INVEST White Paper

Ultra deep water and ultra deep drilling technologies for 21st Century Mohole

Engineering Development Advisory Committee
J-DESC, JAPAN

Corresponding Author: Yoshiyasu WATANABE, Tokai University
ywata@scc.u-tokai.ac.jp

Abstract

Project Mohole was suggested in 1957 and started in1961 off the coast of Mexico, but ended in 1966 with 177 m drilling depth and 3560 m water depth. Since then, reaching the Moho has been a dream of mankind. Today, the project is called 21st Century Mohole, which requests the operating water depth of more than 4000 m and drilling depth of more than 7000 m.

Steel riser drilling system is the main current in the oil industry and Shevron succeeded in drilling the 3866 m deep hole under 3051 m water depth in GOM in March 2003[1). Further more, Discoverer Clear Leader, whose operating water depth is 3,658 m and drilling depth capability is 12,192 m, was constructed in March 2009 and Shevron plans to operate it in GOM for five years [2).

Here, the present state of various technology developments such as managed pressure drillings, BOPs, casings and risers which will contribute to the 21st Century Mohole will be reviewed and the outlook of the application of these technology developments to ultra deep water and ultra deep drilling will be discussed.

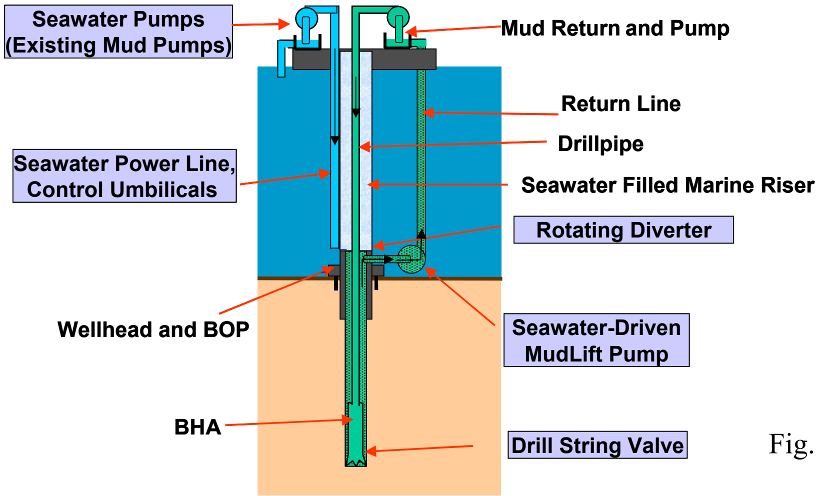
1. Present state of deep water drilling technology developments

(1) Dual Gradient Drilling (DGD) system[3) and Riserless Mud Recovery (RMR) system[4),5)

As shown in Fig. 1, DGD system returns drilling mud and cuttings from the seabed to the rig while drilling the top-hole section of the well, where the pore pressure and fracture pressure is proximate. As shown in Fig. 2, DGD system makes the difference between the pore pressure and fracture pressure of the top-hole increase and saves the quantity of casing strings.

AGR Drilling Services calls the DGD system as RMR system with using riserless drilling for top-hole section instead of riser drilling, which is shown in Fig. 1. AGR, together with their Joint Industry Project partners Shell, BP and the Norwegian Research

Council, have undertaken a successful field trial of the RMR system at 1500 m water depth, prior to the installation of the riser in Malaysia in September 2008.



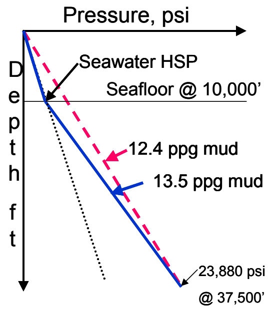


Fig. 2 Comparison of pressure gradient between single and dual gradient drilling

Fig. 1 SubSea MudLift Configuration

(2) Electro Hydraulic Multiplex Control System (EH-MUX) for BOPs [6]

Cameron has developed EH-MUX for BOPs, which is required for subsea exploration in deep waters to provide rapid actuation of the subsea BOPs. This system reduces response time normally encountered with hydraulic control signals which may require excessive amounts of time, potentially resulting in unsafe conditions.

Helix Energy Solution developed a Surface BOP Well Control Package for the use of 3,048 m water depth[7], where EH-MUX is adapted as shown in Fig. 3.

