RESEARCH IN SURFACE TEMPERATURE MEASUREMENTS AT CZECH METROLOGY INSTITUTE (CMI), CZECH REPUBLIC

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Abstract: This paper shows the research focused on main error sources in one of the toughest challenges - accurate surface temperature measurement using contact sensors. The objective is to introduce an estimation of typical values of the uncertainty budget components, based on the set of measurement experiments realized in the CMI's laboratory of surface temperature.

The results should provide a view on several most common uncertainty components and their possible influence on the total measurement uncertainty for typical surface temperature probes. The work described in this paper focuses on the investigation of the influence of the probe orientation, surrounding airflow velocity, short-term and long-term drift, homogeneity of used materials, pressure of application and mass of the probes; in the temperature range of (50 to 500) °C.

Key-Words: - Surface Temperature Measurement, Contact Temperature, Sensor's orientation, Airflow Velocity Influence

1. Introduction

The research project - EMPIR "Research in Surface Temperature Measurements", NUMBER: "14IND04-RMG1 EMPRESS - Enhancing process efficiency through improved temperature measurements" included characterization of the surface temperature calibration devices and behavior of the sensors used in collaboration with Czech Metrology Institute (CMI). The results of this work will be used for a design of the next generation of surface temperature calibration devices. During the research, experiments for investigating several uncertainty and error sources, connected to the surface temperature measurements were realized, employing classical commercial contact surface thermometers under various conditions at temperatures up to 500 °C.

2. Research and analysis of the surface temperature sensors

The objective of this research was to investigate the influence of several uncertainty contribution sources on the temperature indicated by commercial surface temperature sensors.

➢ Homogeneity of the surface temperature calibration device.

For characterization of the homogeneity of the surface temperature calibrator at different temperatures, dynamically compensated probe (employing the system of two thermocouples and heater to measure and compensate the heatflux) was used. The homogeneity of some materials in the range up to 500 °C was also investigated.

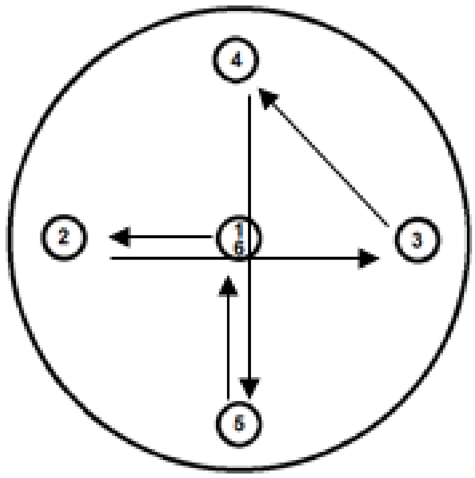

Fig 1: Investigation on homogeneity

➢ Weight of the sensors and pressure under which the surface thermometers are applied.

The weight of sensors was measured to subtract the influence of the static pressure (which differs according to the sensor type) from the results of pressure-temperature dependency measurement. The surface area that contact with the measured surface was computed for each probe to allow computing of the pressure applied on the surface. This was done to investigate the dependences of measured temperature values on the pressure at which the surface temperature sensors are applied on the surface.

