CHAPTER-5

FLOW OF GAS FROM HYDRAULIC FRACTURE TO HORIZONTAL WELLBORE

In shale gas reservoirs, for increasing the rate of production a horizontal well will be drilled into the shale formation so that the connectivity between the formation and the wellbore can be increased. In this model, a horizontal wellbore has been considered in the 5^{th} layer from the top. The gas flow into the horizontal wellbore is only from the induced or hydraulic fractures and no gas will flow from the matrix blocks to the wellbore.

5.1 Pressure variation in Matrix Blocks:

A nonlinear PDE, which represents the flow of gas in the matrix is developed and then compiled using JAVA to get the pressure variation in all the blocks. Figure 5.1 represents the shale reservoir with no hydraulic fractures.

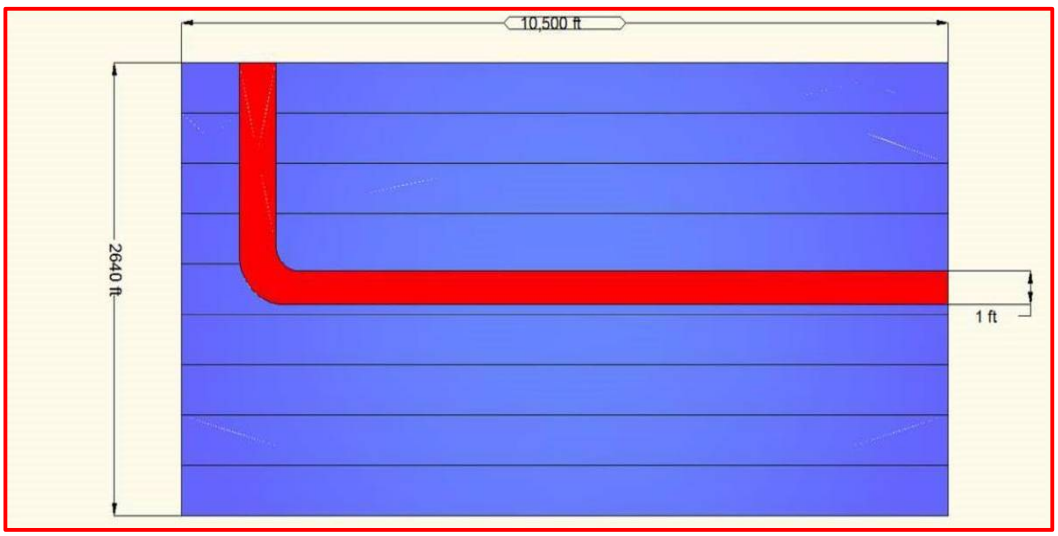

Figure 5.1: Shale reservoir with horizontal wellbore and no hydraulic fractures.

The model has been divided into 9*9*9 blocks. Each block will be having different pressure drops during the gas production, but the rate of pressure change in all the matrix blocks is almost same. The variation of pressure in all the matrix blocks is shown in Figure 5.2.

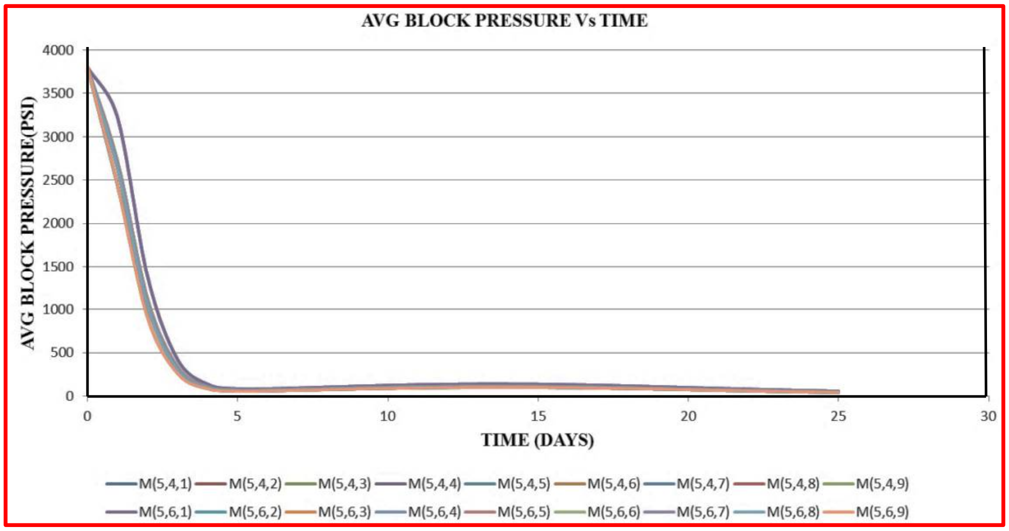

Figure 5.2: Individual matrix block pressure variation with time.

