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Fracture Modeling under Laser Scanning Confocal Microscope for the Transformation of Ultra-deep Tight Sandstone Reservoirs

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Abstract: In recent years, with the continuous development of resources, countries began to expand the exploration and exploitation of resources. Tight sandstone beds have been the focus of resource development in recent years. The purpose of this study is to provide a theoretical basis for the development of tight sandstone layers by exploring the transformation effect of fracture modeling on super-deep tight sandstone reservoirs. Firstly in this paper, the principle of the laser scanning confocal microscope, advantages and disadvantages and so on various aspects has carried on the detailed introduction, then the fracture types and formation mechanism of tight sandstone in detail, finally by means of fracture modeling experiment, establish the 3 d data model of crack, and on this basis, from three angles analyzes the crack modeling on ultra-deep tight sandstone reservoir. The experimental results show that the degree of fracture porosity is limited to the ability to improve the porosity of the reservoir, and the porosity of most fractures is less than 0.1%, accounting for 61%. The permeability of sandstone reservoirs without fracture matrix is between (0.01-0.1)×10-3μm2, and that of sandstone reservoirs with fracture matrix is generally between (1-10)×10-3μm2. The maximum permeability of this type of reservoirs is 25.8×10-3μm2, which is 1 to 2 quantity levels higher than that of those without fracture matrix. In general, fracture modeling plays an important role in the transformation of tight sandstone reservoirs in two aspects: the transformation of reservoir physical properties and the control of reservoir resource production.

1. Introduction

In recent years, due to the continuous development of conventional reservoir resources, all countries in the world are increasing the new development of resources, so as to maximize the continuous satisfaction of normal energy demand [1]. Therefore, the development of super-deep tight sandstone has become a hot spot in recent years. In the ultra-deep dense perforated reservoir, due to the strong influence of compaction, the matrix porosity in this area is generally less than 10%, and the permeability is also less than $1\times10^{-3}\mu m^2$, so the seepage system in this area will be greatly hindered and it is difficult to produce an efficient seepage system [2-3]. However, in tight sandstone reservoirs, there are generally a large number of structural fractures, which play a significant role in improving the material properties of tight sandstone reservoirs [4]. Therefore, it is of great significance to explore the effect of fracture modeling on the transformation of tight sandstone reservoirs, to improve the success rate of resource exploration in this region and to promote the continuous expansion of exploration fields [5].

Due to the development of laser scanning confocal microscopy (LSCM) technology, its application in ultra-deep tight sandstone reservoirs has been increasingly expanded in recent years, and scholars at home and abroad are paying more and more attention to laser scanning confocal microscopy (LSCM) and ultra-deep tight sandstone reservoirs. In literature [6], the author introduces the technical principle of laser scanning confocal microscope, and gives detailed instructions on its application field and specific experimental operation, which promotes the further development and application of the technology. In literature [7], the author conducted fracture modeling with the help of various measurement data such as drilling coring and laser scanning, and analyzed the specific effects of fracture development on sandstone reservoir from two perspectives of static qualitative analysis and dynamic quantitative analysis with the help of the experimental analysis method of laser confocal microscope. In the literature [8], the author focused on the analysis of the main types of fractures in ultra-deep tight sandstone, and introduced the specific characteristics of each type of fractures in detail.

To delve into confocal laser scanning microscope fracture modeling for reformation of ultra-deep tight sandstone reservoir, this paper firstly in this paper, the principle of the laser scanning confocal microscope, advantages and disadvantages and so on various aspects has carried on the detailed introduction, then the fracture types and formation mechanism of tight sandstone in detail, finally by means of fracture modeling experiment, establish the 3 d data model of crack, and on this basis, from three angles analyzes the crack modeling for reformation of ultra-deep tight sandstone reservoir [9-10]. The research in this paper not only promotes the further development of the super-deep dense rock formations, but also lays a theoretical foundation for future studies in related fields [11].

