paper

An Advanced Physics-Informed Neural Operator for Comprehensive Design Optimization of Highly-Nonlinear Systems

An Aerospace Composites Processing Case Study

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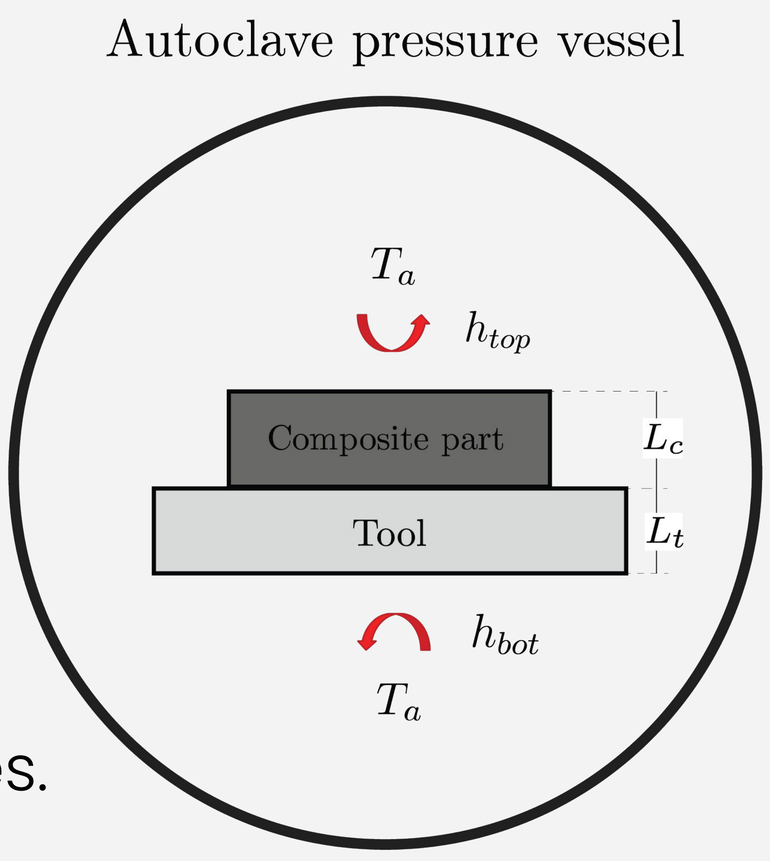
Background

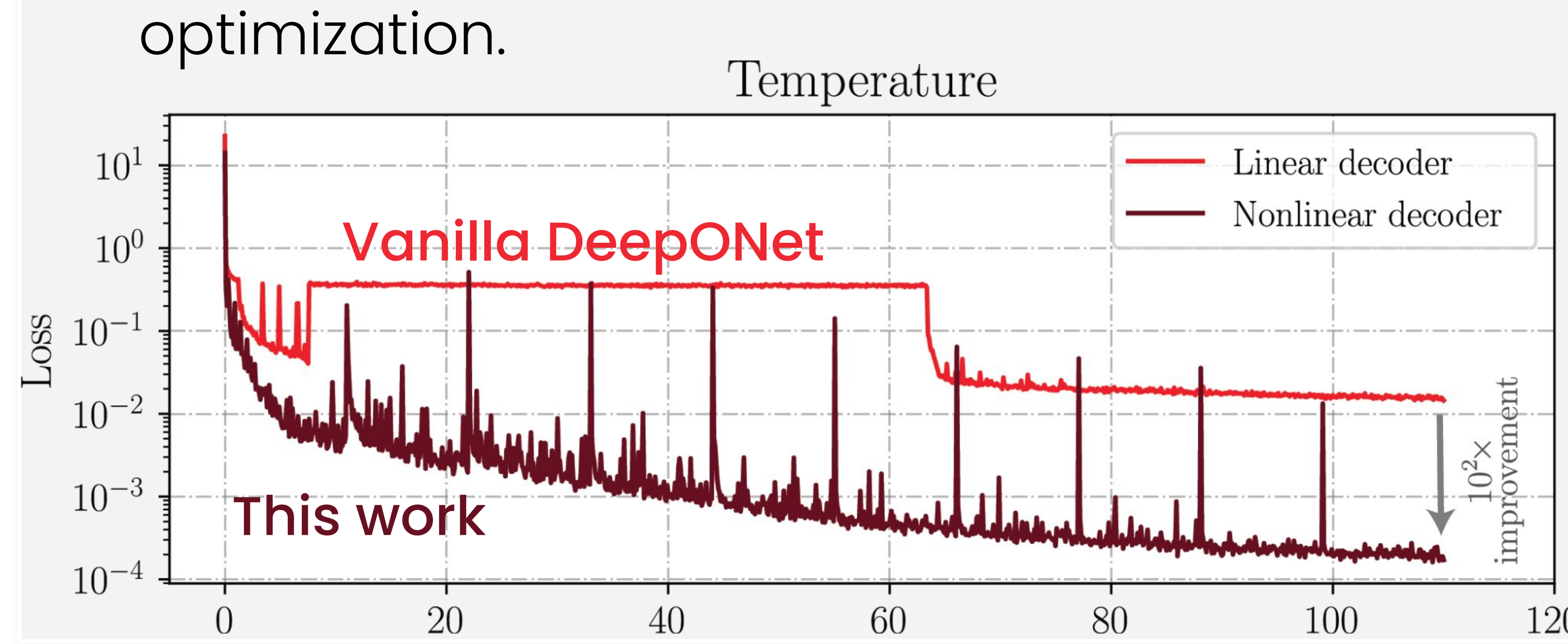
In aerospace engineering, optimizing the design and processing of composites under various conditions is challenging due to their nonlinear and complex behavior.

