Hydraulic Fracturing Applied to Stimulation of Gas Drainage From Coal

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INTRODUCTION

Hydraulic fracturing is routinely applied to stimulation of oil, gas, and coalbed methane wells around the world. The stimulation effect is achieved in coal seams as in other reservoirs, by producing a conductive fracture, connecting the well to the coal reservoir. The conductivity of the fracture is usually maintained by placing a round and sieved sand proppant in the fracture channel. The proppant prevents the fracture faces from closing back completely on one another after the treatment. The design of the fracture treatment, therefore, centers on selecting fluids, injection rates, and slurry concentrations that will produce the desired propped fracture channel.

HYDRAULIC FRACTURE GROWTH IN COAL

A hydraulic fracture is produced by first isolating a section of the wellbore using either perforations through selected intervals of the well casing or some sort of packers. The fracturing fluid is then pumped through an injection string into the isolated section, causing the pressure to increase until a fracture opens at the borehole wall. Continued pumping then forces fluid into the fracture, which pressurizes it, causing it to open and extend deeper into the coal. Initially the fracture grows quite quickly, but as the treatment continues, more and more of the fluid injected at the wellbore is lost from the hydraulic fracture into the surrounding coal. This fluid loss is one of the most important processes that controls how fast and how far the fracture will grow. The amount of fluid that leaks off can be controlled, in part, by selecting different fracturing fluid, water, gel, or foam and by varying the injection rate. Because coal permeability is stress dependent, the leakoff process in coal is non-linear. As fluid is lost from the hydraulic fracture, the pore pressure in the coal around the fracture increases, which results in an increase in the permeability of this coal, contributing to additional leakoff.

Non-linear leakoff arises because of the naturally fractured nature of the coal seam. A second important aspect of hydraulic fracture growth in coal also results from the natural fractures in the coal. As the hydraulic fracture grows though a naturally fractured rock, it propagates along and across the natural fractures. The hydraulic fracture channel formed then develops branches and offsets along its extent. This complex hydraulic fracture geometry in coal has been documented by mining and mapping the propped fracture formed by the treatments (e.g. Figure 1). T-shaped branched fracture geometries, which often form at material property boundaries, are also commonly produced, but not often designed for.

In contrast to the multiple branched fracture shown in Figure 1, hydraulic fractures that are relatively planar may form, as shown in Photo 1. The nature of the fracture formed by a treatment is strongly dependent on properties of the coal seam being treated such as the existence of natural fractures, faults and shears, and the in-situ stress conditions. Fracture geometry near the borehole or well will depend on the orientation of the borehole with respect to the natural fractures and the in-situ far field stress. Use of thicker, more viscous fluids, such as crosslinked gels and foams, are believed to reduce the amount of fracture complexity compared to using less viscous fluids like water. However, coal is chemically active and exposure to organic polymers in gels may cause damage to the coal permeability. Correctly formulated and tested fracturing fluids and fluid breaker systems are required to avoid damage to permeability and fracture conductivity.

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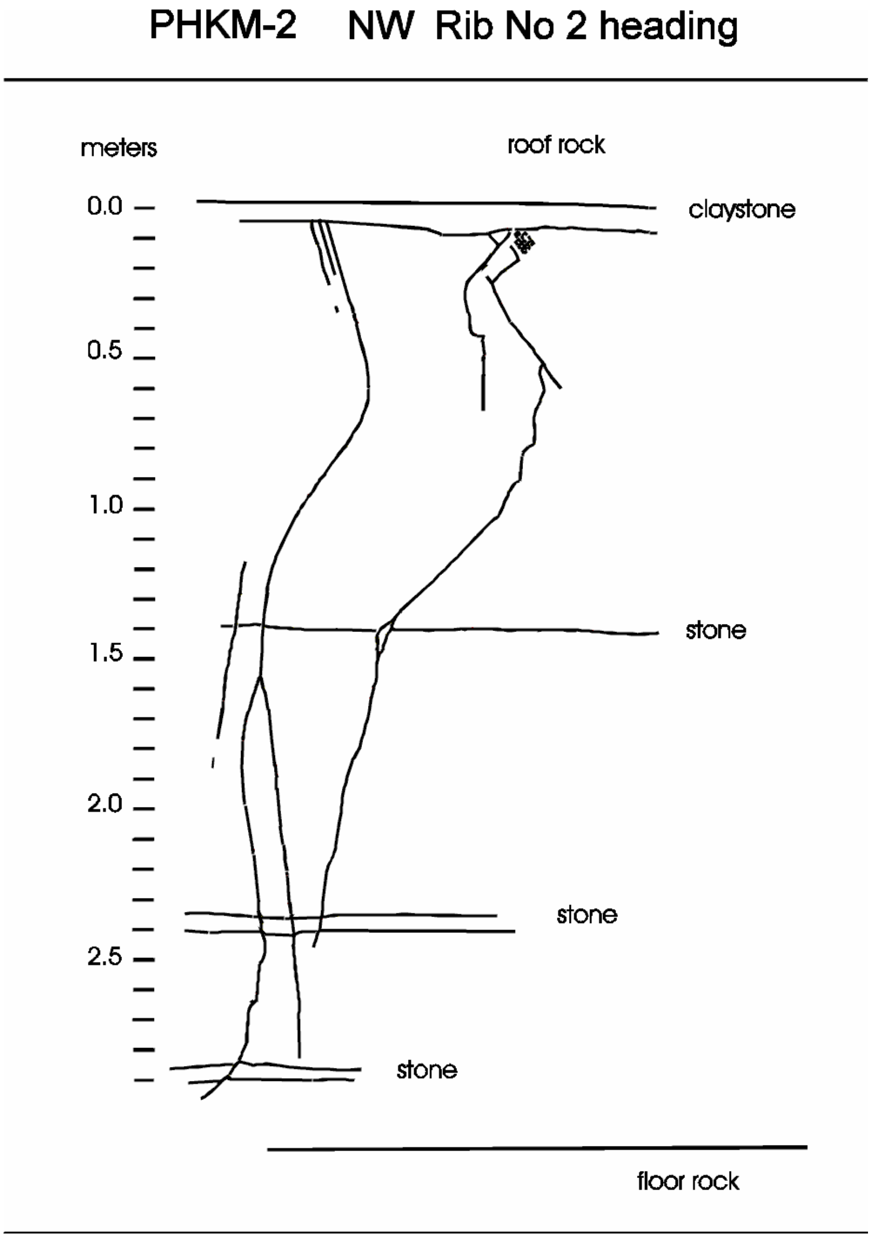

