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“A Condition Monitoring System for Blades of Wind Turbine Maintenance Management .”

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Chapter 1
A Condition Monitoring System for Blades of Wind Turbine Maintenance Management

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Abstract Wind energy is one of the most competitive and efficient renewable energy. It requires an efficient management system to reduce costs, predict failures and increase the production. The main objective of this paper is to design the appropriate tests and develop a condition monitoring system (CMS) to display the surface temperature of any body state using infrared radiation. The data obtained from this system lead to identify the state of the surface. The CMS is used for maintenance management of wind turbines because it is necessary an effective system to display the surface temperature to reduce the energy losses. This paper analyses numerous scenarios and experiments on different surfaces in preparation for actual measurements of blade surfaces.

Keywords Maintenance management · Fault detection and diagnosis · Infrared sensors · Non-destructive tests · Wind energy

1.1 Introduction

The renewable energy industry is undergoing continuous improvement and development worldwide. This industry requires high levels of reliability, availability, maintainability and safety (RAMS) for wind turbines [6, 7, 11, 12, 15]. Condition monitoring (CM) is defined as the process of determining the condition of system [2, 10]. The objective of this work is to detect ice or other disturbing element on the surface of the wind turbine blade. A thermal infrared sensor is used to measure the radiance emitted by the blade surface.

The process of obtaining thermal information cannot be easy because there are situations where it is unfeasible take conventional measurements. For this reason, it

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is impossible to use devices based in direct contact. Data acquisition using infrared thermography is an increasing technique used due to its speed, efficiency and non-destructive nature. Nondestructive testing are those that do not affect the system and its properties remain constant after the measurement tasks [3–5, 13, 14]. Any type of material generates thermal energy that radiates outward due to a temperature gradient. Infrared thermography is based on heat transfer by radiation, capturing the infrared radiation emitted by bodies at different levels of the electromagnetic spectrum for temperatures, therefore there is no physical contact with the body in question and the properties or system conditions are not altered. This technology is quick and effective, and it is able to get reliable thermal data in different areas where traditional thermal sensors are unfeasible or physical contact is impossible [8].

The measurements made by infrared thermography display the surface temperature of the bodies, not the thermal state inside them. This is the major disadvantage of infrared thermography and, therefore, it is not possible quantify the thermal processes occurring within the surface of the measured bodies. Infrared emissions of the bodies are not visible to the human eye and it requires to use sensors that transform the infrared energy into electrical output [1].

1.2 Equipment

1.2.1 Sensor

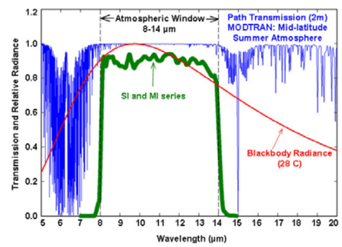
To take acceptable data, it is essential to use a reliable sensor. Each of these sensors is formed by a thermopile that it will measure the surface irradiation, and a thermistor, which calculates the temperature of the sensor body. These two components provide an output signal in millivolts, that using equation adapted Stefan-Boltzmann [9] for each sensor. It is possible to transform this information into temperature values. These laws indicate that the transferred radiation is proportional to the fourth power of the absolute value temperature, being m y b adjustment coefficients provided by the manufacturer, S_D is the signal collected in millivolts and T_T total temperature in °C.

$$T_T = \sqrt[4]{T_D^4 + m \times S_D + b} - 273.15.$$

The sensor must define the temperature of the bodies inside the measuring area demarcated by a germanium lens of 8-14 μm and a field of view of 22 °. Furthermore, it is able to provide temperature values with an error of $\pm 0.2°$ C when operating in a range of $-10°$ to 65 °C.

Fig. 1.1 shows the response of this sensor in a given wavelength. The experimental values of the sensor and a black body shows an approximate range.

Fig. 1.1 Spectral response of radiometers [6]



1.2.2 Wireless Recovery Data

This equipment uses the sensor described previously but it is connected by radio waves to a wireless station with a datalogger that records and stores the collected data. The instrument employed is CWB100, and it is possible to analyses the data in real-time. Furthermore, it is possible to create a wireless network that can be adapted to the needs of measurement, changing the pattern and number of sensors. When the network is designed and programmed, the sensor starts to record data and get different variables: Tt (temperature sensor), Tb (body temperature sensor) and Ti (room temperature). It is useful to create a network capable to inspect several blades in real time.

Fig. 1.2 Wireless sensor making measurements in pipe

1.3 Methodology

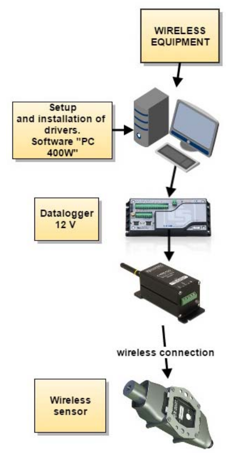
In order to check the reliability of the infrared sensor, a wind turbine section has been measured. The sensor is arranged such that the field of view encompasses the entire section of the blade.

1.3.1 Data collection.

To verify the reliability of the temperature data obtained by the sensor, different scenarios are considered in the experimental platform described above. The temperature data obtained in all the tests are:

- Th1: Temperature of the thermocouple 1.
- Th2: Temperature of the thermocouple 2.
- Tt: Temperature sensed by the sensor CWS220E.
- Tb: Temperature of the body CWS220E.
- Ti: Ambient temperature.

