# 各向异性气藏中分支水平井的压力分析

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**摘　要**　水平井试井分析技术在国内外尚属一个新的课题，难度大、可借鉴的方法少，而研究水平井开发过程中地层压力的分布和变化是解决该类井试井分析的前题。对分支水平井各向异性地层，导出气藏拟压力的瞬时点源解，利用瞬时源函数和Newman乘积原理，给出气藏中各种分支水平井的Green函数。求得地层拟压力分布的解析表达式，对于某些常用的水平井布局，给出了Green函数一览表，便于应用。文中所述方法也适用于尖灭角内水平井的情形。

**主题词**　气藏　水平井　丛式井　压力分布　尖灭　Green函数

采用水平井开发是提高油气田产量的手段之一，而采用分支水平井开发更具有高的经济效益。特别是对于海上和沙漠腹地的油气田开发，分支水平井更具有它无可代替的优越性。关于油气田开发中单个水平井的压力分析已有一些作者进行了研究，但对分支水平井压力分析尚未见报道。本文对于各向异性气藏，即铅直方向渗透率 $K_v$ 与水平方向渗透率 $K_H$ 的比值 $K=K_v/K_H\neq1$ 的地层，首先求出拟压力 $m(p)$ 微分方程的瞬时点源解。然后对于地层上顶封闭或有气顶、下底封闭或有底水的情形，导出各种分支水平井布局的源函数、Green函数，进而给出气藏中无量纲拟压力的解析结果。

## 数　学　基　础

讨论地层厚度为 $h$、孔隙度为 $\varphi$ 的等温气藏，引用文献〔1〕所定义的拟压力

$$m(p)=2\int_0^p\frac{p}{\mu Z}\mathrm{d}p \tag{1}$$

和真实气体的状态方程 $p=RTZ\rho/M$，则描述气藏

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有利于储层的横向预测。在CDP2050和CDP2500附近的断层也较明显，压制了干扰，加强了有效波，

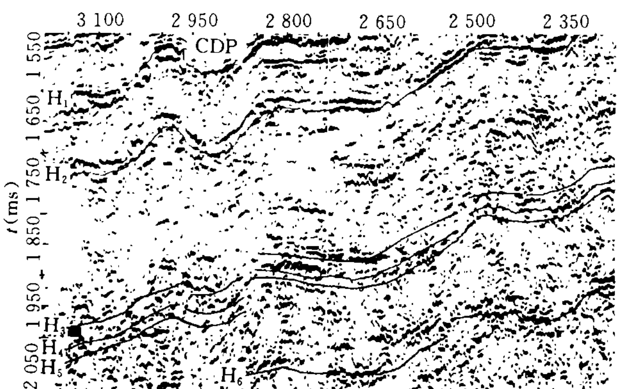


**图5　经滤波处理的2D叠偏剖面**

**Fig. 5. 2D stacking migration profile treatde by filtering.**

即提高了其信噪比和分辨率（当然，离井越近效果越好），为进一步进行构造精细解释、波阻抗反演和储层研究奠定了基础。可见，运用VSP进行地震高分率处理是可信的。

运用VSP及其零相位子波进行地面地震高分辨率处理，压缩了地震子波，托宽了频带宽度，从而改善了地面地震的信噪比，提高了其分辨率。它既可用于处理2D叠偏剖面，也可以对已进行过常规高分辨处理的剖面进行再处理，进而达到地面地震的精细处理，为储层研究和横向预测以及构造解释提供了精确的地震信息。

本文图件由斯仑贝谢GeoQuest巴黎解释中心提供，特此致谢。

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拟压力 $m(p)$ 的微分方程可近似地用下列线性化方程表示：

$$\nabla^2 m=\frac{1}{\chi}\frac{\partial m}{\partial t} \qquad \chi=\frac{K_H}{\varphi\mu_i c_i} \tag{2}$$

