Effect of Bell Geometry in High-Speed Rotary Bell Atomization

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Abstract

High-speed rotary bell atomizers are dedicated instruments for high quality application of paints, used mainly in the automotive industry. Atomization is achieved through a well-defined disintegration process of a thin film at the edge of the bell. Based on experimental observations, it is well known, that the bell geometry, i.e. bell diameter and the exact form of the bell edge, corresponds to certain properties of the produced paint film. The approach of the present contribution is to support this empirical knowledge with physical properties, i.e. the disintegration process and the resulting droplet size distribution. Both, Nanolight short exposure and Fraunhofer diffraction are applied to obtain these results. It was found, that the initial idea of the serrations to produce very narrow droplet size distributions, is not achieved. In contrast, the specific geometry of the serrations leads to bimodal droplet size distributions and to an umbrella-shaped outer spray cone consisting of larger droplets. In contrast, unserrated bells produce almost log-normal shaped size distributions. In all cases, the bell speed is the dominant parameter for mean droplet size control.

Introduction

High-speed rotary bell atomizers are used in the painting industry to achieve paint films with high quality properties in terms of levelling, colour and metallic effect. This quality is mainly related to the fine atomization even of high viscous liquids due to very high speeds in conjunction with the thin films disintegrating at the bell edge. Furthermore, reasonable transfer efficiencies are achieved through the electrostatic support of the deposition process.

Practical experiences indicated that certain properties of the paint film, e.g. the metallic effect during base coat application, could be directly related to the geometry of the bell edge. Mainly three different forms are used, i.e. a smooth bell edge without serrations, straight serrations and cross-formed serrations. From a physical point of view, the geometry of the bell edge will directly influence the disintegration process and the subsequent formation of the droplet size distributions. Of course, droplet diameter and droplet velocity will also further influ-ence the deposition process on the target and, hence, the resulting orientation of the flat flakes inside the drop-lets. To improve the basis knowledge in this field, it is the aim of the present contribution, to map different disin-tegration figures and size distributions as a function of the application parameters (bell speed, paint flow rate etc.) and the bell geometry (diameter and geometry of bell edge).

Materials and Methods

The investigations were performed using a state-of-the-art rotary bell atomizer supplied by Dürr Systems GmbH. In Fig. 1, the rotating bell is shown, which is driven by a frictionless air turbine. Behind the bell, a series of shaping air nozzles is arranged, re-directing the tangentially accelerated droplets in radial direction towards the target. The atomizer was mounted on a dedicated paint robot that incorporated all necessary measuring and controlling devices.

The geometry of the serrated bell edges is shown in fig. 1. A typical pitch of five serrations in 2 mm is observed, with a length of the serrated area of approximately 2 mm. As discussed below, the precision of the serrations in the sub-millimetre, if not in micrometer scale, is of significant importance, as the paint films formed on the bell surface are in a thickness range between 20 and 40 µm at the bell edge [1]. Especially in the case of the crosswise serrations, the axial distance of the machining tool has a significant influence on the bell geometry directly at the location of detachment of the paint film.

As major measurement techniques a so-called Nanolight instrument, delivering a short exposure time of 20 ns, and a Fraunhofer diffraction instrument (Spraytec) were used. Typical frame size was approximately 5x5 mm. The flash was synchronized with the video camera yielding a frame rate of 25 1/s. The short exposure time of the flash delivers 'frozen' images of the disintegration process even at the highest bell speeds; a frame-to-frame identification of fluid ligaments or droplets is not possible, however.

The diffraction instrument to measure droplet size distribution was also arranged very close to the bell edge. The distance of measurement volume axis to the bell edge was approximately 10-15 mm to obtain the true

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droplet production without any significant influence of size dependent aerodynamic separation within the developing spray cone. The instrument was set to have a measurement range between 0,5 and 300 µm.