2. Basic Knowledge

2.1. Laser Scanning Confocal Microscope

The concept of a common laser scanning confocal microscope was first proposed in the mid-20th century, and Marvin's patent is the first to explain how the technology works. According to the basic principle and structure of the traditional optical microscope, the laser scanning device is added in this technology, and the point light source is generated by the laser scanning through the grating pinhole, and the focal plane is scanned point by point. When the optical signal of the collection point passes through the detection pinhole successfully, it is detected and collected by the photomultiplier tube in a timely manner. Under the role of signal processing, the final data results are input to the computer and successfully imprinted. Compared with the ordinary fluorescence microscope, the laser scanning confocal microscope has the following advantages: first, it can effectively suppress the image blur, and the image acquired is more clear; Secondly, the confocal software can be used for optical section and 3d reconstruction, so as to establish a three-dimensional three-dimensional image, which greatly improves the appreciation of the three-dimensional space of detection specimens. Thirdly, multi-channel fluorescence can be realized in real time with the aid of optical disc wheel. Fourth, the ZOOM function of laser scanning confocal microscope can make the objective lens give full play to its resolution. Fifth, can carry out the local optical operation; Sixth, the detection speed and detection effect are improved, and the positioning is more clear and accurate.

In order to make the detailed structure of single layer and multi-channel obtained by laser scanning confocal microscope clearer, it is necessary to select specific scanning methods for different types of research specimens and samples. Generally speaking, scanning methods of laser scanning confocal microscope include XY scan, XYZ scan, XYT scan, XT/YT/ free curve/point scan and XYL scan, etc. XY scan is mainly used for the analysis of fluorescence positioning, while XYZ scan is mainly used for the study of sample space position, which can obtain the sample information of 3d image. XYT scanning can analyze and process the real-time changes of fluorescence. XT/YT/ free curve/point scan is used to record the fluorescence changes according to the time change. The image acquisition speed of this scanning method is much higher than that of XY scan. XYL scanning can analyze and scan the change of fluorescence intensity in the whole plane band, which is generally used to determine the optimal fluorescence spectrum. In addition to the above scanning methods, there are other types of scanning methods in the laser scanning confocal microscope, which require the experimenter to independently select according to specific experimental requirements. In addition to the above advantages, laser scanning confocal also has the following disadvantages: first, the common laser excitation spectral lines are less, the laser excitation spectral lines are not only narrow and located in the ultraviolet region of the laser cost is higher; Second, laser irradiation will produce relatively high radiation, will cause a certain degree of damage to human living cells; Third, under the laser irradiation, a large number of fluorescent dye molecules will produce a variety of types of cytotoxic effects.

2.2. Formation Mechanism and Characteristics of Fractures

Generally speaking, the fracture types in the tight sandstone reservoir area are diverse, among which the most typical fractures are shear, tensile, bedding and dissolution fractures. The formation mechanism and characteristics of each fracture type are different. The research on the formation mechanism and specific characteristics of each type of fracture can promote the fracture modeling. Based on this, the author will give a detailed description of the genetic mechanism and specific characteristics of the above four typical fractures. Shear fracture is a kind of structural fracture in nature. When all three principal stresses are compressive stresses, the shear stress derived from them is much higher than that generated by the shear stress resistance strength corresponding to the rock itself, so the fracture is called shear fracture. The formation of shear fractures is influenced by the mechanical characteristics of rocks, the sedimentary substratum and the specific stress properties. The specific characteristics of shear fractures are as follows: first, the direction of fracture displacement is parallel to the fracture plane; Secondly, the fracture plane and sandstone plane present a state of intersection, and the intersection Angle is acute. Thirdly, the scratch marks on the fracture surface are more obvious, and the distribution of these scratch marks is a continuous step state. Fourth, most of the fractures are high-angle or vertical, and only a few are low-angle or horizontal. Fifth, the width of the crack is relatively uniform, the specific plane of the crack is relatively straight and smooth, and in general, it occurs in groups, usually belonging to two groups of conjugate cracks. The second is the tensile fracture, which is also common in structural fractures. The tensile stress derived from the three principal stresses is larger than the tensile strength generated by sandstone itself, and the fractures generated on this basis are called tensile fractures. The direction of tensile stress under tensile fracture is obviously parallel to the direction of minimum principal stress. Moreover, the three main stresses are all of the compressive stress, which will cause the expansion crack, and the tensile crack is formed when at least one of the three main stresses is the tensile stress. The specific characteristics of the tensile fracture are as follows: first, the displacement direction of the fracture is perpendicular to the fracture plane; The fracture plane is parallel to the sandstone plane. Third, it is usually an open slit; Fourth, the crack surface is relatively coarse vegetables, and presents a kind of uneven state; Fourth, the Angle of crack Angle is relatively low to some extent, usually its Angle is lower than 40 degrees, the width is relatively large; Fifth, calcite fillings often appear in this type of fractures. Sixth, the number of single well fractures of this type is relatively small, and the plane presents a distributed distribution state. Two of the most common fracture types are introduced here, and the other two will not be described one by one.