式中，$Z$ 为真实气体的偏差系数；$\mu$ 和 $C$ 分别为气体的粘度和压缩系数，在恒定温度下一般来说是压力 $(p)$ 的函数；下标 i 代表地层原始值。对式(1)利用中值定理并代入状态方程，可得：

$$m(p)=\int_0^{p^2}\frac{\mathrm{d}p^2}{\mu Z}=\frac{p^2}{\overline{\mu}\overline{Z}}=\left(\frac{RT}{M}\right)^2\frac{Z^2}{\overline{\mu}\overline{Z}}\rho^2 \tag{3}$$

将 $\overline{\mu}$、$\overline{C}$ 和 $\overline{Z}$ 平均值应用于方程(3)，得拟压力 $m(p)$ 与密度 $\rho$ 的近似关系式：

$$m(p)=\left(\frac{RT}{M}\right)^2\frac{\overline{Z}}{\overline{\mu}}\rho^2,\ m_i=\left(\frac{RT}{M}\right)^2\frac{\overline{Z}}{\overline{\mu}}\rho_i^2, \tag{4}$$

于是拟压力微分方程(3)可转化为密度平方的微分方程。气藏中瞬时点源问题的提法如下：在 $t=\tau$ 的瞬时向多孔介质内点 $M'(x',y')$ 注入质量为 $\delta m$、体积为 $\delta V$ 的气体，则平面问题的方程和定解条件应为：

$$\frac{\partial^2\rho^2}{\partial x^2}+\frac{\partial^2\rho^2}{\partial y^2}=\frac{1}{\chi}\frac{\partial\rho^2}{\partial t} \tag{5}$$

$$\rho^2(x\to\infty,y\to\infty;t)=\rho_i^2 \tag{6}$$

$$\rho^2(x,y;t=\tau)=\begin{cases}\rho_i^2 & \text{在点 } M' \text{ 以外}\\ \infty & \text{在点 } M' \text{ 处}\end{cases} \tag{7}$$

用直接代入法容易证明，上式的瞬时点源解为：

$$\tilde{\rho}^2(x,y,t)=\rho_i^2\pm\frac{A}{t-\tau}\times\exp\left[-\frac{(x-x')^2+(y-y')^2}{4\chi(t-\tau)}\right] \tag{8}$$

上式右端第二项取负号对应于生产(即压力降落)情形，反之为注入的情形；带"～"的量对应于瞬时源解。利用质量守恒可以定出常数 $A$ 为：

$$A=\frac{\rho_i\delta m}{2\pi\varphi\chi}=\rho_i^2\frac{\delta V}{2\pi\varphi\chi} \tag{9}$$

利用式(4)，得瞬时点源拟压力解(对于降落情形)为：

$$\tilde{m}=m_i-m_i\frac{\delta V}{2\pi\varphi\chi(t-\tau)}\times\exp\left[-\frac{(x-x')^2+(y-y')^2}{4\chi(t-\tau)}\right] \tag{10}$$

点汇强度 $q=\mathrm{d}V/\mathrm{d}\tau$ 作用时间从 $\tau$ 到 $t$ 的持续源汇解为：

$$m=m_i-m_i\int_0^t\frac{q}{2\pi\varphi\chi(t-\tau)}\times\exp\left[-\frac{(x-x')^2+(y-y')^2}{4\chi(t-\tau)}\right]\mathrm{d}\tau \tag{11}$$

将以上结果与文献[3]对油藏的结果相比可见：气藏拟压力方程瞬时源函数是油藏压力方程瞬时源函数的 2 倍，这与定义式(1)中系数 2 有关。

## 几个基本源函数

利用式(10)所给出的瞬时点源解，通过适当的积分，容易求得一些线源或条带源的基本源函数。考虑到地层各向异性，对坐标变量需作变换，即令：

$$z^*=z/\sqrt{K},\ h^*=h/\sqrt{K}$$

其中 $K=K_V/K_H$。为简洁起见，引进下列无量纲量：

$$x_D=\frac{x}{L},\ y_D=\frac{y}{L},\ z_D=\frac{z}{h},\ z_{wD}=\frac{z_w}{h}$$

$$h_D=\frac{h}{L},\ L_{wD}=\frac{L_w}{L} \tag{12}$$

$$t_D=\frac{K_H t}{\varphi\mu_i c_i L^2},\ m_D=\frac{m_i-m}{m_i q_D},\ q_D=\frac{Q_{sc}p_{sc}T}{\pi K_H h^* m_i T_{sc}}$$

