Project Report

1. 问题：① 油气两相、干气、黑油模型
② 平面、均匀、各向同性、岩石不可压、忽略毛管压力
③ 单井、生产井、忽略表皮效应
④ 边界无流动

2. 输入：① GeoModel：

$Nx = 11 \quad Ny = 11 \quad Nz = 1$

$dx = 200ft \quad dy = 100ft \quad dz = 300ft$

$K = 10\,mD,\ \phi = 0.25,\ D_{top} = 5000ft$

② Well：

$(6,6,1)$

$$\begin{cases} BHP > 2000\,psi, & OilRate = 5000\ BBLs/day \\ BHP \le 2000\,psi, & BHP = 2000\,psi \end{cases}$$

$T = 1000\ days$

$radius = 0.25ft$

③ PVT：

$C_R = 0$

$\rho_{oil} = 46.244\ lbm/scf;\ \rho_{water} = 62.238\ lbm/scf,\ \rho_{gas} = 0.0647\ lbm/s$

$\mu_o = 6e\text{-}8\ p^2 - 4.589e\text{-}4\ p + 1.1179 \quad (psi;\ cp)$

$\mu_g = 3e\text{-}10\ p^2 + 1e\text{-}6\ p + 0.0133 \quad (psi;\ cp)$

$B_o = -3.922264e\text{-}8\ p^2 + 0.0003\ p + 1 \quad (psi;\ 1)$

$B_g = 3592.7\ p\wedge(-1.0226) \quad (psi;\ 1)$

$$k_{ro} = \begin{cases} 0, & sg \ge 0.85 \\ \left(\frac{0.85 - sg}{0.85}\right)^{1.5}, & sg \le 0.85 \end{cases}$$

$$k_{rg} = \begin{cases} 0.85\wedge1.5, & sg \ge 0.85 \\ sg\wedge1.5, & sg \le 0.85 \end{cases}$$

$$R_s = \begin{cases} 1, & p > 3824.321712 \\ 0.0000476\ p\wedge1.206511, & p < 3824.321712 \end{cases} \quad \left(psi;\ \frac{mscf}{STB}\right)$$

④ Initial Condition:

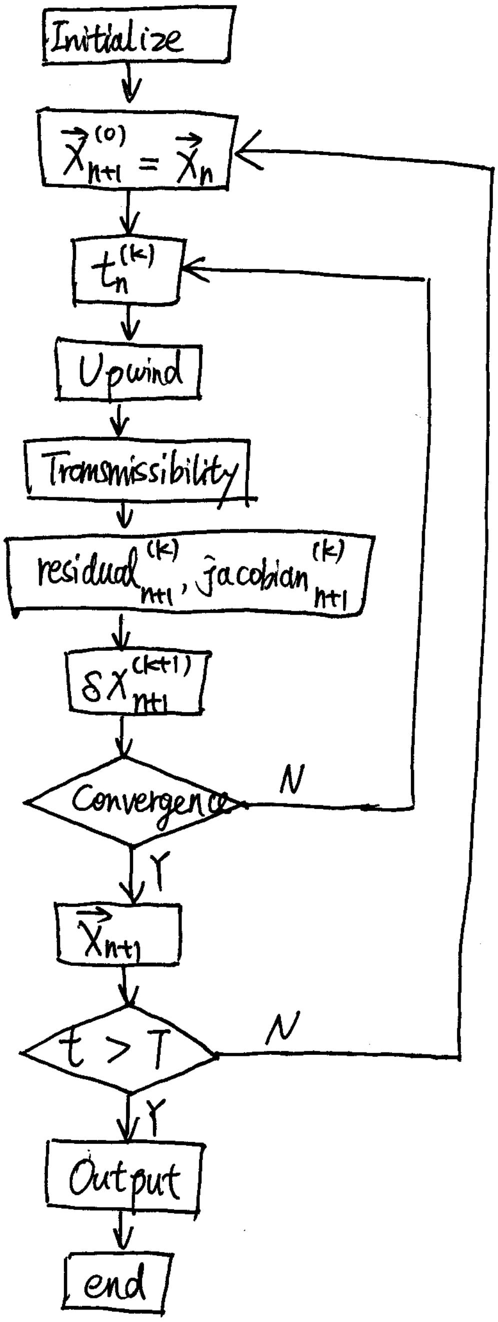
$p = 5039.623$ psi

$S_g = 0$

⑤ Boundary Condition:

