

SEC 储量动态评估与分析

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摘要:自1999年以来, 中国石油公司陆续在境外上市, 储量管理与国际接轨面临巨大挑战, SEC 油气储量评估方法和理念对油气储量计算影响很大。在油气储量计算、评审和 SEC 储量评估的基础上, 总结了类比法、容积法、递减法、物质平衡法和油藏模拟的使用阶段及适用条件。其中, 递减法是最常用的方法, 具有易预测产量和经济生命周期等特点, 因此提出了该方法在应用过程中须注意的问题, 探讨了如何选用递减方法、初始产量、递减率和递减单元及稳产期和废弃点的确定方法。在油田未来规划不确定或油田措施频繁的情况下, 须采用两段式或多段式对剩余经济可采储量进行预测。储量动态评估和分析计算结果与油藏实际开发相结合, 可使动态分析更加符合实际。

关键词:油气储量 动态评估 递减法 递减率 评估方法

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SEC 储量评估规则^[1]是在美国上市的油公司必须遵循的储量评估标准, SEC 储量动态评估是储量评估中的主要工作, 动态评估指采用动态数据(产量、递减率、时间、压力、含水率、价格等)对油田未来进行评估(储量^[2]、可采储量、经济可采储量、经济生命年限等)。

1 SEC 储量动态评估方法

SEC 储量动态评估方法有类比法、容积法、递减法^[3]、物质平衡法、油藏模拟5种。类比法用于开发初期或未开发油藏, 通过类比成熟油藏开采过程来预测目标油藏的动态。在油田开发早期, 由于没有确切的地质和开发动态资料, 类比法是最为常用的方法; 当采用新的开发技术时, 类比法也同样重要。建立作为类比的成熟油藏档案, 从而对物性参数、流体参数、油藏类型、规模、油藏开采特征等多项参数进行比较。目标油藏与其他成熟油藏可类比, 目标油藏的物性、流体性质须相当于或优于类比油藏。

容积法用于油田开发前期或初期^[4], 以地质资料为依据, 是油田开始生产之前较好的方法, 但在油田开采的任何阶段都不能忽视, 容积法和类比法可一起使用。该方法可用于估算油藏体积, 预测岩石的物性和流体性质、油藏原始压力和温度等^[5-6]。

递减法要求油藏至少生产6个月, 在开发中、晚期使用效果最好。根据动态趋势预测未来产量, 储

量直接与产量相关, 储量是时间或累积产量的函数。常用的动态趋势包括: 油、气、水产量随时间的变化, 流体比率(水油比、气油比)随时间的变化等。

物质平衡法用于可采储量采出程度为10%~70%的油气藏, 与容积法一起使用预测天然气或石油地质储量。使用该方法须掌握准确的油藏静压和产量数据, 对于强水驱气藏, 当压力变化非常小时, 计算结果不可靠; 该方法不适用于特低渗透和非均质性较强的气藏^[7]。

油藏模拟^[8-9]在任何阶段都可使用, 但是只有历史拟合程度较高时, 才能用于储量评估。油藏模拟使储量的评估过程一体化, 软件的功能越来越强, 可模拟更复杂的油气藏。模拟结果在评估储量时, 模型是最理想的状况, 模拟结果一般不能直接应用于真实储量的评估。

SEC 储量动态评估方法中最常用方法是递减法, 该方法具有简单易于操作、时间和产量相对应及易预测产量和经济生命周期等特点, 能够反映油藏的动态变化, 可根据动态趋势预测未来产量(剩余经济可采储量)。

2 动态评估中递减法应注意的问题

只有在油井生产条件和油藏条件基本保持不变的情况下, 才能运用递减法得到精确的分析结果。在评估中既要满足递减法的应用条件, 又要满足储

量评估的要求,须了解油田的生产过程,合理选择方法、评估单元和递减率等^[10]。

方法的选择 在动态评价分析油藏时,采用不同的递减方法,结果差别很大。须根据油藏生产情况,确定采用何种递减方法,一般指数递减的递减速度比双曲递减的递减速度大得多,对油藏评价剩余经济可采储量、经济生命周期影响很大。例如庆祖集油区某区块采用双曲递减法评估,剩余经济可采储量为 23.6×10^4 t; 而采用指数递减法评估,剩余经济可采储量为 19.7×10^4 t,比双曲递减减少了17%。

