Revolutionary IV Design Relies on Upfront CFD Technology

Ben Powers

Developing a revolutionary product requires deviating from the well-beaten product development path. The product-development processes you use will dictate just how innovative your products end up. The development and manufacture of Fluidnet's new infusion pump demonstrates this point.

Fluidnet used CFdesign upfront CFD software to design a new generation of flow sensor and flow resistor for its new IV.

At Fluidnet, we're revolutionizing the IV therapy market with a fully featured infusion pump that weighs less than two pounds, and fits in the palm of a hand. It is ultra-quiet and so efficient that it can operate on battery power for days. But, the most revolutionary aspect is what goes on inside, and to develop that, you need technologies such as upfront CFD. Fluidnet used CFdesign upfront CFD software to design a new generation of flow sensor and flow resistor for the administration set used with our IV pump.

CFdesign enables multi-tasking engineers to perform computational fluid dynamics analysis early in the design cycle, when it is most cost-effective to explore and validate designs. Virtual prototyping of different design options replaces traditional testing methods, saving the more costly physical prototyping for final design verification.

Expanding Dynamic Range

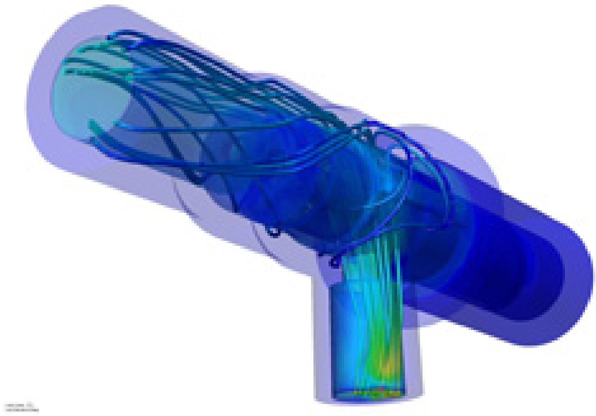
In IV therapy, there is a clinical need to deliver fluids at rates from .1 ml/hr to 6,000 ml/hr. This is an extremely large dynamic range for a mechanical system. The driving pressure our pump uses to move the fluid can vary only by a factor of 3-4X, which doesn't come close to allowing the full range of flow rates.

We needed to find a means of adjusting fluidic resistance within the flow path by four orders of magnitude. After extensive searching, we could not find any stock resistive valves that would give us proportional control over the entire range.

We came up with a concept for a custom flow resistor that had the potential to perform in a purely logarithmic manner, which gives us proportional control over the full range of flow rates. If the resistor knob is rotated 10 degrees, for example, the flow rate increases by about 10x, no matter where the initial flow rate is set. With precise control and a large dynamic range, we can keep fluidic driving pressures low (from one tenth to one thirtieth below our competitors). Low driving pressure translates to better safety for the patient receiving the infusion.

CFdesign allowed us to quickly iterate through design versions and tweak dimensions to obtain the desired performance. When prototypes were obtained after the design was completed, we found that the actual performance matched up almost exactly to the results predicted by CFdesign.

Real-Time Flow Observation



Traces within a CFdesign simulation show the velocity of flow through the Fluidnet flow sensor and resistor. CFdesign provided a detailed internal performance picture of flow through tiny channels, providing information and insight not obtainable with even the most sophisticated physical test methods.

We followed a similar path in developing the flow sensor. In this case, the innovation we needed was an inline sensor that wouldprovide a real-time observation of flow. We refer to this as closed-loop control of flow, which means we are continuously aware of how and what we are pumping. This window into the flow is unique; competitors simply assign a flow rate and assume that it happens.

The sensor scheme we chose is very similar to a standard rotameter flow gauge, which uses a tapered tube and float to meter variable-area flow. But, we had to do extensive redesign to get the cost down and meet our exact requirements.

CFdesign allowed us to iterate on the design and assess performance changes associated with tolerance shifts. We could then optimize the design to fit our needs. Again, results predicted by CFdesign and actual results were almost dead on.