Figure 5.2 represents that the pressure variation in all the blocks is almost similar. As a result, for calculating the flow rate through the horizontal wellbore the pressure variation in the surrounding blocks can be considered. In oil and gas industry, Borisov (1964) proposed a formula 5.1 for representing the flow of gas in the horizontal wellbore.

$$q_g = \frac{[-2\Pi\beta_c dk(p_{i,j,k} - p_{wf})]}{\mu B\left[\ln\left(\frac{\sqrt{A}}{r_w}\right) + \ln(C_H) + S - \frac{3}{4}\right]} \text{------------------------------ (5.1)}$$

Where, $k = \sqrt{(k_x k_z)}$.

$d = \Delta y$.

$A = c.h = \Delta x.\Delta z$.

$\ln c_H = 6.28\ \frac{c}{h}\sqrt{\frac{k_z}{k_x}}\left[\frac{1}{3} - \frac{X_o}{C} + \left(\frac{X_o}{C}\right)^2\right] - \ln\left(\sin\frac{\pi Z_0}{h}\right) - 0.5\ \left[\ln\left(\frac{c}{h}\sqrt{\frac{K_z}{K_x}}\right)\ \right]$-1.088.

$p_{i,j,k} = pressure\ in\ the\ surrounding\ blocks\ of\ horizontal\ wellbore, psi.$

$p_{wf} = well\ flowing\ pressure\ in\ the\ horizontal\ wellbore, psi.$

$r_w = radius\ of\ the\ wellbore, ft.$

$S = Skin\ Factor.$

Figure 5.3, represents the rate of flow of gas from the matrix block in the horizontal wellbore.

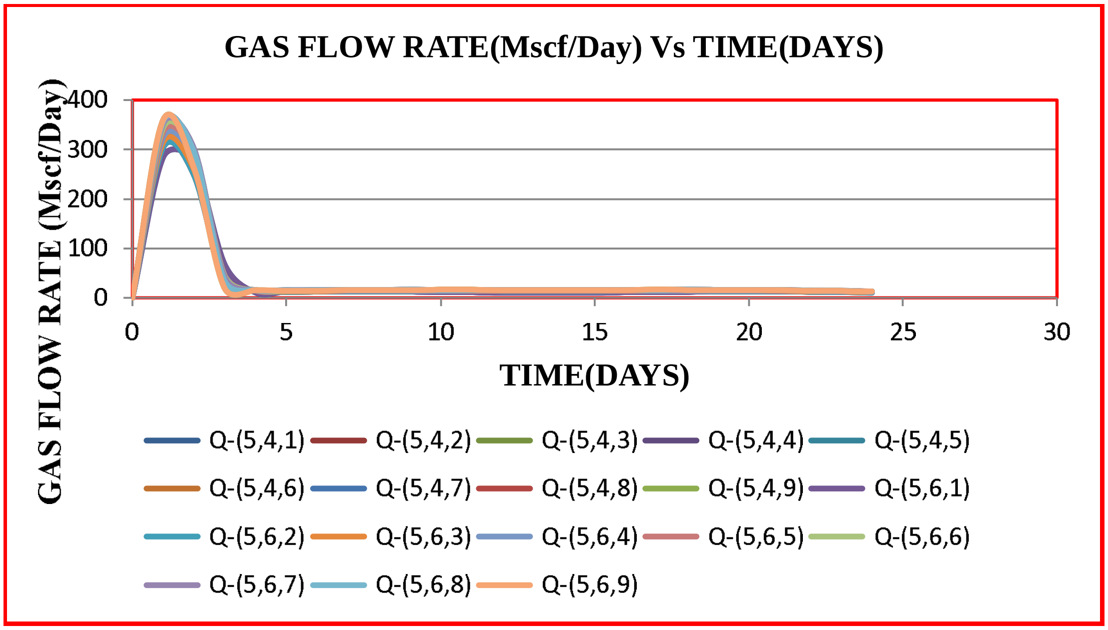

Figure 5.3: Gas flow rate variation with respect to time in different matrix blocks.

