A New Tool-less Layered Fracturing Technology and Its Pilot Application in Deep Thick Formations*

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Abstract

Multi-layer fracturing technology is challenging because of the risk of packer failure and high cost in the deep thick formation. It depends largely on the effectiveness of packer tools. However, a new degradable fiber ball could be successfully used to temporarily block the open perforations, and then the layer with higher fracturing pressure is broken down. This paper presents a new tool-less layered fracturing technique and its pilot test results with this special material. A series of laboratory experiments were conducted to evaluate the feasibility of this new technique. Degradable fiber balls were applied to perforated pipes under simulated reservoir conditions. The ball carried by the fluid first sealed the perforation holes and then increased the pressure in the pipe to simulate the resistance to pressure. In addition, the fluid was heated up to 140°C to simulate the degradation rate of fiber balls. Throughout these processes, the flow rate, temperature and pressure were continuously monitored for subsequent analysis. Experimental and application results showed that: (1) fiber balls could be thoroughly degraded at 140°C temperature after six hours; (2) at a pressure difference of 50-70MPa, its deformation rate was less than 1.5%, which indicated its higher compression capability; (3) it could effectively block the perforation holes at 90°C and a pressure difference of 20MPa; (4) The blockage of perforations by the fiber ball could significantly enlarge the net pressure in the wellbore. This technique was applied for 35 wells in a deep and thick oil reservoir, which had achieved a great success and the post-treatment oil production was enhanced by 50-60% compared with conventional stimulation techniques.

