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REDUCED MODELLING, DATA TRAINING AND REAL-TIME PREDICTION TOOLS FOR MATERIAL PROCESSES

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

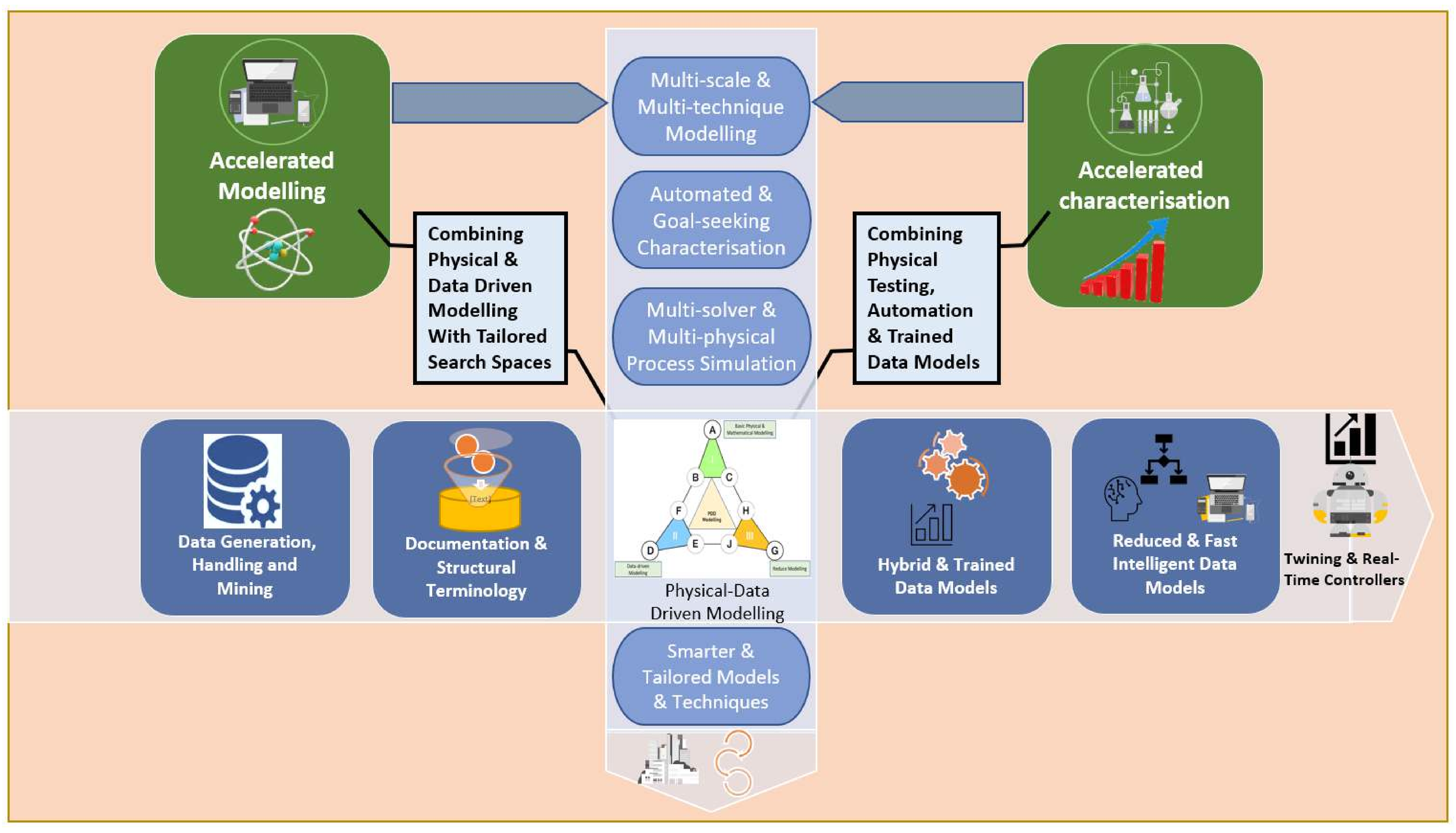
REDUCED & REAL-TIME MATERIAL & PROCESS MODELLING

Reduced and real-time material and process modelling enable material-based manufacturers to control and optimize their production chain, resulting in improved efficiency and reduced costs. They can also accurately predict the behaviour of materials and their associated processes, leading to reduced waste, improved quality and more sustainable production schemes. They are type of modelling that use data bases from experiments and off-line detailed simulations to create fast models that can predict the behaviour of materials and their evolution during manufacturing processes. They can also be used for controlling and optimization of the design production routines for new and existing materials and processes.

