Time-Pressure Correlation to Estimate Dewatering Time for Coalbed Methane Reservoir at Saturated and Undersaturated Condition*

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Abstract

Coalbed Methane (CBM) reservoirs are naturally fractured, low pressure, water saturated gas reservoirs. In a coal seam reservoir, while some free gas may exist in the coal deposits, the majority of the gas is adsorbed on the surface of the coal matrix. At undersaturated condition, when reservoir pressure is above critical desorption pressure, only water is produced. Initially the natural fractures of the coal are typically water saturated. This water has to be removed in order to achieve any significant gas production. Dewatering of the coal seam reduces the hydrostatic pressure of the reservoir, which allows the gas to be desorbed from the coal matrix. At the same time, lowering the water saturation level of the reservoir increases the relative permeability of gas, thereby permitting the desorbed gas to flow to the wellbore. Dewatering processing consumes much time and it is not effective for well development. The problem encountered during dewatering process is to determine the time gas began to flow where the reservoir is still undersaturated condition. In this paper, the authors recognize dewatering time using a time-pressure correlation and show correlations indicating the relationship between the initial pressures at saturated and undersaturated condition versus dewatering time. For saturated conditions, a typical condition for CBM reservoir, correlation by Thungsuntonkhum will be employed. At this condition, there will be two-phase water and gas production. The correlation shows that gas flow rate and water flow rate will be calculated from the integral function of pressure as Darcy flow because it is assumed there is no diffusion while the cleat is filled by water. For undersaturated conditions, the King and Ertekin correlation will be employed by assuming there is diffusion phenomenon using Fick's Law. Time-pressure correlation will show a linear relationship for both dewatering time in the first and second definition.

Introduction

Coalbed Methane (CBM) is methane gas that is formed naturally during coalification process and trapped within the coal matrix. CBM reservoirs are usually naturally fractured, low pressure, water saturated gas reservoir. During the progression of coalification from peat to anthracite, methane and water may be generated. The amount of water produced from most CBM wells is relatively high compared to conventional natural gas wells because coal beds contain many fractures and pores that can contain and transmit large volumes of water. The water in coal beds contributes to pressure in the reservoir that keeps methane gas adsorbed to the surface of the coal (Rice and Nuccio, 2000).

Initially, the natural fractures of the coal are typically water saturated. At undersaturated conditions, when reservoir pressure is above critical desorption pressure, only water is produced. This water has to be removed in order to achieve any significant gas production. Dewatering of the coal seam reduces the hydrostatic pressure of the reservoir, which allows the gas to be desorbed from the coal matrix. At the same time, lowering the water saturation level of the reservoir increases the relative permeability of gas, thereby permitting the desorbed gas to flow to the wellbore. Proper dewatering of CBM wells is the key to efficient gas production from these reservoirs. The time required in dewatering stage can last for several months to several years, depending on the level of maturity and moisture content of the coal formation (coalification) itself. Dewatering processing consumes much time and it is not effective for well development time. The problem encountered during dewatering processes is to determine the time of gas began to flow where the reservoir is still undersaturated condition. In this paper, the authors would like to recognize dewatering time using time-pressure correlation.

Method

First, we defined critical desorption pressure as the pressure when the first gas is released from the coal matrix. Critical desorption pressure, for example as illustrated on Figure 1, is the pressure on the sorption isotherm that corresponds to the initial gas content (Aminian, 2003). By lowering pressure of coalbed methane cleat system in dewatering process until its critical desorption pressure, gas will desorb from the coal matrix.

Second, we define dewatering time into two different terms, as shown on Figure 2 and Figure 3, based on the flowing gas presence in dewatering process: (1) the time needed from dewatering process until the first gas desorb; and (2) the time needed from dewatering process until the maximum gas production rate.

For saturated condition at typical condition for CBM reservoir, correlation by Thungsungtonkhum (2001) will be employed. At this condition, there will be two-phase water and gas production. The correlation shows that gas flow rate and water flow rate will be calculated from the integral function of pressure as Darcy flow because it is assumed there is no diffusion while the cleat is filled by water.