上式中取参考长度为水平井半井长 $L$，$z_w$ 为水平井至地层下底的距离。下标 sc 对应于标准状况下的量。

据式(10)积分，给出几个用于水平井的基本源函数(表 1)。

表 1　几种简单的一维源函数

Table 1. Several kinds of one-dimensional source functions

| 序号 | 地　层 | 源 | 源函数 $(m_i-m)\varphi/m_i\delta$ |
|---|---|---|---|
| 1 | 无限大平面 | 垂直于 $x$ 向直线源 | $2\exp\left[-\frac{(x-x_w)^2}{4\chi(t-\tau)}\right]\Big/\sqrt{4\pi\chi(t-\tau)}$ (13) |
| 2 | 无限大平面 | 宽度 $2L$ 条带源 | $\mathrm{exf}\frac{L+(x-x_w)}{\sqrt{4\chi(t-\tau)}}+\mathrm{erf}\frac{L-(x-x_w)}{\sqrt{4\chi(t-\tau)}}$ (14) |
| 3 | 条带形区域上下封闭 | 垂直于 $z$ 向直线源 | $\frac{2}{h^*}\left\{1+2\sum_{n=1}^{\infty}\exp\left[-\frac{n^2\pi^2K^2\tau_D}{h_D^2}\right]\cos(n\pi z_{wD})\cos(n\pi z_D)\right\}$ (15) |
| 4 | 条带形区域上下定压 | 垂直于 $z$ 向直线源 | $\frac{4}{h^*}\sum_{n=1}^{\infty}\exp\left[-\frac{n^2\pi^2K^2\tau_D}{h_D^2}\right]\sin(n\pi z_{wD})\sin(n\pi z_D)$ (16) |
| 5 | 条带形区域上封闭下定压或上定压下封闭 | 垂直于 $z$ 向直线源 | $\frac{4}{h^*}\sum_{n=1}^{\infty}\exp\left[-\frac{(2n-1)^2\pi^2K^2\tau_D}{4h_D^2}\right]\cos\left(\frac{2n-1}{2}\pi z_{wD}\right)\cos\left(\frac{2n-1}{2}\pi z_D\right)$ (17) |

式(13)中 $x_w$ 表示直线源至 $y$ 轴的距离。式(14)中 $x_w$ 表示条带源中线至 $y$ 轴的距离,它对应于式(12)中的 $L_w$。式(15)~(17)参照文献[3]并对各向异性地层作了相应的修正。

## 分支水平井的瞬时源函数

分支水平井问题是较复杂的三维问题。根据 Newman 乘积原理,三维问题的 Green 函数可以通过三个一维瞬时源函数的乘积求得。因为 $z$ 向源函数已由式(15)~(17)给出,所以下面着重研究各种分支水平井问题在 $xy$ 平面上的瞬时源函数 $G_{xy}=G(x,y;t-\tau)$。

**1. $xy$ 平面上任意一个线段源的源函数**

为了求得水平井所在地层的拟压力,先考虑 $xy$ 平面上的任意线段源 $AB$,如图1所示。它与 $x$ 轴的夹角为 $\alpha$,长度 $AB=2L$;源中点为 $C$,$oC=L_w$(如果是下水道式水平井,$L_w$ 就等于井的半长度 $L$)。对于这样的问题,可以作坐标旋转,即转化为在 $ox'y'$ 坐标系中讨论。显然线段源 $AB$ 所诱导的源函数由表1中 I $(y')$ 和 II $(x')$ 的乘积给出;最后在 $oxy$ 坐标系中写出:

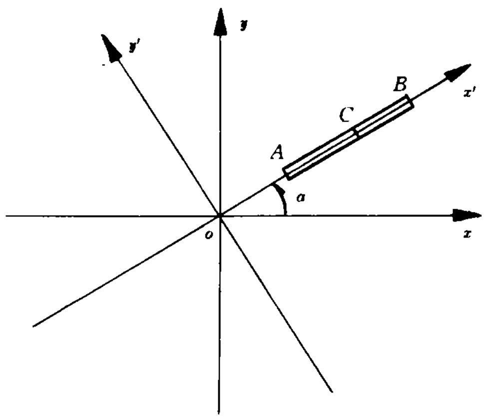


**图1 平面上任意线段源示意图**

**Fig. 1. Schematic drawing of arbitrary line segment Source on plane.**

$$G_{xy}=\frac{1}{L\sqrt{\pi}}G'_{xy}$$
$$=\frac{1}{L\sqrt{\pi}}\times$$
$$\left\{\frac{1}{\sqrt{t_D-\tau_D}}\exp\left[-\frac{(-x_D\sin\alpha+y_D\cos\alpha)^2}{4(t_D-\tau_D)}\right]\times\right.$$
$$\left[\mathrm{erf}\,\frac{1+(x_D\cos\alpha+y_D\sin\alpha-L_{wD})}{2\sqrt{t_D-\tau_D}}+\right.$$
$$\left.\left.\mathrm{erf}\,\frac{1-(x_D\cos\alpha+y_D\sin\alpha-L_{wD})}{2\sqrt{t_D-\tau_D}}\right]\right\} \tag{18}$$

**2. $xy$ 平面上 $N$ 个线段源的源函数**

如果 $xy$ 平面上有 $N$ 个线段源,其延长线均通过坐标原点。它们与 $x$ 轴的夹角分别为 $\alpha_1,\alpha_2,\cdots,\alpha_N$,长度分别为 $2L_1,2L_2,\cdots,2L_N$,其中点至坐标原点的距离分别为 $L_{w1},L_{w2},\cdots,L_{wN}$。对于这种情形,可引进半井长平均值 $L_a=(L_1+L_2+\cdots L_N)/N$ 以及无量纲量

$$L_{iD}=\frac{L_i}{L_a},L_{wiD}=\frac{L_{wi}}{L_a},t_D=\frac{K_Ht}{\varphi\mu_ic_iL_a^2} \tag{19}$$

下面为简要起见,把 $t_D-\tau_D$ 写成 $\tau$。则 $xy$ 平面上任意多个线段源的源函数可写成 $G_{xy}=G'_{xy}/L\sqrt{\pi}$,而

$$G'_{xy}=\sum_{i=1}^{N}\left\{\frac{1}{\sqrt{\tau}}\exp\left[-\frac{(-x_D\sin\alpha_i+y_D\cos\alpha_i)^2}{4\tau}\right]\times\right.$$
$$\left[\mathrm{erf}\,\frac{L_{iD}+(x_D\cos\alpha_i+y_D\sin\alpha_i-L_{wiD})}{2\sqrt{\tau}}+\right.$$
$$\left.\left.\mathrm{erf}\,\frac{L_{iD}-(x_D\cos\alpha_i+y_D\sin\alpha_i-L_{wiD})}{2\sqrt{\tau}}\right]\right\} \tag{20}$$

## 分支水平井的拟压力

上面导出了 $xy$ 平面上的瞬时源函数 $G_{xy}$ 和 $z$ 向源函数 $G_z$。为便于无量纲化,将式(15)~(17)给出的 $G_z$ 写成 $G_z=(2/h^*)G_z'$,或 $G_z'=(h^*/2)G_z$。注意到持续源积分式(11)中 $q=Q/2L=Q_{sc}p_{sc}TZ/2L\bar{p}T_{sc}\approx Q_{sc}p_{sc}T\bar{Z}/2L\bar{p}T_{sc}$,最后得:

$$m_D=\frac{\pi K_Hh^*(m_i-m)T_{sc}}{TQ_{sc}p_{sc}}$$
$$=\frac{\mu_ic_im_i\sqrt{\pi}\bar{Z}}{\bar{p}}\int_{\tau=0}^{\tau=t_D}G'_{xy}G'_z\mathrm{d}\tau \tag{21}$$

