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A Spherical Directional Anemometer Sensor System †

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Abstract: In this work, the authors propose a novel directional anemometric system, showing a compact design and the absence of external mechanical moving parts. The measuring principle is based on a dual channel spherical wind conveyor structure, combined with a pressure difference sensing technique of the conveyed air flows by the employment of electromagnetic inductive transducers.

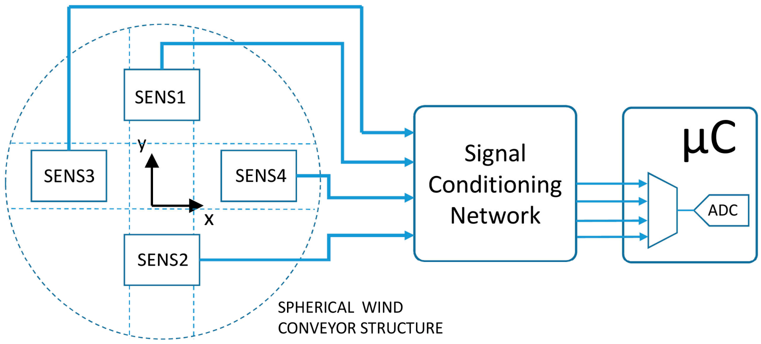
Keywords: zero-bias wind sensor; directional anemometric system; sensors system; CFD analysis

1. Introduction

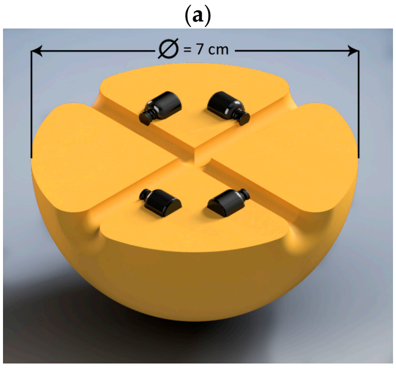
In the last years wind related industries have invested a huge amount of money and resources to improve their products and systems. Their major goal has been the optimization of costs, operations, production, quality and time, that have been obtained through different improvement methods, tools and wind monitoring techniques [1–6]. These monitoring systems are necessary in different situations: from itinerant activities like sports (e.g., sail and ski) to bridges or urban buildings monitoring. Currently, different types of wind meters exist. A well-known solution is certainly the electromechanical or cup sensor, typically used in fixed stations [7–10]. Alternatives are usually based either on the pressure measurement or on the heat exchange with the air flow [11–13]. Such solutions are preferable for portable applications and installations in severe conditions. There are two modes of operation for the hot wire anemometers: Constant Current Anemometer (CCA) and Constant Temperature Anemometer (CTA). For both the cases the electronic circuitry is a part of the anemometric system and has a direct influence on the probe characteristics. The basic principle of the system operation is the heat transfer from the heated wire to the cold surrounding fluid. The presented system results in a full change of paradigm with respect to that proposed in [13], providing a robust and low power solution suitable for portable applications. Theoretical analysis and CFD (Computational Fluid Dynamic) simulations of the spherical structure are shown, while simulation results are here presented and discussed.

2. The Proposed System

In this work, zero bias passive physical sensors are employed, transducing the wind energy into electrical signals, which are properly conditioned, digitalized and processed by means of a low power Atmel microcontroller (Figure 1a) and a signal conditioning network which are the only implemented active components. In addition, a holed spherical structure has been designed, which has the dual function of channeling the incident wind into two orthogonal inner pipes and of protecting the sensors from the weather (Figure 1b). The latter consist of a millimetric membrane, a coil and a permanent magnet, as for loudspeaker architecture. As the wind flows parallel to the membrane surface, local vortices and a pressure difference occurs between the two sides of the film, inducing a vibration proportional to the wind speed intensity [14]. This vibration causes a variation on the magnetic field inducing an electromotive force through the coil, that represents the measuring information. The inner pipes have been designed to have a Poiseuille profile, with a suitable Reynolds number and following advanced stability criterions [15] so to guarantee a laminar, stable flow and to avoid vortices in the whole pipes volume. This allows a stable wind speed measurement as high as 18 m/s. Since the pipes are orthogonal ones to each other, by computing the wind speed for each flow channel, it is possible to geometrically calculate the total vector wind speed and direction along the horizontal plane, as $\vec{U} = A \cdot U_x \cdot \hat{x} + B \cdot U_y \cdot \hat{y}$, where $\vec{U}$ is the wind vector, U_x and U_y are the measured wind components, respectively, and A and B are calibration coefficients. The cross-point of the two pipes provides a pressure drop, therefore a speed lowering occurs in the second half, with respect to the inlet section of the tube. This allows to measure the orientation of the velocity vector, through a dual pressure measurement in the two sections of each tube.



(**a**)

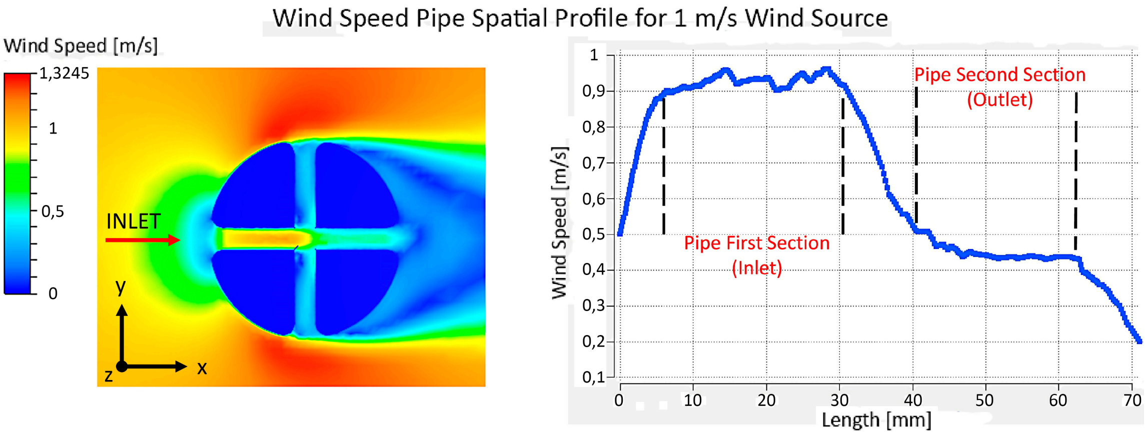


(**b**)

Figure 1. (**a**) block diagram of the proposed anemometric system; (**b**) horizontal half-section view of the implemented spherical structure.

In Figure 2a, the Computational Fluid Dynamic simulation of the spherical structure is shown, for an inlet wind flow parallel to the x axis of the local coordinates reference for the system. Results clearly demonstrate how the air flows only in the x direction, while the velocity decrease in the second half of the x pipe, because of the pressure drop, providing the information about wind flow orientation. This behavior is better evident in Figure 2b, where the wind speed profile is reported for the whole x-pipe of the sphere.

As the employed sensors produce an electromotive force when excited by the wind flow, they could be exploited, for a future development, as part of autonomous energy harvested systems [16–19], towards an endless lifetime portable wind measurement device.



(**a**) (**b**)

Figure 2. (**a**) XY cut-plane wind speed profile for the proposed spherical structure; (**b**) spatial wind speed distribution along the symmetry axis of the x-pipe**.**

3. Conclusions

We have here proposed a zero-bias, passive physical sensors, employing the anemometer functionality of transducing the wind energy into electrical signals. The system is compact, low power and useful for many industrial and portable applications.

Conflicts of Interest: The authors declare no conflict of interest.

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