For undersaturated conditions, the King and Ertekin correlation will be employed by assuming there is diffusion phenomenon using Fick's Law. Dewatering time can be determined by plotting gas rate vs. time. Then, it will be defined dimensionless dewatering time as:

$$q_w = \frac{0{,}00708kh}{\ln\frac{r_e}{r_w}\mu_w B_w}\int_{pd}^{p_{atk,rw}=0} k_{rw}(s_w, p)\,dp$$

$$q_g = \frac{703x10^{-6}kh}{\ln\frac{r_e}{r_w}\mu_w Z}\int_{pd}^{p_{atk,rw}=0} k_{rw}(s_w, p)\,dp$$

$$q_{gm} = 2{,}697\sigma D\rho_c V_c(G_c \quad G_s)$$

$$t_D - \frac{t_{dewatering}}{t_{gas\ rate\ is\ declining-1000days}}$$

Undersaturated

From single well reservoir simulations on Figure 4, it is shown that CBM production is divided into several stages: dewatering phase, production phase, and declining phase. Production time reached lower production peak compared with a conventional gas reservoir and slowly decline over several years so that CBM has a long lifetime. It is also shown that declining water production in reservoirs will increase gas production.

Discussion and Conclusion

Dewatering time in the first definition is determined from the start of the process of dewatering and production of gas started coming out. By making various types of the dimensionless dewatering time at first definition vs. dimensionless pseudo pressure, we will get the graph x. The equation representing this graph is a third-order polynomial equation. Furthermore, the second definition is determined from the dewatering process until the start of gas production rate reached a maximum value. In general, maximum gas rate always occurred 100 days after the first gas produced.

This can be due to the range of 100 days is still a process of desorption of gas produced of the coal matrix as the input data reservoir. Just like at the time dewatering first definition, which represents the graph of this equation, is the third-order polynomial equation. Both of these polynomial equations have a different intercept due to the time shifting of 100 days. Dewatering time of the third type is determined from the intersection of the graph of the rate of water production and gas production rate. The equation represented in this graph is the third-order polynomial equation. From the following equations, we see that the relationship between the pseudo pressure dewatering times has a relationship and especially the reservoir with properties in this case, that relationship is the polynomial.

Authors show correlations indicating the relationship between the initial pressures at saturated and undersaturated condition versus dewatering time. The correlation between pressure and dewatering time shows linear relationship, both for dewatering terminology type 1 and dewatering terminology type 2. The correlation is only valid for coalbed methane fields, which have similar reservoir properties described in this paper and it is formed in dimensionless correlation equations.

1. Time-Pressure correlation for saturated condition is tD = 0.9325 PD2+0.1249PD-0.0917 (Figure 5).
2. Time-Pressure correlation for undersaturated condition (Type 1) is tD = 7.5814 PD3-0.1636PD2+0.7621PD-0.0008 (Figure 6).
3. Time-Pressure correlation for undersaturated condition (Type 2) is tD = 7.5814 PD3-0.1636PD2+0.7621PD+0.00992 (Figure 7).

References

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Rice, C.A., and V. Nuccio, 2000, Water produced with coal-bed methane: U.S. Geological Survey Fact Sheet FS-156-00, p 1-2.

Thungsuntonkhum, W., 2001, Well deliverability of undersaturated coalbed reservoir: SPE paper 71068, 3 p.

