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Review

Research Progress on Pressure Sealing Materials for Fractured Gas Reservoirs

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Abstract: To study a kind of plugging material suitable for gas invasion in gas reservoirs fractured pressure plugging material. Gas invasion in carbonate gas reservoirs is frequent and will be accompanied by lost circulation and overflow, which will affect the safety and efficient production of oil and gas wells, and even cause serious safety hazards. In this regard, this paper summarizes the research process and problems encountered in the application of reverse pressure plugging materials in Carbonate rock fractured gas reservoirs. At the same time, it introduces the types of main plugging materials in the world and the research progress of plugging materials (polymer gel plugging technology, ultra-low permeability (non permeability) drilling fluid technology, etc.), the theory of plugging materials (rigid plugging theory, flexible plugging theory, etc.), as well as the characteristics of typical plugging materials and plugging material technology.

Keywords: plugging materials, type of plugging material, technical characteristics of plugging materials

1. Introduction

At present, researchers in China are generally committed to developing new sealing materials to meet the complex pressure sealing needs of different construction and industrial fields. Various types of sealing materials can adapt to complex mining environments, and these developments have made modern high-pressure sealing materials more efficient, reliable, and safe. At present, the country attaches great importance to the development of energy, while driving the development of sealing materials. In the future, with the continuous progress of science and technology, it is expected that more innovative plugging materials and technologies will emerge to meet the constantly changing plugging needs. And in order to ensure the performance and safety of high-pressure sealing materials. Researchers have developed various methods and equipment to evaluate the physical properties, pressure

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resistance, and corrosion resistance of sealing materials, while monitoring the effectiveness of sealing materials, resulting in generally good quality and adaptability of sealing materials.

Overall, China has made significant progress in the field of sealing materials in the general direction. Currently, various types of sealing material theories in China are flourishing, and these theoretical types are technically related to each other, jointly forming the basic knowledge in the field of leakage prevention and sealing. Through theoretical research and application, leakage problems can be effectively prevented and addressed, ensuring the safety of equipment, structures, and the environment. The research on plugging materials is developing towards diversification, efficiency, and environmental friendliness. With the continuous progress of technology and the growth of demand, it is expected that the research on plugging materials will continue to make new breakthroughs and progress.

For the delayed expansion plugging materials, high temperature and high salt plugging materials and Carbonate rock gas reservoir plugging materials commonly used in China, literature shows that gas invasion often occurs during drilling, and plugging materials with different functions are required under different mining environments. At present, the main materials used for plugging include fibers, chips, silicon, etc. The different proportions of the same material can lead to different application effects. It is crucial to choose a plugging material that can meet both the backpressure requirements and good plugging effect. Therefore, on the premise of ensuring the performance of cement slurry, starting from the mechanism of material action and focusing on the stability of the material, a new type of backpressure leak stopping material was finally developed and its performance was evaluated.

2. Data review

2.1 Theoretical types of leakage prevention and blocking

(1) Rigid plugging theory: The rigid plugging theory refers to the use of rigid plugging materials of fixed shape and size (particle size) to bridge and fill lost wells. Effectively plug the leakage.

(2) Flexible sealing theory: The flexible wind theory refers to the use of flexible sealing materials of non fixed shape and size (particle size). Using soft plugging materials mixed with drilling fluid, under the action of pressure, temperature, and other factors, combined with its own soft characteristics, effectively plugging leakage.

(3) Polymer gel plugging technology: the particles in the gel solution and the polymer are linked by multiple Chemical bond under certain conversion conditions to form an elastomer with a spatial network structure.

(4) Ultra low permeability (non permeability) drilling fluid technology: Ultra low permeability drilling fluid technology utilizes surface chemistry principles to form an ultra-low permeability membrane on the surface of rocks, which forms micelles at rock crevices and natural fractures. The micelles act as a barrier to restrict permeability and lock in sealing materials at the loss zone. This technology is better at sealing the loss zone.

(5) Micro foam drilling fluid technology: micro foam drilling fluid can form micro foam network structure, which can form honeycomb foam gel in the leakage layer, and act as bridging particles and filling particles in the drilling fluid for plugging.