- **Numerical methods** can be slow, computationally intensive.
- **PINNs** lack generalization and adaptability to dynamic process configurations.
- **Vanilla DeepONet** fails to capture high nonlinearities.



Main contributions

- An advanced Physics-Informed Deep Operator Network (PIDON) to address the complexities in simulating highly nonlinear aerospace composite processes.
- PIDON with enhanced predictive accuracy and efficiency, enabling real-time design optimization.



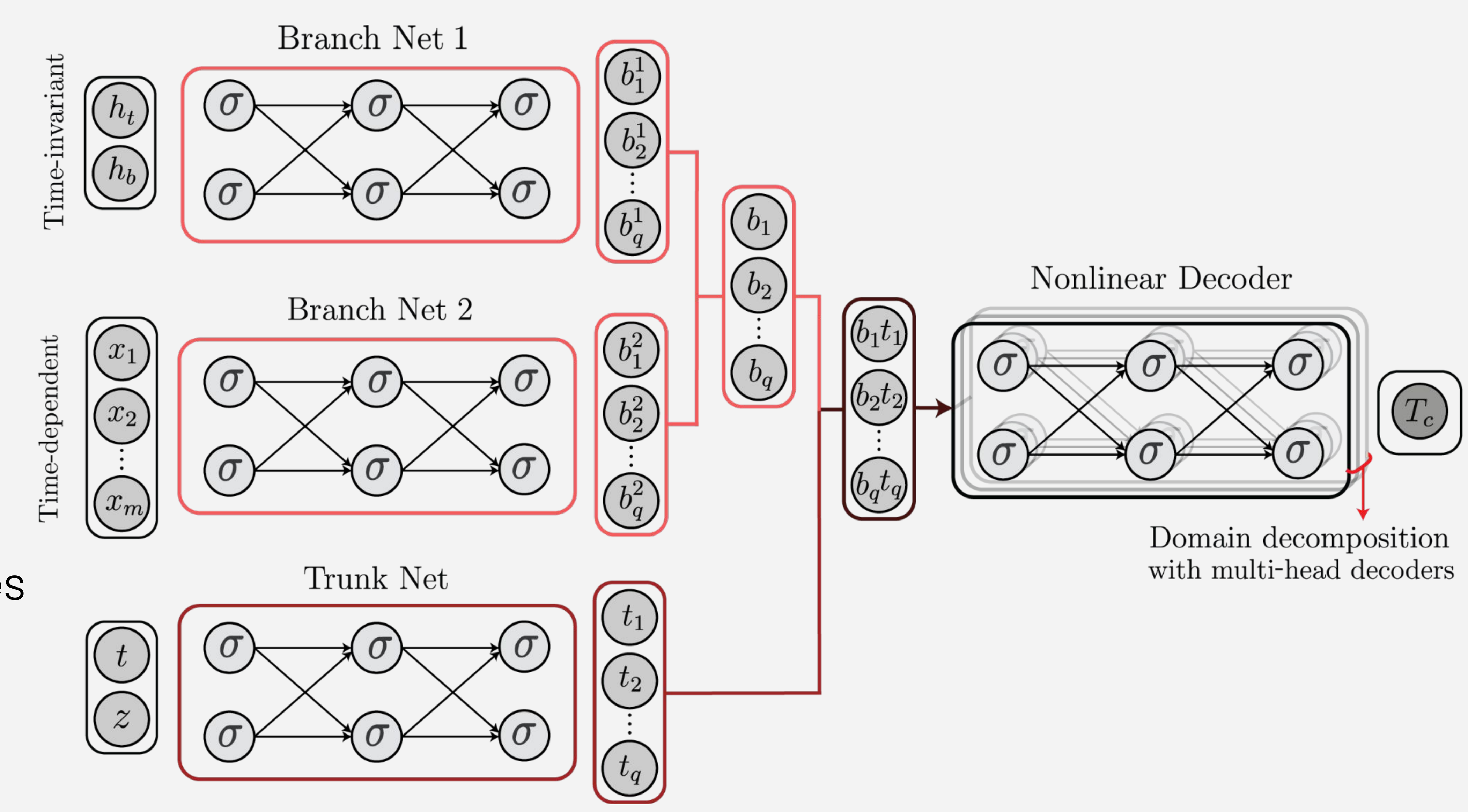
Physics-informed DeepONet architecture

Nonlinear decoder: Improves the representation of complex system behaviors.

