UDC 62

O. Vasilevskyi, A. Woods, M. Cullinan

RESEARCH ON DIRECT LASER MELTING PROCESSES OF METAL POWDERS IN THE BUILD CHAMBER OF THE EOSINT M280 SYSTEM USING A DEVELOPED OPTICAL WINDOW

The University of Texas at Austin, Austin, TX 78712, USA

Abstract.
A specialized metrological optical window with an infrared camera is proposed for studying the laser melting processes of metal powders.The proposed optical window enables temperature monitoring of metal powder laser melting during additive parts manufacturing.Based on the monitoring results, it becomes possible to implement automatic quality control of the laser melting process by generating feedback control signals to regulate the laser power.

Keywords: optical window, laser melting, infrared thermography, additive manufacturing, laser power

In recent years, additive manufacturing (AM) has gained significant traction in high-tech industries such as aerospace, medicine, automotive, defense, and tooling [1,2]. Unlike traditional subtractive methods, AM creates components layer by layer, enabling the production of intricate and highly customized designs. One of the most advanced AM techniques, Laser Powder Bed Fusion for Metals (LBP-BF/M), allows for the fabrication of complex, high-precision parts. Continued technological advancements have expanded the capabilities of LBP-BF/M, making it suitable for a wide range of demanding applications. However, the quality of the metal laser melting process is highly sensitive to factors such as melting temperature, scanning speed, laser power, and environmental conditions. Improper settings can lead to various defects, including porosity, keyhole formation, and the balling effect caused by surface tension [3,4]. To address these challenges, developing a specialized optical window equipped with an infrared (IR) camera for the EOSINT M280 system is a pressing scientific task. Replacing the standard window, this innovation enables real-time temperature monitoring during the laser melting process and provides a pathway for closed-loop laser power control, thereby improving LBP-BF/M process quality.

The optical window developed for the EOSINT M280 system with the FLIR A700 IR camera is shown in Figure 1.

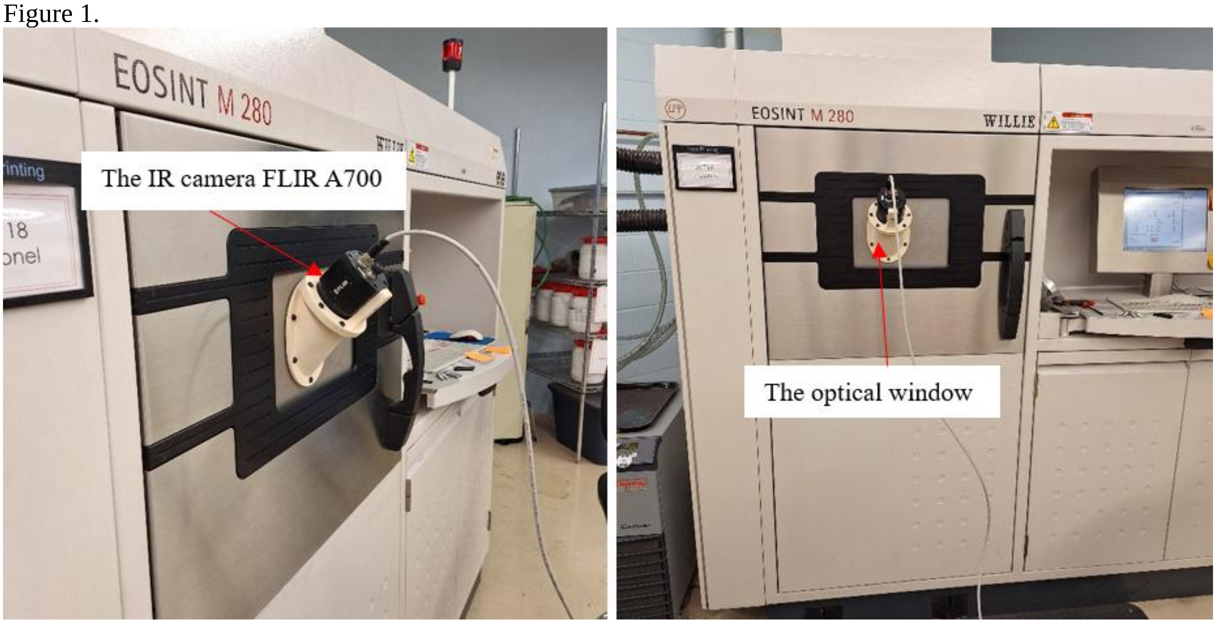
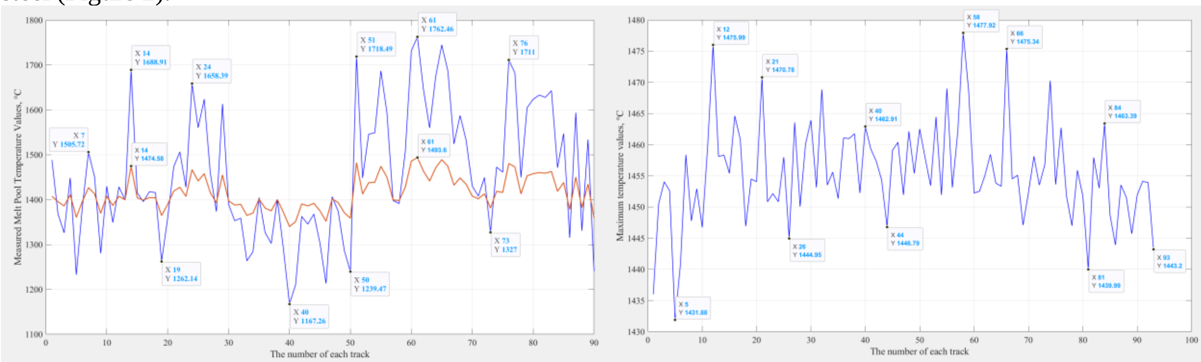


