Why 100 Mesh in Unconventionals:

Thoughts on the Increased Use of 100 Mesh Proppant in Unconventional Plays

Introduction

It is axiomatic that hydraulic fracturing (HF) is about increasing surface area; that is, the creation of, or access to, surface area for hydrocarbons to flow from a zone of lower permeability to one of a higher permeability. This means that: 1) the goal is create or access surface area in formations with hydrocarbons (i.e., the reservoir) and limit the creation (and cost) of surface area in non-reservoir formations; and 2) provide sufficient permeability (conductivity) so that hydrocarbon flow across the created and accessed surface area is enhanced, which ultimately increases well production. Perhaps more succinctly, we frac to provide a high conductivity pathway that makes it much easier for a hydrocarbon molecule, some far distance from the wellbore, to reach the wellbore and be produced.

We often use the roadway system around a big city as an analogy for hydraulic fracturing. In the horse-and-buggy age, folks rarely went to the city even when they lived just five or 10 miles away because the journey to the city was so difficult and time consuming (perhaps two to four hours…). This is analogous to hydrocarbon flow to a wellbore in low permeability formations. In contrast, folks routinely live 40 or 50 or more miles away from a city today, yet commute to work in the city every day. This is possible not just because the horse and buggy has been replaced by the automobile (though this is a component) but because city planners have constructed large, multi-lane, high-speed highways that are able to efficiently (ok, not always!) move people from somewhere out in the suburbs to the city. These multi-lane, high-speed highways have the capacity (think conductivity…) to handle large volumes of automobiles and still move them quickly into the city. Like a high-conductivity hydraulic fracture that reaches way out into the reservoir, the multi-lane, high-speed highway reaches out to the suburbs to make it both easier and more efficient for folks to reach downtown. And just like a hydraulic fracture, the farther out the highway reaches, the more folks can work downtown (i.e., increased drainage area), and there is a point where more lanes of traffic do not increase the number of workers downtown because those folks don't exist (i.e., infinite conductivity is achieved relative to the amount of folks wanting to get to downtown).

So hydraulic fracturing design consists of two important components: 1) creation of the hydraulic fracture in the reservoir (i.e., the creation or access to surface area); and 2) propping open the HF in order for it to be far more conductive than the reservoir itself (because, if it were not, there would be no increase in production regardless of the surface area created!). Why the importance of propping open the HF? Because without the proppant, the HF will close during production (as the pressure in the HF is reduced) and potentially lose nearly 100% of its conductivity – essentially returning the reservoir to pre-frac flow conditions.

Hydraulic Fracturing in Unconventionals

In Unconventionals, which tend to have ultra-low permeability, hydraulic fractures are necessary to make economic wells. Unlike in a high-permeability reservoir, even if the near-wellbore region was not damaged from drilling fluids the surface area to flow in a horizontal in an Unconventional reservoir would not provide economic production. Many Unconventionals are also naturally fractured (or have planes of weakness or bedding planes), which may provide 'free' surface area for flow, if they can be connected to the wellbore with an HF. As such, a fundamental frac design question for Unconventionals becomes "Do I want to create all my surface area via a hydraulic fracture or do I want to use the hydraulic fracture to connect to natural fractures (or weakness planes), which will provide the needed surface area?".

The concept of connecting to, and stimulating, natural fractures and/or weakness planes was given the term "Shear Stimulation" (largely after Warpinski from his papers in the late 1980s and early 1990s), wherein a hydraulic fracture caused nearby natural fractures and weakness planes to slip in shear and ride up on surface asperities (both generating microseismic energy and increasing the aperture and effective permeability of the natural fracture system). The primary field evidence for Shear Stimulation became the pattern of the recorded microseismic events (recall that microseismicity is the acoustic representation of rock failure). When the pattern was linear (or planar in 3D), this was taken to represent solely the creation of a hydraulic fracture. When the microseismic pattern was more symmetric, this was taken as proof of Shear Stimulation of natural fractures and weakness planes, and the greater the symmetry of the pattern of MS events, the greater the "complexity" of the stimulated area around the hydraulic fracture. Furthermore, this led to the common perception (now disproven in many Unconventional Plays) that increasing complexity was, *a priori*, proof of a better stimulation and would lead to better production from the hydraulic fracturing stage.

Besides the significant impact of natural fractures on hydraulic fracturing operations for Unconventionals, at least two other significant differences have arisen between HF operations in conventional and Unconventional plays. The first of these differences has been the switch from high-viscosity, crosslinked frac fluids to low-viscosity "slickwater" frac fluids ("slickwater" has a viscosity in the two to five centipoise range, and the name is derived from the addition of a small amount of polymer that delays the transition into turbulent flow – and associated higher friction losses – when the fluid is pumped). This transition in frac fluids was driven by the desire to limit the loss of proppant conductivity due to gel damage in association with the belief that only a low proppant conductivity was needed to achieve infinite conductivity conditions because of the low formation permeability. However, slickwater, because of its low viscosity, does not provide good proppant transport. Consequently, the second significant difference from conventional hydraulic fracturing was the trend in Unconventionals hydraulic fracturing towards increased pump rates (as high as 120 bpm or higher) to improve proppant transport. Later, as it was confirmed that even these high pump rates did not provide good proppant transport inside the hydraulic fracture itself, a misperception arose that high pump rates increased the "complexity" of the stimulation (which led many presenters to mistakenly use an image of shattered glass as the analogy to hydraulic fracturing in Unconventionals). Note that, quite critically, high pump rates are also used to provide near-wellbore flow diversion when multiple clusters are used in a single frac stage.