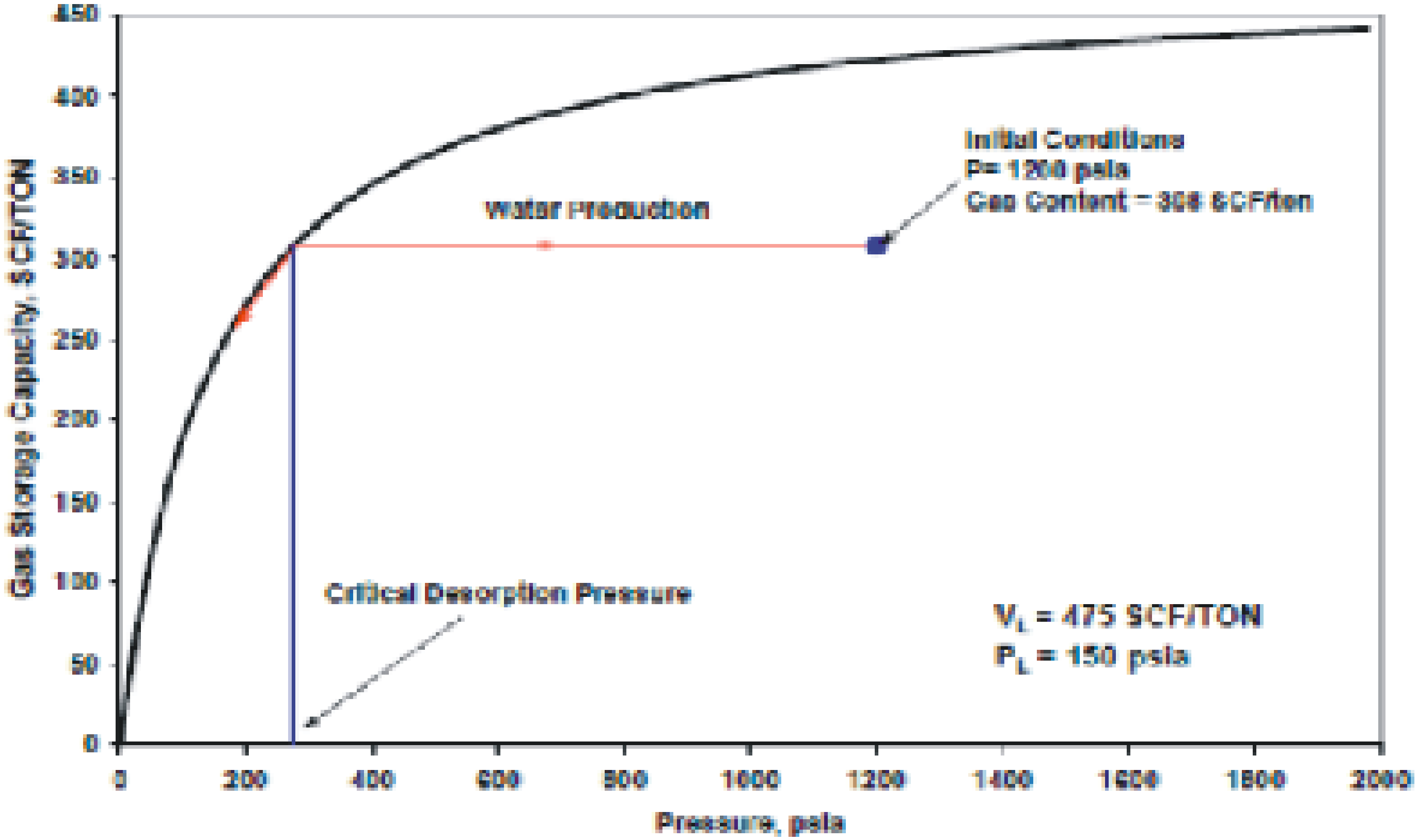

Figure 1. Critical desorption pressure in Typical Langmuir Isotherm (Aminian, 2003).

