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DISPOSAL OF OILY CUTTINGS BY DOWNHOLE FRACTURING INJECTIONS: SLURRY PRODUCT SPECIFICATIONS ISSUES

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ABSTRACT

The technique of using on-site injection of oil contaminated drill cuttings is attracting considerable attention as a cost effective means of complying with environmental legislation concerning discharges of drilling wastes. The slurrification and injection of oil based cuttings into a casing annulus, a process developed in 1989 by a major oil and gas producer/operator, has proven to be a significant step toward reduction of such environmental waste. This paper discusses the development of the cuttings reinjection, slurrification, slurry properties and benefits of quality slurry, and behaviour of solid laden slurries in a fracture in conjunction with down-hole disposal operations.

INTRODUCTION

Subsurface injection is a world-wide common method of waste disposal, and many injection wells have been operating for years with massive volumes of material, being injected. The major difference between such normal disposal operations and disposal of drill cuttings and impure mud is the high percentage of solids to be injected with the corresponding requirement for injection above fracture closure pressure (Sirevag and Bale, 1993). Cuttings re-injection, where hydraulic fractures are created in subsurface strata to contain the drill solids, satisfies the environmental and economic criteria for achieving zero discharge of oily drilling wastes. Hydraulic fracturing is well established as a means of well stimulation (Veatch, 1983), and its use as a means of deep disposal of radioactive wastes has also been documented (Belter, 1972 and Haase, 1983). Since a process of subsurface injection of drilling wastes was developed in 1989, only a few papers address this means of disposing of drill cuttings.

Two methods of injection are practiced: through the well tubing and through the well annulus (annular injection). Wells which have tubing for injection are referred to as dedicated wells. Few of these wells have been drilled specifically for injection. Most are converted wells that have exhausted from their original purpose. Annular injection occurs by injecting through the annulus between the surface casing and the casing immediately inside of it. The tubing can then be used for other purposes. One well can be used for disposing of all wastes at a production pad, which may have up to sixty wells (Fristoe, 1991).

Cuttings re-injection is an established practice in Alaska (Smith, 1991), the Gulf of Mexico (Malachosky et al., 1991) and recently has been employed in the North Sea (Minton, 1992). The initial proposal for cuttings disposal via subsurface injection involved creating a drilling cuttings/sea water slurry by first grinding the cuttings, then mixing with sea water to produce a pumpable slurry (Smith, 1991). Operations in the Gulf of Mexico typically use a modified centrifugal pump shearing system to grind the cuttings

(Malachosky), 1991). A compact vertical roller mill (Minton, 1992) and modified autogenous crushing mill (Sirevag and Bale, 1993) are used in the North Sea.

Once sufficient slurry was available and its properties had been checked, it would be injected into a dedicated disposal well or down the well annulus using a small positive displacement triplex pump. In the annular injection operations, the cuttings slurry was pumped through a valve to the casing spool and into the casing annulus to fracture the formations below the surface casing shoe (Fig. 1).

Sirevag and Bale (1993) stated that the properties of drill cuttings slurry were found to be very similar to a 'typical pre-spud mud'. In hydraulic fracturing terms, the 75 microns (150 US Mesh) size, would correspond with typical silica flour size fluid loss additives while 1000 microns is approximately equal to the average grain diameter of 16/30 US Mesh proppant (i.e. about 50% larger than the quite common 20/40 US Mesh size proppant used in many propped fracturing applications).

CUTTINGS SLURRY CHARACTERISTICS

Slurry characteristics impact both the injection and fracturing operations. The ground cuttings slurry should be tailored to the injection scheme adopted. Wilson et al. (1993) pointed out that parameters requiring optimisation include solids loading and particle size distribution; rheology (to avoid settling-out of larger particles, and potentially blocking the injection annulus); fluid loss and dehydration of the pumped slurry within the fracture. These all impact the grinding specifications of the cuttings process equipment, and need to be addressed at the planning stage.

Normally, the composition of cuttings slurry would have water, solids and oil. Typical drill cuttings slurry properties is given in Table 1.

Slurries having 15% to 30% solids by volume (30% to 50% by weight) have the necessary viscosity of 50 to 100 qt/sec. (measured by using a Marsh Funnel) required to keep the larger particles in suspension (Wilson et al., 1993). On the other hand, different areas will take different dilution rate, which depends on the cuttings characteristics (e.g. clay content), thereby influencing the ratio of water to cuttings (solid particles).

