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Data Science and Numerical Simulations: Shaping the Future of Metal Process Modeling

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INTRODUCTION & AIM

DATA SCIENCE, NUMERICAL SIMULATIONS AND MATERIAL PROCESSES:

With the emergence of data science techniques, such as reduced order schemes, real-time modeling, machine learning (ML), and smart control schemes, material process modeling and simulations are undergoing a revolutionary phase. Although traditional analytical methods and advanced numerical simulations still provide estimations of multi-physical material processes, generating real-time predictions remains challenging for these techniques. This poster presents the outcomes of research on the simultaneous use of data models and detailed numerical simulations, highlighting their unique roles in control and data generation for future process modeling.

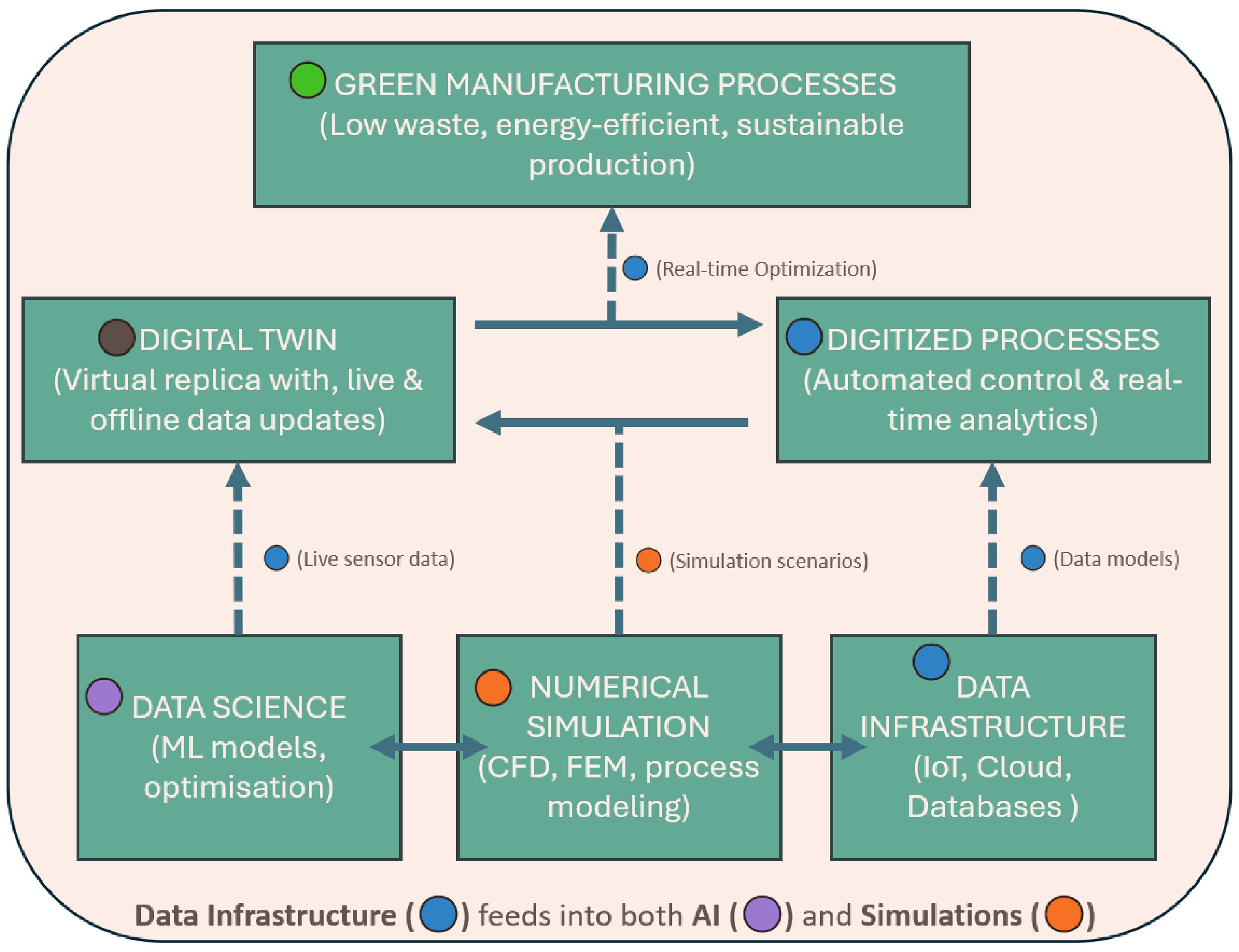
This research scrutinizes the efficient use of simulation techniques for creating fast databases and utilizing these databases for real-time predictions in metal processes, including;

