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A SIMULATION-DATA-BASED MACHINE LEARNING MODEL FOR QUALITY PREDICTION OF CONSOLIDATED THERMOPLASTIC PARTS

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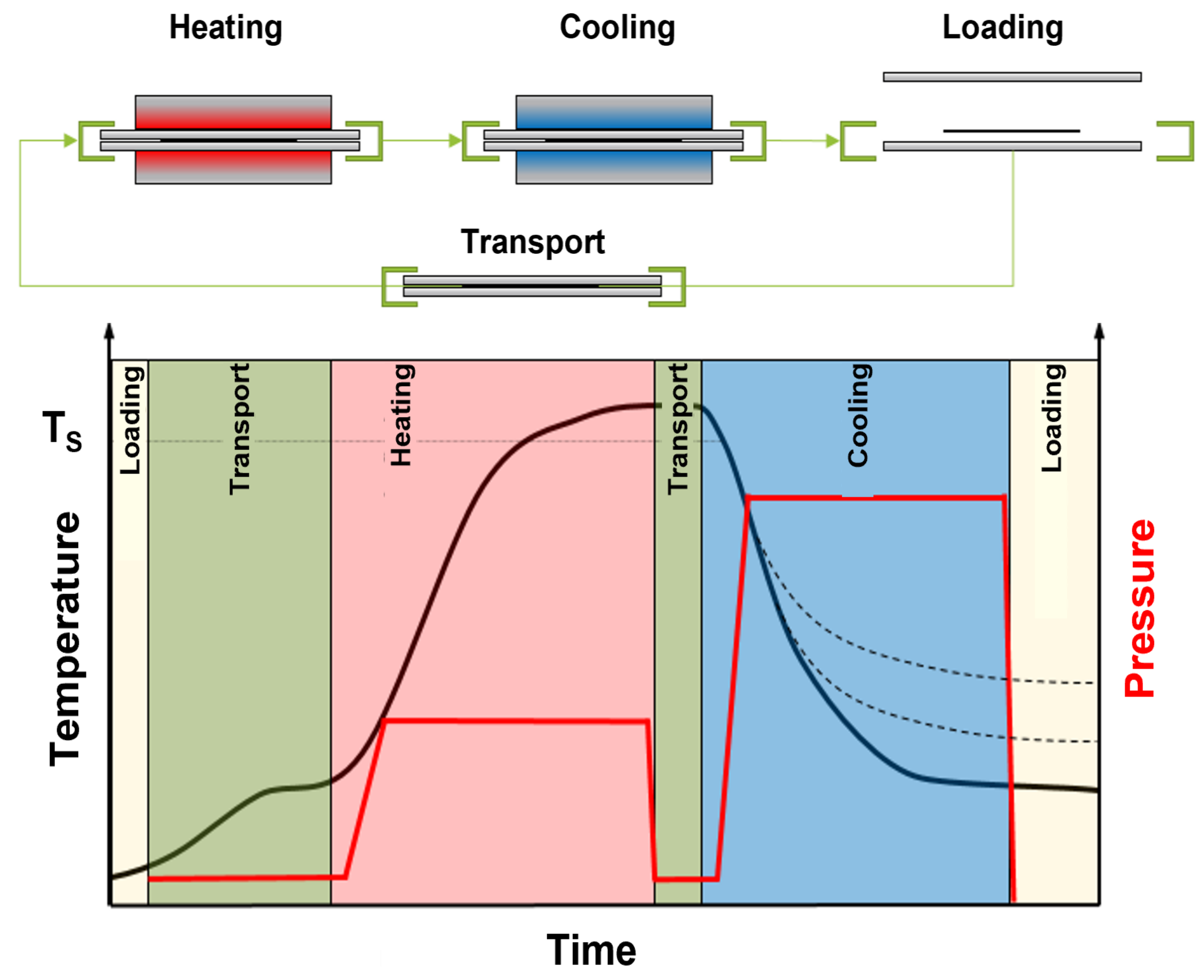
Introduction

