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筛管内砾石充填防砂水平井产能影响因素优化设计

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摘 要:砾石充填防砂方法是应用较早,被认为是目前防砂效果最好的方法之一。本文建立了砾石充填防砂水平井产能计算模型,利用正交实验对其主要参数进行了优化设计。采用 VB. net语言编写了优化设计软件,采用优化设计软件对孤岛 13P513水平井参数进行了优化,并分析了参数对产能的影响。现场应用表面该方法具有一定的应用价值。

关键词:水平井;砾石充填;产能;优化

中图分类号: TE257　　**文献标识码**: A

油井出砂通常是由于井底附近地带的岩层结构遭受破坏引起的。其中,弱固结或中等胶结砂岩油层的出砂现象较为严重。油井出砂还与油藏深度、压力、流速、地层胶结情况、压缩率和渗透率、流体种类和相态(油、气、水的情况)等有直接的关系。对于胶结特别疏松的稠油油藏,为了具备较好的防砂效果,一般应采用砾石充填完井方式。对于地质条件不宜采用裸眼,而又需要防砂的疏松储层,应采用套管内砾石充填防砂。套管内井下砾石充填后,人工充填在套管壁与绕丝筛管之间的砾石充填层,起着防砂滤器的作用[1]。随着水平井在油田开采中的应用,水平井砾石充填防砂的具体应用成为一个重要的研究课题。本文建立了筛管内砾石充填防砂水平井的产能计算方法,并对孤岛 13P513井的产能影响因素进行了分析。

1 砾石充填防砂水平井产能计算模型

若水平井位于油层中部,对于砾石充填防砂井产能的求解由以下几部分构成:

①垂直平面内水平井单位长度上的流量为:

$$q = \frac{2\pi k_0 L \Delta P}{\mu_o B_o \ln\left(\frac{h}{2 r_w}\right)} \tag{1}$$

垂直平面上的渗流阻力为:

$$R_{f_v} = \frac{\Delta P}{q} = \frac{\mu_o B_o}{2\pi k_0 L} \ln \frac{h}{2\pi r_w} \tag{2}$$

②水平面内水平井的流量表达式为:

$$q = \frac{2\pi k_0 h \Delta P}{\mu_o B_o \ln\left(\frac{a + \sqrt{a^2 - \left(\frac{L}{2}\right)^2}}{L/2}\right)} \tag{3}$$

水平面内渗流阻力为:

$$R_{f_h} = \frac{q}{\Delta P} = \frac{\mu_o B_o}{2\pi k_o h} \ln\left(\frac{a + \sqrt{a^2 - \left(\frac{L}{2}\right)^2}}{L/2}\right) \tag{4}$$

③井筒内的压降

若水平井进行管内砾石充填防砂完井,则流动阻力由下列几部分组成[3]:

1.1 流体通过射孔孔眼周围压实环的压降 ΔP_1:

$$\Delta P_1 = \frac{\mu_0}{k_{dp}} \frac{q_o B_o}{L n_p 2\pi L_{p1}} \ln \frac{r_{dp}}{r_p} + \beta_{dp} \rho_0 \left(\frac{q_0 B_0}{L n_p 2\pi L_{p1}} \right)^2 \left(\frac{1}{r_p} - \frac{1}{r_{dp}} \right)$$

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$$=\frac{q_o\mu_o B_o}{2\pi k_o h}\left[\frac{1}{k_{dp}}\frac{k_o h}{L n_p L_{p1}}\ln\frac{r_{dp}}{r_p}+\beta_{dp}\rho_o\frac{q_o B_o k_o h}{\mu_o L^2 n_p^2 2\pi L_{p1}^2}\left(\frac{1}{r_p}-\frac{1}{r_{dp}}\right)\right]$$

$$=\frac{q_o\mu_o B_o}{2\pi k_o h}S_{G1} \tag{5}$$

式中 L_{p1} —水泥环外射孔孔眼长度,

$L_{p1}=L_p-(r_w-r_c)$, m;

$$S_{G1}=\frac{1}{k_{dp}}\frac{k_o h}{L n_p L_{p1}}\ln\frac{r_{dp}}{r_p}+\beta_{dp}\rho_o\frac{q_o B_o k_o h}{\mu_o L^2 n_p^2 2\pi L_{p1}^2}\left(\frac{1}{r_p}-\frac{1}{r_{dp}}\right)$$

