RESERVOIR CHARACTERIZATION USING PRESSURE DERIVATIVE METHOD IN NA-20 WELL SENJA FIELD

Nadhira Andini[1*], Muh. Taufiq Fathaddin[1] dan Cahaya Rosyidan[1]
[1]Petroleum Engineering Department, FTKE, Universitas Trisakti

ABSTRACT

The pressure behaviour of a well can be easily measured and is useful in analysing and predicting reservoir performance or diagnosing the condition of a well. Since a well test and subsequent pressure transient analysis is the most powerful tool available to the reservoir engineer for determining reservoir characteristics, the subject of well test analysis has attracted considerable attention. A well test is the only method available to the reservoir engineer for examining the dynamic response in the reservoir and considerable information can be gained from a well test. A well test is the examination of the transient behaviour of a porous reservoir as the result of a temporary change in production conditions performed over a relatively short period of time in comparison to the producing life of field. The build up can be both the part of the test when the well is shut in and a value represented by the difference in the pressure measured at any time during the build up and the final flowing pressure. The most common megods of transient (time dependant) pressure analysis required that data points be selected such that they fell on a well-defined straight line on either semi-logarithmic or cartesian graph paper. The well test analyst must the insure that the proper straight line has been chosen if more than one line can be drawn through the plotted data. This aspect of interpretation of well test data requires the input of reservoir engineer. Equally important is the design of a well test to ensure that the duration and format of the test is such that it produces good quality data for analysis. The results obtained from transient pressure analysis are used to discover the formation damage by detemining skin. This experiment will be analyzed oil well which is NA-20 well in Senja field. The results from the analysis of the data obtained on NA-20 well is 4.84 mD permeability, skin +1.42, pressure changes due to skin (ΔPskin) 264.384 psi, and flow efficiency 0.842 with 851.61 ft radius of investigation. The result from the analysis of the well showed that NA-20 well in Senja field have formation damage.

Keywords: well test, pressure build up, pressure derivative, skin

**Corresponding author*:
E-mail: nadhirani@yahoo.com
Tel: +62-821-7029-3408

INTRODUCTION

A well test is the examination of the transient behaviour of a porous reservoir as the result of a temporary change in production conditions performed while measuring all the relevant parameters. It is usually performed over a relatively short period of time in comparison to the producing life of a field. The aim of well testing is to evaluate the well & reservoir and to determine the ability of a layer or formation to produce. If the tests are carried out properly and then the results are analysed well, then a lot of valuable information is obtained, such as formation permeability, formation damage around the wellbore due to drilling and complexity, reservoir pressure and reservoir boundaries. This experiment will be analysed by using Pressure Build Up test and will also analyse curve derivative type. In this analysis the Horner plot and Derivative plot are used to determine the reservoir characteristics of NA-20 well, moreover to find the reservoir model and the indication of formation damage due to skin factors (Notes et al., 2001).

FUNDAMENTALS OF WELL TESTING

Well Bore Storage

Wellbore storage is an early transient phenomenon whose effect decays in time and occurs every time a rate change takes place. Usually the well rate is controlled at the surface by means of a valve or choke. When the valve or choke is opened, wellbore fluids are initially produced at the wellhead while production at the perforations remains zero. During this early time period the wellbore is said to be unloading or decompressing. Eventually, the perforations will also start to produce and in time equal the production at the wellhead.

During constant production, wellbore storage effects are negligible. At the point of shut-in, wellbore storage is referred to as afterflow. Whilst the rate at the wellhead is zero, production at the perforations continue, gradually decaying to zero. Wellbore storage is expressed in units of volume per unit of pressure, barrels per psi, with the nomenclature of C.

Skin

This is a dimensionless value attributed to the near wellbore damage or stimulation. Reservoir permeability in the near wellbore area is frequently altered as a result of drilling, production, or stimulation of the well. For example, the invasion of drilling fluids, or migration of fines during production tends to lower the permeability in the near wellbore region. The well is subsequently referred to as damaged under these circumstances and this is represented by a positive skin value. Conversely, stimulation treatments such as acidizing or fracturing may create an increase in the near wellbore permeability relative to the overall reservoir permeability. This is summarised below:

- Skin > 0, Damaged
- Skin = 0, Neutral
- Skin < 0 Stimulated (not usually less than -5)

The value is dimensionless and is represented by the letter S.

