J. Marine. Sci. Appl. (2009) 8: 246-251
DOI: 10.1007/s11804-009-8113-1

Development of the artificial seabed technology and implementation pretrial well in the South China Sea

GUO Yong-feng*, JI Shao-jun and TANG Chang-quan

China Oilfield Services Ltd., Beijing 101149, China

Abstract: This paper introduces the recent highly significant activity of China Oilfield Services Ltd. (COSL) in the South China Sea, where COSL conducted pretrial drilling in June of 2008. The paper discusses some key research and new practices which led to the fabrication of related equipment which was evaluated in the trial. The market for deepwater drilling in the world has grown over the past 10 years but there are few drilling vessels or platforms suitable for drilling in deepwater or super deepwater. China needs equipment capable of deepwater drilling operations. COSL has some semisubmersible platforms, but they are only considered suitable for operations in water depths less than 475 m. An enabling technology, referred to as an artificial seabed, has been under development by COSL since 2004, and it applies the research results and experiences of many experts in deepwater drilling. COSL hopes this technology will allow drilling to depths of approximately 1 000~1 500 m with its current platforms. The paper presents research progress and improvements in fabrication and necessary upgrades to equipment for extending deepwater drilling. The pretrial well was executed at a water depth of nearly 500 m. COSL will drill the trial well around 2009 at the same location in the South China Sea.

Keywords: deep water; artificial buoyancy seabed; model test; maximum loading forces; pretrial well
CLC number: TE952 **Document code:** A **Article ID:** 1671-9433(2009)03-0246-06

1 Introduction

China has been producing and importing lots of oil/gas every year to satisfy the domestic consumption. The big oil companies and service companies have found out more ways to explore new oilfields both offshore and onshore, to increase the production of oil and gas[1]. A deepwater gas field was discovered in Liwan, deeper up to 1 470 m in the South China Sea by both CNOOC and Husky Co. in the summer of 2006. Big or gas fields are discovered in the areas of deepwater in China, especially South China Sea.

There are many difficulties in entering the deepwater oilfield in China. One of them is short of deepwater vessels or ships. As the biggest service companies of the petroleum industry in China, COSL (China Oilfield Services Ltd.) has only three semisubmersibles which could operate in the maximum water depth of 475 m. However, the water depth in Liwan gas field is 1 470 m.

To drill in the deepwater, a new vessel of COSL, the sixth generation drilling rig, was in construction in 2006. COSL selected two ways to step into deepwater[2]. One is to build a deepwater semisubmersible in cooperation with other company, the other is to modify and add some equipment to existing semisubmersibles to turn them into the deepwater drilling rigs. It needs a long time, approximate 4~5 years, to fabricate the vessel used for deepwater drilling, so COSL plans to adopt proper facility to improve existing semisubmersibles for drilling in deepwater. The improved semisubmersibles will drill in deepwater before new deepwater vessels start in operating[3].

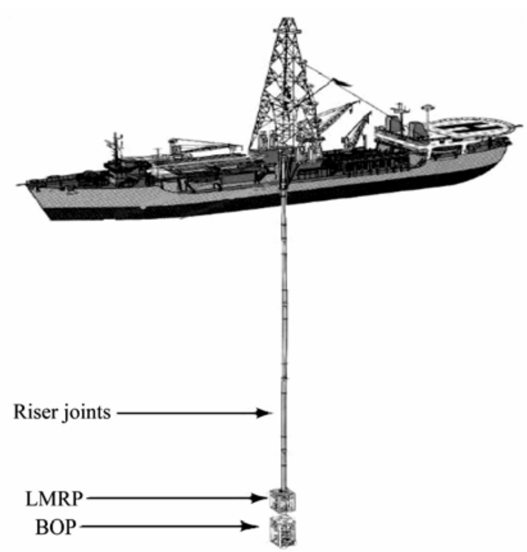

Fig.1 Drillship in Liwan

Of course, the cost of improved semisubmersibles would be lower than that of an ordinary deepwater vessel. It is

Received date: 2009-02-27.
***Corresponding author Email:** guoyongf@cnoocs.com

estimated that the newly fabricated semi-submersible will drill in the water depth ranging from 1 500 m to 3 000 m and the improved semisubmersibles will operate in shallower water of 1 500 m.

