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TECHNOLOGY ASSESSMENT FOR
DOWNHOLE VIBRATION MONITORING & CONTROL SYSTEM

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INTRODUCTION

The objective of this project is to develop an autonomous downhole system to monitor the vibration induced by the process of drilling oil and gas wells, and use these measurements to control an active vibration damper (AVD). The overall system is called the Downhole Vibration Monitoring and Control System, or DVMCS. Use of the DVMCS will significantly reduce the vibration of at the bit and through the entire bottomhole assembly (BHA). This, in turn, will provide significant improvements in the efficiency of the drilling process through several mechanisms:

- By keeping the bit from bouncing, the drilling process can proceed 100% of the time, rather than intermittently.
- By adjusting the stiffness of the damper, the weight actually applied to the bit (WOB) can be maintained in the optimal range, enhancing the efficiency of drilling, and increasing the rate of penetration (ROP).
- By reducing the harmful effects of shock and vibration in the drillstring, the AVD will reduce the likelihood of costly failures of components including drill bits, motors, and expensive measurement-while-drilling (MWD) systems.

This report considers the current technologies that are used to control vibration, a description of the underlying technology used in the DVMCS, a search of the literature and patents in the field, and some overall conclusions regarding the anticipated value of this effort.

BACKGROUND & CURRENT TECHNOLOGY

The current methods of controlling bit bounce and vibration may be grouped into two categories: surface and downhole.

The surface approach relies upon the driller to vary the rotational speed (RPM) and weight-on-bit (WOB) to reduce the vibration. The simplest means relies on the driller's 'feel' of the brake to monitor vibration and, although somewhat individualistic and idiosyncratic, it has been fairly effective in many areas. There are also more sophisticated systems that use accelerometers and other devices to sense downhole vibrations at the surface, or look for variations in the applied torque as an indicator of "stick-slip" effects. More recently, automated drilling systems have been introduced to control the surface drilling parameters to optimize drilling.[1] The surface measurement systems may be complemented by tools designed to monitor downhole shock and vibration parameters and relay them to the surface *via* measurement-while-drilling (MWD) technology.[2] The difficulty with this approach, particularly in extended reach or horizontal drilling, is that changing parameters at the surface may not have the desired (or any) effect at the bit. The accumulated effect of drillstring drag against the borehole walls, stabilizer hang-up, buoyancy, *etc*., may effectively decouple the bit from the surface. All of these make effective control of the drilling process problematical.

The most common downhole solution to drilling vibration is the installation of a shock sub in the bottomhole assembly (BHA). These are essentially shock absorbers which can help mitigate the effects of drilling vibration under certain conditions. Their primary purpose is to protect equipment that is mounted above them, rather than decrease vibration at the bit. A further limitation on these devices is that they are designed to work well at particular rotation rates and WOB. Under other conditions, they can resonate and exacerbate the vibration problem, rather than alleviate it.[3]

In summary, all the current means of intervention are essentially passive systems or require operator intervention. These include a number of means to measure bit bounce and vibration downhole and some even include systems to transmit the data to the surface[4]. There are also downhole systems to dampen shock in known, specific environments (shock subs.) Finally, there is the traditional recourse of the driller's skill at detecting adverse conditions through the feel of the brake and making intuitive changes to the perceived conditions. All these methods provide some level of relief in particular environments; none works everywhere and none is universally applicable.

The DVMCS offers the first approach that will monitor downhole vibration and act to reduce it in an autonomous closed-loop system without intervention from the surface.

BACKGROUND OF THE DVMCS

The underlying technology of the AVD component of the DVMCS is widely used on the surface. Several devices use magnetorheological fluids (MRF) to vary the parameters of shock absorbers and suspensions. MR fluid consists of a suspension of fine iron particles in a fluid, which is generally oil. Under normal circumstances, these particles have a small or negligible effect on the properties of the oil. Upon the application of a magnetic field, however, the particles agglomerate into long strings along the magnetic flux lines. These macroscopic assemblages greatly resist any fluid flow, and significantly increase the viscosity of the fluid. (As in all such processes, there is a saturation condition, and the viscosity *vs.* field curve displays the classical hysteresis shape. The transition in either direction is essentially instantaneous (~ 1 msec). As a result, an MRF damper can react very promptly to any change in conditions.

MRF dampers are use in a number of applications, ranging from earthquake damage prevention[5] to automobile suspensions[6]. The present downhole use of this technology is unique, and is protected by a U.S. Patent obtained by APS Technology[7].

The feedback circuit to control the AVD will be based on one or more measurements taken downhole. The laboratory prototypes included a variety of sensors, including accelerometers (at the bit and above the AVD), displacement sensors to measure the absolute movement of the AVD and the relative motion of its two halves, and a load cell for measuring the force applied to the bit. Of these the most useful and practical sensor for controlling the AVD appears to be an LVDT (Linear Variable Displacement Transformer) to measure the relative displacement of the inner and outer halves of the AVD. The instantaneous motion is an indicator of the magnitude and frequency of the vibration. By integrating motion to give a rough absolute position measurement, the WOB can be inferred as well. This feedback system will be evaluated in the field trials.

LITERATURE & PATENT SEARCH

A search was performed on the Society of Petroleum Engineers "e-Library" (http://spe.org/spe/jsp/basic/0,2396,1104_1561_0,00.html) for papers regarding downhole vibration. While this collection is by no means exhaustive, it includes all papers published in SPE journals or presented at its general meetings and special topical symposia. It is highly unlikely that any significant technology could be introduced into the petroleum industry without its appearing somewhere in this index.