3. Fracture Modeling Experiment

In order to promote the smooth development of fracture modeling experiments, this paper selects super-deep dense sandstone in the west of China as the research object, so as to deduce the general rule of heavy fracture modeling.

3.1. Experimental Ideas of Fracture Modeling

In order to provide sufficient data support for the experiment of this paper, the author consulted wanfang, cnki and other relevant paper information websites, and consulted a total of 121 relevant research materials. Through the study of the existing research data, the author found that the specific method of traditional fracture modeling has a great dependence on the two aspects of imaging logging and core, and requires a high measurement cost, and the final measurement data has some errors. The proposed fracture density body not only promotes the effective solution of the above problems, but also effectively solves other types of problems existing in the prediction and specific modeling of fractures with the assistance of laser scanning confocal microscopy. At the same time, the accuracy of different types of information can be played effectively according to different measurement scales. Especially for small and medium scale cracks in fault fracture development mode under the action of the concrete restriction, on the basis of rock mechanics to explore the specific cause of the cracks, and from the level of concrete mechanism similar to explain the specific patterns of fracture development, and with the aid of stress field of the construction of the finite element method and the way, for this article selected the superdeep dense sandstone area modeling the cracks in the concrete, to simulate the distribution of stress field in rock failure based on the specific to predict its spatial distribution. Then, the simulation results of sandstone phase, concrete construction structure and stress field are comprehensively compared, so as to establish a 3d fracture density body, and a concrete model of natural fracture space is constructed by means of discrete fracture network modeling.

3.2. Steps of Fracture Modeling

(1) Fracture development feature acquisition

The first step of fracture modeling is to acquire and summarize the characteristics of fracture development. In the ultra-deep dense sandstone region in western China selected in this paper, the survey of landscape laser scanning confocal microscope revealed that the main direction of fracture development was northeast to southwest, and a small part of the fracture development direction was southeast. In addition, due to the action and control of some geotectonic fault zones, the main geological stress in this area extends to the north-south direction. On the basis of the statistical analysis of the concrete results observed in the core, the natural fractures developed in the core Wells were selected for further investigation, and the specific development degree of fractures reached 100%. Moreover, the types of fractures selected in this paper are mainly structural fractures, followed by those with straight lines of shear stress and tensile stress, and most of the fractures are concentrated in the locations of silty sand rocks. In this region, high-angle fractures are the main types of fracture development. Most of the fracture inclinations are concentrated between 65 degrees and 90 degrees. A few lei feng types belong to oblique cracks, and there are no low-angle cracks in this area. The final opening range of the crack is between 40 m and 2mm, and most of the openings are concentrated in the range of 40-80 m. Generally speaking, the overall fracture opening degree is relatively small, and the closed seam occupies a relatively high proportion. Most of the larger cracks were filled with dolomite, accounting for 15 percent. Through comparative analysis of the fracture density of the core pairs, it can be found that the average fracture density in the study area selected in this paper is 3/m, and about 75% of the fracture density is greater than 3/m, which is a relatively developed natural fracture zone.