Fibre-reinforced thermoplastic composites have become increasingly popular for lightweight applications due to their excellent mechanical properties and potential for recycling. These composites are based on **unidirectional (UD) tapes**, which can be easily processed into complex shapes using automated manufacturing techniques. An important step in the manufacturing of components from these tapes is **consolidation**, which involves heating and pressing several layers of the tape together to fuse them into a single piece. The **optimization** of novel manufacturing processes in industrial contexts can be challenging due to the time and cost constraints of experimental approaches. To overcome this challenge, computational approaches have emerged as a cost-effective and efficient solution. A typical workflow consists of (a) the replacement of systematic experimentation by **physical modeling**, creating artificial data for (b) the subsequent replacement of computationally expensive physical models by **fast surrogate (non-parametric) models**, and (c) the calibration of the surrogate models by **experimental observation**. In this study, we use the ground truth generated by a computational fluid dynamic (CFD) model to train a surrogate fast neural network (NN) which was subsequently **calibrated to experimental data**.

Manufacturing Process



Data

Input Data

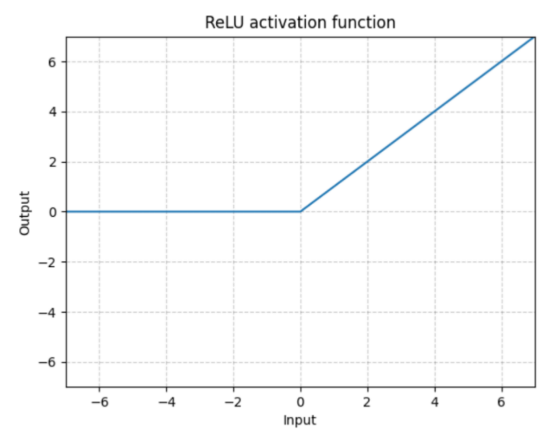
	Low setting	Mid setting	High setting	Lower Bound	Upper Bound
Hot Press Temperature	473.15 K	523.15 K	573.15 K	473.15 K	623.15 K
Hot Press pressure	100000 Pa	300000 Pa	500000 Pa	50000 Pa	800000 Pa
Cold Press Temperature	333.15 K	373.15 K	413.15 K	313.15 K	413.15 K
Cold Press pressure	1000000 Pa	2000000 Pa	3000000 Pa	1000000 Pa	9000000 Pa
Holding Time/Cycle Time	5 s	10 s	15 s	0 s	500 s

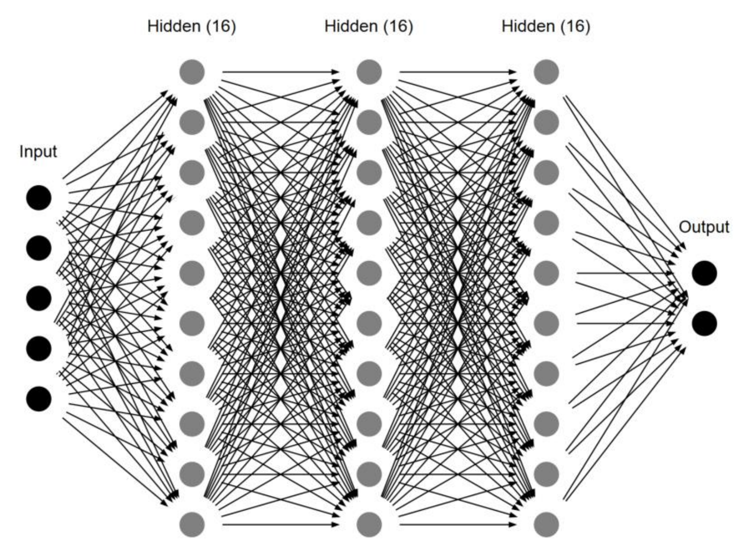
Output Data

- Degree of Bonding (DoB)
- Displacement (relative change of thickness)