式中,$\bar{p}$ 取值 $(p_i+p_{wf})/2$,$Q$ 是单个水平井的产量。

图2示出几种常用的分支水平井布局。其中(a)是二分支水平井或垂直于直线断层的单井;(b)是三分支水平井或120°尖灭角内其井筒轴通过尖灭角顶点的水平井;(c)和(d)分别为四分支和六分支水平井或90°和60°尖灭角内的水平井。对于这四种情形,式(21)中所用的源函数 $G_{xy}$ 如下:

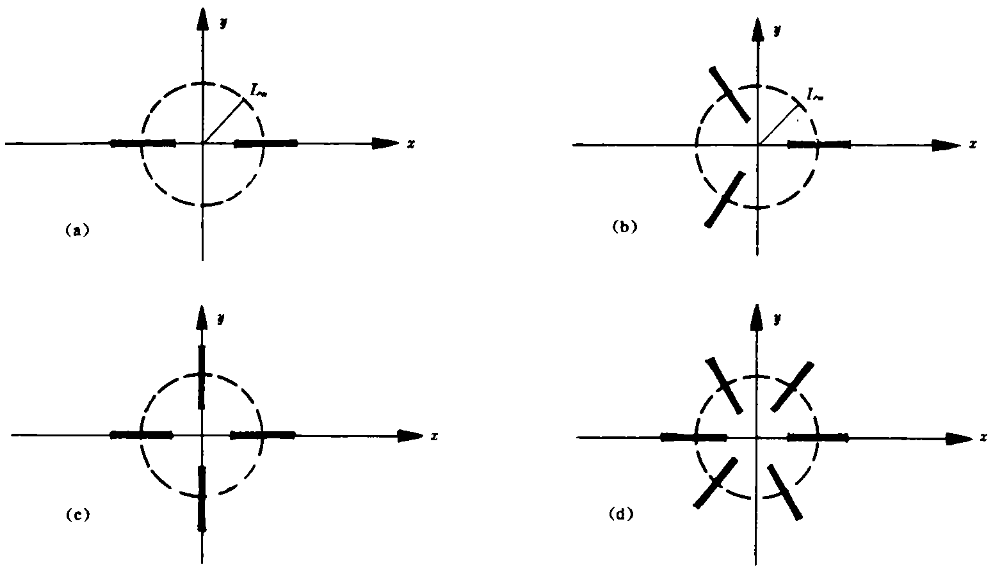

**图2　几种常用的分支水平井布局**

**Fig. 2. Several kinds of branch horizontal well distribution in common use.**

(1)二个分支水平井或垂直于直线断层的单个水平井

$$\begin{aligned}G_{xy}=&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{y_D^2}{4\tau}\right)\left[\operatorname{erf}\frac{1+x_D-x_{wD}}{2\sqrt{\tau}}+\right.\\&\operatorname{erf}\frac{1-x_D+x_{wD}}{2\sqrt{\tau}}+\operatorname{erf}\frac{1+x_D+x_{wD}}{2\sqrt{\tau}}+\\&\left.\operatorname{erf}\frac{1-x_D-x_{wD}}{2\sqrt{\tau}}\right]\end{aligned}\tag{22}$$

(2)三个分支水平井或120°尖灭角内位于角分线上的水平井

$$\begin{aligned}G_{xy}=&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{y_D^2}{4\tau}\right)\left[\operatorname{erf}\frac{1+(x_D-L_{wD})}{2\sqrt{\tau}}+\right.\\&\left.\operatorname{erf}\frac{1-(x_D-L_{wD})}{2\sqrt{\tau}}\right]+\frac{1}{\sqrt{\tau}}\times\\&\exp\left(-\frac{\left(\sqrt{3}x_D+y_D\right)^2}{16\tau}\right)\times\\&\left[\operatorname{erf}\frac{2-\left(x_D-\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}+\right.\\&\left.\operatorname{erf}\frac{2+\left(x_D-\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}\right]+\\&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{\left(\sqrt{3}x_D-y_D\right)^2}{16\tau}\right)\times\\&\left[\operatorname{erf}\frac{2-\left(x_D+\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}+\right.\\&\left.\operatorname{erf}\frac{2+\left(x_D+\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}\right]\end{aligned}\tag{23}$$

