An Innovative Umbrella-type Rotor of Horizontal Axis

Wind Turbine to Regulate Power and Reduce Wind Thrust

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Abstract

- Innovative umbrella-type rotor is proposed, aiming at active power regulation and wind thrust reduction.
- Corresponding folding mechanism is designed to refine loads on hub. Truss-frame structure principle is sufficiently used.
- Wind tunnel experiments are conducted to offer supporting data.
- Multi-body dynamic analysis of umbrella-type rotor is conducted.
- Umbrella-type rotor is found to effectively regulate power and wind thrust. The innovative rotor bears lower wind thrust than the pitch regulated type.
- Torques and moments acting on the hub are considerably reduced and bending moment is converted to the tension mode.

Umbrella-type rotor concept

Innovative rotor concept
- Blades is folding upstream at hub.
- Folding axis inclines to blade extension direction, tilting down to the rotor revolution direction.
- Pitching and coning coupled.
- Rotor coning leads to extra wind thrust reduction.

Folding mechanism
- Inclined hinge connects blade and hub.
- Screw rod is fixed on hub center line, driven by the motor.
- Link rod connects blade root and slider with spherical joints.
- Slider is driven to move along the screw rod and blades are folded.
- Bending moment on hub is converted to link rod tension and screw rod compression.
- The patent authorization is in process [1].

Wind tunnel experiment

Experiment setup
- Rotor test system: measure rotor mechanical power.
- Rotor is evaluated by Cp (power coefficient) and Ct (thrust coefficient).

Blade profile and tested rotor
- Blade: scaled down “NREL PHASE VI” blade with a length of 0.3 m, pitched at 18.18°.
- Rotor: 3 blades with a diameter of 0.65 m.
- Inclined angle: 30°, 45° and 60° and pitch regulated rotor.

Experiment scheme
- Wind speed: 4 m/s; Hinge incline angle: 45°.
  - Rotor potential to regulate Cp and Ct.
- Speed: 200 RPM (const.); Power: 0.521 watt (const.);
  Rotor: incline angle of 30°, 45°, 60° and pitch regulated; Wind speed: increasing from 4 m/s.
  - Fold angle variation along wind speed and Cp regulation sensitivity comparison.
  - Wind thrust comparison between umbrella-type and pitch regulated rotor.

Wind tunnel experiment results

- Drastic drop of both Cp and Ct, and a shift of TSR to lower range.
  - Potential to reduce power and wind thrust, and to limit speed in high wind speed.

Constant power output and Cp regulation sensitivity
- Under increasing wind speed condition, fold angle adjustment is less in case of larger incline angle to limit power output growth.
- Larger incline angle leads to higher Cp regulation sensitivity.
  - Incline angle magnitude dominates rotor power regulation sensitivity.

Case study: rotor multi-body dynamic analysis

- Analyzed rotor consists of 3 “NREL PHASE VI” blades which are pitched at 3°.
- Rotor hinge incline angle is 45° and fold angle is 20°. Revolution rate is 71.63 RPM and wind speed is 10 m/s; Incl.33 m, Incl.515 m, K=0.54 m.
- Wind loads are calculated using the code developed by the authors. Blade gravities and centrifugal forces are obtained based on data provided in Ref. [2]. The loads are applied to each blade which is divided into 11 elements. The multi-body dynamic analysis is conducted using ADAMS software.

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<tr>
<th>Inclined hinge</th>
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<td>37.91 N</td>
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<td>4775 N</td>
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- Moments on inclined hinge are much less than that on fixed connector.
  - Bending is converted to link rod tension which is between 31466 N to 17344 N.
  - The folding mechanism well refines the load distribution on hub.

Conclusions

- An innovative umbrella-type rotor is proposed. Experiment result indicates that innovative rotor is capable in regulating Cp and Ct.
- Constant speed of 200 RPM and power output of 0.521 watt in increasing wind speed are achieved with the umbrella-type rotor models.
- Innovative rotor is more desirable in reducing wind thrust than pitch regulated type.
- Rotor coning leads to extra wind thrust reduction.
- Inclined angle magnitude dominates rotor power regulation sensitivity.
- Folding mechanism for umbrella-type rotor is proposed. Bending moment on hub is reduced and converted to link rod tension mode.

Acknowledgement

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Reference