2.2 Classification of plugging materials

(1) High filtration plugging material:This material consists of fiber materials, permeable materials, porous inert materials, diatomaceous earth, filter aids, etc. Under the action of pressure difference, rapid loss occurs, solid phase accumulates and thickens, forming filter cakes., Subsequently, the leakage channel is compacted and blocked, forming a high permeability microporous structure blockage, which is suitable for handling leakage, local leakage, and small leakage.

(2) Bridging and plugging materials: Bridging and plugging materials refer to single inert materials and composite materials graded from a single inert material. They have the advantages of simple operation and production. The main function is to reduce partial leakage and return leakage caused by pores and cracks,

(3) Flexible elastic plugging material: Flexible elastic materials have good elasticity, certain deformability, toughness, and chemical stability (can be deformed arbitrarily, have strong tensile toughness, and high strength). Usually composed of graphite. It can adaptively seal pores or cracks of different shapes and sizes under the dual effects of expansion filling and internal compaction.

(4) Polymer gel plugging material: polymer gel plugging material can prevent pressure transmission and fracture induced propagation; It has strong resistance to viscosity and shear dilution; Good binding effect with inert bridging agents; At the same time, the solid content is low, not limited by the leakage channel, and enters pores or cracks through compression deformation; The crosslinked gel shows good viscoelasticity, softness and toughness after formation.

(5) Cement slurry plugging materials: Cement slurry plugging materials include a mixture of cement, gypsum, lime, and other slurries, with the main material being cement. By improving the process, the plugging effect is improved. This plugging material has strong pressure bearing capacity and significant effects on severe loss layers. The disadvantage is that it is easily diluted and washed away by water.

2.3 Current status of research on plugging materials

At present, the research on new sealing materials in China is steadily advancing, but it is still not mature enough. Many new sealing materials are still in research and development, and have not yet been put into production and use.

There are two types of conventional plugging materials, PC-B66S and C-B72S. Although both materials have certain plugging effects, they are not ideal. Through indoor evaluation, the main conventional materials currently used are for conventional permeable leakage layers, which have good plugging effects, but for fractured leakage layers, the plugging effect is not ideal. Therefore, a new elastic plugging material PCB62S was

synthesized using conventional materials in the conventional leakage laboratory, and its plugging effect in the cement slurry system was systematically evaluated. However, the plugging material has poor oil resistance, high temperature resistance, and back pressure resistance, and cannot resist high pressure. Another type of blockage material, walnut shell, forms an oil and gas blockage layer. When it is in drilling fluid, the blockage efficiency is high and the pressure is strong. However, under oil-based conditions, it exhibits an oil repellent state and is insoluble in oil-based drilling fluids, unable to form an effective blockage layer. In fractured gas reservoirs, strong heterogeneity and complex gas invasion result in poor sealing performance of drilling fluid, and the back pressure bearing capacity for solidification and blockage is still insufficient. The existing sealing materials cannot meet the reverse pressure sealing needs of special fractured gas reservoirs. Nowadays, the reverse well pressure plugging is generally solved by adjusting the particle size of plugging materials in the world, and Thixotropy cement slurry or long fiber materials are usually used for plugging. However, due to the differences in lithology, rock types, and leakage types in different areas, the use of plugging techniques and materials has also changed. However, temporarily changing the sealing material based on different issues is clearly not a good method. Therefore, it is necessary to develop a new type of backpressure sealing material for fractured gas reservoirs.

2.4 Development of Modern Pressure Sealing Materials

Among numerous leak sealing technologies, the most common and effective method in China is to use various sealing materials for bridge sealing. However, commonly used bridge plug plugging agents still have certain defects, and there are often two situations when dealing with lost circulation: firstly, the plugging agent does not penetrate into the lost circulation layer, but accumulates a large amount on the surface of the lost circulation layer. Under the erosion of drilling fluid and the scraping effect of drilling tools, secondary or multiple leaks are prone to occur; The second issue is that although the sealing material has entered the leakage layer, the formed sealing layer is not dense enough, and the leakage pressure of the leakage layer cannot be effectively increased, resulting in continuous leakage. In order to improve the pressure bearing capacity of the formation and achieve the purpose of sealing the lost circulation layer, research on pressure bearing sealing technology has begun.

