STRESS AND PERMEABILITY CHANGES WITH FLUID PRODUCTION - THE STRESS PATH

The effective stresses in a coal seam will change when fluid drainage occurs. Under the effects of drainage the effective vertical stress will increase by the change in fluid pressure as fluid is withdrawn, provided the surface is free to subside. This is occurs where drainage takes place over a wide area. The horizontal strains are held constant by the strata surrounding the coal seam. Horizontal stress changes in coal, where both a reducing fluid pressure and shrinkage via gas desorption occur (see *Shrinkage Behaviour*) are described in *Fluid Movement in Coal Seams* and in equations 1 and 2. These equations incorporate the elastic properties of Young's modulus and Poisson's Ratio which are likely to be non-linear in coals (see *Mechanical Properties*).

$$\Delta\sigma'_{h/1} = \Delta P\left(1 + \left(\frac{v}{1-v}\right)\right) - \frac{E}{1-v^2}\left(\Delta\varepsilon_{sh/1} + v\Delta\varepsilon_{sh/2}\right) \quad (1)$$

$$\Delta\sigma'_{h/2} = \Delta P\left(1 + \left(\frac{v}{1-v}\right)\right) - \frac{E}{1-v^2}\left(\Delta\varepsilon_{sh/2} + v\Delta\varepsilon_{sh/1}\right) \quad (2)$$

Where:

$\Delta\sigma'_{h/1}$ is the effective stress change in the horizontal plane in direction 1;

$\Delta\sigma'_{h/2}$ is the effective stress change in the horizontal plane in direction 2;

ΔP is the change in fluid pressure;

$\Delta\varepsilon_{sh/1}$ is the strain change due to shrinkage in the horizontal plane in direction 1;

$\Delta\varepsilon_{sh/2}$ is the strain change due to shrinkage in the horizontal plane in direction 2;

E is Young's modulus;

v is Poisson's ratio.

The importance of stress change is that it affects the permeability of the coal, as described by equation 3 (*Fluid Movement in Coal Seams*).

$$\log k = \log k_0 - 1/b \times (\text{effective stress}) \quad (3)$$

Where:

k is the absolute permeability in a direction within the coal;

k_0 is the permeability at zero effective stress;

b is the stress-perm coefficient.

www.sigra.com.au
Sigra Pty Ltd
93 Colebard St West, Acacia Ridge, QLD, Australia, 4110
+61 7 3216 6344 info@sigra.com.au

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If a coal seam has a high permeability the changes in permeability are unlikely to be significant because the stress-perm coefficient (*b*) is usually high. However in the case of low permeability coals it is of extreme importance to be able to determine whether the permeability will increase or decrease with drainage. This is the key to determining whether it is possible to extract gas from the seam for either commercial gas production, or to conduct seam drainage for mining purposes.

To determine how the horizontal effective stress in the coal is expected to change it is desirable to know initial values as coal is generally quite nonlinear in its mechanical properties and it is useful to calculate the mechanical properties of the coal at an appropriate stress level. Unfortunately precise measurement of the stresses in a seam is difficult because coal cannot be generally be overcored (*In-Situ Stress Meassurement Through Overcoring*) and hydrofracture generally only produces a stress level result across the lowest stressed cleat set (*Stress Measurement by Hydrofracture*). Therefore the approach generally taken is to use the tectonic strain values (*Stresses through Sedimetary Strata – Tectonic Strains*) calculated from stress measurements in the roof and floor rocks and apply them to the coal seam, using the appropriate values of Young's Modulus and Poisson's Ratio and thus generate the likely values of stress therein. If the opportunity presents itself the minor principal stress should be confirmed by hydrofracture, otherwise it is necessary to estimate the likely in seam stress and undertake a sensitivity analysis on how changing these values will affect stress change estimates.

With a knowledge of both the gas content of the coal (*Gas Content Measurement – Core Desorption, Chip Desorption* and *Gas Content Without Coring*) and a knowledge of the sorption isotherm (*Gas Storage*) it is possible to calculate the sorption pressure (bubble point)l. Field measurements of reservoir pressure are determined by DST (see *Drill Stem Tests*) or by permanent reservoir pressure measurement (see Reservoir Monitoring). These pressure measurements, along with a stress estimation, provide the starting points of the stress change calculation.

Until gas is desorbed from the coal the stress change in the coal may be calculated using equations 1 and 2, without the use of the shrinkage terms. Once gas is desorbed the values of shrinkage strain must be used. These may be arrived at by utilising measurements of coal shrinkage and gas pressure (*Shrinkage Behaviour*).

The calculation of stress change needs to be undertaken in a stepwise manner in order to deal with the effects of nonlinearity in both the shrinkage behaviour and in the mechanical properties of the coal.

A result of such a stress path calculation is shown in Figure 1. The two horizontal effective stresses increase with a drop in reservoir pressure from 2050 kPa to 1250 kPa. Below this pressure the effects of shrinkage are significant and the effective stress decreases are marked. As the coal in question has a very low permeability the implications of this are important. It is likely that drainage will be very slow until the reservoir pressure is dropped to 1250 kPa whereupon the process of drainage will speed markedly. Getting the coal to this reservoir pressure may require closely spaced horizontal holes and the use of stimulation such as hydrofracture to enhance initial drainage.

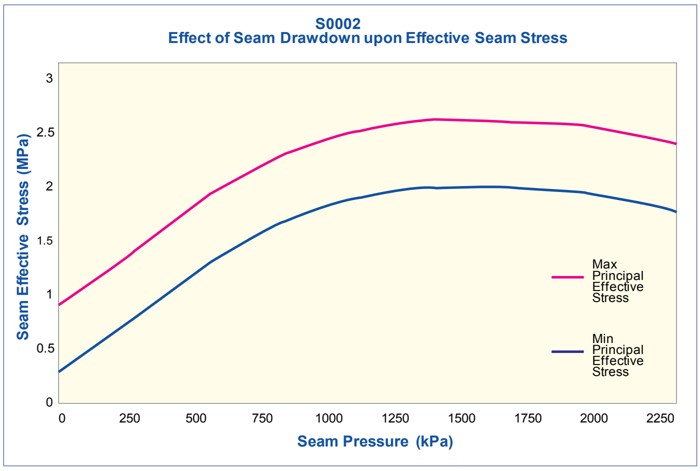

Figure 1: The stress path due to drainage of a Bowen Basin coal.

Where the coal is very impermeable and the effective horizontal stresses do not decrease, and may indeed increase, with dropping fluid pressure there is no possibility to drain the seam without some artificial means to reduce the in-seam stress. Material must then be removed in a substantial manner to reduce the stresses. In mining terms this is generally achieved by mining an adjacent seam more amenable to being worked.