- Creating a snapshot scenarios matrix by varying process parameters to develop an appropriately sized database for data solvers and interpolators.
- Applications of these models in metal processes, in order to to integrate these techniques into digital twin and shadow frameworks.

METHODOLOGY

GREENER AND MORE EFFICIENT METAL PROCESS TECHNOLOGY:

Data quality and availability issues have slowed the development of data models, while long computational times have hindered the use of advanced numerical simulations for process control. While many data processing and handling schemes exist within the data science field, only a few are suitable for material process applications, due to their transient and multi-physical natures. As more physics and phases are considered in numerical simulations, the computational time and resources required become enormous, even for today's parallel and clustered computers. Recently, integrating certain data techniques within numerical simulation frameworks has drastically reduced computational time (e.g., recurrence computational fluid dynamics). Consequently, both data models and numerical simulations, along with experimental validations, play crucial roles in generating accurate and reliable metal process modeling. These methods are used to produce final data models for real-time predictions during transient metal processes.

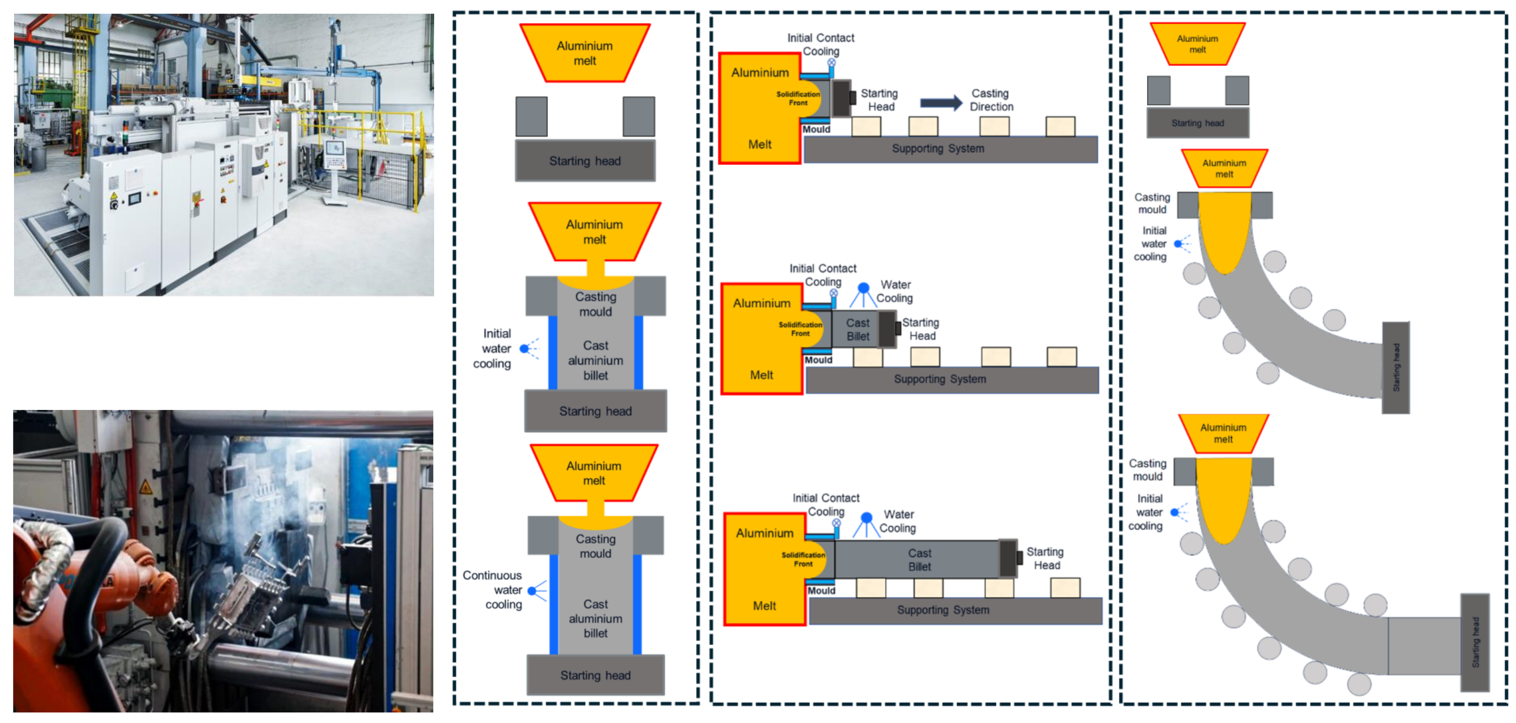


FRAMEWORK & RESULTS

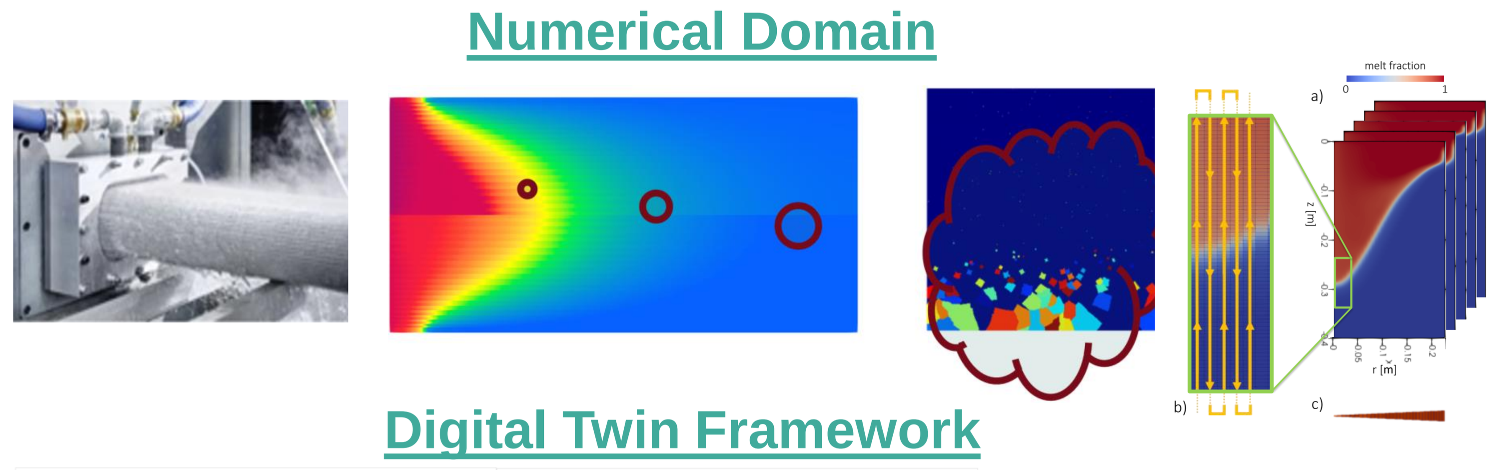
Milestones Achieved Throughout the Research Work:

- **Prediction Goals Definition**: The prediction goals at various length and time scales were established to design the database across these scales.
- **Execution of Snapshot Scenarios**: Numerical simulations were set up to generate response data for selected scenarios.
- **Database Generation**: Based on the dimensions and sizes of data spaces for process parameters, one or multiple databases were created.
- **Data Model Creation**: Data solvers and interpolators were employed to develop data models for the processes.
- **Validation and Utilization:** Validation scenarios were utilized to verify the accuracy and reliability of the predictions, and the data models were subsequently employed.

