SHALE GAS: ANY ALTERNATIVES TO HYDRAULIC FRACTURING?

In the United States and in Europe, hydraulic fracturing is one of the most controverted aspects of the shale gas debate. The dialogue of the deaf around the impacts on the environment generates many overstatements from both camps. The arguments put forward by the two sides deserve attention, but one would be wrong to stay stuck there: research is already in motion and new techniques are emerging.

Hydraulic fracturing is used for the production of hydrocarbons but also for deep geothermal exploration. It was implemented for the first time in 1947 in Kansas. Two years later, the first commercial fracturing treatments were conducted in oil wells in Oklahoma; but it is only with the massive exploitation of shale gas, during the last decade, that the process has become extremely widespread. In 2008, over 50,000 well fractures were carried out around the world and it is estimated that over one of two wells drilled today undergoes a fracturing treatment.

The hydraulic fracturing technique

Hydraulic fracturing is the injection under high-pressure of a fluid in a wellbore, at a specified depth. When the pressure applied by the fluid compensates the lithostatic gradient (weight of the rock above the place where the pressure is applied) and the local resistance of the rock, a fracture is created that can extend over several hundreds of meters, provided that enough fluid is injected to keep sufficient pressure in order to sustain the load. During the process, a proppant (generally grains of sand or ceramic) is injected to prevent the crack from closing. Drilling water contains additives suited to the type of rock encountered, to facilitate the fracturing operation and to retain the created cracks. These cracks act as drains, granting access to volumes of rock located far from the wellbore, but close enough to the created drain.

Hydraulic fracturing has first been applied to conventional geological reservoirs. However its use in low permeability fields called Tight Gas Reservoirs (TGR, thousand times less permeable than conventional reservoirs) has faced real problems. TGRs contain gas which offers a very limited recovery rate when using conventional methods: from 3 to 10% of the hydrocarbons. Hydraulic fracturing can increase this performance. The extracted gas originates from a volume of rock near the surface of the crack, through which the gas will migrate due to the difference of pressure. Gas production consists in draining this zone where permeability is low.

This technique reaches its own limits: the performance is increased, but once the drainage is carried out, the production undergoes a very rapid decline. The gas trapped between the drained areas remains inaccessible.

Shale formations combine two difficulties: the low permeability of the rock (i.e. its permeability is insufficient to allow significant fluid flow) and a natural heterogeneity of the environment.

Natural cracks, artificial cracks
Shale is a clastic sedimentary rock that has been strengthened during the geological evolution of the Earth's crust. The organic materials that it contained originally transformed into kerogen, a source of hydrocarbons – in our case, of "thermogenic" methane (generated by an increase of temperature and pressure). Accumulated by sedimentation, shales have a structure similar to that of a slate (they are called anisotropic). The gas is stored between the slices. Thus, shales are both the bedrock and the reservoir from which the gas is extracted.

During their geological evolution, these rocks undergo what one could call "natural" fractures. Indeed, shale formations are even less homogeneous than TGRs or conventional reservoirs. Their physical properties, e.g. their permeability, depend on stratigraphy and they contain cracks at multiple scales: at the scale of a layer – or microscopic scale – but also over several tens of meters – the macroscopic scale. At the macroscopic level, it is quite common to observe crack planes (e.g. perpendicular to the layers) with a fairly regular spacing of a few meters. These faults can be as large as several tens of meters.

The purpose of the hydraulic fracturing is not only to create a macro-fracture (a drain), it is also to connect and reactivate the initial cracks at all scales in order to pull out the gas. Thus, the interactions between the cracks created by hydraulic fracturing and this network of cracks must also be taken into account. The created crack will be much more permeable than the secondary network. The fluid under pressure will have problems to penetrate this existing network. Pressure will not always be important enough to reactivate it.

The questions raised by hydraulic fracturing concern primarily two aspects. First, the rise of methane to the ground surface or to water tables has fueled public debate, but the extent of the phenomenon is still being discussed. It seems, for example, that the famous movie Gasland confused biogenic methane, found at the surface, with thermogenic methane formed in the depths of the ground. In any case, the question arises especially at the level of wells and drill pipes.

The second aspect requires more attention: the water used during the fracturing process contains chemical additives that could contaminate water tables. Beyond the debate between opponents and defenders of shale gas extraction, who tend to exaggerate or minimize risks, there is a public health issue that cannot be overlooked or denied. Under these circumstances and while waiting for the necessary feedback from experience, the alternatives to hydraulic fracturing must be carefully examined.

Changing the fluid?