The proposed framework herein is trying to exploit reduced order modelling (ROM) and data training based on:

- Efficient material models for computational material science
- Concepts of integrating data science into material process simulations
- Smart material data management using machine learning (ML)

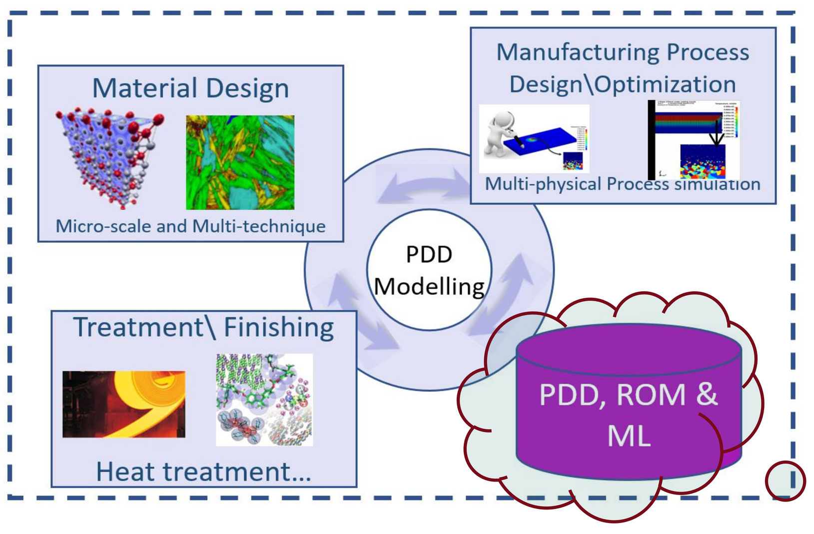
PHYSICAL-DATA DRIVEN MATERIAL\PROCESS MODELLING FRAMEWORK



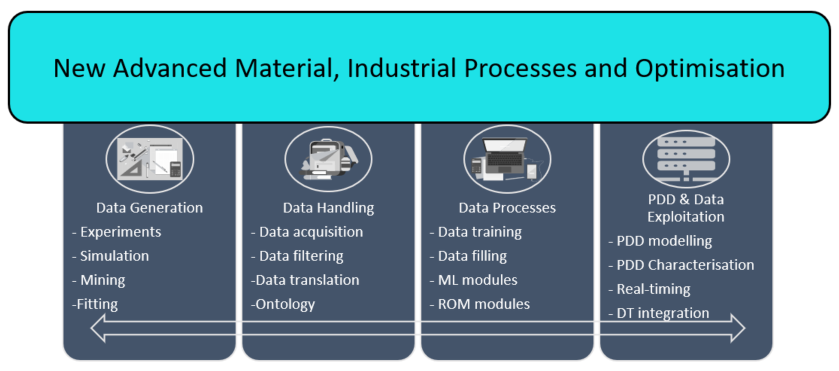
Crossing of physical & data sciences modelling schemes:

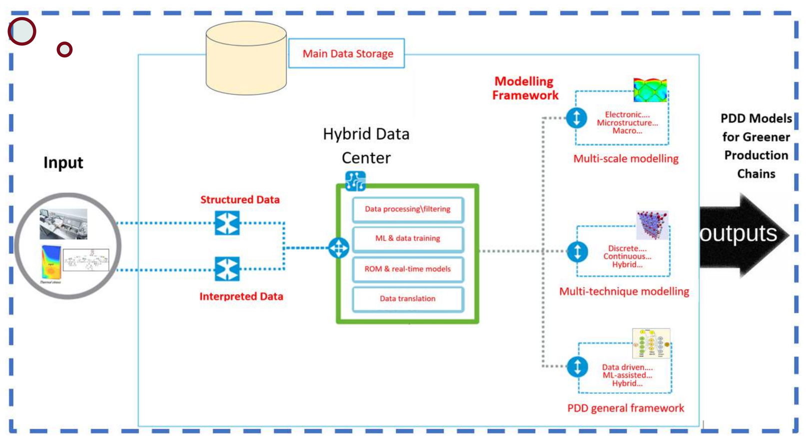
- Physical modelling (multi-scales, multi-physical) ⟺ Data fitting, auxiliary models
- Experimental material & process parameters ⟺ Data-driven accelerated characterization
- FE detailed numerical simulations ⟺ Real-time controlling & optimization tools