In response to the problem of high leakage in oil and gas wells, Zhao Kai and others have developed a new type of high-pressure microchip. In the case of high leakage in oil and gas wells, fiber sealing materials are insufficient to effectively block the leakage. However, the use of sheets can easily cause blockage in the sealing layer. The special process is used to produce flake grey insulator with inorganic multidimensional molecular structure, which makes the microchip structure very stable. Therefore, such wells with large leakage of oil and gas wells should give priority to the use of new high-voltage microchips. In the process of sealing formation loss, its sheet-like structure can play a role in grafting and cutting, effectively sealing and reducing fracture loss and permeability loss. This product can be used

together with blocked fibers to form a unique network structure. On this basis, a new type of pressure sealing agent was developed: pressure sealing agent C-L73S. This new type of pressure sealing agent is suitable for fractures, pores, and pressure effects, and has good application performance: effective sealing of fractures, microcracks, pressure loss formations, and high porosity and permeability formations; It is inert and non-toxic in weak acidic and alkaline environments; Therefore, C-L73S can be used as a reference for the research and development of reverse sealing materials for fractured Carbonate rock gas reservoirs.

At present, cement-based intelligent sealing materials have been developed, mainly composed of cement-based coatings, shape memory alloys, fillers, etc. After the cement-based intelligent sealing material enters the lost circulation formation, it is affected by temperature changes and will form a temperature sensitive response. At this point, the SMAS inside the material will be subjected to strain forces, causing the shell to crack and detach until it is completely deformed and restored to its original state. Then multiple linear SMAS overlap, forming a bridge that blocks the internal natural alkali, causing the blocking working fluid to quickly solidify and accelerating the sealing process. Simply put, its working principle is the spherical temperature controlled intelligent sealing material (sensing) entering the channel and SMAS. After sensing and deforming the temperature changes at the leakage point in the formation, the outer layer (change) of the cement-based core-shell structure ruptures and separates. Subsequently, the alloy in a linear state will combine with the leakage hole wall and form a bridging effect, ultimately forming a network structure. The cement-based fragments separated from the outside of SMAS undergo self expansion and compression deformation after SMAS bridging, filling the pores of the network structure and transforming the leakage point from large gaps to small gaps. When large pores become small pores, the cement slurry solidifies under the action of a rapid curing agent, which can play a good bridging and sealing role, thus effectively sealing. A water absorbing expansion material for resin delayed expansion plugging agent has been developed, which ensures that there is no significant difference in the water absorbing expansion ability between the inside and outside of the material, reducing or slowing down the overall water absorbing expansion ability of the water absorbing expansion material, and avoiding the disadvantage of slow and rapid water absorption and expansion. After discovering that the plugging material required high temperature resistance and water absorption, a high-temperature resistant delayed water absorption expansion plugging agent was prepared, which was obtained by hydrophobic modification of the hydrophilic groups on the surface of the water absorption expansion resin. With changes in water temperature and time, water slowly enters the core of the plugging agent from the gap between the hydrophobic chains on the surface of the delayed expansion plugging agent, showing a trend of slow water absorption and expansion in the early stage and rapid water absorption and expansion in the later stage. Compared with existing delayed expansion plugging agents, this delayed expansion plugging agent has excellent delayed water absorption and expansion effect, preventing the plugging agent particles from expanding during the process of entering the loss layer. Under the influence of factors such as time or temperature entering the formation, the plugging agent particles quickly absorb

water and expand upon reaching the loss layer, thereby achieving good reverse sealing effect on the loss layer.

There has also been unprecedented development in foreign plugging materials, where a certain amount of particulate material can be mixed with crystalline polymers of different sizes to form a new type of material, which can immediately expand when encountering water, and can quickly seal very serious well leaks. When there is a huge leakage caused by drilling in a certain area, different particle materials, aggregates, and hydrates with different particle diameters should be transported underground to cause expansion and seal to solve the problem of well leakage. Among them, various types of water absorbing and expanding resins as well as expandable plugging materials. It has played a significant role in plugging oil wells.

