Wastewater Treatment

Improving an induced vortex grit chamber using Computational Fluid Dynamics

By Denis Aubin, Mike Bruneau and John Cigana

The headworks of a wastewater treatment plant is not only the first step of the wastewater treatment process, but also an essential one, as it sets the tone for overall treatment performance. Generally speaking, the headworks is composed of a mechanical screen, grit chamber and solids handling equipment.

Modern grit chambers remove grit by inducing a vortex pattern. A drive paddle in the induced vortex unit maintains organics in suspension and circulation under all flow conditions. Grit slurry pumps periodically remove accumulated grit from the hopper at the bottom of the grit chambers.

Efficiency of the grit chambers is important for the remainder of the wastewater treatment process. Removing solids increases treatment efficiency, improves downstream hydraulics, and protects against excessive wear and tear in pumps. Traditionally, for design purposes, grit particle sizes have included particles larger than 65 mesh (0.008 in.) with a specific gravity of 2.65. Removal of at least 95% of these particles has always been the target of grit removal design, but empirical studies in the literature validating these performances have been rare.

Enhanced performance at the headworks stage is critical for advanced treatment technologies like membranes, MBRs and MBBRs. These are all sensitive to the presence of gross solids and grit deposition. Grit removal performance is also critical to lagoon-type treatment rehabilitation.

Research objective: defining a 360° Induced Vortex Grit Chamber

A research program was established recently to define a variangle (full 360° rotation) Induced Vortex Grit Chamber (IVGC) design, identified as the MECTAN V®. The objectives of this program were to create a new configuration that would:

• Position the outlet channel in any desired direction to facilitate the plant design without affecting the unit’s performance, thus the variangle.
• Provide enhanced grit removal efficiency compared to the classic results and general market requirements.

Finally, this research program would lead to a predictive model based on field performance and computer modeling.

Background and methodology

Classic grit chamber design is typically referred to as 270°, referring to the rotation angle of the water from the inlet channel to the outlet channel. This implies that the inlet and outlet of the unit are on the same side of the induced vortex tank. In order to fully understand the performance of the classic design, the exact geometry of a 270° induced vortex grit chamber was modeled through CFD (Computational Fluid Dynamics).

The Fluent® software (ANSYS) was used for this modeling, as shown in Figure 1. The models were established using a classic design IVGC unit installed in Ridgecrest, California. The grit removal performance obtained through CFD simulations were then validated with empirical data from onsite trials. At the time of testing, the Ridgecrest WWTP was at 25% of nominal flow. Even though not considered close to the actual expected 100% design flow, but close to average daily flow for many WWTPs, these tests have provided considerable data for developing the new technology.

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The sand dosage method was used during these performance tests in Ridgecrest. The quantity of injected sand was sufficient and the velocity in the channel was high enough to avoid the settling of sand before the grit removal system. While sand was injected, two samples, at equal flow rates, were taken simultane-
ously, one upstream and one downstream of the grit chamber, using two submersible pumps installed at the inlet and outlet of the grit chamber.

Samples were then sent to an external laboratory where analyses of sand granularity and density were done. Grit samples were sieved through three different mesh sizes: 50, 70 and 100 (corresponding to 300, 250 and 150 µm). Thus, four ranges of grit were obtained, corresponding to particle sizes <100, 100-70, 70-50 and >50 mesh (corresponding to <150, 150-200, 200-300 and >300 µm).

Figure 2 is a typical grit removal efficiency curve for a classic design IVGC at 100%, 75%, 50% and 25% of design flow. The four computed curves on this figure clearly show one of the great benefits of the IVGC design: grit removal efficiencies increase with decreasing influent flowrate. This is extremely positive since 100% of design flow is rarely achieved on a continuous basis. Removal efficiencies are therefore always better during average daily design flow, which is anywhere between 25% to 50% of design flow.

**CFD development of the variangle flow path design and test sites**

The project’s central objective was to develop a new and more efficient variangle configuration, while adapting the design to current approaches.

While very practical for bypass installation, the classic design requires the outlet channel to be parallel to the inlet channel in order to connect to the downstream treatment systems. In the late 1980s, configurations using in-line inlet and outlet configurations appeared. This approach addressed the flow direction issue, but did not fully address the grit removal performance.

