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Analysis of the exploitation potential of well DA1

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Abstract: DA1 well exploited two sets of reservoirs, volcanic rock of Ying1 member and conglomerate of Ying4 member. In the initial stage of exploitation, the well had a high productivity. After an operation in 2010, the production situation of the well changed dramatically. In this paper, through the comparison of the production situation before and after the operation, the geological situation and the adjacent well, the operation pollution situation of the well is analyzed, and the exploitation potential of the well is analyzed, the measure scheme of plugging removal is put forward, and the stimulation prediction and economic benefit evaluation of the well are carried out, proving that the measure is effective and feasible.

Key words: Operation pollution; mining potential; plugging removal.

1. Gas well overview

The DA1 well is a development well with a west-dipping monoclinic structure and two sets of volcanic rocks in the first member and conglomerate in the fourth member. From March 25, 2007 to May 28, 2007, the well was tested after pressure. The 158 and 161 I zones achieved open flow of 63,000 m3 / day and 49,000 m3 / day respectively, indicating high gas well productivity. The well was put into operation on November 13, 2007, with a cumulative production of 68 million cubic meters of gas and 8,937 cubic meters of water up to now. In 2010, the well experienced an operation. Due to the pollution, the production situation of the well changed dramatically after the operation, and the wellhead pressure and daily gas production decreased significantly.

2. Operation pollution analysis

From September 2010 to October 2010, DA1 well was overhauled and plugging due to the high safety risk due to the pressure of the technology sheath. During the operation, the well was killed for several times and there were large losses, so it was decided to restore the process and maintain the production.

2.1 Comparison of production conditions

Before the operation, the wellhead pressure of this well is 18.1MPa and the daily gas volume is 70,000 m3. After the operation, the wellhead pressure drops sharply to 6MPa and the daily gas volume drops to 38,000 m3, while the water production only drops 0.8 m3 and the water-gas ratio increases. As shown in FIG.1, the current wellhead pressure of this well is only 5.4MPa and the daily gas volume is 11,000 m^3.

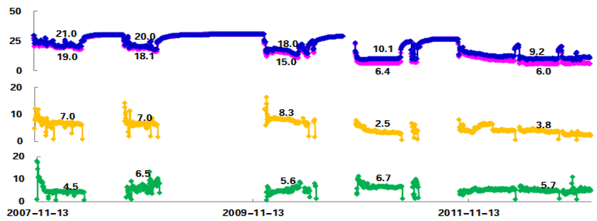

Fig. 1 Production curve of well DA1

2.2 Contrast of geological condition

The current average open flow rate of well DA1 is 14,500 m3 /d, which is 76% lower than the original average open flow rate. Before the operation, the formation pressure dropped slowly, producing 43.99 million cubic meters of gas per unit of pressure drop. After the operation, the pressure dropped 21.7%, and the gas production per unit of pressure drop dropped to 12.9 million cubic meters. The well control dynamic reserves have decreased significantly from 520 million cubic meters before the operation to 360 million cubic meters today.

2.3 Near well contrast

A longitudinal comparison between this well and two non-kill Wells in the same block during the same period shows that the production situation of the non-kill Wells DA2 and DA3 did not change significantly before and after the operation, as shown in Figure 2 and Figure 3, while the productivity of the DA1 well declined sharply after the killing operation.

