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Vertical-axis wind turbine experiments at full dynamic similarity SUBRAHMANYAM DUVVURI, MARK MILLER, Princeton University, IAN BROWNSTEIN, JOHN DABIRI, Stanford University, MARCUS HULTMARK, Princeton University — This study presents results from pressurized (upto 200 atm) wind tunnel tests of a self-spinning 5-blade model Vertical-Axis Wind Turbine (VAWT). The model is geometrically similar (scale ratio 1:22) to a commercially available VAWT, which has a rotor diameter of 2.17 meters and blade span of 3.66 meters, and is used at the Stanford university field lab. The use of pressurized air as working fluid allows for the unique ability to obtain full dynamic similarity with field conditions in terms of matched Reynolds numbers (Re), tip-speed ratios (λ), and Mach number (M). Tests were performed across a wide range of Re and λ, with the highest Re exceeding the maximum operational field Reynolds number ($Re_{\max}$) by a factor of 3. With an extended range of accessible Re conditions, the peak turbine power efficiency was seen to occur roughly at $Re = 2\,Re_{\max}$ and $\lambda = 1$. Beyond $Re > 2\,Re_{\max}$ the turbine performance is invariant in Re for all λ. A clear demonstration of Reynolds number invariance for an actual full-scale wind turbine lends novelty to this study, and overall the results show the viability of the present experimental technique in testing turbines at field conditions.

Subrahmanyam Duvvuri
Princeton University

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