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Outline

1. Motivation
2. Experimental Methodology
3. Experimental Results
4. Case Study
5. Conclusions

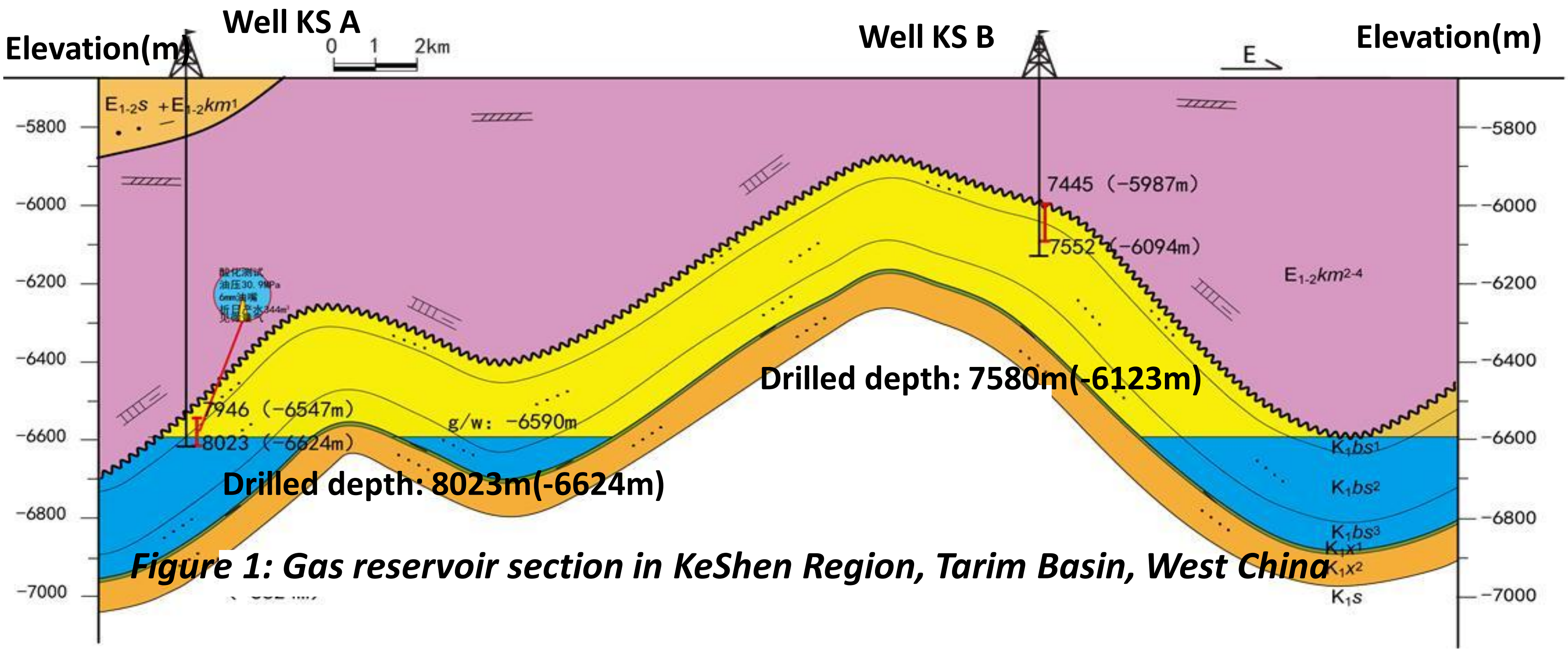

Figure 1: Gas reservoir section in KeShen Region, Tarim Basin, West China

Geology Feature

- HPHT
- deep thick formation
- low matrix permeability
- developed natural fractures

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Challenges and advanced Technology

- long well-construction period
- high cost to commercially develop
- multi-layer completion technique
- layered fracturing technology

Number	reasons	results
1	complex pipe string	• much difficult to predict their mechanical safety • and thus engineering risk will easily increase in the treatment
2	many packers	• difficult to examine their leak tightness • maybe not reliable to separate each layer
3	the lower Packer 1	• impossible to add balancing pressure in the annular space • there is a limit pump pressure to protect these packers from unsealing
4	operating these complex separate-layer strings	• a big headache to do well testing and other treatment after fracturing

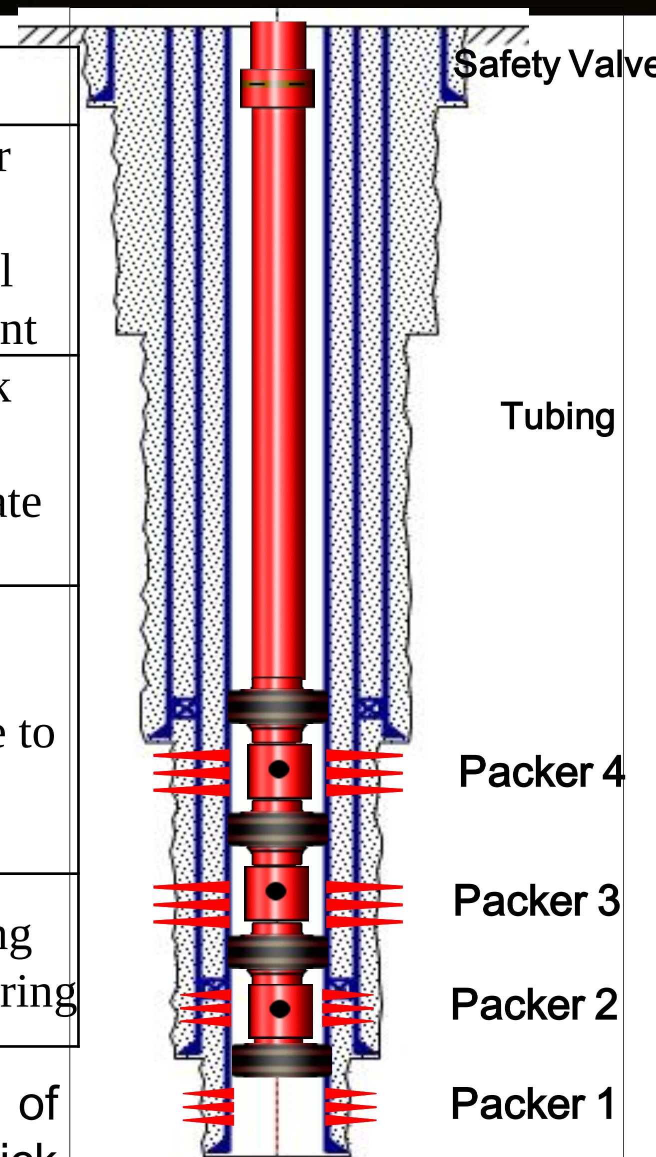


Figure 2: Layered fracturing string

Multi-layer fracturing technology is challenging because of the risk of packer failure and high cost in the deep thick formation.

