Technology for Subsea 3D Printing Structures for Oil and Gas Production in Arctic Region

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Abstract. The article considers an unconventional technology of offshore oil production and the prospects for its further development. The complexity of Arctic shelf development and the use of subsea production units have been analyzed. An issue of the subsea drilling unit construction technology with the help of 3D printers has been considered. An approximate economic efficiency calculation of the 3D printer technology introduction has been given.

1. Introduction

Amid the low oil prices in 2016, the production of oil and gas condensate in Russia grew by 2.5% compared with the same period in 2015 and amounted to 547,499 million tons.

In January 2017, Russia increased its oil export, despite the officially claimed reduction of its production (according to Reuters)

According to media reports, the production was reduced by Russia by 110 thousand barrels per day, while export increased by 114 thousand barrels.

Such amount of oil per day has not been produced in Russia throughout the whole post-Soviet period of its history, sais Bloomberg news agency. According to the agency, the peak of oil production volume of 11.4 million barrels a day was produced in the USSR in 1987 [1]

The process of oil production is complicated by the increase in the number of flooded wells. In crude oil water content reaches 90%. In this regard, oil and gas professionals are forced to seek unconventional methods to increase and stimulate oil production [2-6].

In connection with oil reserves depletion on the continent, oil companies are gradually moving from continent to shelf [7,8].

According to Russian estimates, the Arctic shelf may contain up to 80% of Russia’s potential hydrocarbon resources. The urgency of offshore oil production becomes economically inevitable. Unfortunately, it should be noted that today in Russia there are no required technologies and technical means for the development of new offshore fields in the Arctic.

For a long time it has been assumed that the ocean oil is concentrated only on the shelf. But exploration has discovered giant fields at the depths of 2-4 km under water. According to the author [9] this is not the shelf but a continental slope.

A competent and sophisticated state program for oil and other natural resources production on the Arctic shelf is a prerequisite for the country's economic power [10].
In 2008 non-profit public organization "Bellona" conducted an analytical review (the review author is Vladislav Larin) of subsea drilling rigs for offshore oil-gas field development in Russian Arctic seas [10].

The development of new offshore fields in the Arctic is complicated by harsh climatic conditions in the region. One of the proposed solutions is the use of subsea production units. Such units are developed by the design bureau, which in due time designed nuclear submarines. They propose to build subsea drilling systems, subsea support vessels, icebreakers, floating nuclear power plants, etc., for the development of Arctic fields.

“Bellona” believes that the development of the Arctic shelf itself is associated with numerous environmental risks, not to mention the fact that no country in the world has any experience of work in such conditions. These risks will increase significantly due to the use of nuclear energy. In the case of an emergency, it will be very difficult (if not impossible) to implement post-accident cleanup. Moreover, the economic component of such projects looks very unconvincing.

“Bellona” has doubts about the development of oil-gas fields in the Arctic, as this understudied region is the most vulnerable on the planet and will not sustain a large industrial load [11].

2. Research

The most common technology of offshore oil production is the use of a floating drill rig [12]. To ensure environmental safety during the development we need fundamentally new requirements [13].

The authors propose to discuss a subsea drilling unit construction with the help of 3D printers.

The 3D printing technology is evolving rapidly and finds application in various fields of activity. The method of creating a layered object based on a virtual three-dimensional model has been successfully used in engineering, electronics and medicine. Using the technology of 3D printing it is possible to create buildings and architectural structures.

Approximately since the mid 2000-s various universities have been parallelly conducting the research work focused on the possibility of using 3D printing in the construction industry.

In 2012, Professor Behrokh Khoshnevis from the University of Southern California, presented his innovative project –construction of buildings using a 3D printer.

The space agency of NASA, rather than construction companies, was the first to get interested with new opportunities in the field of construction. It has provided a special grant to study the possibility of use of 3D technology in construction of facilities for space exploration on the Moon. 3D printers don't need air to operate. They can perform operation in the most extreme conditions including vacuum space or very high temperatures [14].

Use of 3D printing technologies for subsea construction of buildings has never been studied (Figure 1). Therefore, research in this area could lead to new breakthrough technologies capable of radical transforming equipment and methods for ocean mining, especially in the Arctic and Antarctic regions containing new energy resources. This stipulates high relevance and scientific significance of these studies.
Diagram of box concreting is shown in Figure 3. The concreting technology has been developing, as mentioned above, in civil engineering. The proposed concreting technology is characterized by the occurrence of caisson.