Stimulation Challenges in Unconventionals

So what does all this have to do with the use of 100 mesh? The answer to that involves: 1) natural fractures; 2) what fracture conductivity is really needed to achieve infinite (or near-infinite) conductivity conditions; 3) the need to prop open a fracture to maintain its conductivity during production; and 4) proppant transport.

Hydraulic fracturing is, largely, a material balance process. The volume of fluid (both with and without proppant) pumped into a well must go somewhere – either into a created hydraulic fracture or into leakoff into the formation. The greater the leakoff volume, the less fluid available to create the hydraulic fracture or keep it open to place proppant. Historically, in naturally fractured reservoirs, 100 mesh proppant was added as leakoff control. That is, as the leakoff into natural fractures became severe enough to prevent hydraulic fracture growth and/or proppant placement (giving rise to the concept of "screenout" wherein the HF was not open enough to accept proppant), 100 mesh was pumped to plug off, and prevent flow into, natural fractures. Obviously for this to work in practice, the aperture of the natural fractures had to be close in size to the diameter of the 100 mesh proppant.

Proppant conductivity is strongly a function of stress on the proppant, the strength of the proppant, and the diameter of the proppant. The big debate between using sand as proppant in Unconventionals versus man-made proppant comes down to the conductivity dependency on stress and how much conductivity is needed to achieve near-infinite conductivity conditions. Unquestionably, man-made proppant can handle higher stress while providing good proppant pack conductivity, but does the cost for that additional conductivity show up as increased production? 100 mesh sand is going to be more stress-sensitive and provide a lower level of conductivity because of its size; however, not only is the price very competitive, but its small size might have other benefits.

As fracture aperture increases with net pressure in the fracture (where net pressure is the pressure minus the normal stress to the fracture – often Shmin) during stimulation, it is obvious that fracture aperture (both the hydraulic fracture and natural fractures) will reduce during production (as pressure in the fracture declines). In the hydraulic fracture, proppant is pump to keep the fracture open (i.e., conductive) during production. In the early conceptual model(s) for Shear Stimulation in Unconventionals, slippage along the natural fractures and weakness planes (as evidenced by the microseismic data) led to a miss-matched fracture surfaces where peaks (asperities) on each side of the fracture were in contact and kept the fracture open. However, there is now ample field data that natural fractures close during production. Many operators report declining drainage areas with production. Equally important, there are now ample cases of well-to-well communication during a hydraulic fracture treatment that does not appear on later production or well test data. Clearly then, some of the natural fractures close during production. One way to combat this would be to get proppant into the natural fractures.

As we have shown in our work (e.g., Nagel et al., 2013, Rock Mechanics and Rock Engineering), many hydraulic fractures in Unconventionals do not conform to the conceptual model of having an elliptical cross-sectional profile. Rather, aperture along the HF is highly variable and, in fact, can be larger away from the wellbore as opposed to always being a maximum at the wellbore (as in the conceptual, elliptical model). Recall also that with the typical application of slickwater fluids in Unconventionals, proppant tends to build dunes at the bottom of the fracture, in a process called saltation, rather than remain suspended with the frac fluid. This, coupled with the complex aperture variations along hydraulic fractures in Unconventionals (driven by the interaction with the natural fractures and weakness planes), means that proppant transport is a significant challenge.

On 100 Mesh in Unconventionals

So how does 100 mesh possibly fit in? 100 mesh sand potentially offers:

- A low cost (potentially the lowest cost) option for proppant that is believed to provide the necessary conductivity;
- A size that is most likely to navigate the variable aperture along the hydraulic fracture;
- A size that is most likely to be able to enter and prop open a natural fracture; and
- A size/density that is reasonably favorable for proppant transport.

In simplest terms, 100 mesh is the most likely proppant candidate to be transported out into the hydraulic fracture and prop open natural fractures. The key being to prop open the natural fractures and retain their production contribution during pressure depletion.

Can it be that simple? And if so, why isn't everyone using 100 mesh and why did the emphasis on 100 mesh not happen sooner?

Is it that simple? Perhaps. Recall that 100 mesh was historically pumped as leakoff control. Why did 100 mesh plug natural fractures then and now it can prop them open? First, 100 mesh was not always effective at leakoff control. There are many cases where it had no impact, regardless of the quantity pumped. In addition, natural fracture aperture is not a set value but rather varies as a function of rock type and reservoir environment (e.g., stress and pressure). Equally important, natural fracture aperture during a stimulation, like the hydraulic fracture itself, is a function of net pressure – and net pressures in many Unconventionals are significantly higher than their conventional counterparts. Consequently, the conditions in many Unconventionals are potentially favorable to getting 100 mesh into natural fractures rather than bridging and plugging the natural fractures. However, it also possible that 100 mesh is plugging off natural fractures in some cases, which diverts the frac fluid into creating greater hydraulic fracture dimensions and potentially greater surface area for production.

Like many trends in the oil and gas business, the increased usage in 100 mesh is driven by a number of factors and perceptions. As these factors change, or the perceptions are replaced by hard data, the trend may accelerate or stop entirely. Our belief is that there are solid reasons (at least in the near-term) to expect the trend towards increased 100 mesh usage to continue.