UDC 62

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IMPROVED METHODOLOGY FOR MEASURING THE EMISSIVITY OF METAL POWDERS

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Abstract.

A specially designed chamber is proposed to accurately measure the emissivity coefficient of metal powders over a wide temperature range using an infrared (IR) camera. This measurement setup significantly reduces the oxidation of metal powders during heating to high temperatures. As a result, it enables precise determination of the actual emissivity values, which is crucial for accurate IR camera calibration when studying sintering or melting processes in additive manufacturing.

Keywords: measurement, infrared thermography, additive manufacturing, emissivity

. Accurate temperature measurement of metallic materials is a key factor in ensuring the quality and consistency of parts produced via metal additive manufacturing (AM). Temperature serves as a critical process parameter for real-time monitoring and intelligent control, particularly in AM systems enhanced by machine learning techniques [1–3]. Reliable thermal data enables improved process stability, defect reduction, and better predictability of material behavior during melting and solidification.

However, accurate temperature measurement in metal additive manufacturing requires precise knowledge of the metal powder's actual emissivity. In our previous studies, we proposed a methodology for determining the emissivity of metal powders, which was validated through experiments involving the heating of 316L stainless steel powder [4]. As shown by the study [3, 4] of the emissivity of 316L stainless steel powder during heating to temperatures above 400 °C, the emissivity value begins to increase. This increase was associated with the onset of the oxidation process at temperatures of 400 °C and higher. To reduce the influence of oxidation at high temperatures, we proposed the design of a specialized chamber that allows for the simultaneous heating and temperature measurement of 316L stainless steel powder in a completely enclosed argon atmosphere.

The chamber is a 31.75 cm x 31.75 cm x 33.02 cm box with walls made of aluminum 6061, as this material is easy to machine to our precise specifications (Fig. 1-3), and uses a 110 V high-frequency induction heater (model USS-HFIH00001-110V) to heat the metal powder. Each wall of the chamber has features specific to our new setup. The top wall has a square cutout covered by a removable lid. The lid has a circular hole cut out from the center with holes surrounding it for the window to be attached. The window must be able to handle high temperatures without melting or decomposing and allow for the IR spectrum to be viewed through it. The lid also has attachment points for the camera mount that consists of an aluminum ring that sits around the window and a vertical rod to attach the IR camera to. The IR camera (FLIR A700) sits right above the window and is 18.4 cm away from the metal powder sample. The top wall is connected to the chamber via toggle latches on each wall. The back wall has holes where the induction heater coil feeds in and out of the chamber allowing the coil to side in the center of the chamber. The right wall has a space for thermocouples to be attached for direct temperature measurements of the metal powder. The left wall has two ports, one inlet and one outlet, for argon gas to enter and flush the oxygen out of the chamber. The front wall has a square cutout covered by a removable lid to be able to switch the IR camera placement from the top to the front side. We ensured an airtight seal across the entire chamber by putting rubber gasket material between each piece of aluminum, putting a rubber gasket between the aluminum and the window, and filling the space between the wall and induction coil with epoxy. We also put alumina insulation on the inside of the chamber to reduce the heat transfer from the sample directly to the chamber walls and protect the IR camera from overheating. The insulation will also help reduce heat loss from the metal powder sample allowing the sample to get hotter.

The 316L stainless steel powder is held in a cylindrical sample holder of the same material with a shallow cutout for the metal powder to sit in. The cylinder is tall enough for the metal powder to be held in the induction coil. We paint the rim of the sample holder with blackbody paint to serve as a reference emissivity for the IR camera measurements. The sample holder also has a small hole drilled into the side just below the surface of the sample cutout that reaches to the radial center of the cylinder for a thermocouple to be inserted to measure the temperature of the metal powder sample. Since the metal powder and the sample holder are made of the same material, this set-up becomes difficult to reset for repeat experiments at sintering and melting temperatures. At higher temperatures (when sintering starts to occur), the sample holder will be exchanged for a ceramic sample holder that will not melt with the metal powder at higher temperatures. The thermocouple setup with the stainless steel sample holder cannot be used with the ceramic sample holder as ceramic is difficult to machine.