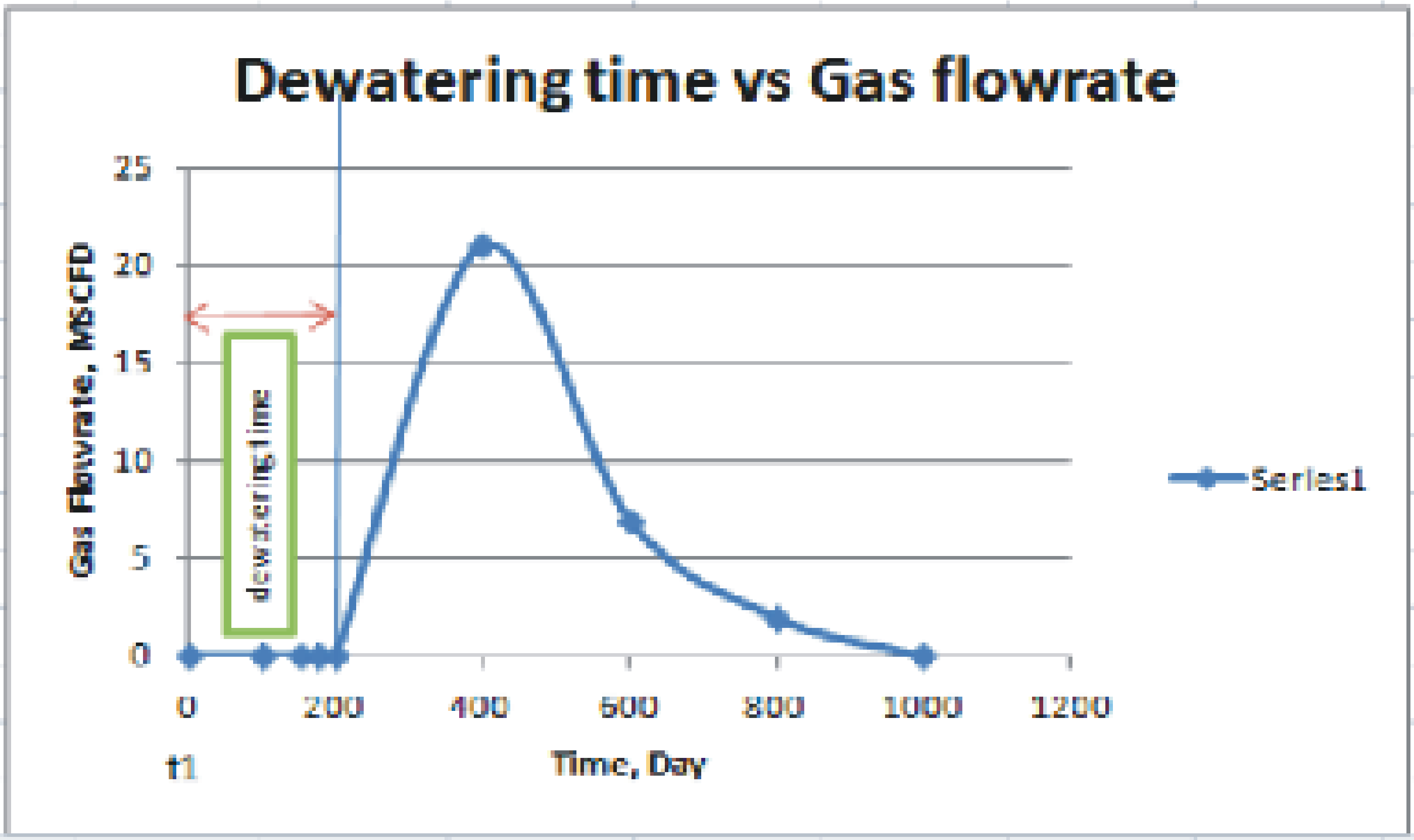

Figure 2. Dewatering time terminology type 1 which shows that dewatering time is defined as the first times gas produced in well.

