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高压砾石充填防砂气井产能预测与评价*

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摘要　提出了以防砂产能比作为防砂措施对气井产能造成影响的评价指标。高压砾石充填防砂后在井筒附近形成管外砾石层、孔眼砾石层、筛套环空砾石层等附加阻力区域。考虑气体紊流特征,计算上述附加区域中的单向流和径向流压降方程,推导出各种情况下防砂后产能比的计算方法;结合防砂前气井流入动态,根据防砂产能比可预测防砂后气井流入动态。形成一套简单实用的高压砾石充填防砂气井产能评价与预测方法。该方法计算简单,需要的基础数据少且易于提供,计算结果可靠。

关键词　气井　防砂　高压砾石充填　产能预测　流入动态

中图分类号: TE358. 1　　**文献标识码**: A

高压砾石充填是目前最有效也是最常用的气井防砂方法。砾石充填气井的产能预测与评价是进行防砂工艺参数设计以及经济效果评价的基础。目前关于防砂气井产能预测的研究主要集中在根据渗流理论直接使用地层参数计算砾石层压降和产量等方面,这种预测方法比较复杂且要求地层渗透率、孔隙度等基础参数准确。但对于疏松砂岩地层,由于长期开采、出砂严重等原因,井筒附近地层参数较开发初期可能已经发生了较大的变化,提供这些参数的准确值存在很大困难。因此,目前尚没有简单实用、结果可靠的防砂气井产能评价与预测方法。

针对高压充填防砂气井,研究防砂措施造成的附加阻力区域及其流动压降,推导防砂产能比的计算方法,根据防砂前气井生产资料预测防砂后的流入动态,形成一套简单可靠的高压砾石充填气井产能评价与预测方法。

1　砾石充填附加阻力区域及其压降计算

如图 1所示,气井进行高压砾石充填后造成的附加流动区域由外到内分别为管外砾石充填层、射孔孔眼砾石层和管内环空砾石层。管外砾石层和管内环空砾石层中的流动均为径向流,射孔炮眼砾石层中的流动为单向流。

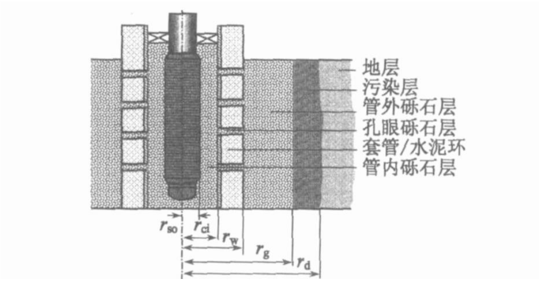

图 1　高压砾石充填气井流动区域示意图

设厚度为 h的圆柱形油藏,内外边界的半径分别为 r_i、r_o,内外边界压力分别为 p_i、p_o。根据考虑非达西流的 Forchherier方程得到径向流压力分布方程[1]

$$p_o^2 - p_i^2 = A q_{sc} + B q_{sc}^2 \tag{1}$$

$$A = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k h} \left(\ln \frac{0.472 r_o}{r_i} \right)$$

$$B = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_g \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_i} - \frac{1}{r_o} \right)$$

充填有砾石的射孔孔眼中为单向流,同样根据 Forchherier方程可得到单向气流的压力方程[2]

$$p_o^2 - p_i^2 = A q_{sc} + B q_{sc}^2 \tag{2}$$

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$$A = \frac{2\mu_g}{S_D H_p k_f \pi r_p^2} \frac{p_{sc} Z T}{Z_{sc} T_{sc}} L$$

$$B = 3.4844 \times 10^{-3} \frac{2\beta_g \gamma_g Z T}{\pi^2 r_p^4 S_D^2 H_p^2} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 L$$

利用方程 (1)和方程 (2),给定流量和一个边界的压力,可计算另一个边界的压力和压力差。

2 高压砾石充填防砂产能比计算

防砂产能比表示气井防砂后的产能与不防砂情况下产能的比值[3],表示防砂措施对气井产量的影响;产能比大于 1表示防砂后气井增产,小于 1则表示减产。已知产能比后可以根据防砂前流入动态计算得到防砂后的流入动态曲线。

