Chemical Fixed Point Sealing Technology in Oil Well

Lili Zhang* Haijun Yan Huijun Hao Gang Xie Aijun Wei Lili Wei Lei Sun Hongfeng Wang

1Engineering Technology Research Institute of Huabei Oilfield Company, Renqiu, Hebei 062552, China
2CNPC Engineering Technology R & D Company Limited, Beijing 102200, China
3International Engineering Company, Bohai Drilling and Exploration Engineering Company, Ltd., Tianjin 300280, China.
4Oil and Gas Test Company, Bohai Drilling and Exploration Engineering Company, Ltd., Tianjin 300280, China.
*Corresponding author’s e-mail: cyy_zhangll@petrochina.com.cn

Abstract. When most oil fields have entered high water cut stage, the distribution of oil and water is more and more complex. Profile control and water shutoff is an important technology for water control and oil stabilization. Some types of water invasion in special reservoirs such as bottom water coning or edge water propelling in horizontal wells, water invasion in micro fracture and big pore carry more challenges for profile control and water shutoff technology. Beyond that this technology is also affected by the plugging agent injection’s uncertainty and migration randomness. On the basis of earlier research, this paper introduces the plugging agent formulas, technology and field application of three types of technologies which are as follows, casing channeling treatment technology, water invasion plugging technology in interlayer and water invasion in horizontal well. The three types of fixed point sealing technology can achieve the accurate injection of shutoff agent and good results had obtained in site test.

1. Introduction
Profile control and water shutoff is an important technology on water control and oil stabilization that has been commonly used in many oil fields. The water and oil relation becomes more and more complex in high water cut oil field. Water invasion in special reservoir such as bottom water coning or edge water injection in horizontal, water invasion in interlayer of thick oil layer, water invasion in fracture and big pore which have brought challenges for water control and water shutoff technology.

Water and oil wells have been operated repeatedly for profile control and water shutoff under the conditions that the reservoir is undetected and residual oil is unpredicted. The injection uncertainty and randomness of migration of plugging agent both restrain the effect of profile control and water shutoff. Fixed point sealing technology is on the initial stage. Mechanical water plugging technique has complicated process and is limited by the type of well. The chemical sealing in annulus is proposed by Du Yong and Zhou Zhaochuan, etc, it won’t work without the packer. Despite of the bigger agent injection radius, the commonly used general injection technique tend to contaminate the oil reservoir. Such kind of plugging agent as oil well cement is easier to cause accident. People in our country have studied the factor of plugging agent’s placement on profile control and water shutoff.
Zhao Xiutai simulates the process of profile control and water shutoff in big pore reservoir using visual areal sand-packed model. But there are not many reports about field application. In this paper, three types of fixed point sealing technology are studied, the result shows that they can achieve the accurate injection of shutoff agent and obtain good results in site test.

2. Cyclic plugging to channel outside casing
Factors that leading to water channeling outside casing are numerous. Pressure rises too rapidly in the process of injecting cement plugging agent to work continuously because of its property. The key techniques in this system include synthesis, modification, matching of material, chemical reaction rate control and execution program. The applied temperature scope is from 40°C to 120°C. Through running in retrievable bridge plug inserted with a tube and perforation etc, the plugging agent cyclic channel is formed. The agent can be placed at desired position to plug water.

2.1. Thermosetting resin
Thermosetting resin is mainly composed of phenol formaldehyde resin and epoxy-modified phenolic resin. To ensure the controllability of reaction rate and curing strength, unsaturated resin, curing agent etc are added in different proportion according to reservoirs temperature. Before the injection to formation the agent is viscous liquid, and it will be solidified finally with hardly any permeability. The thermosetting resin has good chemical stability, mechanical property and high curing strength, it overcomes the disadvantages of curing shrinkage of cement slurry.

Viscosity: 50-300mPas, reaction time: 3~8h, tensile strength ≥15MPa, compressive strength ≥25MPa, shear strength ≥12MPa, the dissolved rates in the acid, alkali and salt are ≤0.5%, ≤0.45%, ≤0.3% respectively.