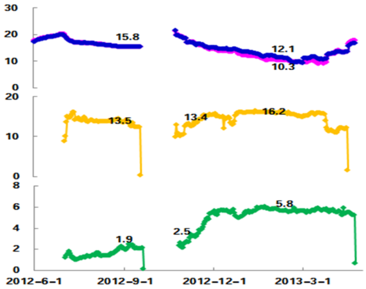

Fig. 2 Production curve of well DA2

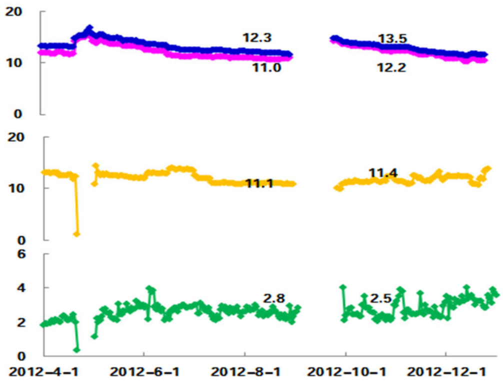

Fig. 3 Production curve of well DA3

2.4 Analysis of operation pollution

A total of 521 square meters of killing fluid were injected in the operation, and the loss reached 188 square meters. The types of killing fluid include Nacl killing fluid, solidified water, gel and solidless killing fluid. The damage factors of this well can be summarized into five categories according to the damage types and causes of oil and gas formations, as shown in Table 1 [1]. It causes blockage of part of the orifice throat and pollutes the formation. At the same time, it causes blockage of the seepage channel, which makes it difficult for gas to enter the wellbore and reduces the gas production of a single well. Second, the well mining volcanic rock, conglomerate, is a low porosity and low permeability reservoir, in the long-term kill fluid immersion, strong clay expansion, reduce the permeability of the reservoir, resulting in formation pollution; Thirdly, in the production process of this well, there is a two-phase flow of gas and water. Due to the different working conditions between the stratum and the bottom hole, part of the phenomenon of "calcium scale" may appear, leading to the increase of the skin coefficient near the well. Fourth, during the operation, a certain amount of plugging agent was added for plugging, and the construction amount reached about 80m3. The formation pollution caused by plugging agent was one of the important factors leading to the decrease of gas production in the well. Fifth, in the production after the operation, the water gas ratio of the well increased, and the test data showed that there was fluid accumulation at the bottom of the well, which resulted in the water lock effect in the production process.

Table 1 Shows the types and causes of oil and gas formation damage

type		Element of injury			Mechanism of damage
		Reservoir (internal cause)	Formation fluid (internal cause)	External fluid (external cause)	
Water sensitivity		Montmorillonite, illite/montmorillonite mixed layer, hydrated mica, illite, chlorite, kaolinite	—	Fresh water working fluid	Lattice expansion, dispersion, migration
Salt sensitivity				High salinity working fluid	Dispersion and migration
Acid sensitivity	HCL	Chlorite, montmorillonite, mixed layer, kaolinite, iron calcite, iron dolomite, biotite, heavy minerals containing iron	—	Hydrochloric acid	Fe（OH）$_3$ precipitates and the acid-etched particles are released and transported
	HF	Calcite, dolomite, clay, mica, feldspar, quartz	K^+、Na^+、Ca^{2+}、Mg^{2+} in formation water	Hydrofluoric acid	Fluosilicate, fluoaluminate precipitate，CaF_2 precipitate
Alkali sensitivity（PH>8）		All kinds of clay, feldspar and quartz	Ca^{2+}、Mg^{2+}、CO_3^{2-}、HCO_3^-、SO_4^{2-} in formation water	High OH^- Concentration working fluid	Silicate precipitation, inorganic mineral precipitation, dispersion, migration, lattice expansion
Velocity sensitive		Clay minerals, microcrystalline quartz, microcrystalline feldspar,	—	Strong mining makes formation fluid flow at	Dispersion and migration

		microcrystalline carbonate minerals, fibrous anhydrite, amorphous materials		high speed	
Sand production		Formation particles, clastic particles, loose sandstone formation	—	Strong mining makes formation fluid flow at high speed, and the amount and concentration of acid are too large	Weak consolidation, destruction of rock cementation, particle migration
scaling	inorganic	Carbonate, part of clay, salt crystals	Salt in formation water	High PH, different ion types and content, production caused by temperature, pressure changes	$CaCO_3$、$CaSO_4 \cdot 2H_20$ Inorganic salt precipitation
	organic	—	Paraffin and bitumen in crude oil	Gas injection, acid solution, steam inhalation	The solution-precipitation equilibrium is disrupted
External blockage		—	—	A solid phase carried by a foreign liquid	Solid ions were deposited and bridged in the pore throat

3. Analysis of exploitation potential

3.1 Gas well potential analysis

The current well controlled dynamic reserves of this well are 360 million cubic meters, the cumulative gas production is 68 million, the recovery degree is only 18.33%, the remaining reserves are large, the potential of the gas well has not been fully played, and the subjective ability to explore potential. This well is located in the high part of local structure, with favorable structural position, good reservoir property, porosity development and strong storage and permeability capacity. After measures, it is expected to restore high productivity. The physical conditions of this well are similar to those of well DA4 and well DA5, as shown in Figure 4. However, these two Wells have higher productivity and good production situation under the condition of no operation pollution, and their recovery degree is higher than that of this well.