Network Architecture

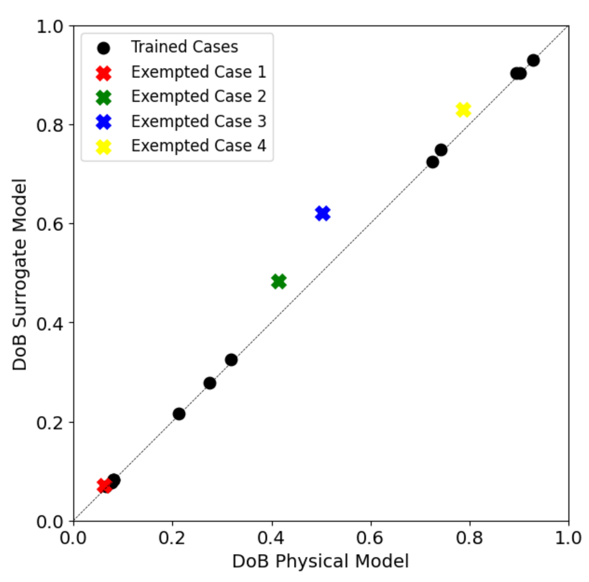
Hidden Layers	3
Nodes per Hidden Layer	16
Activation Function	ReLU





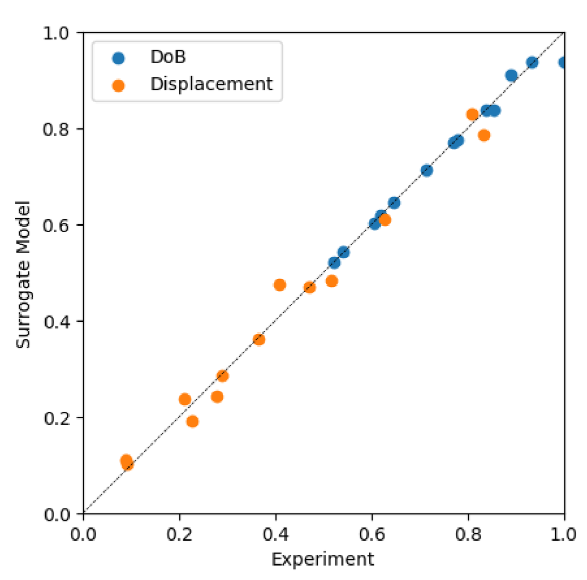
Results

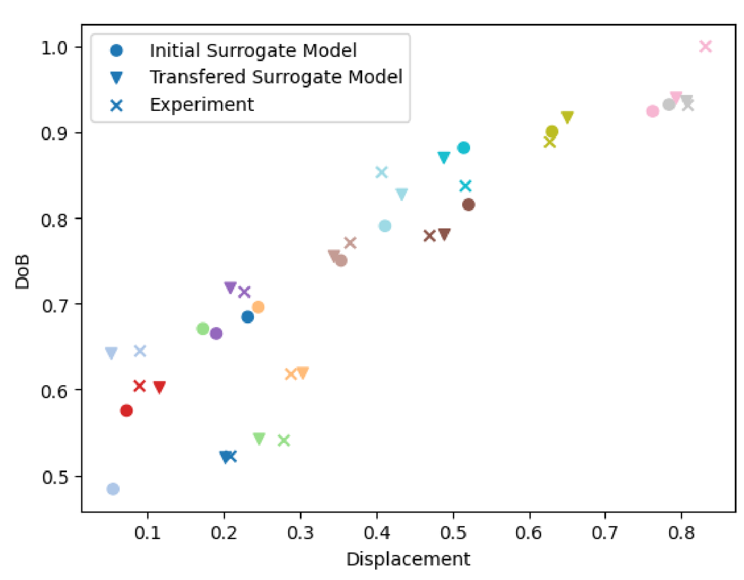
Initial Learning



Exempted Case Number	MSE
1	$7.57*10^{-5}$
2	$5.05*10^{-3}$
3	$1.37*10^{-2}$
4	$1.75*10^{-3}$

Transfer Learning





Conclusion

We used a neural network as a **universal function approximator** to predict the complex time dependence of specific parameters of the consolidation process. It was possible to obtain an accurate and robust model based on a **few process points**.

The NN can fundamentally use **endpoints only** to predict the outcome. While NN will necessarily pick up systematic inconsistencies or inaccuracies inherent to the physical model, data-driven models confer the advantage that they can be **corrected by a transfer learning step**.

We have investigated several transfer approaches by using the ILSS, and tape thickness.

The presented workflow permits the **prediction of quality parameters** from process settings within seconds, enabling efficient process optimization and control.

This hybrid approach thus provides a cost-effective and efficient solution for optimizing the consolidation step of the **composite manufacturing chain**.

Acknowledgments

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