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Hydrates Production Prediction With Computer Modelling Group (CMG) Stars. A Comprehensive Review

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Abstract: *Hydrates are an enormous energy resource with global circulation in the permafrost and in the oceans. Even if conventional estimates are deliberated and only a small fraction is recoverable, the pure size of the resource is so huge that it demands assessment as a potential energy source. In this research work, we discuss the hydrate production prediction with Computer Modeling Group STARS (CMG STARS). In this paper different literatures reviews have been visited concerning hydrate production prediction with CMG STARS and this have been done through consulting internet search in which secondary data were extracted. It was observed that most literatures does not quantify the knowledge on how hydrates production prediction with CMG STARS can be done. It was recommended that in the future, the research work on hydrate production prediction with CMG needs to be done by performing sensitivity analysis of different reservoir parameters which affect production process and commences the simulation model for the production prediction*

Keywords— Hydrates production, CMG STARS, permafrost, hydrate dissociation, non-stoichiometric, one factor at a time (OFAT), Arctic region

1. INTRODUCTION

Energy call is anticipated to increase uninterruptedly in the upcoming years for meeting the human society's grows. In contrast, the ever-scarcer fossil energies including petroleum, coal and natural gas impede human society's continuous development. Therefore, it is essential and urgent to develop new alternative energy sources. Solar energy, wind energy, ocean energy, biomass energy and nuclear energy have undergone profoundly the development of the different levels in the different countries [1].

Gas hydrates are non-stoichiometric combination of gas molecules and water molecules under the conditions of high pressure and low temperature.

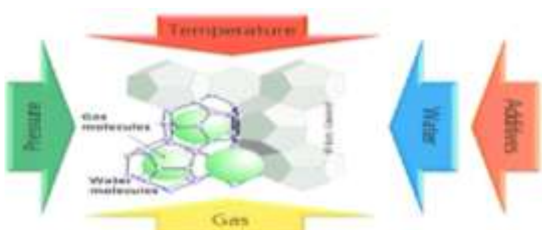

Figure1: Influencing factors (sI) for hydrate formation [2]

Typically has been termed as the crystalline solid compounds consisting of a gas molecules surrounded by the cage of water molecules due to the hydrogen bonding and Van der Waal's forces. The crystalline structure formed are classified as sI, sII, and sH. Its stability favor the situation having deep-water sediments of the world's ocean [3-5].These gas hydrates is composed of natural gas molecules trapped inside the ice structure. It is estimated that gas hydrates is twice as much carbon as all other fossil fuels (coal, natural gas, and oil) combined. Scientists and the world in general believe that in 1810, Sir Humphrey Davy, first obtained hydrates by cooling a saturated solution of chlorine in water well below 9°C [6].

It is believed that natural gas hydrate are widely dispersed in permafrost region and offshore places. With the growing knowledge on the distribution and gas hydrates saturation in sediments, the global assessments of hydrate-bound gas have decreased by at least one order of magnitude. Currently more than 230 Natural Gas Hydrate deposit have been discovered [7, 8] and these deposits found in both permafrost regions and in Arctic regions [9, 10].

The three main mechanisms of hydrate dissociation for gas production include: (1) depressurization, in which the pressure is lowered below the level of equilibrium value of stability region PH, at the prevailing temperature [11]; (2) thermal stimulation, in which the temperature is increased above the dissociation temperature TH, at the prevailing pressure [12]; and (3) the use of inhibitors injection (methanol, glycol and salts), shifts the equilibrium temperature and pressure from stability region and causes hydrate decomposition [13].

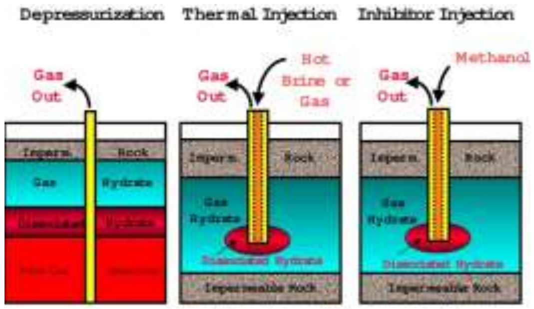

Figure 2: Hydrates production methods [14].

Commercial reservoir simulator (CMG STARS simulator) is possible to be used to construct the hydrate production prediction and make the forecast of the gas production to be feasible in gas industry by establishing the simulation model.

