The Effect of improving recovery rate of low permeability reservoir

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Abstract

The shale gas reservoir usually exhibits laminated characters, and the bedding planes are full of formation. The bedding planes will affect the effect of stimulate reservoir volume, while affect the production of shale gas well. At present, the research on the influence of shale gas production mainly focus only on the hydro-fracture and nature fracture, but the bedding planes. In this paper, the research, based on the open characters of bedding planes, field knowledge, and experiment results, has studied the bedding effect on the production of shale gas by numerical simulation methods.

Keywords

Shale gas, bedding effect, stimulation, physical modeling experiment, numerical simulation.

1. Introduction

Shale gas well production greatly depends on the stimulated reservoir volume or network, which formed by hydraulic fracture and nature fracture [1], and provide flow channel for oil and gas. However, the research only focus on the hydro-fracture and nature fracture [2-4], but the bedding planes at present. The bedding planes play a very important role in every aspect of drilling and completing, including well hole stabilization and stimulate reservoir volume formation [5-8].

2. Tilmeter

There are many obvious beddings in the Longmaxi shale formation from outcrop observation in the wild (shown in Fig.1). Tilmeter interpretation result shows that, range in the volume fraction of vertical fracture from 30%-100%, and fracture geometry is very complex, which shows horizontal bedding fracture exist. Therefore, the research on the bedding effect on production is necessary. specialists and experts have had some exposure to the characteristic about bedding development, formation mechanism, and effect on hydraulic fracture. This research build simulating model with bedding characteristic to explore the influence on production of bedding planes, based on field data, experiment results, and numerical analysis of mechanics.

Fig.1 Longmaxi marine strata shale outcrop in south China

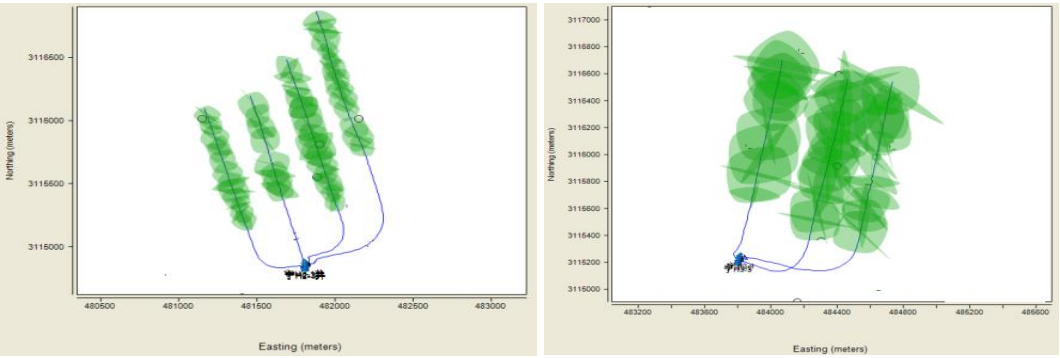

Fig.2 Tilmeter result in X2(left), X3(right)

Table1. The fracture morphology & Production in Pad X2, X3

X3-1		X3-2		X3-3		X2-1		X2-2		X2-3		X2-4	
stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%	stage	Vertical fracture volume fraction%
1	87	1	78	1	65	1	51	1	40	1	79	1	62
2	55	2	82	2	45	2	70	2	69	2	58	2	37
3	64	3	70	3	47	3	76	3	64	3	54	3	56
4	80	4	78	4	63	4	83	4	60	4	52	4	40
5	95	5	74	5	54	5	82	5	58	6	55	5	62
6	100	6	87	6	52	6	65	6	47	7	63	6	60
7	100	7	81	7	52	7	68	7	32	8	17	7	66
8	100	8	75	8	100	8	78	8	42	9	0.71	8	69
	100	9	74		100	9	64	9	54			9	33
9	100	10	100		59	10	40	10	54			10	71
10	79	11	72			12	59	11	62			11	55
11	81	12	72			13	44	12	56			12	52
12	76					14	57	13	58				
								14	52				
								15	53				

3. The bedding opening characteristic

3.1 Physical modeling experiment

The small-size indoor experiment of hydraulic fracturing is made in lab under true triaxial test condition, the vertical stress is normal to the bedding planes, size of rock is 30cm×30cm×30cm, the wellbore is drilled 170mm in deep, using diamond bit(OD 24mm). analog casing (OD 20mm ,ID 15mm)is set deep in 135-165mm, with high-strength steel tube, which is closed weld at bottom, and sealed connect to the fracturing pump pipe line with internal thread at top. 1.5mm wide hydraulic fracturing channel was symmetric-cut on the steel tube, and Slot position was filled with cotton. The casing was cemented with wellbore, using high strength adhesive, the slot position intersects the direction of maximum horizontal main stress at 45°. water was pumped in for experiment.

Physical modeling experiment in laboratory shows that, bedding can be different degree opened under different stress conditions and rock sample. 3 kinds of cases are obvious in the experiment (shown in Fig.3): 1) portion of bedding were opened by artificial fractures, and had extension; 2) most of bedding were opened by artificial fractures, they communicated with natural fractures and formed fracture network; 3) the bedding became the primary artificial fracture, which limited hydraulic fractures extension, and the shape of fracture is single.

