Submodelling simulation of plastic injection for nano roughness replication

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Plastic injection application for aim4np

Within the www.aim4np.eu project, a metrology platform hosting an Atomic Force Microscope [AFM] will be used for the determination of the nanomechanical properties of surfaces of objects at a production site enabling inline process control.

Plastic injection was chosen as a case system for the validation-study. The goal is to determine the influence of the surface micro/nano roughness of a mould and the performance of the injection moulding process. Moulds and moulded plastic parts have been characterized by AFM and other techniques, and computer models have been developed to simulate the effect of mould surface roughness on the appearance of the final plastic piece.

Commercial software is not suitable to combine mesh sizes in range of mm with nano roughness in range of 10nm as shown in figure 1.

Different strategies have been pursued in order to implement available codes to the micro/nanometre range. A first innovative approximation consists in simulating a rough surface by a regular array of semicircles using submodelling. This technique usese macrosimulations to obtain boundary conditions as shown in figure 2 to perform nanosimulations. Such an approximation has revealed to be successful and fairly describes the actual morphology of the coated diamond-like carbon films used to protect the stainless steel surfaces of the moulds. Comparison of Sq roughness values of mould and plastic parts in range 5-40 nm are shown in simulation and compared to experiments to conclude that roughness of plastic part is lower than mould part as predicted by simulation.

Figure 1. Simulations of plastic injection filling with commertial software leading to errors on predictions of nanoreplication of roughness due to mesh transitions.

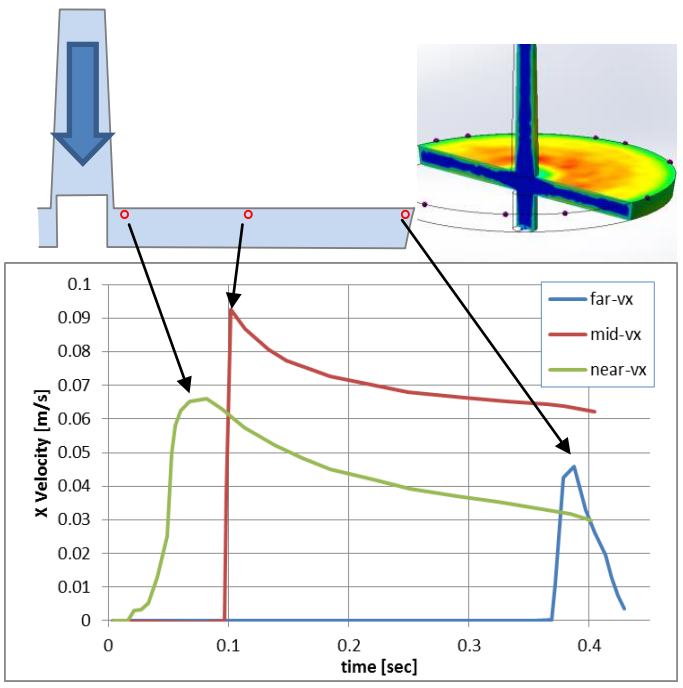

Figure 2. Boundary conditions from commercial software used for nano replication.

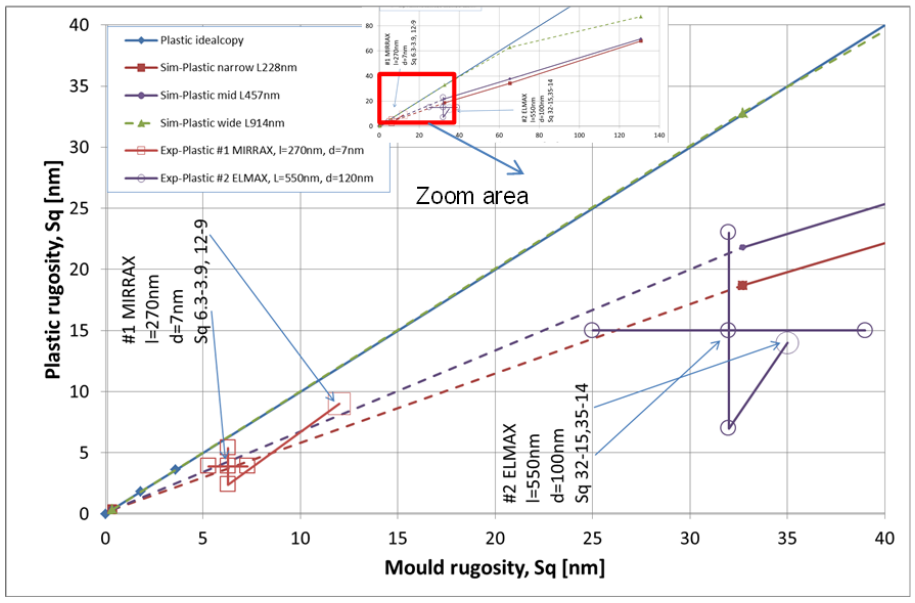

Figure 4. Roughness correlation between mould and plastic part.

Figure 3. Results of nano simulation to replicate mould roughness.

Results for roughness correlation

Simulations of different mould roughness where performed to obtain the plastic roughness as shown in figure 3. Simulations are in agreement with experiments to conclude that plastic part has a lower roughness value.

The relation of mould roughness with plastic part roughness is shown in figure 4 with two experiments from two different moulds. Further experiments are undertaken to obtain more experimental points with the same roughness but with different pitch to analyse the influence of aspect ratio, temperatures, pressures and polymers used for the injection.

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1) aim4np = automated in-line metrology for nanoscale production, www.aim4np.eu