1. 2　流体通过射孔孔眼的压降:

$$\Delta P_2=\left\{\frac{\mu_o}{k_G}\frac{q_o B_o}{L n_p\pi r_p^2}+\beta_G\rho_o\left(\frac{q B_o}{L n_p\pi r_p^2}\right)^2\right\}L_p$$

$$=\frac{q\mu_o B_o}{2\pi k_o h}\left[\frac{2k_o h}{k_G L n_p r_p^2}+\beta_G\rho_o\frac{q_o B_o k_o h}{\mu_o (L n_p r_p^2)}\right]L_p$$

$$=\frac{q\mu_o B_o}{2\pi k_o h}S_{G2} \tag{6}$$

式中 $S_{G2}=\left(\frac{2k_o h}{k_G L n_p r_p^2}+\beta_G\rho_o\frac{2q_o B_o k_o h}{\mu_o (L n_p r_p^2)}\right)L_p$;

L_p - 套管外射孔孔眼的长度, m。

1. 3　流体通过筛套环形空降的压力:

只是公式中用水平井的长度 L 代替公式中的油层射开厚度 hp。如按单向流计算时:

$$\Delta P_3=\left\{\frac{\mu_o}{k_G}\frac{q_o B_o}{L n_p\pi r_p^2}+\beta_G\left(\frac{q_o B_o}{L n_p\pi r_p^2}\right)^2\right\}(r_c-r_s)$$

$$=\frac{q\mu_o B_o}{2\pi k_o h}S_{G31} \tag{7}$$

式中 $S_{G31}=\left(\frac{2k_o h}{k_G L n_p r_p^2}+\beta_G\rho_o\frac{2q_o B_o k_o h}{\mu_o (L n_p r_p^2)}\right)(r_c-r_s)$

按径向流计算时:

$$\Delta P_3=\frac{q_o\mu_o B_o}{2\pi k_G L}\ln\left(\frac{r_c}{r_s}\right)+\rho_o\beta_G\left(\frac{q_o B_o}{2\pi L}\right)^2\left(\frac{1}{r_s}-\frac{1}{r_c}\right)$$

$$=\frac{q_o\mu_o B_o}{2\pi k_o h}S_{G32} \tag{8}$$

式中 $S_{G32}=\frac{k_o h}{k_G L}\ln\frac{r_c}{r_s}+\beta_{dp}\rho_o\frac{q_o B_o k_o h}{\mu_o L^2 2\pi}\left(\frac{1}{r_s}-\frac{1}{r_c}\right)$

而井底附近总的渗流阻力为:

$$R_w=\frac{\Delta P_1+\Delta P_2+\Delta P_3}{q_0} \tag{9}$$

根据水电相似原理,从供给边缘至水平井井底的总的阻力为:

$$R=R_{fv}+R_{jh}+R_w \tag{10}$$

则水平井的产量公式为:

$$q=\frac{\Delta P}{R}$$

$$=\frac{2\pi k_o h\Delta P}{\mu_o B_o\left[\ln\left(\frac{a+\sqrt{a^2-(L/2)^2}}{L/2}\right)+\frac{h}{L}\ln(h/2r_w)+S_G\right]} \tag{11}$$

式中; $S_G=S_{G1}+S_{G2}+S_{G3}$;

$$a=\frac{L}{2}\left(\frac{1}{2}+\sqrt{\frac{1}{4}+\frac{1}{\left(\frac{0.5L}{r_e}\right)^4}}\right)^{0.5}$$

(11)式条件为; $l>h$, $L/2<0.9r_e$, (11)式是产量 q 的隐式函数,需迭代求解。

式中 L - 水平井的长度, m;

h - 油层的厚度, m;

r_w - 水平井筒的半径, m;

k_o - 束缚水下油的有效渗透率, m^2;

μ_o - 油的粘度, Pa s;

q - 井的产量, m^3/s;

r_e —油藏供油半径;