Fig. 1.3 Process diagram



1.3.2 Experiments

Note that this sensor is ideal for inspecting curved surfaces (Fig. 1.4). The measurements of the blade section were taken at room temperature and the results are shown in Fig. 1.5.

The results in Fig. 1.5 shows that the first measurements are almost constant until the ambient temperature increases drastically. This increasing caused the temperature of the object rises to rediscover thermal equilibrium. The measurements are recorded at long intervals of time, therefore the thermal values demonstrate stable values.

Experiments about variations in emissivity were also done. In order to highlight the emissivity of the elements, the system was coated with aluminum (Fig. 1.6) because this element has a very low emissivity. The main results are presented in Fig. 1.7.

Fig. 1.7 shows that the ambient temperature increases again. Therefore, it is affecting the measurement system. In this case, the highlighted variable is the temperature measured by the wireless sensor, because this result is affected by the low emissivity value

For the last experiment, the blade section was frozen, and the temperatures given by the thermocouple and by the infrared sensors where collected.

1.3.3 State of the surface

The state of the surface is one of the most important variables in the infrared thermography. The tests were taken in the same wind turbine blade section at different states. Temperatures collected on the surface of the previously blade are represented

Fig. 1.4 Wind turbine's blade employed in the experiments

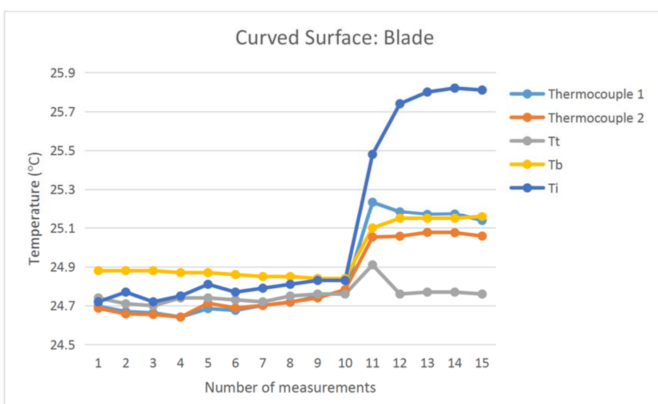


Fig. 1.5 Temperature of the blade with all the equipment

in Fig. 1.8. The data are affected by the emissivity of each surface. The experiments were carried out for three types of scenarios:

- Ambient temperature
- Frozen surface without ice.
- Frozen surface with ice.

Fig. 1.8 shows that it is possible to distinguish between the 3 different states of the wind turbine blade employing a infrared sensor and with the help of a surface with low emissivity.

1.4 Conclusion

This paper presents a condition monitoring system employed to analyses the status of the blades' surfaces of the wind turbines, performance with wireless infrared sensor. This equipment has a very high accuracy, providing data with an error of $\pm 0.2^{\circ}$

Fig. 1.6 Surface of the blade with aluminium

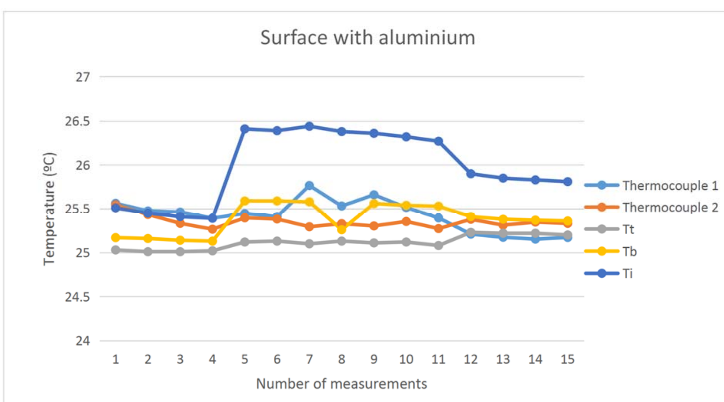


Fig. 1.7 Temperatures with all the equipment in surface with aluminium

C if the data emissivity of the body to be inspected are adequate. This component has advantages over thermal imagers the low price and versatility to be configured. It is possible to identify each of the states considered in the blade in real time. In this work it has been able to distinguish between three states, which are: blade at room temperature; frozen blade without ice; and frozen blade with ice. In summary it is possible to determine temperature and superficial status of a piece.

Due to its speed, autonomy, efficiency and non-destructive nature, this type of testing is efficient for their use in wind energy maintenance system. A proper preventive and predictive maintenance of facilities is ensured and, furthermore, the system is able to predict failure and reduce costs. Finally, it is determined that the overall system complies with the initial specifications of the paper and it is fully prepared to carry out test in real blades of wind turbines.

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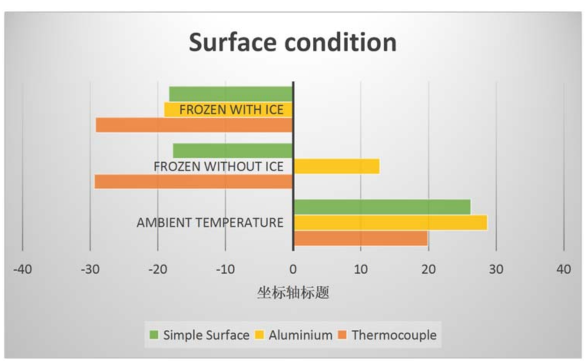

Fig. 1.8 Temperatures affected by the emissivities of the surfaces

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