Nanoparticles: Promising Solution to Overcome Stern Drilling Problems

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ABSTRACT

General solution to overcome stern and frequently occurring drilling problems lies in controlling the rheology of drilling fluids. Pipe sticking, lost circulation, erosion, formation damage, thermal instability, poor hole cleaning, high torque and drag are few problems that incurs enormous costs on overall drilling operations in form of expensive drilling fluids, breakdowns, fluid loss, high power requirement, and mainly limited functionality. The nanotechnological research leading to create tailored made nanoparticles is a promising step change research for smart fluids development. The nano particles based drilling mud enables the design and development of new drilling muds for efficient drilling operations at significantly low cost. Use of nano based drilling muds has long been in discussion and some researchers have tested in laboratory but no mathematical and analytical model reported. Based on initial studies and easy availability we selected Attapulgite and after milling, characterization, surface treatment, and adding into drilling muds showed useful results. We initiated developing a scheme, starting from synthesis and characterization of nanoparticles, measurement and optimization of properties by response surface technique, establishing correlation between rheological properties, ultimately leading to performance tests at well simulators. Preliminary results of Attapulgite crop up hopes of testing more nanomaterials for further improvement.

Keywords: Drilling fluids, nanoparticles, drilling problems lost circulation, pipe sticking

1 BACKGROUND

The worldwide energy demand is anticipated to go up almost 60% over the next 30 years, a challenging trend that may be met only by radical breach in energy science and technology. The industry needs stunning discoveries in underlying core science and engineering. Even though advancements in alternative energy sources is much under consideration but it is well implicit that these alternative will not be sufficient to meet the rapidly escalating demand and hence hydrocarbon fuels are expected to remain the dominant energy source in future. The stimulation to maintain the future adequacy of oil reserves has mobilized the geologists and the drilling industry to look for ways and means to enhance existing technologies for improved oil recovery from existing resources by deep drilling and develop new technologies like coiled tubing drilling for economically viable drilling from small reservoirs. Consequently, the only way to maintain future competence in oil and gas extraction is understood to be by following means:

- Access deep lying and complex reservoirs which are not accessible due to technological limitations.
- Develop technologies such as Coiled tubing drilling (CTD) which are cost efficient in order to make the extraction from small reservoirs economically feasible.

The Hindrances offered in achieving aforementioned targets are the drilling problems encountered that limits the capabilities of the overall drilling program and hence add to the overall drilling costs. Therefore it is an unstated fact that resolving drilling problems can enable to push the limits of the existing drilling technology and can endow with economically and technically viable drilling operations. One of the key to resolve frequently occurring and harsh drilling problems is controlling the rheology of the drilling fluids.

2 ROLE OF DRILLING FLUIDS

Drilling fluids, commonly referred to as the drilling muds, are a vital part and the life blood of a successful drilling operation. The cost of the fluid system often represents one of the single peak capital expenditure in drilling a new well. Fluid costs can shoot up swiftly when drilling deep holes, complex formations or in remote locations. To minimize the cost of drilling fluids and ensure an efficient drilling program, fluid properties must be maintained incessantly during drilling operations. These fluids must be engineered to perform well as conditions change during the drilling process. The drilling fluid is expected to perform multiple tasks concurrently, like cooling the drill bit, lubricate the rotating drill pipe (or sliding tube in coiled tubing drilling), and effective hole cleaning, but if the fluid lacks in any of the functional requirements could lead to severe drilling problems like, lost circulation, formation damage, pipe sticking, erosion of the bore hole, poor hole cleaning, and high torque and drag that significantly reduces the efficiency of drilling. The occurrence of these problems becomes more plausible in high temperature and pressure environments due to the degradation in fluid properties and hence is a major stumbling block in drilling deep valuable reservoirs. Consequently, the instability of fluid at high temperature and pressure is an apprehension amongst the drilling industry. Various conventional polymeric and surfactant additives that have been tested for superior performance of the drilling fluids have high cost and degrade at HTHP conditions, which lead to unwanted changes in rheological properties. In the light of aforesaid functional requirements of drilling fluids, it is thus a topic of utmost interest for the researchers and drilling industry to develop tailored made drilling fluids that could be able to perform the job with best level of agreement and maintain their paramount functionality over a wide range of variables like temperature, pressure, types of formations and drilling environments. The rheology of the drilling fluid determines the serviceability of the fluid and proportionally the probability of encountering undesirable predicaments in the drilling operation. The viscosity, density and the gelling strength of the drilling fluid are the key factors that determine the functional specifications of the drilling fluids with the obvious inference of the fact that they should remain constant over a wide range of operating condition. The multifarious nature of the oil well drilling operation have always kept the drilling industry activated in scrutinizing the resources to expand knowledge of having definite set of rheological properties to suit particular conditions and improve their working range.