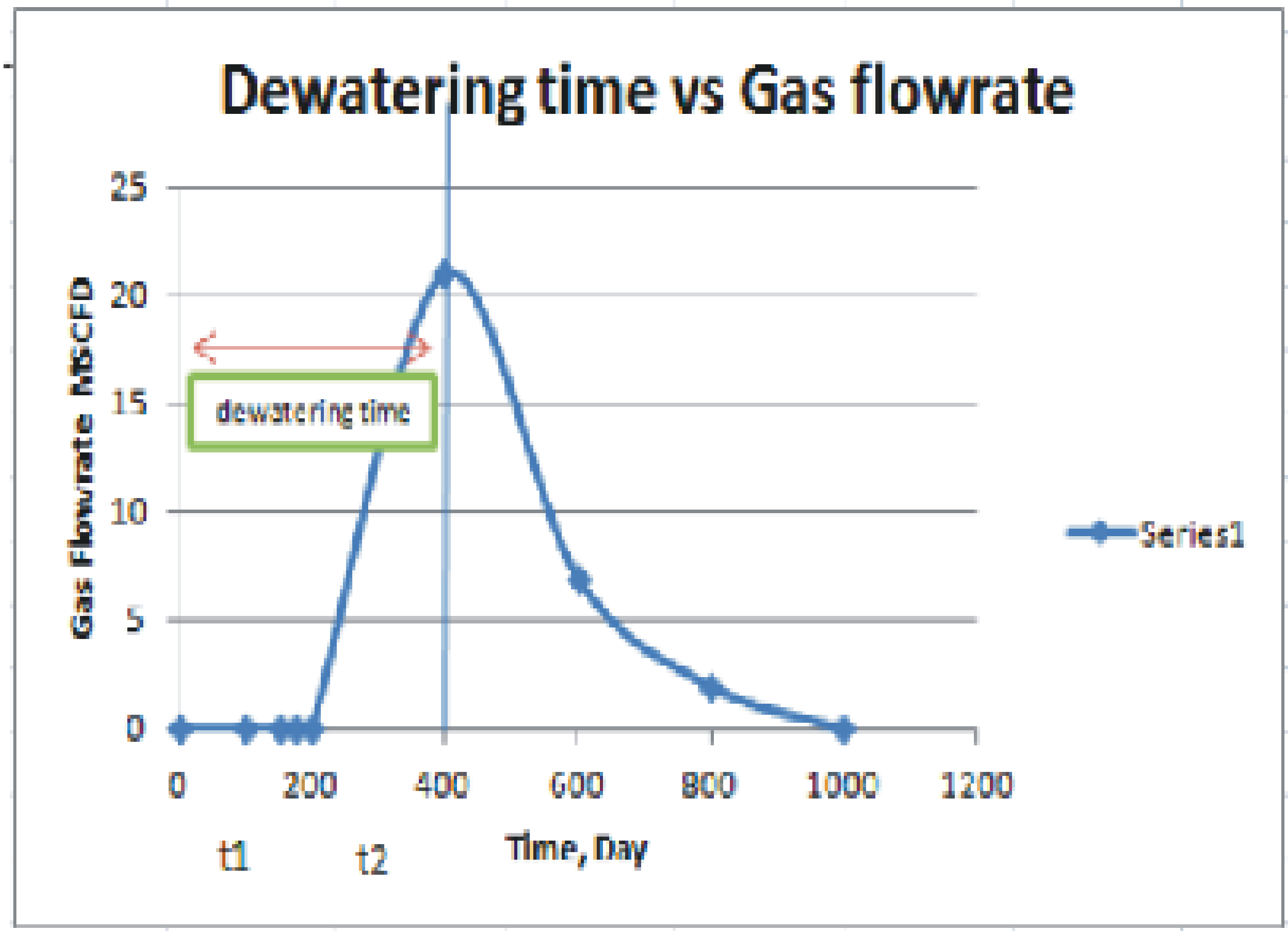

Figure 3. Dewatering time terminology type 2 which shows that dewatering time is defined as the maximum producing gas in well.