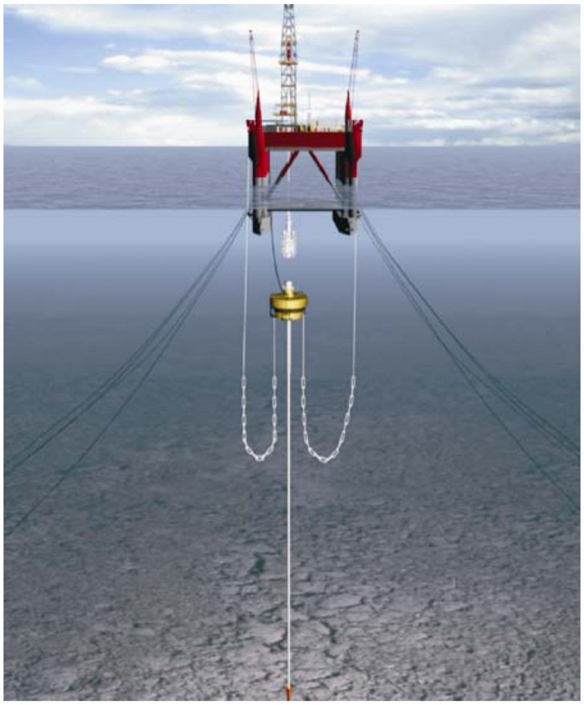

Fig.2 Concept of ABS

2 Atlantis concept for deepwater drilling

It is simple about Atlantis concept, also called artificial buoyancy seabed (ABS) concept to drill in deepwater. The concept of Atlantis was invented by a Norwegian in 1993, and the main principle was to form an artificial seabed by a buoyancy module between the under section of semi-submersible and mud line. The upper section of the buoyancy module connects the risers and lower section will connect the seafloor or the mud line through some special casings, which are called tie pipes in general. A conventional blow out preventer (BOP), rather than a sub-sea BOP, is installed at the top of the buoyancy.

The ABS provides a buoyancy assisted stable semi-submersible 200 m to 400 m below the sea surface using a tieback of 22-in casing string from the first casing in the well as an anchoring system[4]. This means that the BOP and riser do not have to run to the seabed in deepwater. Less expensive rigs can carry out the drilling, which is anchored by the taut-leg polyester moorings, and the subsea equipment will not be subjected to very low temperatures which are associated with flow assurance problems. Installation of the buoy can be achieved by standard anchor handlers instead of heavy lift vessels. The profile of the system is shown in Fig.3.

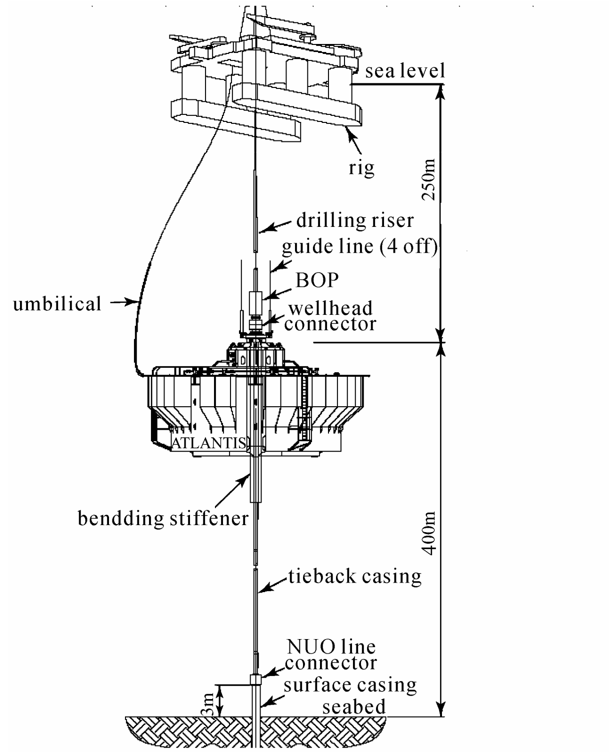

Fig.3 Illustration of ABS

3 Series of tests for ABS concept

After reviewing the concept of Atlantis or ABS, COSL started to design and execute a series of tests in labs, pools, and even lakes in the areas of south and west China. To prove the feasibility of the concept to drill in deepwater, an artificial buoyancy seabed was fabricated in 2002 and the marine trials were carried out in Stavanger of Norway in April 2003, as shown in Fig.4. They were conducted through the cooperation of both COSL and the company, ADTH, from Norway[5].

Fig.4 ABS unit's marine trials in Stavanger, Norway

The main conclusions can be drawn from the marine test:

- The towing operation can be successfully performed.
- The ABS unit can be submerged to 200 meters water

in a controlled manner by the chain weight method. This operation can be done in less than one hour.