PHYSICAL-DATA DRIVEN: FROM MATERIAL DESIGN TO PROCESSES



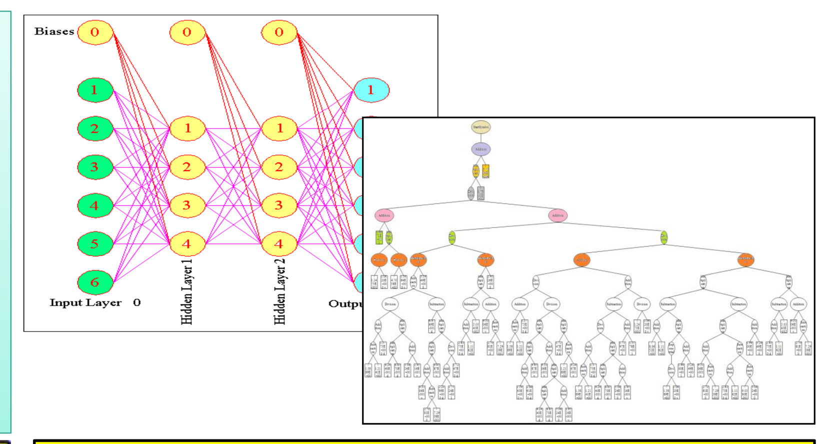
- Effectively develop new advanced PDD models based on digitally integrated modelling.
- Accelerate innovation process by better interpretation and more effective use of available experimental data.
- Overcoming gaps in modelling at different stage in the production chains.

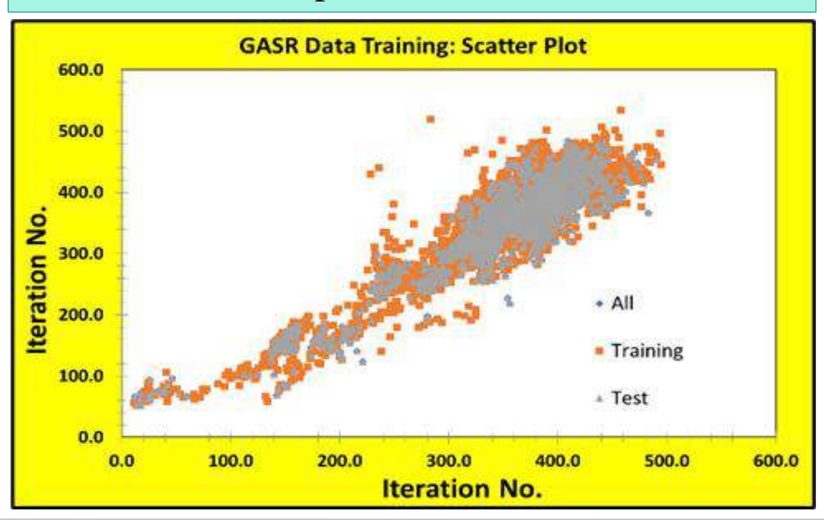


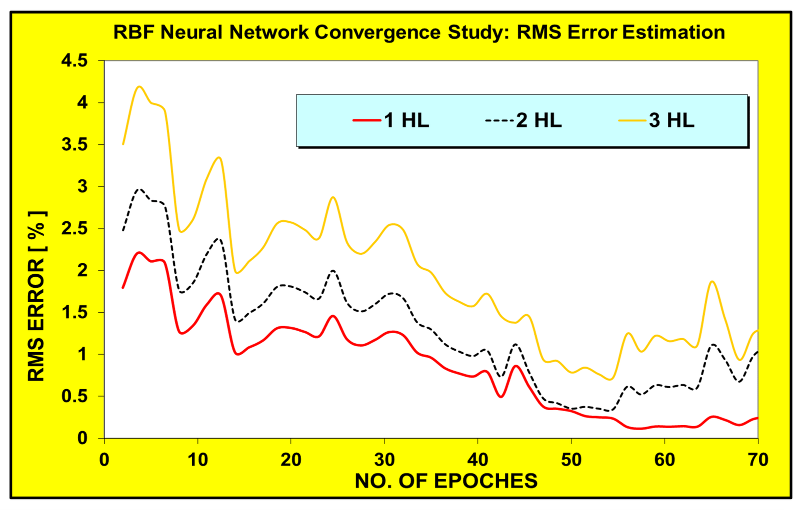


MACHINE LEARNING: DATA TRAINING & DATA LEARNING SCHEMES

- Performing detailed data searches in multi-dimensional search spaces for optimised state of material processes \ sub- processes.
- Performing training and data handling routines using ML technology for process optimisation.
- Semantic integration of data from numerical simulations\experimental trails in data base.

