# Design and smart control of sensors for optimal performance: application to wind sensing in Mars

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## Abstract

Sensor performance in terms of time response and sensitivity can be dramatically enhanced by operating sensors under what may be called a “constant state operation”. This means that any change in the sensor due to external factors (including the ones to be measured) is compensated by a smart control, so that the state of the sensor does not change with time. This idea has been applied to thermal anemometry in Mars (for REMS, TWINS and MEDA missions) using constant temperature operation and differential thermal conductance estimators.

In the case of our miniature spherical wind sensor for future missions, this principle requires a careful thermal design, ensuring that single time constant operation is achieved, [1-3]. Experiments show that it is possible to obtain response times (1s) well below the open loop time constants. Additionally, the performance of the sensor at the Aarhus Martian wind tunnel is presented, as well as experiments in the Reynolds regime 1000-10e4, with equivalent Mars wind velocities in the range 100-150m/s.

## 1. Introduction

The main challenge in wind anemometers for Mars is the thin atmosphere (6-12mbar). The approach in the REMS, TWINS and MEDA wind sensors is placing the silicon dice in direct contact with the air. This way, sensitivity is maximized and the associated time constants are of the order 1-5s. By working under constant temperature operation, time response is reduced to 0.5s. In parallel with these sensors, a wind sensor with spherical geometry has been developed (see Figures 1 and 2).

## 2. Description of the spherical sensor

The sensor is composed of 4 equally shaped sectors, conforming a 10 mm diameter sphere, that are placed on two superimposed PCBs, which act as supporting structure and provide signal routing (see Figure 1). A customized silicon die which includes a Pt resistor is attached to each sector to sense temperature and provide heating power. Finally, two additional dice are placed on the supporting PCBs to control the temperature at the core of the sphere, on the PCBs. Maintaining the core at the same sector temperature, heat transfer between both elements is minimized.


***Figure 1**: Photograph of the wind sensor of spherical geometry. Three of the sectors can be observed.*

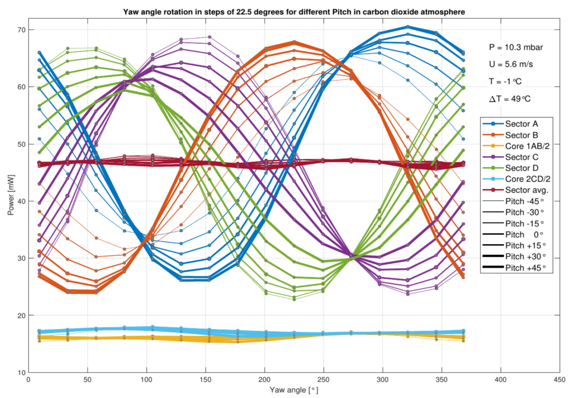


***Figure 2**: Power dissipated in the four sectors when the yaw angle is swept 0-360º, for different pitch angles, at constant wind speed (5.6 m/s). The average power in all sectors can be seen at the center of the graph. The power dissipated at the core resistors is shown at the bottom.*

The sensor is operated at the same constant temperature in the core and in all sectors. From the heating powers injected on the 4 resistors in the sectors and the air temperature, the thermal conductance of each sector is calculated. From these 4 signals 3D wind speed recovery can be made.

The performance of the sensor under typical Martian wind conditions (Reynolds below 200) has been previously explained [1]. Figure 2 shows the behavior of the sensor measured at one of the Martian wind tunnels in Aarhus.

## 3. Dynamical response

Figure 3 shows the time evolution of the power signals when there is a change in angle (at approximately t=20s). The top graph is the raw power signals applied by the controls to each of the 4 sectors. The bottom graph is the average of several similar changes. As it can be seen the time response is approximately 0.7s.

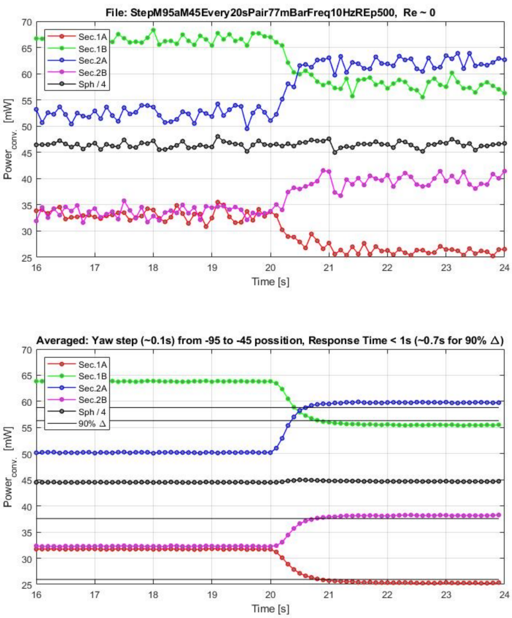


***Figure 3**: Time evolution of the sector power signals when angle is changed at t=20s. (top) Raw power signals. (bottom) Averaged power signals for different experiments performed under identical conditions.*

## 4. Preliminary results in Dust devil regime

Direct Numerical Simulations of the incompressible Navier-Stokes and energy equations indicate that it is possible to measure in the Dust Devil regime, [4]. Figure 4 shows a snapshot of the normalized temperature of a simulation at Re1000.

Additionally, experiments have been carried out for Reynolds number in the range 1000-2000, which translated to typical Mars conditions imply wind speeds of 65-130m/s (see Figure 5). As it can be observed in Figures 4 and 5, when the sector is on the wake of the sphere, the thermal conductance has a second maximum. Experiments and simulations coincide. These preliminary results indicate that it is possible to measure under extreme Martian winds, reaching the scale of Dust Devils.

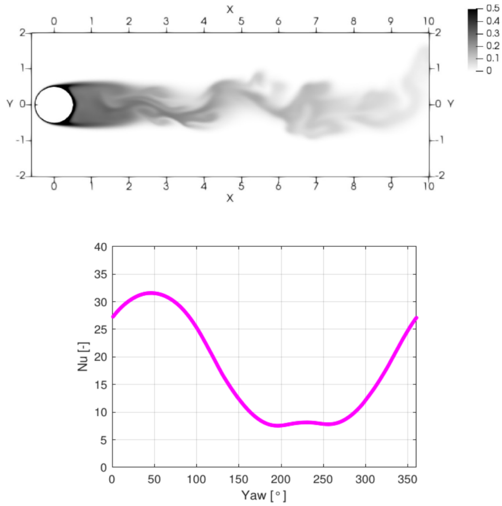


***Figure. 4:** (top) Figure from [4] showing a snapshot of the temperature field in the wake of the sphere for Re1000 obtained from direct numerical simulations of the incompressible Navier-Stokes and energy equations. (bottom) Average Nu number for Re1000 on one of the sectors as a function of yaw angle.*

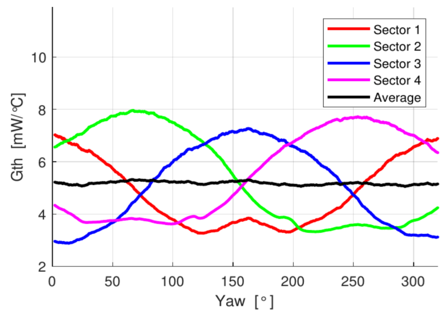


***Figure 5:** Thermal conductance of each sector, and average value, as a function of Yaw angle for Re1000. Equivalent $U_{Mars\text{-}flow}$ velocity under typical Mars conditions of 65m/s.*

## 5. References

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