2.1 未防砂情况下的产量计算

设油藏压力为 p_r、井筒流压为 p_{wf}。未防砂情况下的地层流动分为 2部分。

(1)地层边界 r_e 到污染半径 r_d 处的径向流,根据方程 (1),有

$$A_{01} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_f h} \left(\ln \frac{0.472 r_e}{r_d} \right)$$

$$B_{01} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_g \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_d} - \frac{1}{r_e} \right)$$

$$p_r^2 - p_d^2 = A_{01} q_0 + B_{01} q_0^2 \tag{3}$$

(2) 污染半径 r_d 到井筒半径 r_w 之间的径向流,根据方程 (1),有

$$A_{02} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_d h} \left(\ln \frac{0.472 r_d}{r_w} \right)$$

$$B_{02} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_g \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_w} - \frac{1}{r_d} \right)$$

$$p_d^2 - p_{wf}^2 = A_{02} q_0 + B_{02} q_0^2 \tag{4}$$

将方程 (3)与方程 (4)的压降方程相加得到

$$p_r^2 - p_{wf}^2 = (A_{01} + A_{02}) q_0 + (B_{01} + B_{02}) q_0^2 \tag{5}$$

解方程得到压差 $(p_r - p_{wf})$下的产气量为

$$q_0 = \frac{-(A_{01} + A_{02}) + \sqrt{(A_{01} + A_{02})^2 + 4(p_r^2 - p_{wf}^2)}}{2(B_{01} + B_{02})} \tag{6}$$

2.2 砾石充填防砂情况下的气井产量计算

假设污染半径 r_d 大于管外充填半径 r_g,如图 1所示。则整个流动分为 5个区域。

(1)地层边界 r_e 到污染半径 r_d 处的径向流,与方程 (3)相同

$$A_{11} = A_{01},\ B_{11} = B_{01}$$

$$p_r^2 - p_d^2 = A_{11} q_1 + B_{11} q_1^2 \tag{7}$$

(2)污染半径 r_d 到管外充填半径 r_g 的径向流,根据方程 (1),有

$$A_{12} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_d h} \left(\ln \frac{0.472 r_d}{r_g} \right)$$

$$B_{12} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_g \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_g} - \frac{1}{r_d} \right)$$

$$p_d^2 - p_g^2 = A_{12} q_1 + B_{12} q_1^2 \tag{8}$$

(3)管外充填半径 r_g 到井筒半径 r_w 的径向流,根据方程 (1),有

$$A_{13} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_g h} \left(\ln \frac{0.472 r_g}{r_w} \right)$$

$$B_{13} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_{gg} \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_w} - \frac{1}{r_g} \right)$$

$$p_g^2 - p_w^2 = A_{13} q_1 + B_{13} q_1^2 \tag{9}$$

(4)井筒半径 r_w 到套管内径 r_{ci}的射孔炮眼中的线性流,根据方程 (2),有

$$A_{14} = \frac{2\mu_g}{S_D H_p k_g \pi r_p^2} \frac{p_{sc} Z T}{Z_{sc} T_{sc}} (r_w - r_{ci})$$

$$B_{14} = 3.4844 \times 10^{-3} \frac{2\beta_{gg} \gamma_g Z T}{\pi^2 r_p^4 S_D^2 H_p^2} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 (r_w - r_{ci})$$

$$p_w^2 - p_{ci}^2 = A_{14} q_1 + B_{14} q_1^2 \tag{10}$$

(5)套管与筛管环空中的径向流,根据方程 (1),有

$$A_{15} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_g h} \left(\ln \frac{0.472 r_{ci}}{r_{so}} \right)$$

$$B_{15} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_{gg} \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_{so}} - \frac{1}{r_{ci}} \right)$$