The search yielded 33 papers, of which about 15 were unique and relevant. (Often a paper is presented at more than one conference, or appears later in one of the refereed journals.) The earliest reference to a downhole vibration monitoring system was in 1988[8]. A number of others, in addition to those cited above, describe methods for combining downhole measurements with surface ones to optimize the drilling process. A few of these papers do so in 'real time' (*e.g.*, every two minutes or so) using data transmitted to the surface *via* MWD signals[9,10]. No closed-loop downhole system has been described.

In addition, a search of the U.S. Patent database was performed. This was also not intended to be an exhaustive search, since such a search was performed at the time of the original patent application. Again, while there were many devices used to detect downhole vibrations and shock[11], none was found that ***actively controls*** them downhole.

APPLICATIONS

Model calculations have shown that the use of the DVMCS can provide significant increases in ROP, particularly in hard rock drilling where the vibrations are most severe. The most attractive area for use of this system is in deep drilling, since the benefits of improved penetration rates and longer bit runs increase significantly when round trip times become very large. Once proven, however, we believe that the benefits of the DVMCS will more than justify its use over a wide range of drilling operations.

Overall, by reducing the costs and time required to drill deep wells, the DVMCS will make the economics of deep drilling more attractive. This will enable the exploitation of deep reserves that may not be feasible today.

CONCLUSIONS

The Downhole Vibration Monitoring and Control System, through its use of a unique active vibration damper utilizing magnetorheological fluids, offers the possibility of significant cost and time reductions in drilling. This is particularly true in deep drilling in hard rock. Initial laboratory testing has shown the feasibility of this approach, and field tests, scheduled for 2005, should demonstrate its effectiveness in the true drilling environment.

No prior art has been located which would preclude the development and protection of this technology. We anticipate significant interest in it from the oilfield service industry and their customers, the oil and gas exploration and production companies.

REFERENCES

[1] *cf.*, *e.g.*, M. Hofschröer, "Automated drilling application for gaining higher efficiency on extended reach wells," presented at the SPE/IADC Middle East Drilling Technology Conference & Exhibition, Abu Dhabi, UAE, 20-22 October 2003, paper **85336**

[2] *cf.*, *e.g.*, C. Marland *et al*., "Understanding downhole vibration transmission and disruption in the Gulf of Thailand,, presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 18-20 October 2004, paper **88449**.

[3] T.M. Warren *et al.*, "Shock Sub Performance Tests," presented at the 1998 IADC/SPE Drilling Conference, Dallas, March 3-6, 1998, Paper **IADC/SPE 39323**, The authors note: "Most of the shock subs tested showed a definite reduction in the axial accelerations experienced in the drillstring *above the shock sub…. The accelerations at the bit were little affected*, but even at the same accelerations the dynamic forces at the bit were probably reduced. Clearly the best place to run the shock sub is near the bit to minimize both axial and lateral accelerations. Even though it provides some benefit in terms of reducing axial vibrations when run at the top of a packed BHA, *it increases the risk of encountering high lateral vibrations when run in this position. These vibrations may cause more problems in terms of fatigue damage than will be offset by the reduction in the axial vibrations*." [*emphasis added*.]

[4] *cf.*, *e.g.*, M. Hutchinson *et al.*, "An MWD Downhole Assistant Driller," presented at the SPE Annual Technical Conference and Exhibition, Dallas, TX, 22-25 October, 1995, Paper **30523**.

[5] B.F. Spencer Jr. *et al.*, "Phenomenological Model of a Magnetorheological Damper," Journal of Engineering Mechanics, ASCE, **123** 230-238, 1997, http://www.nd.edu/~quake/papers/MRD.Journal.pdf .

[6] *cf.*, *e.g.*, "Magnetic Ride Control," *GM Tech Links,* Vol. **4**, No.1, *pp.* 1-2, January, 2002, http://service.gm.com/techlink/html_en/pdf/200201-en.pdf

[7] M. Wassell, "Magnetorheological fluid apparatus, especially adapted for use in a steerable drillstring, and method of using same, U.S. Patent **#6,257,356 B1**, issued 10 July 2001. Note that this patent covers a broad range of uses of MRF in downhole drilling applications. A patent application specifically addressing the DVMCS technology was filed on 7 November 2003.

[8] D.A. Close *et al.*, "Measurement of BHA Vibration Using MWD," presented at the 1988 IADC/SPE Drilling Conference, Dallas, TX, 28 February – 2 March, 1988, paper **17273**.

[9] S.C. Rewcastle & T.M. Burgess, "Real-Time Downhole Shock Measurements Increase Drilling Efficiency and Improve MWD Reliability," presented at the 1992 IADC/SPE Drilling Conference, New Orleans LA, 18-22 February 1992, paper **23890**. Note that the objective of this paper is to minimize shock damage to the BHA components, and not primarily to increase ROP.

[10] D. C.-K. Chen, *et al.*, "Integrated Drilling Dynamics System Closes the Model-Measure-Optimize Loop in Real Time," presented at the SPE/IADC Drilling Conference, Amsterdam, 19-21 February 2003, paper 79888.

[11] *cf.*, *e.g.*, R.L. Schultz *et al.*, "Spectral power ratio method and system for detecting drill bit failure and signaling surface operator," U.S. Patent # **6,681,633**, issued 27 January 2004.