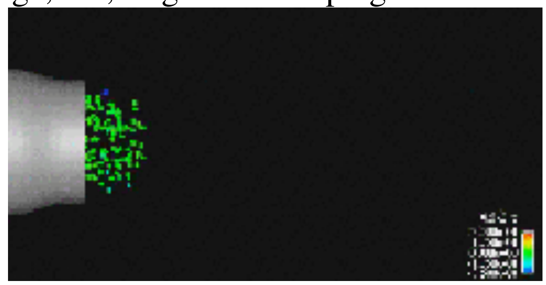
Penn State Researcher Uses EnSight to Help Water Jet Engineers

By: Douglas Clark

For many people, the mention of tiny bubbles might evoke the pleasant thought of champagne. But for Brian Edge, a PhD candidate in mechanical engineering at The Pennsylvania State University, tiny bubbles have little to do with popping corks and celebration—they're serious business. In the world of computational fluid dynamics and water jet design, the behavior of bubbles as small as a few microns can mean the success or failure of a new jet design.

Working out of Penn State's Applied Research Laboratory in State College, PA, Edge is developing software that will make it easier for engineers and designers to understand these bubbles' behavior, so they can build more effective jets. His software simulates the flow of water and bubbles through a given jet design to predict bubble behavior under varying conditions.



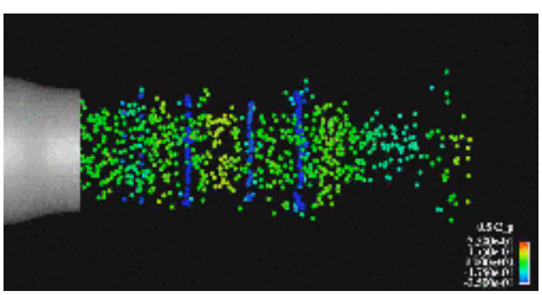
In addition to the challenge of writing this sophisticated software, Edge also faces the challenge of transforming his software's data into a format that will allow engineers to share their work with others who lack a scientific background, such as upper management or potential backers.

For Edge, the obvious answer was to use animation to show exactly what happens as water flows from a jet.

Bedeviling Bubbles

The main objective of Edge's software is to determine when and where a phenomenon called cavitation takes place. This is where the bubbles come into play. When air is introduced into water, most of the bubbles formed in the process either eventually float to the surface or are absorbed into the water. Some microscopic bubbles, however, do remain.

For the designer of a jet, how these tiny bubbles will react when they meet with a jet's turbulence is the big question. Jet turbulence naturally causes pockets of high and low pressure, and when these small bubbles are exposed to low pressure, they expand to form larger bubbles, or "cavities," in the water. Bubbles that are only a few microns in size can quickly expand to a few millimeters or even centimeters. This rapid expansion of a bubble in a low-pressure environment is cavitation. The process also works in reverse. In other words, just as bubbles cavitate or expand upon entering an area of low pressure, they collapse upon leaving it.



For a jet designer, expanding and collapsing bubbles present three distinct problems. First, they can dramatically decrease a jet's efficiency. When larger bubbles form in the water flowing through a jet, the jet is no longer pushing water but is pushing the much-less-dense bubbles. For a propulsion jet, that means less forward thrust.

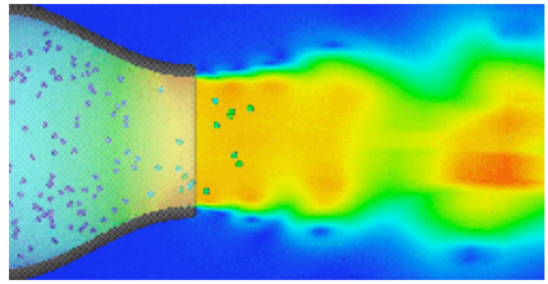
Second, cavitation causes damage to nearby surfaces. As harmless as it sounds, the rapid expansion and contraction of bubbles is a very violent phenomenon and releases a great deal of energy. Any surfaces or equipment near the jet could seriously be damaged if exposed to cavitation.

Third, cavitation produces a great deal of noise. For designers of jet-propelled commercial vessels, for example, reducing noise may only be for comfort and convenience. For other applications, such as a small craft used by marine biologists to study ocean life, reducing noise to an absolute minimum may be critical.

