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DRIVING INNOVATION IN MANUFACTURING

State-space modelling for robomould processes

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Intelligent operation and maintenance

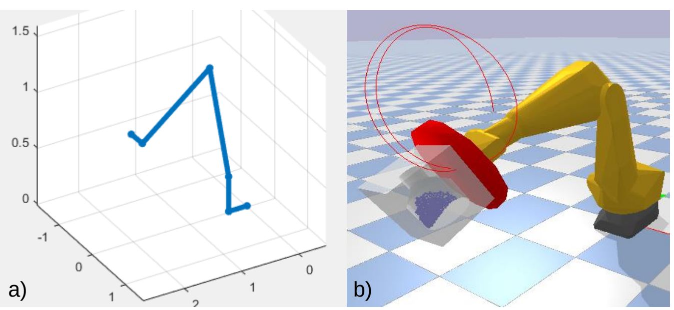
DMMS-D

Goal

The goal of this work is to use a state-estimation approach for a robomould process to predict the influence of the movement and the temperature cycle of the mould, and predict the quality of the parts. Hereto, a digital twin is developed that combines semi-analytical models together with novel higher order motion and thermal models. This system will be updated by (operational) measurement data.

Motivation

Robomoulding[1], robotized rotational moulding is a novel polymer processing technique allowing to produce hollow complex parts in a more robust and economical way as compared to traditional rotational moulding. Polymer powder is placed in the mould, which is mounted on a robotic arm, and is electrically heated and rotated. The powder gets distributed along the inside of the mould and solidifies into a stress-free part. The finished product is a stress-free product which results in a high durability and has no seams. This makes it an appropriate process for applications like storage tanks for liquids and gasses. Currently, to find the right process parameters (path, speed and temperature), mainly a trial and error method is used. As the process cycles are relatively long, this results in a long calibration time together with wasted polymer powder and energy. So it is of high interest to optimize the calibration process.



a) Matlab MBD simulation of a robotic arm
b) MBD-DEM co-simulation of a robomould process

Approach

To improve the process, first a digital twin will be setup. This model incorporates the motion and the temperature propagation within the mould and the material.
Next, the validated twin will be used to predict product quality and generate optimal process parameters.

Multi-body model (MBD)	**Discrete element model** (DEM)
Input	
Logged data • Joint positions • Motor current	Logged data • Temperatures • Mould motion
Output	
• Joint forces • Mould motion	• Wall thickness • Inertia
The MBD-model is a kinetic model that calculates the mould movement with forward kinematics and obtains the joint forces using inverse kinematics.	The DEM-model is equipped with a thermal model and the powder flow is modelled based on experimental data. The model simulates the powder flow and the layer buildup.
MBD – DEM co-simulation	

By combining the MBD model, the DEM model and inline measurements, the following gains will be obtained:

- Sensor fusion
  Accessible measurements e.g. temperature, motor current, joint positions, etc. can be combined in the model and used to estimate the state of the product.
- Validation
  The co-simulation will be able to predict the product quality. This can validated by performing measurement on the actual product. (wall thickness, dimensions, colour, bubbles in the plastic, etc.)

Robomould process @ KUL – campus Diepenbeek

Results

As fore future results, we aim for a more efficient way to find the optimal process parameters. The cost of the modelling and computational work would be lower than the cost of the use of the trial and error method.

- The process can be simulated preliminary to the production process and the optimal parameters (mould motion and temperature) can be predicted. These simulations can run overnight and have zero spill of powder material.
- When very low computational time is achieved, the digital twin can run in parallel. This offers a real time quality estimation of the product and the process can be adjusted if necessary.

Key take-aways

- By simulating the process, the optimal parameters can be found more easily. This eliminates a labour intensive task.
- By implementing a digital twin, the in-process quality of the product can be obtained and process can be further optimized.

Further reading

- ref1: Kuijt, J., Kuijt B., Harleman, F., Claus, F., Potargent, J. (2016). Apparatus for rotational molding of plastic material. EP 2 844 446 B1. Bilzen, BE. Gevers Patents.