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Low Shear Mixing With a Novel Impeller Design

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ABSTRACT

Hydrofoil impellers are considered to be low shear devices. Recent research indicates that hydrofoils may produce very high local energy dissipation that may lead to particle attrition, cell damage, or product degradation. This paper presents a novel approach to low shear mixing for shear sensitive mixing applications. Lab studies were performed on shear sensitive solids with the hydrofoil impeller and with the new low shear impeller at uniform solids suspension in both cases. The long term mixing indicated no particle attrition while using the Low Shear Impeller and significant damage to solids with the hydrofoil impeller.

INTRODUCTION

The scope of this work was to define an impeller design as a viable alternative to the low shear hydrofoil that provides desired results in applications requiring uniform suspension of shear sensitive solids. The experiment also provides scale up data for a pilot facility and full scale installation.

A unique blade configuration was utilized in the design of an impeller for mixing shear sensitive materials. The wide, large diameter blades promote high flow and uniform distribution of shear. The impeller provides mixed radial and axial flow action, creating greater efficiency than radial action alone. It has a high power number, thus low RPM. With smooth surface operation and easy clean-ability, it lends itself to clean-in-place (CIP) systems with no horizontal surfaces and broad, low-angle vertical projections. The design does have size limitations and for applications that require high polishing, it may have high cost. This design has been dubbed "Super Low Shear (SLS) Impeller".

Hoefken at al presented data on measurements of local energy dissipation for three types of impellers and compared the ratio of local to global dissipation. Hydrofoil impeller, due to high tip speed, has the highest ratio.

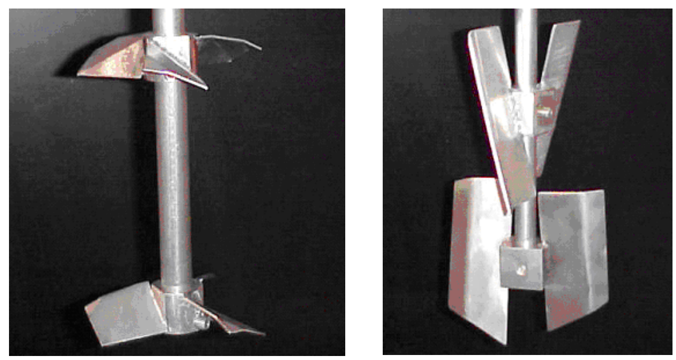
Hydrofoil Impeller = 104
Pitched Blade Impeller = 31
Rushton Turbine = 52

Additional calculations made for 19 m³ vessel using Hoefken data show identical trend. For 60 s blend time the Hydrofoil impeller produce local dissipation of 3.4 W/kg while PBT will produce only 1.8 W/kg.

DESIGN of EXPERIMENT

Experimental and CFD models were setup to provide information on suspension uniformity and particle attrition. The purpose of the experiment was to test impeller performance and to provide scale-up data for full scale installation. Local Dissipation Rates were verified with PIV measurement.

Two different impeller designs were tested; a 3 bladed MHS impeller (wide blade design frequently used for solids suspension) and the Super Low Shear impeller.



MHS Impeller

Fig 1. Impeller types used in testing

The test vessel configuration had a conical bottom and 5 sampling ports. Dimensions are shown in the diagram below. Vessel volume was 18 liters (4.77 gallons) and vessel diameter was 304mm (12").

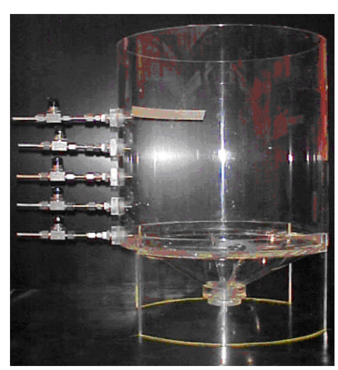


Fig 2. Test Vessel

RESULTS

Uniform suspension was determined by measurements of the solids concentration at 5 different fixed levels of the vessel at four different RPM levels. A minimum RPM for uniform solids suspension was established from graphing RPM vs. concentration.
For MHS impeller, uniform suspension level was achieved at 432 RPM. For SLS impeller uniform suspension level was achieved at 132 RPM.

