VERIFICATION OF THE EMISSIVITY VALUE OF SELECTED REFERENCE PAINTS FOR NON-CONTACT TEMPERATURE MEASUREMENT

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Abstract

The paper deals with the issue of temperature dependence of emissivity in reference paints for surface homogenization during non-contact temperature measurement using infrared camera. Two different paints for high-temperature applications are under investigation. Emissivity is measured with a FLIR E95 infrared camera using procedures according to ČSN EN ISO 18434-1 standard. The obtained results are important especially for practical applications in which it is necessary to quantitatively measure the variable surface temperature on objects for which the homogeneity of the surface cannot be unequivocally guaranteed.

Keywords: Emissivity, Reference Paint, Infrared Camera

1. INTRODUCTION

Accurate temperature measurement using infrared cameras requires correct determination of five measuring parameters: Emissivity ε (-), Reflected apparent temperature $T_{Refl.}$ (°C), Ambient temperature $T_{Amb.}$ (°C), Relative atmospheric humidity (%) and measurement distance (m). In practise, the measurement parameters are compensated directly in the internal SW of infrared camera. Real bodies emit and absorb less thermal radiation than blackbody, and this fact is corrected by factor called emissivity. The emissivity is generally given by equation (1):

$$\varepsilon = \frac{M_R}{M_{BB}} \ (-) \tag{1}$$

where:

M_R – the radiant exitance of real body ($W \cdot m^{-2}$)

M_{BB} – the blackbody radiant exitance ($W \cdot m^{-2}$)

Emissivity characterizes the properties of surface of measured object and it is the most important measuring parameter in non-contact temperature measurement. Emissivity depends on many factors: wavelength of infrared radiation, temperature, type of material (chemical composition), surface roughness, heating time, measuring angle, geometry and arrangement of surface, deposits on measured surface (oil, grease, dust and dirt) and surface oxidation. The emissivity of each measured surface should be therfore evaluated individually. [1,2].

High-emissivity reference paint is a special type of paint used for non-contact temperature measurement with infrared cameras. Many materials such as metals, glass and plastics with shiny surfaces have very low emissivity and high reflectivity. High reflectivity makes practical quantitative measurements imprecise and often impossible. By modifying problematic surfaces using a reference paint, reflectivity is minimized and surface emissivity is homogenized, which is often highly variable, especially with metals. Provided that the emissivity of the paint is known, it can be used to determine the emissivity of the examined surface using the comparative method according to ČSN EN ISO 18434-1 standard.

The problem of accurate measurement arises especially in aplications in which the surface temperature changes significantly in the order of tens to hundreds of degrees Celsius. The main goal of this paper is to map the temperature dependence of emissivity for selected reference paints, which will help to make practical temperature measurements more accurate

Reudiger Brandt et al. [3] from Institute for Nuclear Technology and Energy Systems IKE (University of Stuttgart, Germany) measured the emissivity in the temperature range from 950 to 1300 °C for HE6 and HE23 paints using a pyrometer. Paints were applied to samples of the high-temperature nickel-based alloy Nimonic 75. The results for the normal direction measurement show that the emissivity gradually decreases with increasing temperature. The drop in emissivity is not significant, but it is noticeable. Some paints available in the Czech Republic are marked by the manufacturer with a single emissivity value. In practice, however, it is not clear at what temperature this value is valid. On the other hand, for some paints, the manufacturer states the temperature dependence. These facts contributed to the creation of this research.

2. EXPERIMENT

Therefore an experiment was designed, the essence of which was the measurement of emissivity of two black paints **ThermaSpray 800** (resistant to 800 °C) and **LabIR HERP-HT-MWIR-BK-11** (resistant to 1000 °C) sprayed on X5CrNi18-10 stainless steel samples. Emissivity was measured during cooling of pre-heated samples in the temperature range of 50 to 500 °C. The measurement principle was based on the contact method according to ČSN EN ISO 18434-1 [4] standard. The block diagram of the measurement arrangement shows **Figure 1**.