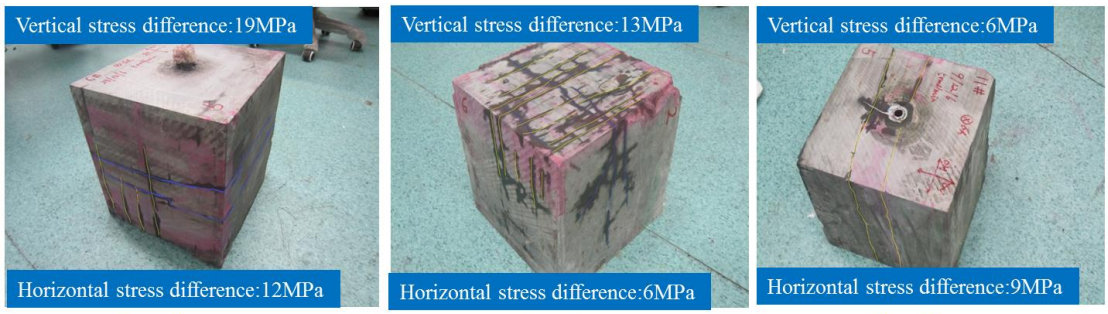

Fig.3 Physical modeling in laboratory

3.2 The numerical method

A simulating model with bedding characteristic was build, combined method of finite element and discrete element, to investigate bedding effect in shale. Based on the linear elastic fracture theory, rock failure to follow the maximum tensile stress criterion and Mohr coulomb criteria, considering the seepage flow stress coupling of crack-block system, adopt finite element discrete element hybrid method

A numerical model with bedding characteristic is established to analysis the bedding shale formation by using the combination method of finite element analysis and distinct element analysis. The numerical analysis shows that: the bedding effect is relative to the stress condition and development of beddings. The development of bedding is characterized by bonding strengths.

Under characteristics of normal stress conditions(shown in Fig.4), $\sigma_v > \sigma_H > \sigma_h$, vertical stress are maximum, the numerical simulation results shows that: 1) when the bedding is not development, artificial fracture extend vertically, the bedding opened is limited; 2) when the bedding is development, both vertical fracture and horizontal fracture are opened, vertical fractures are primary, network fracture is formed and communicated well.

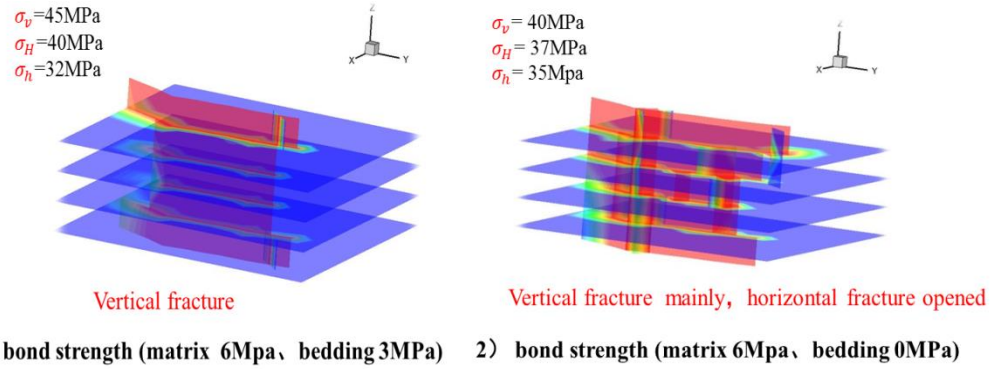

Fig.4 Numerical simulation results under normal stress state

Under the characteristics of strike-slip fault stress conditions(shown in Fig.5), $\sigma_H > \sigma_v > \sigma_h$, horizontal stress are maximum, $\sigma_v$is closed to σ_h, the numerical simulation results shows that :1) when the bedding is not development, artificial fracture can open the bedding, but not extended vertically , horizontal fractures are the primary, communication vertically is not ideal.

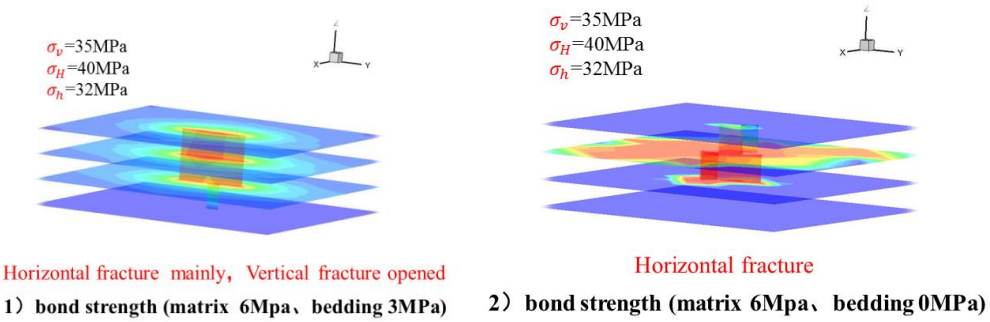

Fig.5 Numerical simulation results under strike-slip fault stress state

3.3 Analysis summary

The preliminary recognition on the bedding planes in shale was formed through experiment and numerical simulation:1) the bedding opening play an important role in the formation of network, propagation between fracture height and bedding fracture restricted each other; 2) required conditions for the bedding opening: cementation strength is moderate, and σ_v is close to σ_h.

4. Conclusion

According to the results of numerical simulation analysis and the summary, drawing the conclusions:

(1) The bedding open degree mainly affect the initial production;

(2) During the early production, the influence of bedding open degree is greater than the effect of fracture height;

(3) On the intermediary and later stage, the influence of the fracture height becomes more significant.

4.1 Recommendations

(1) If the stress state permitting the extension of fracture in vertical, the target area of horizontal should be selected in the concentrated bedding interface position to favor the gas output quickly in the drilling construction design.

(2)The difficulty of sand adding and sand volume of bedding fracture should be given full consideration, and filling bedding fracture in maximum possible to provide the gas flow channel, under the premise that guarantee vertical fracture sand efficiency in the design of fracturing construction.

Acknowledgments

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