①Tool-less layered fracturing ②diverting fracturing within the crack ③diverting fracturing at the wellbore

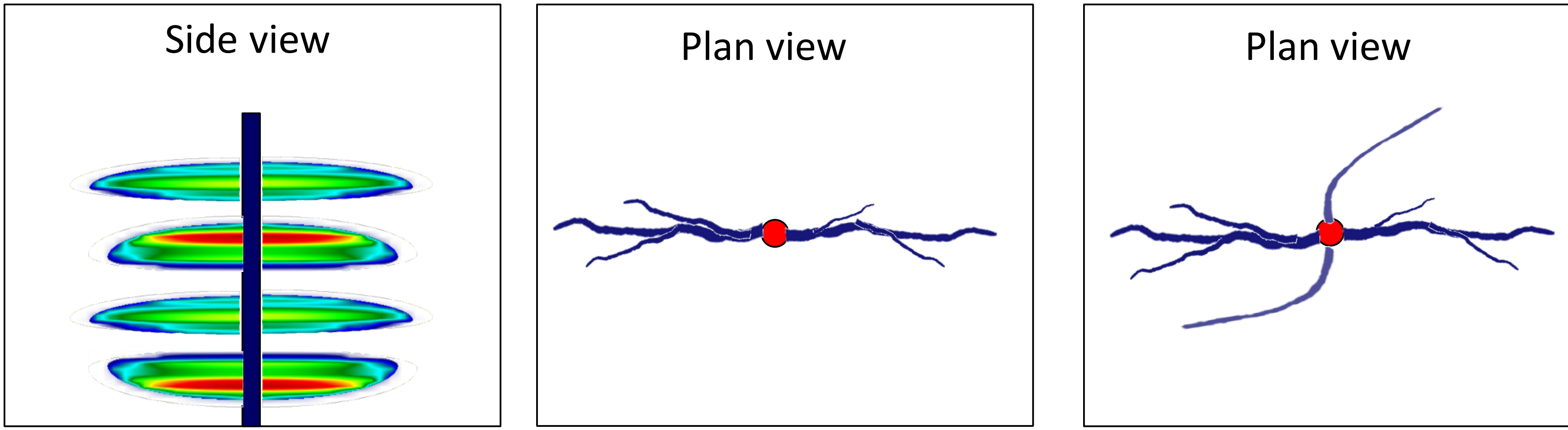
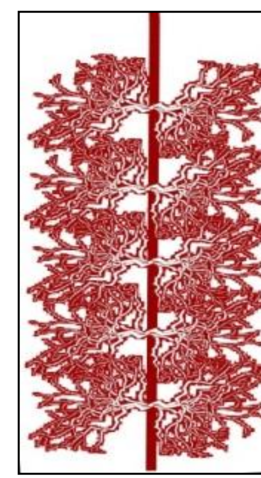


Figure 3: The desired fracture pattern of fracturing

Incorporation the concept of SRV fracturing similar to the stimulation of horizontal well into the deep-thick formations of vertical well



Advanced Technology:

- Degradable fiber balls are used to block these open perforation holes, and then the layer with higher fracturing pressure is broken down. Therefore, fracture diversion is achieved in the longitudinal direction (along the wellbore).

The difference from conventional balls

- Conventional balls could not enter into the perforated holes, and they will be just seated on the outer side of holes. Thus there is a low seal efficiency on holes.
- Fiber balls can enter into the holes because of their deformation capacity under fluid pressure. Thus its seal efficiency is more than that of conventional balls.
- Fiber balls can be automatically degradable at reservoir temperature.

