Towards hyperspectral in-situ temperature measurement in metal additive manufacturing

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The industrial use of additive manufacturing for the production of metallic parts with high geometrical complexity and lot sizes close to one is rapidly increasing as a result of mass individualisation and applied safety relevant constructions. However, due to the high complexity of the production process, it is not yet fully understood and controlled, especially for changing (lot size one) part geometries.

Due to the thermal nature of the Laser-powder bed fusion (L-PBF) process – where parts are built up layer-wise by melting metal powder via laser - the properties of the produced part are strongly governed by its thermal history. Thus, a promising route for process monitoring is the use of thermography. However, the reconstruction of temperature information from thermographic data relies on the knowledge of the surface emissivity at each position on the part. Since the emissivity is strongly changing during the process due to phase changes, great temperature gradients, possible oxidation, and other potential influencing factors, the extraction of real temperature data from thermographic images is challenging. While the temperature development in and around the melt pool, where melting and solidification occur is most important for the development of the part properties. Also, the emissivity changes are most severe in this area, rendering the temperature deduction most challenging.

A possible route to overcome the entanglement of temperature and emissivity in the thermal radiation is the use of hyperspectral imaging in combination with temperature emissivity separation (TES) algorithms. As a first step towards the combined temperature and emissivity determination in the L-PBF process, here, we use a hyperspectral line camera system operating in the short-wave infrared region (0.9 µm to 1.7 µm) to measure the spectral radiance emitted. In this setup, the melt pool of the L-PBF process migrates through the camera's 1D field of view, so that the radiation intensities are recorded simultaneously for multiple different wavelength ranges in a spatially resolved manner. At sufficiently high acquisition frame rate, an effective melt pool image can be reconstructed. Using the grey body approximation (emissivity is independent of the wavelength), a first, simple TES is performed, and the resulting emissivity and temperature values are compared to literature values. Subsequent work will include reference measurements of the spectral emissivity in different states allowing its analytical parametrisation as well as the adaption and optimisation of the TES algorithms. An illustration of the proposed method is shown in Fig.1.

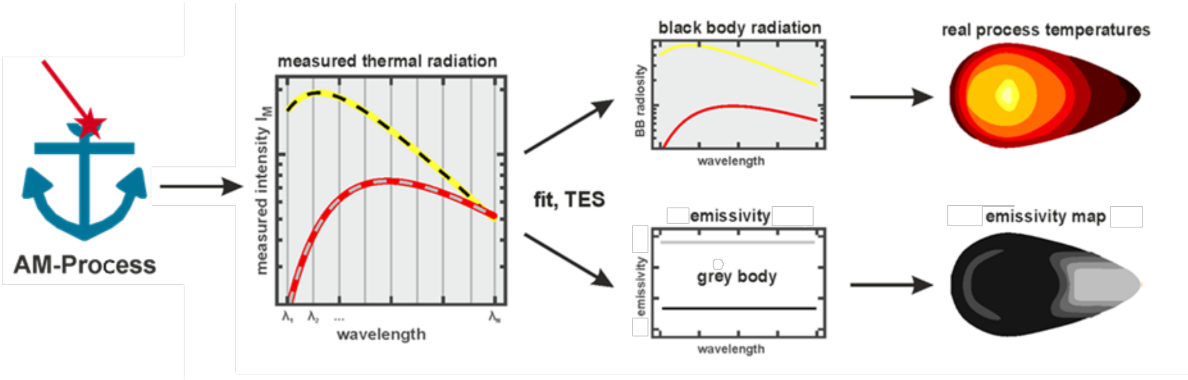

Fig. 1. Schematic illustration of the proposed method. The yellow and black (dashed) lines correspond to a region in the centre of the melt pool with high temperature and low emissivity (liquid metal), the red and grey (dashed) lines correspond to a region behind the melt pool (on the very right- hand side), where the material is solidified and possibly oxidised, at a lower temperature and with a higher emissivity.

The investigated method will allow to gain a deeper understanding of the L-PBF process, e.g., by quantitative validation of simulation results. Additionally, the results will provide a data basis for the development of less complex and cheaper sensor technologies for L-PBF in-process monitoring (or for related process), e.g., by using machine learning.

References

[1] https://www.bam.de/thermography