# Using enzymes to enhance oil recovery

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Biofuels are no longer the only beneficiaries of enzyme-assisted energy production. Enhanced-oil-recovery (EOR) techniques are benefiting from enzymatic treatment as well, as technology provider Jumpstart Energy Services recently explained.

Enzymes, the broad class of protein-based catalysts found in all living matter, have been used to accelerate the rate of chemical reactions in various manufacturing industries. Biofuel production has recently generated the most attention for enzymes in terms of energy production, in which the catalysts are used to accelerate the biological breakdown of cellulosic material into sugars suitable for biofuel production. The US Department of Energy recently announced a 4-year, USD33-million investment in projects aimed at improving enzyme systems for this purpose.

But the oilfield is not to be left out, and Jumpstart Energy Services is aiming at EOR techniques for application of its enzyme technologies. "We call our application enzyme-enhanced oil recovery (EEOR)," said John Gray, President and Founder of Jumpstart. "We focus on combined EOR technologies where enzymes bring benefit to existing secondary or tertiary production."

Jumpstart represents an enzyme fluid technology, sold under the trade name Greenzyme, that is a water-soluble formulation reportedly made from DNA-modified proteins extracted from oil-loving microbes in a batch fermentation process. The enzyme itself is nonliving, which provides EEOR an advantage over microbial EOR techniques that may require a detailed pretreatment involving the injection of a fermentable carbohydrate nutrient base into the reservoir. With the EEOR technique, only a dilution of the enzyme into the injection water is required. No subsequent nutrients are required either, which allows for a broader range of well treatment applications.

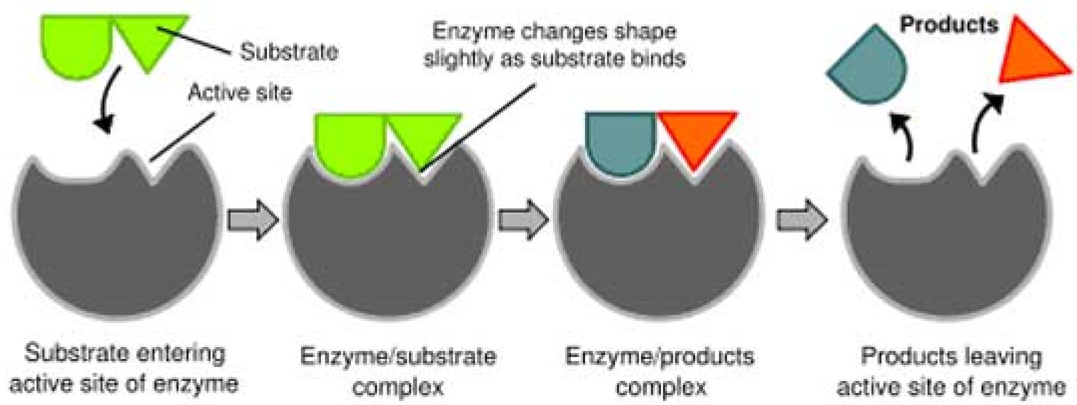
Greenzyme is reportedly ideally suited for sandstone, waterdrive formations with <30º API oil, >20% porosity, and >100-md permeability for single well treatments, but can have broader ranges in other applications such as waterfloods. "We've had success in fractured limestone formations as well," Gray said.

### Intertek laboratory tests shed light on EEOR mechanism

In order to explain how EEOR works, Jumpstart began laboratory tests at Intertek's Westport Technology Center designed to make an initial determination of the mechanism for any downhole oil-production improvement. These tests included comparing nonenzyme-treated and enzyme-treated 26ºAPI oil samples (a 10% concentration of Greenzyme diluted in water was used) that were both heated under pressure in order to simulate reservoir conditions.

Allan Hartman, Jumpstart's Vice President of Business Development, postulated that the enzymatic treatment may be improving oil recovery by catalyzing the breakdown of larger molecules in the oil into smaller molecules, which might improve the flow characteristics of the oil including heavy oil. A SARA (saturates, aromatics, resins, and asphaltenes) analysis supported the breakdown hypothesis in terms of the saturate content, as the enzyme-treated sample had a 5% lower saturate content than the nonenzyme sample.

Further analysis by means of high-resolution gas chromatography demonstrated that while the nonenzyme-treatment samples had clearly visible hydrocarbon peaks out to at least $C_{44}$ (44 carbon atoms on a molecule, typical for high-carbon content paraffins), the enzyme-treated samples presented much smaller peaks beyond $C_{30}$, and no visible hydrocarbon peaks past $C_{37}$. According to Jumpstart, the observed reduction in high-carbon-number paraffins and a corresponding reduction in the molecular size of the waxes point to a positive contribution from the enzyme.




