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Tiny Bubbles to Make You Happy

The ethanol industry is feeling the heat and pressure to remain profitable. One way to ease the pressure is to increase yields. Arisdyne Systems Inc. wants to help ethanol producers increase yields by increasing heat and pressure (on a microscopic scale) using controlled-flow hydrodynamic cavitation.

by Ryan C. Christiansen

As a retired U.S. Navy captain and a mechanical engineer, Fred Clarke knows a thing or two about cavitation. In the Navy, cavitation would be the sudden formation and collapse of low-pressure bubbles in liquids by means of mechanical forces, such as those resulting from rotation of a marine propeller. However, at Arisdyne Systems Inc., it has a different application. Clarke is the executive vice president for Arisdyne a Cleveland, Ohio-based company that wants to bring the benefits of controlled-flow hydrodynamic cavitation to the ethanol industry.

Hydrodynamic cavitation can be produced by passing a liquid through a constricted channel at a specific velocity. The formation and implosion of bubbles in the liquid releases tremendous localized energy in the form of shockwaves.

“The collapse of those bubbles has been measured at temperatures around 5,000 degrees Celsius and pressures near to the equivalent of the bottom of the ocean or 1,000 atmospheres of pressure—very, very high,” Clarke says. “When that happens, you end up with a micro-shockwave that is not altogether different than the blast of a bomb. That shockwave happens at the microscopic level in the fluid, and whether the waves are destructive or productive depends on your ability to control the process," he says.

“You're talking about a phenomenon that every engineer in this country was told never to let happen—never let cavitation occur, because it will tear apart a pump or a propeller or something that you don't want to have eroded away. That happens when you don't control the zone in which the cavitation occurs," Clarke says. However, Arisdyne's controlled-flow cavitation technology controls the location, size, density, and intensity of the implosion of bubbles in the zone to create optimum process conditions, he says.

Higher Yields

For ethanol producers, using controlled-flow hydrodynamic cavitation could mean obtaining higher yields of ethanol from the same amount of corn. In a dry mill ethanol plant, the process could be used to reduce the size of mechanically milled starch particles inside the slurry, thereby increasing the surface area of the particles, resulting in a faster hydrolysis of starch to sugars.

"The analogy I use is that it's the difference between putting a sugar cube in hot tea versus putting powered sugar grains in the tea," Clarke says. "The dissolving occurs tremendously faster [with granular sugar] because more of the tea can surround the sugar and cause it to disappear."

Arisdyne is working with ethanol technology firm Delta-T Corp. to determine just how much more ethanol might be produced using slurries processed using controlled-flow hydrodynamic cavitation. Arisdyne is cavitating corn slurries at its lab in Cleveland and then sending them to Delta-T's lab in Williamsburg, Va., for performance testing.

"I found Arisdyne through my normal patent searching and I was intrigued that they have a patent application out there where they are looking at enhancing yield through hydrodynamic cavitation and, specifically, in dry mill ethanol plants," says Mark Shmorhun, director of research and product development at Delta-T. "We're looking to confirm both enhancements in yield and whether there are any other unexpected benefits or drawbacks to the technology."

Clarke says so far, test results are positive. "Our early tests are confirming," he says. "The release of starch has been more than 5 percent above what is handled at a current plant," which Clarke says is just the starting point; it might easily be increased through optimization.

Delta-T is hopeful, Shmorhum says, because there is good evidence that the technology should work as proposed. "There is a good body of work on cavitation and what it can do for particle size reduction," Shmorhum says. "Cavitation has applications, broadly, [and] this is a new application of an existing and fairly well-understood technology. The theory and the body of evidence out there points to what I would say is a reasonably high probability of success for this technology."

Shmorhum says Arisdyne's technology is attractive in that it should be easy to implement in an existing dry mill plant. "The Arisdyne technology is attractive to me because of the simplicity of the concept," he says. "I like things that are elegant and straightforward and this one has those attributes. Relatively speaking, it's not a complex operation to deploy and, in theory, it should be able to enhance yield through particle size reduction and by better preparing the starch for hydrolysis and fermentation."

Award-Winning Technology

Arisdyne's proposed use of controlled-flow hydrodynamic cavitation to increase yields at dry mill ethanol plants helped the company to win a 2009 Northeast Ohio Technology Coalition (NorTech) Innovation Award. Arisdyne also secured more than $7.5 million in funding during its first year of operation, including an investment from Chevron Technology Ventures.

"One of the things that really sets them apart is their partnerships," says Dave Karpinski, vice president for technology innovation, manufacturing and electronics at NorTech. Karpinski notes that Arisdyne has managed to secure a $1 million Third Frontier grant from the state of Ohio. "That program is vetted by the National Academy of Sciences, so it was kind of a reinforcement of the merits of the technical case that their technology had," he says. Karpinski also notes that Arisdyne has partnered with the Ohio Agricultural Research and Development Center at Ohio State University—Wooster where Arisdyne benefitted from the expertise of Dr. Frederick Michele Jr., an associate professor of biosystems engineering who worked on cellulosic ethanol biorefinery process technology at the National Renewable Energy Laboratory in Golden, Colo.

"One of the things that I realized at NREL was that the cost of particle-size reduction is very high once you get to a small particle size," Michele says. "However, the energy input for [Arisdyne's technology] to reduce particle size beyond those very small sizes is very low—much lower than doing something like hammer-milling. And so it dawned on me that there may be an application here that may improve starch yield from corn, being able to reduce the particle size and make it more accessible to enzyme conversion."