Figure 1 – The EOSINT M280 system is fitted with an optical window incorporating the FLIR A700 IR camera

The ZnSe optical window supports the transmission of infrared wavelengths in the range of 3 to 12 µm. Comprehensive technical specifications can be found on the manufacturer's website [5]. The FLIR A700 IR camera operates across a wide temperature range – from 300 to 2000 °C – offering high-precision measurements with an accuracy of 2%. It functions within a spectral range of 7.5 to 14 µm and features a dedicated output for generating feedback control signals [6].

Using the proposed optical window, it became possible to measure the melting temperatures of metal powders. For example, when studying the processes of laser melting of IN718 alloy powder and 316L steel powder, the results of temperature measurements were obtained at a laser power of 285 W for IN718 alloy and 195 W for 316L steel (Figure 2).



a) IN 718 alloy at 285 W laser power; b) 316L steel at laser power 195 W

Figure 2 – Melting Temperature Measurements of Inconel 718 and 316L Powders

As seen in Figure 2, the in situ measured temperatures obtained during the LPBF/M process show that the recorded values often exceed the actual temperatures. This is due to the following factors:

- optical artifacts and signal noise: Infrared sensors detect thermal radiation intensity, which may not always correlate directly with actual temperature. Fluctuations in material emissivity, along with interference from spatter, fumes, vapor, and reflections off chamber walls or previously solidified layers, can distort the measurements;

- localized overheating and energy concentration: The laser introduces a highly concentrated energy input into a small melt pool area. Consequently, the temperature in this zone often exceeds the melting point to ensure consistent melting behavior and proper flow of the molten material;

- melting and evaporation phenomena: Under high laser power, localized material evaporation can occur. If the sensor captures an area undergoing intense evaporation, the resulting temperature readings may be significantly overestimated.

To eliminate the above factors, we proposed to apply Kalman filtering to the measured temperature values using an IR camera [7, 8]. Based on theoretical information on the concept of uncertainty [8-16], before applying the Kalman filtering algorithm, the Type A measurement uncertainty – describing process noise Q_k=$u_A^2(\bar{T})$ – was calculated, along with the combined Type B uncertainty, which characterizes measurement noise $P_{k-1} = u_{B_{inst}}^2$. The measurement results after applying Kalman filtering are shown in Figure 2a (brown line). As a result of the research on the melting temperatures of metal powders, it was found that the maximum experimental Type A measurement uncertainty did not exceed $u_{AIN718}(\bar{T})$ =43°C for the melting of IN718 powder and $u_{A316L}(\bar{T})$ =11.8°C for the melting of 316L steel powder. Meanwhile, the combined Type B uncertainty was $u_{B_{inst}}$=40.5°C.

Thus, the use of the developed optical window with an IR camera, combined with signal filtering, enables in-situ monitoring of metal powder melting temperatures. This approach allows for quality control of the laser melting process by regulating laser power through a feedback mechanism.

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Vasilevskyi Oleksandr **–** Senior Research, The Walker Department of Mechanical Engineering, the Cockrell School of Engineering, The University of Texas at Austin, ***e-mail: oleksandr.vasilevskyi@austin.utexas.edu***

Woods Alexandra - Bachelor's student, The Walker Department of Mechanical Engineering, the Cockrell School of Engineering, The University of Texas at Austin, ***e-mail: alexandra-woods@utexas.edu***

Cullinan Michael **-** Associate Professor, The Walker Department of Mechanical Engineering, the Cockrell School of Engineering, The University of Texas at Austin, ***e-mail: michael.cullinan@austin.utexas.edu***

O. Vasilevskyi, A. Woods, M. Cullinan

ДОСЛІДЖЕННЯ ПРОЦЕСІВ ПРЯМОГО ЛАЗЕРНОГО РОЗПЛАВЛЕННЯ МЕТАЛЕВИХ ПОРОШКІВ У БУДІВНІЙ КАМЕРІ СИСТЕМИ EOSINT M280 ЗА ДОПОМОГОЮ РОЗРОБЛЕНОГО ОПТИЧНОГО ВІКНА

Анотація.
Запропоновано спеціалізоване метрологічне оптичне вікно з інфрачервоною камерою для дослідження процесів лазерного плавлення металевих порошків. Запропоноване оптичне вікно дає змогу здійснювати моніторинг температури під час лазерного плавлення порошків металу в процесі адитивного виготовлення деталей. На основі результатів моніторингу стає можливим автоматичне керування якістю процесу лазерного плавлення шляхом формування сигналів зворотного зв'язку для регулювання потужності лазера.
Ключові слова: оптичне вікно, лазерне плавлення, інфрачервона термографія, адитивне виробництво, потужність лазера

Vasilevskyi Oleksandr **–** старший науковий дослідник, департамент механічної інженерії імені Уокера, Техаський університет в Остіні, e-mail: oleksandr.vasilevskyi@austin.utexas.edu

Woods Alexandra **–** студент бакалаврату, департамент механічної інженерії імені Уокера, Техаський університет в Остіні, e-mail: alexandra-woods@utexas.edu

Cullinan Michael – доцент, департамент механічної інженерії імені Уокера, Техаський університет в Остіні, e-mail: michael.cullinan@austin.utexas.edu