March 2022

ROBUST EMISSIVITY MEASUREMENT SYSTEM

HP INC

Robust emissivity measurement system

1. Abstract

Emissivity is an important property of the materials used in technologies such as MultiJet Fusion and Metaljet, as it affects the radiative thermal exchange and, because of this, also the temperature measurements that rely on a device such as a pyrometer or a thermal camera. Due to that, it has a direct impact on the actual temperatures to which the system is controlled.

The device object of this article enables the emissivity measurement for diffuse materials, such as metallic or plastic powder; in particular, in the thermal infrared wavelength range (8 to 14 micrometers), but the methodology could be extended to other parts of the spectrum or focused on a smaller region. This device can either be used as a separate tool in the process or integrated in other machine, and the results can be used for process adjustment or tracking.

The device and the procedure followed rely on the comparison of the increase in reflected energy coming from a constant source between a known emissivity sample and the sample which emissivity is of interest. The procedure has inherent robustness thanks to the measurement by comparison, as:

- There is no high accuracy needed in the temperature of the source, if it has stabilized and in a reasonable range.
- There is no high accuracy needed in the readings from the pyrometer, if the uncertainties that affect it (internal temperature, third surfaces reflections) don't change quickly through the test or between the measurement of the sample and the reference.
- It can admit some uncertainty on the emissivity of the reference sample if this emissivity is low (0-0.1)

The concept has been prototyped and has shown good performance compared with the measurements provided by a commercial emissometer.

Description of invention

2. Problems solved

Emissivity variability is a known issue between different batches of powder (especially metallic one), and between different materials. This has a direct impact to the actual temperature at which the top layer of the powder is controlled, and because of this, it can lead to gradients in the powder (between top layer and other heating elements), or Part Quality variability between batches, as the effective temperature and drying rate of the binder would be different.

Knowing the emissivity of the materials allows better tracking of variabilities in the process and enables a better adjustment of the process settings for each material.

3. Prior solutions

Another partial solution applied to the emissivity variability involves keeping controlled the temperatures of the system that, together with the emissivity, influence the temperature measured by the thermal camera. The goal in this case is to operate at a point at which the sensitivity to emissivity variability between batches is the lowest.

However, this mechanism relies on keeping constant at an specific value some temperatures that have spacial non uniformity and cannot be measured directly (it needs to be done through characterization and modelling, and then estimating during the process). This implies several uncertainties and, while it helps reduce the effect of the variability in this property, does not provide a full solution (and of course, does not allow to have a track of the differences between batches)

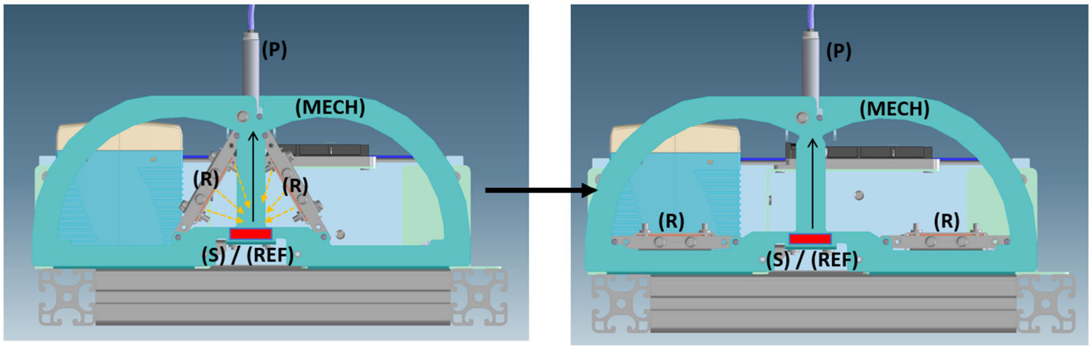
On the other hand, there are also commercial hand-held emissometers that could be used for external tracking of the material property but not easily integrated in the process. They are also expensive and not robust to metallic powder.

4. Description

The system object of this article can be implemented in many ways, but in general, the hardware is composed of:

- A radiative source (R), that emits mainly in the thermal infrared region and has high emissivity in that range, and which level of emitted radiation can be kept at stable values (for example through temperature control).
- A sample (S), together with a support to hold it.
- A reference (REF), which must be diffuse and with low and known emissivity.
- A radiative measurement device, such as a pyrometer (P), that detects radiation in the wavelength window in which the emissivity needs to be measured.
- A mechanism (MECH) that allows:
    - The sample (S) and the reference (REF) to be positioned in an alternate way in front of the pyrometer (P), with a certain angle (can be directly perpendicular or not, depending on the angle in which the emissivity needs to be measured) that must be the same for both.
    - Alternating the view factor between 0% and a given amount (the closer to 100%, the better the accuracy, but the concept has been prototyped with around 50%). This view factor refers to the portion of the hemisphere seen from the sample (S) or reference (REF), when they are at the point in which they are measured by the pyrometer (P), occupied by the radiative source.