(2) Establish sedimentary facies - lithofacies model

The specific differences in lithology are also important factors affecting fracture development. Under the influence of sedimentation, the rock composition, structure and the monolayer thickness of the rock will have certain differences, so the specific development degree of fractures will have certain differences. The detection of the lithofacies spatial distribution model in the study area can provide reliable constraints for the prediction of fractures to a certain extent. By referring to relevant research data, the author established the difference and correlation of fracture development degree in different sedimentary microfacies by means of sequential indication simulation method and sedimentary microfacies constraint. Thus, the sedimentary plane status and the specific thickness of sandstone in this area are analyzed in detail, and the basic model understanding of the thickness and distribution of sandstone is established. Based on the constraints of sedimentary microfacies, the final hard data is interpreted as lithologic data on a single well. On the basis of the sequential indicating simulation method, zuzihong finally established the lithofacies model. It has a high probability distribution consistency.

(3) Build a fracture model

Before the formal fracture modeling is realized, the comprehensive analysis of fracture density and the relationship between near and far faults is needed. Based on the laser scanning confocal microscopy in this paper and the existing research data, it can be found that the distance from the major fault is inversely proportional to the fracture density, that is, the greater the distance from the major fault is, the smaller the fracture density will be, and the degree of fracture openings will gradually decrease. Moreover, as the distance from the main fault keeps increasing, the sensitivity of fracture density is stronger than that of fracture opening, and its specific correlation is also higher than that of fracture opening. This indicates that the effective and differential stress of the surface layer of the fault will decrease together after the fault is generated, which results in that the energy required for the fracture opening degree to change in the opening is much lower than the energy generated when the fracture density changes. Based on the comprehensive analysis of the cracks, considering the nature of the rock, sandstone thickness and tectonic location, such as Angle, in the above on the basis of the analysis of fracture, fracture development concept of three-dimensional space model is established, the model will be the internal structure of concrete can be divided into fault nuclear and induced fracture zone, and according to the stress state of concrete can be divided into shear zone, fracture zone and weak deformation zone.

Based on the above analysis and the existing research data, this paper finally established the fracture model, that is, the modeling of discrete fracture network. This method of fracture modeling helps to establish a concrete spatial distribution model of underground fractures with real characteristics by defining the specific spatial distribution, geometric states and specific directions of fractures. Regarding the specific spatial distribution of fractures, the final input establishes the specific density of fractures by means of trend modeling, and takes the quadrilateral of surface morphology as the final definition of the fracture assemblage morphology. The extension rate of the quadrilateral is equal to 2, and the length of fractures is consistent with the exponential distribution. The fracture opening degree is based on the correction data after the core measurement. Based on the simulation results of stress field, the concrete constraint of bearing is carried out. On the basis of the above data, a 3d data model of the fracture is established. It is found through experimental detection that the model established in this paper can better demonstrate the relationship between the fracture and the fault.

3.3. Statistics of Experimental Data

Measure with laser scanning confocal microscope is presented in this paper, in order to assure the success of fracture model was established, the need for measurement data record and finishing, the measurement data record is complete, with the aid of SPSS statistical analysis software for statistical analysis of experimental data and related graph drawing software rendering into experimental data with the help of computer, on the basis of the analysis of experimental data the chart above, it is concluded that this article related to fracture modeling of ultra deep tight sandstone reservoir reformation of the experimental conclusion. Generally speaking, in order to ensure the accuracy of data analysis results, the accuracy of experimental data records must be guaranteed first.

4. Crack Model Analysis

4.1. Fracture Modeling and Modification of Reservoir Physical Properties

Through the specific experiment of the above fracture modeling, the author finds that the transformation of the super-deep tight sandstone reservoir by fracture modeling is firstly reflected in the transformation of reservoir physical properties, which is mainly reflected in the following two aspects:

(1) Promote the improvement of porosity of ultra-deep tight sandstone reservoirs

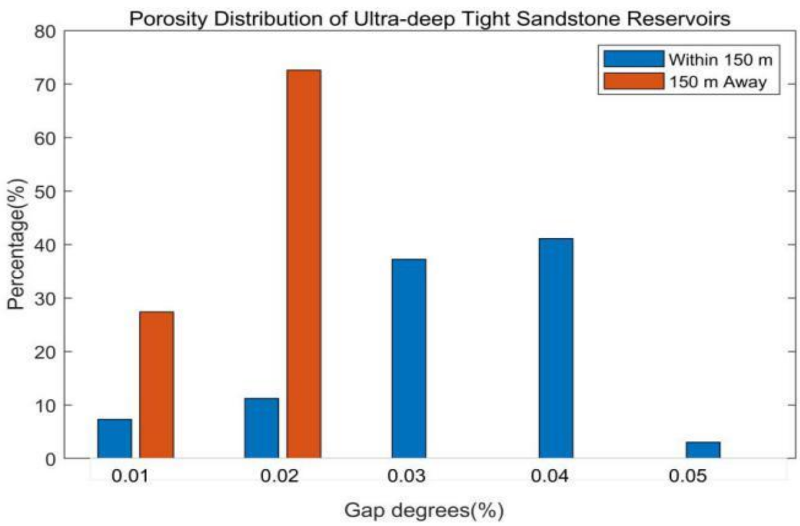

Figure 1. Porosity distribution of ultra-deep tight sandstone reservoirs

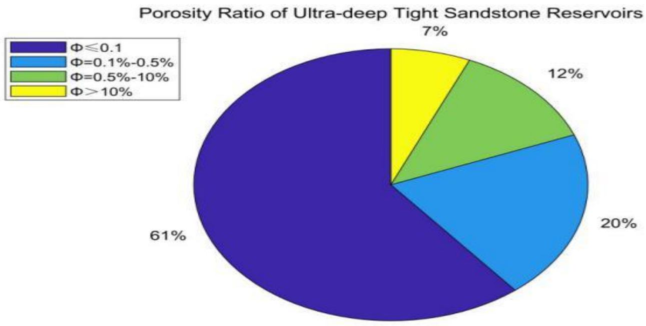

Figure 2. Porosity ratio data of ultra-deep tight sandstone reservoir

Figures 1, 2 for the laser scanning confocal microscope badad porosity, specific imaging data of two figure of super deep tight sandstone reservoir porosity respectively specific distribution and proportion, data of Figure 1, Figure 2 we can see that crack modeling to improve reservoir matrix porosity aspects of the role is limited, as a whole, most of the fracture porosity is lower than 0.1%. From the point of the super deep tight sandstone area, part of the upper strata due to compression and bending deformation, tension sew proportion is larger, the opening degree of fracture is relatively large, not only such cracks around the filler by partially leaching dissolution unconformity surface fluid transformation function, so as to make the located just below the unconformity surface within 150 m of fracture porosity is at a higher level, the main numerical interval between 0.03% and 0.04%; Located 150 m outside the scope of the unconformity surface, because of the decrease of fluid leaching dissolution modification, and squeezed under the action of bending, mesh, diagonal cracks appear more development, and also keep the small opening degree, 150 m away so uncomformity surface is less than or equal to 0.02% of the overall gap degrees, from the laser scanning confocal microscope scanned the core of the actual data, the degree of fracture pore to improve the ability of reservoir porosity is limited, so most of the fracture porosity is lower than 0.1%, the proportion is 61%.

(2) Promote the improvement of the overall permeability of the reservoir

Table 1. Comparison of reservoir matrix and fracture permeability data

Project	802	803	804	805	806	807	808	809
Reservoir matrix	0.05 ($\times10^{-3}\mu m^2$)	0.028 ($\times10^{-3}\mu m^2$)	0.427($\times10^{-3}\mu m^2$)	0.127($\times10^{-3}\mu m^2$)	0.003($\times10^{-3}\mu m^2$)	0.026($\times10^{-3}\mu m^2$)	0.001($\times10^{-3}\mu m^2$)	0.117($\times10^{-3}\mu m^2$)
Cracks in the building	2.717 ($\times10^{-3}\mu m^2$)	0.983($\times10^{-3}\mu m^2$)	25.760($\times10^{-3}\mu m^2$)	1.153($\times10^{-3}\mu m^2$)	0.426($\times10^{-3}\mu m^2$)	3.740($\times10^{-3}\mu m^2$)	8.260($\times10^{-3}\mu m^2$)	1.093($\times10^{-3}\mu m^2$)
*Data are derived from the results of experimental collation								

