International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)
ISSN 2455-4863 (Online) www.ijisset.org Volume: 4 Issue: 8 | 2018

Analysis and Measures for Sand Fracturing Screenout of Complex Fault Block Oil and Gas Reservoir

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Abstract: *Fushan Oilfield is a low-porosity and low-permeability complex fault block oil and gas reservoir. Remarkable post-fracturing production have been achieved through fracturing. However, some wells have sand screenout while fracturing, which does not only affect the post-fracturing production but also cause serious economic losses. According to the screenout of fracturing wells in Fushan Oilfield, the specific causes of sand screenout are analyzed by combining with reservoir geological characteristics, fracturing design, logging curve and fracturing treating curve. The shale content of the reservoir is high with strong plasticity. Deviated well and multi-layer perforations near wellbore area easily form multiple fractures, the wellbore is close to the fault and the fluid leak-off changes largely, and the stress differences between the fracturing layer and the upper and lower interlayers is small which result in the fracture height out of control. These are the main reasons for the sand screenout in Fushan Oilfield. In order to reduce difference during fracturing and improve the success rate of fracturing, technical measures are proposed to solve screenout in fault block reservoirs in Fushan Oilfield. That is, 30-50 mesh and 20-40 mesh proppant are added together. Multi-stage slug reduces the influence of multi-fracture and optimizes perforation, controlling fracture height and detecting fault distance technology. The 13-layer of 7 fracturing wells show that only one layer has sand screenout, and the other layers are good.*

Keywords: *Complex fault block; hydraulic fracturing; sand screenout; multiple fractures; deviated well*

1. INTRODUCTION

Fushan Oilfield is a low-porosity and low-permeability reservoir with low natural productivity. Due to multiple tectonic movements in the Fushan sag, multiple fault blocks are formed, with a minimum of less than 1 km². Fault blocks are many and small with complex distribution. The reservoir features of Fushan oilfield are high temperature, many layers, small thickness, thin interbed and complex oil and water distribution. In addition, there are many uncertain factors in the process of fracturing, and some wells have sand screenout to different extents. Sand screenout does not only affect the post-production but also directly affect operation periods and the fracturing of the subsequent intervals [1]-[3]. Therefore, it is necessary to analyze the causes of sand screenout, and propose measures to improve the success rate of fracturing.

1. Analysis of sand fracturing screenout

As for a well with fracturing sand screenout, possible causes of sand screenout can be comprehensively analyzed according to main parameters of sand screenout layer (Table 1), single well fracturing design, logging curve, fracturing curve and fitting results.

Table 1 *Main parameters of sand screenout well*

Well No.	Well depth	Well inclination (°)	Perforation length / number of sections	Shale content %	Distance from the fault m	shale/sand layer stress differences MPa	Sand concentration whilescreenout kg/m^3
ZH 1-6X	1276.9-1284.3	32.9	7.4/1	26.3	430	3-5	248
	1245.3-1250.3	32.9	5.0/2	22.1	430	4-7	248
CH 5X	3872.0-3874.6	44.5	2.6/1	6.7	300	2-4	231
HD 6-1X	3667.0-3689.9	30.9	7.9/3	5.6	50	5-8	385
L 103-10X	3010.5-3026.0	39.4	11.2/4	14.6	280	5-7	231
	3075.3-3086.4	39.4	4.6/2	7.6	280	4-7	231
H 129X	3574.3-3578.2	23.2	2.0/2	8.5	80	6-9	228

1.1 Reservoir characteristics

The reservoir features are high shale content, strong plasticity, difficulty in fracture extension, narrow fracture width and easy sand screenout.

ISSN 2455-4863 (Online) www.ijisset.org Volume: 4 Issue: 8 | 2018

Because of high shale content, high stress and strong plasticity, during fracturing, the surface pressure is high, and the artificially created fractures are difficult to extend, and the fracture width is narrow. Therefore, sand screenout occurs easily when pressure and pump rate are limited.