Permeability

Permeability is a measure of the ability of a porous rock to transport a fluid through it and is measured, usually, in Darcys, D, or millidarcies, mD. Based on the amount of fluid phase flowing in a rock, rock permeability can be divided into:

1. Absolute permeability, which is a measure of the ability of a rock to drain one type of fluid so that there is no other type of fluid in the rock.
2. Effective permeability, which is a measure of the ability of rocks to drain more than one type of fluid so that there are several other types of fluid in the rock.
3. Relative permeability, which is the ratio between effective permeability and absolute permeability.

Porosity

Porosity is the amount of void (space) in a porous rock measured as a percentage of the whole rock When rocks are deposited and formed during the last geological period, some empty space that develops become isolated from other empty spaces with excessive cementation. Thus, a lot of free space is interconnected while some pore spaces are completely isolated. This leads to two different types of porosity, which are:

1. Absolute porosity, which is the ratio between the total volume of pore space both related and unrelated in rock to the total volume of rock.
2. Effective porosity, which is the ratio between the volume of pore space that is interconnected to the total volume of rock.

Radius of Investigation

When a change of flow rate occurs in a well, ie, initial flow, a change in the reservoir pressure from its initial undisturbed state is created. Over time this pressure disturbance propagates further away from the wellbore. The radius of investigation is defined as the distance that a significant pressure disturbance has propagated away from the well.

PRESSURE BUILD UP

Pressure Build Up Test Analysis

Pressure build up tests are performed with the well is shut in and not flowing. In all cases, a build up is recommended. The well must be flowing, ideally at a constant rate, before the well is shut-in and the rise in bottom-hole pressure recorded. Almost without exception, a build up will produce better quality pressure data than a drawdown.

Besides the issue of data quality which in itself is important, the other compelling reason a build up is used is that it is the only time in a well test when the flow rate is categorically known without any margin of error. It is always zero (Abdassah, 2005).

Characteristics of Pressure Build Up Plot Curves

The characteristics of the pressure build up curve can describe the changes in pressure experienced by the well tested. Pressure response curves are divided into 3 parts toward changes in pressure, which are: initial data segments (early times), middle time segments (middle times) and advanced times (late times). This time division is divided to assist in performing pressure transient analysis. An explanation of the distribution as follows (Maulana, Fathaddin, & Oetomo, 2018).

- Early Time Region (ETR)
  In this section the transient pressure moves towards the formation closest to the wellbore. During the ETR interval, the curve is affected by the wellbore storage and skin effects. This can be seen as a curved line as a deviation from a straight line.
- Middle Time Region (MTR)
  In this part the pressure of transient moves from the bulk formation hole. At this time, what is called the infinite acting where a straight line of semilog occurs. The expiration time of the MTR occurs when the radius of the investigation begins to detect a boundary from the well being tested. In this period, permeability, conductivity or transmissibility (kh), formation damage, and initial formation pressure can be determined.
- Late Time Region (LTR)
  In this section, the curve reflects a straight line that has reached the final limit of the well tested or the influence of the well being tested. To find out the distance that has been taken during the test, it is called a radius of investigation (ri). The existence of a deviation from the straight line Horner (middle time segment) can be caused by many things. Usually the initial data segment is affected by: wellbore storage, skin factors, phase segregation (gas hump), while the advanced

segment is affected by the reservoir boundary, the effect of production wells or injection around the well being tested, and others.

Pressure Derivative

Based on the characteristics of pressure, this pressure derivative method curve arises because the final determination of the wellbore storage effect by using the Horner analysis method cannot provide the right result and also the Horner analysis method cannot provide accurate results when used to analyze reservoirs that are so complex. In the Horner analysis method, the final determination of the wellbore storage effect is marked by a change in deviation on the pressure curve or commonly called a slope unit, then this slope unit is added with a half cycle (Bourdet, 2002).

Pressure Derivative Type Curve

Pressure derivative type curve is a derivation in pressure and is also a refinement of the Gringarten Curve by Bourdet. Bourdet re-plots Gringarten type curve on the log scale. The plots carried out by Bourdet can be seen in Figure II.7 which shows the early time time during flow dominated by wellbore storage indicated by a straight line. The transition period from pure wellbore storage to infinite acting forms a "hump" with different heights depending on the value of the skin factor (Bourdet, 2002).

