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A Proposed Modified Equation for One Phase Steam Geothermal Well

Rudi Siburian

rudi.siburian@yahoo.com

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ABSTRACT

Modelling of one phase steam in geothermal well is usually using an equation derived with assumption of incompressible fluid flow. This equation actually is addressed to analyse fluids with small compressibility such as water, whose density change is very small and can be neglected. Previous studies suggested that this equation can be used to analyse steam flow when the velocity is relatively low, about 103 m/s (0.3 Mach number). Based on observation data, velocity of flowing fluid in MBB-3 reached 115 m/s. When the velocity approaches or exceeds 0.3 Mach number (Ma), a good match between model and data observation is difficult to achieve.

To achieve a better wellbore steam flow model, we need to develop an equation based of compressible fluids was developed. This modified compressible equation was derived from combination of continuity, momentum, and energy equations.

This modified compressible equation as a result from this research was validated with observation data from MBB-3 well of Wayang Windu field, and also compared to model from Cullender and Smith correlation. The result shows that the modified compressible flow model gives better agreement with observation data compared both previous incompressible equation and Cullender and Smith correlation.

1. INTRODUCTION

This study was initiated after problem found on one phase geothermal wells, and MBB-3 well Wayang Windu field, West Java, Indonesia. Based on MBB-3, the result of flow modelling of this well is not in good match. When calculating bottom hole pressure (Pwf) with measured data in wellhead (top-down modelling), the result from model is smaller than the measured data. And when calculating well head pressure (Whp) with measured data in bottom hole (bottom-up modelling), the result from model is higher than the measured data. Same problem also appear when quantitatively well modelling from PTS data (Pressure, Temperature and Spinner) is in proceed. Pressure, temperature and mass flow rate curve between measured data and model in not in good match (Figure 4).

Problem on this MBB-3 might be happened because on some abnormal things on wellbore. Cause of this abnormality might be from casing damage, the consequence is diameter used as calculation is different from its measured data. Another guess is, the problem might be happened because of well head pressure is relatively low, so pressure differences is getting bigger, effecting fluid flow velocity become so high.

MBB-3 is a one phase steam well. Figure 1 and 2 will describe pressure, temperature and saturation temperature of this well versus its measured depth. Whereas Figure 3 and table 1 provides casing configuration of MBB-3 well. MBB-3 is a 1938 m directional well with, 10-3/4 slotted liner at the bottom, 13-3/8 casing at the top as production casing and the angel reached 60^{o}.

