CFD Saves $50,000 in Design of Stormwater Separator

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Stormwater discharges make a significant contribution to pollution problems in most urban areas. This is because pollutants such as litter, oil, grit, pesticides, metals, and fertilizers tend to settle on impervious surfaces such as streets, parking areas, driveways and sidewalks. A heavy rainstorm can wash these untreated pollutants into drainage systems. Typically these inlets eventually discharge into nearby streams. Recent environmental studies have shown that stormwater runoff plays a significant role in the problems of 13% of polluted rivers, 21% of polluted lakes and 45% of polluted estuaries.

Hydro International, a supplier of innovative products for the control and treatment of stormwater and waste-water, recently used CFD to help develop an economical but effective system for the removal of sediment and other pollutants from stormwater in smaller industrial, commercial, and residential facilities.

Many industrial and commercial facilities need to address the impacts of stormwater runoff as part of the Environmental Protection Agency's (EPA) National Pollution Discharge Elimination System (NPDES) Phase II Stormwater Program. Phase II is the second component of a two-part program to improve the quality of the nation's streams, rivers, lakes, and estuaries by managing storm-water runoff from urban and suburban areas, construction projects, and industrial sites.

Phase I, issued by the EPA in 1990, covered medium and large municipalities, construction sites over five acres in size, and ten categories of industrial activity. The Phase II program is the next step and covers smaller municipalities, urban areas adjacent to municipalities, and construction sites larger than one acre.

In developing a product to address the challenges of facilities covered by Phase II requirements, Hydro's goal

Courtesy of Stacey Marden

was to build a separator that would remove 90% of sediment and avoid the washout of stored pollutants while also capturing oil and floatables. The idea was to let the fluid motion through the device do all of the work so it could operate without any moving parts and without filtration systems that could potentially clog and require maintenance. Engineers recognized from the very beginning of the design process the challenges involved in meeting these goals through hydrodynamics alone.

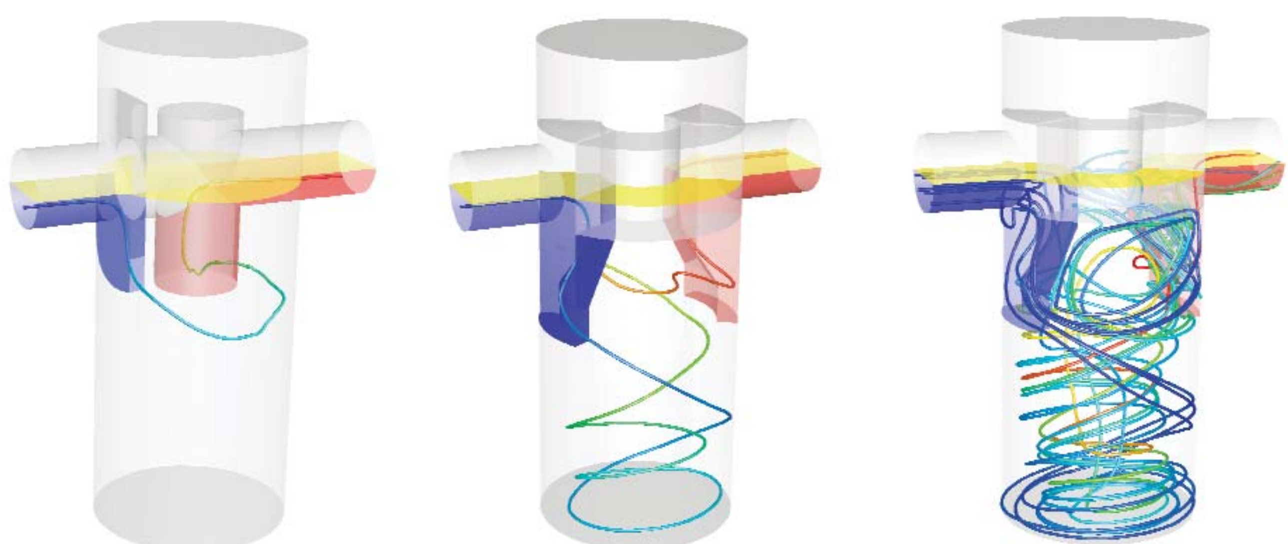
The traditional approach to designing this type of separation device is to build a prototype, test it to find out how it works, make assumptions on how its performance could be improved, and then build another prototype to start the process anew.

There are several problems with the traditional approach. First, the geometry of hydrodynamic separators is typically quite complex, so the cost of building and testing a prototype can exceed $20,000 and take more than eight weeks. Second, while the physical testing of prototypes can easily determine the performance of a device, it provides very little insight into why the device performs as it does. This is because it is difficult to visualize the fluid flow, even when the prototype is made of a clear material. The only way to obtain even limited visualization is through high-speed video imaging, which adds substantially to the cost of testing. The result is that engineers are frequently left guessing as to why a prototype failed to perform as hoped; instead, they must rely upon their intuition or guesswork to design the next prototype.