No flow

3、流程图



4. 离散方程

1° 组分质量守恒方程

$$\begin{cases} \sum_l m_{\bar{o},o} - m^{w}_{\bar{o},o} = \frac{1}{\Delta t}\Delta_t M_{\bar{o},o} \\ \left(\sum_l m_{\bar{g},g} + \sum_l m_{\bar{g},o}\right) - \left(m^{w}_{\bar{g},g} + m^{w}_{\bar{g},o}\right) = \frac{1}{\Delta t}\Delta_t \left(M_{\bar{g},g} + M_{\bar{g},o}\right) \end{cases}$$

2° 离散方程

$$\left(\frac{\lambda_o}{B_o}T_o\right)_{i-\frac{1}{2}}\left(p_{o,i-1}-p_{o,i}\right) + \left(\frac{\lambda_o}{B_o}T_o\right)_{i+\frac{1}{2}}\left(p_{o,i+1}-p_{o,i}\right) + \left(\frac{\lambda_o}{B_o}T_o\right)_{j-\frac{1}{2}}\left(p_{o,j-1}-p_{o,j}\right) + \left(\frac{\lambda_o}{B_o}T_o\right)_{j+\frac{1}{2}}\left(p_{o,j+1}-p_{o,j}\right) - \left(q^{w}_{o}\right)_i = \frac{dV\cdot\phi}{C_{UnitConversion}\cdot dt}\left[\left(\frac{S_o}{B_o}\right)^{n+1} - \left(\frac{S_o}{B_o}\right. \right.$$

$$\left(\frac{\lambda_g}{B_g}T_g + \frac{\lambda_o}{B_o}T_o\cdot R_s\right)_{i-\frac{1}{2},j}\left(p_{g,i-1,j}-p_{g,i,j}\right) + \left(\frac{\lambda_g}{B_g}T_g + \frac{\lambda_o}{B_o}T_o\cdot R_s\right)_{i+\frac{1}{2},j}\left(p_{g,i+1,j}-p_{g,i,j}\right) + \left(\frac{\lambda_g}{B_g}T_g + \frac{\lambda_o}{B_o}T_o\cdot R_s\right)_{i,j-\frac{1}{2}}\left(p_{g,i,j-1}-p_{g,i,j}\right) + \left(\frac{\lambda_g}{B_g}T_g + \frac{\lambda_o}{B_o}T_o\cdot R_s\right)_{i,j+\frac{1}{2}}\left(p_{g,i,j+1}-p_{g,i,j}\right) - \left(q^{w}_{g} + R_s\cdot q^{w}_{\bar{o}}\right)$$

$$= \frac{dV\cdot\phi}{C_{UnitConversion}\cdot dt}\left[\left(\frac{S_g}{B_g} + R_s\frac{S_o}{B_o}\right)^{n+1} - \left(\frac{S_g}{B_o} + R_s\frac{S_o}{B_o}\right)^{n}\right]$$

传导率： $\Upsilon_o(p, S_g) \equiv \frac{\lambda_o}{B_o}T_o$, $\Upsilon_g \equiv \frac{\lambda_g}{B_g}T_g$

$$\Upsilon = GeoTerm * FluidTerm$$

比如， $GeoTermX = \frac{k\cdot dy\cdot dz}{dx}$

$$(FluidTerm\ Oil)_{i+\frac{1}{2},j} = \begin{cases} \left(\frac{k_{ro}}{B_o\cdot\mu_o}\right)_{i,j}, & p_{i,j} > p_{i+1,j} \\ \left(\frac{k_{ro}}{B_o\mu_o}\right)_{i+1,j}, & p_{i,j} < p_{i+1,j} \end{cases}$$

井传导率：定义 γ_o^w 为 $q_o^w = \gamma_o^w (p_o - p^w)$，则

$$\gamma_o^w (p, S_g) = WI \cdot \lambda_o$$

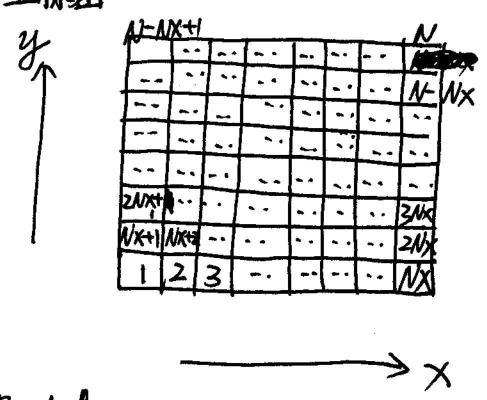
其中 $$WI = \frac{2\pi k \, dz}{\ln(\frac{r_o}{r_w})}$$