Uniform Suspension in 18 liter vessel	**SLS**	**MHS**
Impeller RPM	132	432
Mixer Power (Hp)	0.0098	0.0088
Mixer Power (W)	7.34	6.58
Global Dissipation (Hp/1000 gal)	3.61	2.85
Global Dissipation (W/kg)	0.41	0.37
Unit Torque (in-lb/gal)	1.00	0.27
Unit Torque (N-m/kg)	0.026	0.0078

Fig 3. Experimental data summary

Particle attrition is a function of dissipation level and duration (time) of mixing. It can be quantified by measuring shifts in particle size distribution. Attrition tests were run at three different RPM levels. Dissipation is responsible for particle damage. Measurements of particle size distribution was done at various time intervals during mixing

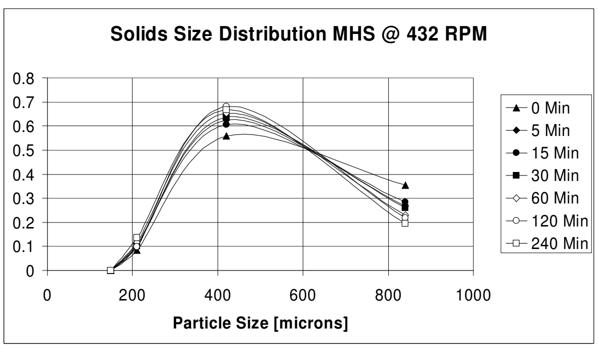


Fig 4. Particle Size Distribution for mixing with MHS impeller

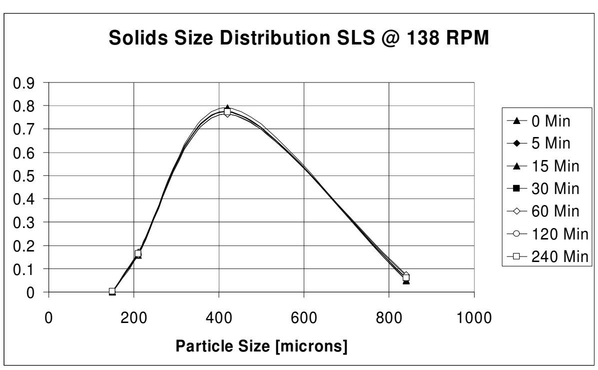


Fig 5. Particle Size Distribution for mixing with SLS impeller

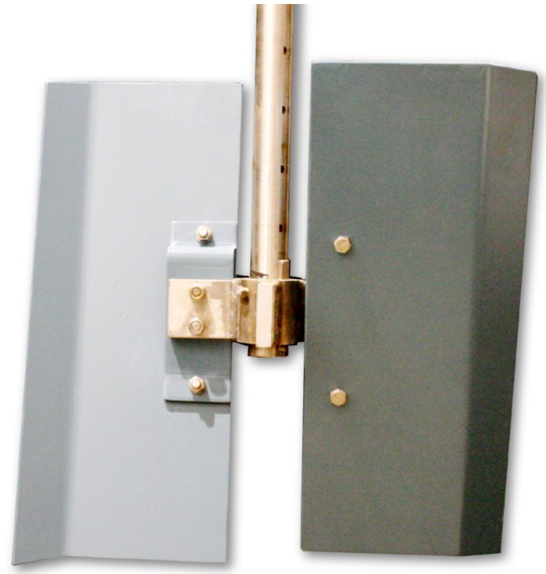


Fig 6. Full scale impeller prototype 0.76 m diameter

CONCLUSION

Both experimental findings and CFD modeling demonstrate the difference in performance between a traditional hydrofoil and the Philadelphia Mixing Solutions low shear impeller.

Particle attrition for uniform suspension was proven to be much less with the SLS impeller than with the MSH hydrofoil impeller.

The experimental data validates the CFD model predicting lower strain rates for the SLS impeller than the MHS hydrofoil impeller.

The SLS impeller can be effective for application where low shear and high flow are required.

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