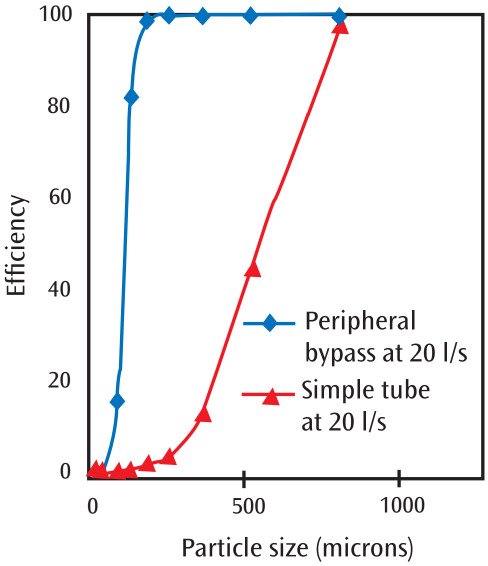
Hydro International has overcome these difficulties by using CFD to simulate the performance of hydrodynamic separators and other flow-intensive devices. One major advantage of CFD is that a model can be created and evaluated within a week and at less than 20% of the cost of physical prototyping. Another advantage is that CFD provides far more information about the reasons behind the performance of a design concept. For example, it can provide flow velocity and direction throughout the analytical domain and can also trace the path of particles of different sizes as they flow through the system.

Using CFD, Hydro engineers modeled several design concepts prior to the prototyping stage in order to finalize the design as much as possible before building their first separator. The engineers were seeking a design that provided the following flow characteristics.

First, they were looking for a structured rotational flow around the vertical axis of the chamber in order to produce the centrifugal forces that contribute to separation. Second, they wanted to see high and uniform downward velocity through the middle of the chamber and little or no vertical velocity around the outer walls, where rotation should dominate. Finally, in simulating particle flow through the device, engineers were looking to



A single pathline is used to represent the flow field in the original simple tube (left) and improved peripheral bypass (middle) designs where the inflow is shown in blue, the outflow in red, and the water surface in yellow; no organized circulation was observed in the lower chamber of the original design; several pathlines (right) are used to further illustrate the flow field for the improved design; all pathlines are colored by residence time from blue (minimum) to red (maximum)



Capture efficiency of the simple tube and peripheral bypass designs operating at 20 liters/sec

capture at least 90% of the particles entering the device, and avoi washout.

Hydro engineers began by modeling a simple cylindrical design that featured a large central tube for outlet control and a bypass within the treatment chamber. The CFD results showed that this design did not come close to meeting the company's performance requirements. The device lacked structured rotational flow and the vertical flow velocity in the central region was also lower and less consistent than desired. It came as no surprise that the separation efficiency of this design was not particularly high. It only removed the medium to coarse sized particles allowing over 90% of the finer particles to escape. While the performance of this design was disappointing, it contributed to the design process by providing insights on the geometrical requirements for good separation efficiency. Engineers modeled several other designs that showed relatively weak performance but provided additional design insights.

Next, engineers modeled a more complicated peripheral bypass design that features two opposing tangential inlet/outlet chutes and provides bypass around the chamber periphery. This design was conceived based on the insights obtained from the earlier designs. The goal of achieving structured rotational flow was met by introducing the stormwater tangentially through the inlet chute. The outlet chute is positioned to discharge treated stormwater in a direction opposite that of the circulating flow, allowing solids to be swept past the opening. An integral bypass eliminates the need for an additional structure. Higher flows bypass the treatment chamber where a stable flow regime is maintained, preventing the washout of stored pollutants. A draw-off port diverts floatables to the treatment chamber prior to bypass.

The simulation of the peripheral bypass design showed that it met all of the original design objectives. A structured rotational flow was clearly visible around the outer section of the chamber. A high and consistent downward velocity was seen in horizontal cross-sections of the chamber. Most importantly, CFD predicted that the design would capture over 90% of the target sediment at the design flow rate of 20 liters/sec. The simulation also showed that at 30 liters/sec, over 90% of the target sediment would be retained in the sediment storage area.

Physical testing by Hydro International and witnessed by the Maine Department of Environmental Protection (DEP) verified the CFD predictions. In the Maine DEP tests using OK110 sand, the device performed at an average efficiency above 90% for fine particle removal over a series of six tests. This was well above the 80% level required to achieve certification. Hydro released the product, called First Defense®, based on this design, targeting factories, parking lots, vehicle maintenance yards, strip malls, convenience stores, truck stops, condominiums, apartments, and other facilities that are affected by the new Phase II regulations. The product has been successful, exceeding budgeted sales projections to date. Hydro International management believes that its success is partially due to the use of CFD to quickly and inexpensively iterate to an optimized design that provides the performance needed by the intended market at an economical price. ■

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