Table 2 is the logging interpretation of the ZH 1-6x well. It can be seen from the table that the shale content of the pay zone is above 20%, the gamma is greater than 100 API. Fig. 1 is the fracturing curve of the ZH 1-6x well. It can be seen from the curve that the plasticity of the reservoir is obvious, no obvious broken pressure is seen, and it is extremely sensitive to the sand concentration. Whenever the sand concentration increases, the treating pressure rises. The high shale content layer usually shows that the pressure is always increasing. When the low sand concentration enters the reservoir, the pressure rises slowly, and the sand screenout usually occurs in the front slug or the low sand concentration stage. During fracturing of ZH 1-6x well for the first time, sand screenout occurred when the sand concentration was 248kg/m^3, and the sand screenout occurred again when the sand concentration was 248kg/m^3.

Table 2 *Logging interpretation of theZH 1-6X well*

Well depth m	Layer thickness m	gamma API	Deep detection resistivity Ω•m	AC μs/m	Porosity %	Permeability mD	Shale content %	Oil saturation %
1227.5-1228.0	0.5	110.7	75.2	228.2	9.4	2.14	28.8	30.3
1228.0-1228.9	0.9	76.2	84.1	227.0	9.8	4.93	10.5	37.3
1238.9-1240.4	1.5	84.3	33.3	186.5	0.5	0.01	13.7	0.0
1245.3-1246.3	1.0	105	26.3	199.1	3.4	0.01	20.7	0.0
1249.0-1250.3	1.3	100.6	29.9	228.8	10.3	6.71	23.5	31.0
1276.9-1284.3	7.4	123.3	37.8	206.8	4.8	0.02	26.3	0.0

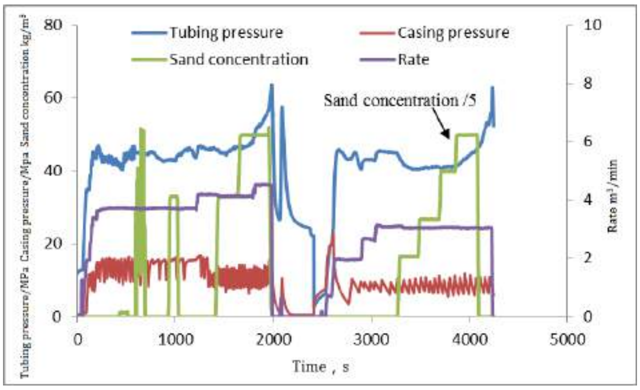

Fig.1 The fracturingcurve of ZH 1-6x well

1.2 Deviated well and multi-perforated interval

Deviated well and multi-perforated interval form multiple fractures easily, and the fractures bend and extend, which results narrow fracture width, difficult sand adding and sand screenout.

Due to the faults, it is difficult for vertical well to meet the requirements of complex geological conditions. Most of the wells are deviated wells with a slope between 20°~40°. Generally, the direction of deviated wellbore is inconsistent with the maximum stress direction. When the deviated well is fracturing, fractures extend from a plurality of perforations. The fracture initiation direction is not along the direction of the maximum stress, but the fracture extends from a certain inclination angle to the maximum fracture stress direction, it increases the near wellbore friction. Therefore, the deviated well fracturing will form multiple fractures, which results in narrow fracture width. So, the failure to meet the minimum requirement that the proppant enters fractures. This is also the cause why the deviated wells are difficult to fracture [4-7]. Fig. 2 is a schematic diagram for three kinds of multiple fractures. A indicates that multiple fractures occur in near-wellbore area and are connected in the further wellbore area. B indicates that multiple fractures occur in near-wellbore area and are not connected in the further wellbore area. C indicates that after measures are taken, the fractures in near-wellbore area are reduced and connected in the further wellbore area.

