Model-based analysis and experimental validation of residence time distribution in twin-screw granulation

Ashish Kumar[a,b], Jurgen Vercruysse[c], Maunu Toiviainen[d], Pierre-Emmanuel Panouillot[d], Mikko Juuti[d], Valérie Vanhoorne[c], Krist V. Gernaey[e], Thomas De Beer[b,1], Ingmar Nopens[a,2]

a. BIOMATH, Dept. of Mathematical Modelling, Statistics and Bioinformatics, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium

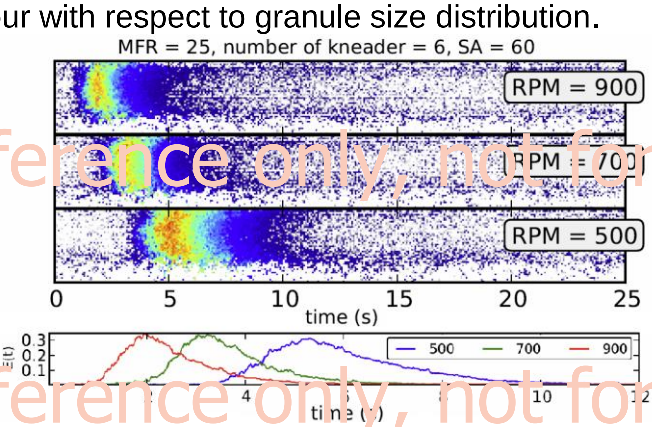
b. Laboratory of Pharmaceutical Process Analytical Technology, Dept. of Pharmaceutical Analysis, Faculty of Pharmaceutical Sciences, Ghent University, Ghent, Belgium

c. Laboratory of Pharmaceutical Technology, Dept. of Pharmaceutics, Faculty of Pharmaceutical Sciences, Ghent University, Ghent, Belgium

d. Optical Measurement Technologies, VTT Technical Research Centre, Kuopio, Finland

e. Center for Process Engineering and Technology, Department of Chemical and Biochemical Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

The residence time distribution (RTD) in a twin-screw granulator provides interesting information to understand the mixing and different granulation rate processes such as growth and breakage during granulation. Currently, visual observations and experimental data are used to determine the RTDs. However, in order to predict the mixing more accurately, modelling of the RTD is desirable. In this study, an analytical model based on classical chemical engineering methods for dynamic transport modelling was developed. The simulation data were compared with the experimental residence times obtained from near infra-red (NIR) chemical imaging (see fig.) to validate the model. Simulation results and experimental data were used to characterise the impact of process (feed rate and screw speed) and equipment parameters (number of kneading discs and stagger angle) on the residence time and macro-mixing. To characterise the macro-mixing in the axial-direction, the Péclet number (Pe) and the number of equally sized stirred tanks from a Tank-in-Series (TIS) model were calculated based on mean residence time and variance values resulting from the experiments. Results showed that the mean residence time of powder in the barrel was greatly influenced by the screw-speed, followed by the number and the stagger angle of the kneading discs. The calculated Pe and number of tanks showed that feed rate and stagger angle, although having much less effect on mean residence time, played a significant role in macro-mixing at high barrel filling conditions (low screw speed and high feed rate). This is reflected by almost a doubling of the number of tanks from a TIS model (from 10 at 30º to 22 at 60º). The latter indicates an increased axial segregation. This contributes to the understanding of back-mixing in a twin-screw granulator and to predicting RTD, which can later be used in improved physical models aiming at a more realistic prediction of twin-screw granulation behaviour with respect to granule size distribution.



[1] Shared last authorship

[2] Email: Ingmar.Nopens@ugent.be