$$p_{ci}^2 - p_{so}^2 = A_{15} q_1 + B_{15} q_1^2 \tag{11}$$

将方程 (7)～(11)的压降方程相加得到砾石充填气井的产能方程

$$A_1 = A_{11} + A_{12} + A_{13} + A_{14} + A_{15}$$

$$B_1 = B_{11} + B_{12} + B_{13} + B_{14} + B_{15}$$

$$p_r^2 - p_{wf}^2 = A_1 q_1 + B_1 q_1^2 \tag{12}$$

求解方程 (12)得到防砂后压差 $(p_r - p_{wf})$下的产气量为

$$q_1 = \frac{-A_1 + \sqrt{A_1^2 + 4(p_r^2 - p_{wf}^2)}}{2B_1} \tag{13}$$

如果管外充填半径 r_g 大于污染半径 r_d,整个流动分为 4个区域。地层边界 r_e 到管外充填半径 r_g 的流动为径向流动,根据方程 (1),有

$$A_{11} = \frac{p_{sc}}{T_{sc} Z_{sc}} \frac{\mu_g Z T}{\pi k_f h} \left(\ln \frac{0.472 r_e}{r_g} \right) \tag{14}$$

$$B_{11} = 3.4844 \times 10^{-3} \left(\frac{p_{sc}}{Z_{sc} T_{sc}} \right)^2 \frac{\beta_g \gamma_g Z T}{2\pi^2 h^2} \left(\frac{1}{r_g} - \frac{1}{r_e} \right)$$

该情况下方程 (12)、(13)中系数 A_1、A_2 分别为

$$A_1 = A_{11} + A_{13} + A_{14} + A_{15}$$

$$B_1 = B_{11} + B_{13} + B_{14} + B_{15} \tag{15}$$

2.3　砾石充填防砂产能比

根据产能比的概念[3],给定地层压力 p_r、井底流压 p_{wf}下高压砾石充填气井的防砂产能比为

$$R(p_{wf}) = \frac{q_1(p_{wf})}{q_0(p_{wf})} \tag{16}$$

3　砾石充填气井的流入动态预测

对于常规气藏,描述气井流入动态关系的二项式方程为[1]

$$p_r^2 - p_{wf}^2 = A q_{sc} + B q_{sc}^2 \tag{17}$$

方程 (17)线性化后得到

$$\frac{\bar{p}_r^2 - p_{wf}^2}{q_{sc}} = A + B q_{sc} \tag{18}$$

使用气井防砂前正常生产时的一组井底流压 p_{wf}与产量 q_{sc}数据,对方程 (18)使用最小二乘法进行线性回归可得到系数 A和 B,之后便可绘制防砂前气井的流入动态曲线。

根据砾石充填施工参数确定管外充填半径和充填砾石层的渗透率,使用方程 (16)可计算防砂产能比 R。则相同的井底流压下,防砂后的气井产量为

$$q' = qR \tag{19}$$

计算得到各井底流压下防砂后气井产量后,便可绘制防砂后气井的流入动态曲线。

根据上述分析,砾石充填气井产能预测的核心是评价防砂措施对气井产能造成的影响,归结为防砂产能比的计算。这样,只要知道气井防砂前的生产情况,便可准确预测防砂后的生产动态。高压充填气井产能评价的基本思路和程序如图 2所示。

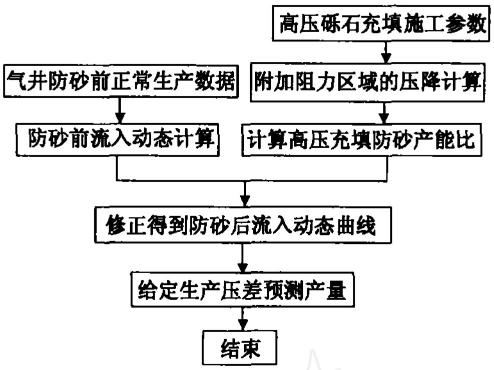

图 2　砾石充填防砂气井产能预测程序

需要注意的是,文中方法虽然在计算防砂产能比时也使用到地层渗透率参数,但结果对其依赖性并不大,计算防砂前的产量和防砂后的产量中都使用了该参数,使用方程 (16)计算产能比时对地层渗透率具有一定的约去效应。另外,方程 (16)的计算结果反映砾石充填防砂措施对气井产能的影响,而真正防砂后流入动态预测是以防砂前的实际生产数据作为依据的,所以文中的方法具有更高的可靠性。