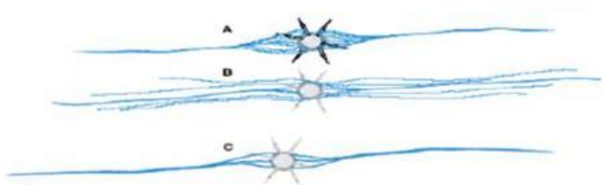

Fig. 2 Schematic diagram for complex effects and multiple fractures in near-wellbore area

In general, when the deviated well is fracturing, the fracture width of each fracture is very narrow and the fracture length becomes shorter due to the effect of multiple fractures (Fig. 3). The net pressure in the fracture rises, which increases the surface pressure to a certain extent and makes it difficult to control the fracture height. More importantly, the fracture is short and narrow, which makes it difficult for the proppant to pass through the fracture, results in fluid entry without

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proppant entry and sand screenout.

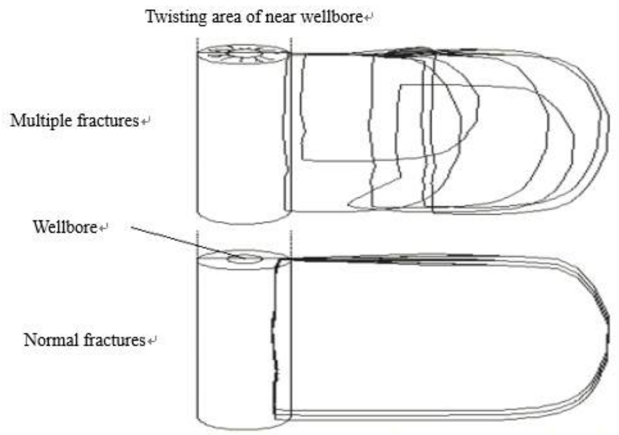

Fig. 3 *Normal fractures and multiple fractures*

From the fracturing curve and the evaluation after fracturing, some wells show multiple fractures during fracturing. Fig. 4 is the fracture profile for the L 103-10x well. The length of the perforation is 11.2m with 4 perforated intervals and an inclination angle of 39.4°. It can be seen from the diagram that when there are multiple perforated intervals, multiple fractures form easily in the near-wellbore area and extend. The fractures are short and narrow, and the fracture width is obviously reduced. Fig. 5 is the fracturing curve of the well. The surface pressure has been slowly increased at the beginning of fracturing. After the slug enters the reservoir, the surface pressure fluctuates greatly. This indicates that the reservoir is sensitive to the sand concentration, the fracture width is narrow, and it is difficult for the proppant to pass through. Sand screenout occurs when the sand concentration is 165 kg/m^3.

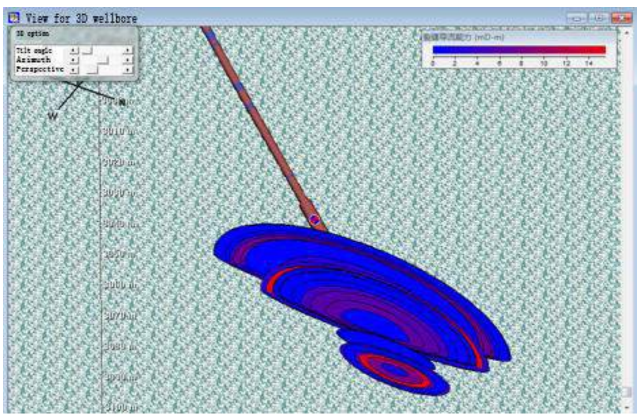

Fig. 4 *Fracture profileof L 103-10x well*

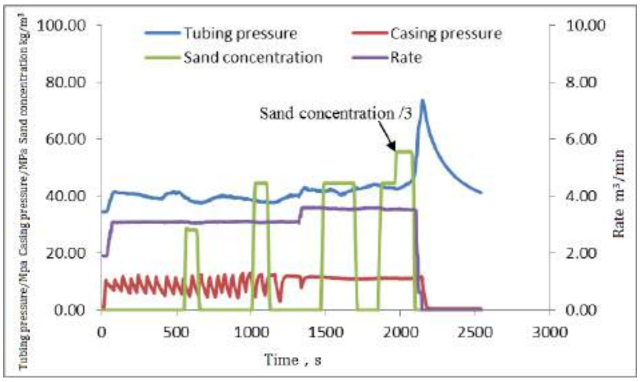

Fig. 5 *Thefracturing curve of L 103-10x*

1.3 Distance between wellbore and fault

The wellbore is close to the fault, and the leak-off changes greatly, which easily results in sand screenout.