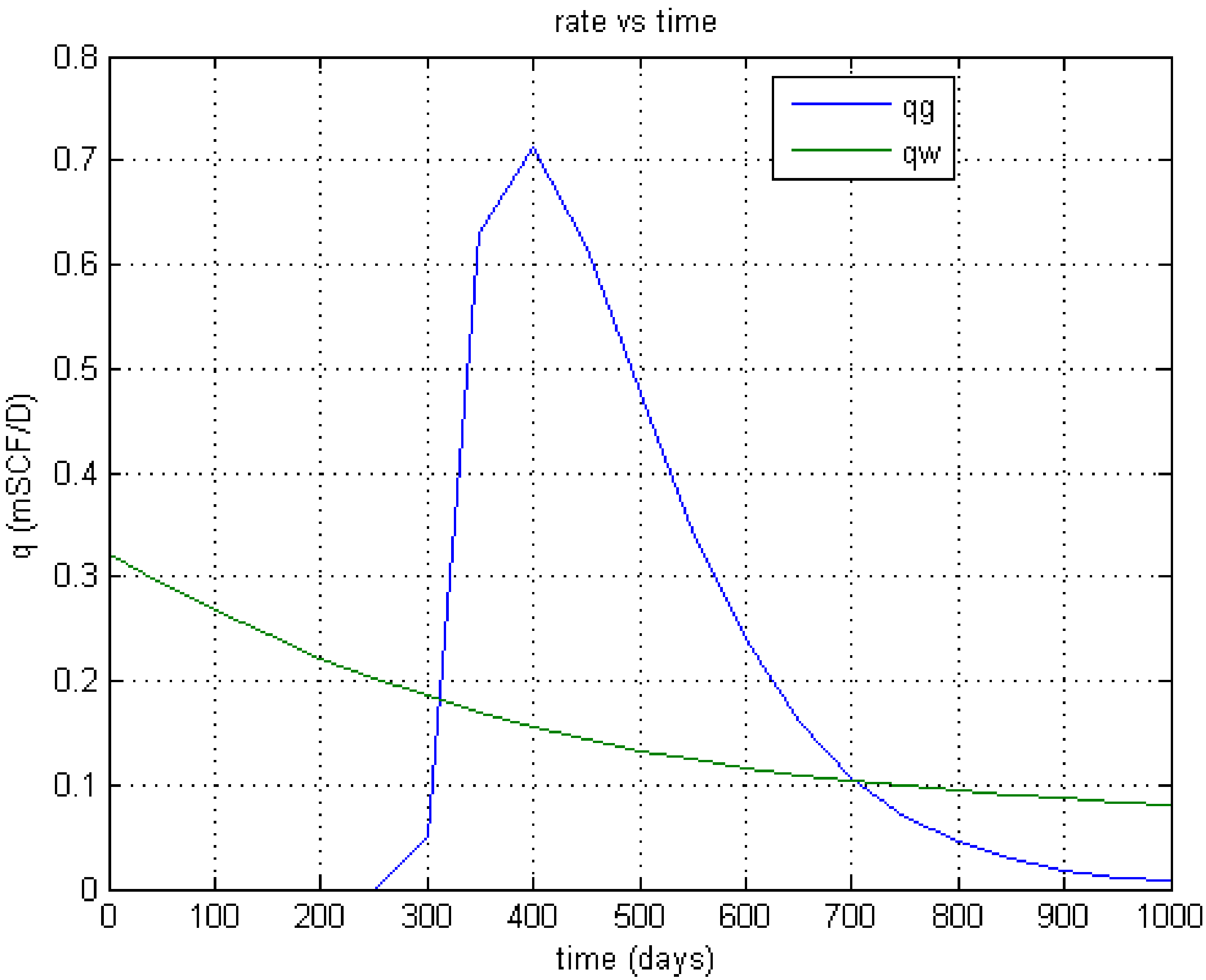

Figure 4. Time-rate correlation for CBM reservoir at saturated condition.

