Cornstarch might have ended the Gulf spill agony sooner

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The attempt to kill the Macondo well in the U.S. Gulf by pouring heavy mud down the well bore may have been defeated by an instability that led to turbulent mixing of the oil and the mud. The instability, called the Kelvin-Helmholtz instability, is also responsible for waves in the ocean and, occasionally, waves in the sky, as shown here

(PhysOrg.com) -- On May 25th, 2010, the online arm of Upstream, a newspaper for the international oil and gas industry, reported that British Petroleum had started top-kill procedures on the Deep-Horizon well in the U.S. Gulf.

“The company said that the operation, which will pump heavy mud down the wellbore in an attempt to gain control of the oil flow and ultimately kill the well, began at 1 pm CST,” Upstream reported.

The article continued: “Earlier BP chief Tony Hayward gave the top-kill procedure a 60 percent to 70 percent chance of success.”

Physicists watching the situation with interest, were skeptical. One of them, Jonathan Katz, PhD, professor of physics at Washington University in St. Louis, had earlier suggested a simple fix, a change to the mud recipe, that might have altered the odds.

His plan was not adopted and the top kill failed.

After the attempted top kill failed, Katz and colleagues at Lawrence Livermore National Laboratory ran experiments with a scale model of the oil well to test his idea.

Their analysis, in press at Physical Review Letters, a peer-reviewed scientific journal that focuses on the rapid dissemination of significant, or notable, results, shows that had Katz’s recipe been followed, the top kill might have worked, plugging the gushing well in May en instead of two months later.

Making waves

When the top kill was proposed, Katz was serving on the science panel Secretary of Energy Steven Chu had organized to advise the Obama administration about the oil well disaster. Katz and Richard Garwin, an eminent physicist who was also a panelist, discussed the kill plan and realized they had misgivings.

“We were worried that a phenomenon known as a Kelvin-Helmholtz instability would disperse the dense mud into tiny droplets that would be carried out of the well by the leaking crude oil,” says Katz.

A Kelvin-Helmholtz instability can occur whenever two fluids move past

one another at different speeds. When wind blows over water, for example, the instability manifests itself in the form of waves that rise gently and then curl into chaotic turbulence.

The oil platform drilling the Macondo well, the Deepwater Horizon, exploded and burned on April 20, 2010. The explosion killed 11 men and injured 17 others. As the world watched in stunned disbelief, the crippled well continued to spew oil for the next three months, until it was capped on July 15. It wasn't declared "effectively dead," however, until early in September.

The two physicists made some calculations that showed the interface between the descending kill mud and the ascending crude oil would be similarly unstable.

Katz then realized that a novel mud might suppress the instability. Something had to be added to the mud that would change its dynamic properties.

Ketchup vs. Quicksand

To work for the top kill, the mud would need to behave less like ketchup

and more like quicksand.

Ketchup is what is known as a shear-thinning fluid. Initially it resists flowing. It begins to flow only when the pressure of your fingers on the bottle produces a stress on the condiment that is greater than what is called the yield stress. But after that, it flows freely.

Or as they used to say in the ketchup commercial “Anticipation is making me wait.”

Other examples of shear-thinning fluids are toothpaste, mayonnaise, mustard, and –crucially-- drilling mud, which is typically a slurry, or watery mixture, of clay and other minerals.

To suppress instability the mud needed to be a shear-thickening rather than a shear-thinning fluid--like the quicksand. As every reader of the Worst Case Scenario Survival Handbook knows, when you fall into quicksand, it is important to move slowly. The faster you move, the more the quicksand resists your movement.

The additive Katz suggested wasn’t esoteric or expensive. It was the kitchen staple cornstarch.

If you mix cornstarch and water, pour it in a cookie pan and slap it with your open hand, it doesn’t spatter. You can let your hand sink into it but you can’t easily jerk it out. Children play with it, and recipes for cornstarch "oobleck" can be found on the web.

“It can flow slowly as a liquid, but turns stiff and elastic when flow is rapid,” Katz says. “If an instability were to occur, this stiffness would suppress it, and the novel mud would sink in the well, accumulating at the bottom until its pressure became sufficient to stop the leak.”

A foregone conclusion

But the oil industry is conservative and BP stuck with variations on methods that had worked in the past even though Katz and Garwin predicted falure.

In late May, crews pumped more than 30,000 barrels of heavy mud down the well in a top kill attempt. As the physicists had feared, the well spat out the mud and crude oil like a toddler spewing strained peas.

The leak was not stopped until mid-July when the well was finally capped.

Afterward Katz couldn't help but wonder whether his suggestion would have worked. Together with collaborators at the Lawrence Livermore National Laboratory, he constructed a model oil well consisting of a six-foot length of transparent plastic tube filled with a clear oil.

"We poured cornstarch 'mud' into the top of the oil column and observed that, as predicted, the instability was suppressed. The surrogate "mud" sank rapidly through the oil to the bottom of the tube," Katz says.

Based on this experiment, the addition of a shear-thickening polymer like cornstarch to a dense top-kill mud might have allowed slugs of mud to descend against the upwelling oil instead of being ripped up and spat out of the well. Eventually, the column of mud would have prevented any further infiltration from the oil reservoir, killing the well.

Katz hopes there will never be an opportunity to repeat the experiment at full scale and under field conditionsm but recommends the Boy Scout motto 'Be prepared.'

Provided by Washington University in St. Louis