(3)四个分支水平井或直角断层内位于角分线上的水平井

$$\begin{aligned}G_{xy}=&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{y_D^2}{4\tau}\right)\left[\operatorname{erf}\frac{1+(x_D-L_{wD})}{2\sqrt{\tau}}+\right.\\&\operatorname{erf}\frac{1-(x_D-L_{wD})}{2\sqrt{\tau}}+\operatorname{erf}\frac{1-(x_D+L_{wD})}{2\sqrt{\tau}}+\\&\left.\operatorname{erf}\frac{1+(x_D+L_{wD})}{2\sqrt{\tau}}\right]+\frac{1}{\sqrt{\tau}}\exp\left(-\frac{x_D^2}{4\tau}\right)\times\\&\left[\operatorname{erf}\frac{1+(y_D-L_{wD})}{2\sqrt{\tau}}+\operatorname{erf}\frac{1-(y_D+L_{wD})}{2\sqrt{\tau}}+\right.\\&\left.\operatorname{erf}\frac{1+(y_D+L_{wD})}{2\sqrt{\tau}}+\operatorname{erf}\frac{1-(y_D-L_{wD})}{2\sqrt{\tau}}\right]\end{aligned}\tag{24}$$

(4)六个分支水平井或60°尖灭角内位于角分线上的水平井

$$\begin{aligned}G_{xy}=&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{y_D^2}{4\tau}\right)\left[\operatorname{erf}\frac{1+(x_D-L_{wD})}{2\sqrt{\tau}}+\right.\\&\operatorname{erf}\frac{1-(x_D-L_{wD})}{2\sqrt{\tau}}+\operatorname{erf}\frac{1-(x_D+L_{wD})}{2\sqrt{\tau}}+\\&\left.\operatorname{erf}\frac{1+(x_D+L_{wD})}{2\sqrt{\tau}}\right]+\frac{1}{\sqrt{\tau}}\times\\&\exp\left(-\frac{\left(\sqrt{3}x_D+y_D\right)^2}{16\tau}\right)\times\\&\left[\operatorname{erf}\frac{2-\left(x_D-\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}+\right.\\&\operatorname{erf}\frac{2+\left(x_D-\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}+\\&\operatorname{erf}\frac{2+\left(x_D-\sqrt{3}y_D-2L_{wD}\right)}{4\sqrt{\tau}}+\\&\left.\operatorname{erf}\frac{2-\left(x_D-\sqrt{3}y_D-2L_{wD}\right)}{4\sqrt{\tau}}\right]+\\&\frac{1}{\sqrt{\tau}}\exp\left(-\frac{\left(\sqrt{3}x_D-y_D\right)^2}{16\tau}\right)\times\\&\left[\operatorname{erf}\frac{2+\left(x_D+\sqrt{3}y_D-2L_{wD}\right)}{4\sqrt{\tau}}+\right.\\&\operatorname{erf}\frac{2-\left(x_D+\sqrt{3}y_D-2L_{wD}\right)}{4\sqrt{\tau}}+\\&\operatorname{erf}\frac{2-\left(x_D+\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}+\\&\left.\operatorname{erf}\frac{2+\left(x_D+\sqrt{3}y_D+2L_{wD}\right)}{4\sqrt{\tau}}\right]\end{aligned}\tag{25}$$