- Control of subsea valves, change of trim and level control are verified.
- ROV activities in the 200 meters deepwater can be carried out.

There were 8 tests being designed and carried out. Some of them were designed to prove the feasibility of the facility, and others to prove the performances of the facility[6]. The contents of tests that prove the feasibility of the facility are shown in Table 1.

A series of feasibility reports about this concept were based on the summary of the tests. And several seminars were held and workshops were established in the cities of China to discuss the concept. It is concluded that the ABS can be a replacement for the deepwater drilling vessels that operate in the water of 500 m to 1 500 m[7].

COSL will carry out more tests before upgrading the facility of ABS and starting the trial well for this concept.

Table 1 Tests to prove feasibility of ABS unit in deepwater

No.	Time	Places	Method	Purpose of test
1	August, 2004	Shanghai Jiaotong University	Simulating by sea construction software of computer	Instructive strength
2	August, 2004	Shanghai Jiaotong University	Model test in the pool of 5 m deep	Instructive strength and stability
3	March, 2005	Harbin Engineerin g University	Simulating by FEM software of computer	Static response between drill semi-submersible and the facility
4	March, 2005	Xi'an Jiaotong University	Simulating by FEM software of computer	Dynamic response between drill semi-submersible and the facility

4 Tests to prove feasibility of frame

After completed the feasibility report, COSL arranged a lot of tests again as presented in Table 2. Meanwhile, a test about the mechanic properties of facility was conducted by ADTH in Marintek Ocean Laboratory, Trondheim, Norway[7].

The purpose of these tests is to acquire the data about properties of the facility, including the mechanics of not only statics but also dynamics, hydraulics, and environment, and so on. The tests give the data about the maximum resistant force under the current impact, the maximum offset of the facility during bad weather, the maximum lift force when buoyancy is vacuumed, and the maximum bend when current impacting becomes biggest.

Table 2 Tests to prove performance of the facility in deepwater drilling

No.	Time	Places	Method	Purpose of test
1	March, 2005	Shanghai 708 Shipping Institute	Review to historical casing and simulation of software	Risk analysis of the facility in operation
2	March, 2005	Beijing Marine Institute	Motion Analysis by historical casing and simulation of software	Motion analysis
3	March, 2005	Qingdao Ocean Environment Institute	Review to historical casing and simulating of software	Predicting the environment effect on the facility
4	March, 2005	Shanghai Jiaotong University	FEM simulating further	Analysis of mechanics in details
5	April, 2005	Marintek Lab of Norway	Model test in pool of 10 m deep	Disconnect in case of emergency
6	April, 2005	Kunming city	Big model test in the lake of 140m deep	Simulating the operation in deepwater

5 Large model test in lake

To prove both feasibility and properties of the facility, COSL designed and executed a large experiment in the lake of 140 m deep in Kunming, China.

5.1 Test procedure

The test in Kunming was a large-scale experiment for deepwater drilling, and it took almost one month. Ten tons of steel was used to build the model and modify the vessel, besides, four sets of monitor instrument were installed for the test. The key stage lasted 2 days to perform the load testing of the facility in the lake. The model in this test consists of a 6-in, 150 m long pipe[8].

It is not only important but also necessary to carry out a large-scale model test before drilling a test well. The analogy method in the dimension analysis was used to design a series of models in the lake of 140 m deep to simulate the drilling procedure in the deepwater.

Not only geometrical similarities but also physical similarities were applied to the tests. In the geometrical analogy, it is introduced by the engineers from the method in dimensional analysis, which the scale is 1:10 in geology in the direction of axis; in other words, the ratio is 1:10 between the model and the prototype. The pipe would be simulated to the casing of 20 inches in deepwater environment. There are 27 inspecting points by the sensors of both stress and strain, from above of water to under water, until the bed of the lake.

5.2 Testing program in the lake

- Investigate the environment of the lake;
- Draw the rough charts about the trial of the ABS unit model;
- Calculate the main data for the trial work, such as geometric and physical and hydraulic data;
- Invite some experts to check the results, and propose suggestions in seminars;
- The report of calculating had been sent to a special committee for review, then it was approved by the committee;
- To purchase materials and manufacture facilities for simulating deepwater drilling in the lake according to the data calculated;
- To install the frame for simulating the rig of the deepwater drill in the vessel, and other measuring instrument in relative vessels that would be a part of the experiment;
- Start to operate in the lake after finishing the trial test of ABS unit model;
- Review and propose the data transmit from various instruments during the trial in the lake, and explain the result of tests, then make out the final report about the lake test for the model of ABS unit.