Two sets of full-scale testing were completed at fully operational installations in Soledad, California, and Jackson, Kentucky. The sand dosage methodology described for the Ridgecrest test was also used for the validation in Soledad and Jackson.

**Soledad Wastewater Treatment Plant**

The unit in Soledad, California, was one of the first variangle units to be installed. The municipal wastewater was fed by gravity into the 16-ft-diameter unit. The feed rate only provided 25% of total design flow to perform the tests of the variangle concept.

Figure 3 compares different results obtained through CFD modeling and empirical data.

The black line represents the grit removal efficiencies that a classic IVGC would yield at 100% of design flow. The dashed magenta line represents the efficiency for the same 100% design flow but with a variangle configuration. It can be clearly seen that the grit removal performance is enhanced by a variangle design, across all grit sizes.

Furthermore, when comparing on this same figure the grit removal efficiencies at 25% of design flow (the conditions where the tests were performed in Soledad) for the variangle design and a comparable classic design, it becomes clear from the empirical sand dosage tests that the efficiency of the smallest grit sizes (between 100 and 150 microns) is enhanced by the variangle design.

It was determined that the sand dosage test method could typically exaggerate grit distribution in the channel, so, from
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This particle size is typically considered as very fine grit and very difficult to capture.

Jackson Drinking Water Plant

The Jackson, Kentucky drinking water plant uses a grit removal system, as it draws muddy and gritty water from the nearby river. The 7.5-ft-diameter grit tank was installed after the intake pumps. Although not tested at 100% design flow, this installation did provide the opportunity to test the variangle concept at 60% of total design flow.

Figure 4 also compares different results obtained both through CFD modeling and empirical testing.

The black, orange and pink curves present the CFD-generated grit removal efficiencies for an equivalent classic IVGC design at 100%, 75% and 50% of design flow. The dashed blue colour curve shows what the expected grit removal efficiency would be with a variangle design at 100% of design flow. Again, it is clear that the variangle design offers better grit removal performance than the equivalent classic design at 100% of flow, as grit removal efficiencies are better across the board than with a classic design.

The sand dosage tests were performed at 60% of design flow. The real-world results obtained on grit removal efficiency again show the superior performance of the variangle design over the classic design. For example, for a 100 micron grit

**Imbrrium expands its Australian presence**

Humes is a longstanding licensee of Imbrrium’s Stormceptor oil and sediment separator technology. Under a new agreement, it will also manufacture, sell and distribute Imbrrium’s Jellyfish Filter stormwater treatment technology throughout Australia.

According to Scott Perry, Managing Director of Imbrrium, the Jellyfish Filter can remove more than 85% TSS, 60% total phosphorus, 50% total nitrogen, high levels of metals and sediment particles as small as 2 microns from stormwater.

**Upcoming Events**

May 6-9, OWWA
Niagara Falls, ON

June 10-14, AWWA-ACE
Dallas, TX

June 19-22, AWMA-ACE
San Antonio, TX
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By interpolating between the 50% and 75% curves for the classic design, the expected efficiency would be in the range of 50% grit removal efficiency. This represents a huge improvement in grit removal performance at sizes considered extremely difficult to intercept.

Table 1. Expected grit removal performance for a variangle design (2.65 specific gravity).

<table>
<thead>
<tr>
<th>Particle size (microns)</th>
<th>Particle size (MESH)</th>
<th>Grit removal efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 300</td>
<td>Above 50</td>
<td>96%</td>
</tr>
<tr>
<td>Above 210 and below 300</td>
<td>Above 70 and below 50</td>
<td>87%</td>
</tr>
<tr>
<td>Above 150 and below 210</td>
<td>Above 100 and below 70</td>
<td>75%</td>
</tr>
<tr>
<td>Above 100 and below 150</td>
<td>Above 140 and below 100</td>
<td>68%</td>
</tr>
</tbody>
</table>

CFD backed performance for grit removal

Computational fluid dynamics is a powerful and flexible tool that allows the study of a wide variety of applications in the water industry. Field tests are bringing additional credit to the use of CFD as a design tool. This study combined both CFD evaluation and field results with the objective of developing and validating a variangle IVGC. As a conclusion, Table 1 presents the grit removal performances that were achieved through this study. Ongoing field results and continuous CFD modeling are being considered in order to enhance and provide for even more accurate prediction of grit removal performances with the Fluent® CFD program.

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