Impact of Uncertainties in Formation Thickness on Parameters Estimated from Well Testing Part 1: Gas Reservoirs

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Abstract: Well testing is of great importance in petroleum engineering, to have a kind of firsthand knowledge and estimating formation permeability, wellbore damage/ skin, etc. These parameters are further required to estimate production rate from a well and at the same time gives an idea of its productivity. These reservoir related parameters calculation is strongly dependent on formation thickness. Any uncertainty in formation thickness leads to ambiguous results, which in turn influences further reservoir development studies. This study focuses on analyzing the impact of such uncertainties and highlighting their effect on the resulting estimations, while considering cases of gas, oil and multiphase flow reservoirs one by one. The obtained results in case of gas reservoir shows that uncertainty in formation thickness has strong influence on well test estimated data.
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1. Introduction

Conducting well test is of prime concern in the petroleum industry to check the potential of a reservoir(Shahin and Al-Awadly,2011). Usually when it is conducted the drilled well do not have sufficient facilities to handle produced fluid(s), which can be harmful to the living organisms, vegetation and the soil itself, due to which sometimes different methods have to be adopted to reduce such disadvantages, like, decomposing the produced hydrocarbons(Okoro, Agrawal and Callbeck,2012). Keeping in view such drawbacks, well test data need to be analyzed critically to rule out the chances of repeating such jobs.

Reservoir thickness has strong influence on test data interpretation and can be measured by using well logs, coring techniques, etc. These methods have their own limitations thus owing to different range of uncertainties in formation thickness estimation. According to Siemek et al.(Siemek and Nagy,2004) in-accuracy in reservoir thickness can range from ±5% to ±60%. While estimating, parameters based on conducted well test or in other words, during well test analysis, thickness plays a significant role in calculating different formation properties. This paper thus focuses on analyzing such variations and their extent on calculated results in case of gas reservoir.

2. Parameters Affected by Formation Thickness

Formation thickness (F.H), in term of petroleum engineering or production geology can be described as a thickness of oil or gas formation, from where they are produced. F.H directly and indirectly affects number of parameters and the following parameters have been included in this study:

Permeability can be determined by using the following equation(Lee, Rollins and Spivey,2003).

$$k = 162.6 \frac{B_{g,avg.}\ \mu_{g,avg.}}{m\,h} \qquad (1)$$

Further the radius of investigation, i.e., the distance from the well to which the pressure transient has moved can be estimated(Lee, Rollins and Spivey,2003) by using equation (2).

$$r_i = \left(\frac{kt}{948\phi\mu c_t}\right)^{0.5} \qquad (2)$$

Similarly the drainage area can be calculated(Lee, Rollins and Spivey,2003) by using equation (3) through by using the value of radius of investigation obtained by using eq.(2).

$$A = \pi r_i^2 \qquad (3)$$

The influence of uncertainty in formation thickness can be analyzed indirectly(Lee, Rollins and Spivey,2003;Chaudhry,2003) by using the following equation (4) and further details can be found as discussed by Lee et al.(Lee, Rollins and Spivey,2003) and the effective wellbore radius can be calculated by using the following equation(Lee, Rollins and Spivey,2003;Chaudhry,2003).

$$s = 1.151\left[\frac{b}{m} - \log\frac{k}{\phi\mu_{g,avg.}c_{t,avg.}r_w^2} + 3.23\right] \qquad (4)$$

$$r_{wa} = r_w e^{-s} \qquad (5)$$

3. Case Study

The following set of data (table 1) has been used to analyze the effect of formation thickness uncertainty on above discussed parameters:

Table 1. Gas reservoir and well data

h (ft)	59
ϕ(%)	23
$B_{g,avg.}$	0.59
$C_{t,avg.}$ (psia^{-1})	69.78 x10^{-6}
$\mu_{g,avg.}$ (cp)	0.0313
m	0.212
b	1.427
t(hrs)	50
r_w(ft)	0.254

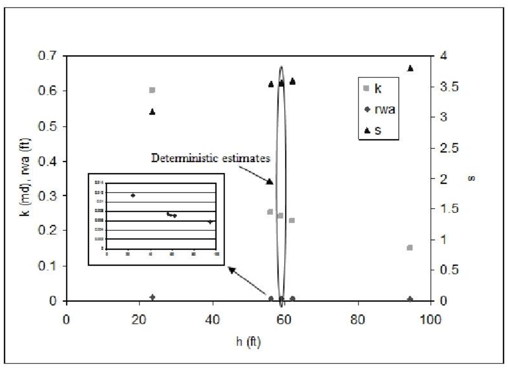

Figure 1.Influence of F.H uncertainty on permeability, effective wellbore radius and skin

Considering 59 ft as the deterministic values, uncertainties have been incorporated and the resulting formation thickness estimations are given in table 2. These set of formation thickness values are used to calculate the effect of F.H on formation permeability, skin, radius of investigation, drainage area and effective well bore radius.

