

拟三维压裂设计软件在户部寨气田压裂中的应用\*

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摘 要 针对户部寨气田的储层特点,在优选压裂液、支撑剂的前提下,考虑井网布局的基础上,运用拟三维压裂优化设计软件,优选压裂设计参数,通过模拟计算,求得较为合理的裂缝几何参数,进行压裂优化设计,现场施工后取得了较好的效果。

主题词 户部寨气田 气井压裂 压裂设计 应用

户部寨气田地质概况

1) 储层特征。户部寨气田其主要储层分布在 ES<sub>3</sub> 与 ES<sub>4</sub> 段,气藏埋深 3 200 ~ 3 500 m,孔隙度 3 % ~ 12 %,平均孔隙度 8.3 %,渗透率为 (0.1 ~ 1) × 10<sup>-3</sup> μm<sup>2</sup>,地层温度 112 ~ 131 ℃,含油饱和度 7.7 % ~ 29.5 %,压力系数 0.85 ~ 0.95,属常温、常压系统,储层极为致密,物性差,而且储层非均质性严重,并具有较强的水敏性,还存在应力敏感性。

2) 压裂状况。近年来户部寨气田沙四段共压裂 37 井次,共加入压裂液 6 540.8 m<sup>3</sup>,平均单井加砂 30 m<sup>3</sup>,平均砂比 24.9 %,平均排量 3.7 m<sup>3</sup>/min,破裂压力 25.1 ~ 62.2 MPa,停泵压力 3.6 ~ 67.5 MPa。从压裂效果来看 16 层压裂 25 次,压后平均单井日产油约 7 t,平均单井日产气 2 000 m<sup>3</sup>。老井压裂 6 层 11 次,压后平均单井日增油不到 1.82 t,平均单井日增气 5 000 m<sup>3</sup>。

压裂液、支撑剂优选

1) 采用压裂预前置液。预前置液由于其本身无控制滤失能力,全部液体均侵入地层,能够有效控制深部气藏产生的水锁、贾敏、粘土矿物分散和运移、油水乳化、离子沉淀等有害反应。预前置液的表面张力 22 mN/m,界面张力 0.1 mN/m,破乳率 95 % (95 ℃, 1.5 h),对岩心伤害率 2.0 %。

2) 低伤害压裂液。采用低伤害羟丙基瓜胶—有

机硼压裂液。在地层温度条件下,170 s<sup>-1</sup>剪切 90 min,粘度 100 mPa·s;交联时间 2 ~ 4 min;水化液粘度 (125 ℃): 5.4 mPa·s (常规破胶 24 h), 3.0 mPa·s (强化破胶 2 h);残渣含量 4.6 %;滤失系数 6.3 × 10<sup>-4</sup> m/min<sup>1/2</sup>;对地层岩心伤害率 13.0 %。

3) 支撑剂。选用高强度烧结陶粒,69 MPa 破碎率 10 %。

压裂软件模拟计算

(1) 地层基本参数

表 1 中部 1—3 井的地层压力、渗透率由试井解释得到。对于岩石力学参数,应用邻井数据计算而得。

(2) 优化设计模拟计算

根据该气藏储层参数和水力裂缝可能方向,并

表 1 压裂目的层基本数据表

井 号	部 1 - 3	部 1 - 8	部 1 - 10
压裂井段 (m)	3 454.1 ~ 3 588.9	3 153.1 ~ 3 192.8	3 240.3 ~ 3 305.8
砂层厚度/层数 (m/n)	26.8/11	20.6/10	37.1/16
地层温度 (℃)	125	105	115
孔隙度 (%)	7.6	10.5	6.6
渗透率 (10 <sup>-3</sup> μm <sup>2</sup> )	0.56	0.8	0.2
地层压力 (MPa)	37.9	31	33
杨氏模量 (10 <sup>4</sup> MPa)	3.8	3.5	3.6
波松比	0.23	0.22	0.22

