Energy Costs in Drilling

Posted by Heading Out on August 16, 2009 - 10:57am
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Tags: drilling, energy cost, geothermal, google, granite, hydrothermal spallation, potter drilling, tech talk, waterjets [list all tags]

Just as the thread on post on Drilling was winding down two weeks ago, horizonstar posted a comment about the tools that Potter Drilling is developing for geothermal drilling, with $4 million worth of help from Google. The comment takes you to a Grist post, from which I am now going to pinch the top illustration.

Hole in granite drilled by Potter Drilling using hydrothermal spallation. Note the fine nature of the pile of material removed.

Now (if you will forgive the vanity) I will add a picture from my doctorate, and an experiment that I carried out in 1967.

Hole drilled through an 8-inch thick granite block using a 9,500 psi water jet. (Figure 7.13 in Waterjetting Technology)

Now if you look at the two holes you might think that the top hole is the better, and more efficiently drilled. This post is going to try and explain why in fact it is the bottom hole that is better.

It will become one of two posts that I plan on writing on the relative performance of different tools in drilling, including ideas such as lasers, electron beams and the infamous REAM. There is a video of the two stages of the development of the Potter drill in an article in Popular Science from a couple of months back that is worth watching, since it explains their idea.

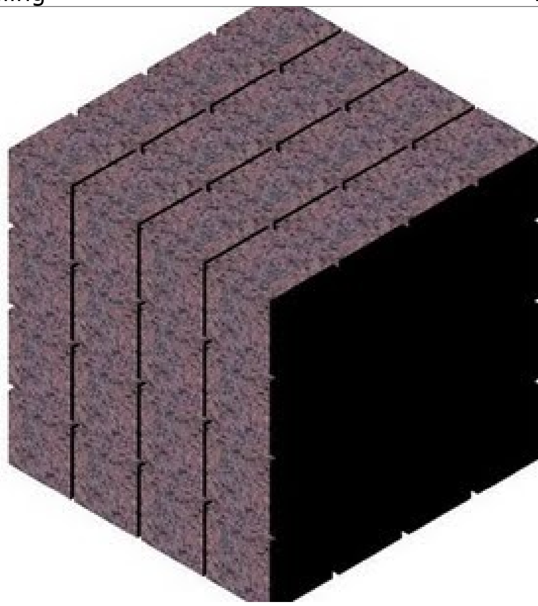
So why isn't their approach a good one – well there are a couple of reasons, let's start with the basic idea of breaking rock. Way back when the world used a lot of coal men still mined it using a pick and a shovel. In using the pick the miner would attack cracks in the surface of the coal and grow the crack so that he could wedge out larger lumps of coal, rather than picking out the coal in small pieces. If he did it effectively he would use something on the order of 4 joules of energy to mine each cubic cm of coal he mined (4 j/cc).

If you are breaking out rock from the solid the amount of energy you need depends on the surface area of the rock that you have to form to break the rock out. Assume that it takes 1 unit of energy to hold the molecules across a sq. cm of rock together. If I want to split the rock through that cm of contact I am going to have to break all those connections and (if the process is 100% efficient) this will take just slightly more than that unit of energy to make the break. Now here is the important bit:

Granite split into two 50-cm x 1 m x 1 m pieces

If I take a cubic block of rock that is say 1 meter in size, and split it down the middle I will cut through 1 sq m of rock over the fracture that I create. So with that same amount of energy holding the rock together (which we call surface energy) it will take 100 x 100 = 10,000 units of energy to make that one crack.

Now if, instead of breaking that rock into just two bits I broke it into a sixty-four, by making three cuts vertically parallel to the front, three cuts vertically perpendicular to the front and three cuts horizontally, then I would have split the rock into 64 pieces each 25 cm on a side, but it would have taken 9 cuts of a sq m each, and required an input of 90,000 units of energy to break the rock into the smaller sizes.



Block broken into sixty-four pieces with nine meter-square cuts.

Thus the smaller the size the pieces are broken into then the more energy that you have to put into breaking the rock to make those smaller pieces. Consider that if you are breaking the rock into a fine powder (as the pieces are with the hole drilled at the top) then if those particles are 0.25 mm on a side then the energy input becomes that much greater (4,000 cuts along each direction – 12,000 cuts amount to a total of 12,000 times the energy needed if we just broke the rock out in two big bits).

So breaking the rock out in bigger bits is better – but how can we do this with fluids. Well, this is the difference between the thermal process and a water-jet based process. With the thermal process what you generally rely on for the fracture in granite is a phase change in the quartz element of the rock that occurs at about 1300 deg C. This causes the rock to spall and has been used in the granite industry for initial channeling around the blocks to be quarried. (It is very noisy and fairly slow – around 14 sq ft/hour of production). The particles produced are very fine, and the energy required is around 12,000 joules/cc.

Water cuts into the granite in a different way, first penetrating into the cracks between the different grains of the rock , and then as that water wedge is pressurized by the following jet, forced deeper into the crack, growing it and breaking the individual rock grains away from the surface. These grains are much bigger (so the hole wall that you can see in the second picture is rougher), so the energy required to drill can be down in the hundreds of joules/cc instead of thousands.

The other advantage that waterjets have (if configured with sand in the water) is that they can drill through any rock the drill comes up against. That is not the case with the thermal lance, since some rocks just melt into globby messes when heated, and that has to be pushed away (ask the folks at Los Alamos about the nuclear powered thermal drill that they invented one time – they showed how to do that). And the question is pushed to where when you are drilling holes thousands of meters deep.

And just to respond to the point about pipe-dreams that was mentioned about these ideas being impractical – Gulf actually drilled to about 5,000 m deep with an abrasive waterjet drill about 1970. So these ideas do have some practicality. But I'll return to that aspect in my next post.

Oh, and just to show that you can break out meter sized blocks - this was from when we were excavating the rock under the Arch in St Louis to put in the OmniMax Theater.

Breaking out thousand-pound blocks of rock while excavating the Omnimax Theater under the Arch in St. Louis