3 NANO ENHANCED DRILLING FLUIDS (NEDF) PROSPECTS

The onset of nanotechnology has revolutionized the science and engineering faction, and due to its huge domain of applicability, like every other industry, the drilling industry can also pull out terrific benefits from nanotechnology out of which one of the most promising prospects is the use of nanoparticles in drilling muds in order to have a definite operational performance, stability and suitability to adopt well with a wide range of operating conditions with minor changes in composition and sizes [1]. The use of nano particles in drilling fluids will enable the drilling technologists to swiftly modify the drilling fluid rheology by changing the composition, type or size distribution of nanoparticles to suit any particular situation, discourage use of other expensive additives, and improved functionality. The use of nano particles synthesized from different materials has been used to achieve certain targets and are reported in the literature [2, 3]. In addition to the superior performance the most attractive feature of Nano-Enhanced Drilling Fluids (NEDF) is their low cost. The technical and economic benefits associated with nanoparticles are so favorable and can be summarized as:

Cost:

- Reduced cost of the drilling fluids and hence the drilling operation by using nanoparticles as a replacement to expensive additives
- Improved oil recovery by accessing deep lying challenging reservoirs
- Reduced non productive time due to elimination of problems, thus saving enormous costs

Technical:

- Favorable for use in new technologies like Horizontal/directional drilling and CTD
- Controlled under-balanced drilling operations

4 PROSPECTIVE PERFORMANCE

As mentioned earlier, that the use of nanoparticles has reported in literature, but do not encompass a detailed application to diverse problems at a time. A detailed prospective of the use of nanoparticles to surmount well acknowledged drilling problems is presented. Comparative performance charts between base fluids (ordinary mud without any additives), base fluids with regular additives and base fluids with nano particles are presented and their relation in reducing identified problems is discussed:

4.1 Pipe sticking

It has a major impact on the drilling efficiency and well costs and is affected by many parameters like mud type, fluid loss and mud cake properties which are dependent on drilling fluid rheology and change in any rheological property of the drilling fluid can significantly influence the above mentioned factor and hence reduce the differential pipe sticking. Nano-based drilling mud with potential to reduce adhesive tendency of mud cakes by forming a thin non-adhesive nano-film on the drill string surface play an important role in reducing the pipe sticking problem [4]. Superior carrying capacity (gel strength) can be imparted to the drilling fluid by nanoparticles, and thus reducing the pipe sticking and inefficient hole cleaning problem.

4.2 Lost circulation

Loss of Circulation is partial or complete loss of the drilling fluid to the formation and can occur due to naturally occurring fractures, crevices and channels. The driller has no control over these circumstances and occurs due to properties of the drilling fluid or mud. The weight of

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the mud keeps on increasing due to suspended cuttings as a consequence of the lack of ability of the drilling fluids to carry and transport the drill cuttings to the surface. The use of nano-particles will impart a carrying capacity sufficient enough to transport and drop off cuttings efficiently and to maintain its density and hence pressure over a wide range of operational conditions, ultimately leading to reduction of lost circulation. Fig.1 shows the expected reduction in friction coefficient by using nanoparticles, in comparison to ordinary base fluid and base fluid with regular additives.

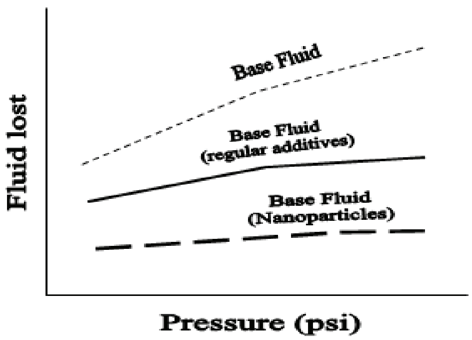

Fig. 1: Reduction in fluid loss with increasing pressure

4.3 Erosion of the borehole:

It occurs as the fluid comes into contact with obstructions; it can begin to rotate causing a swirling effect that can erode the side of the hole. To minimize erosion, viscosity and velocity of the fluid should be optimized. The goal is again to optimize the viscosity of the drilling fluid by using nano-particles in order to eliminate or lessen the erosion. The comparison of a regular base fluid (without additives, a base fluid with regular additives and a base fluid with nano particles as a replacement of regular additives shows the expected improvement in drilling fluid performance, by optimizing the viscosity such as to have a low flow viscosity and thus erosion. The expected comparative reduction in fluid loss with a nano enhanced drilling fluid is predictable which shows a reduction in velocity and hence erosion with increasing viscosity (Fig.2).