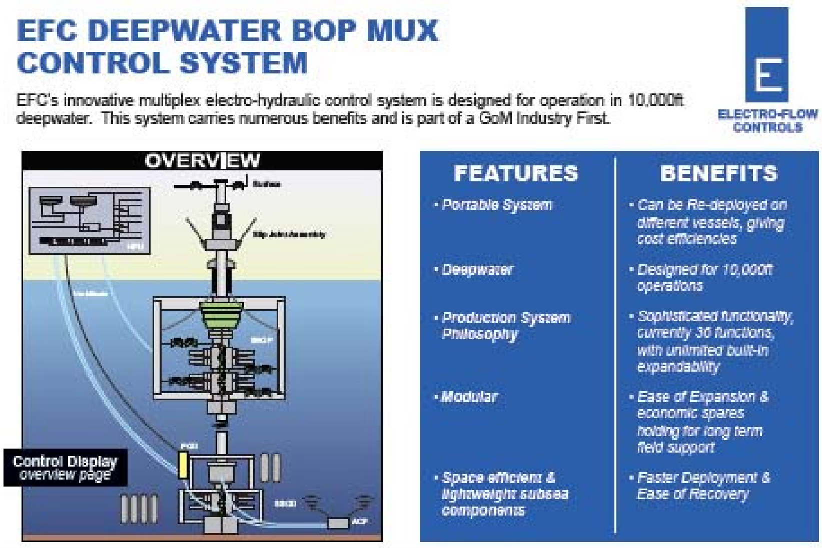


Fig. 3 EH-MUX designed by Helix Energy Solution

(3) Surface BOP

Surface BOP sits on the riser top, which locates above the sea surface or under the sea surface free from the effect of wave and tide. In this case, as the riser needs to endure the well pressure, the diameter of the riser and the maximum quantity of the casing strings become small. Furthermore, the drilling is limited to generally benign sea and weather conditions and the inner pressure of the riser could be limited to 5,000 psi (16-in. SBOP riser) or 10,000 psi (10 3/4-in. SBOP riser) [8].

Fig. 4 designates the Surface BOP Well Control Package for 10,000 ft water depth, designed by Helix Energy Solutions [7]. It consists of Surface BOP, Emergency Disconnected Package and Subsea Shut-Off Device.

(4) Expandable Casing

The diameter of the casing pipe is maximum at its upper end and decreases when the pipe goes down. The minimum diameter of the casing pipe at its lower end is determined by the minimum diameter of the drilling pipe that passes through the inside of the casing pipe. Expandable casing technology means that the casing pipe is expanded by an oversized hardened mandrill, which will be pulled through the pipe as shown in Fig. 5.

The commercial application of the expandable casing started in 1999 and nearly 700 installations have been achieved to May 2007 worldwide by Enventure Global Technology [9]. Accordingly, the expandable casing technology is applicable to the casings for the ultra deep water and ultra deep drilling.

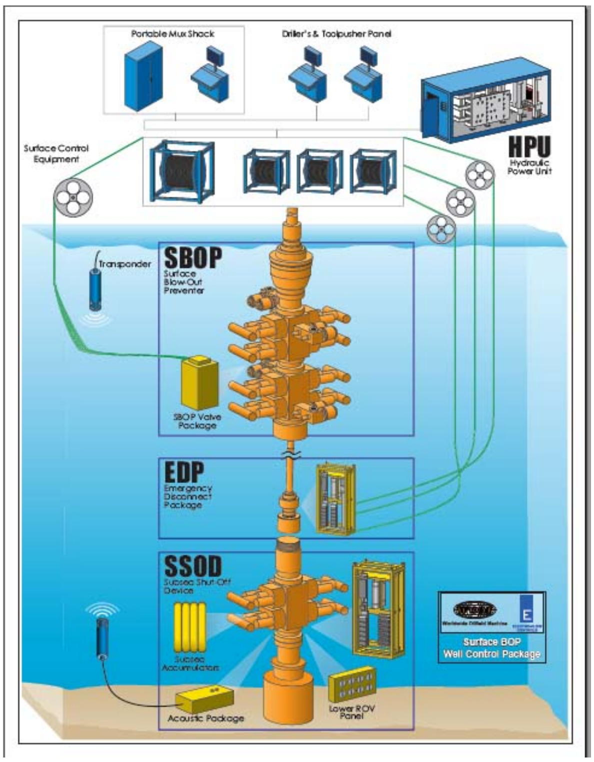


Fig. 4 Surface BOP system designed by Helix Energy Solutions [7]

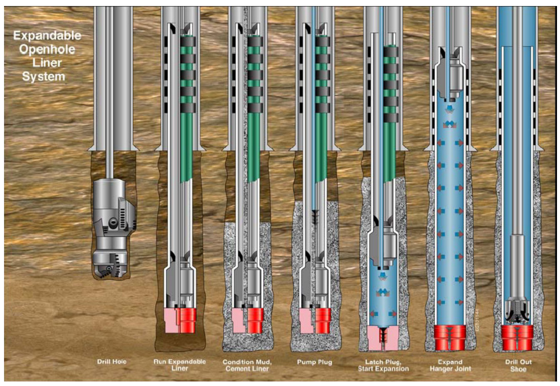


Fig. 5 Expandable casing technology by Enventure Global Technology

(5) CFRP Riser

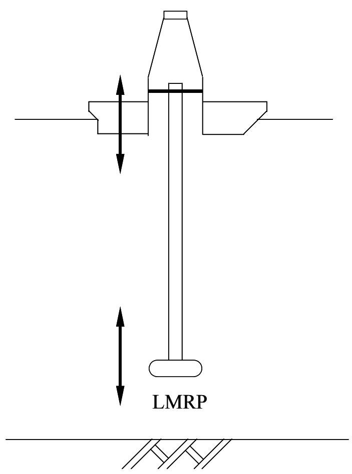
Regarding the riser, the axial resonance of the riser with the heaving of the drill ship should be avoided in case of ultra deep water drilling. The axial period of the riser T, where the drill ship is in riser hung-off condition, is estimated as