Multiple branch networks: Allow the model to capture a wide range of physical phenomena.

Domain Decomposition: Divides the problem into smaller, more manageable sub-problems.

Curriculum Learning: Gradually increases the complexity of training tasks to enhance model performance.



Model component analysis

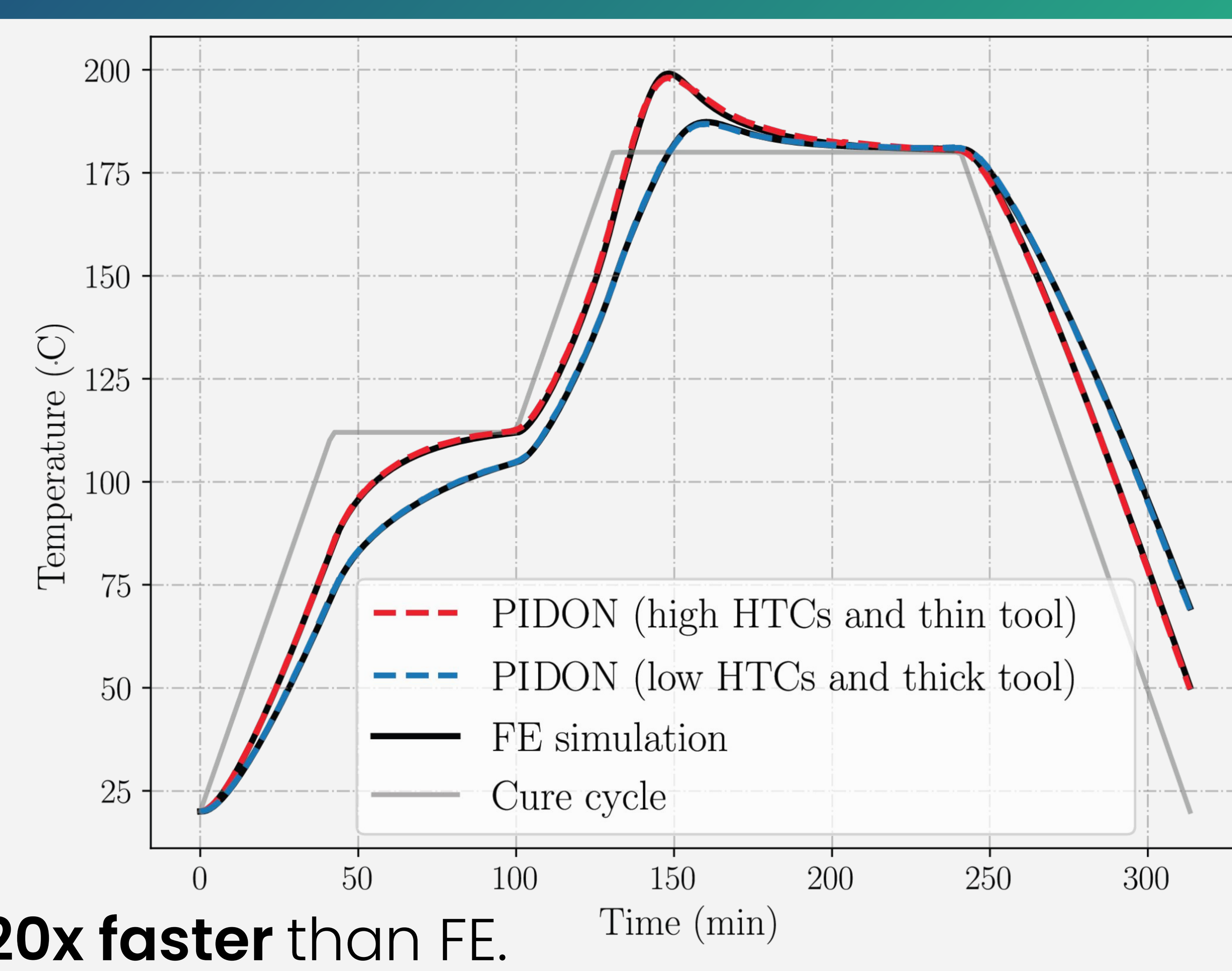
Effect of **curriculum learning**:

Design space size (Rel. L_2 error x 10^{-3})	Regular training	Curriculum learning
Small	6.8	**2.8**
Medium	9.22	**3.27**
Large	13	**4.32**

Effect of **domain decomposition**:

Metric	Number of nonlinear decoders		
	1	5	7
Max error (°C)	6.1	3.1	**2.3**
Seconds/epoch	40	56	61

Comparison with FE simulations



- **20x faster** than FE.
- **Real-time predictions** for dynamic configurations.
- Excels in **high-dimensional design** input spaces.