Figure 1. Sample

2.2. Application example
Yong 11 well is one development well of FU Shan oilfield in Hainan. 167A layer of Yong 11 well was perforated in June 10th 2015, by June 15th the total liquid yield is 76.1m³, oil is 54.45m³, from 16th to 18th the water yield is 10~20m³, no oil is extracted. There is water layer above and below 167A layer because of the unqualified cement quality. Water is channeled to the wellbore through perforation of 167A layer with the rising production pressure difference. To recover the capacity of 167A layer, cyclic plugging to channel outside casing technology is used.

Focusing on water channeling below 167A layer, layer 2155~2155.5m is perforated. Running in retrievable bridge plug inserted with a tube, the plugging agent is injected to water channel with cyclic plugging techniques. Focusing on water channel above 167A layer, the 167A layer is protected by sand, layer 2125~2155.3m is perforated, the plugging agent is injected to the above water channel (perforation is avoided of casing coupling). After completion, swabbing drainage from November 19th to 26th, the daily oil production is from 4.5m³ to 18.95m³, the daily water production is from 12.89m³ to 0.76m³.
3. Selective water shutoff in thick oil formation

Most oil fields have entered the high water cut stage, the heterogeneity of formation is stronger. The conventional water plugging and injection profile modification technology is not incompetent now, especially for those complicated water-yielding in thick oil formation. The commonly used plugging agent can shut-off the water and oil layer at the same time. The selective plugging agent of emulsified thickened oil proposed by Gao yujun has low strength. The oil-soluble material the main agent is processed into water-based emulsion at certain condition. Accumulation and adhesion of the main agents and other assistant agents will happen after being injected into formation which forming plug to water layer. Because of the oil solubility of main agent it can form temporary plug to oil layer and the plug will be eliminated soon. Fix-position plugging will be achieved at a lower speed of injection rate and pressure at which the plugging agent can be entered to water layer selectively.

3.1. Property of plugging agents

The plugging agents brown emulsion has good compatibility with water before injection to the formation and the oil solution ratio is 86.3%. Core flow experiment shows that plugging rate is over 93% and breakthrough pressure increases by about 10 times.

3.2. Application example

The main target layer of development is Chang2, Chang213 which belongs to lithologic-structural reservoir. The buried depth is 1100~1300m, average effective porosity is 18.2%, air permeability is 33.8mD, and the sedimentary type is distributary channel on delta plain. Nature fracture and high permeability channel cause the rising of water cut. Based on the analysis of reservoir characteristic, selective plugging agent is used in layer. This technology has been applied in 8 wells, as Dong 76-18, Dong 78-19 etc successively.

4. Fix-point plugging with modified cyanogen coagulation

Bottom water coning or edge water propelling in horizontal wells usually cause water flooding in partial or whole. The technique of water plugging in horizontal well is in the early stage. Drawing lessons from dam cracks and waterproof, fix-point plugging with modified cyanogen coagulation is proposed. It had been applied in 3 wells, among them the L horizontal with screen pipe completion used this technology for the first time.
4.1. Formula system
Cyanogen coagulation (contain –NCO performed polymer ) is a chemical grouting material with polyurethane and it has bad inter solubility with water and oil. Isocyanate group can react intensely with water and polyurethane is produced in addition polymerization. The reaction equation is described as follows.
To realize the reaction rate controllability and inject ability, cyanogen coagulation is modified. On the basis of theory of compact packing of particle size distribution, hollow glass bead is doped in cyanogens coagulation. The hollow glass bead has low density (0.4~0.6g/ml), high strength (12~25MPa) and can disperse uniformly in slurry surface.
Point contact replacing surface contact makes the bubble volume and reaction rate controllable and the uniform solidification is formed finally.

| Temperatures  ℃ | Solvent          | Assistant                | Dosage %  | Glass bead % | Initial setting time (h) | Curing time (h) | Expansion multiple |
|-----------------|------------------|--------------------------|-----------|--------------|--------------------------|----------------|------------------|
| 25-50           | Organic ester/ketone | Amine/dibutyltin Dilaurate | 0.05-0.3  | 0.05-0.5     | ≥2                       | 18~24          | 2                |
| 50-70           | ———              | ———                     | ———       | ———         | ≥2                       | 12~18          | 2~3              |
| 70-90           | Benzoyl chloride | 0.1-0.4                 |           |              | 1~2                      | 9~13           | 3                |

4.2. Bearing capacity of plugging agent
Test result shows that compressive strength is ≥12MPa. The agent is integrity after being compressed. Pressure test shows that cyanogen coagulation can also react in high pressure.