After multiple tectonic movements, the tectonic shape of the Fushan depression is a large nose-like structure. The cutting of the two groups of faults in the northeast and northwest makes its structure complicated, forming multiple fault blocks and fault noses. The size of each fault block and fault nose is small, totaling 170 with the minimum of less than 1km^2. As the fault distribution is complicated, it is difficult to determine the direction of in-situ stress. The well is close to the fault, and some are only tens of meters away from each other. It is easy for hydraulic fracture to have the increasing of leak-off and cause sand screenout.

The H 129x well is about 80m away from the Yong'an fault in the southeast. The risk of hydraulic fracture communicating fault is huge. Fig. 6 is the fracturing curve for the well. The treating pressure in the pad fluid stage has been rising, and the surface pressure is slightly reduced after the two slugs. The surface pressure drops sharply at the slurry stage, it is reduced from 82.79 MPa to 74.5 MPa within 4 min, decreasing by 8.29 MPa. After that, the surface pressure increases rapidly, and sand screenout occurs when the sand concentration is 228 kg/m^3. In the layer for sand screenout caused by serious leak-off of the fracturing fluid, the pressure curve generally shows that the drop of pressure is too fast or the pressure changes suddenly and pressure rises rapidly when the sand screenout occurs. According to the characteristics of the reservoir and the fracturing pressure, the sand screenout is caused as the wellbore is near to the fault and hydraulic fracture communicate fault.

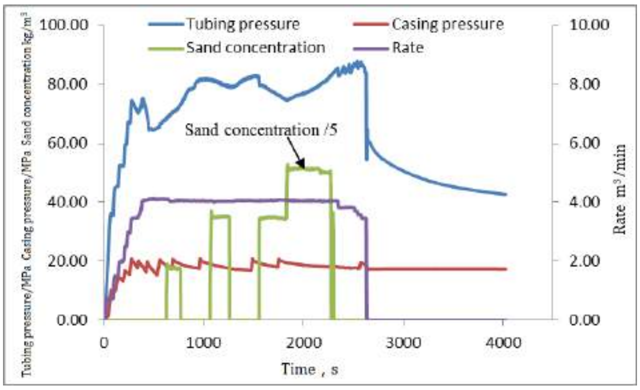

Fig. 6 *The fracturing curve of H 129x well*

1.4 Stress differences between pay zone and the upper and lower interlayers

The differences of stress between the fracturing layer and the upper and lower interlayers is small, and the fracture height extends excessively at the vertical direction, and fractures having a certain length and width cannot be formed, which results in sand screenout.

Table 3 is the logging results of the CH 5x well. The payzone is 3872.0-3874.6m with a thickness of 2.6m. By calculation, the stress differences between the fractured layer and the upper and lower interlayers is about 2-4MPa. The shale is thin, and the stress shielding is not obvious. The hydraulic fracture easily penetrates the interlayer and extends along the height. It is difficult to get an effective fracture length and width [8-9]. The fracture profile of the well is shown in Fig. 7. The length of dynamic fracture is 65.4 m, the length of propped fracture is 43.8 m, and the height of dynamic fracture is 71m, and the height of propped fracture is 47.4 m. This indicates that the fracture height of the well is completely out of control. The fracturing curve of the well is shown in Fig. 8. The treating pressure in the pad fluid stage is continuously reduced, and the pump rate is always increased to 4m3/min. For the thin layer with a thickness of 2.6m, the rate with 4m3/min is relatively high. Moreover, the stress differences between the pay layer and the upper and lower interlayers is small, and the shale interlayer is thin, which makes the fracture extend excessively at the vertical direction. The pressure is slowly increased after adding the sand. Sand screenout was formed when the sand concentration reached 231kg/m^3.

