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Master's Thesis

Porosity and tortuosity of a random porous medium

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Abstract

This paper introduces the basic characteristics of porous media, including the definition and measurement of porosity, concept and calculation method of tortuosity, and discusses the relationship between porosity and tortuosity. This paper also analyzes the influence of circle distribution parameters on porosity and tortuosity. Through experimental design and data collection, the influence mechanism of distribution density, radius size and distribution mode on porosity and tortuosity are discussed in detail. Moreover, the influence of external conditions such as temperature and pressure and competitive adsorption of multicomponent gas on the characteristics of porous medium, and suggested model modification under the action of comprehensive factors. Through the thorough study of random porous media, this paper reveals the characteristics of its porosity and tortuosity and their influence on the overall performance of the media, which provides specific suggestions and directions for the optimization of porous media. The paper also looks forward to the future research direction and trend, including deepening the research on data acquisition and processing, expanding the application scope of circle distribution parameters, and conducting in-depth research combined with practical applications.

Keywords: random porous medium; porosity; tortuosity; mathematical models

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1. Introduction

1. Research background and significance

In the field of nature and engineering, random porous medium is a common medium, whose characteristics determine the flow law and transmission performance of fluid in it. Soil, rock, filter and so on all belong to the category of random porous media, which have complex pore structure and curved fluid channels, leading to the complex flow phenomenon of fluid flow inside them. For a deeper understanding of fluid behavior in random porous media, studying their porosity and tortuosity becomes key [1].

Background, the porosity of the random porous medium determines the fluid accommodating capacity and the possibility of fluid passage. The size of the porosity directly affects the permeability and diffusion of the fluid in the medium, which determines the transmission performance of the medium. The tortuosity describes the bending degree of the fluid flow path in the medium, which affects the flow resistance and flow velocity of the fluid. Therefore, studying the porosity and tortuosity of random porous media is important to understand the behavior of fluids in complex media [2].

In the research sense, the deep study of the porosity and tortuosity of random porous media results in revealing the flow and transmission mechanism of fluids in complex media. This is of great theoretical significance for soil science, geological engineering, petroleum engineering, chemical industry and other fields, and can provide a theoretical basis for the research in related fields. The results can provide ideas and methods for optimizing the performance of random porous media and improving the efficiency of fluid flow. For example, in petroleum engineering, studying the porosity of reservoir rocks can optimize the solutions of oil and gas recovery. In the chemical field, the catalytic efficiency of the catalyst can be improved by adjusting its pore structure. Therefore, the study of the porosity and tortuosity of random porous media has important applications.

2. Introduction to the random porous media

Random porous media is a special type of media, mainly characterized by the stochasticity and complexity of its internal pores. The presence of these pores allows the medium to exhibit unique properties and behaviors in fluid transfer, heat transfer, and chemical reactions. The definitions and characteristics of random porous media and typical examples are detailed below.

Definition and features

Random porous media are complex systems composed of a large number of pores with an irregular shape, size, and distribution. The presence of the pores gives the medium a porous structure that has a significant influence on processes such as fluid flow and heat transfer. Due to the stochastic nature and complexity of the pore, the flow path of the fluid in the medium becomes irregular, and the flow velocity also shows the characteristics of random distribution. This flow characteristics valuable random porous media in fluid dynamics and heat conduction.

Porosity is an important parameter describing the percentage of pore volume of the total volume. The size of porosity directly affects the passage ability and efficiency of heat transfer efficiency. Generally speaking, the larger the porosity, the stronger the fluid passage ability, and the higher the heat transfer efficiency. However, the increase in porosity also results in decreased strength and stability of the medium, so the porosity and other factors need to be considered comprehensively in practical applications.

Besides porosity, tortuosity is also an important parameter to describe the characteristics of random porous media. The tortuosity describes the degree of deviation between the actual flow path in the medium and the rectilinear distance. Due to the complexity and irregularity of the pore, the fluid flow path in the medium often bends and deflection, which results in increased flow resistance of the fluid and reduced heat transfer efficiency. Therefore, the effect of tortuosity

must be considered when studying the flow and heat transfer problems of random porous media.

Typical examples:

Random porous media are widely found in nature and in the engineering fields. In nature, soil, rock and other natural media are the typical random porous media. These media are widely distributed on the earth, and have important effects on the flow of groundwater and the exploitation of oil and natural gas. Random porous media also play an important role in the engineering field. For example, in the design and manufacture of filters, catalyst carriers, thermal insulation materials, etc., the characteristics of porous media and the flow of fluids in them need to be considered.

Soil is a common random porous medium. It is composed of solid particles, water, air, etc., in which the gaps between the solid particles form the pores of the soil. The porosity and tortuosity of the soil have an important influence on the permeability of water and air, the water retention ability of the soil, and the growth of crops. Therefore, the random porous properties of soil need to be fully considered in the study of hydrological characteristics and agricultural production.

Rock is another common random porous medium. In the exploitation of oil and gas, the porosity and permeability of rock are important indicators to evaluate the reservoir performance. Due to the complex and irregular pore structure of rocks, the flow and heat transfer process of fluid in them are also very complex. Therefore, when studying the hydrodynamic and thermodynamic properties of rocks, specialized methods and techniques are needed to simulate and calculate the fluid flow in rocks.

Random porous media also play an important role in industrial fields such as filters and catalyst carriers. These media are usually made of granular materials, and their pore structure and surface properties have important effects on key indicators such as filtration efficiency and catalyst activity. Therefore, the characteristics of the

porous medium and the flow of the fluid need to be fully considered in the design and manufacture of these products.