By consulting relevant research data, the author found that for sandstone reservoirs with low permeability, the specific porosity usually provided by fracture modeling is 0.5% small, and the maximum porosity is only maintained at about 1%. Therefore, generally speaking, fracture modeling cannot be regarded as the main reservoir space type, and the knowledge simply exists as an efficient seepage channel, which greatly improves the permeability of the ultra-deep tight sandstone reservoir. The Table 1 shows the permeability comparison data of sandstone reservoirs with different matrices. According to the imaging data of the laser scanning confocal microscope in this paper, the porosity provided by the fracture modeling detected in this paper is usually lower than 0.4% and the average porosity is 0.13%, which only accounts for 7.3% to 26.7% of the total porosity. However, the actual scanning data of the core plunger shows that the permeability of sandstone reservoirs without fracture matrix is usually between (0.01-0.1)×10-3μm2, and that of sandstone reservoirs with fracture matrix is generally between (1-10)×10-3μm2. The maximum permeability of this type of reservoirs is 25.8×10-3μm2, which is generally 1 to 2 quantity levels higher than that of those without fracture matrix. From this, we can conclude that although fracture modeling plays a limited role in improving the porosity of sandstone reservoirs, it can promote the permeability of sandstone reservoirs significantly.

(3) Promote the effective improvement of reservoir pore structure

Through the study of this paper, the author found that the fracture modeling not only makes the fracture itself an effective seepage channel for oil and gas and other related xiyuan, but also the dissolution generated by the fracture modeling can promote the continuous improvement of the matrix material characteristics of the super-deep dense sandstone. During the cretaceous period, in this paper, the testing of the super deep tight sandstone region in general its specific diagenetic environment is half-light and half salt water resources medium, in the initial stage of crack modeling based on the role of atmospheric fresh water along the substrate on both sides of the rock formed a kind of calcite cement dissolution, but overall the dissolution is still in the limited scope. In the paleogene period, the formation water was generally in an alkaline state due to the increasing speed of water deepening. During this period, a large number of minerals accumulated to form sandstone layers, and many fillings were generated in the cracks of sandstone. Many minerals cannot fully fill the dissolution pores of the initial stage because of the overall high precipitation rate. As a result, a limited range of relatively high porosity zones is retained at both ends of the filling crack. Late with some strong natural gas injection, formation water is rich in organic acids along the initial stage of crack modeling flow, thus some of the filling material of cracks formed acid dissolution, this will further expand the opening of crack and realized between different matrix pore connected to each other, thus making the structure of the sandstone reservoir is an obvious improvement, promote the overall penetration ability of ascension. By consulting relevant data, the author found that the specific PH value of formation water at this stage is usually between 4 and 7, and only a few areas of formation water show alkaline state, so it can be seen that the dissolution caused by fracture modeling is still in the state.

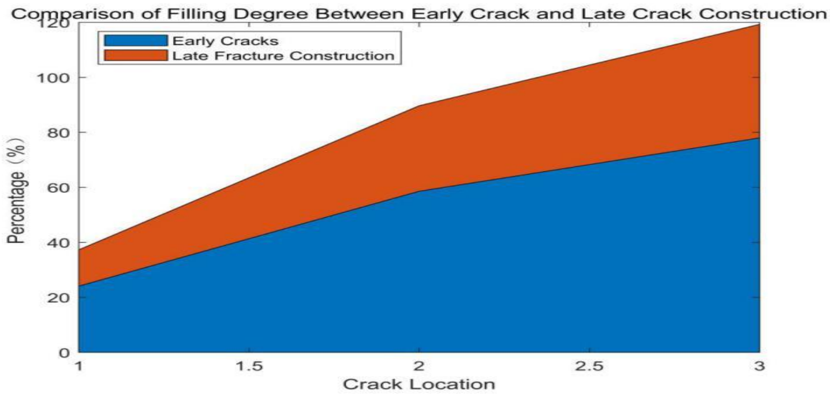

Figure 3. Comparison of filling degree between early and late fractures under fracture modeling

