Towards Simulation of Clogging Effects in Wastewater Pumps: Modelling of Fluid Forces on a Fiber of Bonded Particles using a Coupled CFD-DEM Approach

Anna Lyhne Jensen, Dept. of Energy Technology, Aalborg University, Aalborg, Denmark
Henrik Sørensen, Dept. of Energy Technology, Aalborg University, Aalborg, Denmark
Lasse Rosendahl, Dept. of Energy Technology, Aalborg University, Aalborg, Denmark

Long Abstract

Introduction

Resilience to clogging is a key requirement for wastewater pumps. Simulating clogging effects is a complex task, and consequently prototypes of wastewater pumps are currently tested experimentally, using cloths or similar objects, to investigate if these objects cause clogging. This experimental design approach significantly slows down the design process of wastewater pumps compared to the design process of other pump types, which are widely based on simulations. In order to facilitate the design process of wastewater pumps, the long term aim of this study is to develop a framework for simulation of clogging effects. To achieve this, a reliable cloth model and a reliable coupling between cloth and fluid is developed to simulate the experimental clogging tests. In order to simplify the problem and enable validation, the present study focuses on a single flexible fiber and the coupling between a fiber and the fluid phase.

1. Methods

The fiber is modelled as a string of bonded particles using the Discrete Element Method (DEM) with a bond model based on Potyondy and Cundall [1] and Guo et al. [2]. Preliminary results of cloth drape using this approach are presented in Fig. 1.

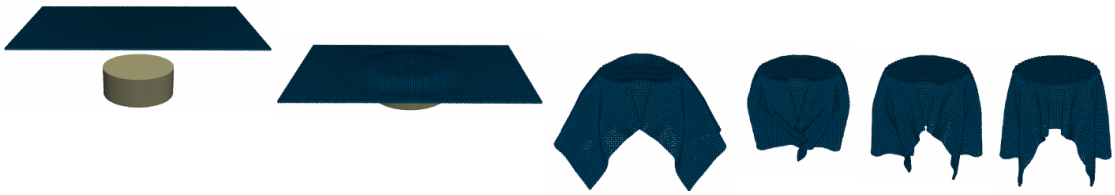

Figure 1. Preliminary results of cloth drape for a cloth formed of bonded DEM particles

The present study focuses on modeling the fluid forces on a flexible fiber by a two way coupling between the bonded DEM system and Computational Fluid Dynamics (CFD). Coupling between CFD and DEM has been implemented by Tsuji et al. [3] for spherical particles in fluidized beds and has subsequently been used for several applications. However, the non-spherical shape and the deformability of the fiber forms a challenge to modelling of fluid forces, since the overall shape of the fiber has an impact on the drag on each of the spherical particles forming the fiber. Yamamoto and Matsouka [4] modelled a flexible fiber in simple shear flow, investigating the period of rotation and the rotation orbits of the fiber and comparing to experimental results. A similar case study will be conducted to validate the coupling between fluid and fiber before using the coupling model to simulate interactions between the cloth model presented in Fig. 1 and fluid.

When the fluid-cloth coupling model has been developed and validated, future work implies applying this coupling model to the simulation of fluid-cloth interaction in a pump.

References

[1] D.O. Potyondy and P.A. Cundall. A bonded-particle model for rock. International Journal of Rock Mechanics and Mining Sciences, 41:1329–1364, 2004.

[2] Y. Guo, C. Wassgren, B. Hancock, W. Ketterhagen, and J. Curtis. Validation and time step determination of discrete element modelling of flexible fibers. Powder Technology, 249:386–395, 2013.

[3] Y. Tsuji, T. Kawaguchi, and T. Tanaka. Discrete particle simulation of two-dimensional fluidized bed. Powder Technology, 77:79–87, 1993.

[4] S. Yamamoto and T. Matsuoka. A method for dynamic simulation of rigid and flexible fibers in a flow field. Journal of Chemical Physics, 98:644–650, 1992.