The aim of this research paper, is to visit different literatures on the hydrate production prediction with CMG STARS, in which studies about hydrates production and prediction model using CMG STARS simulator are extensively visited.

2. BACKGROUND AND LITERATURE SURVEY

The authors in [15], developed a model that incorporates two hydrate-bearing sand units using detailed reservoir geological and structural information obtained from past and recent drilling programs, their analysis revealed that 2D reservoir models with homogeneous demonstrations for porosity and hydrate saturation significantly underestimate production potential.

Using Advanced Processes & Thermal Reservoir Simulator (STARS) that approximates the production design and response of this gas hydrate field, the authors in [16, 17], developed a model of field scale reservoir for Sunlight Peak, and in their model it was found that the proximity of the reservoir from the base of permafrost and the base of hydrate stability zone (BHSZ) has significant effect on gas production rates. Generally it was concluded that Sunlight Peak gas hydrate accumulation behaves differently than other Class III reservoirs (Class III reservoirs are composed of a single layer of hydrate with no underlying zone of mobile fluids) due to its smaller thickness and high angle of dip [18].

According to the authors in, [19-21], the gas hydrate decomposition can be represented by the following kinetic equation:

$$CH_4.\mathrm{n}H_2\mathrm{O} \pm \mathrm{Heat} \ \rightarrow + \ CH_4 + \mathrm{n}H_2\mathrm{O}$$

It is the endothermic equation where there is a gaining of heat in high quantity during the decomposition process, in which CH_4.nH_2O is the kind of hydrate, and n is the corresponding hydration number which lies between 5.75-7.4.

The authors in [22-24] dedicated themselves in developing the simulator for numerical simulation of gas production. Empirically, in the last three decades, a lot of excellent accomplishments were achieved, but the major issues such as gas production mechanism from NGH, governing factors, efficiency and economic evaluation were still not solved.

The author in [25] studied the relationship between controlling mechanisms and hydrate dissociation models as well as the features of dissociation front advance have been identified by use of 12 well-designed scenarios considering different thermal boundary conditions, intrinsic permeability, and hydrate dissociation models, and the author revealed that a piston-like dissociation mode was formed while the dissociation of hydrate reservoirs was controlled by either the fluid flow mechanism or the heat transfer mechanism.

The author in [26] developed the geological model, representative of the Gulf of Mexico subsurface, with sand and shale layers with a fault running through them and the author revealed that Permeability and porosity of the hydrate formation zone decreased as solid hydrates form in the pores, from numerical simulations of gas hydrate formation and the study of rock and fluid flow properties during hydrate formation, it was found that the important reservoir characterization tool, can be used for estimation of the hydrate reserves as well as determination of well placement and production strategies.

The author in [27], investigated the effects of the geomechanical mechanisms on the gas production of a depressurized Class-3 hydrate deposit, Four-Way-Closure Ridge and it was found that there was a lower gas production rate and a longer production plateau when geomechanics were considered in the fluid flow modeling.

According to Sun *et* al in [28], the sensitivity analysis on one factor at a time (OFAT) was performed and an orthogonal design were used in the simulation to investigate which factors dominate the productivity ability and which was the most sensitive one, their results showed that the order of effects of the factors on gas yield was perforation interval > bottom hole pressure > well spacing and also the numerical simulation results showed that under the condition of 3000 kPa constant bottom hole pressure, 1000 m well spacing, perforation in greater intervals and with one horizontal well, the daily peak gas rate can reach 4325.02 m^3 and the cumulative gas volume is 1.291×10^6 m^3.

Nandanwar et al in [29] developed a field scale reservoir model that fully defines the production design and the response of hydrate field and CMG STARS was used as a simulation tool to model multiphase, multicomponent fluid flow and heat transfer in which an equilibrium model of hydrate decomposition was used and deliberate the sensitivity analysis of the effect of the reservoir properties and working parameters on the overall productivity of the reservoir, they found the response of the reservoir to pressure and temperature changes due to depressurization and hydrate dissociation over a period of time.

According to Mohammadmoradi et al in [30], a direct three-phase pore morphological simulation method was proposed, tested and applied to simulate hydrate malformations and forecast fluid possessions and absolute and effective permeabilities of hydrate-bearing geological formations, they proposed this technique in order to simulate capillary-dominant displacements by applying a set of geomaterial procedures directly to the pixels of pore-level porous media images, they used sandy microstructures created based on the particle size distributions of the Mallik gas hydrate deposit, and the sensitivity analysis showed that although the gas relative permeability was less sensitive to the hydrate qualifications, the porosity, grain size distribution, and hydrate content and occupancy remarkably influence the rock absolute permeability.