# 边界元法用于油气藏稳定渗流数值模拟研究

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**摘　要**　油藏工程中通常采用的区域性数值模拟方法在当边界条件较为复杂时，实际应用遇到很大的困难。为解决这一问题，推导出稳定渗流 Laplace 方程和 Poisson 方程的边界元数模解法；给出了计算框图，用示例证明了该方法的正确性。由示例分析可知，由于边界元数模只需对研究区域的边界进行网格剖分，具有降维、计算速度快、精度高以及求解内点方便等特点。

**主题词**　油气藏　稳定流动　渗流　数值模拟　微分方程　边界元法

对稳定渗流的研究，在数学上涉及到如何求解 Laplace 方程或 Poisson 方程。在实际应用中，由于边界条件的复杂性，一般难以得到精确的解析解，通常采用的是区域性数值模拟方法，如有限差分和有限元法。当边界条件复杂时，这些方法的应用遇到了一定的难度，而边界元法在处理这一问题时却较为容易。

边界元法是用以近似求解初边值问题偏微分方程的一种边界型方法。求解时，根据积分定理，将区域内的微分方程变换成边界上的积分方程，然后将边界分割成有限大小的边界元素，把这些元素称为边界单元。把积分方程离散成代数方程组，这样即把求解偏微分方程的问题变换成求解关于节点未知量的代数方程问题。因为边界元法只需对研究区域的边界进行网格剖分，能够降维，可把三维问题降为二维问题，二维问题降为一维问题处理，且计算速度和精度较高，只需输入边界数据即可求解；离散化误差仅来源于边界，区域内的物理量可由解析式的离散形式直接求得，比较方便。

如何将这一先进的数学方法应用到油气藏数值

## 结　论

（1）本文利用源函数、Green 函数法和 Newman 乘积原理给出了气田分支水平井的拟压力。它适用于一般的分支水平井，其 Green 函数由式（20）和式（15）～（17）之一的乘积给出。利用无量纲拟压力表达式（21）可求得地层中的压力分布。

（2）对于几种常用的分支水平井布局，其 $xy$ 平面中的源函数可由式（20）简化为较简单的表达式，这些表达式列于式（22）～（25），并已编制成子程序，方便使用。

（3）本文结果也适用于尖灭角内水平井情形，只要水平井的井筒轴通过尖灭角的顶点；在一定条件下分支水平井与尖灭角内水平井是等价的；这些条件是：①尖灭角内实际井与镜像井总数应与分支水平井的分支数相等。②相应的夹角、井长、井位相同。③分支水平井的总产量应是尖灭角内水平井产量的 $N$ 倍。

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drocarbon evolution, migration and accumulation. The palaeostructure high part of Carboniferous in Indosinian epoch is favourable to the development of burial corrasion pores. Carboniferous sedimentary facies, dolomitization, dedolomitization, paulopost calcite packing etc. have influences on the development of reservoir pores in different degree. Palaeo-present structure combination trap and unconformity—structure combination trap are relative to the formation of Carboniferous gas reservoirs.

**SUBJECT HEADINGS**: Sichuan Basin, Carboniferous, Carbonate rock, Lithofacies and palaeogeography, Karstification, Reservoir, Pore evolution, Gas reservoir.

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He Hongju (*Well Logging Company of Sichuan Petroleum Administration*): **APPLICATION OF VSP IN HIGH-RESOLUTION PROCESSING**, **NGI** 16(6), 1996: 23~26

**ABSTRACT**: Ground seismic resolution can be improved by applying VSP wavelet and spectral property for VSP with the characteristics of stronger reflectance amplitude, higher signal-to-noise ratio, clearer first break than ground seismic facies and for what is recorded by VSP or ground seismic is two way time of seismic wave. Because of ground seismic and VSP with the various frequency, phaes, time deviation and wavelet, it is necessary using VSP to scale ground seismic to ensure the interpretation precision of ground seismic data. Profile resolution can be enhanced by autocorreting VSP reference trace with well-passing ground seismic trace, analysing its wavelet and spectral features, designing a matched filter and doing test in certain range; then doing frequency filtering, phase rotation, time displacement and smooth treatment to achieve the best match VSP with the spectral fecatures of ground seismic; finally filtering well-passing seismic section with the wave filter. Ground seismic resolution reliability enhanced by VSP is proved by theoretical analysis and processed sections and accurate seismic information is provided for careful structural interpretation, reservoir research and cross prediction.