ρ_o —油的密度, Kg/m^3。

3　产能影响因素的优化设计

在确定了油藏的产能之后,面临的问题就是如何对影响采液强度的各因素进行优化设计,使得采液强度在不超过临界产能的范围内达到最大值。下面将防砂井影响产能的主要因素进行优化设计。

产能与油藏参数(如储层厚度、各向异性的程度、偏心距、原油粘度)、射孔的工艺参数(如射孔密度、射孔深度、射孔段长度、孔径及相位角)以及防砂参数(如砾石层渗透率)等有密切关系[3]。对于油藏参数而言在井位确定以后这些参数就是定值,需要优化的是射孔工艺参数以及防砂工艺参数。下面利用正交试验设计对射孔工艺参数以及防砂工艺参数进行优化设计。

对砾石充填完井的射孔密度、射孔深度、孔径、相位角、砾石层渗透率五个因素进行正交试验设计,采用 5因素 4水平的 $L_{16}(4^5)$正交表。经过表头设计、水平翻译,将每组试验数据带入到产能计算公式中计算,对所得到的结果进行极差分析即可得到最优化结果。

4　孤岛油田水平井防砂参数优化设计

利用 VB. net语言编写了筛管内砾石充填防砂水平井产能影响因素优化设计软件,下面通过实例应用来说明各因素对产能的影响。

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3 结论

(1)选取高钢级或高强度套管能有效提高射孔套管的抗挤压强度。

(2)增加壁厚能有效提高套管射孔套管的抗挤强度。

(3)射孔参数对套管抗挤强度的影响:射孔孔密和相位角一定时,随着孔径的增加,套管抗挤强度降低,但降低幅度不大;孔径和相位角一定时候,随着射孔孔密的增加,套管抗挤强度降低,但降低幅度很小;射孔孔密和孔径一定时候,射孔套管的抗挤强度在不同的变化区间变化趋势有所不同,相位角在180度时,套管的抗挤强度最低,强度降低最大。

(4)在保证射孔套管抗挤强度的前提下,为使射孔完井井眼能获得尽可能高的油气产能比,推荐采用大孔径、高密度射孔。同时采用60度或120度相位角。

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井13P513为孤岛油田的一口水平井,其基础参数如下[4]:水平向渗透率为1500mD,垂向渗透率为900mD,地层条件下原油粘度为892.4mPa s,泄油半径75m,原油体积系数 B_o = 1.01,储层厚度 h 为11.3m,井眼半径 r_w 为0.1079m,原油密度0.9954g/mL,水平井长度 L = 250m,偏心距为0,生产压差为2.0MPa,钻井污染带渗透率为1200mD,污染带半径0.3m,筛管半径为0.0635m,套管内径为0.0889m,砾石充填防砂。优化参数见表1。

表1 13P513井正交设计优化参数

孔密(孔/m)	孔深(m)	孔径(mm)	相位角(度)	砾石层的渗透率(um^2)
16	0.659	13	60	60
18	0.712	12	180	15
24	0.686	15	90	7
22	0.642	9	30	80

通过正交实验优化计算得最优参数为孔密16孔/m,孔深0.712m,孔径15mm,相位角180°,砾石层的渗透率为80mD。最优产能为48.04m^3/d.MPa。对产能大小影响因素由强到弱依次为相位角、砾石层渗透率、射孔孔径、射孔深度、射孔密度。

5 结论

本文建立了筛管内砾石充填防砂水平井产能的计算方法,并采用VB.net语言实现了软件化。采用正交试验设计方法对产能的影响因素进行了分析,并对孤岛油田13P513井的产能影响参数进行了优化设计,计算得到了该井的最优产能。

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subdivided into three microfacies as braided channel, plain areas between braided channel and front edge of braided channel The sand bodies of braided channel and front edge of braided channel of turbidite fan have superior condition of forming oil reservoir, which can form lithologic oil reservoir or structural - lithologic oil reservoir easily and these have important value for oil and gas exploration.
Key Words: the third member of Shahejie formation; turbidite fan; sublacustrine fan; slump fan; lithologic oil reservoir; the south of Huanxiling