Figure 3 compares the data of filling degree under the modeling of early and late fractures, in which the two points x=1 represent the fractures at the high part of the anticline, the two points x=2 represent the fractures at the wings of the anticline, and the two points x=3 represent the fractures closest to the fault location. The data in Figure 3 show that the early cracks in the upper part of the anticline, the wing of the anticline and the nearest to the fault position have the filling degree ratios of 24.1%, 58.6% and 78%. After the later fracture modeling, the filling degree of the fractures in the upper part of the anticline, the wing of the anticline and the nearest to the fault were 13.2%, 31.1% and 41.3%, respectively. By comparing the data, we can find that compared with the early fracture fillings, the fillings in the later fracture modeling stage are obviously decreased. Normally, if the fractures are filled with fillers, they not only fail to provide high permeability to the ultra-deep tight sandstone reservoir, but also hinder the continuous flow of liquid material. However, the fracture modeling experiment in this paper shows that the filled fracture in the early stage can be re-installed from the invalid fracture to the effective fracture after the later reconstruction of the fracture modeling, and this transformation is realized by changing the specific structure of the fracture.

4.2. Fracture Modeling Can Control the Stable and High Yield of Sandstone Reservoir

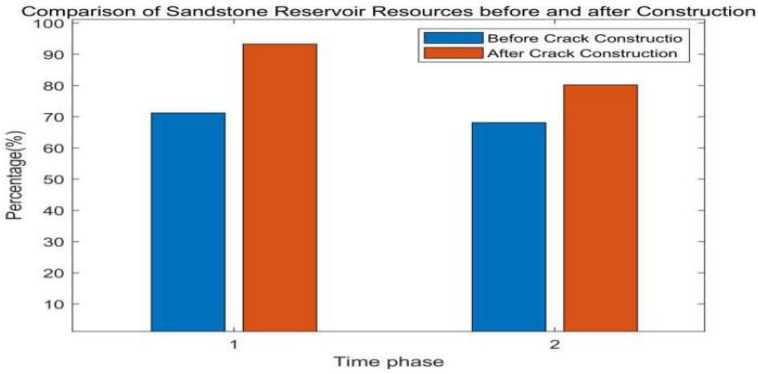

Figure 4. Comparison of sandstone reservoir resource production before and after fracture modeling

Figure 4 shows the comparison of sandstone reservoir resource output before and after fracture modeling. X-axis values 1 and 2 represent the amount and time of resource output respectively. Through the comparative analysis of the data in Figure 4, it can be concluded that, compared with before the fracture modeling, the output quantity of sandstone reservoir resources and the duration of resource continuous output have increased, in which the output has increased by about 22% and the duration of resource continuous output has increased by about 13. The reason for this phenomenon is the influence of the fracture modeling mentioned above on the permeability and the overall structure. The fracture modeling has effectively improved the sandstone reservoir structure, thus improving the effectiveness and permeability of the sandstone reservoir. Based on this, the sandstone reservoir formed a network to communicate between each crack seepage system, the formation fluid pressure from the matrix block to match the supplies and cracks to the supply of wellbore, on the basis of this leads to a high degree of percolation system of reservoir, the construction of this system not only ensures the sandstone reservoir resources, high yield of production, also make the production resources in a long time steady state.

5. Conclusion

Through the crack modeling experiment, this article finally found crack modeling for reformation of tight sandstone reservoir in reforming reservoir reservoir sandstone reservoir physical property and control production stable and high yield two aspects, including the reservoir physical property of reservoir reconstruction by reflected in promoting the superdeep dense sandstone reservoir porosity, promote the improvement of the whole reservoir permeability and the promotion of the reservoir pore structure effectively improve three specific aspects. The research in this paper not only promotes the further development of the super-deep dense rock formations, but also lays a theoretical foundation for the future research on the relevant aspects.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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