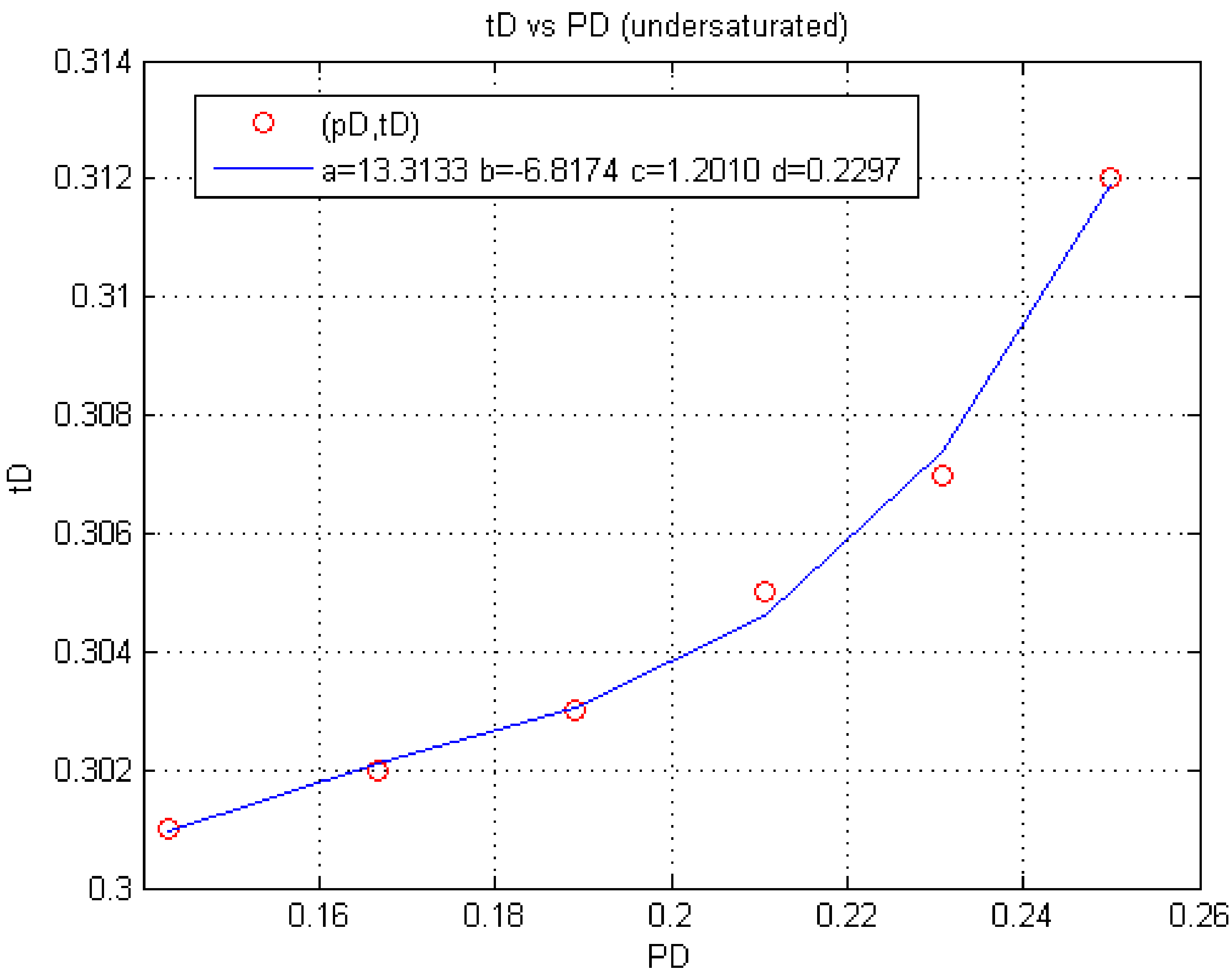

Figure 5. Time-pressure correlation for coalbed methane reservoir at saturated condition.

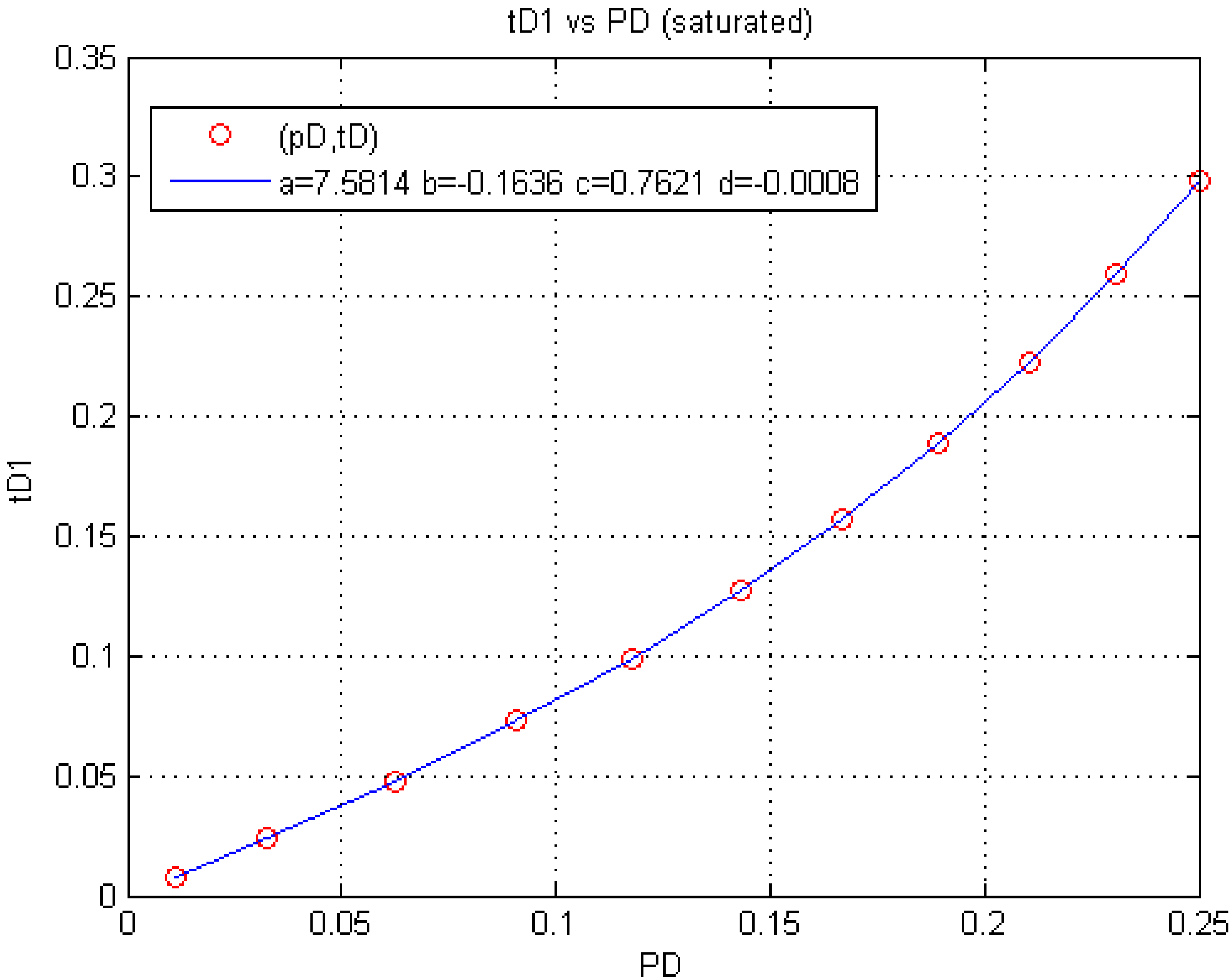

Figure 6. Time-pressure correlation for coalbed methane reservoir at undersaturated condition (type 2).