初始产量的选择 在评估中初始产量(起始点)的选择非常重要,通常在评估中习惯选择最后一个点,在正常情况下这样选择没问题,但是如果油田生产很不稳定,产量波动很大,或最后生产阶段有重大措施(酸化、压裂等)或关井,使产量增加或减少很多,这种情况下起始点选择不确切,对评估结果影响很大。评估人员须了解油藏的动态及油藏产量变化的原因,确定合理初始产量。例如史南油田某区块,2008年中期采用指数递减法评估,在递减率不变的情况下,初始产量由 683 t/d 减少为 619 t/d 时,评估的剩余经济可采储量由 349×10^4 t 减少为 317×10^4 t,减少了9.2%。

递减率的选择 对一个油藏来说,单井递减率不等,综合后油藏总递减率一般会变小。在储量评估中,要分析单井、区块或油藏递减率,最好采用单井平均递减率。递减率对储量评估影响很大,合理确定递减率很重要,虽然对单井影响不大,但对整个油田影响很大。例如平方王油田某区块递减率由8%增大至15.3%,剩余经济可采储量由 140.5×10^4 t 减少为 79.6×10^4 t,减少幅度高达43.3%。

单元的选择 对递减法来说,最好用单井评估,但单井评估工作量太大,短时间无法完成,一般选择开采时间、驱动方式一致的井和区块,作为一个评估单元。例如塔河油田某区块,有新扩边未开发储量,当年新增探明石油地质储量为 $1\,381.16 \times 10^4$ t,已完钻9口直井和1口侧钻井,投入试采井7口,对区块来说,储量增加比例不大,可合并到已开发油藏进行动态评估。

稳产期的确定 当油藏开采阶段为上产阶段、有新钻井或新措施时,一般采用类比法确定稳产期,类比相似油藏在相同生产状况下的稳产期,在评估中稳产期最多不超过3 a。如陈堡油田某区块,2008年中期有新钻井,在储量评估中采用稳产期为1 a;

再如商河油田某区块有扩边储量并入,采用稳产期为3 a进行评估。

废弃点的确定 废弃点的选择采用经济评价计算盈亏平衡点,平衡点即为废弃点。与油(气)价格和操作费有关,若操作费不变,废弃点随油(气)价格升高而降低。

分段式预测 在油田未来规划不确定(或变化很大)或油田措施频繁的情况下,采用一段式预测储量不确切,必须采用两段式或多段式。由于对评估结果影响很大,在评估中要慎用。如王场油田某区块采用一段式计算剩余经济可采储量为 657×10^4 t,采用两段式计算剩余经济可采储量为 370×10^4 t,减少幅度高达43.7%。

3 结束语

SEC储量动态评估,须根据油气藏类型确定相应的评价方法,根据油藏不同区块开发阶段选用不同的评估方法。分析中应注意的问题,须根据油藏的具体情况灵活把握。油藏区块采用动态评估后,须对评估结果进行分析,对多种评估方法得到的结果进行比较,只有剩余经济可采储量与开发实际相符时,动态评估结果才可信。

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19(2):81–83.

Abstract: Inadequate natural energy and poor transmission of pressure will give rise to deep pressure decline after putting into development in low permeable reservoir. Pressure decline will induce damages to rock physical properties and flowing character, i. e. reservoir rock presents stress sensitivity. Simulating changing process of reservoir pressure by flowing test, threshold pressure gradients at different effective overburden pressures are tested, and relationship between threshold pressure gradients and effective overburden pressures is studied. With mercury-injection test, nuclear magnetic resonance spectrometry analysis and rock mechanics test, changing mechanism for threshold pressure gradients in changing process of reservoir pressure is thoroughly analyzed. It was understood that, the threshold pressure gradients increases with reservoir pressure declines, i. e. threshold pressure gradients is sensitive to stress. It is also indicated that the lower the rock permeability, the bigger the increasing amplitude of threshold pressure gradients, which means that the stress sensitivity is stronger. It is suggested that, when calculating rational spacing between wells, it is necessary to consider the effect of reservoir pressure maintenance level on threshold pressure gradients.

