Visible Research of Loading Speed in Vertical Gas Well

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Abstract: For gas well under certain conditions, formation water production is inevitable in the later development; Formation water production is harmful to the normal production, it may cause liquid loading, flooding or even stop production. Based on the study of liquid loading and the rate laws of liquid loading, taking corresponding measures for the gas well is important. Simulating formation liquid production of gas wells with single rate under wellbore conditions, observing and measuring liquid loading rate through the experiment, summing up the liquid loading rate law of wellbore, are significant to the stability of gas well.

Keywords: Airflow carrying liquid, Liquid loading, liquid loading rate.

1. INTRODUCTION

In developed gas reservoir of our country, water production is inevitable in the later production of most gas wells. If the water of gas well is not able to be carried out of the wellbore timely and effectively, it will stay in the bottom and accumulatively cause liquid loading. With the increase of liquid loading, the bottom back pressure rises, causing gas well production decline and even flooding, seriously damaging the economic benefits of gas field.

The discharge of formation water depends on the accurate forecast of liquid loading rate and the effective measures which are taken. The research of liquid loading rate is very important to maintain the normal production of gas well. This paper is based on the indoor simulation of the visual apparatus of water production, conducting analysis on the carrying liquid rate and liquid loading rate for gas well with single rate, summing up the liquid loading rate law of gas well with the experimental data. Through adjusting the different rate of flow, the paper has verified the correctness of loading rate law.

2. THE INTRODUCTION OF EXPERIMENTAL APPARATUS

The experimental frame of physical simulation is shown below**,** according to which the height of the whole experimental apparatus is 12m and the diameter of experimental pipe is 40mm. It can stimulate the demonstration of conventional liquid carrying, the research of liquid carrying rate, the visual research of liquid loading, the influence of sand production on the capacity of liquid carrying and the influence of foaming agent on the capacity of liquid carrying, etc. The core parts of experimental apparatus are the visually metering section of liquid loading and the replaceable section of throttling part.

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Homologous parts of the experimental frame include: liquid injection nipple, uniform gas injection nipple, pressure transducer nipple, depressurizing transducer nipple, gas meter and liquid meter, constant pressure tank and so on.

3. APPLICABLE MODEL EXPERIMENTS FOR CRITICAL GAS FLOW RATE OF LIQUID CARRYING

To verify applicable gas flow rate under suitable conditions to guarantee the normal production of gas well without liquid loading, the paper carried out a series of experiments with the experimental apparatus. The experimental data is shown in Table **1**.

Through the experimental data, liquid flow rate and critical gas flow rate of three main models (Turner model [1], Colemon model [2, 3] and LiMin model [4]) in the tube are calculated, drawing the following correlation curves shown in Fig. (**1**).

When the gas flow rate is larger than the critical flow rate of Turner model, the gas well will not load in the bottom. For natural gas well, formation water can totally be carried to wellhead if only adjusting wellhead pressure timely to make the flow rate of gas well larger than the critical flow of Turner model.

4. THE VISUAL RESEARCH OF LIQUID LOADING RATE

4.1. The Rhythm of Liquid Loading Law

The research of the liquid loading rate has been carried out with the experimental apparatus above and simulated a series of gas flow conditions with single rate. The volume of formation water ranges from small to large. The experimental water is the mixture of formation water and experimental gas is the atmosphere. It has recorded simulating data from the beginning of liquid loading to the condition in which the loading liquid is mostly carried out of wellbore by airflow. When the volume of gas flow rate is 24 m^3/h, the experimental data is shown in Table **2**.

Table 1. Basic experimental data table.