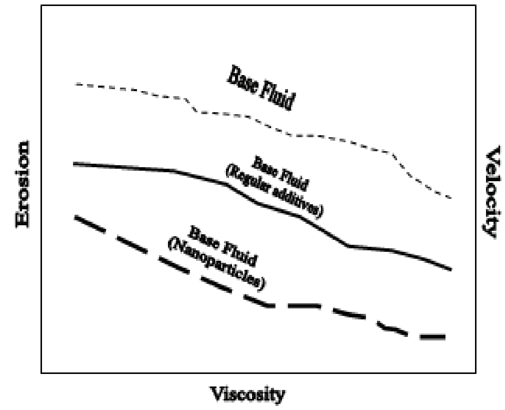

Fig. 2: Reduction in velocity and erosion with increasing viscosities

4.4 Reducing torque and drag

In extended reach drilling there is a dramatic increase in torque and drag problems which are due to the friction between the drill string and the borehole wall. Micro and macro material-based drilling mud have limited capability to reduce this torque and drag problems. The use of spherical carbon beads with a particle size of -10 mesh to +325 mesh for improving the lubricity of drilling fluids have reported in literature and showed some degree of enhancement in functionality of the drilling fluid [5]. Due to fine and very thin film forming capability of nanomaterials, nano-based fluids can provide a significant reduction of the frictional resistance between the pipe and the borehole wall due to the formation of a thin lubricating film in the wall pipe interface. With the increasing load the friction coefficient increases swiftly which can be reduced by using nanoparticles. The friction between the drillstring and borehole increases persistently with the increasing load. A comparative anticipated performance attribute is shown in Fig.3:

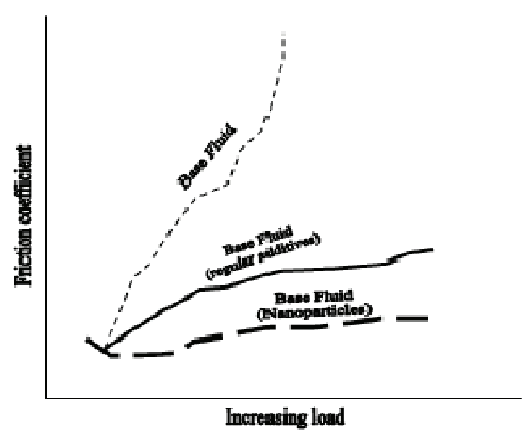

Fig. 3: Reduction in friction coefficient with increasing load

4.5 Thermal instability

The breakage or association of the polymer chains and branches by temperature variation can cause a drastic reduction in viscosity. Hence the maintenance of stability at HTHP conditions is mandatory to fulfill functional tasks of a fluid system. As temperatures above 200 °C and bottomhole pressure above 20 Kpsi are common in HTHP wells and also in deep wells of more than 20,000 ft, thermally stable fluids are essential to drill a well safely and economically in such environments. Nanos having an excellent thermal conductivity are expected to be the materials of choice for such environments. The viscosity of drilling fluid decreases with an increase in temperature and hence deteriorated performance limits the capability to drill deep. The use of nanoparticles in different types, sizes and composition will provide with drilling fluids with definite viscosities that are thermally stable.

5 METHODOLOGY

1. Attapulgite nanoparticles are formed by mechanical attrition process
2. Chemical treatment to mediate the interface between the nano particle surface and the application matrix.
3. Characterization by using chemical and physical techniques.
4. Sampling of drilling mud with different composition, size range, and material of nanoparticles
5. Measurement of rheological properties.
6. Optimization of properties and their dependence on the type, size and composition of nanoparticles can be studied by response surface methodology.

6 OVERALL IMPACT ON PERFORMANCE

The use of nanoparticles will enable to make the drilling operation smooth and cost effective. Also the new technologies like under-balanced drilling with coiled tubing can be facilitated to push their limits to take maximum advantage of their uniqueness. The net outcome of the elimination of the afore-discussed problems will be an improved rate of penetration (ROP) that can save enormous drilling operations cost. A conventional way to observe the effectiveness of a drilling operation is a comparison between the depth reached and the time taken to reach that depth. Nano enhanced drilling fluids will enable to reach the target depth in less time by reducing sufficient non-productive time. Fig.4 shows a tentative performance comparison.

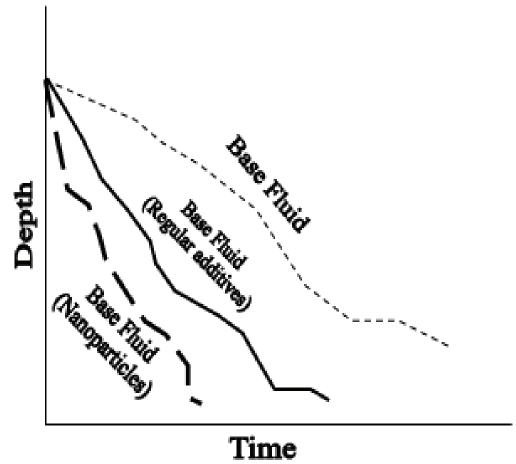

Fig. 4: Improvement in rate of penetration (ROP)

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