4　实例分析

青海涩北气田涩 4 - 9为一口出砂气井,井深 1508 m,套管外径 177.8 mm,射孔直径约 12 mm,孔密 30孔 /m。生产层总厚度约 9.2 m,地层静压平均 13.35 MPa。该井于 2003年 9月进行高压砾石充填防砂施工,砾石尺寸范围 0.4～0.8 mm,砾石总用量 16.0 m^3,施工井段 37.5 m,根据井身结构估计管外充填半径 1.25 m,预测管外砾石层经充填压实并与部分地层粉细砂混合后的渗透率 1.67 μm^2。该井防砂前 8月份的试气数据如表 1。

表 1　涩 4 - 9井防砂前试气数据

日期	气嘴直径 /mm	流压 /MPa	静压 /MPa	生产压差 /MPa	产量 /$m^3 \cdot d^{-1}$	产气指数 /$10^4 m^3 \cdot (d \cdot MPa)^{-1}$
12日	4.0	12.98	13.38	0.403 5	21 744	5.388 8
13日	5.0	12.82	13.36	0.532 0	41 472	7.795 5
14日	5.5	12.73	13.33	0.604 0	48 480	8.026 5
15日	6.0	12.64	13.31	0.665 0	52 728	7.929 0
16 - 19日	6.5	12.31	13.37	1.060 0	63 911	6.029 3

使用文中产能预测方法对高压充填防砂后的产能进行了预测,气井的防砂产能比随井底流压发生变化,平均值为 0.59,平均产气指数 4.14 $\times 10^4 m^3 / (d \cdot MPa)$。利用表 1的数据回归得到防砂前流入动态曲线,根据防砂产能比可计算得到该井防砂后的流入动态曲线,如图 3所示。为了验证计算结果,收集了该井防砂后 2003年 10月到 2004年 5月的每月平均生产数据,实际平均产气指数 3.68 ×

$10^4 m^3/(d \cdot MPa)$,实际防砂产能比为 0.52,预测值的相对误差 11.8%。使用防砂后的实际生产数据回归得到了防砂后的实际 IPR 曲线。

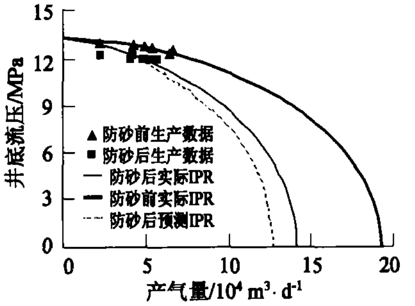

图 3　防砂后 IPR 预测与实际结果的对比

预测得到的防砂后 IPR 曲线与实际 IPR 曲线在高井底流压下吻合得较好,在低井底流压下误差较大,最大误差为 11.76%,平均误差约 5.5%。高流压下吻合较好的部分原因是回归防砂后实际 IPR 曲线时使用的生产数据均为高井底流压下的数据。气井实际均在较高的流压下生产,因此低流压时的较大误差并不影响该方法的应用。

该井防砂后产能比偏低,原因主要是涩北气田为极疏松砂岩,地层出砂为粉细砂,粒度中值 0.02～0.03 mm,高压充填防砂使用的砾石尺寸为 0.4～0.8 mm。砾石尺寸偏大,地层粉细砂极易侵入砾石层,造成砾石层的渗透率急剧降低,对防砂后产能造成较大的影响。不过由于采取了防砂措施,该井能以更大的生产压差生产,所以产量降幅并不大。

5　结论

(1)高压砾石充填防砂措施对气井产能的影响主要体现在其井底附近产生的附加阻力区域,包括管内环空砾石层、炮眼砾石层和管外砾石充填层;管内及炮眼充填对产能不利,而管外充填砾石则对产能有利。防砂措施对产能的影响取决于这 2 个方面的相对作用大小。

(2)提出了以防砂产能比作为防砂措施对气井产能造成影响的评价指标。考虑气体紊流特征,计算各区域中的压降,推导出各种情况下防砂后产能比的计算方法;结合防砂前气井流入动态曲线和防砂产能比可计算防砂后的流入动态曲线,形成了一套简单实用的高压砾石充填防砂气井产能评价与预测方法。该方法计算简单,需要的基础数据少,便于现场应用。计算结果与实际值平均误差 5.5%,方法和结果基本可靠。

符　号　说　明

h——地层厚度, m;

H_p——射孔段厚度, m;

k、k_f、k_d、k_g——渗流介质、地层、污染带、砾石层渗透率, m^2;