Upfront Time Savings

The design process for the flow resistor and sensor started with a simple design concept, such as a flow channel wrapped in a helix around a plunger. That concept was then modeled in SolidWorks. We did not model in great detail, but took care to capture the important parametric dimensions that affect flow.

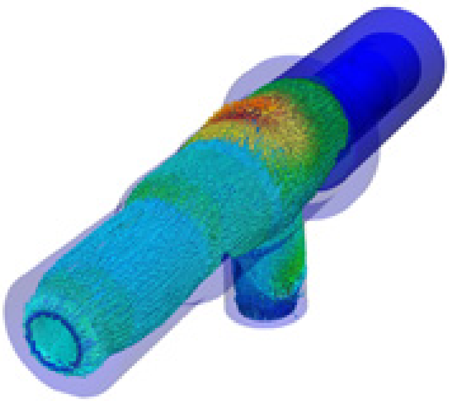
From within SolidWorks, we launched CFdesign and it automatically opened the native geometry and created a fluid body that defined the flow path. The integration with SolidWorks is a huge plus; it probably cut our cycle time in half for each design-simulation iteration.

With the model in CFdesign, we meshed it and applied fluid properties and pressure or flow boundary conditions.

We then ran the analyses and reviewed the results. The goal for the flow resistor was to get a flow rate vs. pressure drop reading at a given resistor position. For the flow sensor, we were looking to balance drag forces on a moving flow object with correcting forces of a retention spring.

In the flow sensor simulations, we brought the model into CFdesign with the flow object in a specific position. We then ran a few analyses with different flow rates imposed on the system and assessed the resultant drag forces. Those resultant forces were then compared to the known spring restoring forces. If necessary, the flow rate was tweaked and the analysis run again.

We went through more than 10 different design concepts for both the flow sensor and resistor. Within those design concepts, there were also several stages of concept refinement once we chose the desired design direction. In the end, we probably went through hundreds of iterations, making the time savings from CFdesign's integration with SolidWorks and automatic creation of fluidic geometry especially significant.



Vectors within a CFdesign simulation show pressure results through the narrow channel of the Fluidnet flow sensor and resistor. Fluidnet used CFdesign to adjust fluidic resistance *within the flow path by four orders of magnitude.*

One of the unique challenges we faced that made upfront CFD so valuable was the very small flow channels (tapering from zero to a .03-inch half circle) required by our design. At that scale, it is very difficult to intuitively picture what's going on.

CFdesign provided a detailed internal picture of flow through tiny channels. This enabled us to predict performance and diagnose tooling errors. In one case, we were seeing strange behavior with some flow resistors that appeared to be related to a molding error. We modeled the error in SolidWorks, ran a CFdesign analysis, and were able to replicate the physical results we were seeing. The visualization of this error proved persuasive in getting the molder to fix the tool.

Saving Years and Millions

After design refinement was complete, we had single-cavity injection molding tools made to test out physical parts. The detail and geometry required for our application precluded standard SLA or machined prototypes. This is where the accuracy of CFdesign simulations came into play; we only needed to produce one set of molds since the resultant parts performed as predicted in the simulations.

If we had been forced to make molds for each of our guesses at the design, we would have had to go through many more rounds of tooling and would have ended up with inferior performance. We also would have been way over budget and beyond our schedule.It would have taken years and more than a million dollars in tooling to get the same result.

A New Freedom

Fluidnet is currently doing clean-room builds of our disposable administration set that includes the flow sensor and resistor, and finalizing the exterior pump design. The simplicity, portability, efficiency, and convenience of the pump will create a new freedom for care providers and patients.

Upfront CFD enabled Fluidnet to form an accurate mental model of how our flow sensor and resistor really worked, and what dimensions would affect performance. That's something that can't be done with experience, intuition or even an unlimited number of physical prototypes.

Ben Powers*, system engineering manager for Fluidnet, managed simulation for the flow sensor and resistor projects.*

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