MAIN INFLUENCE FACTOR ON WATER BEARING ANALYSIS OF FRACTURE - KARST CAVED CARBONATE RESERVOIR OF TAHE OIL FIELD / *Liu Lili, Chen Xiaofan, CuiLigong. State Key Laboratory of Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu* 610500 */Xinjiang ShiYou TianRan Qi,* 2008, 4 *(1) :* 43～44

Abstract: The 4th area Ordovician system reservoir of Tahe oil field is a special type of reservoir, which is of ultra depth, high temperature and high pressure, and the reservoir also has a diverse space, a complex distribution of the perquisite and bad oil material It belongs to strongly heterogeneous fracture - karst caved carbonate composite reservoir, and characterized by multi fracture - karst cave, three - dimensional overlapping This oil field is taken as an example in the paper. According to the changes of single well water content ratio, the affecting factors of the changes of water cut are analyzed, which deeply affects our understanding of this kind of reservoir. It also provides important theoetical basis for us to develop this kind of reservoir reasonably.
Key Words: Tahe oil field; fracture - karst caved reservoir; water bearing change; influence factor

APPLICATION OF NEW TECHNIQUE OF GEOPHYSICAL INTERPRETATION IN SUBTLE OIL / GAS RESERVOIR EXPLORATION / *Gong Hong - lin, CAI Gang, YAO Qing - zhou. Northwest Subsidiary of Research Institute of Exploration and Development, CNPC, Lanzhou GanSu* 730020 */Xinjiang ShiYou TianRan Qi,* 2008, 4 *(1) :* 45～49

Abstract: This paper mainly introduces that using the spectra decomposition technique , full 3 - D visualization and full 3 - D data volume interpretation technique studies idea and method of subtle oil/gas reservoir and uses these three techniques in many 3D seismic surveys in Junngar Basin to identify channels effectively, the boundary of lithologic traps , faults and stratigraphic denudation. A large scale of lithologic oil/gas reservoir in SN31 well was discovered after successful application of these three techniques, which widened a new idea and method for exploration of subtle oil/gas reservoir in Junggar Basin . Good results which have been yielded in its practical application indicate: it is essential that appropriate interpretation techniques and methods should be selected during the exploration of subtle oil/gas reservoir in order to get good results .
Key Words: subtle oil/gas reservoir, Junggar Basin, frequency spectrum, decomposition, full 3 - D visualization, full 3 - D data volume interpretation

EVALUATION OF ECONOMIC RECOVERABLE RESERVES AND ANALYSIS OF VENTURE IN GAS - CAP RESERVOIR OF LAMADIAN OILFIELD / *Liu Zhen - jun, Zhang Wu, Qin Guo - wei Economic Management Deparment, Daqing Petroleum College, DaQing HaLongJiang* 163318 */Xinjiang ShiYou TianRan Qi,* 2008, 4 *(1) :* 50～53

Abstract: Planned economy has been carried out in China for a long time, the economic performance of gas reservoir development has been always neglected and the economic recovery is mainly dependent on technological conditions of production. Therefore, through the studies of characteristics and tectonic of Gas - cap Reservoir of Lamadian oilfield, this Oilfield economic recoverable reserves and economic recovery rate have been forecast by using the cash flow method; at the same time, probability distribution method to estimate risk for Gas - cap Reservoir of proven reserves, probable reserves and possible reserves and to analyze the uncertainties of economic recoverable reserves in this paper, which provides important theoretical bases for the recovery of the Gas - cap reservoir.
Key Words: Economic recoverable reserves; Economic recovery; Reserves evaluation; probability distribution

THE OPTMIUM OF THE PARAMETERS EFFECT ON THE PRODUCTIVITY OF THE HORIZONTAL GRAVEL - PACK PERFORATED WELLS / *Li Yong, Hu Yong - le, Li Bao - zhu, et al Research Institute of Petroleum Exploration and Development, PetroChinas, BeiJing* 100083 */Xinjiang ShiYou TianRan Qi,* 2008, 4 *(1) :* 54～55

Abstract: Gravel - pack sand - control method is an early applied sand - control method. It is considered as one of the best sand - control method. In this article, a model to calculate the productivity of the horizontal gravel - pack perforated wells is established, and VB. net programming language is used to develop an optimum software. By using the software, the parameters of Gudao 13P513 horizontal well are optimized, and the effect of the parameters are analysed.