**Jumpstart describes the enzyme-substrate interaction as an induced fit mechanism. The substrate (paraffin-laden oil) and enzyme bind in a specifc orientation to allow the substrate to break down into smaller molecular weight products.**

The enzyme's contribution to oil recovery may be a multipronged approach, as further testing indicated. "We commissioned a series of viscosity and interfacial-tension tests on these samples at the same time," Hartman said. "There was a sizable drop in viscosity, from 90.3 cP to 76.1 cP, in the presence of the enzyme treatment."

Interfacial-tension tests, which provide an indirect measure of the relative miscibility between oil and water, were conducted on oil/water samples in the absence of enzyme, oil/water samples in the presence of enzyme but prior to a heating/pressure treatment, and oil/water samples in the presence of enzyme and following a heating/pressure treatment. The Intertek report showed oil/water samples alone had fairly high interfacial tensions, on the order of 20.5 mN/m. For both enzyme-treated samples, there was an order of magnitude decrease in interfacial tension. "We expected to see a reduction of interfacial tension which was confirmed by these tests," Gray said, and noted that the heating/pressure step to simulate reservoir conditions did not influence this behavior.

"This indicated to us that in addition to catalyzing the breakdown of higher molecular-weight paraffins, the enzyme also possesses some biosurfactant properties, helping to release the oil from within the formation in the form of small droplets that are carried with fluids moving to a producing well," Gray continued. "The overall effect appears to improve relative permeability and oil mobility."

**Corefloods at PTS Labs show increased recovery of OOIP**

A series of coreflood tests was also carried out at PTS Labs, using a Berea sandstone core saturated with a synthetic brine and a 20ºAPI crude oil. Enzyme solutions at 3, 5, and 7% concentration were flowed through the core sample (5 pore volumes each). After 1 hour of flow, injection was halted and a 48-hour soak was conducted. After 48 hours, flow was resumed using the synthetic brine alone. Oil volumes were monitored and recorded during both presoak and post-soak intervals. Monitoring during the post-soak stopped once a 99.9% water cut was obtained.

"These tests demonstrated some useful results," Gray said. "First, the percent of original oil in place [OOIP] that was produced increased dramatically with enzyme dosage even before the 48-hour soak. At 3% concentration, only 0.66% OOIP was produced, while at 7% concentration, this value increased to nearly 10%."

After the 48-hour soak, the recovery was further improved. "We increased production to 3% OOIP for the 3% dosage, and this production increased up to the 7% dosage, where we produced nearly 13% of OOIP." Later tests with different samples at a 5% dosage demonstrated similar results.

**Field trials support EEOR's promise**

Jumpstart reports that well treatments using Greenzyme have been conducted all over the world through authorized agents, including numerous treatments in China, Indonesia and Venezuela, with encouraging results. Jumpstart has treated several wells in Texas with success. One mature well experienced a doubling in production after enzyme treatment, increasing from 4 BOPD to over 8 BOPD.

Well treatments in Indonesia for 7 oil wells showed a production plateau level of 60 BOPD, with a combined average water cut of 95% prior to treatments. "Each well was treated with four 55-gallon drums of enzyme fluid concentrate that were further diluted. Typical dilution factors are between 5-10% enzyme fluid," said Gray. The operator immediately started to see an increase in oil production despite the high water cut environment. Production data for over a year showed an annual increase of 60%. Hartman's review and further analysis of the


An oil-water-sand mixture treated with a 10% Greenzyme solution (left) shows clean separation of the oil from the sand, into two distinct layers. The notreated mixture (right) shows little oil-sand separation.

production data for these wells showed very rapid payoff. "In some cases due to initial jumps in production, payoff occurred in less than a week." Hartman stressed that Jumpstart had limited information about the wells that were treated in Indonesia beyond production data, including the formation.

According to Gray, several different applications could benefit from enzyme fluid treatment including single oil well stimulation (huff-n-puff), heavy oil (cold production) wells, cyclic steam injection, water floods, and near-wellbore treatment of gas wells, among others. "We are excited about the potential for using enzyme fluid in non-gel hydraulic fracturing to improve overall productivity of the frac job, " Gray stated. "Enzymes have been used to break cross-linked polymer chains as visc-breakers. Our fluid is designed to help release more oil and improve mobility. Greenzyme can be easily incorporated into most non-gel hydraulic frac designs."

In order to identify the appropriate applications for EEOR and screen wells for treatment, Jumpstart works with operators to identify specific wells and review formation parameters. "We want operators to have clear economic returns through improved production, as well as increased recovery of OOIP. This is a win-win situation for everyone," Gray concluded.

For more information on EEOR applications and enzyme fluid technology, please visit www.jumpstartenergyservices.com, or contact John Gray by email (jgray@jumpstartenergyservices.com).