Table 1: Typical Slurry Rheological Properties (after Sirevag and Bale. 1993).

Solid - ~	30% (W/W) 95% less than 75 microns $\pm$ 5% up to 1000 microns
Viscosity -	Plastic Viscosity = 15 cp Yield point = 60 lbf/100 ft^2 Power law properties: n = 0.26 K = 0.1481bf/ft^2/sec Apparent viscosity: at 170 sec^{-1} = 143 cp
Density -	10.4 lb/gal S.G. = 1.25

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SIZE DISTRIBUTION OF CUTTINGS SLURRY

Very little data is available to describe the particle size limitations on the cuttings slurry. Consequently a number of assumptions had to made so as to define the slurring mechanism. Two requirements exist. Firstly, to ensure that the solids remain suspended in the slurry in the annulus/tubing and near wellbore fracture while still pumpable or when pumping is halted, and secondly, to ensure that the particles are not large enough to bridge of across the face of the fracture. A relatively fine grind on the cuttings was therefore seen as being advantageous. This would have the extra benefit of providing inherent viscosity in the slurry, obviating the need to add viscosifying chemicals (Minton, 1992).

Average particle sizes of typical mudstone and limestone cuttings slurry are shown in Table 2. With 50% of particles smaller than 9 microns the slurry has the potential for a high viscosity, easily able to keep the 10% of particles larger than 120 microns in suspension (Wilson et al., 1993).

Table 2: Average Particle Sizes of Typical Cutting Slurry (after Wilson et al., 1993).

100 µm	45 µm	2 µm	D_{90}	D_{50}	D_{10}
88 %	75 %	4 %	120 µm	9 µm	3 µm

BENEFITS OF QUALITY SLURRY

The observed benefits resulting from a solids rich and very fine particle slurry are many (Schuh et. al., 1993). Some of the more important ones are given here:

1. Finely milled and dense slurries are stable with no risk of settling in the process tanks or pipework or in the well annulus/near wellbore fracture.
2. Dense slurries require less surface injection pressure.
3. Dense slurries results in lower volumes to handle on surface and less volume to formation giving a longer injection life.
4. Less erosion of equipment due to lower pumping rate and particle size.
5. The large surface area created during milling is able to absorb oil more easily to maintain a water wet system.
6. A very fine and consistent slurry is much less likely to plug or screen of the injection zone.
7. Slurry can be successfully injected into the narrow fractures created by low rate/low volume injection.

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PARTICLE MOVEMENT AND DEPOSITION

When a particle is injected into the fracture, it travels along with the fluid away from the wellbore and settles downward at a rate that depends on the fluids properties and surrounding conditions. Significant sedimentation may occur both during pumping and after pumping ceases.

The particle motion inside the fracture occurs horizontally, caused by fluid flow, and vertically (downward), caused by gravity. The horizontal velocity of the particle is observed experimentally to equal the average fluid velocity, that is, the particle moves in the same column of fluid. The vertical particle velocity (also known as a settling velocity) is governed by fluid properties as well as solids loading, particle size and specific gravity (Daneshy, 1978).

Fluid rheology plays quite dominant role in predicting the settling velocity of the particle. Unlike Newtonian fluids, the viscosity of cuttings slurry varies greatly within a fracture due to the wide variations in local shear rate. The average settling velocity in fracturing fluids is strongly influenced by the extent and viscosity of the low shear rate regions (Kirby and Rockefeller, 1985). In an actual multiparticle system, the settling rate of each particle is hindered due to collision with neighbouring particles, and this results in a much slower settling rate than for a free settling single particle. A high settling velocity will result in particle segregation at the bottom of the fracture. In contrast, a very low settling velocity will permit the particle to remain in suspension distributed over the total fracture height.

Direct injection into permeable formation would create fluid loss from the solids laden slurry and a filter cake will be formed on the fracture face. Continued fluid loss will then tend to dehydrate the slurry, eventually plugging the fracture. The possibility of this near wellbore plugging would also be increased by the 'start/stop' nature of injection which would occur during breaks in drilling activity. This would totally destroy wellbore/fracture communication and prohibit any additional injection into the formation from that wellbore.

CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

The disposal of oil based cuttings by slurrification and reinjection is a mechanically viable alternative compared to the conventional land-based disposal. Since the first downhole injection of cuttings slurry in 1989, considerable research and engineering effort has gone into improving the effectiveness of these operations. Properties of the slurry impact both the injection and fracturing operations. These properties should be studied in detail since they give an indication of the ability of the slurry to suspend/transport solid particles. Cuttings slurries/suspensions pumped downhole must have adequate stability to prevent settling that resulting plugging in the drilling annulus and near wellbore fracture.

Knowledge of the settling velocity of solid particles in fluids is vital to provide understanding of suspension stability. To achieve suspension stability, careful consideration must be given to certain parameters/variables that require optimisation including particle size distribution, solids content and fluid rheology. Although the information pertaining to the terminal settling velocity in newtonian fluids is well

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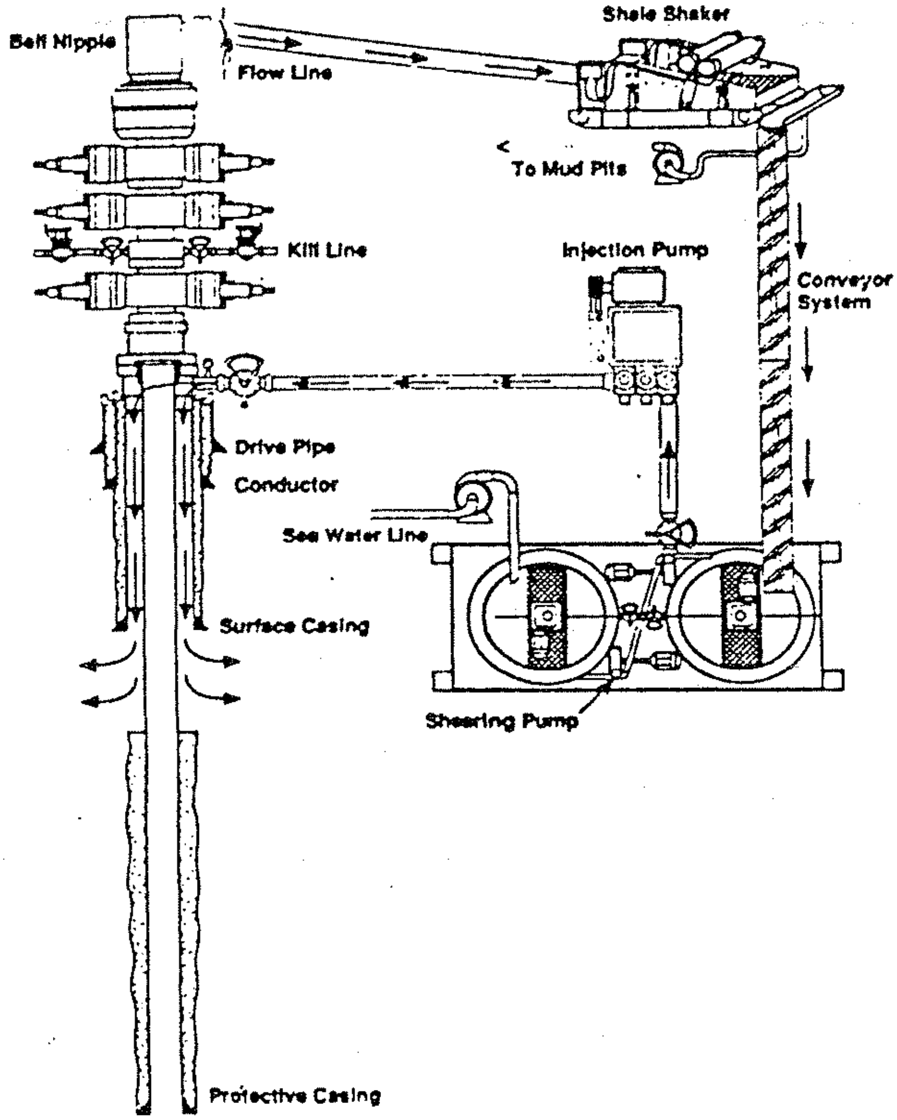

Figure 1 : OBM Cuttings Shearer Process Schematic
(Sirevag and Bale, 1993)