Although various paint systems were investigated, the present contribution focuses on automotive clear coat systems having a Newtonian viscosity of 88 mPas. In total, more than 500 different parameter setting were investigated, varying both the relevant application parameters and the geometry of the bells.

Results and Discussion

As expected, the geometry of the bell edge a significant influence of the primary break-up of the paint film. In general, both types of serrations lead to the expected disintegration figure, characterised by long and stable jets extending up to a length of approximately 10 mm. For the crosswise serrations, an interesting structure is obtained characterized by the presence of pairs of jets with different diameters. There might be two reasons for this: First, a simple imperfection in the geometry of the serrations that is formed in a 2-step machining process, second, the interaction between the volume forces and the edges of the grooves having different azimuthal angles. It should be noted, that the typical paint film thickness at the beginning of the grooves is less than 40 µm.

The disintegration process without serrations may be described as film disintegration. Here, the extension of the film is strongly depending on the bell speed, nevertheless, even at a speed of 50 000 1/min small films can be still observed. This is in contrast to former investigations [2], in which a critical, We-number dependent flow number q_{crit} has been derived. According to this model, jet disintegration should be dominant.

It is expected, that the different disintegration processes lead also to different droplet size distributions. A comparison of volume weighted size distributions of the three different bell geometries at a paint flow rate of 400 ml/min and bell speeds of 20 000 and 40 000 1/min is provided by Fig. 2. At high speed the size distributions of the serrated bells are fully bimodal. Consequently, two separate spray cones are observed at certain application conditions, an inner cone consisting of small droplets and an outer umbrella-shaped cone of larger droplets. Truly, this effect is undesirable. One major aim of the serrations, to obtain specifically narrow size distributions, is not achieved at all.

References

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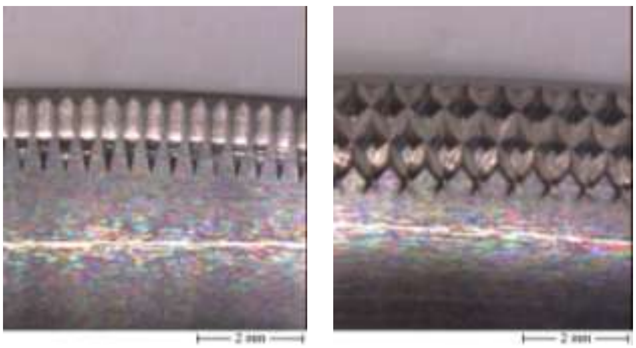

Figure 1: Bell edge geometry with straight serrations (left) and crosswise serrations (right)

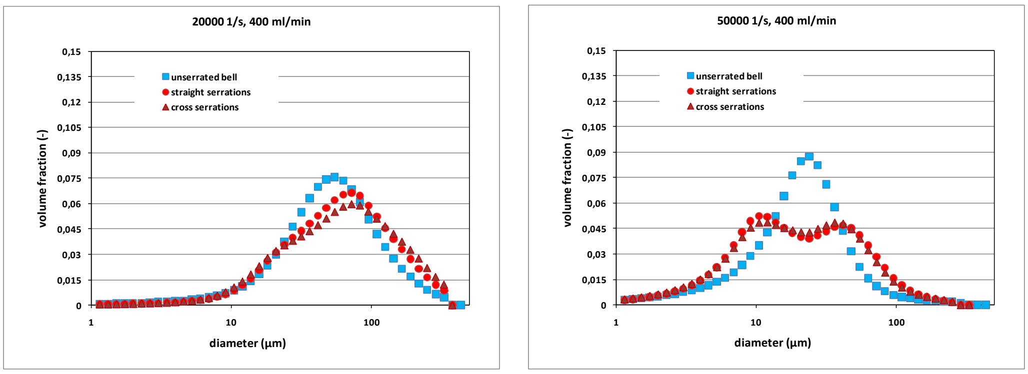

Figure 2: Comparison of the droplet size distributions at bell speeds of 20 000 1/min and 50 000 1/min