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Multi-objective optimization of airfoil shape for efficiency improvement and noise reduction in small wind turbines

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The power output of a wind turbine depends on the aerodynamic and geometrical characteristic of its airfoils, and therefore, the proper airfoil design for wind turbine blades is highly important. Furthermore, due to the usage of small wind turbines within city limits, the emitted noise is also a major issue. In the present work, "XFoil" and "NAFNoise" programs were used for flow analysis around blade cross sections (airfoils) and predicting the corresponding noise emission, respectively. Multi-objective optimization was carried out for maximizing the airfoil lift-to-drag ratio (C_L/C_D) and minimizing the sound pressure level. With two above objective functions and by defining decision variables along with introducing physical and engineering constraints, genetic algorithm method was applied for optimization process. Moreover, 'Fuzzy Bellman-Zadeh' decision-making method was applied for selecting final optimal point from Pareto front. The results of this new method of airfoil shape analysis at various wind velocities showed about 26% average increase in C_L/C_D and 1.11% average decrease in noise emission in comparison with that for typical highly used S822 airfoil in small wind turbines. © *2014 AIP Publishing LLC*. [http://dx.doi.org/10.1063/1.4895528]

NOMENCLATURE

A	empirical spectral shape
C_0	speed of sound (m/s)
D_h	directivity function
f	frequency (Hz)
G_1 to G_5	empirical functions
h	trailing edge thickness (m)
I	turbulence intensity (%)
K	local wave number
l	turbulence length scale (m)
L	span of the airfoil section (m)
M	Mach number
M_c	convective Mach number
r_e	effective observer distance
Re_c	Reynolds number based on the chord length
$(Rec)_o$	reference Reynolds number depending on the angle of attack
St	Strouhal number
SPL_p	trailing edge noise along the pressure side of the airfoil
SPL_s	trailing edge noise along the suction side of the airfoil
SPL_{inflow}	turbulent inflow noise (dB)
$SPL_{LBL\text{-}VS}$	laminar boundary layer vortex shedding noise (dB)
$SPL_{TBL\text{-}TE}$	turbulent boundary layer trailing edge noise (dB)
$SPL_{TEB\text{-}VS}$	trailing edge bluntness vortex shedding noise (dB)

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