\*本文系中石化集团公司深层气田整体压裂改造技术研究项目的成果之一。

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考虑井网布局,利用拟三维设计软件,依靠压裂数据库的支持,进行压裂优化设计。

1) 压裂井层的模糊逻辑判断技术。输入包括井深、产层净厚度、孔隙度、地层流体粘度、流压、含水饱和度、驱油面积、表皮系数、含水饱和度、渗透率等数据后,软件计算出初步结论,即表征目地层是否适合压裂的模糊逻辑值。结果表明,这三口井的模糊逻辑值均在 0.7~0.9 之间,是较好的压裂井层。

2) 优化目标函数的确定。优化目标函数有:产量(初始产量、稳产量),采收率(无水采收率、最终采收率),采油速度,经济效益(净现值、内部收益率、投资回收期)。优化采收率法由于涉及油田开发方面的许多比较复杂的因素和问题,真正目标优化资料录取比较复杂。净现值法设计裂缝模型因素和油田开采经济分析问题,裂缝模拟的准确性和经济分析模型的可靠性均会对优化结果产生影响。累计增产量法着重分析油层内有效裂缝对增产量的影响,避开了裂缝形状和经济因素,因此,该方法在目前仍有一定的实用价值。因此,以压后最大、最经济的累计产量为目标函数优化压裂规模和支撑半缝长,模拟计算出后得到水力裂缝几何参数。优化设计结果见表 2,图 1 是部 1-10 井的优化结果。

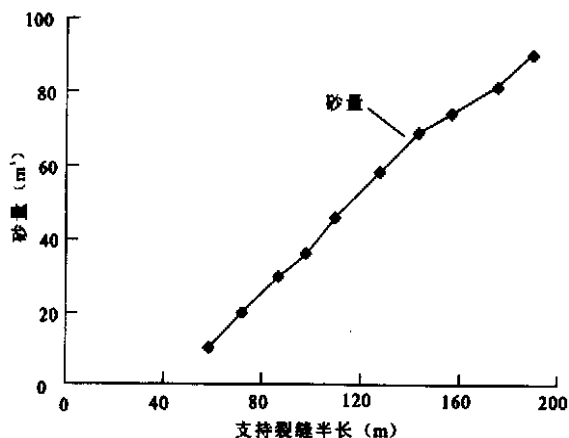


图 1 部 1—10 井砂量优化曲线

由模拟计算结果可以看出,部 1-10 井最优化支撑半缝长为 110 m,优化的加砂量为 46 m<sup>3</sup>。

表 2 模拟计算结果及设计施工参数

井 号	部 1 - 3	部 1 - 8	部 1 - 10
支撑半缝长 (m)	148/ 135	155.5	110
平均缝高 (m)	35.5/ 27.2	38.6	70.1
最大缝宽 (mm)	9.8/ 9.5	10.9	12.4
预前置液体积 (m <sup>3</sup> )	30	15	15
前置液体积 (m <sup>3</sup> )	105/ 85	90	150
支撑剂体积 (m <sup>3</sup> )	27/ 19	30	46
平均砂比 (%)	27.1	28.9	30.7
施工排量 (m <sup>3</sup> / min)	4.0	3.8	4.8
压 裂 方 式	投一压二、油套混注	油套混注、合层压裂	油套混注、合层压裂

## 压裂效果

压裂施工时,严格按照压裂设计施工,压后效果见表 3。其中部 1-8 井因正在压后排液阶段,尚未投产。

表 3 压裂效果

井 号	部 1 - 3	部 1 - 8	部 1 - 10
压后日增气 (10 <sup>4</sup> m <sup>3</sup> )	0.83	未投产	0.8
累增气 10 <sup>4</sup> m <sup>3</sup> )	454		160

## 结 论

1) 针对储层特点,优选压裂液、支撑剂,并在优选施工参数、优化施工规模、泵注程序、施工排量的基础上,优质施工,是提高压裂效果的重要保证。

2) 运用先进的设计软件,求得较接近实际的裂缝几何尺寸,是提高低渗气藏压裂效果的有效手段。

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**REALIZING HOLE TRAJECTORY CLOSED-LOOP CONTROL BY CONTROLLABLE DECENTRALIZER**