Table 2. Deterministic and uncertainty incorporated values of formation thickness

h,ft (Deterministic value)	h,ft (including uncertainty)
59	23.6
	56.05
	61.95
	94.4

4. Results and Discussion

The obtained results using equations (1) to (5) are shown in the following figures 1 and 2:

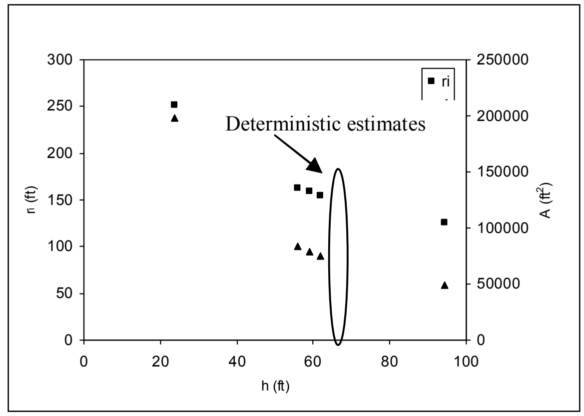

Figure 2. Effect of uncertainty in payzone thickness on radius of investigation & drainage area

The obtained results show that, inverse relationship exists between F.H and permeability, effective wellbore radius (r_{wa}), radius of investigation & drainage area. While, a direct relationship exist between variation in F.H and formation damage. i.e., as the formation thickness increases skin increases.

Further, the % deviation in the estimated parameters based on uncertainty with reference to deterministic values has been calculated using the following equation and the obtained results are shown in figure (3).

$$\% \text{ Deviation} = \frac{\text{Deterministic value} - \text{Uncert. value}}{\text{Deterministic value}} \times 100 \qquad (6)$$

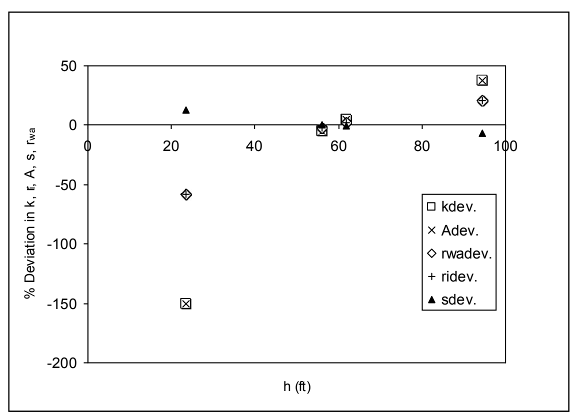

Figure 3. Percentage deviation in estimated parameters with reference to deterministic values

The above figure shows that the pessimistic and optimistic values of formation thickness based on uncertainty have highest and same deviation in calculated permeability and drainage area values (-150% to 4.76%). Similarly, comparatively it has lesser and similar effect on radius of investigation and effective wellbore radius (-58.11% to 2.4). The obtained results also show that the degree of uncertainty in F.H has least influence on skin values, with a deviation of -0.68% to 12.87%.

5. Conclusion

The uncertainty in formation thickness affects all other estimated reservoir parameters. This study shows that these variations can be significant, especially in case of permeability, in particular. Which is a very crucial parameter, because of its usage in reservoir deliverability analysis and fluid dynamics studies. Therefore, uncertainty in formation thickness should be dealt with great care to cope with sources of errors in a better manner during gas reservoir exploitation.

6. Nomenclature

A	area
b	intercept
B_g	gas formation volume factor
C_t	total compressibility
h	formation thickness
k	permeability
m	slope
r_i	radius of investigation
r_w	wellbore radius
r_{wa}	effective wellbore radius
s	skin
t	time
ϕ	porosity
μ	viscosity

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