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An innovative method to calibrate a spinner anemometer

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Abstract

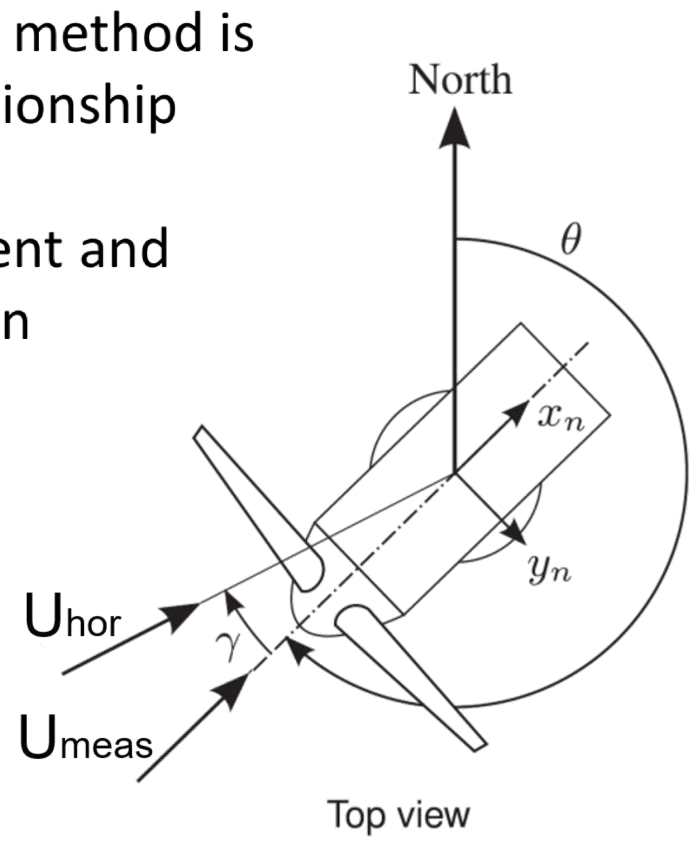
A spinner anemometer (**iSpin**) is an anemometry platform consisting of three sonic anemometers, placed on the spinner of a wind turbine. The strength of iSpin lies in measuring the flow **in front** of the rotor area, rather than behind it, like a conventional cup anemometer. iSpin is an excellent option when information is desired about the flow right before it enters trough the rotor swept area and can be used to measure **yaw misalignment**, **flow inclination**, but also the horizontal **wind speed**. A visual representation of iSpin can be seen in the figure below. iSpin is produced by ROMO Wind and is currently installed on a fleet of over 300 turbines across Europe.

Fig. 1: The iSpin system.

Objectives

Before iSpin can be used to measure yaw misalignment, it needs to be calibrated using a '$\boldsymbol{K\alpha}$ **calibration**'. Previous calibration methods were based on a reference yaw misalignment signal, measured with a yaw position sensor. The downside of this method is that such a signal is not always available for a spinner anemometer calibration.

The wind speed measured by iSpin directly relates to the yaw misalignment. This relationship can be seen in the figure below, and in a simplified way can be expressed as $U_{hor} \approx U_{meas} \cdot \cos(\gamma)$. The objective of the new calibration method is to use this relationship **to calibrate** the yaw misalignment and find a calibration Factor 'K_α'.



Method

The underlying assumption in this research is:

For a correctly calibrated system, the wind speed measured by iSpin is unaffected by the yaw misalignment of the turbine.

In order to test this hypothesis a turbine has been yawed in and out of the wind to yaw misalignments of **+/- 90 degrees 6 times in a row.** Giving the following yaw misalignment time series:

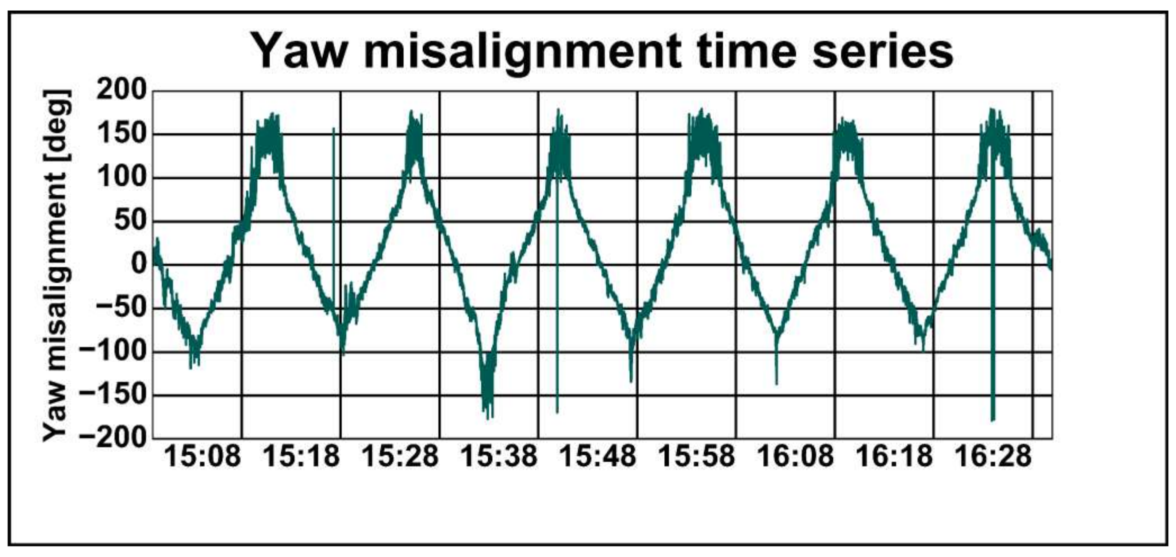


Fig. 2: Yaw misalignment test time series.

Plotting the yaw misalignment versus the wind speed (See plot below) shows clearly the relationship between the two signals. Furthermore it can be seen that this relationship is influenced by the calibration factor K_α.

The correct calibration factor is obtained by finding the **horizontal fit** with the lowest Root Mean Squared Error (RMSE):

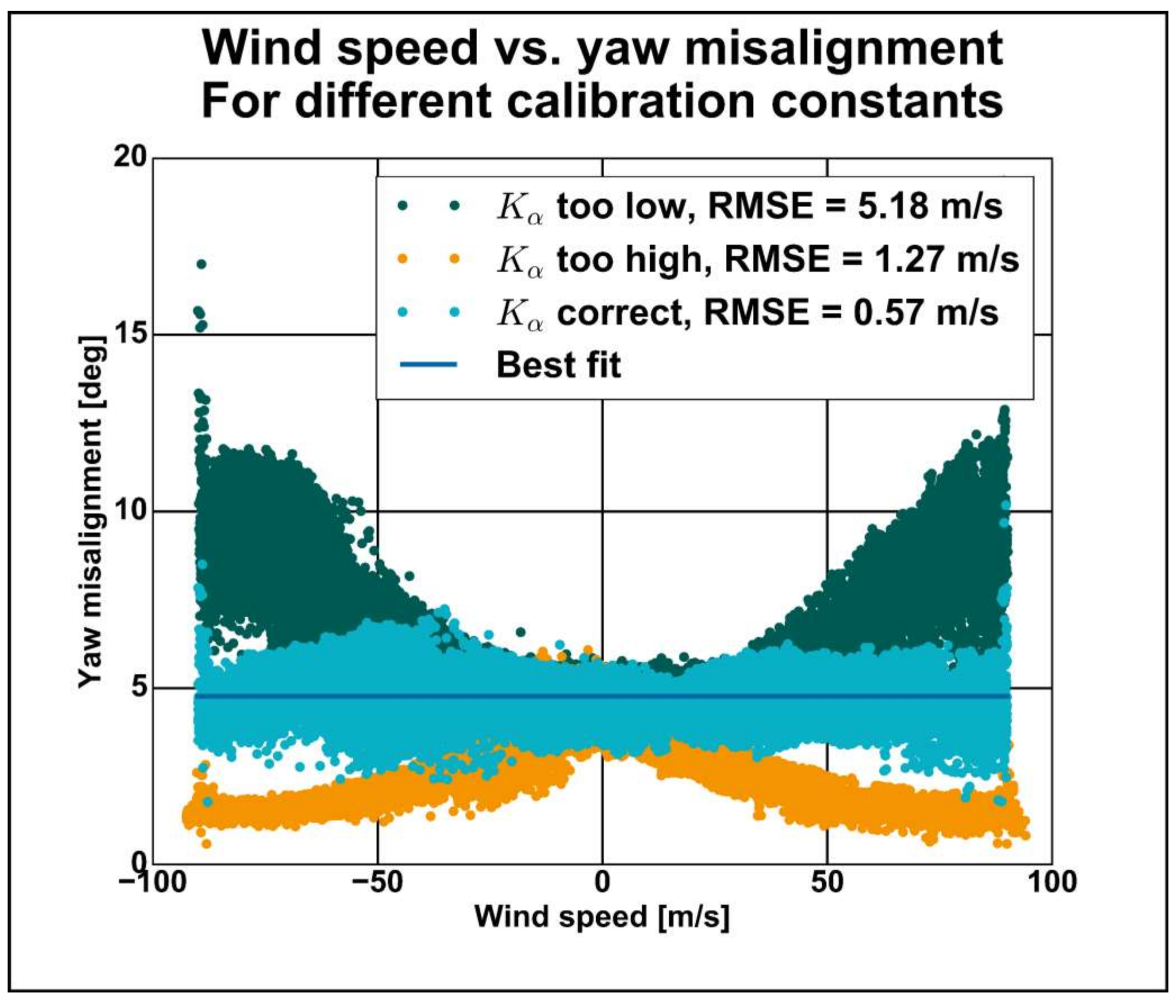


Fig. 3: Wind speed versus yaw misalignment for three different K_α.