Key Words: horizontal well; gravel - pack; productivity; optimum

EFFECT OF HELIX DISTRIBUTING PERFORATION ON CASING COLLAPSING STRENGTH / *Gao Juan, Fan Wei, Jiang Xiang - zu, et al. Geophysical and Oil Resource College, Yangtze University, Jingzhou HuBei* 434023 / *Xinjiang ShiYou TianRan Qi*, 2008, 4 *(1)*: 56～58

Abstract: One of important cause of casing damage is casing perforation. Finite element mechanical model of perforatedcasing is established, and effect of perforating on casing strength, especially influence of perforation diameter, perforation density and perforation phase angle on casing strength is studied by using elastic and plastic finite element numerical modeling method. Under outer pressure condition, finite element analysis of stress concentration coefficient in perforated casing is studied with different steel grade, wall thickness, perforation diameter, perforation density and phase angle. Analysis result provides reasonable model for optimization design of perforating well completion and reliable foundation of sustainability computation for reasonable design for perforating sections of casing.

Key Words: helix distributin perforation; perforating casing; collapsing strength; elastic and plastic finite element method

TECHNOLOGY DEVELOPMENT OF HEAVY OIL TESTING IN ULTRA - DEEP WELL AND ITS APPLICATION / *Wang Kuojun, Sun fu, Shi Ming - jiang et al. Yangtze University, Jingzhou HuBei* 434023 / *Xinjiang ShiYou TianRan Qi*, 2008, 4 *(1)*: 59～63

Abstract: The tectonic belt of Tarim Oilfield and the Tahe Oilfield in the exploration process have been found in the burial depth of 5700m in heavy oil layer in recent years. As reservoir type is complex and testing techniques and technologies supporting are limited; exploration work has been large by restriced, so exploration for ultra - deep reservoir of heavy oil exploration has not been broken through. According to ultra - deep heavy oil reservoir characteristics and the nature of Tahe and Tarim Oilfield, By combining with the deep and heavy oil testing technology in the development of TUha LuKeqin heavy oil Testing Process, Development and its application of ultra - deep show heavy oil production testing technology were accomplished after study of the reservior characteristics, crude oil property and process techniques, the successful completion of the Lungu15, TK612, Lungu41 show good results.

Key Words: Ultra - deep; heavy oil layer; Testing Technology.

APPLICATION OF CYCLIC WATERFLOODING IN DEVELOPMENT OF BLOCK WENXI6 / *Yuan Zhao, Yang Shu - ping. Research Institute of Exploration and Development, TuHa Oilfield Company, CNPC, HaMi Xinjiang* 838202 / *Xinjiang ShiYou TianRan Qi*, 2008, 4 *(1)*: 64～66

Abstract: In light of the singularity of main layer, severe flooding and production reduction occurred after well pattern thickening, a new way must be used to solve these problems. Based on experiences of cyclic waterflooding in sandstone oilfield at home and abroad, study on feasibility of cyclic waterflooding in block Wenxi6 was conducted by use of numerical reservoir simulation, then water injection cycle was optimized and opportunity of cyclic waterflooding was demonstrated, in the end a detailed plan was put forward. Field application of the plan has obtained some good results.

Key Words: Wenxi6; cyclic waterflooding; reservoir numerical simulation; parameter; opportunity; effect

THE RESEARCH ON THE WATER - FLOODING PERFORMANCE OF THE HORIZONTAL WELL IN SANDSTONE RESERVOIR / *Wang Tao, Li Yu - cheng, Lei Yu, et al. Development department, Tarim Oilfield Company, Petrochina, Korla, Xinjiang* 841000 / *Xinjiang ShiYou TianRan Qi*, 2008, 4 *(1)*: 67～70

Abstract: Super - deep sandstone reservoir of HD oilfield in Tarim basin was developed by the horizontal wells. Now it is at middle - water - cut stage, and in some locations there are high water content wells. In this paper we use waterflooding feature plot, combining with the development dynamic data of the oilfield, pool and wells and them analyze the water uprising law and causes for change in the horizontal well, at the same time we evaluate