An example implementation of this can be seen in Figure 2 and Figure 3



Position 1: view factor from (S)/(REF) to (R) = 0.5

Position 2: view factor from (S)/(REF) to (R) = 0

Figure 1

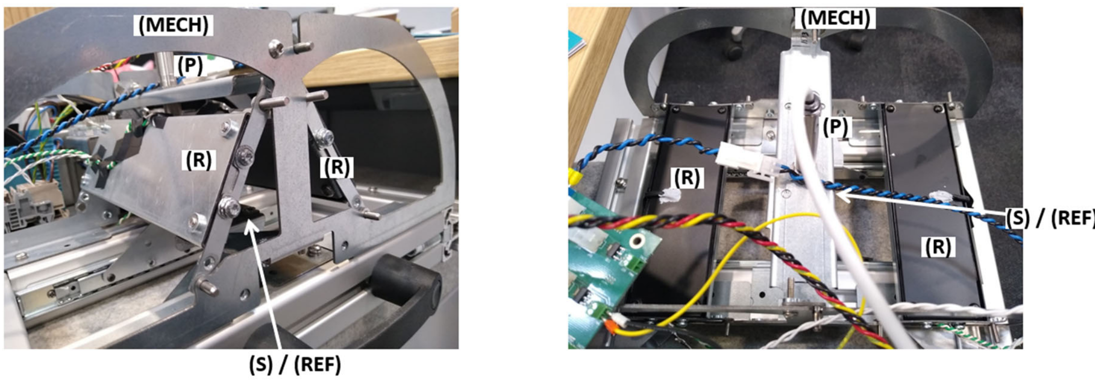


Figure 2

The procedure to be used for measuring the emissivity of the sample consist in the following steps:

1. Stabilization of the radiative source (R).
2. Positioning the reference (REF) at the point at which the pyrometer (P) points to it.
3. Using the mechanism (MECH) to cycle the view factor between 0% and maximum view factor at least one time, while measuring incoming radiation to the pyrometer (P).
4. Removing the reference (REF)
5. Positioning the sample (S) at the point at which the pyrometer (P) points to it.
6. Using the mechanism (MECH) to cycle the view factor between 0% and maximum view factor at least one time, while measuring incoming radiation to the pyrometer (P).
7. Removing the sample (S)
8. Calculating the sample (S) emissivity [E_S] using the reference (REF) emissivity [E_REF], the radiation increase measured in Step 3 [DELTA_REF] and the radiation increase measured in Step 6 [DELTA_S], using the first equation in Figure 4. Radiation increase quotient can be approximated by the second equation in Figure 4, when using a Pyrometer / Thermocamera configured to assume that the emissivity of what it reads is 1.

$$\epsilon_S = 1 - (1 - \epsilon_{REF}) * \frac{\Delta_S}{\Delta_{REF}}$$

$$\frac{\Delta_S}{\Delta_{REF}} = \frac{T_{High,S}^4 - T_{Low,S}^4}{T_{High,REF}^4 - T_{Low,REF}^4}$$

Figure 3

An example of the readings obtained in Step 3 and Step 6 can be seen in Figure 5.

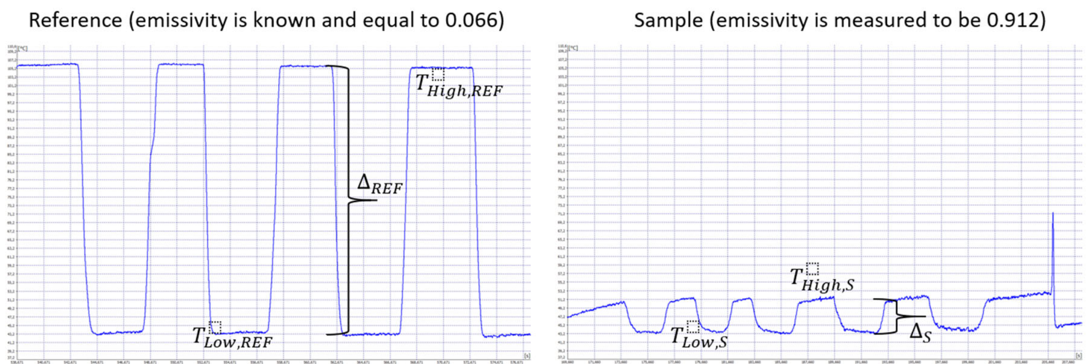


Figure 4

More details on the procedure and results used to demonstrate the concept can be found in the attached presentation (Emissivity setup – proof of concept.pptx).

5. Advantages

- Very low cost compared with commercial, non-robust and non-integrable solutions (around 10% of the cost)
- Could be integrated together with another device of the process, such as the printer, as well as be implemented as a standalone device.
- Low sensitivity to temperature of the sample, the reference, or the radiative source: if they are stable, they do not need to be set at a particular value or even known.

- Low sensitivity to the accuracy of the radiative measurement device, and in particular its internal temperature, as it relies on the radiation increment and not the punctual measurement.

Disclosed by Carlos Eduardo Caballero and Esteve Comas. HP Inc.