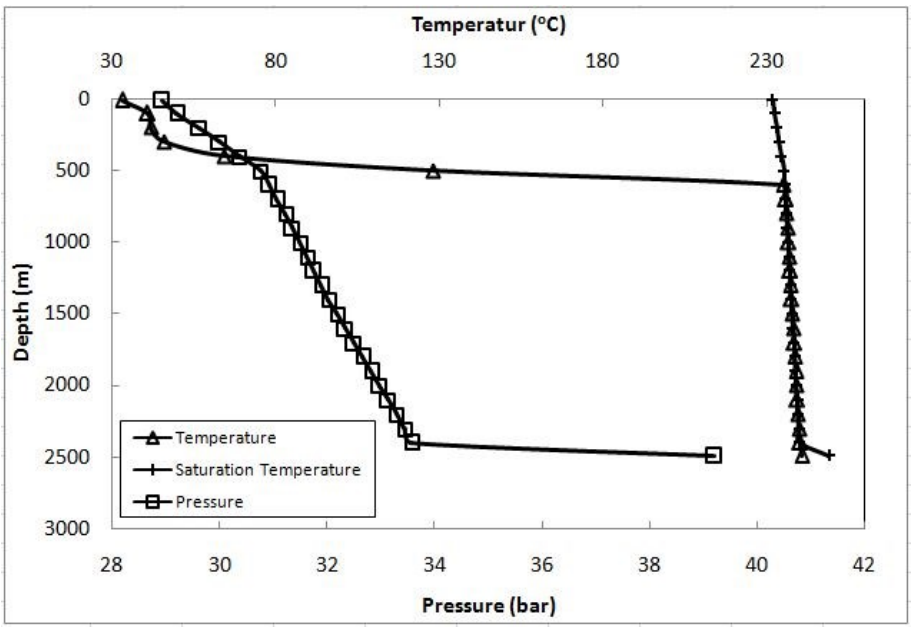

Figure 1: PT shut In of MBB-3

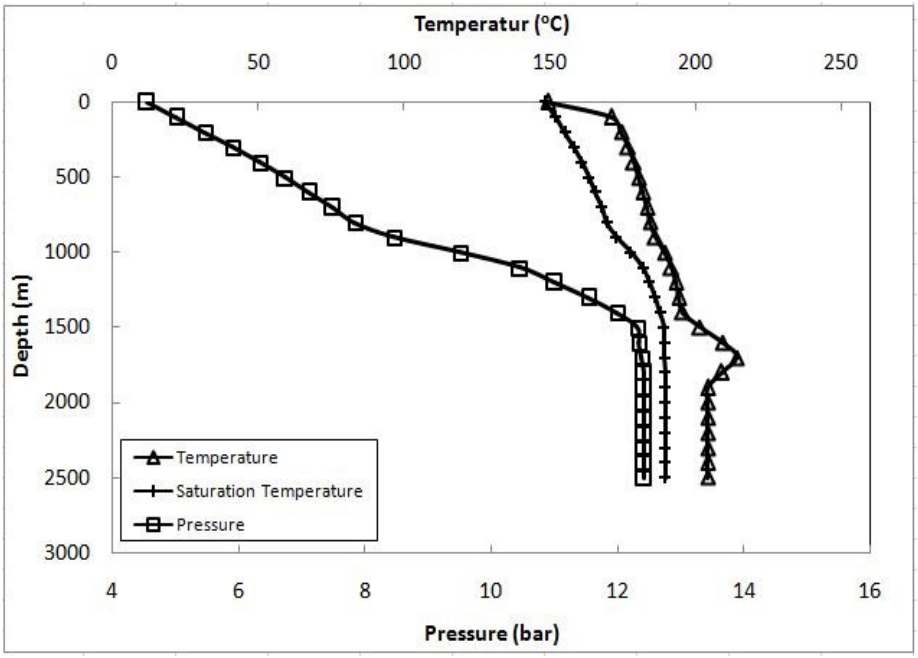

Figure 2: PT Flowing of MBB-3

Table 1: **Geometry of MBB-3**

Depth (m)		Casing ID (m)	Roughness(m)	Angle, °
0	516	0.315	0.000045	5
516	890	0.315	0.000045	25
858	1938	0.255	0	60

2. FLOW MODELLING PROBLEM IN MBB-3

The basic pressure drop equation usually used on geothermal and oil & gas industry until today is equation as form of elevation, friction and acceleration ;

$$\frac{dp}{dz} = g\rho\cos\theta + \frac{f\rho v^2}{2d} + \frac{\rho v dv}{dz} \quad (1)$$

This equation actually for incompressible flow which derived from continuity and momentum equation (Hasan - Kabir, 2002), but still can be used for compressible flow if the flow velocity is below ± 0.3 of its speed of sound, about 100 m/s (Fox – McDonald, 2003). When the velocity of the fluid is getting closer to 0.3 of its speed of sound (Mach number), problem like we have in well MBB-3 might be because of this incompressible equation.

As shown in Figure. 4, there is gap/ difference between observation and simulation curve. Maximum flow velocity recorded on this well is 115 m/s (Figure 5), which is already higher than 0.3 Mach number (Ma). Figure. 4 is well modelling start from bottom of well to the top of the well, usually called bottom-up modelling.

