Simulation of the coating film appearance for spray application

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The coating film topography depends on the substrate structure, the application parameters and the coating material's levelling properties. Substrates consisting of several materials with different surface structures and differently inclined areas make a homogenous coating film structure difficult. By means of simulations, the paint film structure is intended to be controlled so that the theoretical optimum is reached and the experimental effort can be reduced. The focus is on spray application in the automobile industry where appearance requirements are particularly high.

In the self-developed simulation program, the shot noise model is used to form the initial coating film topography by superimposing ball caps. The droplet size distribution can be measured or specified by a fictitious probability distribution within the program. In the next simulation step, the initial topography partly levels. The levelling model includes the following components of structure change: sine component of the weight force, cosine component of the weight force, surface tension component, surface tension gradient component, sheer force on the surface and evaporation (based on terms taken from ref. 1 and 2).

$$\frac{\partial h}{\partial t} = \frac{\rho g \cos\theta}{3\mu}\nabla\cdot\left({h_L}^3\nabla h_{Ofl}\right) - \frac{\rho g \sin\theta}{3\mu}\frac{\partial({h_L}^3)}{\partial x} - \frac{\sigma}{3\mu}\nabla\cdot\left({h_L}^3\nabla\nabla^2 h_{Ofl}\right) - \nabla\cdot\left(\frac{{h_L}^2}{2\mu}\nabla\sigma + \frac{{h_L}^3}{3\mu}\nabla^2 h_{Ofl}\nabla\sigma\right) - \frac{\tau}{2\mu}\frac{\partial({h_L}^2)}{\partial x} - E \quad (1)$$

During levelling, the substrate may be fixed at a static angle or rotate. At any point of the levelling process, topography key figures can be read out for the structure wavelength ranges Wa to We (0.1-30 mm) known from the wave-scan device in the automotive industry. As the topography and the visual perception of the topography often differ, a virtual projection of stripe patterns was integrated into the program, too.

Fig. 1 shows a simulation example of a 100 µm thick 2-component PUR high-solid coating film containing a low-molecular binder system with a viscosity minimum during baking. As a result in the horizontal case, the simulation prognosticates that the topography key figures will still change significantly in the oven, when the viscosity falls below 1 Pas. When the viscosity minimum in the oven is higher than 1 Pas the topography is fixed in the drying phase.

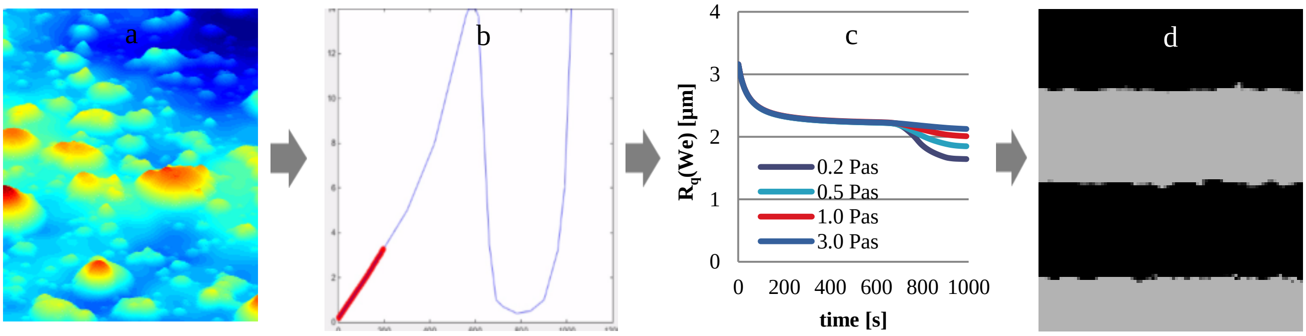

Fig. 1: Data generation in the program: (a) superimposed droplets, (b) uploaded viscosity-time dependence, (c) a topography key figure with variation of viscosity minimum in the oven,(d) exaple of stripe projection

In the future, simulations and experimental results will be compared to make the program more precise, if necessary. Afterwards it will be extended in order to calculate coating properties such as the viscosity-time course as a self-optimising system for every combination of substrate structures and inclination angles.

References

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