11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

WINGLETS – MULTIOBJECTIVE OPTIMIZATION OF AERODYNAMIC SHAPES

SOHAIL R. REDDY[1], HELMUT SOBIECZKY[2], ABAS ABDOLI[1] AND GEORGE S. DULIKRAVICH[1*]

[1] Department of Mechanical and Materials Engineering, MAIDROC Laboratory, Florida International University, Miami, FL 33174, USA
{sredd001@fiu.edu, aabdo004@fiu.edu, dulikrav@fiu.edu} http://MAIDROC.fiu.edu

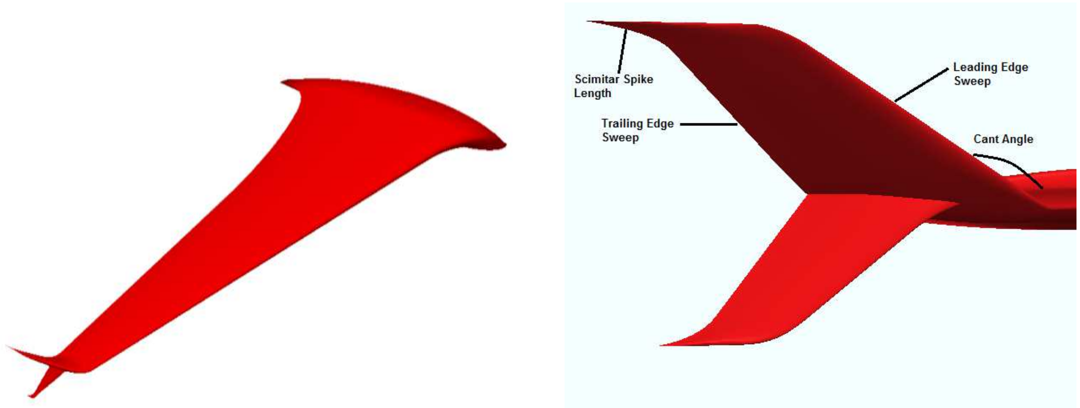
[2] University of Technology, Institute of Fluid Mechanics and Heat Transfer, Vienna, Austria
E-mail: helmut@sobieczky.at Http://www.sobieczky.at/aero/

Key Words: *Winglets, Aerodynamic Shape Design, Multi-Objective Optimization*

Abstract. Various configurations for airplane wing tip winglets have been investigated by performing 3D aerodynamic analysis. An existing blended winglet has been equipped with a secondary lower element to create a split winglet configuration. At winglet tips, a trailing edge extension was added to create scimitar streamwise spikes. A total of eight variables were used to define the winglet geometry. The presented design methodology utilizes a second order continuous, 3D geometry generation algorithm based on locally analytical surface patches. This algorithm requires a minimal number of design parameters to be varied in order to create vastly different 3D geometries of the winglets attached to a clean wing which is blended with the fuselage. A 3D, compressible, turbulent flow analysis was performed using a Navier-Stokes solver on each configuration to obtain objective function values. Each configuration was analyzed at free stream Mach number of 0.25 and an angle of attack of 11 degrees to mimic takeoff conditions of a passenger aircraft. Multi-objective optimization was carried out using modeFRONTIER utilizing a radial basis function response surface approximation coupled with a genetic algorithm. Maximizing coefficient of lift and lift-to-drag ratio, while minimizing coefficients of drag and magnitude of coefficient of moment, were the four simultaneous objectives. Performance benefits of individual components of the optimized geometry were also investigated.

The split-scimitar winglets feature a traditional blended winglet design retrofitted with a secondary lower ventral strake (Figure 1). Both the blended winglet and the ventral strake are caped with a blended-sweptback tip spike. The effects of each of these individual components were investigated in this work. A multi-objective optimization was carried out to find a design satisfying the four simultaneous objectives: minimize coefficient of drag and the magnitude of the coefficient of moment, and maximizing the coefficient of lift and lift-to-drag ratio.

From Table 1 it is clear that optimized scimitar split-winglets with streamwise tip spikes offer significant increase of lift and lift-to-drag ratio, while simultaneously lowering aerodynamic drag and significantly lowering aerodynamic moment.



a) b)

Figure 1: A Boeing 7E7 wing with a scimitar winglet (a) and some of the geometric design parameters for scimitar winglet (b).

Table 1: Objective function values and percentage improvements for various wing+winglet configurations

Configurations Evaluated	**C_L**	**ΔC_L %**	**C_D**	**ΔC_D %**	**C_m**	**ΔC_m %**	**C_L/C_D**	**$\Delta(C_L/C_D)$ %**
Naked Boeing 7E7 wing without winglets	0.6510	0	0.1310	0	-0.121	0	4.97	0
Pareto optimized standard blended winglet	0.6732	3.41	0.1252	-4.43	-0.0932	-22.97	5.38	8.25
An initial (non-optimized) split winglet configuration	0.6750	3.68	0.1240	-5.34	-0.103	-14.87	5.44	9.45
Pareto optimized split winglet without tip spikes	0.6916	6.23	0.1239	-5.73	-0.0870	-28.10	5.58	11.23
Pareto 2996 case optimized split winglet with tip spikes	0.6936	6.54	0.1218	-7.02	-0.0830	-31.40	5.69	14.48

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