Fig. 1: Vertical section through a propped hydraulic fracture in the Great Northern seam at Munmorah Colliery, NSW.

HYDRAULIC FRACTURE STIMULATION

Smith and Shlyapobersky (2000) list three reasons for carrying out hydraulic fracture stimulations:

1. to bypass near-wellbore damage,
2. to form a conductive channel in the reservoir,
3. to change the fluid flow path in the reservoir.

Near-wellbore damage is caused by a number of factors, which include stress concentrations around the well and drilling induced damage such as cuttings and drilling fluids plugging the permeability pathways around the borehole. In addition, the permeability of the coal may be damaged during production if fines migrate in the seam or if precipitants form near the borehole because of pressure and associated water chemistry changes. This damage is characterised by what is called the wellbore skin effect and is one of the parameters measured by injection or production well testing.

Photo 1 A hydraulic fracture propped with white sand in the roof coal at Dartbrook Coal Mine, NSW.

By placing sufficient proppant in a hydraulic fracture that extends a sufficient distance, a conductive channel is formed in the coal seam that acts as a conduit for the water and gas to travel along. The fracture faces expose a large area of the seam to the lower producing pressure, allowing the water and gas to drain directly into the propped fracture at an accelerated rate. Hydraulic fracture treatments are designed to place a propped conductive fracture in the coal seam that will efficiently stimulate production from the seam. The stimulation effect achieved depends both on the conductivity and size in length and height of the fracture and on the permeability and thickness of the coal seam. Effective stimulation of a low-permeability seam requires longer moderate conductivity hydraulic fractures, while stimulation of a high-permeability seam requires shorter high-conductivity fractures.

The fractures which are formed drain fluid and reduce the pressure in the seam around them. Fewer wells or boreholes are then required to drain the seam or, alternatively, the seam can be drained more quickly using the same number of holes. In addition, fractures placed in horizontal holes serve to connect the borehole with over and underlying coal by forming conductive channels through stone or dull unfractured coal layers.

FRACTURING VERTICAL WELLS FOR COAL SEAM GAS DRAINAGE

Vertical wells drilled in advance of mining to drain seam gas require stimulation to accelerate the drainage process and to allow fewer wells to effectively drain the area targeted. A typical distance between wells might be 200 to 400 m. Hydraulically fractured wells at this spacing might require five years or more to drain 50 percent of the gas in place. Closer spaced wells drain the gas more quickly, but the total costs of drilling, completion and operating rapidly increase. Therefore, using vertical wells to drain gas before mining requires significant lead-time and upfront investment. There is good scope for mines to partner with a coal seam methane producer to reduce the cost to the mine significantly. Hydraulic fracturing is routinely used to stimulate coal seam methane wells and experience here and in the U.S. indicates that the effect of the hydraulic fracture on eventual mining of the seam is negligible (Jeffrey et al., 1997, Jeffrey et al., 1998, Diamond and Oyler, 1987).

FRACTURING HORIZONTAL DRAIN HOLES

Horizontal wells are drilled and hydraulically fractured in oil and gas reservoirs. The fracture treatments are undertaken to stimulate production and connect the horizontal well into layered reservoir formation. The horizontal layering in the reservoir invariably imparts a permeability anisotropy to the rock. The vertical permeability is typically significantly lower than the horizontal permeability. In addition, hydraulic fractures bypass the near wellbore damage zone, which can be a significant factor in reducing the productivity of any horizontal well or drainage borehole.

Hydraulic fractures can be placed in horizontal drain holes by running inflatable straddle packers on an injection string. Fluid bypass or even fracturing of the coal under the packers may occur (Jeffrey, 1999). Several trials of placing hydraulic fractures in coal seams have been carried out (Croft, 1980, Kravits, 1993, Jeffrey, 1999) with some success reported by Kravits. Special pumps and blenders are needed if sand is included in the treatment, but some stimulation effect can be achieved using only water. If proppant is pumped, the treatments must be large enough to extend and open a fracture to a width sufficient to accept the sand before the slurry stage is pumped. The benefit of including sand is in the larger stimulation effect or higher conductivity that can be achieved and the potential to reduce the number of horizontal holes needed to drain a volume of coal. The potential for loosing the straddle packer system in the hole will vary with seam and borehole conditions, but can be a significant cost in some cases. Alternative methods of fracturing horizontal holes have been developed in the petroleum industry and might be adapted to fracturing horizontal drain holes in coal.

CONCLUSIONS

Hydraulic fracturing can be used ot place a high conductivity channel in the coal seam. The conductive channel stinulates gas and water drainage rates by bypassing near borehole damage and forming a low pressure drain in the coal. As a result, gas drainage rates are increased.

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