deformation is adjusted to the aerodynamic requirements.

**Detailed design for wing upper cover**

In the project LaWiPro – Laminar Wingshell Production, design concepts for an enhanced wing upper cover concerning manufacturing uncertainties are generated. Besides the classical design criteria as strength, stability and damage tolerance, aerodynamic criteria, especially waviness, must be fulfilled too and are considered in the design process.

The concepts include newest cognitions about spring-in calculation and compensation as input for an integrated design and also a predeformation in toolings for an optimal flight shape is considered. Undertaken investigations lead to an upper cover with integrated stringers and rib caps, which allows a shorter and easier assembly process of the wingbox. This concept allows a parallel proceeding during production. In one process, a few layers are draped around rib-stringer-bay-sized cores for generating first stringer and rib cap plies. Parallel, the outer wingshell part is layed automatically via tapelaying. The parts are combined later for a single autoclave loop. Also new manufacturing concepts with heated tools are developed. The main advantage of this design concept is the missing of rivets on the upper shell, which assists laminarity.

**Multifunctional and multimaterial solutions for NLF-wing leading edge**

As laminarity begins at the leading edge, appropriate designs for this part must be found too. In LaWiPro, a multimaterial design concept is developed, which provides enhanced damage tolerance characteristics. Due to the material mix erosion protection is integrated in the structure. Aerodynamic requirements for small steps and gaps in the interface area are also considered. The shape is optimized for a gapless interface, and additional required stiffness for small deformation is placed via internal structure. This concept also renounces the usage of rivets on the outside. In future projects, additional concepts will be developed and functionality concerning operational questions like de-icing, bird strike or replaceability will be investigated.