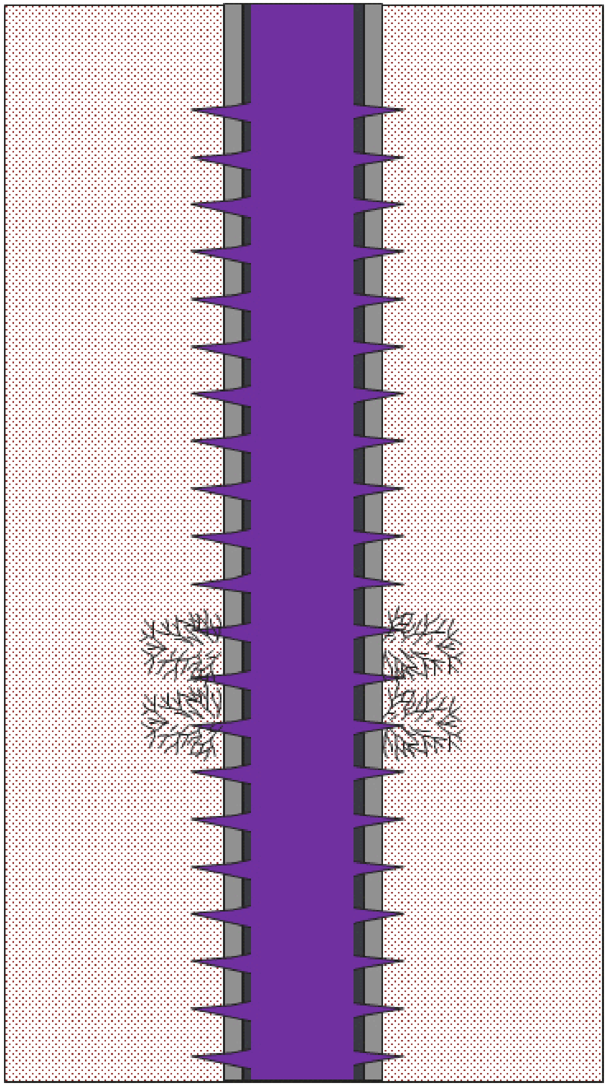


Figure 4: Tool-less Layered fracturing

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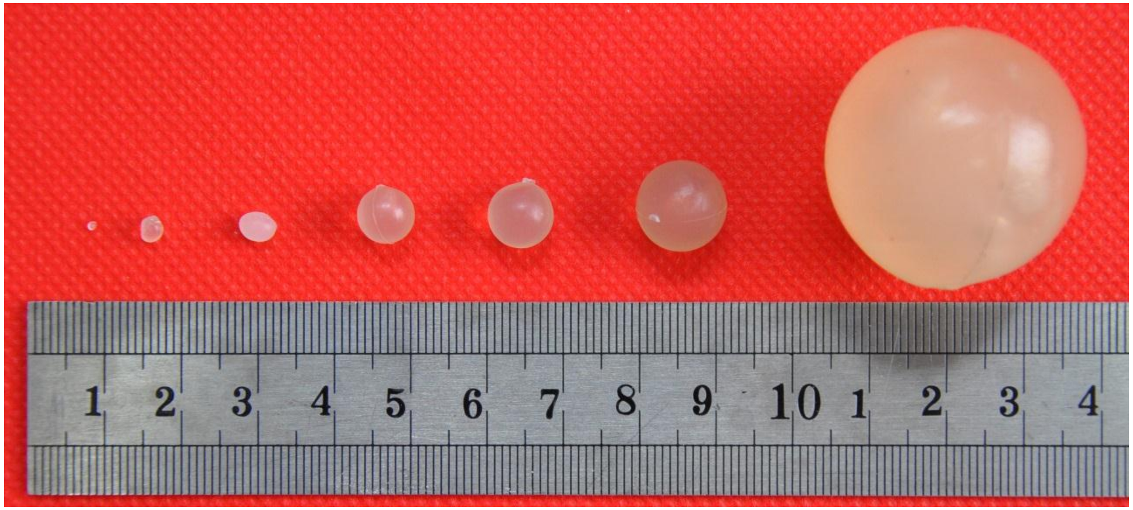

Figure 5: Different size of fiber balls

- Degradation experiment
- Comprehensive diverting experiment in the laboratory
- Blocking and deformation experiment in the field