5.2 <u>Pressure variation in Induced or Hydraulic Fractures:</u>

A nonlinear PDE, which represents the flow of gas in the induced or hydraulic fractures is developed and then compiled using JAVA to get the pressure variation in all the hydraulically fractured blocks. Figure 5.4 represents the shale reservoir with four hydraulic fractures.

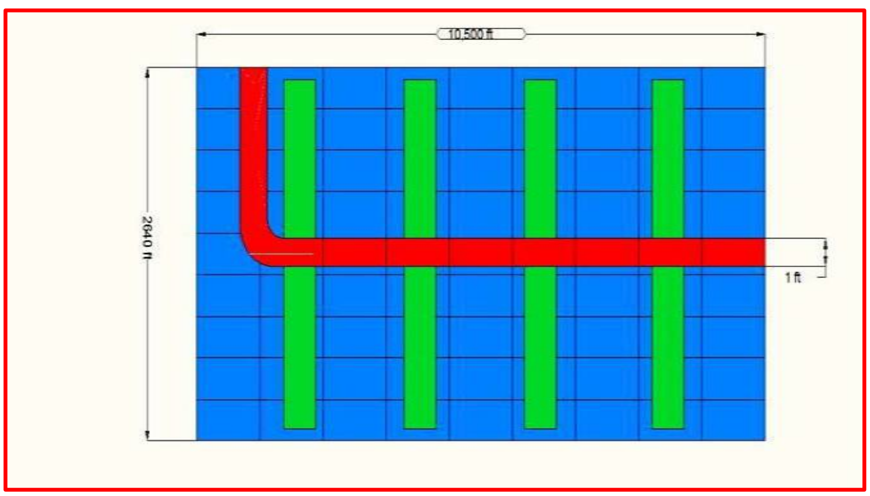

Figure 5.4: Schematic representation of shale reservoir with horizontal wellbore and four Hydraulic fractures.

In this case, the gas flow into the horizontal wellbore will be only from the hydraulically fractured blocks and there is no gas flow from the matrix blocks to the wellbore. As the model has 5 layers, one hydraulic fracture contains four blocks on each side of the wellbore. Each block will be having different pressure drops during the gas production from the shale reservoir. In this work, it has been proven that the rate of variation of pressure in the hydraulically fractured blocks is almost same. Figure 5.5 represents the variation of pressure in the hydraulically fractured blocks.