The technology of manufacturing an anti-washout concrete mix has been practically developed on an industrial scale. The results of research of concrete rheological properties for underwater concreting have been obtained. In recent time concrete mixes for underwater concreting are widely used in construction and repair works in hydraulic structures, construction of the underwater parts of bridge footings, foundations, power transmission poles [15].

Concrete mixes for underwater concreting have been developed for more than 20 years [16,17]. Anti-washout additives to concrete grouts for underwater concreting have been developed. An example is the Rescon T additive. This additive was granted with an FCB certificate of the Research Institute of Cement and Concrete in December 1983, Tr Heim NTH Norway-STF 65 № A83089 and certificate number S131-1 of National Scientific Research Institute of Sweden [18].

According to the authors of the article, the development and experimental study of the basics of the technologies for subsea 3D printing of structures for oil and gas production in the Arctic region, will provide:

- a solution for new scientific and engineering tasks of creating a technology able to excell significantly all the existing oil-and gas production technologies based on offshore and ice platforms;
- an emergence of new national scientific and technical products conforming to international standards;
- significant scientific results which allow creating and launching new products in the scope of field development and oil and gas production technologies in the Arctic region;
the beginning of mass industrial development of the ocean bottom.

The proposed technology of construction of the drilling rig using 3-D printing has the following advantages:

- a fully robotic process of basic facilities construction;
- a possibility of installation and replacement of specialized modules in the basic boxes;
- the modules are manufactured at petrochemical enterprises;
- no shipbuilding industry resources required;
- construction period of 2 - 3 years;
- the cost of construction does not depend on the sea depth;
- ice and atmosphere do not affect the operation of the unit;
- fully robotic operation.

“NPP “Tenzosensor” specialists made an approximate calculation of the proposed subsea unit. Offshore ice-resistant stationary platform “Prirazlomnaya” was regarded as an analogue for comparison. It is assumed that the cost of the project will be about 90 billion rubles, or $ 2.5 billion (as of 18.04.2014 ) [19].

The approximate calculation of the cost of the proposed subsea unit for oil production in two variants is shown in table 1.

Table 1. The cost of the subsea unit for oil production analogous to offshore ice-resistant stationary platform “Prirazlomnaya”

| Characteristics                                  | Var. 1   | Var. 2   |
|--------------------------------------------------|----------|----------|
| Box diameter, m                                  | 15       | 20       |
| Box inner area, m                                | 177      | 314      |
| Box height, m                                    | 50       | 50       |
| Box volume, m³                                   | 8836     | 15708    |
| Required capacity of oil tanks, m³               | 150000   | 150000   |
| Amount of oil tanks, units.                      | 17       | 10       |
| Box wall thickness, m                            | 1        | 1        |
| Box outer area, m²                               | 201      | 346      |
| Box wall cross-section, m²                       | 24       | 32       |
| Box walls volume, m³                             | 1217     | 1610     |
| Volume with regard to the foundation and the dome, m³ | 1522     | 2013     |
| Concrete cost, US dollars per m³                 | 100      | 100      |
| Construction materials cost, US dollars          | 1522001  | 2013000  |
| Cost of work with regard to the overhead cost of 1000%, mln.US dollars | 15 | 20 |
| Total cost of construction, mln. US dollars      | 16.2     | 22.0     |

Approximate unit structure

| Amount of drilling boxes, units. | 5   | 5   |
| Amount of crew boxes, units.    | 3   | 3   |
| Amount of oil tanks, units.     | 17  | 10  |
| Amount of technical boxes, units. | 5   | 5   |
| Boxes in total, units           | 30  | 23  |
| Cost of the unit without equipment, mln. US dollars | 486 | 506 |
| Cost of the unit with equipment, mln. US dollars | 873 | 893 |
| Cost of the unit in billions of US dollars | 1,359 | 1,399 |

The use of 3D printing in construction of a subsea unit suggests the following benefits compared to currently used technologies:

- the cost of subsea units constructed with the use of 3D printing will amount to 1.3 to 1.4 billion US dollars, even with the box wall thickness of 1.0 m and overhead costs of 1000%;
1.2 to 1.3 billion US dollars will be saved using one platform;  
the construction period will be reduced to 2-3 years;  
no need to engage shipbuilding industry resources;  
the impact of ice and atmosphere are excluded

3. Conclusion
If we consider that exploration of the Western Arctic shelf will require from “Rosneft” minimum 15 platforms, and in the case of commercial discoveries at the stages of “development” and “production” another 106 platforms of different types will be required; the total economic effect from implementation of the underwater printing technology can range from 127 to 137 billion US dollars.

The authors consider the described method as an alternative to the existing technologies of offshore oil production.

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