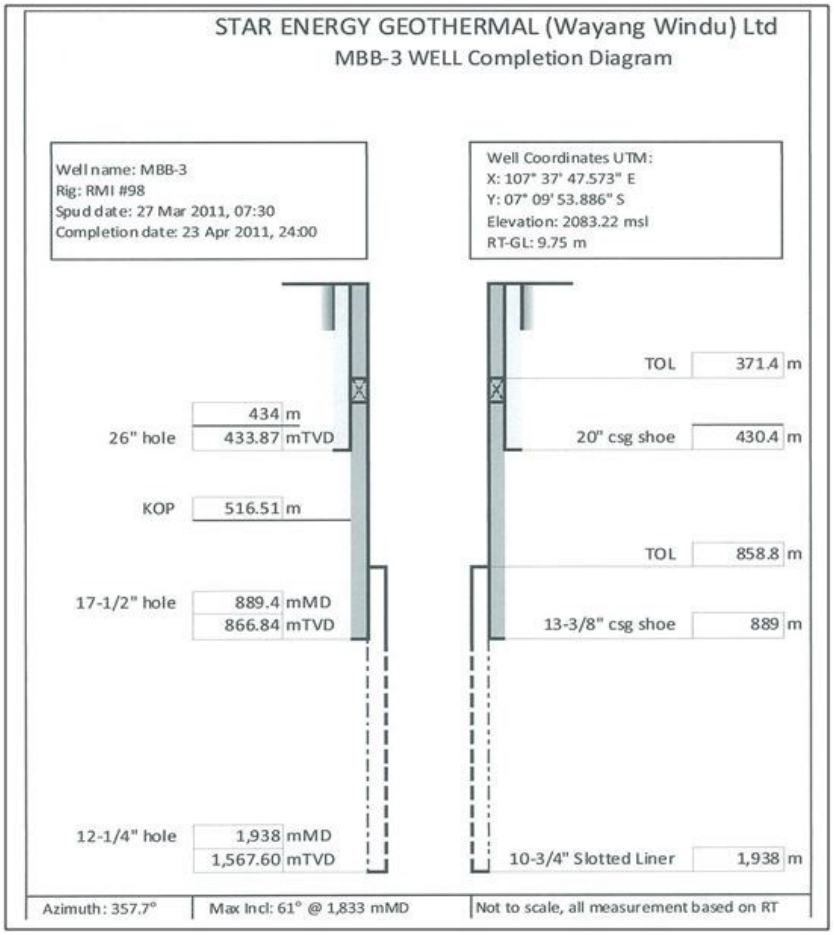

Figure 3: Casing Configuration of MBB-3

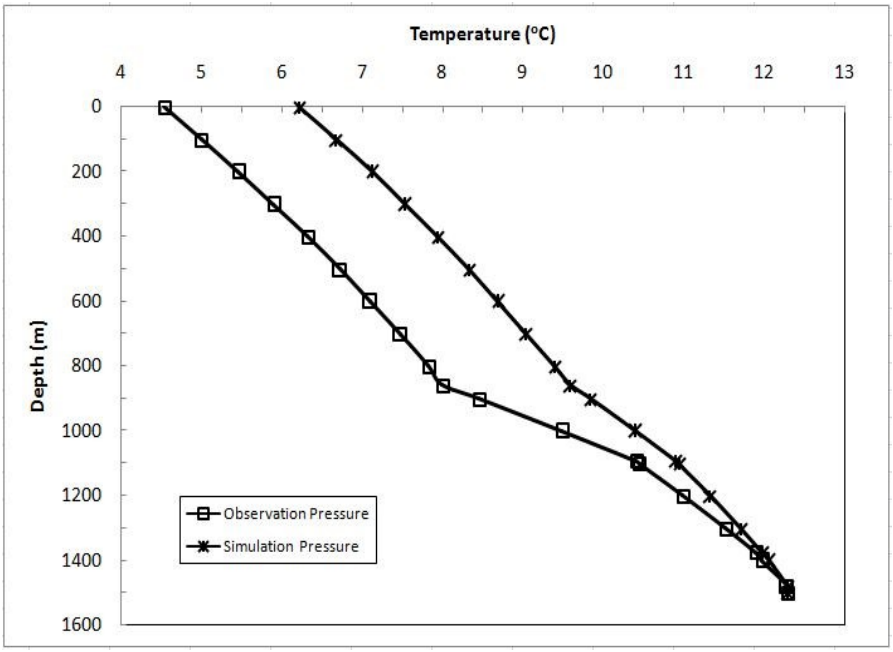

Figure 4: MBB-3 Pressure Observation and Simulation (Indrinanto, 2012)