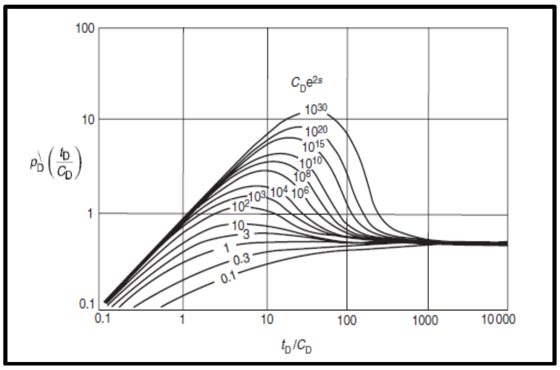

Figure 1. Pressure Derivative Type Curve

Pressure derivative analysis using the Bourdet approach is done by creating log plots between Δt ΔP'{(tp+Δt)/Δt} vs Δt and the plot between ΔP vs. Δt. Then adjust the matching curve to the Bourdet derivative curve and will produce match point values in the form of ΔP, Δt, PD, tD / CD, (CDe2s), teq. Then from these values can determine permeability (k), wellbore storage (CD) coefficient, and skin.

Curve derivative type is introduced by Bourdet, where the coordinate axis is the first derivative function of dimensionless pressure, PD with log effect (tD / CD). Because the derivative function will show changes in the shape of the curve due to the characteristics of pressure changes (due to the nature of the flow), so that it is more sensitive and more accurate in the analysis. All type curves have the same shape on high CDe2S values, which is a problem in finding the suitable type curve by comparing the type curve shape. The advantages of this type curve derivative are:

- Interpretation can be shown on a pressure plot which is the result of a combination of type curve match results with semilog analysis.
- The uniqueness of the behavior of the results of the differential pressure at the beginning and end has two specific match points.
- The shape of the pressure derivative curve for changes in the price of CDe2S, makes the match form always always certain.
- Pressure curve type derivatives can determine changes in changes that occur in slope dp / dt, while for conventional methods it is difficult to know. Pressure derivative plots between PD '(tD / CD) with tD / CD. As long as there is wellbore storage, the curve will form a straight line with a certain slope. When the infinite acting radial flow will begin, the curve becomes horizontal when the PD value (tD / CD) = 0.5. The transition period from pure wellbore storage to the infinite acting period is marked by a slightly soaring and curved line that indicates a skin factor.

ANALYZING

Pressure build up analysis in NA-20 well is using the Horner plot and pressure derivative plot. The first approach is to make a well history plot using software Ecrin 4.20 by inputting reservoir data, petrophysics, and well flow rate data. History plot is made to interpret the state of the actual reservoir. Figure 1 represents that the top graph shows pressure vs time while the bottom graph shows the oil flow rate vs time.

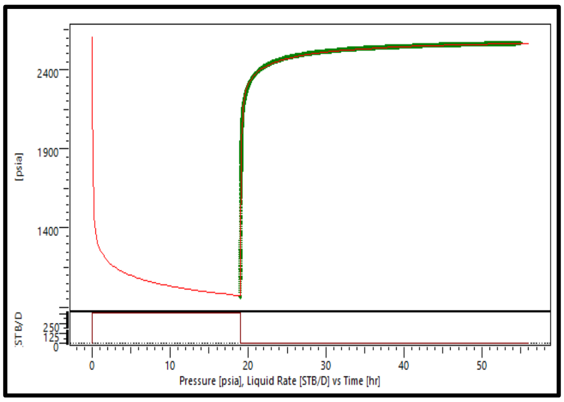

Figure 2. History Plot in NA-20 Well

The next approach is to make log-log plot to see derivative curve from the well. Figure 2 below shows the derivative plot of NA-20 well using Ecrin

4.20 and wellbore storage from the well can be seen when the well is shut-in or at the beginning of pressure build up test. From this log-log plot results can be used to determine the reservoir boundary by matching the pressure derivative type curve model with Ecrin 4.20. After the matching value is known, then the model can be improved.

