MULTI-HOLE PROBE MEASUREMENT ERRORS DUE TO MOVING WAKES

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ABSTRACT

A facility with bars mounted on a rotating disk generates moving wakes in a wind tunnel. A cylindrical probe instrumented with unsteady pressure transducers and static pressure ports is used to investigate measurement errors in moving wakes as a function of bar rotational speed. Flow angle fluctuations due to wake shedding account for up to 16% of the measurement error in wake depth, while the remaining error is attributed to stagnation pressure gradients. The error in time-averaged measurements, which include attenuation effects due to tubing, is independent of bar rotational speed and agrees with the reference averaged measurements within 4% for flow angle and 8.7% for the mass-averaged stagnation pressure loss coefficient.

INTRODUCTION

The accuracy of multi-hole pressure probes used in turbomachinery applications is affected by the unsteadiness associated with moving wakes. Moving wakes are generated in a wind tunnel using bars mounted on a rotating disk driven by an electric motor. Reference measurements of the moving wakes are acquired with a nulled unsteady transducer. A larger-scale, three-hole cylindrical probe is instrumented with unsteady pressure transducers and static pressure ports to acquire both time-resolved and time-averaged measurements of moving wakes, respectively. The accuracy of the cylindrical probe is investigated as a function of two error mechanisms: flow angle fluctuations due to wake shedding, as described by Coull et al. [1], and moving stagnation pressure gradients.

RESULTS AND DISCUSSION

Figure 1(a) shows the instantaneous and phase-locked ensemble-averaged flow angle in the wake when the speed of the rotating bars at the center of the wind tunnel working section is 0.05 times the freestream velocity. Wake shedding causes instantaneous flow angle fluctuations of up to ±16°, while the phase-locked flow angle exhibits a "swing" between −3° and +5°. A statistical distribution of the instantaneous flow angles in the wake due to shedding is obtained, and the measurement error in the wake is calculated according to the method proposed by Coull et al. [1].

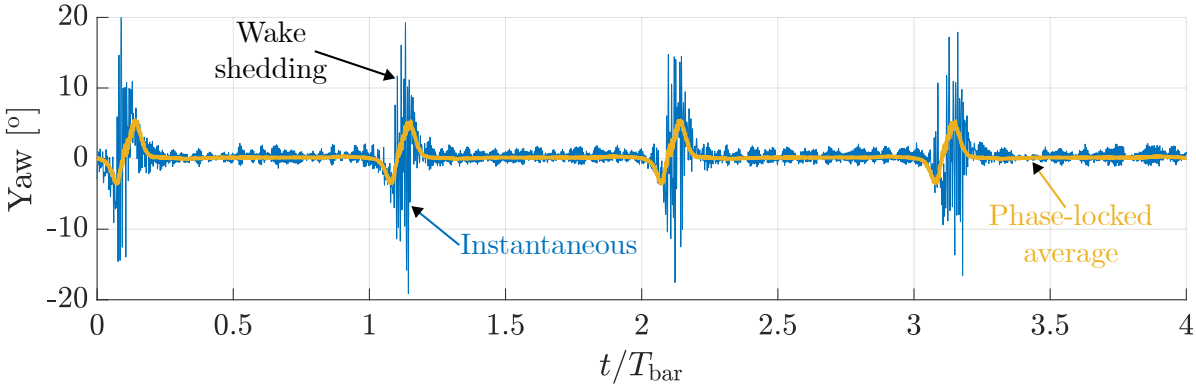
Figures 1(b) and 1(c) show the response of a cylindrical three-hole probe to flow angle fluctuations caused by probe shedding for both yaw angle and stagnation pressure. While the error in the time-averaged yaw angle due to flow angle fluctuations is less than 0.05°, the stagnation pressure coefficient is 0.016 lower than the "true" time average. The fluctuating-incidence error mechanism accounts for 16% of the error in the wake depth measured by the cylindrical probe relative to the reference measurements. The remainder of the measurement error is attributed to stagnation pressure gradients. As the rotational speed of the bars increases from 0.05 to 2.1 times the freestream velocity, the cylindrical probe records fewer shedding cycles per wake passage, and the error in wake depth decreases from 33% to 9%.

The cylindrical probe time-averaged measurements, which include the attenuation effects of the tubing, are compared with averages of the time-resolved data. The time-averaged measurements follow the qualitative trends of the reference measurements for stagnation pressure loss coefficient and flow angle. Errors in the cylindrical probe time-averaged measurements of moving wakes are small, reaching at most 4% for flow angle and 8.7% for the mass-averaged stagnation pressure loss coefficient, and are independent of bar rotational speed.

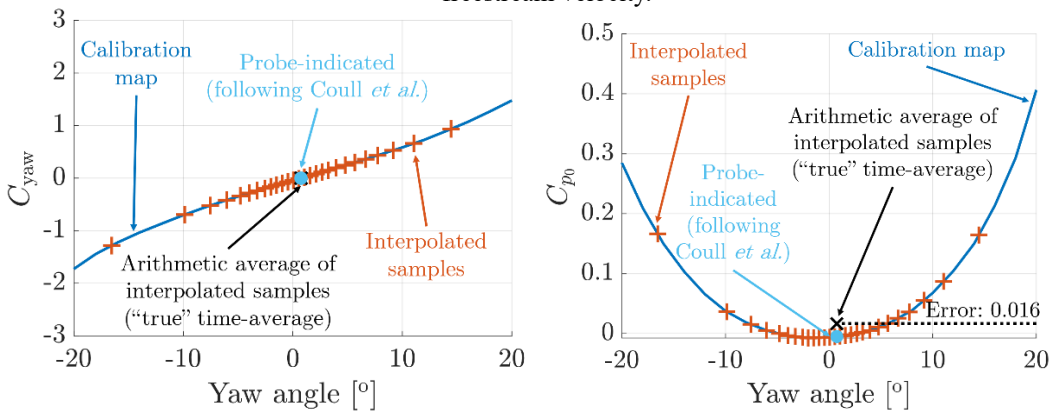
REFERENCES

Coull, J.D., Ng, H., Dickens, T., Serna, J., and Cengiz, K. *Pneumatic-Probe Measurement Errors Caused by Fluctuating Flow Angles*. AIAA Journal 2023 61:7, 2922-2931

FIGURE



(a) Instantaneous and phase-locked ensemble averaged flow angle in moving wakes, with bar speed 0.05 freestream velocity.



(b) Cylindrical, three-hole probe response to fluctuating flow angle due to wake shedding.

Figure 1. Effect of fluctuating flow angle on time-averaged probe measurements.