Hu Jinyan ( Xi 'an Jiaotong University ) and Zhou Jing and Fu Xinsheng ( Xi 'an Petroleum Institute ) . *NA TUR. GAS IND.* v. 22 ,no. 6 ,pp. 58 ~ 60 , 11/ 25/ 2002. ( ISSN1000-0976 ; **In Chinese** )

**ABSTRACT:**At present ,drilling is in a surface open-loop control condition on the whole and its frequent tripping operations make the drilling efficiency be reduced ,the drilling cost be raised and even the designed well trajectory be difficult to be realized. Along with the unceasing increase in both displacement distance and well depth ,the closed-loop control which can solve the question mentioned above has become a forward problem in drilling industry. The controllable decentralizer is an intelligent steering tool developed in combination with these techniques as microelectron ,information ,hydraulic pressure and control ,etc. The hole trajectory automatic control can be realized through the closed-loop control system formed with the decentralizer , thus raising the accuracy of controlling hole trajectory and reducing the drilling cost. For this reason ,according to the steering mechanism of the controllable decentralizer ,the hole trajectory closed-loop control system with the controllable decentralizer and its control tactics are put forward and the closed-loop control method of wing panel cylinder pressure composite vector of the controllable decentralizer is discussed in the paper. The feasibility of this method was examined by simulation experiment , which is of important guiding significance for the controllable decentralizer 's being applied on the spot.

**SUBJECT HEADINGS:** Hole trajectory , Rotary orientation ,Closed-loop control ,Controllable decentralizer

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**APPLICATION OF PSEUDO-3D FRACTURING**

**DESIGN SOFTWARE TO THE FRACTURING OPERATION IN HUBUZHAI GAS FIELD**

Lu Lize ( Natural Gas Management Utility Department , Zhongyuan Oil Field Branch Sinopec ) . *NA TUR. GAS IND.* v. 22 ,no. 6 ,pp. 61 ~ 62 ,11/ 25/ 2002. ( ISSN1000-0976 ; **In Chinese** )

**ABSTRACT:**In light of the reservoir characteristics of Hubuzhai gas field and on the basis of optimizing fracturing fluid and proppant and considering well pattern arrangement , the fracturing design parameters were optimized by applying the pseudo-3D fracturing design software ;and through analog calculation ,the reasonable fracture geometric parameters were acquired and an optimizing fracturing design was completed. Field application results show that this software is quite good.

**SUBJECT HEADINGS:**Hubuzhai gas field , Gas well ,Fracturing ,Fracturing design ,Application

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**APPLICATION OF PRE-PREFLUSH TO FRACTURING REFORMATION IN BAIMIAO GAS FIELD**

Li Mingzhi , Miao Hong and Li Fengxia ( Research Institute of Oil Production Technology , Zhongyuan Oil Field Branch , Sinopec ) and He Wei ( Natural Gas Management Utility Department , Zhongyuan Oil Field Branch , Sinopec ) . *NA TUR. GAS IND.* v. 22 , no. 6 ,pp. 63 ~ 65 , 11/ 25/ 2002. ( ISSN1000-0976 ; **In Chinese** )

**ABSTRACT:**The fracturing pre-preflush was developed in light of the demands for well-in fluid ,such as low damage , strong sand-carried capacity and rapid reverse drainage velocity , etc. ,in gas reservoir fracturing reformation. Several chemical additives were screened from many additives on the basis of analyzing the formation pollution factors caused by fracturing reformation and the formulation of the fracturing pre-preflush was determined through making an experiment in laboratory. The reaction mechanism ,demulsification function and low filtration property of the fracturing pre-preflush and its aid-to-draining character through reducing the surface (interfacial) tension of the well-in fluid are emphatically introduced in the paper. By means of popularization and application in Baimiao gas field ,it was indicated that pre-preflush is of great importance to de-