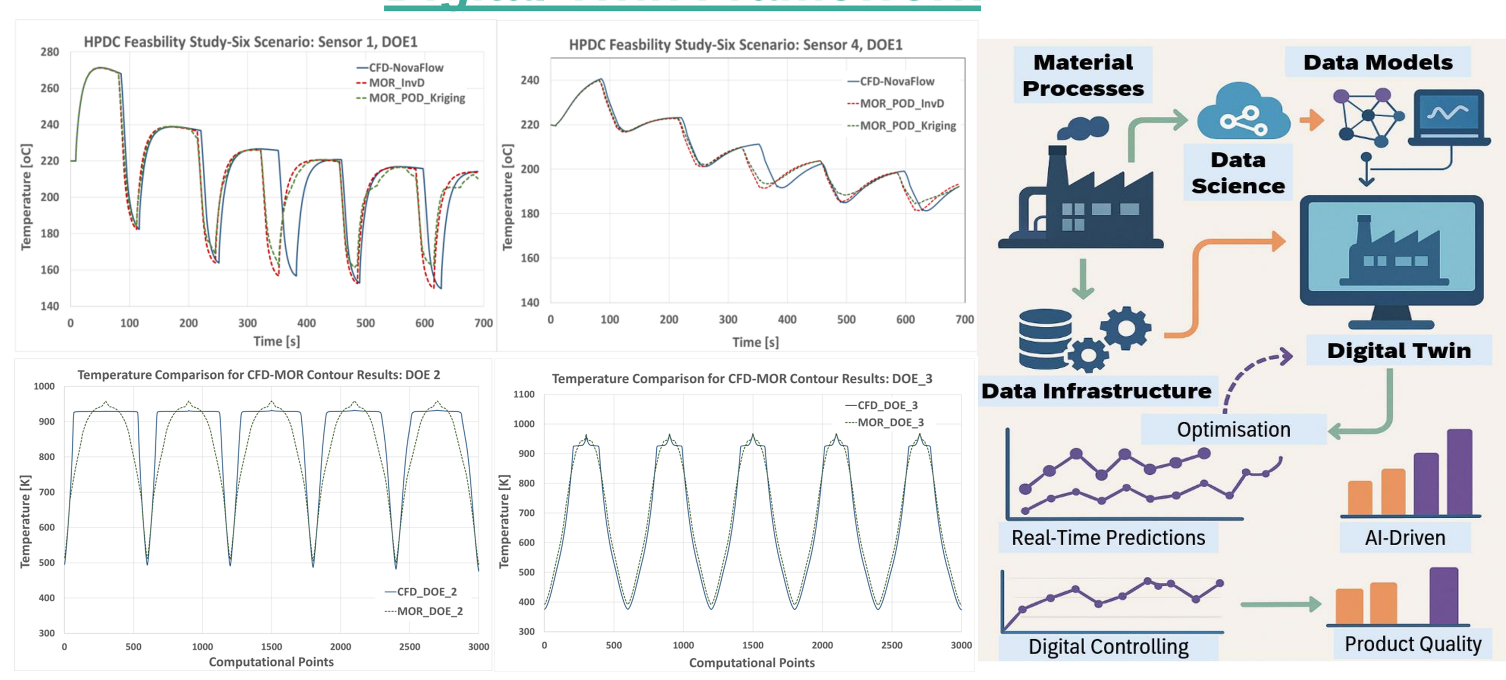
Physical Domain



Numerical Domain



Digital Twin Framework



CONCLUSION

The performance and validation of process data models were thoroughly examined, addressing major challenges related to their utilization. It was observed that a proper combination of data solvers and interpolators can produce satisfactory results.

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