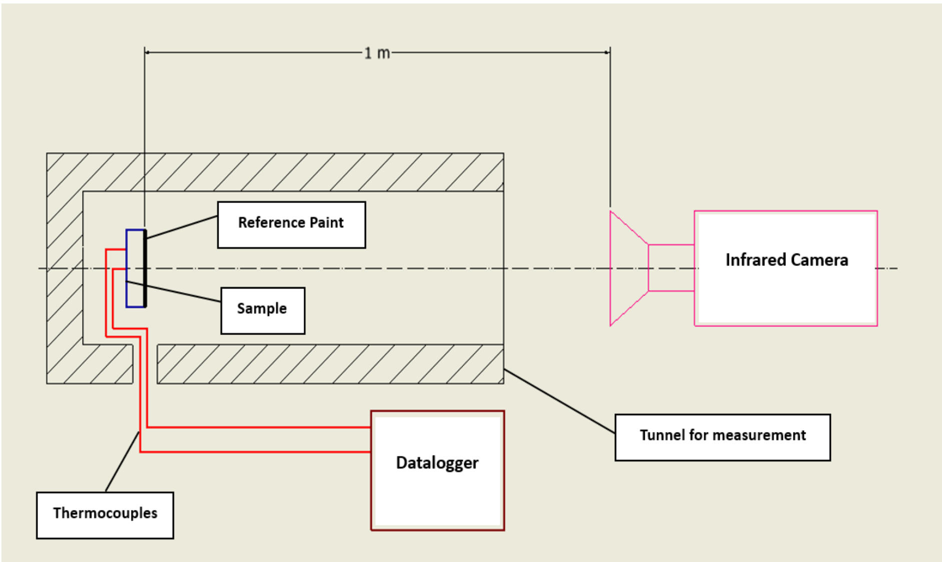

Figure 1 Block diagram of measuring assembly

Experimental measurements were carried out using a FLIR E95 handheld quantitative infrared camera with a spectral range from 7.5 to 14 μm and special measuring tunnel for shielding thermal radiation from surrounding sources. Simultaneously with thermograms, the temperature of samples was measured using a datalogger (AHLBORN ALMEMO 5690-2) and three K-type thermocouples. The evaluation consisted of gradual changes (iterations) of the emissivity in the evaluation SW FLIR Tools, until the temperature measured by infrared camera coincieded with the temperature measured by thermocouples. The measuring workplace is shown in **Figure 2**.

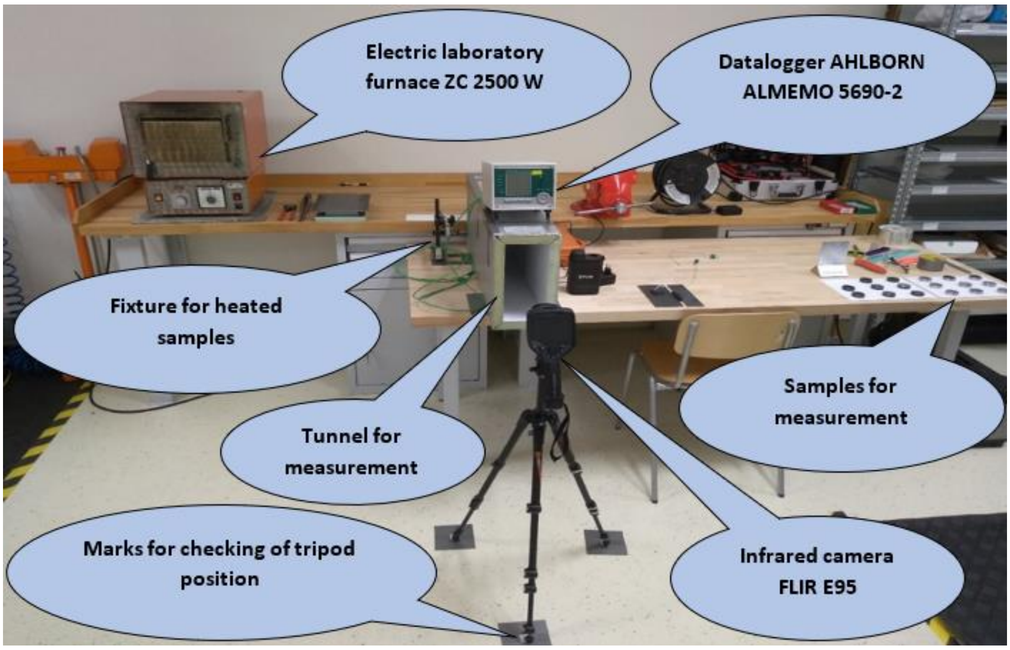

Figure 2 Measuring workplace

Rollers with diameter of 40 mm and a length of 10 mm were used as samples. Before applying the paint, samples were ground on a metallographic grinder to maintain a similar quality of measured surfaces. The roughness was measured with a Mitutoyo Surftest SJ-301 rougness meter and average rougness values are summarized in **Table 1**. Four thin coats of the appropriate reference paint were further sprayed onto each prepared surface. Measured samples were gradually heated in an electric ZC laboratory furnace to a temperature of 700 °C for 10 minutes. Temperature cycle is captured in **Figure 3**.