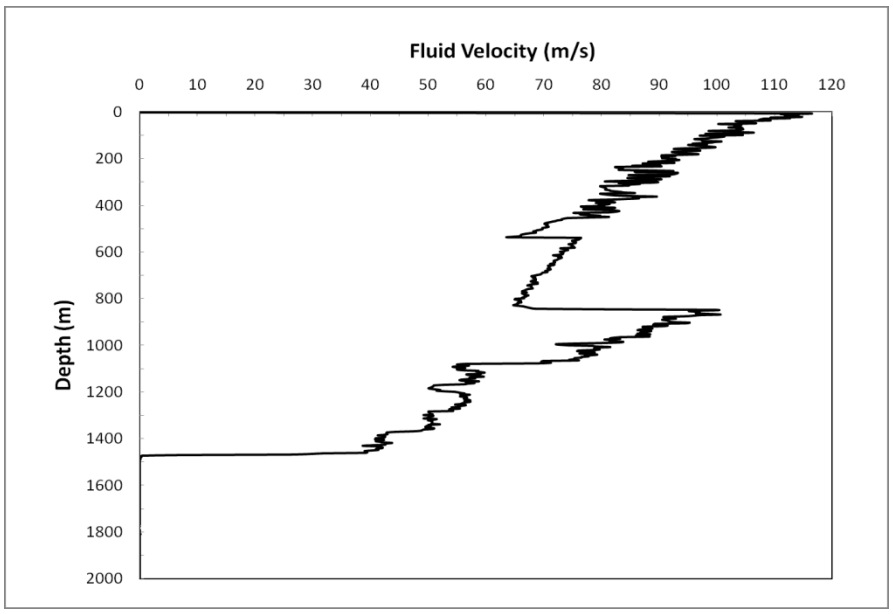

Figure 5: Fluid Velocity in Well MBB-3

3. EQUATION MODIFICATION

When velocity is near or larger than 0.3 Ma, the flow should treat as compressible flow, which means the equation should build from three basic equation ; continuity, momentum and energy equation (White, Fluid Mechanics). Based on this statement, here under are my approach to solve compressible flow on well MBB-3.

At first, the energy equation as shown at Equation. 2, need to change to pressure per-depth equation based as shown at Equation. 3, so later I can combine it with equation 1.

$$h_1 + \frac{1}{2} v_1^{\,2} + g z_1 = h_2 + \frac{1}{2} v_2^{\,2} + g z_2 \tag{2}$$

$$\frac{\rho_1 h_1}{dz} + \frac{1}{2dz} \rho_1 v_1^{\,2} + \frac{\rho_1 g z_1}{dz} = \frac{\rho_2 h_2}{dz} + \frac{1}{2dz} \rho_2 v_2^{\,2} + \frac{\rho_2 g z_2}{dz} \tag{3}$$

Change in potential energy for gas is very small, and so can be neglected, as shown at Equation. 4.

$$\frac{\rho_1 h_1}{dz} + \frac{1}{2dz} \rho_1 v_1^{\,2} = \frac{\rho_2 h_2}{dz} + \frac{1}{2dz} \rho_2 v_2^{\,2} \tag{4}$$

And if I assumed the flow is isenthalpic, the result is Equation. 5, 6 and 7.

$$\frac{\rho_1 v_1^{\,2}}{2dz} = \frac{\rho_2 v_2^{\,2}}{2dz} \tag{5}$$

$$\frac{\rho_1 v_1^{\,2}}{2dz} - \frac{\rho_2 v_2^{\,2}}{2dz} = 0 \tag{6}$$

$$\frac{\rho_1 v_1^{\,2} - \rho_2 v_2^{\,2}}{2dz} = 0 \tag{7}$$

continuity equation in well MBB-3 can be simplified as shown at Equation. 8 and then Equation 9.

$$\rho_1 v_1 = \rho_2 v_2 \tag{8}$$

$$\rho_2 = \frac{\rho_1 v_1}{v_2} \tag{9}$$

with substitution Equation. 9 to Equation 7, as shown at Equation 10 and 11, the result is Equation 12.