Key words: low permeability; threshold pressure gradient; stress sensitivity; net overlying pressure; pore throat

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Zhang Xing, Yang Shenglai, Zhang Ling et al. Experimental study on factors of KlinKenberg permeability in low permeable gas reservoir. *PGRE*, 2012, 19(2):84–86.

Abstract: CNPC found a low-permeability gas reservoir with CO₂ in Jilin oil fields. Because the rock properties and fluid properties are unique, it is not accurate to analysis the effects of gas slippage effect on KlinKenberg permeability and penetration capacity. In view of this specificity, they are determined and analyzed by single-phase gas flow laboratory experiments. Experimental studies show that the KlinKenberg effect is found in the gas flow process in core and the influence factors are important including the core type, confining pressure, gas type and temperature. The KlinKenberg permeability of porosity core is higher than that of micro-fracture core. With the increasing of confining pressure, the slop of permeability-mean pressure curve is not changed, but the KlinKenberg permeability and its amplitude are decreased. Because of the different molecular weights, the KlinKenberg permeability of carbon dioxide (big molecular weight) is higher than that of natural gas and nitrogen gas (small molecular weight). The influence of temperature on gas flow at low temperature is greater than that at high temperature, that is, the KlinKenberg permeability of 20 °C is higher than that of 50, 80 and 140 °C.

Key words: low-permeability gas reservoir; KlinKenberg permeability; gas slippage effect; influence factor; KlinKenberg effect

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Li Lianjiang. Study on drainage gas pattern for offshore gas wells, Chengdao oilfield. *PGRE*, 2012, 19(2):87–89.

Abstract: After the condensate gas wells have been flooded, the choice of drainage gas recovery plan must be considered with the specific production environmental restrictions. In the paper, according to different stages conditions of the liquid production and gas production in a condensate gas well, the approximate drainage gas process pattern for offshore gas wells is studied by the well-bore temperature and pressure drop models. And, an effective feasible and economic drainage gas technology, the electric pump drainage gas recovery scheme, is put forward. Through the implementation of drainage gas recovery scheme, the natural gas output of the well is improved. The drainage gas schemes adopted by the gas well at different production stage can also be referenced for other gas wells nearby.

Key words: condensate gas wells; pressure drop model; temperature drop model; water-out gas production technique; Chengdao oilfield

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Zhuang Li, Zhang Ling. Growth trend study of proved oil and gas reserves based on the upgrade rate of probable reserves. *PGRE*, 2012, 19(2):90–92.

Abstract: Oil and gas reserves growth trend prediction research is the key factor for the oil company to make exploration and development strategy. From the study of contribution of probable reserves to the increased proved reserves of one oil company for ten years, it shows a steady rate at about 50% in the last three years. Upgrade rate of probable reserves can be classified into yearly increased and accumulative probable reserves upgrade rate. Research shows that the accumulative probable reserves upgrade rate has more significant meaning for the prediction of the growth of increased proven reserves next year. Considering the quality of increased probable reserves is very close in the recent years, based on the relationship of increased proved reserves with the accumulative probable reserves, a formula is summarized for the prediction of increased proved reserves, with convincing results tested with actual data. This method can be used by the exploration and development decision-making departments.

Key words: controlled reserve; proved reserve; contribution of controlled reserve; upgrading of controlled reserve; reserve prediction

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Wang Shuhua, Wei Ping. SEC reserves dynamic evaluation and analysis. *PGRE*, 2012, 119(2):93–94.

Abstract: Since Sinopec's public offering in New York and London in 1999, there are great challenges to bring domestic reserves management more in line with international practice, SEC methods and concepts of oil and gas reserves evaluation are having great shock on the domestic reserves calculation and management. Based on our decade years' experiences in domestic reserves calculation, examination and SEC reserves evaluation, this paper analyzes 5 methods in SEC reserves evaluation: analogy, volume, production decline, material balance and reservoir modeling methods; herein, we present the object, basis, scope and conditions in

application of each method; we also discuss key problems in decline method such as selection of decline mode, original point, decline rate and production unit, determining of stable production period and abandoned point, and the reasons for using of 2-stage-prediction method and decline method. These skills can provide important reference for SEC reserves evaluation and analysis, domestic reserves calculation and recoverable reserves calibration, and provide the proof of oilfield stable production.