$$T=2\pi\{(m+m_r/3)/k_r\}^{1/2},$$

where m, m_r and k_r are the mass of LMRP, the mass of the riser and the axial rigidity of the riser, respectively, as shown in Fig. 6. The steel riser is used for "Transocean Discoverer Clear Leader" for 3658 m deep water drilling. However, composite risers such as CFRP (Carbon Fiber Reinforced Plastic) riser are indispensable for 4000 m and over 4000 m deep water drilling. In case of CFRP riser, m_r decreases and k_r increases. Accordingly, the axial period decreases and the resonance can be avoided.

CFRP riser consists of CFRP pipe and steel connectors at the end of the CFRP pipe as shown in Fig. 6. The most important part of the CFRP riser is the connecting part of the CFRP pipe and steel connectors and the axial load is transferred through several pairs of threads provided at the connecting parts.

The development of CFRP riser pipe for the water depth of 4000 m is now being pursued[10]. It is shown that the tensile and fatigue strength of the CFRP riser is enough and the design for the 4000 water depth CFRP riser will be finished after checking the collapse strength under inner and outer pressure.



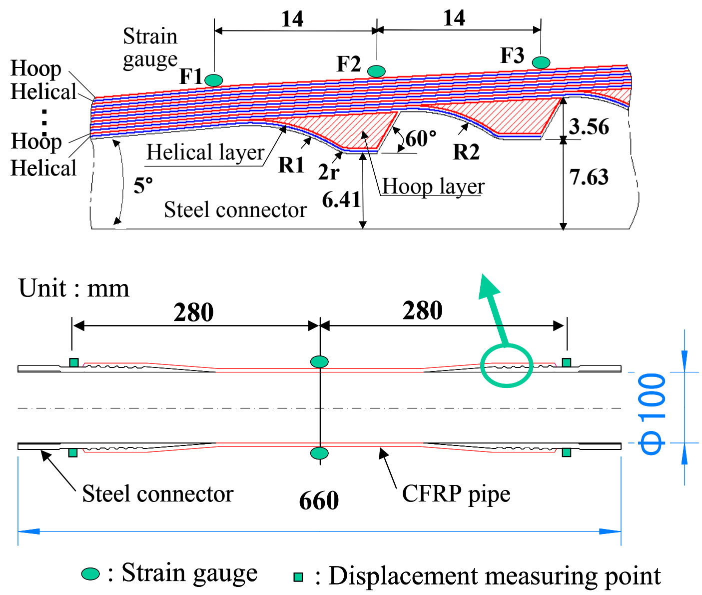


Fig. 6 Riser hung-off condition and connecting part of CFRP pipe and steel connecter

2. Outlook of ultra deep water and ultra deep drilling

The construction of Discoverer Clear Leader, whose operating water depth is 3,658 m and drilling depth capability is 12,192 m, encourages "Chikyu" to operate in the waters of more than 4000 m and drill the hole of more than 7000 m below the seabed. CFRP riser and EH-MUX for BOP are the most promising technologies and with using them, the 21st Century Mohole will be attained by "Chikyu" in the very near future. The technologies of Surface BOP, Expandable Casing and DGD/RMR system will also contribute to "Chikyu".

References

1) J. Dieffenbaugher, R. Dupre, G. Authement, G. Mullen, Y. Gonzalez, P.B. Tanche-Larsen : "Drilling Fluids Planning and Execution for a World Record Water Depth Well", SPE/IADC Drilling Conference, 23-25 February, 2005.

2) Offshore: "New design drillship pushes operations depths to meet future needs", http://www.deepwater.com/_filelib/FileCabinet/pdfs/Offshore_Magazine_Drillships%201.pdf?FileName=Offshore_Magazine_Drillships%201.pdf

3) Jerome J. Schubert: "Dual Gradient Drilling Basic Technology - Lesson 1, Introduction to DGD –", 6 November, 2000.

4) "RMR™ Riserless Mud Recovery System - a dual gradient system –", agr_rmr_roger_stave.pdf

5) http://www.subseaworld.com/technology/agrvs-subsea-riserless-mud-recovery-rmr-technology-is-successfully-field-tested-02471.html: "AGR's subsea Riserless Mud Recovery (RMR) technology is successfully field tested", 2008.10.13

6) http://www.c-a-m.com/content/products/product_detail.cfm?pid=2887:EH-MUX : electro hydraulic multiplex control system

7) Helix Energy Solutions: "Surface BOP Well Control Package for Well Ops Q4000"

8) Drilling Contractor, Nov./Dec.2005: "Pride's near surface BOP concept can increase water depth of semisubmersibles"

9) Mark Holland: "Expandable tubulars add to well-planning options", May, 2007. http://www.epmag.com/archives/features/402.htm

10) Yoshiyasu Watanabe etc.: "Optimization of a Multiple Traplock Structure of CFRP Riser Pipe for Deep Sea Drilling", Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference.