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A New Analytical Model for Wind-Turbine Wakes

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The intention of this study is to propose and validate a simple and efficient analytical model for the prediction of the wake velocity downwind of a stand-alone wind-turbine. Extensive efforts have been carried out to model the wake region analytically. One of the most popular models, proposed by Jensen, assumes a top-hat distribution of the velocity deficit at any plane perpendicular to the wake. That model has been extensively used in the literature and commercial softwares, but it has two important limitations that should be pointed out: (a) Even though this model is supposed to satisfy momentum conservation, in reality mass conservation is only used to derive it; (b) the assumption of a top-hat distribution of the velocity deficit is expected to underestimate that deficit in the center of the wake, and overestimate it near the edge of the wake.

In order to overcome the above-mentioned limitations, here we propose an alternative analytical model that satisfies both mass and momentum conservation, and assumes a Gaussian distribution of the velocity deficit. For this purpose, we apply momentum and mass conservation to two different control volumes which have been previously used in the context of analytical modeling of wakes. The velocity profiles obtained with our proposed model are in good agreement with large-eddy simulation data and experimental measurements. By contrast, the top hat models, as expected, clearly underestimate the velocity deficit at the center of the wake region and overestimate it near the edge of the wake.