5.3 Acquire data from the test

In addition, there are many ways to get data and information, for example, data can be acquired from the face and underside of water cameras, by using the instrument to measure incline, and other instrument of measurement. The engineers did not consult relative materials to prove that there were no other experiments of deep water drilling in other place of the world. Fig.5 is about the situation of the test for deepwater drilling in a lake of Kunming.

Recently, COSL has decided to drill a test well, called ABS, for the facility, to try to drill wells by using a semi-submersible attached to the facility in deepwater. It is scheduled at the beginning of 2009.

Fig.5 Situation of the deepwater drilling test in a lake of Kunming, China

6 Some test results

6.1 Dynamic roll and pitch motions of the Atlantis unit

The measured roll and pitch motions at the natural frequencies of the Atlantis Unit, were in general small, with amplitudes of about 0.2 degrees[9].

The largest dynamic roll and pitch motions of the Atlantis Unit were measured at a towing speed of 2.5 m/s. The maximum measured dynamic roll and pitch amplitudes were 0.21 and 0.18 degrees respectively.

6.2 Dynamic bending moments at the upper end of casing

The maximum measured bending moment amplitudes in roll and pitch around the natural frequencies of the Atlantis unit were about the same in roll and pitch directions[10]. At a towing speed of 2.0 m/s, the maximum dynamic moment amplitude was about 23% of the mean pitching moment (static moment). At a towing speed of 2.5 m/s, the maximum dynamic moment amplitude was about 14% of the mean pitching moment (static moment).

7 Procedure of the drilling operation

The result of using the facility is that operation in deepwater will be the same as shallow water[11]. It will improve the capability of the semisubmersible if ABS facility would be used when drilling, which could increase the operation depth of water, from 457 m to almost 1 500 m. The procedure of drilling operation about making use of the ABS facility is shown as follows, step by step:
Drilling of well commences at seabed.

- Set casing and cement at seabed
- ABS towed towards rig
- ABS ready for submersion
- Prepare to run tieback casing
- ABS in the position below the drilling rig
- Tie-back casing entering ABS
- Connector above seabed

- Tie-back casing connected at seabed
- ABS being raised
- Wellhead landing out
- Air being pumped into ABS
- BOP above ABS
- BOP landed on ABS
- Ready to drill ahead

8 Conclusions

Some preliminary conclusions have been achieved through above discussions.

- The concept of Atlantis is feasible according to the results of tests and simulations by both pool and software being carried out so far.
- The concept of Atlantis has some advantages comparing with DP drilling ship, such as lower cost, and more convenient to operate in some deepwater area, and more effective in operating the semisubmersibles, etc.
- More researches and tests are required before such a concept getting to industrial application.
- Whatever, the concept of Atlantis has been a prospect for the deepwater drilling, especially as an alternative to DP drill ship in the water of 500 m to 1500 m.
- The concept of Atlantis has some defects, for example, the operation period is longer than DP ship, and it would have more risk when operating to drill in deepwater.

For the trial test plan, refer to the Appendix.

Appendix

Trial test well in the South China Sea

1) Site for preliminary trial

- The site of preliminary trial well will be in the South China Sea at 18.685º N, 112.478º E (18 42 N, 112 26 30.12”E), and a water depth of 476 m;
- Preferably at or near actual trial well site/with the same current conditions of trial well site.

2) Purpose

This document provides an overview of requirements and procedures for a preliminary offshore trial of the Atlantis Unit.

The primary purpose of this trial is to assess vessel capability / develop the particular ship handling skills required for deployment, station keeping and recovery of the AU, thereby reducing the risk of accidental events during the actual trial well.

The secondary purpose of the exercise is to function test and calibrate the umbilical, control systems and ROV facilities, with the intention of further reducing the MODU’s exposure to risk during the actual trial work.

Fig.6 Trial test well in the South China Sea

3) To carry out trial test in the sea

- To execute trial test in the South China Sea from May 29th to June 7th;
- It is located at a place 250 km away from the east of Hainan island;
- There were 3 AHVs took part in the operation.

4) Contents of trial test operation

- Drawing the buoyancy in a long distance;
- To install the weight chains;
- The test of sunk buoyancy;
- The test of stability of buoyancy under 250 m from the surface of the sea;
- The test of shift of buoyancy by both AHVs;
- Operating of ROV when the buoyancy is sinking;
- The buoyancy float testing.

References

[1] AVIGNON B, SIMONDIN A, TFE. Deep water drilling performance[C]// SPE Annual Technical Conference and Exhibition. San Antonio, 2002: 77356-MS.

