Analysis of injection pressure

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Abstract. In the daily production of water injection wells, oil pressure is a very important production parameter. According to the existing theory, oil pressure plus liquid column pressure is the injection pressure at the bottom of the well, but this theory is contradictory to some production phenomena. This paper analyzes this problem and concludes that pump pressure is the decisive factor of injection energy, which can better explain the practical problems in water injection production.

1. Introduction
According to the statistics of low pump pressure of an oil production team in Daqing Oilfield, there are 15 water injection wells that can not be injected in 2019 due to low pump pressure. When the pump pressure of the well drops and the injection allocation is not completed, the field workers will enlarge the oil pressure valve to increase the oil pressure. Among them, the pump pressure of 10 water injection wells decreased by 1.69 MPa and the oil pressure increased by 0.8 MPa, but the injection allocation still could not be completed.

The current pressure theory holds that the injection pressure at the bottom is equal to the wellhead oil pressure plus the liquid column pressure. If the oil pressure increases, the bottom hole injection pressure will increase, and the injection volume will increase in other conditions unchanged. But in actual production, after the pump pressure drops, adjusting the oil pressure gate to make the oil pressure rise still can not complete the injection allocation, which proves that the oil pressure has no direct relationship with the bottom hole injection pressure.

2. Analysis of pressure
At present, the injection well pressure theory is a static pressure theory, but the injected water in the wellbore is flowing, so this static pressure theory can not adapt to oilfield production, and there is an obvious problem in this theory, that is, it does not conform to the law of conservation of energy, and the energy will neither be generated nor disappear out of thin air. The current pressure theory holds that the pipeline pressure drops from pump pressure to oil pressure after passing through the oil pressure gate. In general, the pressure difference is greater than 2 MPa, that is to say, there is 2MPa disappears through the oil pressure gate. If the water injection well with an injection rate of 100m³, and the pipe diameter is 0.05m, it can be calculated that the pipe flow velocity is 0.6m/s, and the pipe wall roughness is 0.012. When the gate is only opened 1/4, the loss is only 0.28P, which is a completely negligible number. So where is the energy of 2MPa?
In fact, the production of water injection well should conform to the law of conservation of capacity in pipe flow model, namely Bernoulli equation.

\[ P + \frac{1}{2} \rho V^2 + \rho gh = C \]  

- \( P \) —— pressure potential energy, MPa;
- \( \frac{1}{2} \rho V^2 \) —— kinetic energy, MPa;
- \( \rho gh \) —— gravitational potential energy, MPa;
- \( C \) —— energy constant of pipe flow

That is, the sum of pressure potential energy, kinetic energy and gravity potential energy at any point in the pipe flow is constant. Obviously, the pipe flow before and after the oil pressure gate can be approximately calculated by Bernoulli equation.

\[ P_1 + \frac{1}{2} \rho V_1^2 + \rho gh_1 = P_2 + \frac{1}{2} \rho V_2^2 + \rho gh \]  

When the pressure drops by 2 MPa, this part of the pressure will be converted into water flow velocity. The energy of 2 MPa still exists in the pipe flow. there is:

\[ P_2 - P_1 = \frac{1}{2} \rho V_2^2 - \frac{1}{2} \rho V_1^2 \]  

After passing through the oil pressure gate, the pipe flow velocity changes from 0.6 m/s to 63 m/s. Although the pressure at the oil pressure gauge decreases greatly, the flow rate increases greatly. The
total energy at two different pressure points is the same, but the situation is different. The injection energy at the pump pressure gauge is basically equal to the pump pressure, and the injection energy at the oil pressure gauge is divided into the sum of oil pressure and speed.

### 3. Combining theory with production

3.1. At the front end of the oil pressure gate, the kinetic energy of the fluid can be ignored due to the small pipe flow velocity, where the injection energy is equal to the pump pressure. The decrease of pump pressure represents the decrease of total energy of injected fluid, and then the injection allocation can not be completed. At the back end of the oil pressure gate, the flow rate is high, and the injection energy here is the sum of the oil pressure and kinetic energy. After the pump pressure drops, although the oil pressure remains unchanged or increases, the pressure difference between the pump pressure and the oil pressure decreases, the kinetic energy transformed by the pressure potential energy decreases, and the total injection energy of the fluid also decreases. Therefore, even if the oil pressure remains unchanged or increases after the pump pressure drops, the injection allocation can not be completed.

3.2. The team has three series of S, P and G, among which the S series is the shallowest, but the casing damage rate is the highest. 41.3% of water injection wells have casing damage, which is far higher than the other two deeper series. This abnormal phenomenon is caused by unreasonable water injection mode. Although the oil pressure can be controlled to be lower than the fracture pressure in daily production, the injection pressure at the bottom of the well is equal to the pump pressure plus the liquid column pressure and minus the pipe friction resistance. The bottom hole injection pressure of the three series of layers is similar, but the S series of water injection wells is the shallowest, and the fracture pressure is the lowest. Most of the water injection wells in the S series are injecting water over fracture pressure, which will inevitably lead to the high occurrence of casing damage in the S series.

3.3. In daily production, the injection volume does increase with the increase of oil pressure and decrease with the decrease of oil pressure, but there is no direct relationship between them. When the valve is opened, the oil pressure rises and the difference between pump pressure and oil pressure decreases. In this case, relatively less energy is converted into speed, and the pipe energy loss is proportional to the square of speed. So the lower the pipe flow speed is, the smaller the energy lose in the process of water injection, the greater the bottom hole injection pressure is, and the higher the injection volume is. There will be a phenomenon that the greater the oil pressure, the more the injection volume. To ensure a certain amount of injection, there can be a variety of combinations of pump pressure and oil pressure. The pump pressure decreases with the increase of oil pressure. When the pump pressure is equal to the oil pressure, it is the minimum value. When the oil pressure is equal to the pump pressure, the bottom hole injection pressure is close to the sum of oil pressure and hydrostatic column pressure, which is not only conducive to energy saving, but also conducive to the accurate calculation of bottom hole injection pressure.

In production, if a well has enough pressure data in a short time, we can estimate the pipe loss, and then estimate the actual injection pressure at the bottom of the well.
Table 1. The injection statistics of a well under different pump pressures.

| Situation                  | Pump pressure, Mpa | Oil pressure, Mpa | Injection allocation, m³/d | Actual injection, m³/d |
|----------------------------|--------------------|------------------|-----------------------------|------------------------|
| Normal                     | 13.9               | 11.8             | 80                          | 79                     |
| Point 1 of low pump pressure| 12.3               | 12.3             | 80                          | 68                     |
| Point 2 of low pump pressure| 12.1               | 12.1             | 80                          | 52                     |
| Point 3 of low pump pressure| 12.4               | 12.4             | 80                          | 79                     |
| Test point 1                | 13.3               | 11.4             | 80                          | 56                     |
| Test point 2                | 13.3               | 11.7             | 80                          | 56                     |
| Test point 3                | 13.5               | 12               | 80                          | 80                     |

According to Darcy’s law, the injection rate is proportional to the injection pressure at the bottom of the well when other conditions remain unchanged, so we can infer the relationship between the injection pressures from the relationship between the injection rates. The injection volume at the normal point is the same as that at the point 3 of low pump pressure, so it can be considered that the bottom hole injection pressure of the two wells is basically the same, that is, the pump pressure of the normal point minus the pipe loss is the pump pressure of the point 3 lower than the pump pressure, and the pipe loss can be calculated as 1.5MPa. The injection volume of test point 3 is the same as that of the point 3 lower than the pump pressure and the pump pressure of test point 3 minus the pipe loss is the pump pressure of the point 3. The pipe loss can be calculated as 0.9MPa. With the data of pipe loss at different pressure points, the bottom hole pressure of the pressure point can be calculated.

4. Conclusion

(1). At present, oil pressure is used as an important index of injection status in water injection water injection wells, but in fact, a large part of the injection energy at the wellhead is converted into speed. Oil pressure does not represent the injection energy of water injection wells, and pump pressure is the decisive factor to determine the injection energy.

(2). Because the pump pressure is the decisive factor of injection energy, it is wrong to control the injection pressure by controlling the oil pressure. If several sets of layers with different depths share a set of water injection well pattern, the water injection wells in shallower layers are almost injecting water under the super fracture pressure, which causes a great hidden danger of casing damage.

(3). There is a large energy waste in the current water injection system. The greater the pressure difference between pump pressure and oil pressure, the greater the pipe loss. If the pressure difference between pump pressure and oil pressure can be reduced, the waste of water injection energy will be reduced.

Reference

[1] Jin, Yu., Chen, Tang. (2010) Production performance analysis of oil and gas water injection wells. Petroleum Industry Press, 29 (3): 63-65.
[2] Zhang, Cui. (2015) Fluid mechanics. Tsinghua University Press, 24 (1): 34-38.
[3] Wei, J., Du, Q., Lin, C., etc. (2001) Influence factors and distribution of residual oil in daqing oilfield. Petroleum and natural gas geology, (01): 3-5.
[4] Chao, H., Xu, Y. (1997) Development technology of sustainable and stable production in daqing oilfield [J]. Petroleum exploration and development, 24 (1): 32-39.
[5] Li Yang. 2001. Heterogeneous model of channel sand reservoir. Science Press.
[6] Wang Zhizhang, Cai Yi, Yang Lei. 1998. Variation law and mechanism of reservoir parameters in middle and late development stage, Petroleum Industry Press.