Figure 6: Experimental setup

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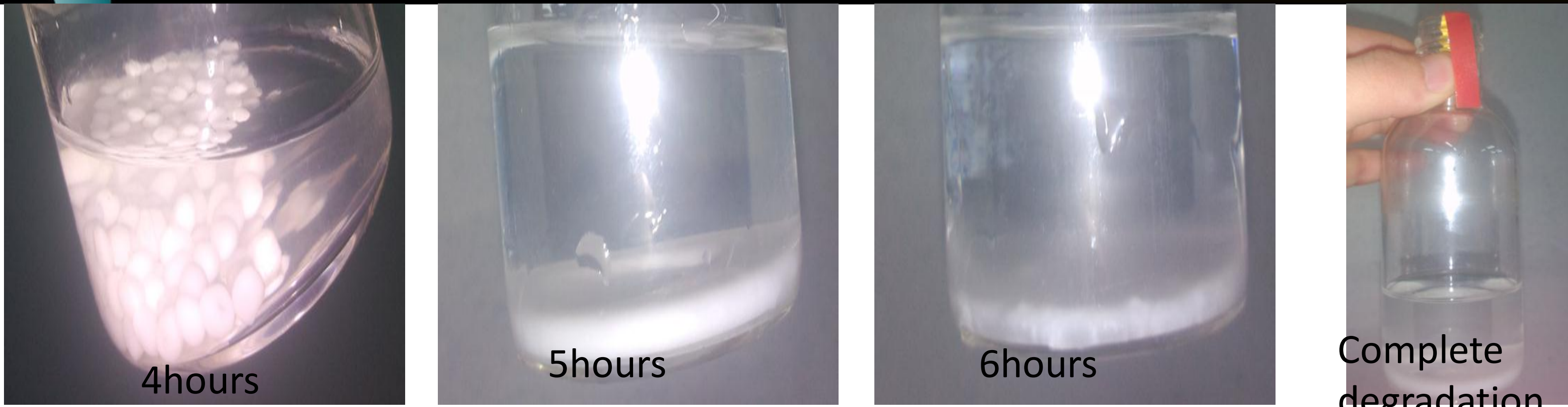

Figure 6: The degradable process of fiber ball dependent on time at constant temperature 140 ℃

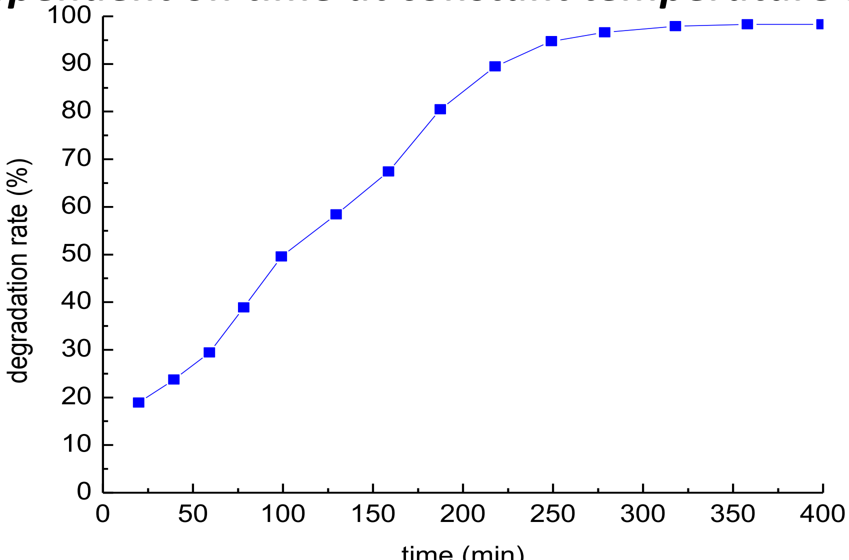

Figure 7: The degradation rate curve of fiber ball dependent on time

- fiber balls could be thoroughly degraded at 140 ℃ temperature after six hours
- the acidic property of its degradable fluid is very useful to improve the reservoir permeability