$$\frac{\rho_1 v_1^{\,2} - \frac{\rho_1 v_1}{v_2} v_2^{\,2}}{2dz} = 0 \tag{10}$$

$$\frac{\rho_1 v_1^{\,2} - \rho_1 v_1 v_2}{2dz} = \frac{\rho_1 v_1 (v_1 - v_2)}{2dz} = 0 \tag{11}$$

$$\frac{\rho_1 v_1 dv}{2dz} = 0 \tag{12}$$

combining Equation. 1 and Equation. 12 we will have Equation 13 and Equation 14.

$$0 = g\rho\cos\theta + \frac{f\rho v^2}{2d} + \frac{\rho v dv}{dz} + \frac{1}{2}\frac{\rho v dv}{dz} - \frac{dp}{dz} \tag{13}$$

$$\frac{dp}{dz} = g\rho\cos\theta + \frac{f\rho v^2}{2d} + \frac{3}{2}\frac{\rho v dv}{dz} \tag{14}$$

Equation. 14 is the final result that we will use to try to solve modelling problem in well MBB-3.

4. RESULT

We call Equation. 14 as *Modified-Compressible Equation*. Modelling MBB-3 well with this new equation resulting better pressure curve compare to incompressible equation (Equation. 1) as shown in Figure. 6. Although, the result from modified compressible is still far from perfect matching with observation data.

In addition, we also utilized Cullender & Smith (C&S) correlation to modelling well MBB-3. The results as shown in Figure. 6 is C&S correlation has better value than incompressible flow, but our modified-compressible equation is still better than this C&R correlation.

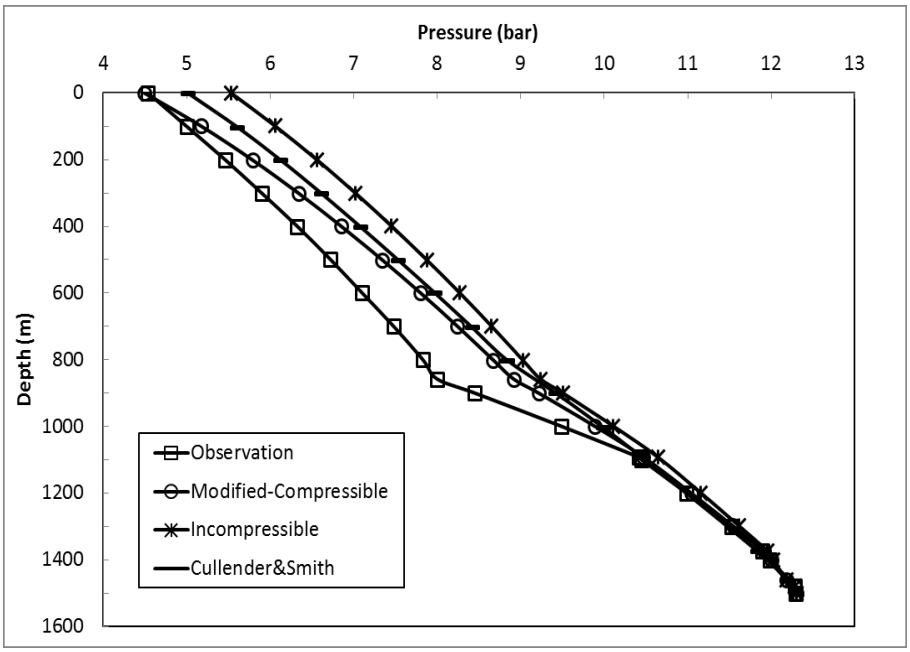

Figure 6: Pressure of Observation, Modified Compressible, Incompressible and Cullender & Smith Correlation

5. CONCLUSION

The main motivation for this study is to achieve better wellbore modelling result to approach data observation as near as possible. The result is the modified-compressible equation has the best result compare to incompressible equation and C&S correlation, but the result itself is still far from perfect.

Therefore, further study is still needed to achieve better result, either its to build another new/ modified equation or other things such as friction factor if possible.

NOMENCLATURE

p = *Pressure (bar)*

z = *depth (m)*

ρ = *density (kg/m^3)*

g = *gravitational acceleration (m/s^2)*

θ = *angle of well*

f = *friction factor, dimensionless*

v = *fluid flow velocity (m/s)*

d = *well casing inner diameter (m)*

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