Lost Circulation Mechanical Model and It’s Application in Permian Igneous Rocks in Shunbei Oilfield

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Abstract. The Shunbei Oilfield is a major discovery of Sinopec in the ultra-deep marine carbonate rock field, and it will become the main battlefield for Sinopec to increase reserves and production. At present, the exploration and development of the Shunbei Oilfield is mainly concentrated on the No. 1 and No. 5 fault zones in the Shunbei area. Due to the complex geological structure, there are a series of drilling technical problems in drilling. Lost circulation will not only lose drilling fluid, produce non-productive time and affect drilling safety, but also limit drilling speed, which is one of the most headaches and difficult problems in drilling. To this end, scholars at home and abroad have carried out a lot of research and exploration, and developed a series of leak-proof and plug-in devices such as non-penetrant, elastic graphite, Form-A-block, fiber cement, water-absorbing resin, thermosetting resin, gel and chemical consolidation. Materials, and formed a variety of supporting process technologies. Granular, fibrous, and sheet composite bridging materials are most commonly used on the site, but ordinary bridging materials are resistant to temperature differences, easily carbonized at high temperatures, and the width of underground cracks needs to be clear when plugging, non-penetrants prevent Lost circulation of microfracture formations. It has poor leak-proof effect on large cracks, because of its low strength, expansion materials such as water-absorbent resin are better for plugging, but the pressure-bearing effect is poor, foreign Form-A-block and Chinese DTR are equivalent High water loss materials have good adaptability to cracks, but the pressure is generally low, fiber plugging methods such as fiber cement and thermosetting resin are complicated in process, high in risk and high in cost, gel plugging technology has good adaptability to plugging, but withstands temperature differences If it is not combined with other materials, it is easy to leak again in the later period due to the decrease in gel strength, chemical consolidation plugging technology has a high success rate in plugging, but the plugging construction time is relatively long. In summary, although great progress has been made in leak prevention and plugging technology at home and abroad, there is less research on igneous rocks, and it cannot meet the needs for leak prevention and plugging in igneous rock formations. Therefore, it is necessary to analyze the second Shunbei Oilfield in depth. Lost circulation characteristics of igneous rocks in the Mesozoic and the difficult points of preventing Lost circulation and plugging. Develop effective materials for preventing and plugging Lost circulation to improve the effect of preventing and plugging.

Keywords: Lost Circulation Mechanical Model; Plugging; Igneous Rock.
1. Introduction
The Shunbei Oilfield consists of four blocks: Shunbei, Shunxi, Adong and Shuntuo. The Shunbei block is also known as Shunbei 1 block. Currently, most of the wells in the Shunbei Oilfield are deployed on the No. 1 fault zone and No. 5 fault zone in the Shunbei area. The geology of this block is very different. Loss and re-Lost circulation are frequent during drilling[1-3]. It is necessary to have a deep understanding of the characteristics of Lost circulation and the problems of preventing and plugging.

1.1. Formation Characteristics
The depth and thickness of the Permian formation in Shunbei Oilfield gradually increased from east to west. The top of Permian of Well Shunbei 1 in the east is about 4500m, with an average thickness of about 480m. The lithology is dominated by tuff and yinganite, and it is mixed with sand and mudstone. The Permian top of the Shunbei 5 well area in the west is about 4774 m, with an average thickness of about 565 m. The lithology is dominated by Dacite rock and mudstone, with tuff and sandstone mixed, and basalt is developed. Tuff is a volcanic clastic rock that often contains pores and joints. Dacite rock is a medium-acid eruption rock, and fractures are usually very developed.