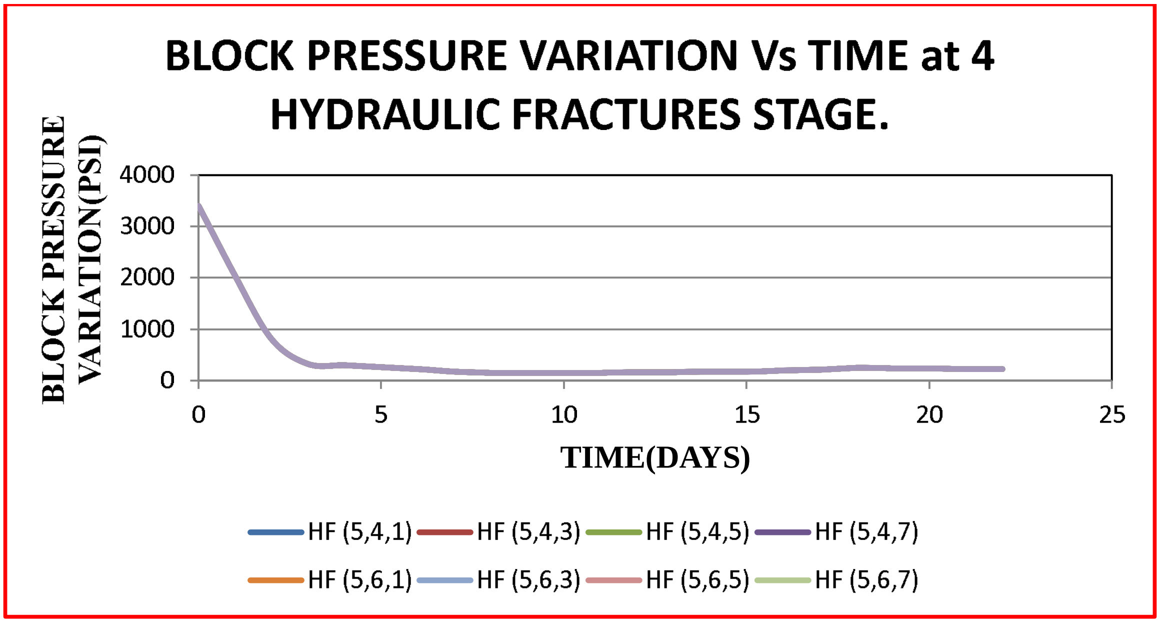

Figure 5.5: Pressure variation at different block of hydraulic fractured zone with respect to time.

Figure 5.5 represents that the pressure variation in all the hydraulically fractured blocks is almost similar. As a result, for calculating the flow rate through the horizontal wellbore the pressure variation in the surrounding hydraulically fractured blocks can be considered. Equation 5.1 is used for determining the flow rate of gas in the hydraulically fractured horizontal wellbore.

Figure 5.6 shows the flow rate of gas from the fractured zone to the horizontal wellbore.

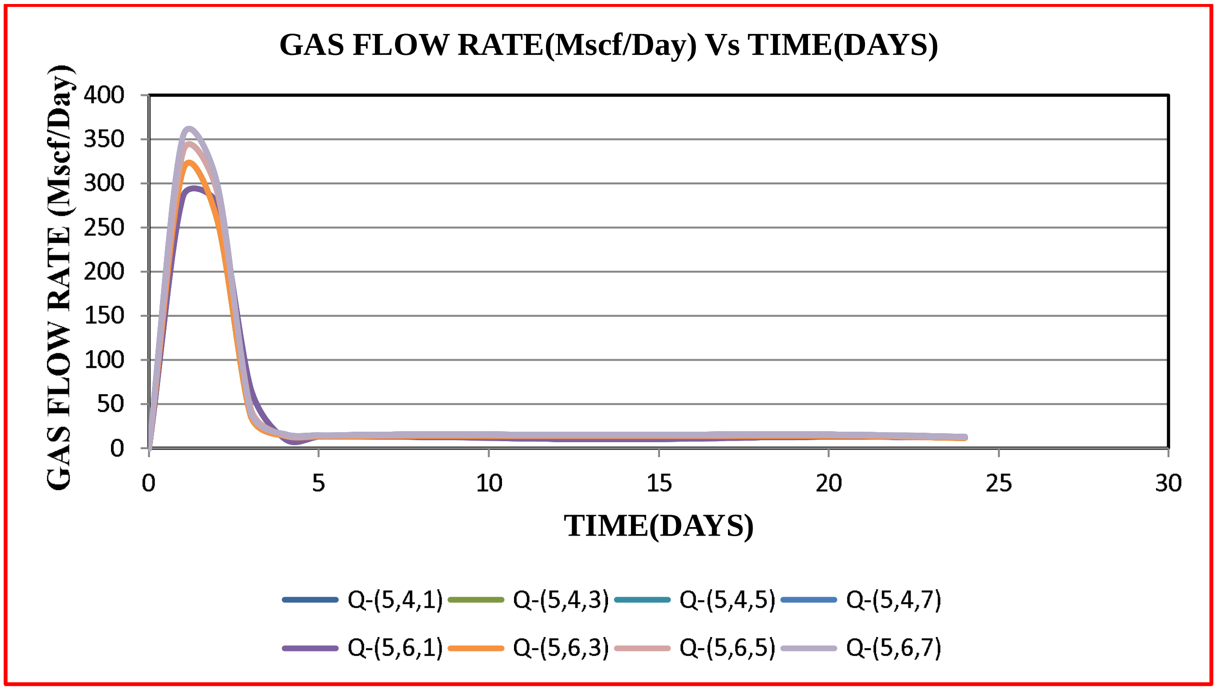

Figure 5.6: Gas flow rate variation with respect to time in different fractured blocks.