Michele says under current dry mill process conditions, as much as 3 percent to 8 percent of starch is not converted to sugars. “There is the potential to release that additional starch and to improve yield at the ethanol plant,” he says, to as much as three gallons of ethanol or more per bushel of corn. “Our results indicate that [using hydrodynamic cavitation], we can get anywhere from a 4 percent to 7 percent increase in the glucose equivalent in a liquid fraction. Our initial tests look promising.”

The Arisdyne Team

A Harvard Business School graduate, Clarke is part of a team that includes Dr. Peter Reimers, president and CEO. Prior to joining Arisdyne, Reimers worked for Archer Daniels Midland for more than 10 years overseeing biodiesel operations in the European Union and in the U.S. Most recently, he was the managing director of long-term technology strategy at ADM and was responsible for launching a new research and development center that focuses on bioenergy technologies. He has served on the board of directors of the European Biodiesel Board, the National Biodiesel Board, and was a member of several biofuel and alternative energy working groups sponsored by the European Commission and the German government.

Clarke and Reimers are joined by Oleg Kozyuk, the chief technology officer responsible for developing new applications for the company’s patented cavitation technology. Kozyuk pioneered the concept of using hydrodynamic cavitation in technological processes in the Ukraine and has more than 180 issued or pending patents worldwide in a variety of areas including hydromechanics, mixing, homogenization, dispersion, nanomaterials, sonochemistry, and biotechnology, which have formed the basis for the launches of a number of companies in a diverse range of industries.

Other Applications

Prior to promoting its technology for use in dry mill ethanol plants, Arisdyne developed a continuous process technology using cavitation for the production of biodiesel. The first reactor was installed at the Middletown Biofuels LLC biodiesel plant in Middletown, Pa., in January 2008. Reimers says ethanol producers might also consider using Arisdyne’s technology for converting corn oil to biodiesel.

“I believe that the ethanol producer today has expertise in originating agricultural goods and they have good knowledge for how to sell and how to handle fuels,” Reimers says. “Why not harvest the corn oil, which is still in the distillers grains, and turn it into biodiesel? Wouldn't that be a nice addition to an ethanol plant?”

For ethanol producers, there may be more applications for cavitation beyond improving ethanol yields from starch and producing biodiesel from corn oil. Michele says Arisdyne is also looking at using cavitation to improve the anaerobic digestion of ethanol coproducts for producing methane. He says the company is working with Cleveland-based Schmack BioEnergy to use cavitation to reduce the size of anaerobic digestion reactors and to decrease retention times.

Michele says cavitation might be used to improve cellulosic ethanol processes. “There may be some applications in cellulosic ethanol similar to what we're doing with corn,” he says, “because, after the pretreatment of the feedstock, you have this material that's been digested, but it still may have greater potential for sugar release if you did something like this with a cavitation approach.”

Shmorhun says Delta-T is also looking at how Arisdyne’s technology might be used elsewhere in the ethanol production process. “We are having a look at the cavitation technology and its applicability to our dry mill designs first and foremost, and potentially where else the technology might be applicable. We're having a look at it," he says.

Addressing Sustainability

Increasing yields from corn ethanol is important because using less corn increases the sustainability of the fuel.

“In selling our proposal to the state of Ohio, what they liked was the fact that we might be able to reduce the corn input (at a 100 MMgy ethanol plant) by 2 million bushels,” Clarke says.

NorTech agrees. “What was compelling for us was the ability of the technology to reduce the cycle time of the process,” Karpinski says. “Any time you reduce the cycle time of a process, it improves your cost position. The environmental impacts of ethanol and biofuels are great, but they suffer from economic disadvantages. We saw this as a great lynchpin to help overcome those cost barriers so that this fuel can have a broader impact on the environment and society.”

Reimers says Arisdyne’s solution can help to assuage multiple sustainability concerns. “If the goal is to make biofuels feasible and to improve the economics, we have a good solution here," he says. "If the goal is to reduce overall greenhouse gas emissions and to make corn-based ethanol a better fuel, then we have a solution here."

Improving the sustainability of corn ethanol should be the first priority, Reimers says. "Under the renewable fuels standard, we need more capacity," he says. "Do you want to do that with new construction or with improvements to existing plants?"

Because Arisdyne's technology might also be used to improve cellulosic ethanol processes, an ethanol producer potentially could increase the sustainability of corn ethanol by utilizing more of the corn plant. "If this works in the corn area, it should clearly give us the ability to step over into stover, and that will make the whole debate about corn being inefficient a lot less a matter of debate," Clarke says.

However, Clarke says Arisdyne is focusing on improving corn starch processing first. "We came to the party with the dance partners that we have and they are in corn," he says.

Looking Ahead
Delta-T hopes to confirm the performance of Arisdyne's controlled-flow hydrodynamic cavitation technology before the fourth quarter of 2009 "and if we're successful, we'll be looking for a full-scale trial sometime toward the end of 2009," Shmorhun says.

Clarke says scaling up the cavitation technology should be fairly straightforward. "The only thing that will limit our scale is the capability and cost of pumps so if a pump can operate at 100 gallons per minute at pressures that are less than 1,000 psi, we can cavitate material. I could put a 100 MMgy cavitation device in the back of my Mini. Our scale-up is not a concern."

Implementation logistics aside, Shmorhun says established corn ethanol producers need to move forward with increasing yields. "The economics are straightforward," he says. "The number one cost of production of fuel ethanol is corn and any enhancement in yield of ethanol per bushel of corn is a significant contributor to the profitability of an ethanol producer. The Arisdyne technology is one approach to enhancing yield and as an industry, we need to be looking at yield enhancement as a top priority."

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