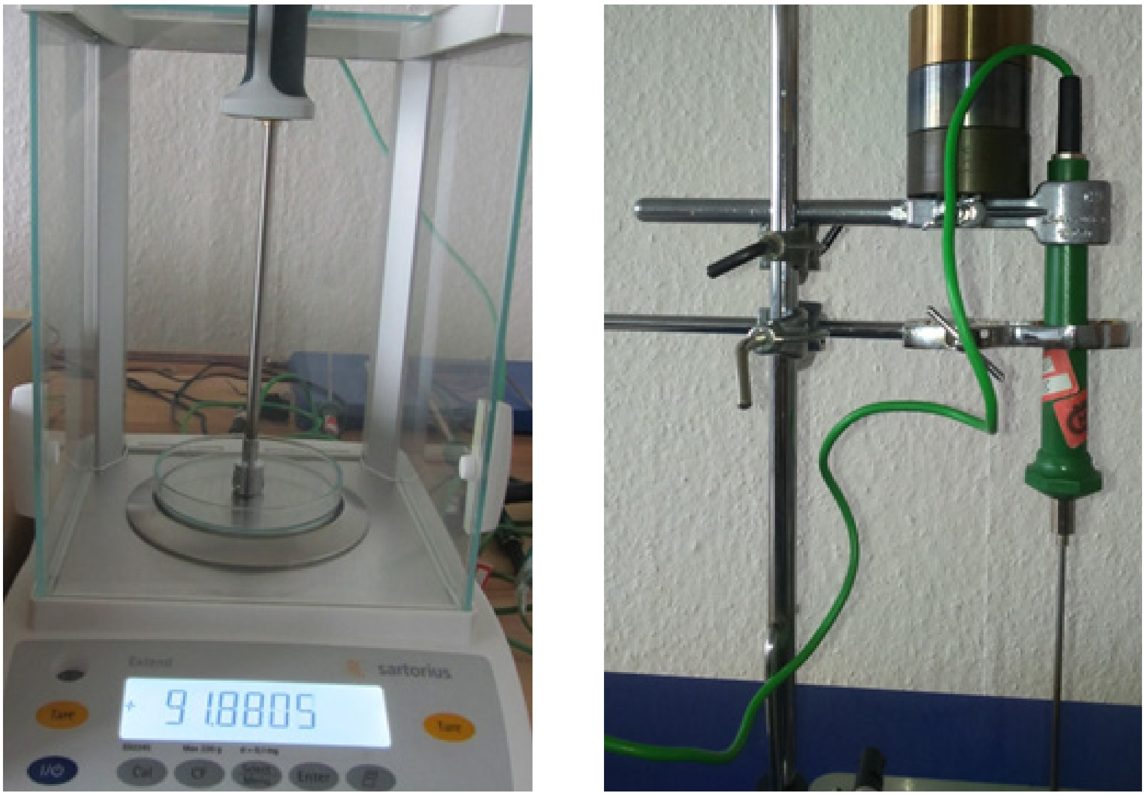

Fig 2: Mass and pressure measurements

➢ Orientation of the sensors.

The influence of the angle between the sensor and the axis normal to the surface on the temperature measurement result was investigated. The critical angle value that was determined between the sensor and surface was 15º.

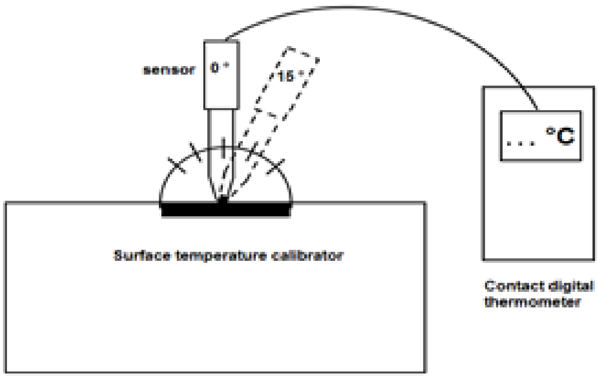

Fig 3: Sketch of experimental setup of orientation of sensor

➢ Measurements of surrounding air velocity.

The measurements were made with fan and airflow meter to measure the air velocity. The fan was set on distance of one meter from the center of the surface. The influence of surrounding airflow velocity on the surface temperature measured by the conventional sensors was investigated. The average airflow without using fan was 0.03 m/s, respectively the force airflow with fan was 1.0 m/s.

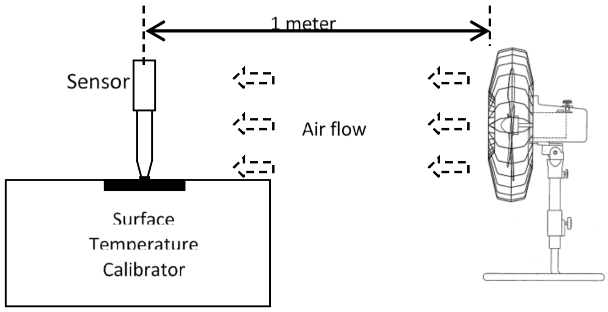

Fig 4: Sketch of the experimental setup of measuring the surrounding air velocity with forced airflow.

➢ Short and long term drift of the sensors.

The investigation of calibration drift is obtained during the whole research period. The drift is calculated from the difference between each measurement and the first one.

➢ Differences in horizontal and vertical surface temperature measurement.

The surface temperature calibration device is able to simulate both the horizontal and vertical oriented surface. In this task, the difference between horizontal and vertical surface measurements was measured. The measurements were performed on surface temperature calibration device with the Aluminum surface. First measurements was performed with a horizontal surface without influence of the pressure, and then on a vertical surface only with touching the surface.

➢ Measurements in baths and heat-pipe furnaces.

A comparison is made between the measurement results of surface temperature sensors in baths and heat-pipe furnaces with different immersion depths and the results of calibration on the surface temperature calibration devices.

The aim of this task was to provide a reliable analysis of several error and uncertainty contribution sources that are usually not taken into account in industrial practice. This was performed within the whole range for every individual commercial surface sensor.

3. Conclusion

The results show that probe, that has a spring contact and bigger surface area was less influenced by external factors than other sensors but more sensitive to the angle changes.

For the other type of surface temperature sensor that has thin tip the contributions are much bigger, because this type of sensors is influenced by many factors as: effect of sensor angle; influence of air flow; influence of pressure and also they are much more unstable during the measurement process than other designs. This indicates that this type of sensors means bigger uncertainty of measurement.

Aim of the work shown above was to show possible errors and uncertainty sources caused by normal use of commercially available contact surface temperature sensors. The surface temperature measurement using traditional contact sensors without error sources measurement and the subsequent corrections practically mean to measure with uncertainties of order of at least 10 °C causing the measurement useless.

4. References

[1] The International Temperature Scale of 1990

[2] Evaluation of measurement data - Guide to the expression of uncertainty in measurement JCGM 100:2008.

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