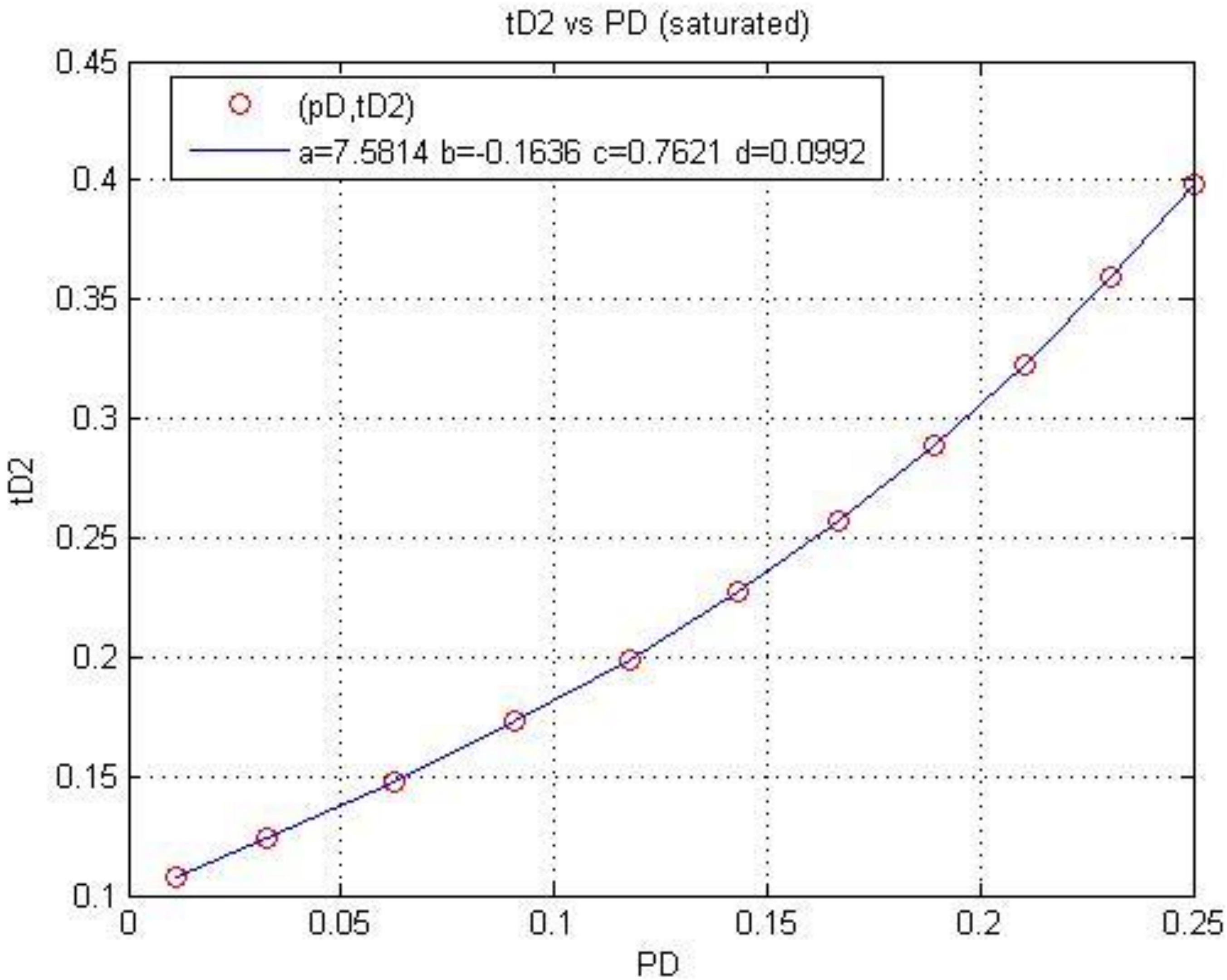

Figure 7. Time-pressure correlation for coalbed methane reservoir at undersaturated condition (type 1).