2008 AIChE Annual Meeting
Philadelphia, PA
November 16 – 21, 2008

Momentous Flow Technology – the other way of mixing.

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ABSTRACT

The continuous rotating flow, referred to as Momentous Flow Technology, may find application in alumina precipitators and anaerobic digesters. This technology allows use of relatively inexpensive mixers for large tall form vessels above 6 m in diameter and with Z/T ~=3.0. Circular flow in a vessel is generated by an axial impeller located in the upper part of the vessel with no baffles. As a result of fast rotation, a tornado like vortex is generated in the vessel center. Lab experimentation in a 0.91 m diameter vessel confirmed that this vortex has the capacity of lifting and uniformly distributing alumina particles up to 63 microns in diameter. The same principle can be applied for economical mixing in anaerobic digesters. The design of full scale units has to be supported by CFD. The 0.29 m diameter model vessel was built to conduct PIV measurements and validate CFD calculations.

INTRODUCTION

The unsteady rotating flow field in a cylindrical vessel called "whirlpool" is widely used in the food industry as a method of separating particles out of suspension (cup of tea method). This phenomenon can be alternatively used as a method for suspension of particles that have density much greater than fluid. Experimental studies of unsteady flow field were performed by Greenspan (1969), Denk (1991) et al and Jakubowski (2007) et al.

The scope of this work was to investigate the possibility of application of the rotating flow for solids suspension in industrial applications and in particular for alumina precipitators and anaerobic sludge digesters. In both applications vessels were 6 m to 20 m in diameter with Z/T~=3.0. The full scale design needs to be supported by CFD simulation; therefore it is important to validate simulation results with measurements. This paper describes the experimental approach to this investigation.

The Momentous (rotating) Flow is induced by a rotating axial impeller located in the upper part of the vessel. Once the entire body of liquid is put in spin, the tornado like vortex is formed in the vessel center. This vortex has the capability of lifting solids particles up to the impeller level and above. After passing the impeller the particles are moved to vessel walls and slowly settle to the conical bottom where they are lifted up again.

In addition to suspension of solids the entire body of fluid is in fast rotational motion. There are no stagnant zones and no possibility of scaling at the walls. When Momentous Flow is applied to anaerobic digester, centrifugal forces push methane bubbles to the center of rotation where they quickly coalesce and escape from the liquid.

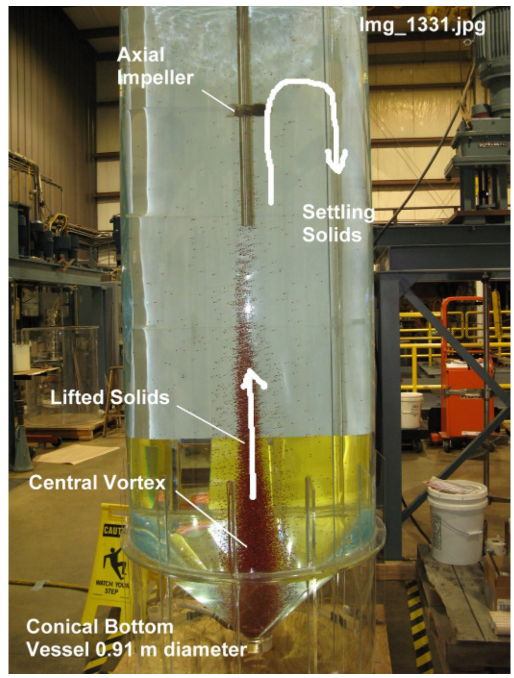

Fig 1. Experimental setup for solids lifting capacity in 0.91 m diameter vessel. Rotating flow in a vessel with no baffles is induced by a rotating impeller located in the upper part of the vessel. For solids suspension application, the bottom should be conical with apex angle no greater than 90º.

MODEL/EXPERIMENTAL

Experimental and CFD models were setup to provide the following information:

- Solids lifting capacity and energy usage. We have used alumina particles with three size ranges: 37-44 micrometers, 64-73 micrometers and 125-149 micrometers. Experiment has used 0.91 m diameter vessel with 2.75 m liquid level and conical bottom.
- CFD modeling of lab setup and full scale installation design. Reynolds Stress Model was used.

- Verification of CFD using lab setup and PIV. The 0.29 m diameter vessel was used for measurement of three components of velocity. Later the data was used for validation of CFD model.
- Determination of scale-up criteria using 0.29 m and 0.91 m vessels.
- Flow behavior in non-Newtonian fluids. Velocity measurements were taken for CMC solution in order to simulate anaerobic digester with 5% solids.

RESULTS

Solids lifting capacity was determined by visual observation. It was concluded during the experiment that 37-44 micrometers fraction was completely suspended off bottom. The 64-73 microns fraction was only partially suspended while the majority of solids were spinning in the conical bottom. The largest fraction of 125-149 micrometers was not suspended at all; however the solids were spinning around the bottom.

CFD Reynolds Stress model does well reproduce experimental findings. The axial motion of the vessel cone is well reproduced.

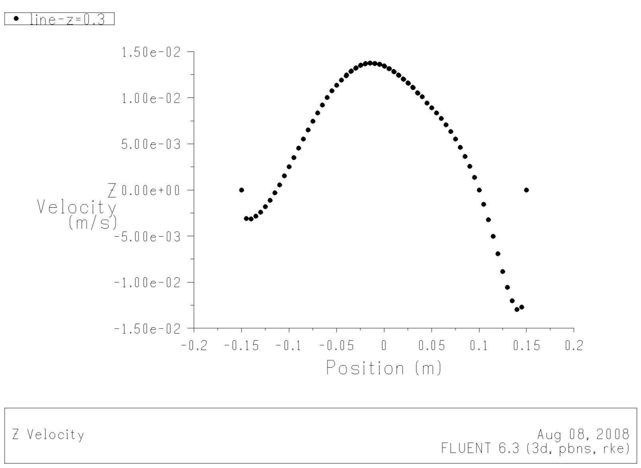

Fig. 2. Vertical component of velocity in rotating flow extracted from CFD at 0.3 m above bottom elevation in water

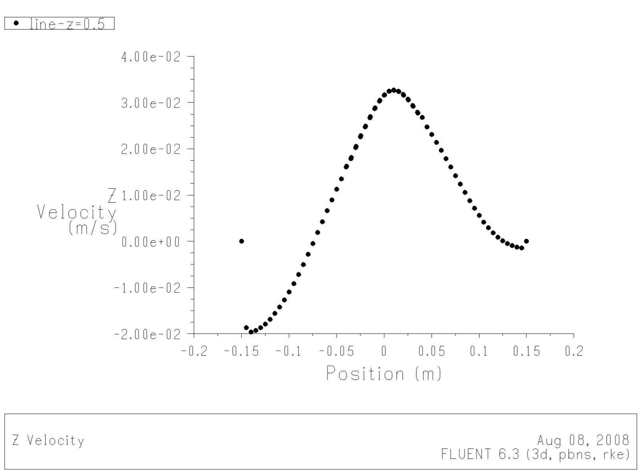

Fig. 3. Vertical component of velocity in rotating flow extracted from CFD at 0.5 m above bottom elevation in water

CONCLUSION

Based on lab test results the Momentous Flow Technology can be successfully applied for solids suspension in tall form vessels. Up pumping hydrofoil impeller has generated flow field that is capable of lifting alumina particles up to 63 microns in diameter. Larger particles can not be lifted using this technology regardless of mixer power.

Energy usage for solids suspension varies upon solids sizes and is in the range of 0.1 – 0.01 kW/m3

CFD Reynolds Stress Model can be used for flow study and illustration of process.

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