L——射孔孔眼长度, m;

p_o、p_i——圆柱形地层和射孔孔眼的外边界与内边界压力, Pa;

p_d——污染半径处压力, Pa;

p_{wf}、p_r——井底流压、地层压力, Pa;

p_g、p_w、p_{ci}——分别为管外充填半径处、射孔孔眼外端和射孔孔眼内端的压力, Pa;

q_0——不防砂情况下的气井产量, m^3/s;

$q_0(p_{wf})$、$q_1(p_{wf})$——井底流压为 p_{wf} 时不防砂和防砂情况下的气井产量, m^3/s;

q_1——气井砾石充填防砂后的产量, m^3/s;

R——防砂产能比,无量纲;

$R(p_{wf})$——井底流压为 p_{wf} 条件下的防砂产能比;

r_o、r_i——圆柱形油藏的外、内边界半径, m;

r_e、r_d——气藏半径、污染半径, m;

r_w、r_p——井眼、射孔孔眼半径, m;

r_g、r_{ci}、r_{so}——管外充填半径、套管内半径、筛管外半径, m;

S_D——射孔密度,孔/m;

T——温度, K;

Z——天然气压缩因子,无量纲;

μ_g——天然气地下黏度, $Pa \cdot s$;

β_g——紊流速度系数, m^{-1};

β_{gg}——砾石充填层中的气体紊流速度系数, m^{-1};

γ_g——天然气相对密度,无量纲。

下标 sc 表示标准状况。

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编辑　付丽霞〕

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Abstract To solve the difference of polymer flooding in interlamination or in - layer, studied the technology of downhole separate injection of polymer solution, developed injection tool of low shearing, et al, and necessary running and pulling test instrument, realized downhole separate layer injection of polymer solution with single - string. Injecting polymer in 3 layers at the same time, and the drawdown reach 3.6 MPa at the flow rate of 180 m^3/d, the rate of shear degradation less than 6%, layered sealing pressure reached to 25 MPa, running and pulling loading smaller than 4 kN. Applications achieved effectively, and control the polymer solution flowing along high permeability reservoir in high speed, improve the development effect of polymer flooding.

Key words polymer flooding low shearing regulating separate layer injection testing

STUDY OF VISCOSITY STABILIZER FOR POLYMER FLOODING

Wu Mingming, Zhao Xiutai, Qiu Guangmin (China University of Petroleum, DongYing 257061, Shandong), Zhang Guorong, Liu Gaoyou

Abstract The viscosity loss of polymer solution will affect the effect of the polymer flooding severely. bases on the characteristics and factors of polymer flooding, two kinds of stabilizers were designed, And evaluated its properties on improving and stabilizing of viscosity in laboratory, shows that the stabilizers not only improved the viscosity of the polymer solution but also stabilized the viscosity. When the concentration of stabilizers is between 800 and 1200 mg/L, the viscosity of polymer solution may be increased by two to five times and this can keeps stable more than 60 days. The rate of the viscosity loss of polymer solution is less than 15%. The stabilizers may be used in polymer flooding and depth profile control because they can compatibility well with the HPAM solution confected by tap water and brine.

Key words polymer flooding viscosity cross - linker stabilizer

DETERMINATION OF PARAFFIN DEPOSITION AND RATIONAL THERMAL - WASH CIRCLE IN PRODUCER DURING POLYMER FLOODING

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Abstract For the serious problem of paraffin deposition during polymer flooding in Daqing Oilfield, analyzed the composition of produced crude oil and paraffin, and tested gas chromatogram of satisfied hydrocarbon, compared the results to water flooding, the content of saturated hydrocarbon in oil sample is lower, while the content of aromatic hydrocarbon and asphaltum is higher, but the difference is small; the content of saturated hydrocarbon and aromatic hydrocarbon in paraffin sample is apparently lower, while the content of asphaltum is much higher. Simulation experiment of dynamic pipe - flow shows that polyarylamide (PAM) has effect on inhibiting paraffin crystal forming and deposition. Analysis results of numerical simulation show that paraffin deposit rate is higher in producer during polymer flooding, generally, the paraffin deposit point is at about 400～600 m, and Rational thermal - wash circle should be less than 30 days.

