CFD Modeling of Pumping Facilities

Steve Saunders

IBIS Group Inc.

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Pump Sump Modeling

Scale physical pump sump modeling has evolved over the past 100+ years and follows an established set of protocols for sump analysis.

CFD analysis of pump sumps is an emerging technology. The common practice is to emulate physical testing with CFD.



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Assessment Criteria

- Pre-swirl
- Velocity distribution
- Vortices
- Settling solids behaviour
- General flow patterns

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Pump Sump Modeling Instrumentation - Pre-swirl Measurement





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$$lpha = rctan rac{V_{{\scriptscriptstyle tangential}}}{V_{{\scriptscriptstyle axial}}}$$

Movement of the rotometer is the result of the cumulative effect of the tangential velocity within the volume "swept" by its vanes.



Pump Sump Modeling Instrumentation - Velocity Profile Measurement

Pitot probes are positioned at equal area centers.

The whole apparatus rotates about the tube centerline to facilitate the circumferential collection of velocity data.

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Deviation from mean axial velocity = $(V_{ax_local} - V_{ax_mean})/V_{ax_mean}$

Pump Sump Modeling Vortex Detection



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Vortex classification illustrations from ANSI/HI Standards



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Pre-Swirl Angle

Pre-swirl angle $\alpha = \arctan \frac{V_{\text{tangential}}}{V_{\text{axial}}}$

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is determined using the averages of V_{tan} and V_{axial} on the plane of the pump impeller eye. For this case, pre-swirl angle was 2.6 degrees

Arrows shown in this illustration are the vector products of just the tangential and radial velocity components.



m/s

Vectors superimposed on top of tangential velocity contours





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Finding Vortices

Vortices typically originate on surfaces in quiet areas where there is some re-circulation.

Initiating streaklines on the top and submerged surfaces reveals the re-circulation zones where vortices may develop.



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Finding Vortices

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Determining Vortex Strength

Virtual Dye Traces – By initiating streaklines at the centers of the re-circulation zones, it is possible to replicate the dye traces used in a physical model.

Note that a steady state CFD model with a symmetry plane acting as the water surface will predict surface vortices, but will not replicate the two phase physics of an air-drawing surface vortex or any vortex that causes a deformation of the liquid surface.

A vortex strong enough to require remedial sump geometry changes will have a rotating flow pattern that persists into the pump impeller eye.

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Alternative Vortex Analysis Methods

Software vendors including ANSYS and Flow Science have vorticity analysis tools included with their post processors.

Red lines in the plot to the right are cores of rotational flow that have been identified using a vorticity analysis tool. Note the core lines coincide with the streaklines in the plot above.

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Questions or Comments?

Steve Saunders IBIS Group Inc. <u>ibisgroup@bellsouth.net</u>

IBIS Group Inc. http://www.ibisgroupcfd.com/