According to [31], developed some mathematical models for gas-hydrate reservoirs and the various governing equations of fluid flow, heat transfer, thermodynamics and kinetics of hydrate decomposition, which were all integral to gas production from hydrate reservoirs, and were solved simultaneously to develop two predictive models to forecast the performance of flat and tilted hydrate reservoirs and they further developed, a material balance equation for hydrate-capped gas reservoir, the solution developed was found to be valid during transient, boundary-affected and boundary-dominated flow.

Reagan et al in [24, 32, 33], used the massively parallel TOUGH+HYDRATE code (pT+H) to assess the production potential of a large, deep ocean hydrate reservoir and develop strategies for effective production and their simulations revealed the challenges inherent in producing from deep, relatively cold systems with extensive water-bearing channels and connectivity to large aquifers, mainly difficulty of achieving depressurization and the problem of enormous water production, also new frontiers in large-scale reservoir simulation of coupled flow, transport, thermodynamics, and phase behavior, including the construction of large meshes and the computational scaling of larger systems were highlighted.

According to authors in [34], a three dimensional finite-difference simulation of heat and mass transfer in a reservoir comprising stratified layers of gas hydrates (50 ft.) and free natural gas (50 ft) was organized and the results showed that in the volumetric depletion gas reservoir, hydrated gas was found to donate about 20 to 30% of the total gas production and this was due to hydrate decomposition as the pressure in the reservoir was lowered.

M. Pooladi-Darvish et al in [35], developed an analytical model to predict the performance of decomposition of gas hydrates in porous media, and used it to perform sensitivity studies to examine the feasibility of commercial gas production from hydrate reservoirs and the results proposed that substantial quantities of gas can be produced from gas hydrate reservoirs where the hydrate superimposes the gas zone.

The authors in [36], studied the effect of the overlying hydrate in enlightening the production performance of the underlying gas reservoir and explored the effect of various parameters on gas production behavior and the rate of gas generated and produced, various parameters like pressure, temperature, and saturation distributions were studied in order to examine the sensitivity of results on individual input parameters and it was decided that the development of gas reservoirs with overlying hydrates led to substantial production rates and that the top hydrates were found to have a large influence on increasing the reserve and enlightening the productivity of the underlying gas reservoir.

Howe et al in [37], simulated the production of gas from a 1 mile by 4 mile reservoir block having hydrate underlain by an accumulation of free gas and the subsequent production profiles were analyzed and found that, the depressurization of the free gas zone lowered the pressure at the gas-hydrate interface below that required for hydrate stability and caused the hydrate to decompose into methane gas and water.

Also the authors in [2], computed the detailed mathematical models of the most relevant chemical and physical processes for the enhanced exploitation of gas hydrate deposits and the basic mechanisms of gas hydrate formation/ dissociation and heat in which the mass transport in porous media were considered and implemented into simulation programs, they found that there was strongly dependence on the deposit conditions, especially multiphase flow rates which were controlled by permeability terms, as well the heat transport within heterogeneous layered deposits led to improved hydrate dissociation and thus higher production rates.

Tabatabaie et al in [38], established analytical model rate of gas generation and hydrate recovery when gas was produced from an inclined hydrate-capped gas reservoir where the geothermal gradient was accounted, then the numerical simulator was used to validate the assumption used in analytical model and the sensitivity analysis of different reservoir parameters were done and the sensitivity results showed how a steeper reservoir that prolongs closer to the base of permafrost leads to less recovery.

Walsh et al in [39], performed the economic studies on simulated gas hydrate reservoirs to evaluate the price of natural gas that may lead to economically worthwhile production from the most promising gas hydrate accumulations, and came up with the result that economic evaluation reliant on the producibility of the target zone, the amount of gas in place, the associated geologic and depositional environment, present pipeline infrastructure, and local tariffs and taxes.