Crunching the Numbers

Edge uses conventional computational fluid dynamics to simulate a water jet. His calculations account for the velocity of the water, the pressure at any given point, and various characteristics of the turbulence coming out of the jet.

He then adds bubbles into the mathematical simulation and calculates their movement and reaction to conditions throughout the flow. The simulations allows for the continuous tracking of how the bubbles respond to velocity and pressure changes, making it possible to predict when, where, and under what conditions cavitation will occur.



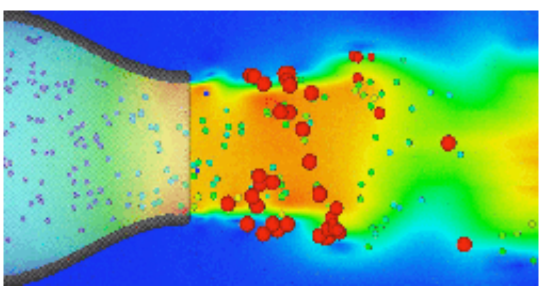
Edge uses custom code to carry out the computations, which are done on government-owned supercomputers that his lab has access to. The result of his work is several hundred gigabytes of data. When represented by conventional scientific means, the results of his work are only easily understood by a trained scientist. Trying to relay the information to a non-scientist is far more challenging. That's where EnSight enters the picture.

Animation Brings It All to Life

Edge used EnSight to illustrate what his jet-simulation software can do. "The power of animation is that I can easily explain my research to an non-technical person. If I show them a plot of bubble size vs. time history, they may not get it. If I can show them an animation where I can actually show little bubbles and show how they're growing and responding to the flow field, and where that's occurring, that's extremely powerful."

Edge had previous experience using other software packages to produce animations. This time, however, EnSight seemed to be the only logical solution because of the hundreds of gigabytes of data involved.

EnSight allows Edge to leave all the data on the supercomputers and work from his desktop computer in client-sever mode. That way, all the heavy processing takes place on the super computers, and the results are simply sent to his desktop computer.



Commenting on EnSight's ability to handle large amounts of data he says, "We really couldn't go with anyone else's software. It's an incredible capability and a huge advantage for EnSight—and for me," he says. "Doing it any other way, I'd have to download all that data to my local computer. Then, I wouldn't have the memory to analyze the data, so I'd have to do it in very small chunks. And I don't even know if I could do it on my computer."

To create animations, Edge modified his custom code to output data in EnSight format. This way, his code writes an EnSight case file that controls the EnSight session, as well as an EnSight geometry file with structured grids, and EnSight boundary files.

In working with EnSight, Edge was pleased to find that its ability to handle large amounts of data was by no means its only advantage. Because EnSight makes it very easy to animate multiple processes at once, Edge was able to work with the water-flow data and bubble data separately, while still being able to represent them both in the same seamless animation.

To bring both of these elements together in one animation, Edge used EnSight's measured/particle capability. This allowed him to output each bubble's scalar and vector data separately. The measured/particle data was then visualized as spheres—to represent the bubbles—and placed within the water flow. He modeled the color and size of the spheres, based on the scalar and vector properties of each bubble.

Throughout the process, Edge also took advantage of EnVideo to evaluate progress and show videos on various platforms. “The ability to use EnVideo on many different platforms is very important, because it gives us a consistent environment to view and analyze data.”

The end result Edge’s work is animation that anyone can quickly understand: in just a few seconds, the bubbles’ complex behavior plays out before the eyes. One has to ask, however, what Brian Edge thinks of when he sees these animated bubbles. Could it be champagne? Because with his mission accomplished, these animated bubbles might just merit a true celebration.

More about Cavitation

Cavitation is much like boiling, except that it occurs when a liquid turns to a vapor due to low pressure, as opposed to an increase in temperature.

While designers of jet propulsion systems generally try to minimize cavitation, it actually has a number of beneficial uses as well. For example, its destructive nature is harnessed in the design of underwater cutting torches, ultrasonic cleaning devices, and other equipment.

Cavitation's usefulness, however, is not limited to cutting and cleaning equipment. It is commonly used to homogenize milk and paints, as well as purify water. Its applications also extend to realm of nuclear physics, where scientists have successfully used sonically induced cavitation to spur nuclear fusion.

We even come across cavitation in daily life. Ever wonder what makes your knuckles pop? It's generally believed to be cavitation at work.

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