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A multibody and discrete element modelling co-simulation approach for robomould process analysis

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EXTENDED ABSTRACT

1 Introduction

Rotational molding is a method of polymer processing by placing a polymer powder in a mould and rotating it on two perpendicular axes, as illustrated in figure 1. As the mould rotates, heat is applied and the polymer powder melts and coats the inside surface of the mould. Once cooled, the solidified polymer is removed from the mould as the final product. The movement and temperature of the mould throughout the process cycle are crucial to the quality of the final product. This method is commonly used for creating large polymer containers and furniture.

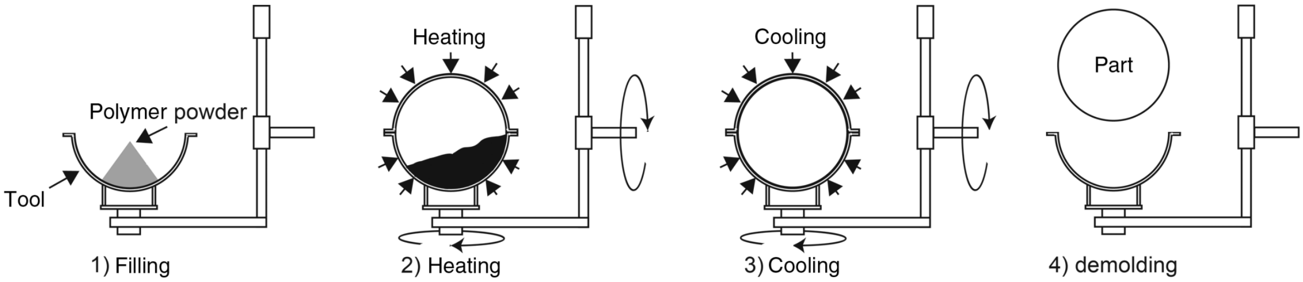

Figure 1: Process steps of rotational molding [1]

Robomould is a more energy-efficient variation of the rotational molding process. Instead of using a bi-axial carousel, a robotic arm is utilized to rotate the mould. Heating is achieved by placing electrical resistors directly on the mould, eliminating the need for an oven. This new setup offers greater possibilities for motion control and other process parameters, resulting in reduced cycle times. The current approach for determining these parameters is through a trial-and-error method, which is time-consuming, resource-intensive and energy-intensive. The goal of this research is to gain a deeper understanding of the process through simulation. However, simulation software for this process is not widely available. Therefore, a co-simulation approach was implemented, combining multibody simulation and discrete element method (DEM) simulation.

2 Methods

The co-simulation approach combines a multibody model with a discrete element method (DEM) model. The multibody simulation acts as the primary simulation, in which the mould is controlled. In the DEM simulation, the mould is subjected to the contact forces of the particles. The modeled setup of the robomould process is illustrated in Figure 2.

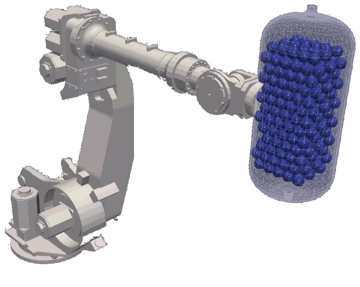

Figure 2: MBD-DEM model

The multibody model is an open-chain system, utilizing revolute joints to represent the robotic arm. The system is modeled using MBRC, an internal tool [2], and employs the Flexible Natural Coordinates Formulation (FNCF) method for the system dynamics.

The DEM simulation package used, is the commercial software Mpacts [3]. In this simulation, spherical particles are generated to model the powder by simulating the same total volume as the powder with particles that have as small a diameter as possible, the overall behavior of the powder is closely approximated. These particles have friction and inertia parameters that can be adjusted to replicate the behavior of the powder. To determine the correct parameters, physical experiments were conducted. One such experiment was a rotating drum test [4], where powder was loaded into a drum and characterized through a vision system [5].

During the co-simulation, the interactions between the particles and the mould are monitored to estimate the distribution of powder within the mould. To validate this simulation, two products were manufactured using different rock and roll motions. Corresponding simulations were then run, using the same powder volume and motion. The thickness of the product wall was measured to quantify the distribution of the powder, which was then compared to the simulated thickness distribution. This comparison allows for an assessment of the simulation's ability to accurately predict the powder distribution and product quality.

3 Results and discussion

Figure 3 shows the results of the simulation and the physical process at a rocking angle of 40 degrees and 80 degrees. It is evident that the rocking angle plays a significant role in the distribution of the powder. As the rocking angle increases, the deviation between the simulation results and the experimental results become more pronounced. The experimental results indicate a more uniform distribution of powder compared to the simulation results. The simulation results show a larger wall thickness, which shifts from the top and bottom to the left and right side of the product.

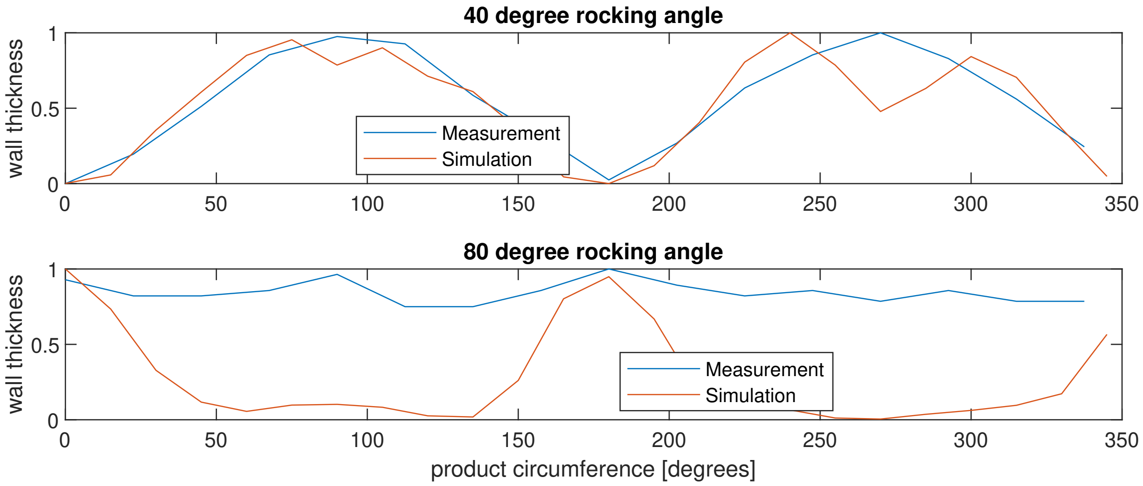

Figure 3: Layer thickness distribution at a rocking angle of 40 and 80 degrees

Further study of this process should be conducted to determine other influential parameters. Additionally, it should be noted that the temperature in this simulation approach is not taken into consideration. Based on domain knowledge, it is understood that the primary driver of the global powder distribution is the motion of the mould. Secondly, temperature, which is fine-tuned across the different surfaces of the mould, also plays a role in determining the wall thickness of the final product.

Acknowledgments

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