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Digital Twin of Injection Molding: Controlling quality properties of recycled plastics by using self re-training machine learning algorithms

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What is a Digital Twin?

A Digital Twin is a digital representation of a physical product, system or process



What is a Digital Twin?









Face Centered Central Composite Design of Experiment (CCF)

machine parameter	-1	0	1
nozzle temperature in °C	250	255	260
mold temperature in °C	40	45	50
injection velocity in cm ³ /s	16	32	48
switching point in cm ³	13	13,5	14
packing pressure in bar	500	550	600
packing time in s	3	4	5
back pressure in bar	25	50	75
cooling time in s	15	17,5	20



Modeling Approaches

Model Structures (selection)





Neural networks with any number of neurons in the hidden layer



Comparison of static and dynamic models



Conclusion:

- Dynamic models (ID) perform well but show a high variance and need high computational times.
- Static models (MLP, PR) provide equivalent results, with lower computational effort.
- Further advantage: model input variables are the machine parameters *s* (usable for optimization).

Comparison of different MLPs





Conclusion:

- MLP with two layers seems to be the best fit for the digital twin.
- Initial temperature in the cavity contains relevant information for the model.

Digital Twin of Injection Molding



Digital Twin of Injection Molding



Digital Twin's Reaction to Recyclate

Scenario:

- MLP was trained using data generated using a smaller CCF.
- Produced parts were shredded to produce recyclate.
- New material was mixed with recyclate (20 %).
- Process was started using raw material to achieve a stable processing point.
- Mixed material was fed into the hopper of the machine.

machine parameter	-1	0	1
mold temperature in °C	29	32	35
injection velocity in cm³∕s	14	17	20
switching point in cm ³	13	13,5	14

Task of the Digital Twin:

- 1. Re-train the models with the new data.
- 2. Make predictions for optimized setpoints to reach the initial quality value.
- 3. Continue 1. and 2. until desired quality value is reached

Digital Twins Reaction to Recyclate



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Lessons Learned

- Dynamic models outperform static models, but the computational effort is a lot higher.
- Static models provide good results and are therefore a sufficient fit for developing a digital twin.
- The initial temperature within the cavity improves the model's performance.
- The digital twin predicts the part quality with a BFR of more than 90 %.
- Unknown influences as the use of recyclate, reduce the validity of the models and their predicted part qualities.
- Re-training results in target-oriented parameter suggestions and the desired quality value can be reached.

Founding of the Project



EUROPEAN UNION Investing in our Future European Regional Development Fund





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Institute for System Analytics and Control Measuring and Control Engineering University of Kassel

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Pictures:

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