

Direct numerical simulations of collision dynamics of wet particles

Citation for published version (APA):

Deen, N. G., Tang, Y., Scholte, J., Kuipers, J. A. M., Antonyuk, S., Heinrich, S., & Crügera, B. (2016). Direct numerical simulations of collision dynamics of wet particles. In *Fluidization XV, 2-27 May 2016, Quebec, Canada*

Document status and date:

Published: 01/01/2016

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

DIRECT NUMERICAL SIMULATIONS OF COLLISION DYNAMICS OF WET PARTICLES

Niels G. Deen, Dept. Chemical Engineering and Chemistry, Eindhoven University of Technology, The Netherlands

N.G.Deen@tue.nl

Yali Tang, Jochem Scholte, J.A.M. (Hans) Kuipers, Dept. Chemical Engineering and Chemistry, Eindhoven University of Technology, The Netherlands

Sergiy Antonyuk, Dept. Mechanical and Process Engineering, University of Kaiserslautern, Germany

Britta Crüger, Stefan Heinrich, Institute of Solids Process Engineering and Particle Technology, Hamburg University of Technology, Germany

Fluidized beds involving liquid injection have a wide industrial application ranging from physical operation, like agglomeration and coating, to chemical processes including catalytic oxidization, fluid catalytic cracking, condensed-mode polyethylene (1). The injection of the liquid results in wet particles, which behave completely different from dry particles and hence lead to much more complicated hydrodynamics of fluidized beds (2). Nevertheless, a fundamental description of the dynamics of wet particles is predominantly missing, which however is crucial for prediction of fluidization behavior effecting on the product quality.

Despite significant investigation, experimental studies of wet collisions under actual fluidization condition (e.g., low particle velocity, thin liquid layer) are virtually impossible to perform and control. Direct numerical simulations can complement experiments by providing quantitative predictions of the micro-mechanical collisional behaviour of one or more particles with well-defined and easy-controlled system parameters. Jain et al. (3) demonstrated that the experimentally observed phenomena of collision between a particle and a wet wall can be reproduced by a hybrid model combining the volume of fluid (VOF) method and the immersed boundary method (IBM). Such simulations will be extended in this work to investigate the effects of liquid layer thickness, impact velocity, particle size and surface tension on the wet restitution coefficient (e_{wet}) under normal collisions as well as oblique collisions. The motion of a solid particle is described by the IBM (Figure 1), which enforces a no-slip condition at the particle surface. Whereas, the VOF (Figure 2) describes the motion of the gas-liquid interface by a piece-wise linear reconstruction of the interface.

Figure 3 plots the trajectories of the downwards velocity of a 1.74 mm glass particle colliding on a wall covered with 400 μ m layer of water. A good agreement on the impact and rebound velocities is observed between the VOF/IBM simulation results and the experimental data. However, unlike the simulation results (snapshots in Figure 3), experimental measurements cannot provide all details of the collision since it happens within a very short time. In addition, numbers of simulations have been performed for investigation of the parameters beyond the critical “sticking” values under normal and oblique collisions. It is found that the normal e_{wet} increases approximately logarithmic and reaches a constant value that is smaller than the dry value when the particle impact velocity increases. On the other hand, the normal e_{wet} almost decreases linearly as the liquid layer thickness increases, but is independent of the collision angle as well as the surface tension. The tangential e_{wet} is found larger than the dry value and the minimum shifts to smaller collision angles with increasing liquid viscosity. An increase of the layer thickness however has no significant influence on the tangential e_{wet} . Finally, on the basis of all the simulation data, a phenomenological model proposed by Sutkar et al. (4) is modified to better predict the wet restitution coefficient.

REFERENCES

1. R. Cocco, J. McMillan, R. Hays, S.B. Karri. Fluidization XIV, 2013.
2. S. Bruhns and J. Werther. AIChE J., 51:766-775, 2005.
3. D. Jain, N.G. Deen, J.A.M. Kuipers, S. Antonyuk, S. Heinrich. Chem. Eng. Sci., 69:530-540, 2012.
4. V.S. Sutkar, N.G. Deen, J.T. Padding, J.A.M. Kuipers, V. Salikov, B. Crüger, S. Antonyuk, S. Heinrich. AIChE J., 61:769-779, 2015.

ACKNOWLEDGEMENTS

We gratefully acknowledge for financial support: DFG, Germany and STW, The Netherlands. Project number HE 4526/9-1.