The authors in [40-45], discussed the corresponding production strategies of gas hydrate, and found that simple depressurization appears promising in Class 1 hydrates, but its appeal decreases in Class 2 and Class 3 hydrates in which most promising production strategy in Class 2 hydrates involves combinations of depressurization and thermal stimulation, and was obviously enhanced by multi-well production-injection systems whereas the efficiency of simple depressurization in Class 3 hydrates was restricted, and thermal stimulation (alone or in combination with depressurization) through single well systems seems to be the strategy of choice in such deposits.

According to the authors in [46], developed the simulator to study the formation and the dissociation of hydrates in laboratory-scale core samples and in hydrate formation from the system of gas and ice (G+I) and in hydrate dissociation systems where ice appears, the equilibrium between aqueous-phase and ice (A–I) was found to have a “blocking” effect on heat transfer when salt was absent from the system in which the results showed that rise of initial temperature (at constant outlet pressure), introduction of salt component into the system, decrease of outlet pressure, and rise of boundary heat transfer coefficient can lead to faster hydrate decomposition.

Sun et al in [47-51], developed a thermal, three-phase, one-dimensional numerical model to simulate two regimes of gas production from sediments containing methane hydrates by depressurization, and the model showed that laboratory-scale experiments were often dissociation-controlled, but the field-scale processes were typically flow-controlled and gas production from a linear reservoir was more sensitive to the heat transfer coefficient with the nearby than the longitudinal heat conduction coefficient, in 1-D simulations.

The authors in [22, 52-60], conducted the parametric study of natural gas production from the dissociation of methane hydrate in a confined reservoir by a depressurizing well and they found that the gas production rate depends on various factors such as, well pressure, reservoir temperature and zone permeability.

The authors in [61-63], developed a three dimensional numerical model to simulate the hydrate dissociation behavior in the porous medium of the reservoir during drilling operations and they found that, wellbore pressure and temperature on the dissociation pressure and temperature, velocity and location of dissociation front, all govern a lot on the hydrate decomposition process.

According to the authors in [64-67], studied the hydrate dissociation in a porous sandstone core by using a computer modeling approach, and results showed that the rate of hydrate dissociation in a core was mainly depend on surrounding environment temperature, outlet pressure condition, and permeability.

Zhao et al in [68-72], developed and validated a two-dimensional axisymmetric model to investigate the effect of heat transfer on gas production from methane hydrate dissociation by depressurization, thermal stimulation, and a combination of the two methods and they found that dissociation behavior was affected by reservoir permeability, with high permeability exhibiting spatial hydrate dissociation, followed by an inward moving decomposition front from the surrounding wall of the sediment core.

3. METHODOLOGY

The methodology employed by this research was an ‘Internet Search’, in which the study visited different sources on the internet to find evidence and facts about the hydrates production prediction with CMG STARS. Where possible the websites of the specific resources were consulted, for instance websites of some journals which put materials in HTML format only rather than pdf or word document. The visited literatures are found on the internet. So generally secondary source of data were mainly used in a large portion of this research to come up with the conclusion.

4. DISCUSSION

According to the visited literatures that have been conducted for hydrate production prediction with CMG STARS, many authors discussed on how to simulate the hydrate decomposition either analytically or numerically by using different reservoirs simulators, but in their discussion they didn’t talk exactly on how to conduct hydrate production prediction with CMG STARS. Also on the sensitivity analysis conducted by some authors, they only stated the parameters which affects the hydrate production without considering the environmental condition for each parameter, as well the favorable conditions of hydrate production was not stated in range of data, to show the effectiveness when the environmental condition changes.

Moreover, some authors only studied the rock fluid properties like initial conditions like temperature, pressure and water saturation without starting the effect of capillary pressure on hydrate production using CMG STARS simulator. No any authors discussed the effect of capillary pressure. Also some authors did the code comparison of different reservoir simulator on hydrate decomposition process, but they didn’t state the good simulator in comparison with other, so as to avoid complexity in simulating hydrate decomposition.

5. CONLUSION AND FUTURE WORK

In this paper, the author visited different literatures about hydrates production prediction with CMG STARS, and the results from most of the literatures concentrated on the hydrate production mechanism, numerical simulation of hydrate decomposition, analytical model of hydrate production, but they didn’t touch on hydrate production prediction with CMG STARS. In the future, the author recommends on performing the research on hydrate production prediction with CMG STARS, in which the description of sensitivity analysis of different parameters in stating the range of data need to be done, the analysis of the geologic parameters that control the occurrence and stability of hydrates in nature need to be done, description about hydrates characteristics in relation to the production factors need to be done also.

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