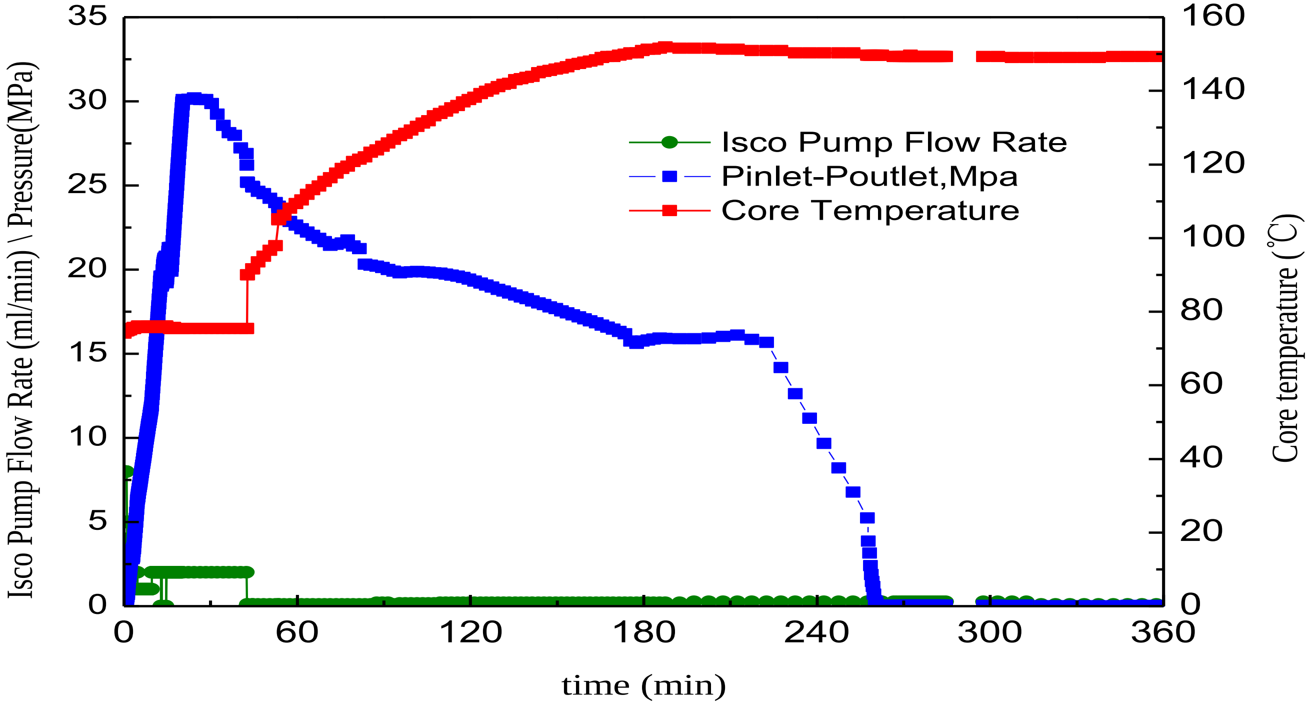

Figure 8: The flow rate, pump pressure and temperature data in the experiment of temporary blocking ability to perforation holes.

- this kind of fiber ball could well bear pressure less than 30MPa, and thus had good temporary blockage ability to perforation holes.
- The pump pressure was gradually decreasing to zero in 4 hours. It indicated that this kind of ball could be automatically degradable at reservoir temperature.

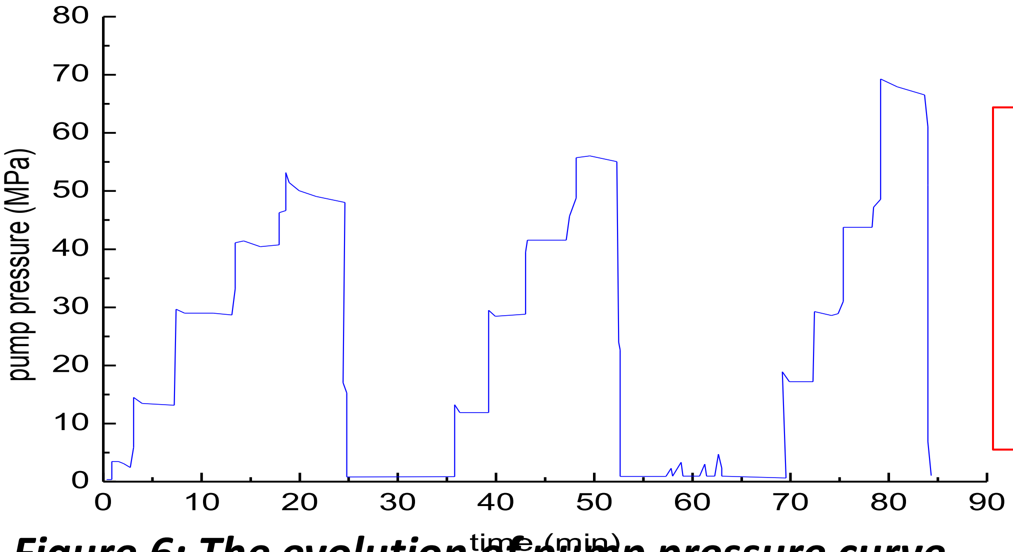

Figure 6: The evolution of pump pressure curve dependent on time in three pressure-bearing tests

- at a pressure difference of 50-70MPa, its deformation rate is less than 1.5%
- Fiber balls has a higher compression capability.