DA1 well **DA4 well** **DA5 well**

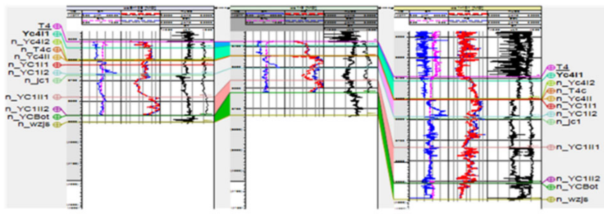

FIG. 4 Stratigraphic correlation between well DA1 and adjacent well Yingcheng Formation

3.2 Analysis of measures

In 2013, the 13Cr anti-corrosion tubing was replaced without killing the well in DA1 well, and no resistance was encountered in all tests, indicating that the wellbore conditions were perfect and the technological conditions were met with measures. Refracturing and plugging are two common ways to stimulate such contaminated gas Wells.

3.2.1 Feasibility analysis of refracturing

Through the statistical analysis of refracturing Wells in DA block, it can be seen that refracturing can increase the production of gas Wells to some extent, but the fracturing cost is large, the payback period is long, the construction process of fracturing is multiple, the construction is difficult, and the risk of construction failure is relatively high. In addition, DA1 well is originally self-injection after pressure, and the fracture characteristics after fracturing are obvious, so it is not necessary to conduct secondary fracturing.

3.2.2 Feasibility analysis of unplugging

Commonly used unplugging methods are: Organic acid deplugging, inorganic acid deplugging, surfactant deplugging and alcohol deplugging. Take DS1 well as an example, before deplugging, the skin coefficient is large, the reservoir pollution is serious, and the daily gas production is low. However, after deplugging, the skin coefficient decreases, the pollution is relieved, the daily gas production increases significantly, and the deplugging effect is good. It is suggested that well DA1 be de-plugged to restore gas well productivity.

3.3 Gas well stimulation prediction and economic benefit evaluation

3.3.1 Production increase forecast

Because of the particularity of gas Wells, the wellhead pressure before and after the measurement is difficult to be consistent. Therefore, it is more representative to count the production as open flow when calculating the stimulation prediction. According to formula (1), the stimulation factor was 1.92 times and the stimulation period was 500 days.

$$J = qsc/\ qsco \quad (1)$$

Where: J -- yield increase multiple, dimensionless;

qsc——Test output after construction, 104m3/d;

qsco——Test output before construction, 104m3/d。

3.3.2 Evaluation of economic benefits

According to formula (2), (3) and (6), it can be calculated that the payback period of plugging removal in well [2]DA1 is 3.3 months, the net present value is 2,300.15 million yuan, the internal rate of return is 30%, the net present value is greater than 0, and the internal rate of return is greater than 10%. The scheme is feasible.

$$T=G/g \quad (2)$$

Where: T -- payback period, month;

G——Project investment: ten thousand yuan;

g——Net increase profit, ten thousand yuan/month。

$$NPV=NPV1-NPV0 \quad (3)$$

Where: NPV——Actual cash inflow, ten thousand yuan;

NPV1——Cash inflow from increased production, ten thousand yuan;

NPV0——Investment in stimulation measures is converted into cash flow, ten thousand yuan。

$$NPV0=V0(1+i/12)n \quad (4)$$

$$NPV = \sum_{j=1}^{n} \left[V_j (1 + \frac{i}{12})^{(n-1)} \right] \quad (5)$$

Where: V j——Net production increase revenue for month j, ten thousand yuan;

i——Bank annual interest rate, dimensionless;

n——Effective period for increasing production, month;

V0——Direct investment in stimulation measures, ten thousand yuan.

$$IRR = a + [NPV_a/(NPV_a - NPV_b)] \times (b - a) \quad (6)$$

Where: IRR——Internal rate of return, %;

a、b——Rate of discount, a>b;

NPVa——When the discount rate is a, the net present value that you calculate is going to be positive;

NPVb——When the discount rate is b, the net present value that you calculate is going to be negative。

4. Conclusion and Understanding

4.1 Well DA1 is a combined production well of volcanic rock and conglomerate of Yingcheng Formation. It has good reservoir properties, high original open flow and high daily gas production at the initial stage of exploitation.
4.2 In 2010, the treatment technology of DA1 well was set with pressure, and the plugging failed, resulting in serious loss of kill fluid, resulting in reservoir pollution and sharp decline in productivity. However, the degree of recovery was low, the gas well itself had good physical properties, favorable structural position, and had potential enhancement ability.
4.3 It is suggested to restore the production capacity of gas well DA1 through plugging relief. This paper forecasts the production increase of this well after plugging measures. According to the forecast, the production increase multiple of this well after plugging measures is 1.92 times, the net present value is 2.30.15 million yuan, and the internal rate of return is 30%.

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