A first option is to change the fracturing fluid. The penetration of the fracturing fluid within the network of existing cracks depends directly on its viscosity. One can easily imagine that by reducing this parameter, fluids will penetrate more easily in the existing cracks and apply enough pressure to reactivate them. This principle being assumed, the problem comes to finding the "right" fluid. There are many candidates: propane, nitrogen, carbon dioxide… In its liquid state, CO_2 has a viscosity ten times lower than water; in supercritical state (normal conditions of deposit), its viscosity is even lower. Beyond a decrease of viscosity, the interaction with rock is also important. If the fluid adheres (adsorption) on the rock, preferentially to the methane, it will improve the extraction of the gas present at the surface of the rock in the secondary network.

Each solution has benefits, beyond the simple fact that the fracturing fluid is no longer water and that strictly speaking, one can no longer speak of "hydraulic fracturing". Nitrogen is not harmful for the environment, and using carbon dioxide can help store it at the same time.

There are also disadvantages and difficulties: replacement fluids are more compressible than water, which makes the process less efficient; CO_2 can recombine with water and form a corrosive acid that will affect the surrounding carbonate rocks. It can also provoke a swelling of the rock and decrease its permeability. It is not clear that the secondary network will not close itself, once the fracturing fluid is evacuated. The retaining of this secondary network remains an unresolved issue.

Electric fracturing

The second approach is dynamic loading. In statics, the surface of crack created in a material is proportional to the energy transferred to the volume of material that will break. Dynamic loading brings a large amount of energy to a small volume of material. In this volume, there is such an amount of energy, that a large area of cracks will be created. As the loading wave spreads inside the material, it will create fragmentations, thereby connecting the initial and newly created network of cracks.

Dynamic loading can be induced for example by explosives placed at the bottom of wells or by electrical impulses, an original technique inspired by tunnel drilling methods. The load applied to the rock in the proximity of the drilling site is a pressure wave generated by an electrical discharge between two electrodes placed in a wellbore filled with water. The amplitude of this wave of pressure can reach up to 200 MPa (2000 times the atmospheric pressure) while its duration is around a hundred of microseconds. This pressure wave will be transmitted to the rock by the fluid inside the wellbore, and will create micro-cracks of decreasing density, according to the distance from the well. Models indicate rock permeability increases only up to several meters from the wellbore.

Electric pulse fracturing could facilitate the reactivation of existing cracks by focusing more easily on the concerned rock volumes and avoiding important needs for water. However, the relevance of this process remains to be seen.

What are the prospects for research?

The two approaches that we have just mentioned are considered to have a moderate environmental impact: water needs and used water reprocessing are much more limited. Regarding the additives contained in the water used during fracturing, it is very likely that in a near future, chemistry science will offer substitutes, as in the case of Guar gum, used as a gelling agent for fracturing fluids and also used in the agri-food field. Dynamic fracturing can also help confine the volume of rock cracked, thus reducing the risk of accidental connection between the network of cracks and its surrounding area.

However, these techniques do not prevent possible gas leaks or contamination of subsurface aquifers related to leaks in the wellbore. These two issues depend on a good control of the conditions of implementation of the wellbore (good quality casing and sealing) and of the extraction process, even regarding conventional resources in non-fractured wells. In this area also, research is very active.

Are we going to achieve environmentally acceptable production processes that are economically viable? This prospect is neither science fiction nor a long-term possibility.

Scientific literature grows month after month with new results from Japanese, American, Chinese and European laboratories.

The use of supercritical CO2 for heavy oil recovery is already a reality; there are nearly a hundred of pilot projects only in the United States. Its extension to shale gas or even coal gas could be a realistic line of research (there are several pilot projects of coal gas extraction based on this principle).

The use of fragmentation by electrical pulse is the subject of several international patents and has whetted the interests of oil companies.

There are also other alternatives: for instance, the heating of the rock mass (as for shale oils) or the effects of bacterial flora in the bottom of the well.

To this already extensive literature, one must add all the work aiming at a better understanding and optimization of hydraulic fracturing while reducing its environmental impact, specifically its water consumption and reprocessing.

In every country possessing shale gas, there is a great temptation to reproduce the shale gas revolution experienced by the United States. Europe possesses this unconventional type of resource, especially France and Poland. However, there is a consensus to admit that the production means, as well as the legal and socio-economic conditions, are so drastically different in Europe that the old continent will not experience the same boom before 5 to 10 years. This period of time should be used to optimize the fracturing processes and develop new alternative techniques. In fact, this is quite timely because everyone agrees to say that no alternative technique will be viable from an industrial point of view before five years at least.

The two approaches discussed in this article require lab studies, but also and above all, the implementation of on-site validation procedures, the creation of underground laboratories equivalent to those of nuclear energy field in France and Switzerland. This would imply drilling in perfectly known rock formations to lead full-scale experiments with enhanced instruments and total transparency in terms of environmental impact. It is important indeed to have testing facilities beyond the laboratory as well as pre-industrial pilots that will define a stage of evaluation and industrial feasibility that digital simulation alone cannot achieve. At this stage and given the need to deploy such considerable means, only a national or European initiative involving public and private actors will be able to create an infrastructure of research at the level of the challenge.

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