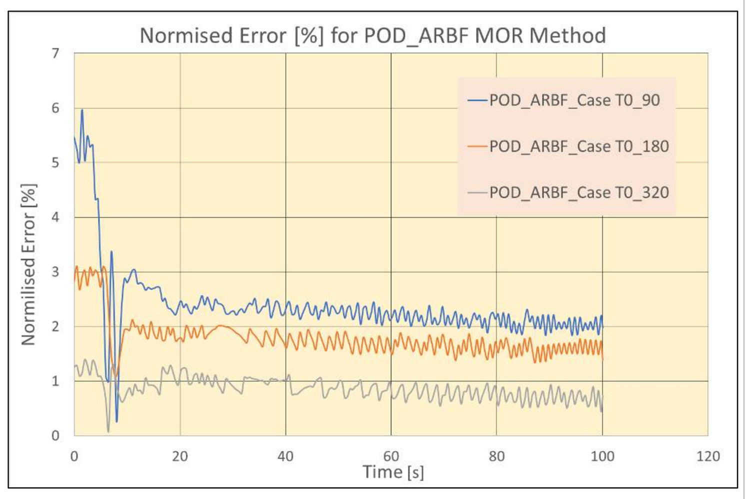


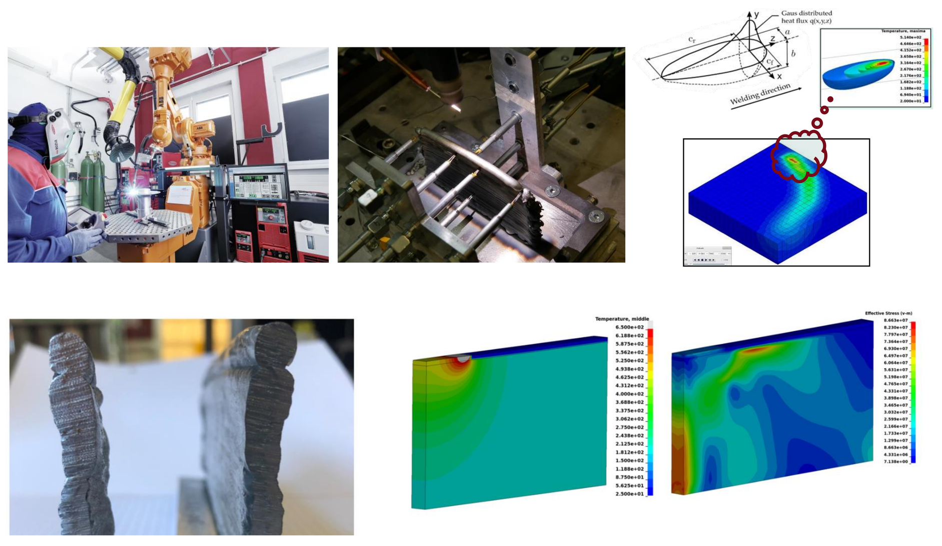


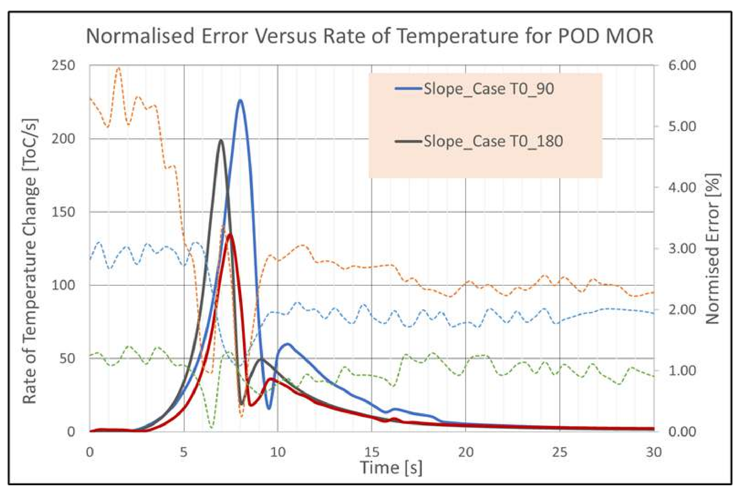


PERFORMANCES OF REDUCED MODELS FOR MATERIAL PROCESSES

- Reduced models provide an efficient predictor tool which can be employed for the real-time controlling and optimisation.
- Data variations during processes can be considered for for real-time predictions.
- For material processes with high heating\cooling rate, reduced models need to be trained further using ML schemes for better performance.