Table 3 *Logging results of the CH 5x well*

Well depth m	Layer thickness m	Deep detection resistivity Ω·m	ACμs /m	Neutron porosity %	Bulk density g/cm^3	Effective porosity %	Permeability mD	Shale content%	Oil saturation %
3852.0 - 3857.8	5.8	26.2	243.9	20.8	2.60	13.3	1.2	27.3	26.3
3859.3 - 3860.1	0.8	28.7	224.2	19.7	2.72	9.1	0.1	25.5	0.0
3864.0 - 3865.4	1.4	49.8	245.4	21.6	2.44	13.6	1.5	24.1	55.1
3872.0 - 3874.6	2.6	179.5	245.4	17.1	2.42	15.3	6.2	6.7	84.3
3891.7 - 3893.4	1.7	48.3	218.7	13.7	2.64	9.0	0.1	18.5	25.9

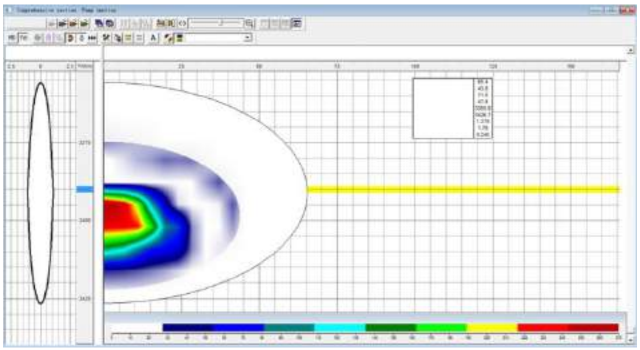

Fig. 7 *fracture profileof CH 5x well*

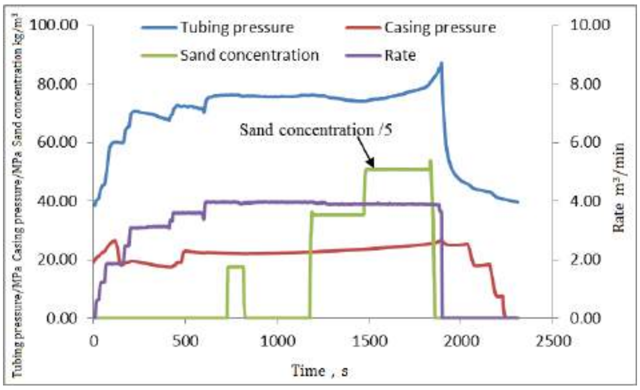

Fig. 8 *Fracturing curveof CH 5x well*

2. PREVENTIVE MEASURES FOR SAND SCREENOUT

Preventive measures for sand screenout are proposed according to the above analysis for sand screenout causes and the geological characteristics of the reservoir.

2.1 Fracturing design

For the layer with high shale content and strong plasticity, properly increase the pump rate and the proportion of the pad fluid, and use the combination of 30-50 mesh and 20-40 mesh proppant to reduce the fracture width requirement of the proppant. It can avoid the risk of sand screenout caused by insufficient fracture width in the strong plasticity of the formation, and improve the success rate of fracturing while improving the fracture conductivity.

In the case of multiple fractures, the fracture width is narrowed, and the high sand concentration of slurry fluid is difficult to enter the formation, which can increase the time of the low sand concentration stage and reduce the high sand concentration stage; Supporting multi-stage slug technology of proppant, fully grind fractures and perforations to reduce the friction of the near-wellbore area.

Optimize the perforation intervals, reduce the number of perforation, and adopt concentrated perforation to avoid the occurrence of complex fractures.