In the above example, it can be seen that the correct K_α is obtained for the fit that is indicated by the dark blue line. Note that, in order to obtain the relationship between K_α, wind speed and yaw misalignment, three **coordinate transformations** are used to transform measurements from a rotating, spinner-based reference frame to an earth-fixed reference frame [1].

Results

The method was applied 4 times in a row on the same turbine, with the same rotor position. The resulting calibration factors are **within 2.7%** of the mean value and are shown below:

	Test 1	Test 2	Test 3	Test 4
K_α	1.46	1.53	1.48	1.53

Table 1: Calibration factors from four successive tests.

Results were also compared to calibrations to a yaw position sensor for 29 different tests. The result can be seen in the figure below.

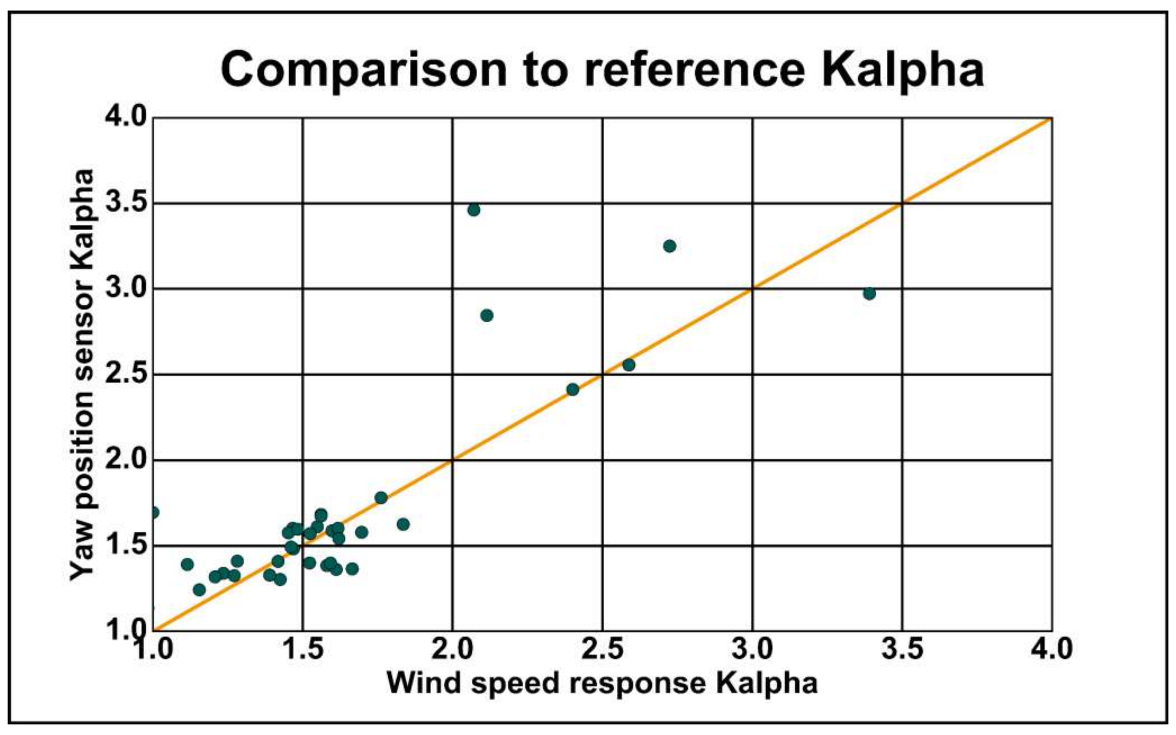


Fig. 4: K_α from proposed method versus K_α from yaw position sensor calibration.

Conclusions

From the results in table 1, it can be concluded that the method is **robust**. Furthermore, the obtained values were similar to those from calibrating with a yaw position sensor.

In order to draw more conclusions, a **quality score** was developed to estimate the goodness of the calibration. The score is computed from the relationship between K_α and the RMSE (fig. 3):

$$QSC = \frac{RMSE(K_\alpha - 0.1) - RMSE(K_\alpha)}{0.1}$$

Using the quality score two main conclusions were drawn:

- The quality of the test increases, as the turbine is yawed to **more extreme angles**, as long as flow over the spinner is still approximately laminar
- The quality of the test increases as flow becomes **less turbulent** (i.e. more stable).

References

1. Pedersen, T. F., Demurtas, G., & Zahle, F. (2014). Calibration of a spinner anemometer for yaw misalignment measurements. WIND ENERGY