[2] FOSSIL B, SANGESLAND S. Managed pressure drilling for subsea applications; well control challenges in deep waters[C]// SPE/IADC Underbalanced Technology Conference and Exhibition. Houston, 2004: 91633-MS.

[3] CHILDERS M A. Operational efficiency comparison between a deepwater jack up and a semi submersible in the Gulf of Mexico[C]// SPE/IADC Drilling Conference. New Orleans, 1989: 18623-MS.

[4] AVELAR C S, SANTOS O L A, RIBEIRO P R. Well control aspects regarding slender well drilling with surface and subsea BOP[C]// SPE Latin American and Caribbean Petroleum Engineering Conference. Rio de Janeiro, 2005: 94852-MS.

[5] CHILDERS M, QUINTERO A. Slim riser–a cost-effective tool for ultra deepwater drilling[C]\\ IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition. Kuala Lumpu, 2004: 87982-MS.
[6] TOUBOUL N, WOMBLE L, KOTRLA J, et al. New technologies combine to reduce drilling costs in ultradeepwater applications[C]// SPE Annual Technical Conference and Exhibition. Houston, 2004: 90830-MS.
[7] JAMES J P, REZMER-COOPER I M, SØRSKAR S K. MABOPP─New diagnostics and procedures for deep water well control[C]// SPE/IADC Drilling Conference. Amsterdam, 1999: 52765-MS.
[8] KARLSEN G, SIKES J D. 6000-ft water depth upgrade of the sonat discoverer 534[C]// SPE/IADC Drilling Conference. Amsterdam, 1991: 21981-MS.
[9] GUO Yongfeng, JI Shaojun, YE Aijie. Predicting performances of device of deepwater drilling by both testing in pool and simulating by computer[C]// 4th PetroMin Deepwater and Subsea Technology Conference and Exhibition. Kuala Lumpur, Malaysia, 2006.
[10] GUO Yongfeng, JI Shaojun, YE Aijie. New device for drilling in deepwater under semi submersible: ABS unit[C]// IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition. Bangkok, 2006: SPE-101349-MS.
[11] GUO Yongfeng, JI Shaojun, TANG Changquan. Feasibility of deepwater drilling in South China Sea by applying ABS unit[R]. Lisbon, Portugal: The International Society of Offshore and Polar Engineers (ISOPE), 2007.

GUO Yong-feng is a senior engineer for China Oilfield Services Limited; and he acquired his master degree in mechanics of drilling from Petroleum University in 1994; he went to Norway for studying and visiting in 2004, 2005 and 2006; he majored in the offshore petroleum development, special in the developing of oilfield in deepwater since 2000. He had published a book on drilling engineering of offshore, and was invited to take part in conferences in America, Indonesia, Portugal, and had the lectures in these conferences.

JI Shao-jun is a senior production engineer for China Oilfield Services Limited. She graduated from China University of Petroleum, major in mechanical engineering. Her current research interests include deepwater drilling device in China offshore, etc.

TANG Chang-quan is a senior production engineer for China Oilfield Services Limited. He graduated from China Jianghan Petroleum Institute, major in logging. His current research interests include deepwater drilling device in China offshore, etc.

深水钻井的“人工海底”技术开发和中国南海预试验井的实施

郭永峰，纪少君，唐长全

（中海油田服务股份有限公司，北京 101149）

摘　要：介绍了中海油田服务股份有限公司在中国南海进行的预试井活动，讨论了将用于深水油田钻井作业的人工海底新技术. 深水钻井市场在最近 10 年中处于不断扩张的过程，目前世界上用于深水和超深水钻采作业的钻井船和平台数目不足.中国目前也需要更多的设备用于深水海洋的钻采作业. 中海油田服务股份有限公司目前拥有的一些半潜式钻井平台可以在水深浅于 475 m 的水深中进行作业. 自从 2004 年以来，中海油田服务股份有限公司与挪威公司合作，进行人工海底技术的研究和改进，这种技术发展的目标是，利用较浅水作业的钻井平台，进行水深 1 000～1 500 m 的油气田的钻井作业. 介绍了该种技术研究和改进的过程，相关装备的生产和更新. 2008 年 6 月，在中国南海的 500 m 水域应用人工海底技术进行了预试验井的作业. 2009 年，中海油田服务股份有限公司将在中国南海的同一海域进行另一次更深入的实际钻井作业.

关键词：深水工程；人工浮力海底；模型试验；最大承载力；预试井