Full factorial design based DEM simulations for blending of cohesion-less bi-disperse spheres in a tote blender

Shiva Vaddagani[a], Chetanand T. Shahare[a], Reddi Kamesh[a], C. Sumana[a], K Yamuna Rani[a], Srikanth R. Gopireddy[b], Nora A. Urbanetz[b]

[a]Process Dynamics and Control group, Process Engineering and Technology Transfer Division, CSIR-Indian Institute of Chemical Technology, Hyderabad, Telangana, 500007, India
E-mail for correspondence: sumana@iict.res.in

[b]Daiichi-Sankyo Europe GmbH, Pharmaceutical Development, Luitpoldstrasse 1, 85276 Pfaffenhofen, Germany

ABSTRACT

Powder blending is one of the important unit operations in many solids processing industries like pharmaceutical, food, chemical, etc. Especially in pharma industries, blending has always been a crucial and challenging process where the specified degree of blend uniformity is to be achieved for final dosage form, and any deviation from this uniformity results in product rejection. It is well known that blending efficiency is highly influenced by many parameters (geometric, operating and material parameters); however, the extent of their impact on different blenders' performance is largely unknown.

In this study, Discrete Element Method (DEM) based simulations are carried out to understand the effect of three parameters, i.e. fill level, blender speed (rpm), and particle size on blending performance, considering a 14L Gallay tote blender reported by Sudah *et al.*[1] as a case study. This blender consists of a top part with rectangular cross-section and a bottom hopper with the axis of rotation passing through the center of the blender inclined horizontally at 30°. The open source software LIGGGHTS is used to perform DEM simulations, where the contact forces between particles and between particles and wall are calculated based on Hertz and Mindlin & Deresiewicz theories.

A bi-disperse cohesion-less feed mixture with a size ratio of 2 and a composition of each component of 50% by weight is considered for all simulations. A 3-parameter, 3-level full factorial design is formulated resulting in total 27 simulation runs, and ranges of parameters are 70%-90% fill level, 45rpm-75rpm blender speed and 4mm-6mm smaller particle diameter. For each of these simulation runs, the blending performance at 120sec is evaluated using the Lacey Mixing Index (LMI) and the relative standard deviation (RSD) by dividing the total mixture into 600 samples of equal mass. From the simulation results, it is observed that irrespective of particle size, the LMI first increases with blender speed, at all fill levels, reaching a maximum, and then starts decreasing. To understand the dependency of LMI and RSD on the three factors considered, multivariate linear regression analysis has been carried out to develop quadratic models with interactions. For each particle size, LMI computed at the best operating parameters using regression model is compared with the corresponding LMI obtained through DEM simulations, and it is observed that these values are matching reasonably well. For all the three sizes, 80% fill level and 60rpm is found to result in maximum LMI and minimum RSD. Additional DEM simulations in the neighborhood of the best operating parameters are also carried out for validation of the regression model, and the LMI and RSD obtained are found to be reasonably close. The LMI at higher fill levels (>80%) is found to be lower which can be attributed to the reduced free space for mixing. Rotation speeds higher than 60rpm are found to result in centrifugation. The present study is helpful in identifying the best operating conditions for blending of bi-disperse particles of different sizes.

REFERENCE

[1] O. S. Sudah, P. E. Arratia, A. Alexander, and F. J. Muzzio, "Simulation and experiments of mixing and segregation in a tote blender", *AIChE Journal,* **51**, 836-844 (2005).