Simulation of plastic injection for nano roughness replication

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Abstract:

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. Under the nanomechanical properties term we include roughness, adhesion and elasticity. The underlying concept is based on the artificially generated stiffness between the surface to be characterized and the metrology platform using a feedback sensor-actuator system.

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. The determination of the link between the nanomechanical properties of the surface of the mould and the functionality of the mould (that is the surface roughness and defect density of the moulded plastic part) is addressed both by means of experimental and simulation techniques. 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.

All available simulation codes devoted to plastic injection have so far been conceived for large pieces in industrial applications (e.g. automotive) with critical dimensions well above the millimetre range. Thus, it was foreseeable that the extension of such codes down to the micro- and nanometre range would be challenging, given the used approximations and boundary conditions in the codes. For this reason, the emphasis was initially laid on the experimental part to address the relevant magnitudes of parameters of technical surfaces, such as roughness and morphology. Trying to directly replicate the roughness of the mould surface was a too demanding objective. It was therefore decided to start with the study of well-defined simple patterns in the micrometre-range.

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 submodeling. Such an approximation has revealed to be successful and fairly describes the actual morphology of the coated diamond-like carbon films used as protection of the stainless steel surfaces of the moulds. Comparison of Sq roughness values of mould and plastic parts in range 5 to 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.