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Part Variation Simulations: An Industrial Case Study with an Experimental Validation

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Abstract : Injection-molded parts are widely used in power system protection products. One of the biggest challenges in an injection molding process is shrinkage and warpage of the molded parts. All these geometrical variations may have an adverse effect on the quality of the product, functionality, cost, and time-to-market. The situation becomes more challenging in the case of intricate shapes and in mass production using multi-cavity tools. To control the effects of shrinkage and warpage, it is very important to correctly find out the input parameters that could affect the product performance. With the advances in the computer-aided engineering (CAE), different tools are available to simulate the injection molding process. For our case study, we used the MoldFlow insight tool. Our aim is to predict the spread of the functional dimensions and geometrical variations on the part due to variations in the input parameters such as material viscosity, packing pressure, mold temperature, melt temperature, and injection speed. The input parameters may vary during batch production or due to variations in the machine process settings. To perform the accurate product assembly variation simulation, the first step is to perform an individual part variation simulation to render realistic tolerance ranges. In this article, we present a method to simulate part variations coming from the input parameters variation during batch production. The method is based on computer simulations and experimental validation using the full factorial design of experiments (DoE). The robustness of the simulation model is verified through input parameter wise sensitivity analysis study performed using simulations and experiments; all the results show a very good correlation in the material flow direction. There exists a non-linear interaction between material and the input process variables. It is observed that the parameters such as packing pressure, material, and mold temperature play an important role in spread on functional dimensions and geometrical variations. This method will allow us in the future to develop accurate/realistic virtual prototypes based on trusted simulated process variation and, therefore, increase the product quality and potentially decrease the time to market.

Keywords : correlation, molding process, tolerance, sensitivity analysis, variation simulation
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