Modified TAB Model for Viscous Fluids applied to Breakup in Rotary Bell Spray Painting

B. Andersson*[1], V. Golovitchev[2], S. Jakobsson[1], A. Mark[1], F. Edelvik[1], L. Davidson[2], J. S. Carlson[1]
[1]Fraunhofer-Chalmers Centre, Chalmers Science Park, Göteborg, Sweden
[2]Department of Applied Mechanics, Chalmers University of Technology, Göteborg, Sweden
bjorn.andersson@fcc.chalmers.se, valeri@chalmers.se, stefan.jakobsson@fcc.chalmers.se, andreas.mark@fcc.chalmers.se, fredrik.edelvik@fcc.chalmers.se, lada@chalmers.se, johan.carlson@fcc.chalmers.se

Abstract

This paper describes the application of the Taylor Analogy Breakup (TAB) model [1] to simulate droplets size distributions obtained in rotary bell spray painting. This application technique is commonly used in the automotive industry for primer, color layers and clear coat. This paper deals exclusively with the clear coat paint material.

The properties of the clear coat differ from what the TAB model has been used for traditionally. In particular, the viscosity of the paint is approximately 100 times that of water. In addition, it is non-Newtonian but may be treated as Newtonian as long as the large shear rate is large enough. For this reason an empirical correction for large viscosity originally described by Brodkey [2] is applied to the TAB model. This correction introduces a dependency of the Ohnesorge number to the stability criterion that is in effect only for larger Ohnesorge numbers. The Ohnesorge number is expressed as $Oh = \mu/\sqrt{2\rho_l \sigma a}$, where μ is the dynamic viscosity of the liquid, ρ_l its density, σ is the surface tension coefficient, and a is the droplet radius. We see that the number increases with decreasing droplet size and that it therefore is not constant during the course of atomization where droplets break and successively becomes smaller and smaller.

The TAB model has previously primarily been used in combustion engine simulation and the spray paint simulation is a new application to the model. Its parameters therefore need to be tuned such that the simulated droplet size distributions match measured ones. The global optimization algorithm DIRECT [3] was used to this purpose. One of the five parameters of the model was found to not affect the obtained size distributions and the optimization was reduced to four free variables. Optimal parameter values found are presented for both the original and the modified TAB models.

Measurements of the droplet sizes in the spray were performed at the Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA) in Stuttgart, Germany with a Spraytec RTS 5001 from Malvern Instruments. A histogram of droplet sizes is obtained for each set of process parameters measured. A total of 17 parameter settings were measured where the paint flow rate, the shape air, and the bell rotation speed were varied. The largest effect on the measured size distributions came from the rotation speed, and the focus in the paper is to capture that effect by performing CFD simulations of the near bell region.

Three different rotation speeds are considered: 30, 40, and 50 thousand revolutions per minute (RPM). Parameters in the breakup model are tuned to all three cases simultaneously in order to obtain good agreement between simulated and measured size distributions. The dependency of the size distributions on the rotational speed is well captured and good results are achieved over a wide range of droplet diameters.

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*Corresponding author: bjorn.andersson@fcc.chalmers.se