1.2. Loss Distribution Law
Statistics on the Lost circulation during drilling and completion of 22 wells in Shunbei Area. Statistics show that the probability of loss during Permian drilling is 50%, and the average single well loss is 561.7 m³. From the perspective of the loss distribution, the loss in the north is lighter, the drilling loss probability is 25%, and the average drilling loss is 10.7 m³, the southern loss is heavier, the drilling loss probability is 80%, and the average drilling loss is 503.5 m³. The probability of loss of the fault zone is 42.9%, and the probability of loss of the Shunbei 5 fault zone in the west is 60%. However, because several wells in the fault zone 1 are particularly serious, the average loss of a single well is greater than that in the fault zone 5. From the perspective of lithology, the Lost circulation points are mostly in Dacite formations, especially near the interface between Dacite and tuff. From the perspective of the missed phase, 11 were lost during drilling, 15 were lost during the completion of drilling, and wells that were lost during drilling were basically lost during the completion of drilling.

1.3. Leak Prevention and Pplugging Difficulties
The Shunbei block uses technologies such as bamboo fiber, shielding temporary plugging agent, bridging, cement, gel, chemical consolidation, and plugging slurry drilling. However, there are still large differences in the effects of leak prevention, low rates of plugging success and Problems such as easy to leak, and the complex time of a single well can reach more than 10 days.
1) The development of multi-scale cracks makes it difficult to choose the particle size of leak-proof and plugging materials. The shape and size of fractures can be identified through coring observation and imaging logging[4-6]. In addition, the size of fractures can be inferred based on the particle size of the plugging material on site.
2) The existing technology has poor adaptability to the formation, and it is easy to recover after plugging. Shunbei block is generally used for plugging Lost circulation, but it is easy to leak during later drilling. According to statistics, more than 80% of the wells have re-Lost circulation, and the average number of re-Lost circulations in a single well is about 3 times, which has seriously affected drilling safety and efficiency.
3) The security density window is narrow, and Lost circulation prevention and collapse prevention are contradictory. In recent years, Chinese scholars have conducted in-depth research on the mechanism of leaks, and have proposed leak pressure models for differential and fracturing leaks[7,8]. According to the actual drilling fluid density and Lost circulation rate in the field, the Lost circulation pressure in the field was inverted, and the equivalent pressure density of most wells was 1.25 ~ 1.28 g/cm³. According to the highest on-site pressure values of wells such as SHB1-1H and SHB3, the equivalent density of fracture propagation pressure is calculated to be 1.33 ~ 1.35 g/cm³. However, the Triassic mudstone has a high collapse pressure in this well, and the actual drilling density is mostly 1.24 to 1.25 g/cm³. The maximum diameter expansion rate can reach more than 100%. Some wells also cause stuck stuck
accidents due to block loss. According to the actual drilling conditions, the collapse pressure equivalent density of the Triassic mudstone is about 1.22 to 1.24 g/cm³. The higher collapse pressure and lower Lost circulation pressure result in a very narrow safety density window for the well, limiting the space for further reducing the density and preventing Lost circulation, which makes it difficult to prevent Lost circulation and increases the risk of plugging operations.

2. Prevent-Lost Circulation Technology
Because the Permian igneous rock developed with lots of fissure, fracture propagation easily, and strong heterogeneity. Leak prevention and plugging should adhere to the principle of “prevention-oriented, combination of prevention and blocking, and co-administration with leak prevention”, and cooperate with the use of technologies such as “reasonable density, plugging while drilling, classified plugging, closed slurry, system optimization and engineering measures” Measures as a guarantee.

2.1. Prevent-Lost Technology
Due to the strong heterogeneity of the formation, and the fracture development degree and fracture width of the formations in different wells and depths are not the same, it is difficult to accurately predict the size of the fractures and the type of Lost circulation before drilling.