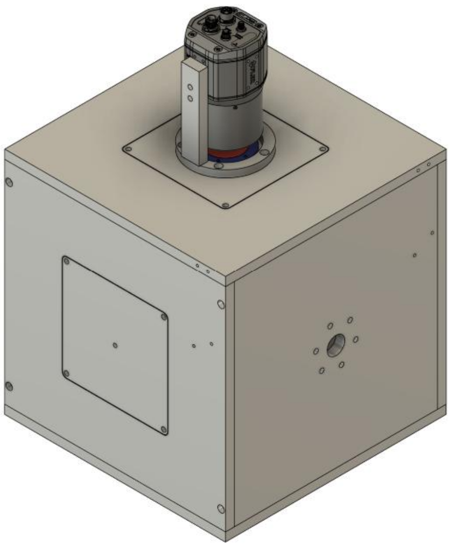

Fig. 1: Outside view of the chamber's front (left), right (right), and top (top) walls, including IR camera.

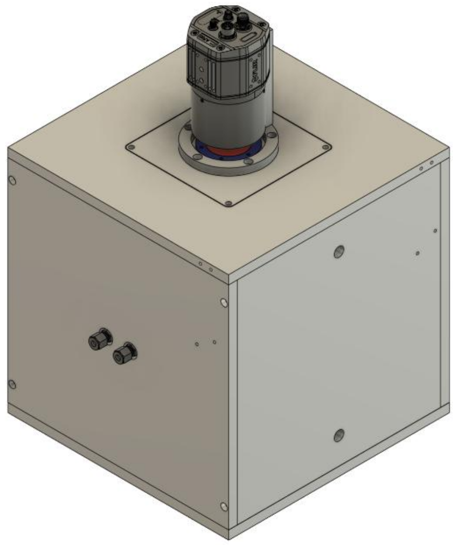

Fig. 2: Outside view of the chamber's back (left), left (right), and top (top) walls, including IR camera.

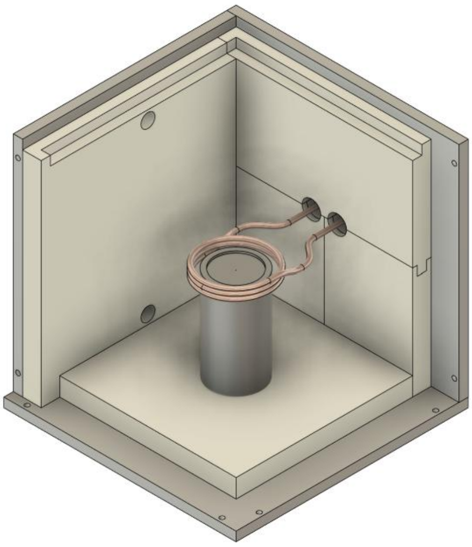

Fig. 3: Inside view of the chamber's back (right), left (left), and bottom (bottom) insulation, including induction coil and sample holder.

The initial experimental studies of the emissivity of 316L steel powder when heated from 400 °C to 800 °C demonstrated that the emissivity value was 0.3 with a deviation of ± 0.03. The expanded uncertainty of the measurement results was obtained based on the methods of quantitative uncertainty assessment, which are described in detail in [4-14].

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ПОКРАЩЕНА МЕТОДОЛОГІЯ ВИМІРЮВАННЯ КОЄФІЦІЄНТУ ВИПРОМІНЮВАННЯ МЕТАЛЕВИХ ПОРОШКІВ

Анотація.
Запропоновано спеціально розроблену камеру для точного вимірювання коефіцієнта випромінювання металевих порошків у широкому діапазоні температур за допомогою інфрачервоної (ІЧ) камери. Ця вимірювальна установка значно зменшує окислення металевих порошків під час нагрівання до високих температур. Як результат, вона дозволяє точно визначати фактичні значення коефіцієнту випромінювання, що є вирішальним для точного калібрування ІЧ-камери під час вивчення процесів спікання або плавлення в адитивному виробництві.
Ключові слова: вимірювання, інфрачервона термографія, адитивне виробництво, коефіцієнт випромінювання

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