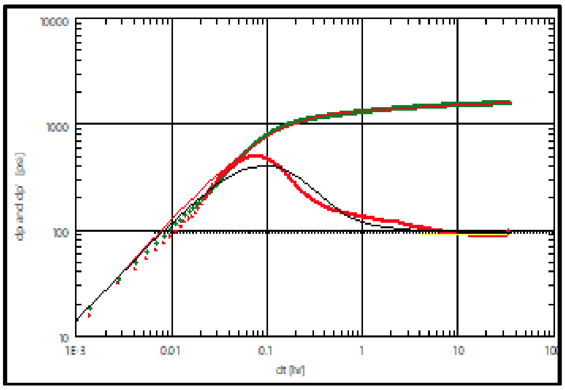

Figure 3. Model Derivative in Well-NA20

Table 1.
Reservoir Model Interpretation NA-20 Well

Interpretation Model Reservoir	
Selected Model	**Result**
Model Option	Standard Model
Well Model	Vertical
Reservoir Model	Homogeneous
Boundary Model	Infinite

This table below shows the interpretation result by using software Ecrin in Well-NA-20.

Table 2.
Interpretation Result Using Software Ecrin in NA-20 Well

Interpretation Result	
Main Model Parameters	
C	0,0017 bbl/psi
Skin	1,42
Reservoir & Boundary Parameters	
Pi	2604,74 psia
k.h	128 md.ft
K	4,84 md
Derived & Secondary Parameters	
ΔP (total Skin)	264,348 psi

From the software, the Horner plot also can be made from semi-log plot as shown in Figure 3.

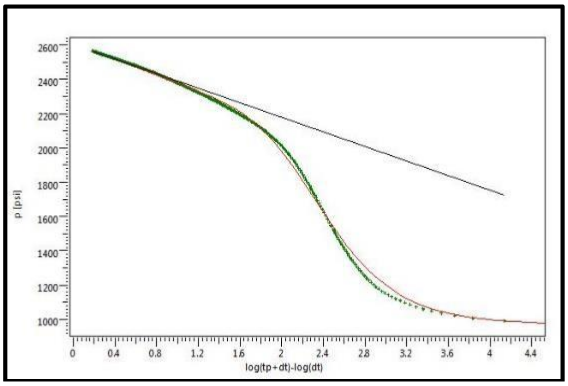

Figure 4. Horner Plot Using Software Ecrin 4.20

Based on the trendline, therefore reservoir parameters can be obtained as shown in Table 3.

Table 3.
Horner Plot Result Using Software

Interpretation Result	
Slope	212,491
Plhr	2329,18 psia
k.h	130 md.ft
K	4,89 md
Skin	1,5

Next, the pressure derivative analysis is also done by using Ms. Excel.

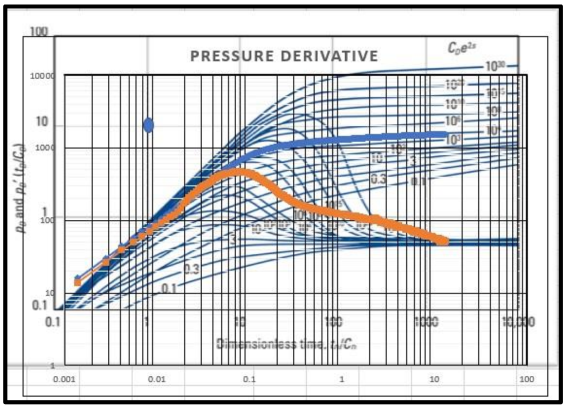

Figure 5. Type Curve Derivative in NA-20 Well

Table 4.
Type Curve Derivative Result in Well NA 20 Using Ms.Excel

Parameters	**Result**	**Unit**
ΔP	2100	-
T_{eq}	0.009	-
Dimensionless Pressure (P_D)	10	-
Dimensionless Time (t_D/C_D)	1	-
C_De^{2s}	10000	-
Permeability (k)	5.24	mD
Coefficient Wellbore Storage (C_D)	544.87	-
Total Skin (S)	1.45	-
ΔPs	305.53	psi

This figure below represents semi-log from Horner plot using Ms. Excel.

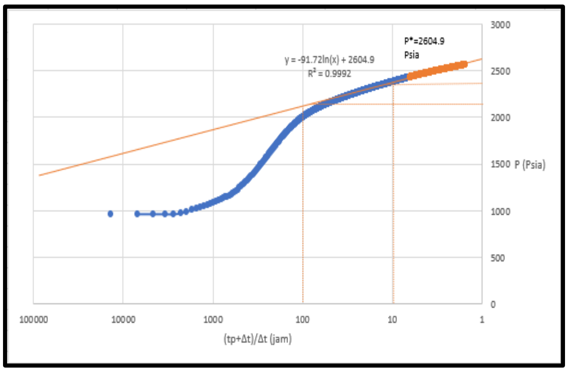

Figure 6. Horner Plot Using Ms. Excel

Table 5. Horner Plot Result Using Ms. Excel

Parameters	Result	Unit
P*	2604.9	Psi
m	211.193	Psi/cycle
k	4.920	mD
Skin	1.729	
Δpskin	317.08	Psia
FE	0.81	
ri	858.619	Ft