2.2. Plugging Technology
Plugging generally requires clear location of the leaked layer, the nature of the layer, and the size of the leaking channel, so as to select the leaking technology. The location and properties of the Permian well Lost circulation are often easy to judge, but the current research on the size of igneous Lost circulation channels is not enough, and the fracture width is often difficult to judge accurately. In order to allow the plugging material to enter the Lost circulation zone for a certain distance, pressure can be appropriately applied, but the pressure value should not exceed the crack propagation pressure, and the pressure capacity can meet the subsequent drilling density. In order to improve the plugging effect and prevent frequent Lost circulation after bridge slurry plugging, high temperature resistant composite deformation materials can be used for plugging. If the pressure capacity of the Permian formation needs to be greatly improved or serious Lost circulation occurs, chemical consolidation and plugging technology can be used to completely cement the fractures to improve the pressure capacity of the formation. In order to prevent repeated Lost circulation, it is necessary that the plugging material has good adaptability to the crack, can enter the crack for a certain distance, and forms a sealing plugging layer. A large number of experimental studies have been carried out indoors, and a high-efficiency pressure-resisting plugging agent SMKZD-1 capable of causing plugging and preventing crack propagation has been developed. The plugging agent consists of high-temperature-resistant, high-strength rigid particles, composite fibers, deformable materials, and nanometer plugging agents. High-strength rigid particles can prevent the leaking material from being crushed when the crack is closed, composite fiber materials can improve the blocking ability, elastic materials can increase the degree of self-adaptation to the cracks, and nanometer materials can reduce the permeability of the crack blocking layer and prevent pressure transfer. Evaluation of SMKZD-1 pair at 120 °C using high temperature leak tester indoors.

Experiments have shown that SMKZD-1 has a good plugging effect on cracks of 1 to 3 mm, the pressure of the plugging layer is greater than 5 MPa, and the plugging material can enter the deep part of the crack, effectively preventing re-Lost circulation caused by cracks and door closure. SMKZD-1, a high-efficiency pressure-blocking plugging agent, was tested on site in Shunbei 4 and Xiahe 1 wells. The plugging was successful at one time, and no re-Lost circulation occurred during later drilling and casing. The plugging mud drilling technology has been applied on-site in multiple wells, such as SHB1-2H, to ensure effective drilling through the Permian formations.

3. Field Application
Well Shunbei A is a super-deep pre-drilling well with a depth of 8 593 m deployed by the Sinopec in the Shunbei block. The well is drilled into a large-diameter φ444.5 mm borehole. The thickness of the
Permian formation is 531 m (4,762 to 5,293 m). According to the Lost circulation situation in the Shunbei block, the Permian igneous rock cracks have developed, and there is a greater risk of Lost circulation. Due to the narrow safety density window of drilling fluids in the Permian formations, too low an increase in the risk of well wall instability, and too high an increase in the risk of Lost circulation. In order to meet the needs of both Lost circulation prevention and collapse prevention, the drilling fluid density of Well A was selected from 1.24 to 1.25 g/cm³. In order to ensure the well wall stability at this density, the nano-blocking agent SMNF-1 and the temperature-sensitive deformation blocking agent SMNA-1 are preferred. At the same time, by adding 1% to 2% of the new polyamine inhibitor SMXJA-1 and 3% to 5% KCl to improve drilling fluid inhibition.

No Lost circulation occurred during the drilling and casing of the 488.65 m igneous rock, and the amount of Lost circulation in the cementing was also low, which ensured the safe and efficient drilling of the large-diameter well and the cementing of the well. The adjacent well Shunbei B used conventional Lost circulation prevention and bridging plugging technology to stop the leak. Three well Lost circulations occurred during the middle of casing completion, and two of them were repeated, and serious Lost circulation occurred during cementing.

4. Conclusions and Suggestions
1. The Permian igneous rock in Shunbei has the characteristics of strong heterogeneity, fracture development and easy propagation of fractures, and this understanding has important guiding significance for Lost circulation prevention and plugging in Shunbei Oilfield.
2. The Lost circulation of Shunbei Oilfield has a certain distribution law. The Lost circulation in the northern region is lighter and the Lost circulation in the southern region is more serious. This law is of reference value for the formulation of a new well leak prevention and plugging plan.
3. There are mainly two types of Lost circulation mechanisms in the Permian, namely differential pressure Lost circulation and fracture expansion Lost circulation. By introducing the new SMGF-1, a new leak-proof and plugging material, it is expected to effectively reduce the Permian drilling fluid Lost circulation problem and improve Leak-proof effect.

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