Serial number	Discharge pressure MPa	Initial pressure MPa	The Angle of string			90°		
			Gas flow	Liquid flow	Temperature 2	P1	P2	Experimental phenomena described
			m^3/h	m^3/h	°C	MPa	MPa	
1	0.0475	0.0500	26.5	0.121	9.5	0.021	0.025	carrying liquid, liquid loading, slug
2	0.0475	0.0500	29.1	0.120	9.8	0.018	0.022	carrying liquid, liquid loading, slug
3	0.0475	0.0500	31.1	0.122	10.1	0.019	0.022	slight carrying liquid
4	0.0475	0.0500	30.8	0.121	10.4	0.019	0.021	carrying liquid, no liquid loading
5	0.0475	0.0500	31.0	0.117	10.8	0.019	0.022	slight carrying liquid
6	0.0475	0.0500	32.7	0.118	12.1	0.019	0.022	no liquid loading, circularity, slug
7	0.0575	0.0600	33.3	0.121	13.9	0.018	0.022	no liquid loading, circularity, slug
8	0.0525	0.0550	36.3	0.118	19.3	0.019	0.021	no liquid loading, circularity, slug
9	0.0525	0.0550	36.8	0.117	19.5	0.019	0.022	no liquid loading, circularity, slug
10	0.0475	0.0500	29.5	0.141	20.8	0.018	0.022	circularity, pill, liquid loading
11	0.0475	0.0500	31.1	0.140	21.6	0.019	0.023	circularity, pill, liquid loading
12	0.0475	0.0500	31.1	0.137	21.1	0.019	0.022	circularity, pill, liquid loading
13	0.0475	0.0500	33.0	0.146	22.4	0.019	0.023	carrying liquid, no liquid loading
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27	0.0450	0.0475	36.0	0.156	21.6	0.019	0.023	carrying liquid, no liquid loading
28	0.0525	0.0625	28.8	0.178	22.6	0.030	0.035	partial carrying liquid, liquid loading
29	0.0525	0.0625	28.8	0.191	21.6	0.030	0.036	partial carrying liquid, liquid loading
30	0.0525	0.0625	29.0	0.211	21.4	0.030	0.037	partial carrying liquid, liquid loading
31	0.0550	0.0650	28.9	0.248	20.9	0.032	0.038	partial carrying liquid, liquid loading
32	0.0550	0.0650	29.4	0.265	20.6	0.032	0.037	partial carrying liquid, liquid loading
33	0.0575	0.0675	29.0	0.279	20.3	0.034	0.038	partial carrying liquid, liquid loading
34	0.0600	0.0700	29.4	0.294	20.1	0.036	0.042	partial carrying liquid, liquid loading
35	0.0600	0.0700	29.1	0.309	19.9	0.034	0.041	partial carrying liquid, liquid loading

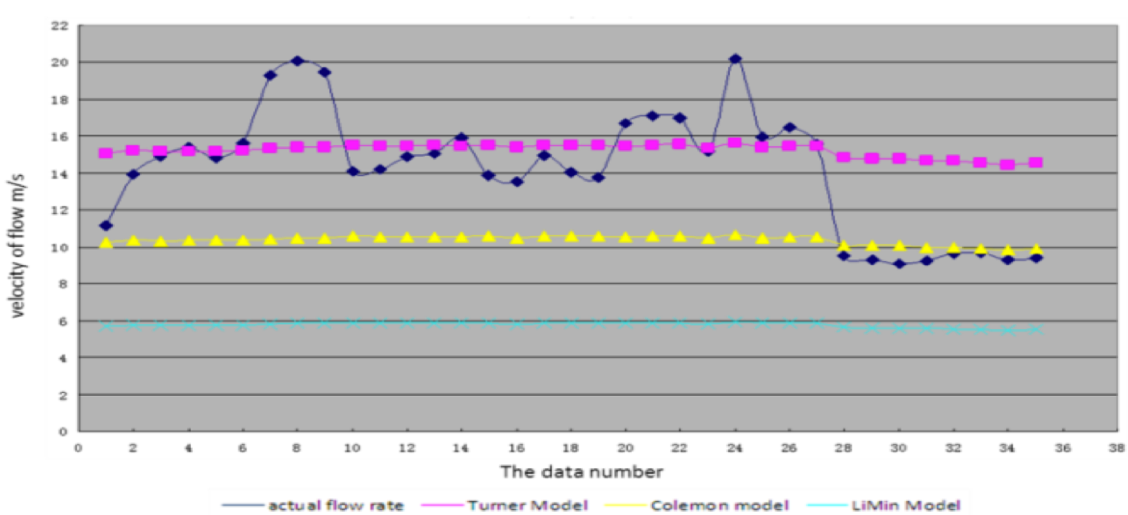

Fig. (1). Corresponding curves of different gas flow rate.

Table 2. Liquid loading law experimental data.

Data serial number	Discharge pressure MPa	Initial pressure MPa	The Angle of string				90°		Percent of liquid loading
			Gas flow	Liquid flow	Liquid loading rate	Temperature2	Pressure1	Pressure2	
			m^3/h	m^3/h	m^3/h	°C	MPa	MPa	
1	0.0250	0.0275	24.3	0.075	0.0592	4.8	0.017	0.021	0.21
2	0.0250	0.0275	23.9	0.084	0.0537	5.5	0.018	0.022	0.36
3	0.0275	0.0300	24.2	0.094	0.0541	6.4	0.018	0.022	0.42
4	0.0275	0.0300	24.2	0.107	0.0489	7.7	0.019	0.023	0.54
5	0.0275	0.0300	24.3	0.126	0.0444	11.6	0.020	0.024	0.65
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27	0.0475	0.0500	23.6	0.554	0.0128	16.1	0.034	0.040	0.98
28	0.0475	0.0500	23.7	0.565	0.0128	15.9	0.037	0.043	0.98
29	0.0475	0.0500	23.6	0.587	0.0134	15.8	0.035	0.042	0.98

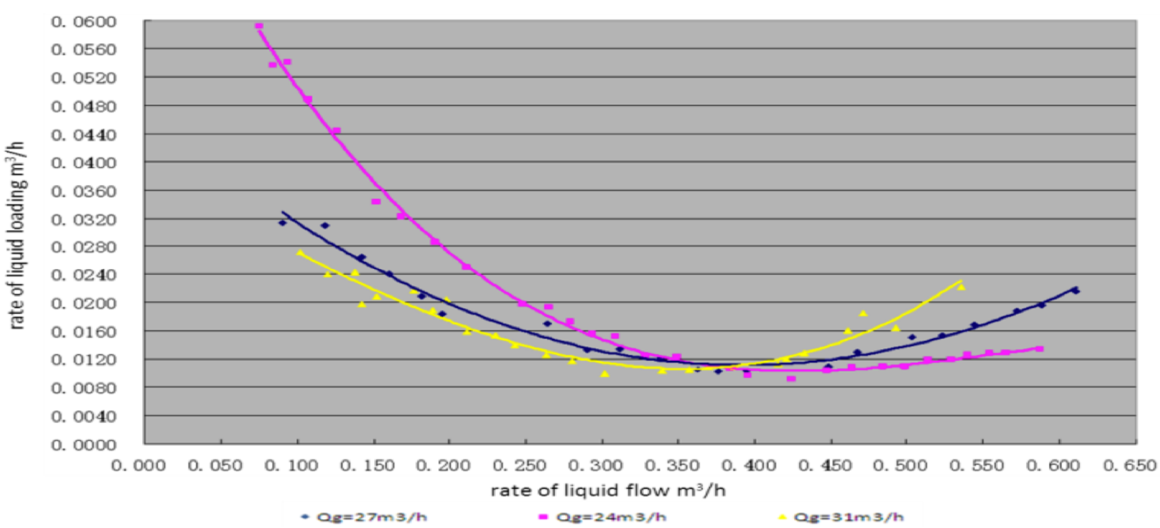

Fig. (2). Rate of loading with different volume of gas flow.

Adjusting the gas flow rate, the same experiment was performed to obtain data; all the data obtained were calculated and collated, drawing the following in Fig. (**2**).

To analyze the curves of the liquid loading rate under different gas flow, it demonstrates that the loading rate shows a trend of decrease under a certain gas flow rate with the increase of liquid flow. If the gas flow becomes larger, the decreasing amplitude of liquid loading rate with the increase of the liquid flow is slower than that before. When the liquid flow rate exceeds a certain value, liquid loading rate increases with the rise of liquid flow. Moreover, the larger the gas flow is, the faster the liquid loads with the increase of liquid rate.

4.2. The Analysis of Liquid Loading

When the gas flow rate is smaller than critical flow rate, only a part of formation water can be carried out, whereas the other part forms loading liquid in the bottom. When the volume of formation water is slight, it just mainly bears the force of gravity, shear stress and gaseous core wellbore when it reaches the wellbore from the bottom. As the gravity plays the main role, the formation water would flow along with the pipe wall straightly to the bottom, so the liquid loading flow rate is quick. When the formation water gradually increases, for the borehole is radial, the surrounding formation water could meet together in the center of the hole with mutual collision. The energy of liquid flow is greatly reduced, but the capacity of gas liquid carrying is not weakened. And at the same time the gas flow rate in the middle of the gaseous core is the strongest, and the capacity of gas liquid carrying is most powerful as well as the existence of the gas entrainment ability (Fig. (**3**)) [5]. Most of the liquid can be carried out of the wellbore by the high gas flow rate. The rest is dispersed by strong gas flow and impacts the pipe wall, forming the liquid loading along with the pipe wall by its gravity. Thus, the liquid loading rate reduces greatly.

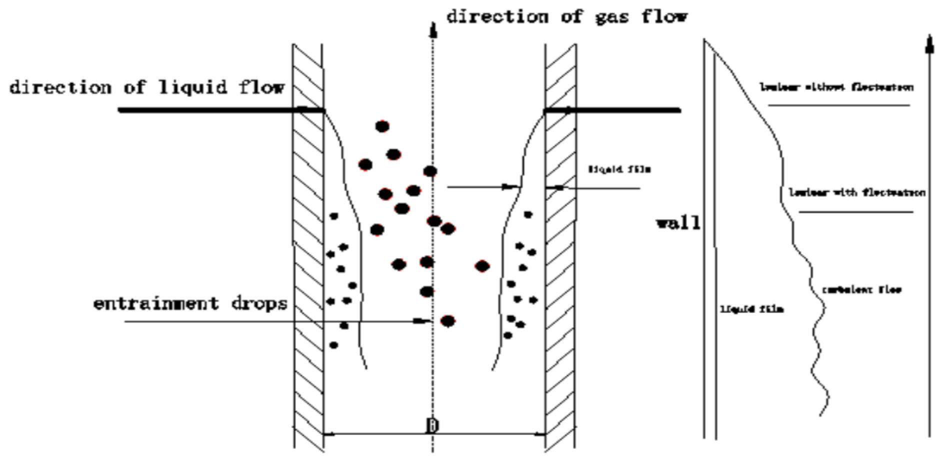

Fig. (3). Entrainment phenomenon.

With the increase of formation water, the radical liquids which meet in the middle of the gaseous core are not completely impacted, mainly divided into two main routes, one flows toward the wellbore with gas, the other one forms liquid loading. But with the powerful liquid carrying capacity of the gaseous core area, the liquid is carried and ultimately taken out of the wellbore. The loading rate decreases significantly when liquid loading rate is less than formation water production.

When the radical liquids meet together in the center and the rate meets a critical value, the liquid loading rate would reach the minimum. When the volume of liquid flow continues to rise, the jets gathering in the center encounter each other, forming the incomplete impact. The radical liquids are divided into two parts after the impaction, one toward the direction of liquid loading and the other toward wellhead. The liquid which turns to the bottom has a certain kinetic energy, resists the flow drag force, and aggravates the amplitude of liquid loading, making the liquid loading more obvious.

CONCLUSION

(1) For the gas wells with water production, to control the wellhead pressure reasonably and make the gas flow rate larger than critical rate of the Turner model, the bottom can normally be produced with liquid.

(2) In the conditions of the gas rate which is smaller than the critical rate, the volume of water rises gradually from small to large, but the rate of liquid loading rate changes from large to small, and later changes from small to large.

(3) The critical rate of liquid loading in gas well and the rhythm of liquid loading rate are important to maintain the normal production of gas well. It makes sense to take a series of measures for gas field.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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