Performance prediction and assessment of reusability and recycling of refractory materials using the NDT sensoring approach and Machine Learning

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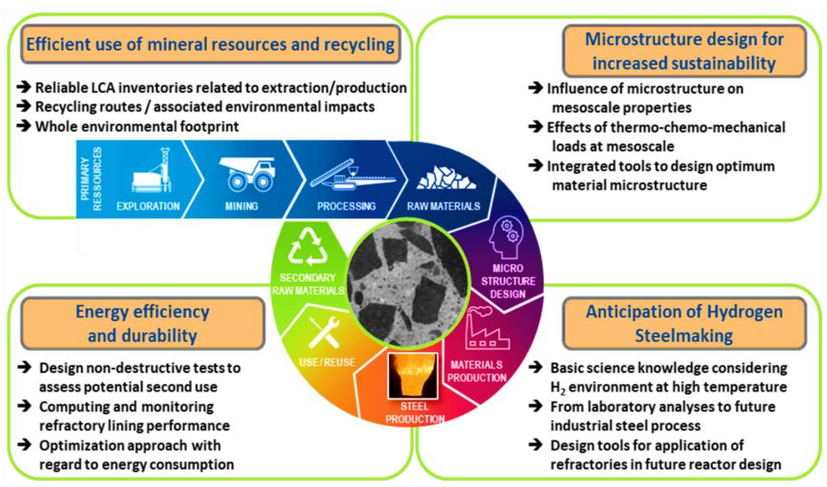
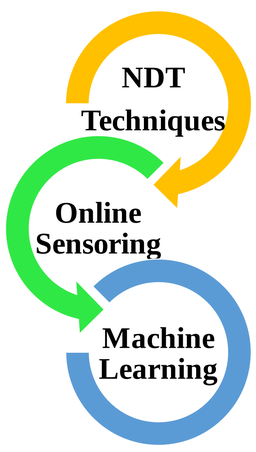
Context:

Refractory materials are necessary for the Iron and Steel (I&S) sector to endure the demanding conditions of its manufacturing processes. These materials' brief service lives, which can range from a few minutes to several months, create substantial problems for consumption, disposal, and environmental effect. There is a rising need for sustainable solutions that are compliant with the European Green Deal's standards for reduced greenhouse gas emissions, increased energy efficiency, and life cycle assessments. The Concerted European Activity on Sustainable Applications of REFractories (Doctoral Network ***CESAREF***), which aims to enhance research and practices linked to refractory material in the Iron & Steel industry, was founded in 2022 to address these concerns.

Objectives:

- CESAREF's PhD13 thesis aims to predict changes in refractory material's properties and assess their potential for reuse, extending their lifespan and reducing costs.
- Machine learning methods will be used to detect and assess the **characteristics of refractory materials** from collected data using **non-destructive evaluation methods**.
- The ultimate objective is to develop an accurate numerical model that can assess the reusability and recyclability of refractory components and enable decision-making based on the 4Rs: **Reduce, Reuse, Recycle, and Replace** [1].





Methods:

In order to safely reuse continuous casting process refractory components, their **thermo-chemical-mechanical properties** must be evaluated via non-destructive testing.

- ❖ **Thermal properties**
- ❖ **Stress-Strain curves**
- ❖ **Mechanical failure**

Before being implemented in the field, a **pertinent monitoring technique** must first be devised at a laboratory size.

- ❖ **Testing of Various NDT methods**

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REUSE 4R
REDUCE
RECYCLE
REPLACE

To assist the end-user in making **4R (Reduce, Reuse, Recycle, and Replace)** decisions, a digital tool to be developed.

Select optimal **machine learning methods** for predicting refractories' thermo-chemical/mechanical properties based on non-destructive testing outcomes.

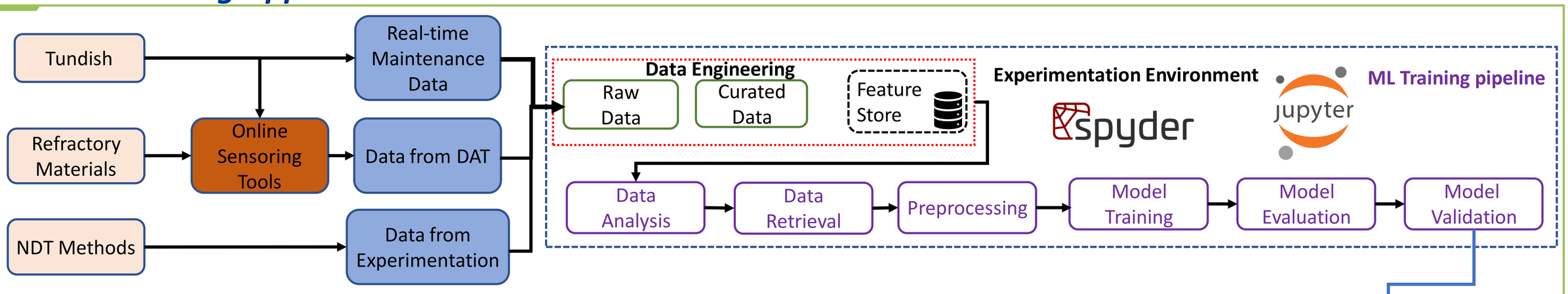
Sensor system development
Understanding of various sensoring system in Tundish.

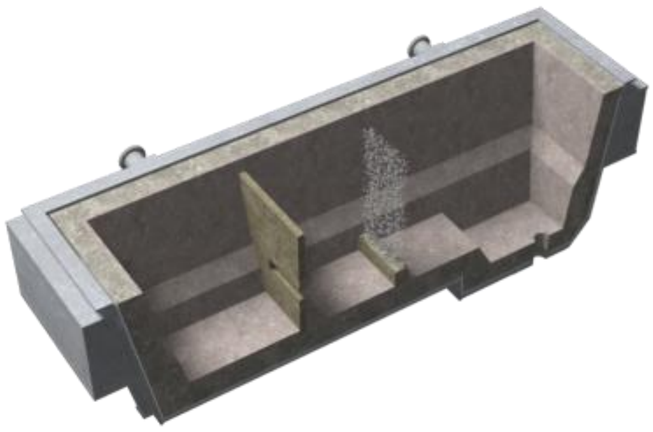
Data generation
Real-time data gathering using sensors using Data acquisition tools (**DAT**) and NDT experimentation.

Machine Learning
Developing a ML algorithms model.

Development of a model
Develop a algorithms model which can be implemented in Industry.

Machine Learning Approach:





Section view of Tundish [6]

Challenges:

- Understanding of **sensor implementation** in the **tundish and refractory linings** [2].
- Selecting a **NDT method** for performing the experiment for data collection [3].
- Preparing the **dataset for machine learning** applications.
- Selecting **machine learning and deep learning models** for the obtained data [4].

Validation:

- **Predicted results to real-time data** from tundish and refractories from plant.
- Validation of experimented data from **NDT methods**.
- To have a **comparisons** of **thermo chemical-mechanical properties** from predicted and real data [5].

- **Refractory Wear Prediction.**
- **Refractory lifetime Prediction.**
- **Production parameter ranking.**
- **Maintenance proposal.**
- **Daily report for tundish.**

Conclusions:

The following Ph.D. primarily focused on research outcomes:

- Understanding of various **online sensoring tools** for refractories.
- Implementation of A.I. to predict refractory wear: **Machine learning algorithms**
- **Non-destructive testing methods** for collecting **experimentation data**
- Monitoring and modeling techniques' insights will help in decision-making about **reduce/reuse/recycle/recreate**.

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