5.3 <u>Flow rate variation under different cases:</u>

In this model six different cases have been considered to study the gas flow rate variations in the horizontal wellbore. The different cases includes,

Case 1: Shale gas reservoir with horizontal wellbore and no hydraulic fractures.

Case 2: Shale gas reservoir with horizontal wellbore and One hydraulic fracture.

Case 3: Shale gas reservoir with horizontal wellbore and Two hydraulic fractures.

Case 4: Shale gas reservoir with horizontal wellbore and Three hydraulic fractures.

Case 5: Shale gas reservoir with horizontal wellbore and Four hydraulic fractures.

Case 6: Shale gas reservoir with horizontal wellbore and Six hydraulic fractures.

The comparison of all six cases on gas flow rate is given in Figure 5.7.

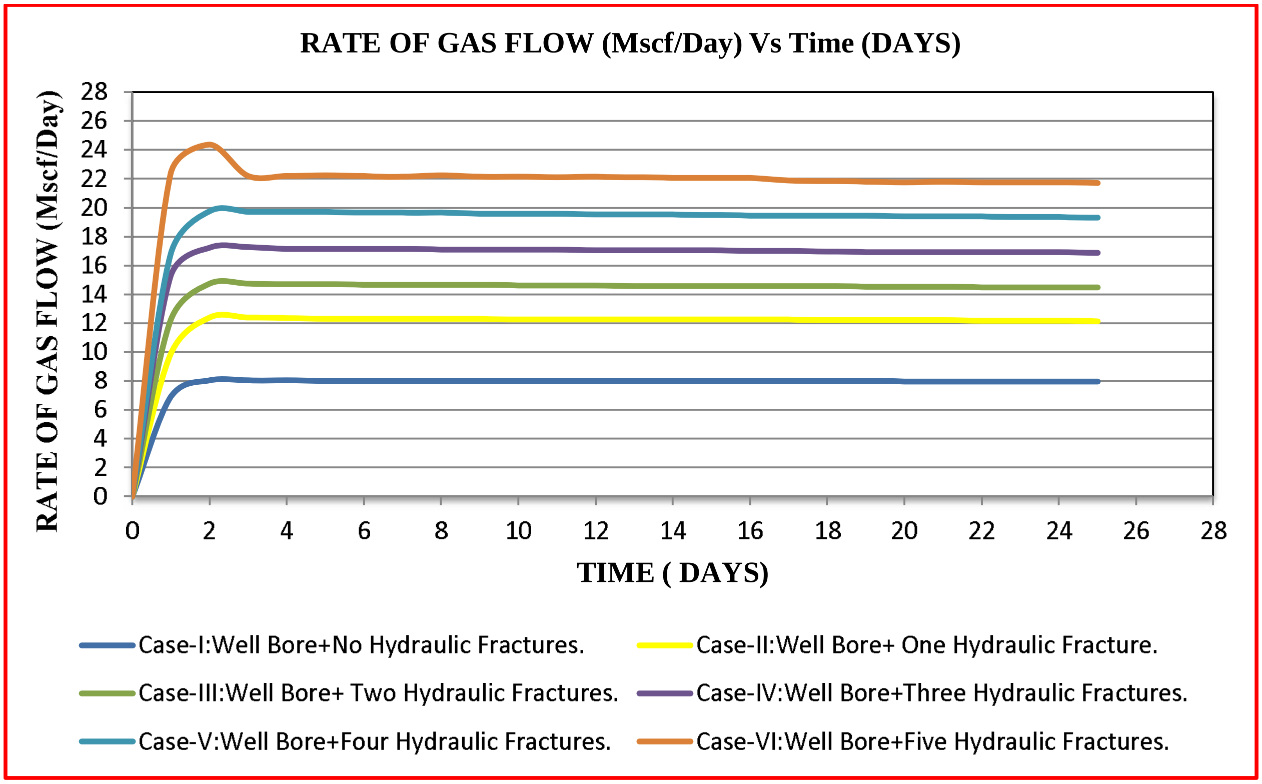

Figure 5.7: Gas flow rate variation with time at different Hydraulic Fracture Stages.

From Figure 5.7, it is clear that the gas flow rate increases with increase in the number of induced or hydraulic fractures.