$$r_o = 0.14 \sqrt{dx^2 + dy^2}$$

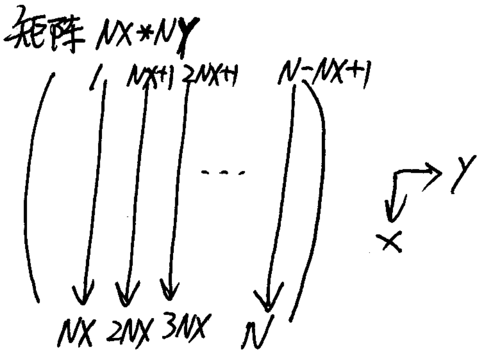
$$\lambda_o = \frac{k_{ro}}{\mu_o \cdot B_o}$$

3、计算模型

① 坐标图：



矩阵 NX*NY



② Residual vector

Residual (2N×1) = ResidualOil (NX·NY) ; ResidualGas (NX·NY)

FlowTerm (NX·NY) : $(i-\frac{1}{2})$ + $(i+\frac{1}{2})$ + $(j-\frac{1}{2})$ + $(j+\frac{1}{2})$ (方框标值为0)

AccumuTerm (NX·NY):

WellTerm (1):

比如，FlowTermOil_XPlus = TransOilX · deltaPX

TransOilX = GeoTermX · FluidTermOilX

FluidTermOilX = FluidTermOil (upwindXPlu

deltaPX = [ ] − [ ] (小框内数据对应相减)

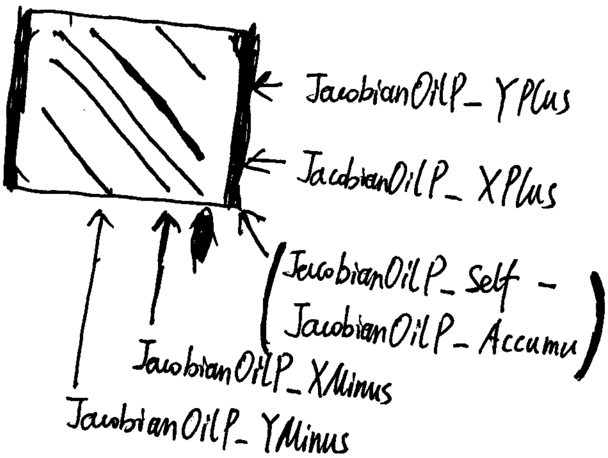
FlowTermOil_XMinus = TransOilX · (−deltaPX) (矩阵沿用上面的值)

$$AccumuTermOil = \frac{dV \cdot \phi}{C \cdot dt} \cdot \left(So \cdot Bo - So\_Previous \cdot Bo\_Pre \right.$$

③ Jacobian

$$\underset{(2N*2N)}{Jacobian} = \left[\begin{array}{c|c} JacobianOilP & JacobianOilSg \\ \hline JacobianGasP & JacobianGasSg \end{array} \right]$$

比如, JacobianOilP =



其中, JacobianOilP_Self = (X+) + (X−) + (Y+) + (Y−)

Y ↑ → X

(X+) = upwindXPlus_Self $\cdot \left(\frac{\partial TransOilX}{\partial P} \right) \cdot$ deltaPX

(取对方框中的对应元素)

− TransOilX

JacobianOilP_XPlus = upwindXPlus_Other $\cdot \left(\frac{\partial TransOilX}{\partial P} \right) \cdot$ deltaPX

+ TransOilX

[redacted]

$$X- = upwindXPlus\_Other \cdot \left(\frac{\partial TransOilX}{\partial P}\right) \cdot (-deltaPX)$$

（取内框中元素）

$$- TransOilX$$

$$JacobianOilP\_XMinus = upwindXPlus\_Self \cdot \left(\frac{\partial TransOilX}{\partial P}\right) \cdot (-deltaPX)$$

$$+ TransOilX$$

（矩阵全部沿用前面的值）

$$JacobianOilP\_Accumu = \frac{dV \cdot \phi}{C \cdot dt} \cdot \left(- So \cdot difBo / Bo^2\right)$$

其中 upwindXPlus_Self，upwindXPlus_Other 是迎风状态乘子。

(NX-1)*NY

Note: 1、气方程井项PVT参数Rs使用PBlock计算（或者应该是把井也视为一个网格）。用迎风格式计算。

2、ECLIPSE计算效率明显优于我的程序。

Problems：1、块五对角矩阵快速解法／高精度解法。

2、大条件数方程如何可能得到高精度解？