Ocean Journal of Chemical and Petroleum Engineering

Review Article

Current Issues of Oil Production at Offshore Fields

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ABSTRACT

The recovery and use of oil has lead to tremendous technological progress worldwide. The amount of power available to the human population has grown, manual labor has virtually disappeared, people are travelling very long distances and labor efficiency has increased at a massive scale. The impact of oil & gas production on our environment – and on mankind's moral compass – has become evident.

We are currently witnessing a high-rate of exploitation of oilfields at the stage of declining production.[1-5] Production decline is a result of the depletion of onshore and offshore oilfields. Naturally, the most common method of oil well operation is the use of low-capacity electric submersible centrifugal pumps (ESP). The operation of such oilfields at the late stage of production using ESPs has created a number of problems: 1) deeper location of centrifugal pumps in wellbores; 2) inability to study oil wells with centrifugal pumps using conventional startup and operation monitoring methods; 3) unprecedented growth in low-capacity ESP faults due to salt deposition.[6-9]

Many large oil producers are preparing for the development of fields in the offshore area of the Arctic Ocean and in the Antarctic, and quite naturally, we tend to hope that the world's water surface will remain pristine – that the oceans and coastal regions will remain conducive to the wellbeing of the planet's great variety of fauna and flora, as well as to human beings.

However, one of the most important tasks in the development of our vast offshore areas entails the revision and advancement of the theory of ESP operation. This theory must provide for the automation not only of the ESP operational control process, but also of the oilfield as a whole. Only upon fulfillment of the aforementioned tasks does it become possible to discuss the ecological safety of oil production in the offshore area of the Arctic Ocean and in the Antarctic.

Keywords: Offshore Field; Electric Submersible Centrifugal Pumps; Control Station

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Citation: *Gareev AA. Current Issues of Oil Production at Offshore Fields. Oce Che Pet Eng Jour.2021;1(1):1-5.*

Received Date: 30 September, 2021; **Accepted Date:** 2 October, 2021; **Published Date:** 5 October, 2021

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INTRODUCTION

Offshore field exploitation using electric centrifugal pumps. Development of the theory of centrifugal pump control automation. Reduction of oil production costs at offshore fields.

In recent years, the technology of oil recovery using electric centrifugal pumps has progressed by leaps and bounds:[10] the creation of compact electric submersible centrifugal pumping units (ESP units) and pump stages made of plastic, the application of valve actuators, the development and testing of pumps with a shaft rotation speed of up to 10,000 rpm, the application of VFDs, separators, various versions of gas handlers and scale inhibitors, the use of pressure and temperature sensors in pumping units, and so on.

To control these centrifugal pumps, control stations (CS) with frequency converters, approximately equivalent in terms of design, were created around the world. However, scientifically-based production engineering is lagging behind in terms of its development – not only in Russia, but in other countries as well, especially as concerns the use of ESP units with a capacity of less than 50 CMPD.

Bearing in mind that these ESP units account for over half of the operating stock of each oil & gas production enterprise, are used after the development of new wells and workovers and provide for over 70% of total oil recovery, today's lag in production technology is becoming a hindrance to the further efficiency growth of oil production using low-capacity ESP units.

The necessity of an operational theory for electric centrifugal pumps is also being driven by the fact[11,12] that, against the backdrop of the depletion of oil formations at producing fields and despite the application of stimulation techniques, the fleet of low-capacity ESP units keeps growing. New oilfields involved in production have hard-to-recover reserves, where the extraction of oil is being performed with low-capacity ESP units. The control of ESP units at hard-to-recover oilfields (equipment selection, operation, etc.) is being conducted under rather unfavorable conditions for centrifugal pumps, where a certain level of control and decision-making skill is required during installation in order to achieve the desired economic benefit. The results yielded and analysis accumulated in examining the causes of ESP unit failures prove that a study of the thermal behavior of electric submersible pumps is capable of providing a clue for researchers towards meeting the challenge of ESP unit control.

Instrumental studies of submersible (downhole) motors indicate that motor temperature is not always related to a pump's thermal behavior. On the contrary, with minimum heat release, i.e. when the motor is running in an operating cycle close to an idle run, the pump generates maximum heat, which may lead to a breakdown of the entire unit.

It should be noted that the control stations currently in use are only concerned with the state of downhole motors and barely deal with centrifugal pumps at all. Therefore, all attempts at automating the centrifugal pump's startup and ramp-up and tracking its operation have thus far been unsuccessful.

Tests of "smart control stations" for the purposes of automation amount to nothing more than semiautomatic/semimanual well operation techniques.

And finally, today's "oil-production technology" is based on empirical laws established for a narrow range of variation among centrifugal pump parameters and the rheological parameters of oil in situ. These empirical laws have been unjustifiably "expanded" for common application. No wonder, then, that the arbitrary expansion of the scope of validity of empirical laws is leading to mistakes or even to conflicting results (separation ratio, speed of gas-bubble movement, range of suction-pressure variations, etc.). Only the use of the fundamental laws of physics is capable of propelling the theory of ESP operation to a new frontier – of providing further enhancements to the economic efficiency of low-capacity ESP units used at hard-to-recover oilfields.

1. The solution of ESP control tasks demands the application of the laws of thermodynamics.

In point of fact, the main cause of ESP failures during the pumping of liquid-gas mixtures is the dissipation of the mechanical energy supplied to the pump and its conversion into heat.[11] The intensity of heat generation and propagation determine the "fate" of the centrifugal pump in terms of its service life. Solving the problem of an ESP's thermodynamic condition during the pumping of multiphase mixtures is rather complicated in theoretical terms; there is no classical solution to this problem in the annals of theoretical thermophysics.[1-2, 13] The lack of a classical solution in analytical expression or in digital form and the unavailability of related educational opportunities for students – future oil engineers in the field of mathematical physics – are combining to aggravate the current problems of ESP operation in oil production.

2. Solving the ESP control task during the pumping of multiphase mixtures will eliminate the problem of the investigation of wells and control of ESP behavior,[3-6] thereby enabling a substantial reduction in production costs.

Indeed, the depletion of producing fields makes the exploration of productive formations and the study of ESP behavior even more complicated. The lack of valid data is leading to many negative effects, reducing the overall economic efficiency of the oil recovery method.

Another not unimportant factor is the unpreparedness of supervising manpower for the operation of such oilfields. At present, not a single institution of higher education in any country offers courses on the subject under discussion.

3. The solution of ESP control issues could help create a scientifically-based pump operation procedure and eliminate such issues as failures and salt deposition.

Current methods of fighting salt deposition in centrifugal pump elements are ineffective to say the least, since they lack a tracking tool.[7-9] At the same time, the application of acids to stop salt deposition is dangerous to the well structure per se and could lead to an ecological disaster due to a breach in the hermetic sealing of the well's structural elements.

4. Developing an automatic ESP unit is impossible without studying the centrifugal pump's thermodynamics, i.e. without the technology of the future. Automation, aka "unmanned operation," will eliminate human errors and allow for the flexible control of a well stock, an oilfield or an enterprise in terms of various parameters of oil production – from energy savings to the maximization of oil output. Automation will undoubtedly make oil production a more environmentally-friendly and profitable business.

5. In order to achieve the aforementioned goals, the course on the theory of the development of oil & gas fields must be updated at technical colleges on the basis of emerging scientific research results.

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