Table 6.
Pressure Derivative Comparison Result

Parameter	Software	Ms. Excel	Unit	Δ (%)
Permeability (k)	4.84	5.24	mD	8.195
Skin Factor	1.42	1.45	-	2.458
ΔPskin	264.348	305.53	psi	15.578

Table 7.
Horner Plot Comparison Result

Parameter	Software	Ms. Excel	Unit	Δ (%)
P @ 1hr	2329.18	2330.131	psia	0.041
Permeability (k)	4.89	4.92	-	0.613
Skin Factor	1.5	1.729	-	15.267

CONCLUSION

Based on the analysation in NA-20 Well which has been stated above, there are several conclusions which are:

1. According to pressure derivative analysis using software Ecrin 4.20 in NA-20 well shows that the reservoir model is homogeneous with boundary model is infinite.
2. The qualitative result from the pressure derivative analysis using software Ecrin obtained on NA-20 well is 4.84 mD permeability, skin 1.42, pressure changes due to skin (ΔPskin) 264.384 psi, and flow efficiency 0.842 with 851.61 ft radius investigation.
3. The qualitative result from the Horner plot analysis using software Ecrin obtained on NA-20 well is 4.89 mD permeability, skin 1.5, pressure changes due to skin (ΔPskin) 276.714 psi, and flow efficiency 0.834 with 855.997 ft radius investigation.
4. The qualitative result from the pressure derivative analysis using Ms. Excel obtained on NA-20 well is 5.24 mD permeability, skin 1.45, pressure changes due to skin (ΔPskin) 305.53 psi.
5. The qualitative result from the Horner plot analysis using Ms. Excel obtained on NA-20 well is 4.92 mD permeability, skin 1.729, pressure changes due to skin (ΔPskin) 317.08 psi, and flow efficiency 0.81 with 858.619 ft radius investigation.
6. Based on the result of both methods, showed that NA-20 well in Senja field have formation damage, thus further action is needed such as reservoir stimulation.

ACKNOWLEDGEMENTS

The author's biggest gratitude is expressed to Allah SWT, mentors for the guidance and PT Pertamina EP Cepu for the data and new knowledge of Well Testing. Thank you to friends and family of the author for the support all along.

REFERENCES

Ahmed, T. (2001). Reservoir Engineering Handbook. Houston, Texas: Gulf Publishing Company.

Andeka, I. P. (2011). Analisis Pressure Build-Up Test dengan Menggunakan Metode Horner Manual dan Saphir 3.20 untuk Identifikasi Kerusakan Formasi Pada Sumur "KB" Lapangan "D", Skripsi Program Sarjana, Teknik Perminyakan, Universitas Pembangunan Nasional.

Bourdet, D. (2002). Well Test Analysis: The Use of Advanced Interpretation Models, Handbook of Petroleum Exploration and Production 3. Amsterdam, The Netherlands: Elsevier Sciene B. V.

Horne, D. R. (1951). Pressure Build-Up in Wells. World Petroleum Congress.

Lee, J. (1982). Well Testing (SPE Textbook Series) Vol.1. Texas A&M University: Society of Petroleum Engineers.

Maulana, M. H., Fathaddin, M. T., Oetomo, H. K. (2018): Well Test Analysis Using Pressure Derivative Method at Gas Well X-1 (Analisis Uji Sumur Menggunakan Metode Tekanan Derivative Pada Sumur Gas X-1). Journal of Earth Energy Science, Engineering, and Technology, Universitas Trisakti, Jakarta.

Notes, C., Bourdet, D., Johnson, P. (2001). Fundamental of Well Test Design and Analysis for BP Exploration Operating Company.

Pappin, A. C. M. (2017). Analisis Pressure Build Up Test Menggunakan Software Ecrin dan Metode Manual Pada SUmur Gas CP-52 & CP-54 Lapangan Chapin, Skripsi Program Sarjana, Teknik Perminyakan, Universitas Trisakti.

Russel, D. G. (1996). Extensions of Pressure Build-Up Analysis Methods. Journal of Petroleum Technology.