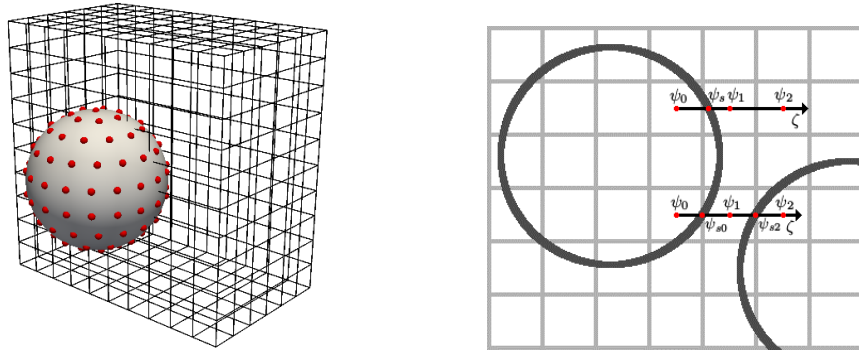


Figure 1. Schematic explanation of the IBM: (left) Representation of a solid particle by Lagrangian marker points distributed over the particle surface; (right) Incorporation of the boundary condition for a general fluid quantity ψ .

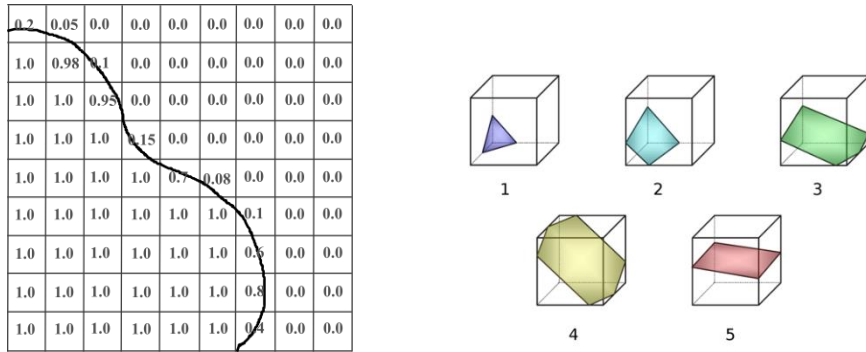


Figure 2: Schematic explanation of the VOF: (left) The value of a colour function indicates the fractional amount of the liquid present at individual grid cell; (right) Five generic types of interface configurations considered in the computation of the fluxes through the cell faces.

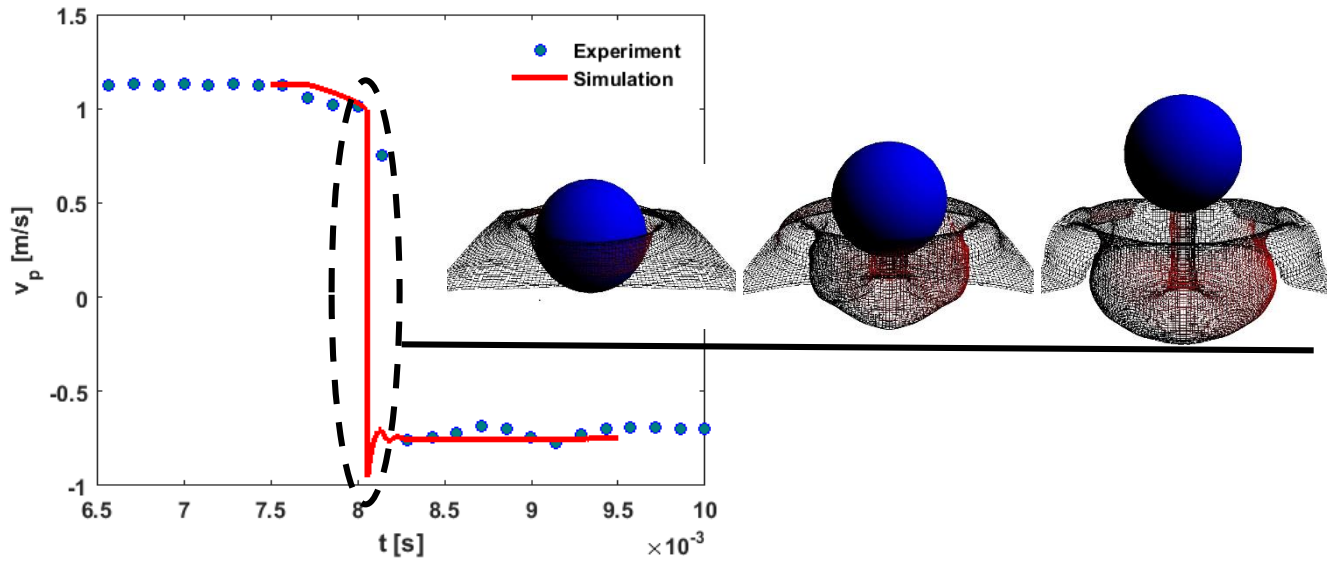


Figure 3. Trajectories of downwards velocity of a 1.74mm glass particle colliding with a wall covered by a 400 μ m layer of water. The symbols are experimental data, whereas the solid line shows the simulation results together with three snapshots when the particle is colliding.