Optimize the design parameters according to the condition of the upper and lower interlayers. When the interlayer is thicker, the pump rate can be appropriately increased. When the interlayer is thinner, the artificial interlayer, variable pumping rate and optimized fracturing scale can be adopted.

For the wells, close to faults, in order to improve the fracturing scale of complex fault block reservoir, the detection fault fracturing technology is adopted. In the design process, the pad fluid volume should be appropriately increased. During fracturing, the pressure should be observed when the fractures connect with the fault, and the fracturing parameters should be adjusted according to the change of the pressure.

2.2 Real-time fracturing analysis

Real-time analysis of the fracturing curve, and make adjustments in time for the abnormal changes of the pressure. In the process of increasing the sand concentration, the slurry fluid should be sampled and debugged in time, and the pressure should be kept in mind. If the pressure rises faster, stop to increase the sand concentration. If the pressure is relatively stable or decline slowly, continue to increase the sand concentration.

2.3 Quality control

Strengthen the supervision of on-site fluid quality, ensure that the viscosity, pH value and cross-linking performance of the fracturing fluid meet the requirements. At the same time, it is required to add the gel breaker according to the design to prevent the addition of the gel breaker, and the fracturing fluid breaks ahead of time.

3. APPLICATION EFFECT

At the beginning of 2017, the improved technical measures were adopted in the 13-layer of 7 wells in Fushan Oilfield. Only one layer was occurred sand screenout. The fracturing success rate was 92.3%. According to the geological characteristics of these 7 wells, the corresponding prevention technical measures were adopted to reduce the occurrence of sand screenout, effectively improve the success rate of fracturing, and providing effective development for Fushan Oilfield.

Taking the well fracturing as an example, the well has the following difficulties: 1) the shale content of the pay layer is very high, the natural gamma is 100~135API, and the shale content is 20%. ~55%, resulting in the fracture difficulty in extending and narrow fracture width; 2) L 38AX is a deviated well, the maximum angle of inclination is 27.25°, which is easy to form multi-fracture; 3) the fracture layer is closer to the fault, the distance with the fault is about 100m. There is a risk that the fracture will extend to the fault during fracturing; 4) The fracturing layer is 3192-3202m, the thickness of the fracturing layer is thin, the stress difference between the fracturing layer and the upper and lower interlayers is small, and the fracture height is easy to get out of control.

In view of the difficulties, the technical countermeasures adopted are as follows: 1) increase the proportion of the pad fluid to 50%, add 30-50 mesh proppant to the slug, and add 20-40 mesh with slurry fluid; 2) three slugs are used in the pad fluid stage to fully grind fractures and perforations, reduce perforation friction and fracture near wellbore friction; 3) using detecting fault fracturing technology; 4) using variable rate technology to control fracture height. The rate of the pad fluid stage is $3.5m^3$/min, and the rate of the slurry stage is $4m^3$/min.

Through the implementation of the above targeted technical measures, the fracturing was successfully completed, the maximum proppant concentration reached $480kg/m^3$.

4. CONCLUSIONS

The shale content of the reservoir is high with strong plasticity. Deviated well and multi-perforated sections near wellbore area easily form multiple fractures, the wellbore is close to the fault and the fluid leak-off changes largely, and the stress difference between the payzone and the upper and lower interlayers is small which result in the fracture height out of control. These are the main reasons for the sand screenout of complex fault block oil and gas reservoirs in Fushan Oilfield.

For the reasons of sand screenout, combined with the characteristics of complex fault block reservoirs, 30-50 mesh and 20-40 mesh proppant are added together, Multi-stage slug reduces the influence of multi-fracture and optimizes perforation, controlling fracture height and detecting fault distance technology are used in the fracturing process. Technical measures can improve the success rate of fracturing while effectively preventing sand screenout.

Strengthening oil and gas well testing and well testing interpretation and comparison analysis and research of well testing before and after fracturing can further improve technical measures to prevent sand screenout during fracturing construction.

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