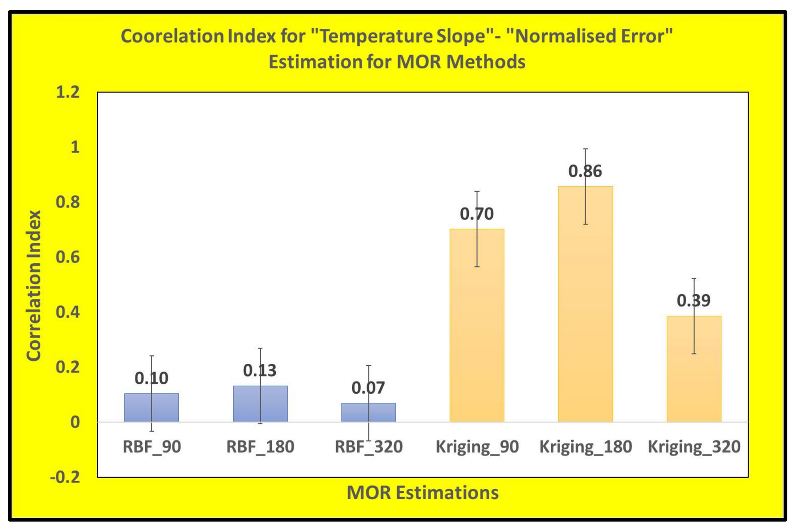


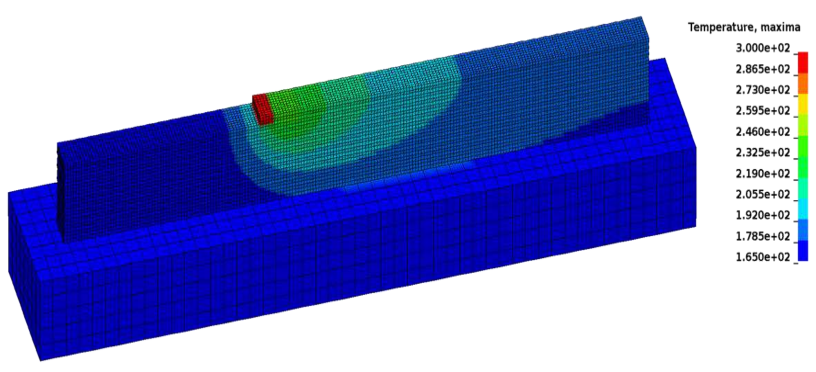


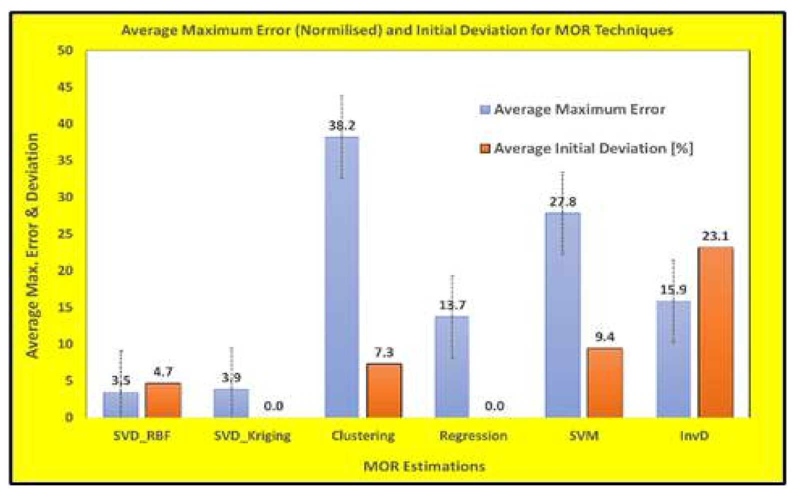


REAL-TIME MODELS AND THEIR PERFORMANCES FOR DIGITAL TWINING

- Accuracy and reliability – They should be able to accurately predict the behaviour of the material processes.
- Scalability and flexibility - They should have ability to scale up or down while being flexible enough to adapt to different changes during material processes.
- Efficiency – They should have ability to use resources in an efficient manner.