Key words polymer flooding pumping well paraffin sample thermal - wash circle

ANALYSIS ON POTENTIALITY OF INDIGENOUS MICROBIAL ENHANCEMENT OF OIL RECOVERY IN BLOCK 1 OF DAGANG KONGDIAN OILFIELD

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Abstract To investigate physical chemical condition, composition of microbial population, rates of sulfate reduction and methanogenesis in formation water of the block 1 of Kongdian Oilfield to study potential of microbial enhanced oil recovery. The amount of thermophilic aerobic saprotrophs, hydrocarbon - oxidizing bacteria, anaerobic fermentative bacteria, sulfate - reducing and methanogenic bacteria in injection and formation water were determined by most - probable - number (MPN) method. the sulfate reduction and the rate of methanogenesis processes were analyzed by radioisotopic method. The results show vary microflora inhabited in the block 1 of Kongdian Oilfield. The numbers of thermophilic aerobic saprotrophs and hydrocarbon - oxidizing bacteria in the injection water reached to 10^5 cells/mL and 10^3 cells/mL respectively. The population density of anaerobic fermentative bacteria in the injection water reached to 10^7 cells/mL, and sulfate - reducing bacteria reached to 10^2 cells/mL. Methanogenic bacteria were range from 1 to 10 cell/mL. Five kinds of bacteria above were also presented in production wells. So it is possible to enhance oil recovery by activating indigenous microbial of hydrocarbon oxidizing, fermentative bacteria and methanogenic bacteria in this area.

Key words Dagang Oilfield indigenous microorganism oil recovery

STUDY OF RECOVERY RATE OF HORIZONTAL WELLS IN SURPRESSURE, LOW - PERMEABILITY WITH BASAL WATER RESERVOIR

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Abstract In order to reasonably develop the unusual low - permeability and high pressure dual - porosity reservoir of Pre - salt carbonatite in Kenkiyak oil field, In this paper takes into account the factors such as pressure sensitization and bottom aquifer drive and studies the production characteristics of horizontal well and reasonable oil recovery rates by the numerical simulation of single well with dual - porosity model. The results show that the effective factors include the formation pressure, the energy of basal water, the pressure sensitivity and etc. In the natural depletion development, small bottom aquifer can improve recovery, and more sensitivity the stress of the reservoir is and less the degree of reserve recovery will be, and there is a maximum degree of reserve recovery in various producing rates. Therefore, account for recovery ratio, formation pressure and water cut, the proper oil recovery rate of Pre - salt carbonate reservoir of Kenkiyak field is 2% - 3%.

Key words horizontal well abnormal pressure stress sensitivity oil production rate basal water

PREDICT REMAINING LIFETIME OF PUMP ROD BY ULTRASONIC SIGNAL

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Abstract No research theory of remaining lifetime of pump rod can be used to in - situ, and can not diagnose it remaining lifetime by engineering examine at present. From endurance testing of pump rod, fined change rules of leading edge of cracking, obtained relationship between depth and area of crack and relationship of crack area and remaining life, use Paris formula, established relation of ultrasonic inspection and crack depth, and relation of crack detection signal and crack spread law, proposed predict method of remaining lifetime of pump rod by ultrasonic inspection. Compared results of remaining lifetime by simulated test and theory predict, indicate it was coincide more than 84%.

Key words ultrasonic fault detection signal crack depth pump rod remaining lifetime

INTEGRATED PRODUCTIVITY MODEL FOR GAS WELL WITH HIGH - PRESSURE GRAVEL - PACK SAND CONTROL

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Abstract Productivity Ratio (PR) is firstly put forward to evaluate the effect of gravel - packing sand control measure on gas well productivity. After high - pressure gravel packing, there will form an additional flow resistance areas composed of gravel inside casing, perforation filled with gravel and the packed area outside the wellbore. Considering the non - Darcy flow, the pressure drop of radial and linear flow across the areas are calculated and the calculation method of PR is established. Combined with performance relationship (IPR) before sand control, the IPR curve after sand controlling could be obtained by PR. The application results indicate that this simplified model needs only fewer data but its results are very reliable.

Key words gas well sand control high - pressure gravel - pack productivity prediction IPR

CHEMICAL PLUGGING BOTTOM WATER TECHNOLOGY OF LENG41 BLOCK

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