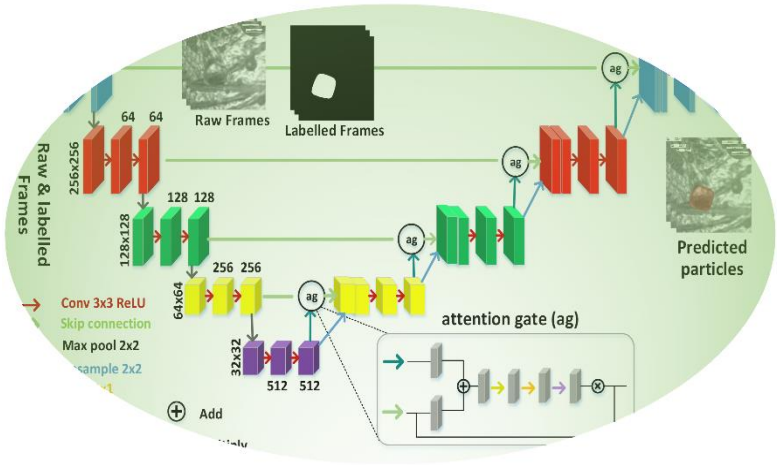
SUCCESS STORY

IC-MPPE
Integrated Computational Materials Process and Product Engineering.

Programme: COMET – Competence Centers for Excellent Technologies

Programme line: COMET-K2 Centre

Type of project: P2.06_Refractory Corrosion, 2018-2021, multi-firm



Automated fast and accurate evaluation of the MgO particle dissolution rate within the molten slag utilizing the deep learning-based approach, image: MCL

DEEP LEARNING FOR REFRACTORY MATERIALS

A DEEP LEARNING-BASED APPROACH ENABLING THE AUTOMATED EVALUATION OF THE PARTICLE DISSOLUTION RATE WITH HIGH PRECISION.

The function of refractory materials is to withstand high temperatures required in e.g. furnaces, kilns, incinerators, and power plants without contaminating other materials. Further, heat in the area where it is needed should be conserved. Oxides of, for example, aluminum (Al), silicon (Si) and magnesium (Mg) are the most important materials used in the manufacturing of refractories.

Refractories often face corrosive wear due to diffusion in liquid slags at high temperatures. Therefore, accurate dissolution experiments and efficient quantification approaches are essential for designing refractory products with more wear resistant and long service life.

Here, high temperature-confocal laser scanning microscopy (HT-CLSM) displays a highly suitable in-situ method to study the underlying dissolution kinetics in the slag over time. However, a major drawback concerns the efficient and accurate processing of the collected image data.

Deep learning (DL) provides intriguing possibilities in the field of image recognition and processing. U-Net architectures have become widely adopted and influential models. A conventional U-Net architecture usually consists of an encoder and decoder, connected by skip connections. Here, the encoder extracts hierarchical features, while the decoder combines them to create the final segmentation. The modular nature of U-Net allows for easy customization and adaptability, making it a versatile solution for a wide range of image segmentation problems.

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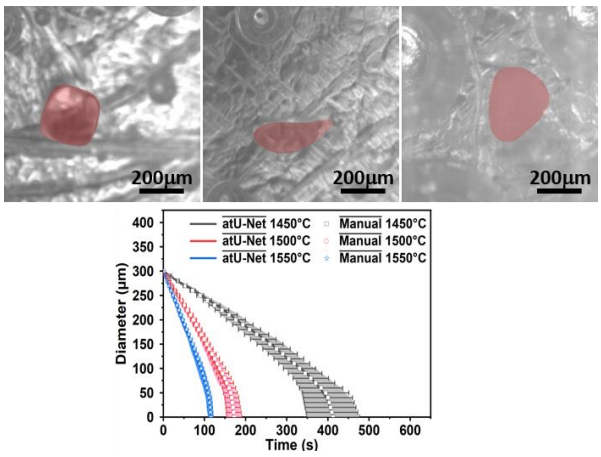
In the COMET IC-MPPE project RefractoryCorrosion, we have developed a deep learning-based workflow to automatically evaluate the dissolution of MgO particles in the slag over a certain period of time. The image data was generated using high-temperature laser scanning microscopy. An Attention-U-Net architecture (atU-Net) was developed and used to analyze the image data in different time steps. The attention gate within the atU-Net architecture makes it possible to localize the MgO particles in the slag while boosting overall prediction performance by decreasing miss-segmentation.

Impact and effects

This approach marks a significant advancement in accelerating the development of refractory materials and opens up new possibilities for improving energy efficiency in industrial processes. The application of the developed atU-Net is not restricted to the evaluation of particle dissolving rates; rather, it offers an approach for accurate and efficient particle tracking and identification in various data types such as scanning electron microscopy (SEM), micro- X-ray computed tomography (µ-XCT), etc., as well as across other domains.



The DL-based approach enables automated, rapid, and accurate assessment of particle dissolution rates regardless of image quality, particle shape, position, and kinetics across varying measurement temperatures. image: MCL

More details can be found in: F.F., Chamasemani, et al., Sci Rep 14, 21279 (2024)
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