Table 1. The data in the pressure-bearing test of fiber ball at field temperature

Ball number	Maximum pressure/MPa	Outer diameter before experiment/mm	Outer diameter after experiment /mm	Deformation rate/%
1	52.2	11.90	11.88	0.17
2	70.0	8.48	8.48	0
3	55.4	11.88	11.70	1.5

Table 2. The degradable experiment of different size of fiber balls at different temperature in the field

number	Temperature/℃	time/h	Diameter/mm	Experimental results
1	100	2	12	not degradable, changes in color
2	120	2	12	not degradable, changes in color
3	140	2	12	not degradable, changes in color
4	140	3	8	changes in shape
5	140	4	8	completely degradable
6	140	4	12	partially degradable
7	140	6	12	completely degradable
8	140	8	12	completely degradable
9	140	8	8	completely degradable
10	150	4	12	completely degradable
11	160	2	12	partially degradable
12	160	9	8	completely degradable
13	160	9	12	completely degradable

These kinds of fiber balls both could be completely degradable in 6 hours.

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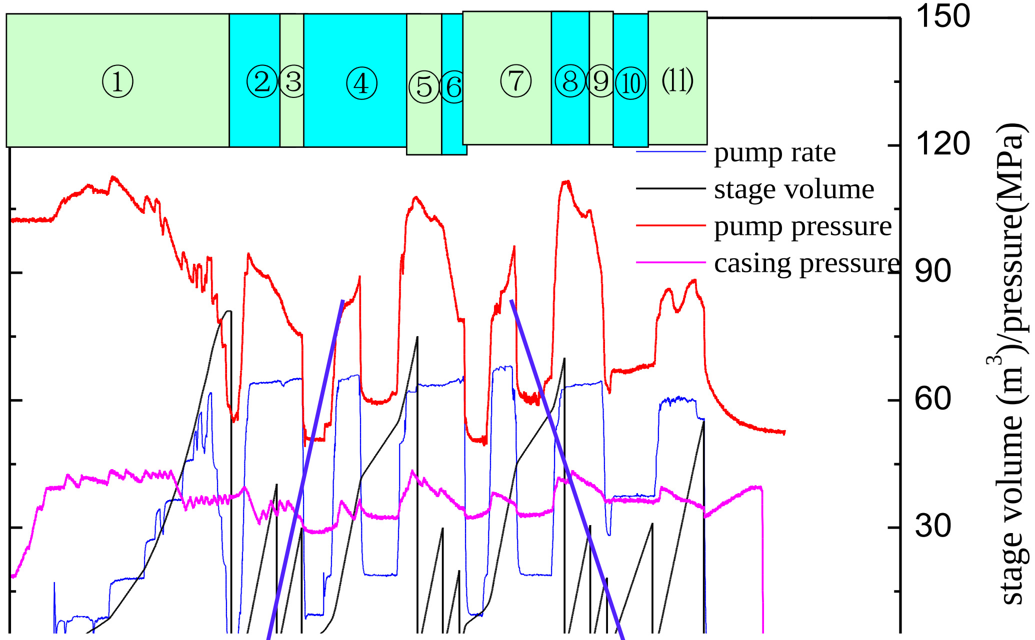

Figure 7. hydro-fracture construction curve of well KeShen 9

The first stage, pump pressure is increased by 19.7MPa

The second stage, pump pressure is increased by 16.9MPa

- 6 and 3 mm degradable fiber balls
- Two stage diverting fracturing
- The blockage of perforations by the fiber ball can significantly enlarge the net pressure in the wellbore.
- The post-treatment oil production is enhanced by 50-60% compared with conventional stimulation techniques.
- this well was called “three one hundred” well.

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Conclusions

- Fiber balls could be thoroughly degraded at 140℃ temperature after six hours, and thus these balls did not affect the flow-back process of fracturing fluid after the treatment
- Their deformation rate was less than 1.5%, which indicated its higher compression capability
- It could effectively block the perforation holes at 90℃ and a pressure difference of 20MPa, and therefore fiber ball had a good blocking ability to perforation holes
- This technique had been applied for 35 wells in a deep and thick oil reservoir, which had achieved a great success

Thanks!

Questions?