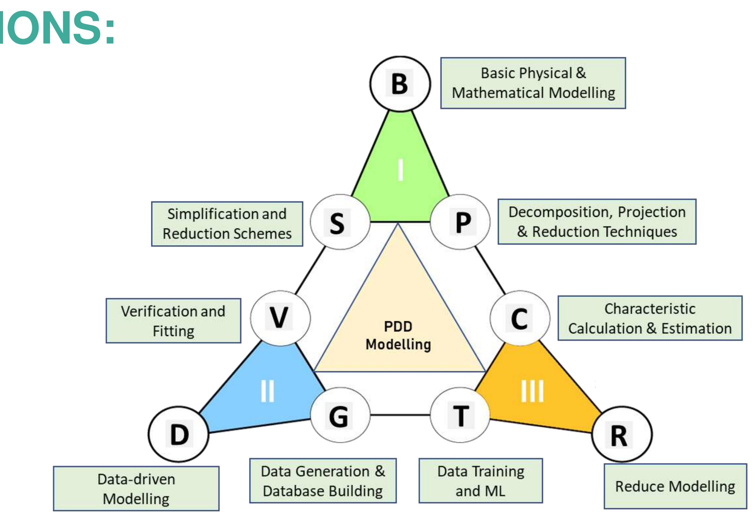




- For thermal-mechanical and multi-physical material processes, reduced models need to be able to cope with rapidly changing data, especially for high cooling and heating rate processes.
- The sizes and variation of data within snapshot matrix can considerably affect the prediction power of these models.
- To carefully verify the performance of these models, it is required to setup a rigorous validation criterion where performance maps at internal, near boundary and extreme condition (extrapolation) of search space are examined.
- Although the use of Neural Network and GASR techniques can greatly increase the predictive power of reduce models, customised training schemes are required for the proper data interpolation and fitting.

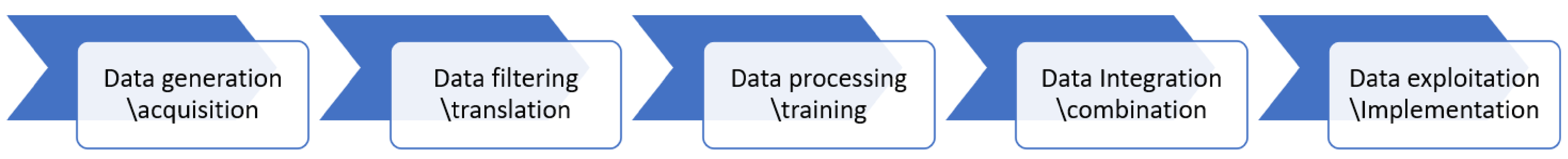
MODELLING OUTCOMES AND DISCUSSIONS:

- Best performance data "solver-interpolator" combinations have proved that accurate results can be achieved.
- ML trained models can significantly improve data representations within the PDD framework to achieve a superior accuracy and agility. Although, they would be auxiliary models and would not replace experimental and numerical process simulations.



TRAINED "REDUCED" AND "REAL-TIME" MODELS:

The development of an accurate real-time and reduced models for material processes with their multi-physical aspects are challenging and careful considerations should be given to data training and testing. Different decomposition and projection techniques can be utilised with interpolation and training power of ML to establish an efficient and accurate reduced model.



Acknowledgment:

The technical/financial support by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Federal State of Upper Austria and also the Austrian Institute of Technology (AIT) are gratefully appreciated. Author would also like to thank Dr Johannes Kronsteiner for his technical input.

References:

Horr A M, 2020. Notes on New Physical & Hybrid Modelling Trends for Material Process Simulations, Journal of Physics: Conference Series, Vol. 1603, No. 1, https://doi.org/10.1088/1742-6596/1603/1/012008.

Horr A M, 2021. Optimization of Manufacturing Processes Using ML-Assisted Hybrid Technique, Journal of Manufacturing Letter, https://doi.org/10.1016/j.mfglet.2021.10.001.