**SUBJECT HEADINGS**: VSP, High resolution, Phase, Frequency, Wave filter, Application.

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Kong Xiangyan (*Mechanics Department of China Science and Technology University*), Xu Xianzhi, Lu Detang: **TRANSIENT PRESSURE ANALYSIS FOR MULTI-BRANCHED HORIZONTAL WELLS IN ANISOTROPIC GAS RESERVOIR**, **NGI** 16(6), 1996: 26~30

**ABSTRACT**: Horizontal well testing analysis is a new project with big difficulties and little ready methods at home and abroad. It is necessary to make clear the pressure distribution and change in horizontal well development. First, the instantaneous point-source solution of pseudo-pressure for anisotropic gas reservoir is derived. Then the instantaneous source function method and Newman multiplication principle are applied to give the Green's function for various multi-branched horizonal wells in gas reservior. Thus the analytic expressions of pseudo-pressure distribution are obtained. For easy to use, the table of Green's function for some simple arrangement of multi-branched horizontal wells is listed. These results are also applicable for the horizontal well in pitchout angles.

**SUBJECT HEADINGS**: Gas reservoir, Horizontal well, Cluster wells, Pitchout, Green's function.

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Fan Xueping(*Chongqing Petroleum Higher Training School*),Huang Jianming:**NUMERICAL SIMULATION RESEARCH OF OIL-GAS STEADY PERCOLATION BY BOUNDARY ELEMENT METHOD,NGI** 16(6),1996:30~33

**ABSTRACT**:Some difficulties are met in practice when applying numerical simulation method to oil-gas engineering in complex boundary conditions. In order to solve the problem,boundary element numerical method for steady percolation Laplace equation and Poisson equation is derived. With its calculation block diagram,the method is verified by an example. Because the method has the characteristics of reducing dimension,calculating fast,high precision and giving the inter solution easy,only dividing the research area boundaries,it should be widely used in reservoir numerical simulation.

**SUBJECT HEADINGS**:Oil-gas reservoir,Steady flow,Percolation,Numerical simulation,Differential equation,Boundary element method.

Xu Bihua(*Southwest Petroleum Institute*),Guo Xiaoyang,Zhang Yulong:**UTILIZING CEMENTING DESIGN AND ARTIFICIAL SIMULATION SYSTEM TO AID THE IMPROVEMENT OF FIELD CEMENTING QUALITY,NGI** 16(6),1996:34~37

**ABSTRACT**:It is very important adopting rational techniques to control various parameters and to ensure displacement quality during cementing. Basic functions,structure,design thinking,main model caracteristics and field application of a cementing design and simulation system cooperatively developed in recent years are introduced. Some methods of Utilizing the system to aid the improvement of field cementing quality are proposed out.

**SUBJECT HEADINGS**:Well cementing,Cementing,Rheology,Computer assisted,Application.

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Liu Jubao(*Daqing Petroleum Institute*),Zhang Xuehong,Sun Chao,Zhong Qigang:**BENT BEAM UNIT ANALYSIS OF DRILL STEM DEFORMATION IN HORIZONTAL WELL,NGI** 16(6),1996:38~40

**ABSTRACT**:In the light of the basic principle of finite element method,the arc bent beam units and rigidity matrix suited to the deformation analysis of drill stem in horizonat well are researched and the relevant computer procedure is worked out. Typical example and compulation result of mechanics analysis of horizontal well drill stem show:For the same structure and in the condition of constant computation precision,the number and compulation time of bent beam units are less than those of straight beam units,which is very important for nonlinear mechanics analysis of the horizontal drill stem with bigger curvature. So it is feasible replacing straight beam units by bent beam units to reduce computation time when doing the mechanics analysis of drill stem with bigger curvautre.

**SUBJECT HEADINGS**:Horizontal well,Drill stem,Deformation,Mechanics,Analysis.

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