Mitteilung

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Aerodynamic Design of a folded Krüger Device for a HLFC Wing

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Over the last decades the cost for fuel for transport aircrafts has increased significantly, further on the need for environmental friendly aircrafts has come into political focus. These issues demand new techniques to decrease the high consumption and costs for energy. The laminar technology offers great potential to decrease the aerodynamic drag during cruise. However the laminar technology is sensitive to surface imperfections and contaminations (e.g. flies), which leads to an undesired transition from laminar to turbulent flow and consequently to unfavorable higher drag. These issues explain why the classical leading edge high-lift system namely slat, as regulary used, does not suit to this technology anymore and Krüger devices become a research area. Especially the shielding of the leading edge of the main element during take-off and landing against contamination is realizable with a Krüger device.

Within this paper the design of a folded Krüger device as developed within the EC project DESIREH [1] for a transport aircraft is presented, a key aspect of this work is the investigation of the trade-off between space allocation of the retracted Krüger device and the aerodynamic high-lift performance. The aim of the aerodynamic Krüger design is to meet at least the high-lift performance of a reference slat device. The targeted aircraft wing is equipped with a hybrid laminar flow control (HLFC) system to artificially generate laminar flow.

The process chain to control the optimization is shown in Figure 1. The process chain covers the geometry generation with the CAD system CATIA V5, mesh generation with the in-house MegaCADs software, and flow computation with the CFD solver FLOWer[2]. The optimization is controlled by the optimization framework CHAeOPS[3] in which the deterministic, gradient-free algorithm SUBPLEX[4] is applied.

The parameterization contains parameters to control the shape and the setting of the Krüger device. Further on within the parameterization space allocation issues (e.g. front-spar clearance, segregation requirements and hinge-point clearance) are considered. The parameterization is defined in a way, that all designs are feasible w.r.t. contamination shielding requirements.

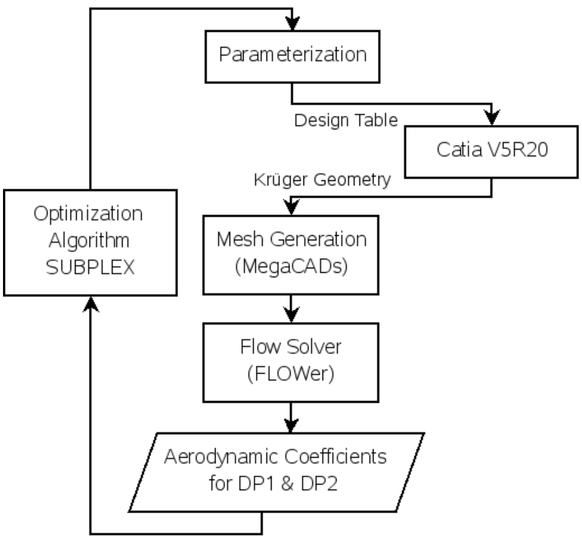

Figure 1: Process chain of the optimization.

Within the geometry generation process the airfoil is extracted in the line-of-flight cut from the three dimensional CATIA model and is afterwards sweep scaled by the front spar angle. The computations are performed in the front-spar-normal system (2D, fully turbulent, turbulence model: SAO, artificial scalar dissipation). The objective function is a blending of two components by the weighted sum approach, i.e. maximum lift coefficient (Ma_{2D}=0.17, Re_{2D} =12x10^6, Reynolds number is based on the front spar normal chord length) and lift coefficient at α=10° (Ma_{2D} =0.21, Re_{2D} =15 x10^6) are equally summed. A penalty term is added to the objective function, if the maximum lift coefficient for the current design is worse than for the initial configuration.

Multiple optimizations were conducted with different spatial clearances of the retracted bull nose towards the upper wing panel. This approach is done to investigate the trade-off between space allocation and aerodynamic high-lift performance of the Krüger device ($c_{l,max}$, $\alpha_{cl,max}$, $c_{l,2D}(\alpha_{cl,max,2D}$-3°)). The optimized shape and setting are presented in Figure 2, Table 1 summarizes the aerodynamic high-lift performance of the investigated configurations. The results clearly show, refer to Figure 3, that with a low spatial clearance of the bull nose in retracted position the high-lift performance can be improved significantly, see configuration V26. By an increase of the spatial clearance for the bull nose the high-lift performance is weakened (bull nose size is decreased). It is recognizable that the decrease of the bull nose size is compensated by an increase of the Krüger panel length, however the aerodynamic high-lift performance can not be maintained, refer to configurations V23 and V24. Within this study it was found out that the aerodynamic high-lift performance is insensitive to the overlap of the Krüger device, but it is sensitive to the deflection angle, the bull nose height, the gap and the smoothness of the curvature distribution at the leading edge and on the upper side of the bull-nose Krüger panel.

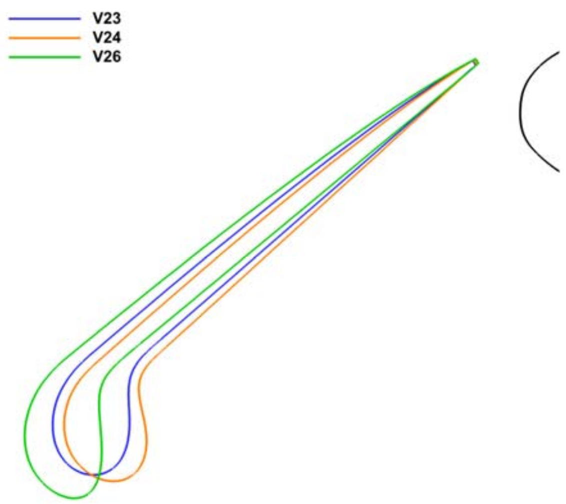

Figure 2: Shape and setting of optimized Krüger devices.

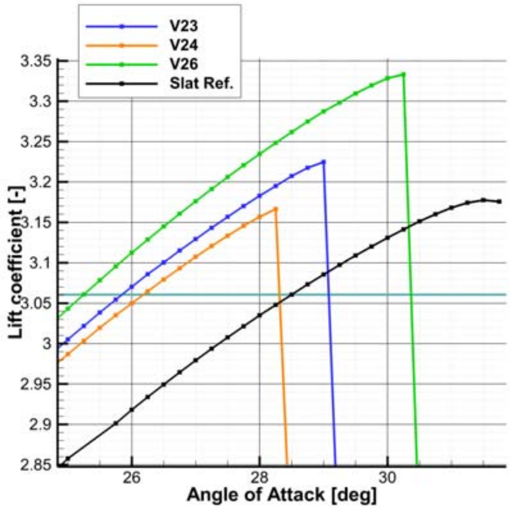

Figure 3: High-lift performance of optimized Krüger devices.

Geometry	Bull nose clearance	$c_{l,\ max,\ 2D}$	$\alpha_{cl,max,\ 2D}$	$c_{l,2D}(\alpha_{cl,max,2D}$-3°)
V26	100mm	3.33	30.25°	3.19
V23	115mm	3.22	29.0°	3.07
V24	125mm	3.17	28.25°	3.00
Slat	**-**	**3.18**	**31.5°**	**3.06**

Table 1: Aerodynamic high-lift performance of investigated configurations.

The current work shows that the replacement of a slat by a Krüger device is feasible w.r.t to the high-lift performance. Further on we could see that there is a direct relation between the bull nose size and its aerodynamic performance. Drawback of this device is the reduced number of possible settings and the increased drag at low angles of attack, where the flow is fully separated on the lower wing side.

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