4.3. Bridging doped with fiber and process pipe with single-flow piston
Ultra fine fiber with rough surface and plasticity is injected into fracture and pore throat. They occupy the space and absorb water to saturation (the density it up to 0.9g/cm³), then the network structure is formed. The network structure is combined with the following slurry. Fluidity test shows that the viscous force increases significantly with the addition of 0.2~0.5% ultra fine fiber. Plugging pipe string is composed of several single-flow pistons, oil sealed isolating liquid, plugging agent slurry, cleaning liquid and substitution fluid. The piston is controlled by the wellhead pressure then the plugging agent can be injected to the right place in isolated space. After the injection, the oil pipe will be lift up and the well is closed for plugging agent’s consolidation, at last the plugging effect is by tested by well flushing circulation.
4.4. Field test

F71H4 well is one L type horizontal well of Jinchen slope at Fanzhuang block in south of Qin Shui basin, Shan Xi. The daily water production is up to 90m$^3$ and no combustible gas is shown. The analysis shows that there is large fracture in the depth of 1709m which communicating the channel of roof and floor water of limestone cave and with no clear information of karst development. Coal-bed methane well has such characteristics of low temperature, lost circulation, collapse and strong sensitivity. Well completion and production were carried on when drilling on large fracture, the fracture of toe is not only the water invasion point but also the objective plugging layer. The adaptability of plugging agent must be considered to make sure it will not contaminate the oil layer. The depth of artificial well bottom is detected after the operation. At the same time circulation at 0.2m$^3$/min should be formed, the plugging agent should be located within 50m of toe. The daily gas production is 1100m$^3$ after recovery and the daily production of water is 20~30m$^3$.

Fixed -point sealing technology with modified cyanogen coagulation has been used in L horizontal well with screen pipe completion for the first time.

5. Conclusion

Cyclic plugging to channel outside casing, selective water shutoff in thick oil formation and fix-point plugging with modified cyanogen coagulation can achieve the accurate injection of shutoff agent and also have good results in site test.

References

[1] WEI Falin, et al. Developing trend and current situation of water plugging technology for slotted pipe horizontal wells[J].Oil Drilling & Production Technology, 2007, 29(1):40-43
[2] GE Honggiang, GOU Jingfeng, LEI Qiling, et al. Chemicals for water shutoff in horizontal wells[J].Oilfield Chemistry, 2009,26(4):387-390.
[3] DU Yong, Research and application of ACP positioning water control technology in edge-bottom water reservoir horizontal well [J].Drilling & Production Technology, 2015,38(5):44-46.
[4] ZHOU Zhaochuan, CHEN Liqin, GAO Shang, et al. Application of annulus chemical plugging for horizontal well with CESP screen pipe in Bohai Oilfield [J]. Fault-Block Oil & Gas Field, 2013, 20(3):400-402.
[5] ZHAO Xiutai, FU Minjie, BAI Baojun, et al. Visualized simulation of fine profile control and water plugging in reservoirs with secondary porous channels[J]. Oil Drilling & Production Technology, 2013, 35 (5) : 84-87.
[6] GAO Yujun, MA Chunbao, BAI Baojun, et al. Selective water plugging in production wells by viscous crude oil admixed with emulsifier[J]. Oilfield Chemistry, 1997,14 (3) : 224-229.
[7] High Polymer Teaching and Research Department of Chemical Engineering, Tianjin University. Development and application of urethane precondensate grouting[J]. Chemistry, 1978(3):11-13.

[8] LIU Shangping, HAO Jian, Zhang Shunjun, et al. Modified urethane precondensates OPPT and WTPT as gelling materials for water shutoff/profile modification agents [J]. Oilfield Chemistry, 1999, 16(4): 314-317.

[9] LIU Xuepeng, ZHANG Pingchang, FENG Minghui, Research and application of composite hollow microbead low density cement slurry ,Oil Drilling & Production Technology, 2014, 36(6): 39-41.

[10] BAO Guiquan, Study on Some Focal Technical Problems of Drilling Engineering for Coal Bed Methane [J].Exploration Engineering, 2007, 12: 4-8.