Quantification of Local Structure of Disordered Packing of Spherical Particles

*Akarsha Srivastava[1], K.D.P. Nigam[1] and Shantanu Roy[1]

[1]*Department of Chemical Engineering, Indian Institute of Technology Delhi, New Delhi, 110016, India*

Corresponding author: *roys@chemical.iitd.ac.in*

Highlights

- Development of experimental method to characterize local structure of packed bed
- Dependence of voidage and tessellation of void space on structural properties such as particle size or D_t/d_p, filling methods
- Estimation of degree of disorder of point processes.

1. Introduction

The way particles pack and arrange themselves in a confined space or a packed column has a defining role on the properties of the catalyst bed [1]. Packing geometry depends largely on factors such as particle size, particle size distribution, shape of particle, particle surface roughness, column diameter, rate of filling the bed and the methods used to pack the catalyst bed. The geometrical arrangement of particles in packing influences the transport properties at microscopic level which in turn have significant effect on overall performance of the packed bed [2]. In this work, the degree of disorder in random packed beds has been quantified using Voronoi tessellation for experimentally generated packing methods which have packing fraction ranging from random close packing limit to random loose packing limit.

2. Methods

For determining the local structure of packings, particles were first packed through an automatically controlled hopper into the column and then an epoxy resin was introduced from the bottom of the packed column to freeze the structure of particles. After the column had been solidified and the resin had been "frozen", it was "sliced" in a lathe machine at fixed axial positions and cross section being photographed simultaneously. Images of cross sections of bed at different axial and radial positions were analysed by image processing software from Nikon "NIS-Elements". Furthermore, Voronoi or Dirichlet tessellation of void space of two-dimensional structure was determined so that area of tessellations ascribing to different packings reveal the local structure of packing. The results corresponding to three packing methods are discussed in this abstract.

3. Results and discussion

Figure 1 shows the packing structure of three types of packings generated experimentally (I, II and III) and further analyzed by the procedure outlined earlier. In the figure it is shown that I, II and III-a represent the binary images of packing, while I, II and III-b shows the intensity surface variation of the image, I, II and III-c demonstrate the tessellated cross-sections of the packing and lastly, I, II and III-d shows the subsequent distribution of area of tessellations. Thus, distributions of these area clearly shows that there is a shift in the peak from I-(d) to III-(d) corresponding to the packing structure that it represents. Also, more disorder can be seen in III-d as compared to II-d and I-d.

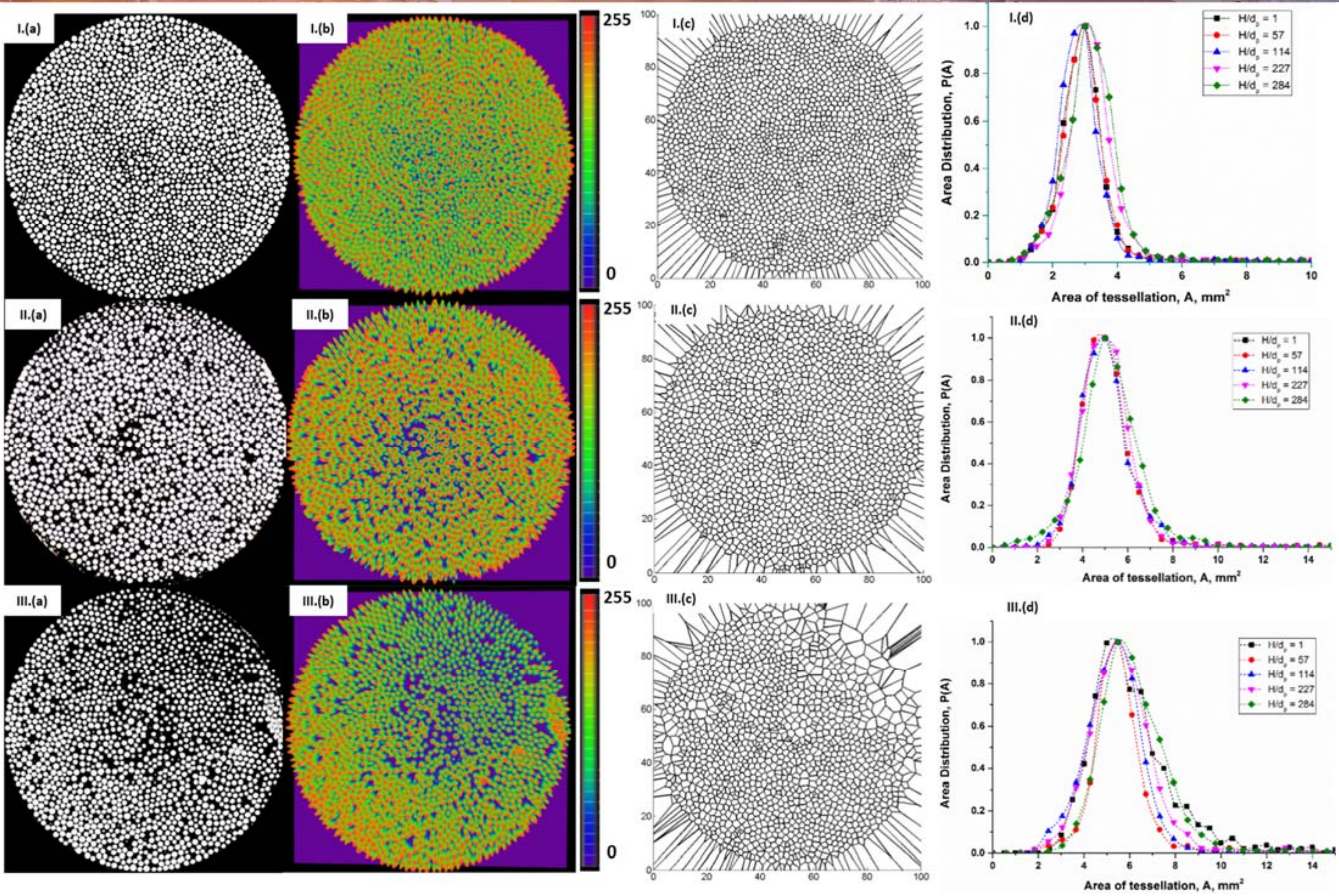

Figure 1. Cross-sectional images of packings generated experimentally by packing method I, packing method II and packing method III; (a) Binary images of cross-section, (b) Intensity profile of processed image which ranges from 0-255, where 0 represent lowest intensity relating to void and 255 represent highest intensity relating to presence of particle, (c) Voronoi tessellation of void space, and (d) Area distributions corresponding to the packing technique along the height.

4. Conclusions

The structure of packed bed has been quantified by both bulk and local structure metrics for different column to particle diameter ratio and three packing methods generated experimentally. Packing fraction relating to different experimental conditions were determined but it did not provide the detailed structure of pore space or characterize the disorder in the packing structure. This is accomplished by determining Voronoi or Dirichlet tessellation of experimentally generated images of cross-section of packed bed at different axial planes. With such a metric, it could be concluded that degree of disorder increases from packing method-1 to packing method-3.

References

[1] Sederman, P. Alexander, L. Gladden, Powder Technol. 117 (2001) 255–269.
[2] G. E. Mueller, Powder Technol. 72, (1992) 269-275.

Keywords
Local packing structure, Image analysis, Voronoi tessellation, Disordered random packing