Table 1 Average roughness values after grinding

$\overline{Ra}$ [μm]	$\overline{Rz}$ [μm]
0,13	1,00

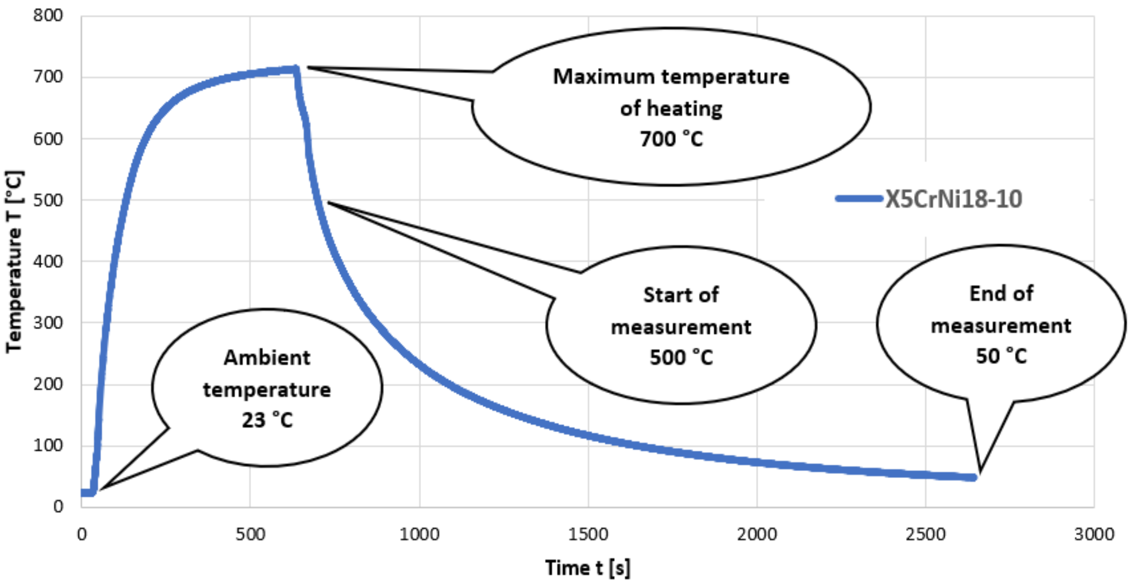

Figure 3 Temperature cycle of measured samples

For the correct measurement of emissivity, it was also necessary (from the thermography equation) to correctly determine the remaining measurement parameters. The reflected apparent temperature was measured using an infrared reflector (**Figure 4**) according to ČSN ISO 18434-1 standard. The reflector was constructed from cardboard and aluminium foil as recommended by the standard. Ambient temperature and relative humidity were monitored using a module from a wireless weather station. The measurement distance (object-objective) was designed to be 1 m, taking into account the size of the measured sample, the resolution of the detector and the used objective of infrared camera. Atmosferic parametesr and the reflected apparent temperature were continuously updated during the actual measurement.

Figure 4 Infrared reflector

3. RESULTS AND DISCUSSION

The measured results are depicted in emissivity- surface temperature coordinates **(Figure 5**, **Figure 6**). Each blue point represents one taken thermogram.