Inorganic plugging agents are mainly composed of cement, which contains various specially made cements, mixed cement slurries, etc. Cement is a commonly used plugging material in drilling and leakage prevention. Its advantage is that after sealing the leakage layer, it has a high pressure bearing capacity. In recent years, a lot of work has been done in various cement additives and adjustment of usage methods, which has greatly improved the expandability of cement slurry, reduced setting time, and improved the initial strength and stability of cement.

As for the drilling fluid pressure sealing material for Carbonate rock fracture and high-temperature and high-pressure reservoir, Su Xiaoming's team has developed GZD, which has good temperature resistance, is a non-toxic and harmless green environmental protection product, and has good water absorption, flexibility and dispersion. And compared with traditional fiber materials, modified lignin fiber materials have higher acid solubility, which is beneficial for later acidification and blockage removal, as well as efficient development of oil fields.

Calcium carbonate, as a rigid sealing material, has been widely used in the petroleum industry and has good reservoir protection performance.

The high compression microcrystalline chip C-L72S has no adverse effect on the conventional slurry performance of cement slurry. And in oil and gas wells with severe leaks, sheet sealing materials have strong bridging ability and stronger sealing ability in the leakage layer. However, sheet sealing materials have a significant impact on the flow of cement slurry, and their effective content in the cement slurry system must be controlled during use. The high compression microcrystalline chip C-L72S can be combined with sealing fibers to form a unique network structure, effectively sealing and sealing losses.

Nano sealing agent: Adding a small amount of nano sealing agent to oil-based drilling fluid can greatly improve the compressive strength of the mud cake. Therefore, the use of nano sealants in drilling can effectively improve the formation's pressure bearing capacity, reduce pressure transmission, and improve the wellbore stability of shale.

GZD: Walnut shell has poor high temperature resistance and wear resistance, and cannot be used as a sealing material for high-temperature and high-pressure formations; Under the same conditions, rigid particle GZD hardly exhibits high-temperature carbonization and high-temperature wear, exhibiting excellent temperature resistance and high-temperature

wear resistance, which can meet the sealing requirements of abnormally high temperature reservoirs. When only a single particle size grade GZD particle is added, there is no negative correlation between the leakage amount and the cumulative leakage amount and the reagent dosage. Increasing the reagent dosage alone not only makes it difficult to achieve effective sealing, but also reduces the density of the sealing layer and increases leakage. However, the addition of B-grade and X-grade GZD particles significantly improved the pressure bearing capacity of the slurry system, significantly reduced leakage, and significantly increased the critical pressure compared to the original, reducing leakage by 97.5%. This indicates that GZD with different particle sizes has excellent synergistic effects, and through self recombination, a sealing layer with strong pressure bearing capacity and low leakage rate can be formed. After adding a small amount of material, the original leakage rate is significantly reduced and the pressure bearing capacity is improved. Based on the optimization experiment of lignin fiber dosage, the performance of the elastic filling material SQD-98 was further optimized. SQD-98 is an elastic deformable material that greatly improves the shear failure resistance of the entire sealing layer after addition. The final result is that as the number of elastic sealing material SQD-98 increases, its minimum oil leakage is also similar, and its pressure bearing capacity is also continuously improving.

This article reviews various types of plugging materials and popular leak prevention and plugging theories in recent years. The core of rigid plugging theory is bridging and filling plugging, which improves the plugging strength by improving the correlation between materials and leakage channels; The theoretical core of improving formation pressure bearing capacity is to adjust the ability of formation rocks to resist tensile failure, which is composed of three parts: "sealing tail", "stress cage", and "crack closure pressure". By using drilling fluid to increase formation fracture pressure, the drilling fluid can block the leakage at the crack entrance. The development of sealing theory is a complex process, starting from the relationship between filling particles and leakage channels, the balance between different particle sizes and leakage channels, and the use of mathematical methods to calculate and process the size of sealing agents. In the development process, theories from various fields are integrated to more efficiently seal the leakage formation. The situation of "leaking and then plugging" has been changed to "not leaking and preventing plugging in one". Through continuous research, the understanding of the various impacts of leakage problems has gradually deepened, so as to more efficiently solve the problem of plugging oil-based drilling fluid leakage.

