Simulation of Electrostatic Rotary Bell Spray Painting in Automotive Paint Shops

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Abstract

The main processes in automotive paint shops are electro coating, sealing and cavity wax, spray painting and oven curing. These processes are characterized by multi-phase and free surface flows, multi-physics, multi-scale phenomena, and large moving geometries, that pose great challenges for mathematical modeling and simulation. The current situation in the automotive industry is therefore to rely on individual experience and physical validation for improving the paint and surface treatment processes. Having access to tools that incorporate the flexibility of robotic path planning with fast and efficient simulation of the processes would be advantageous, since such tools can contribute to reduce the time required for introduction of new models, reduce the cycle-time, reduce the environmental impact and increase quality. In a joint ongoing project with Swedish and international automotive industry such tools are being developed.

In this paper the focus is on spray painting with the Electrostatic Rotary Bell Sprayer (ERBS) technique. Paint is injected at the center of a rotating bell; the paint forms a film on the bottom side of the bell and is atomized at the edge. The droplets are charged electrostatically and driven towards the target car body both by shaping air surrounding the rotating bell and by a potential difference in the order of 50-100 kV between paint applicator and target. Some earlier attempts can be found in the literature, but a systematic validation for realistic geometries is missing. Another major drawback is that the simulation times are prohibitively long for the tools to be industrially useful. This is partly due to the fact that the simulation methods do not handle moving geometries in an efficient way. The aim of this paper is to present a new framework for simulation of electrostatic spray painting based on novel algorithms for coupled simulations of air flow, electromagnetic fields and paint droplets. Particularly important for the computational efficiency is the Navier-Stokes solver. The incompressible solver is based on a finite volume discretization on a dynamic Cartesian octree grid and unique immersed boundary methods are used to model the presence of objects in the fluid. This enables modeling of moving objects at virtually no additional computational cost, and greatly simplifies preprocessing by avoiding the cumbersome generation of a body conforming mesh. The virtual paint software is included in an in-house package for automatic path planning, IPS.

The input to the simulations of the paint film build-up on a target is the process conditions (paint flow, shaping air, downdraft speed, and applicator rotation speed), the robot path, a CAD description of the target geometry, and measurements of the droplet size distribution and air velocities close to the bell. In the results section of the full paper the results from an extensive measurement campaign, which was performed to validate the simulation software, is presented. Several test plates and car fenders were painted with different process conditions and robot paths. The same cases were then simulated and overall the agreement between simulations and experiments are remarkably good. The very efficient implementation gives a major improvement of computational speed compared to other approaches and makes it possible to simulate spray painting of a full car in just a few hours on a standard computer.

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