Key words: reserve; dynamic evaluation; decline analysis; decline rate; reserve estimation method

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Zhang Shoupeng, Teng Jianbin. Acidification technology and implementation of substep elutriation for low permeability reservoir—case of Xia 463 well in Linnan depression. *PGRE*, 2012, 19(2): 95–97.

Abstract: After stimulation, different well achieves different productivity for the low permeability sandstone reservoir. The key is that the stimulation scheme is not formulated based on the reservoir characteristics. Using the rock sections, cast sections, X diffraction analysis and mineral dissolution experiment techniques, we can accurately understand the characteristics of reservoir rock minerals, and then formulating the corresponding acidification techniques of sub-step elutriation. Using this technique for the low permeability reservoir of Xia 463 well herein, the microcosmic test content and methods for low permeability reservoir are discussed on how to correctly formulate process of acidification technique, as well as the field surveillance. Acidification scheme is proved successful by field operation. It is proved that this technique is not only important for production maintenance, but also for the control of water saturation in low permeability reservoir over a long period of time.

Key words: low permeable sand reservoir; matrix acidification; sub-step elutriation; interparticle material; compatibility

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Wang Shihu, Zhang Zhiang, Wang Lei et al. MATLAB hydraulic fracture propagation simulation technique. *PGRE*, 2012, 19(2): 98–101.

Abstract: Hydraulic fracture simulation technique plays an important role in fracture design and evaluation. It has been developed for many years, however, it is mainly paying more attention to time efficiency and so on, petroleum engineers usually choose 2D or p-3D model for simulation. As we all know, with low accuracy step by step, finite difference method can not satisfy the requirement. What we want to do in this paper is just trying to establish a real 3D hydraulic fracture simulation technique in MATLAB with finite element method. And, then we compare it with the results of the mature commercial software such as GOHFER to improve the accuracy of the simulation and give more reference.

Key words: hydraulic fracture; finite element method; real 3D model; fracture propagation; numerical simulation

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Xue Shifeng, Wang Feifei, Wang Haijing. Numerical study of productivity ratio and factors of perforated well. *PGRE*, 2012, 19(2): 102–105.

Abstract: Perforated completion is widely used, in order to study the effect of perforation factors on perforation productivity ratio and get better perforation process selection, 3D finite element models with factors of perforation parameters (perforation depth, diameter, density and phase), compaction and damage for productivity ratio (PR) calculation in perforation completion are established in this paper. The code connecting software COMSOL and MATLAB are used to simulate and analyze 290 different models with their specific parameters. The effect of perforation depth, diameter, density, phase and compaction on perforation productivity ratio is obtained, and the flow pattern near perforation can be observed by the model. Considering oilfield practice, a simple method of PR calculation and the relationship of well PR and model PR are provided, which will be useful for evaluation of productivity and optimizing perforation completion design.

Key words: perforation completion; productivity ratio; influence factors; finite element model; perforation parameters

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Liu Ming, Zhang Shicheng, Mou Jianye. Dissolution pattern of radial wormhole model in carbonate acidizing. *PGRE*, 2012, 19(2): 106–110.

Abstract: In response to the questions of wormholing during carbonate acidizing, this paper derives a radial two-scale continuum model based on former researches, and studies the dissolving pattern and the effect of some key factors on it, and gets the conditions of the occurrence of wormholes. The results show that: the conclusions got from the models accord well with the experiments conducted by former researchers perfectly; with the rise of diffusion efficiency and decrease of injection rate, the diffusion effect becomes stronger relatively and it is easier to form face dissolution; with the decrease of diffusion efficiency and increase of injection rate, the convection effect becomes more apparent relatively, and it is easier to form uniform dissolution; the wormhole, which can provide adequate permeability and minimize the injection volume of acid at most, is formed when the effect of convection and diffusion is equivalent; the magnitude of heterogeneity has an optimal value, below which the wormhole density and breakthrough volume decrease under more heterogeneity, above which the wormhole density and breakthrough volume become insensitive to the heterogeneity.

Key words: carbonate; acidizing; wormhole; radial model; breakthrough volume; heterogeneity

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