In short, sealing materials play an important role and importance in various industries, which can improve safety, reduce losses, save costs, protect the environment, and improve production and work efficiency. Therefore, sealing materials play a crucial role in ensuring the reliability and durability of equipment and systems, as well as protecting the safety of personnel and the environment. Compiling a series of standardized plugging material systems is convenient for development operations, and developing high-performance plugging materials can accelerate the rapid development of the industry.

3 Summary and prospect of research on plugging materials

3.1 Research basis and methods for plugging materials

The influence of sealing materials on the conditions and types of drilling fluid loss zones determines their effectiveness, and the characteristics of well leakage determine the key performance parameter types of sealing materials. Determining the key sealing material performance parameters based on the characteristics of well leakage is the first step in selecting sealing materials.

The proposed quantitative scoring and optimization method for sealing materials is mainly applicable to physical bridging and sealing materials. The key performance parameters of sealing materials are as follows: quantity type, relative importance, and weight should be dynamically adjusted based on the leakage layer engineering, such as geological conditions and types of leakage causes.

3.2 Research prospects

At present, there has been a lot of research on pressure sealing materials, and there are also many materials to choose from, which are sufficient to handle many conventional blocks. However, there is still little research and development on reverse pressure sealing materials for fractured gas reservoirs. However, studying the mechanism of gas invasion in carbonate fractured reservoirs, developing efficient drilling plugging systems and supporting on-site construction plans, enhancing the reverse pressure bearing capacity of drilling fluid plugging agents while drilling, and achieving the goal of preventing gas invasion while drilling are of great practical significance for reducing gas invasion during drilling, improving oil recovery efficiency, and accelerating the overall oil and gas recovery speed.

Sealing material is a material used to repair and prevent liquid or gas leaks. With the continuous progress of technology, sealing materials are also constantly developing and improving. In the future, plugging materials may be expected in the following directions:

1. Efficient performance: In the future, sealing materials will pay more attention to efficient performance, which can achieve fast and reliable sealing effects in a shorter time. This may include developing new chemical components, improving the sealing and pressure resistance of materials, and improving repair techniques.

2. Environmental sustainability: In the future, sealing materials will increasingly focus on environmental protection and sustainability. For example, developing biodegradable plugging materials to reduce their impact on the environment. At the same time, it is also possible to explore the use of renewable or recycled materials to manufacture plugging materials, in order to reduce resource consumption and waste generation.

3. Intelligence and self-healing: Future sealing materials may have intelligence and self-healing functions. By integrating sensors and control systems, leakage can be monitored in real-time and proactively repaired. For example, nanotechnology can be used to develop materials with self-healing capabilities, enabling them to quickly identify, locate, and repair leaks.

4. Expansion of application fields: Future sealing materials are not only limited to industrial fields, but may also be extended to other fields. For example, there is also a demand for sealing materials in fields such as construction, transportation, and biomedicine. Therefore, future plugging materials may adapt to the needs of different application scenarios and provide a wider range of solutions.

In short, with the continuous progress of technology and the continuous evolution of demand, the future prospects of sealing materials are more efficient, environmentally friendly, intelligent, and diversified development directions. This will provide better solutions for leakage issues in industry and other fields.

The continuous development and innovation of drilling plugging materials will further improve the safety and efficiency of drilling operations. In the future, with the continuous progress of technology, it is expected that more advanced plugging materials and technologies will emerge to meet the increasingly complex underground environment and engineering needs.

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Conflict of interest:

This literature review is based on our team's research and analysis, all content is based on our own judgment and understanding of the written. We ensure that the sources of the cited literature are accurately cited and annotated to clarify the knowledge and contributions of others and to avoid plagiarism and plagiarism, follow the principle of academic integrity to ensure the accuracy and reliability of the content.

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Hereby declare.

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