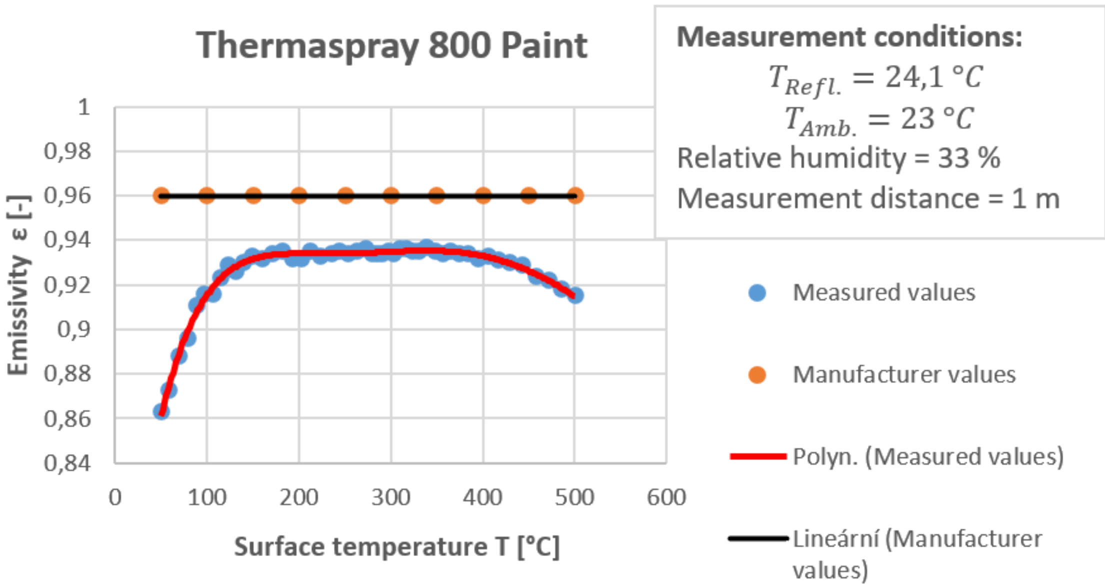

Figure 5 Dependence of emissivity on temperature for Thermaspray 800 Paint

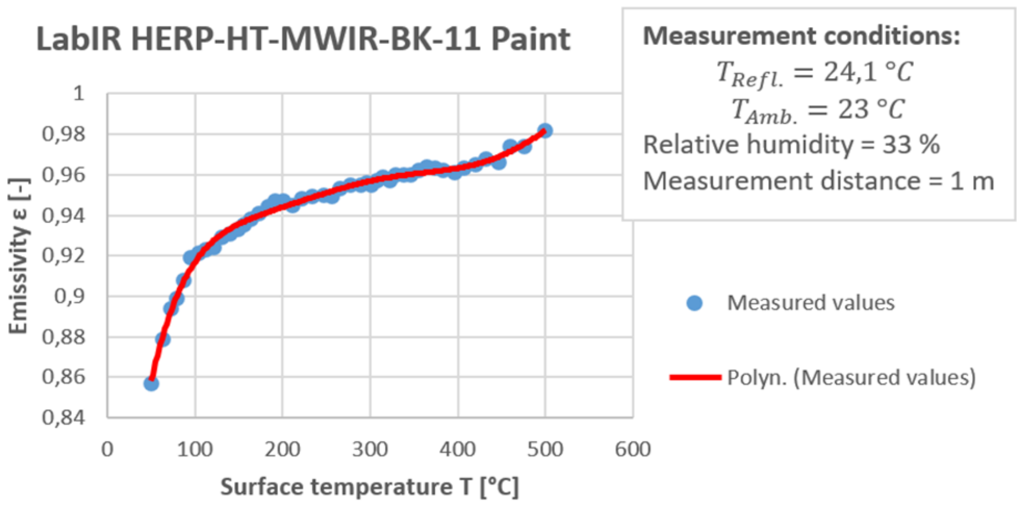

Figure 6 Dependence of emissivity on temperature for LabIR HERP-HT-MWIR-BK-11 Paint

From the graphs above, it can be seen that the exact determination of emissivity is quite difficult. In both cases, occurs significant changes in values. From the graph in **Figure 5**, it can be seen, that this paint (thermaspray 800), after a sharp initial increases (in the range from 50 to 150 °C), holds a relatively stable emissivity value up to 400 °C. On the other hand, for the second paint (LabIR), there is a continuous increase in emissivity with temperature.

4. CONCLUSION

It is evident from measurements that the emissivity is highly variable depending on the temperature. From the point of view of quantitative measurement, the use of Thermaspray 800 paint appears to be better, especially in the temperature range from 150 to 400 °C. An almost constant emissivity value can be observed in this temperature interval. The constant emissivity value enables more accurate temperature measurement by the infrared camera without the need for frequent updates of the emissivity in the infrared camera firmware. The measured charakteristics will be used for further measurements carried out at the Department of Manufacturing Technology of the Czech Technical University in Prague.

ACKNOWLEDGEMENTS

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