3. Concept and function of circle distribution parameters

As a key parameter describing the shape and size of pores in random porous media, the circle distribution parameter plays an important role in the study of fluid flow behavior, transport performance, and the optimization of media performance. This section details the definition, role, and its importance in the study of porous media.

Definition of the circle distribution parameters [3]

The circle distribution parameter, also known as the pore circularity or pore shape parameter, is a parameter used to characterize the degree of pore arity in a random porous medium. In a porous medium, the shape and size of the pore have important effects on the flow behavior of the fluid. The circle distribution parameter describes the circular degree of the pore in the porous medium, and provides an important reference for the fluid flow in the porous medium.

Action of the circle distribution parameters

1. Describe the pore structure: the circle distribution parameters can reflect the shape and size of the pores in the porous media, so as to reveal the characteristics of the pore structure. This is important for understanding the flow path and flow characteristics of fluids in the medium.
2. Predict fluid flow behavior: the circle distribution parameter is one of the important factors affecting the flow of fluid in porous media. Through the study of circle distribution parameters, we can predict the flow behavior of fluid in the medium and flow pressure, which provides important reference for engineering applications.
3. Optimize the media performance: the circle distribution parameters have a significant impact on the transmission performance and mechanical properties of the porous media. By adjusting the pore shape and size of the porous medium,

their circular distribution parameters can be optimized, thus improving the transmission efficiency and mechanical properties of the medium to meet the needs of engineering applications.

4. Characterization method of experimental and numerical simulation: The circle distribution parameters provide a convenient characterization method for experimental and numerical simulation. During the experiment, the value of the circle distribution parameter can be obtained by measuring the pore shape and size of the porous medium; in the numerical simulation, the pore structure of the porous medium can be simulated to simulate and analyze the fluid flow.

2. Analysis of the Basic Characteristics of Porous Media

1. Definition and measurement method of the porosity

As an important physical property of porous media, porosity has important effects on the storage, penetration and conduction capacity of the media. Porosity research is an important topic in many fields such as geology and material science. The definition of porosity and its measurement methods are discussed in detail in this chapter.

Porosity refers to the ratio of the volume of the pore space in the porous medium to the total volume of the medium. It is an important parameter to describe the internal structure of porous media and reflecting the development of pores in the medium. The size of the porosity not only determines the storage capacity of the porous media, but also affects its permeability and conductivity. In the fields of reservoir evaluation, oil and gas exploration, water resources management, etc., porosity is an important index to evaluate the performance of porous media.

There are various methods to measure porosity, including mercury intrusion, gas adsorption, image analysis. Each method has its own scope of application and advantages and disadvantages, which need to be selected according to the

characteristics and experimental conditions. The mercury intrusion method is a common method to measuring porosity. It is to calculate the permeability of mercury on porous media by measuring the intrusion of mercury under different pressures. This method is simple to operate and measures a wide range, but has certain requirements for the shape and size of the sample. The gas adsorption rule uses the adsorption properties of the gas on the surface of the porous medium to calculate the porosity by measuring the adsorption amount of the gas at different pressures. This method causes less damage to the sample, but requires precise measurement equipment and conditions. The image analysis rule uses the imaging technology such as the microscope or the CT scanning to directly observe the internal structure of the porous medium and calculate the porosity through the image processing technology. This method provides an intuitive understanding of the pore shape and distribution, but it is complicated and costly.

In practical applications, selecting the appropriate porosity measurement method is crucial to accurately evaluate the performance of the porous media. We need to choose the best measurement method according to the research purpose, the sample characteristics and the experimental conditions. At the same time, attention also needs to pay attention to the error control and data processing in the measurement process to ensure the accuracy and reliability of the measurement results.

2. Tortuosity concept and calculation method

In the porous medium research, the tortuosity is a crucial parameter that profoundly affects the flow and transmission process of the fluid in the porous medium. In order to understand this concept in depth, the definition of the tortuosity and its calculation method are discussed in detail.

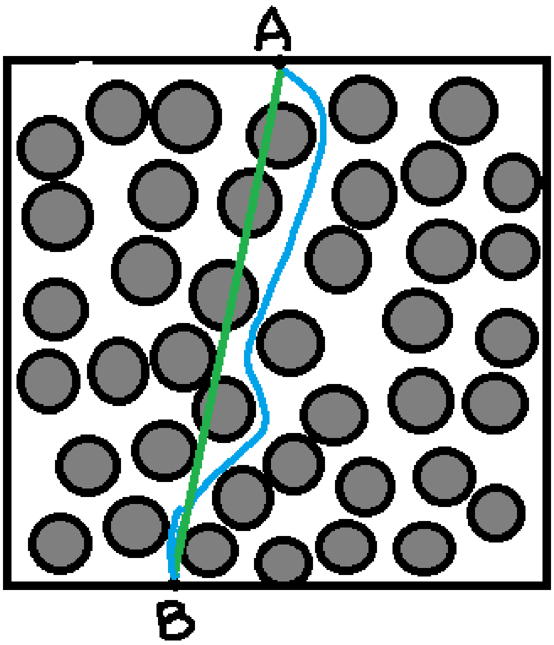

Figure 1. Definition of tortuosity of the porous medium. The blue line is the effective path between points A and B. The green line represents the straight path AB

(I) Definition of the tortuosity

Bend, often understood as the degree of tortuous of the pore path in a porous medium. In porous media, pores are often not straight arranged but present a complex curved morphology. This bending pattern not only increases the flow path of the fluid in the pore, but also increases the contact area of the fluid and the pore wall, thus affecting the flow resistance and transmission efficiency of the fluid. To quantify this degree of bending, we introduce the concept of tortuosity. It reflects the complexity and heterogeneity of pore structure and is one of the important indexes to evaluate the transport performance of porous media.

(2) Calculation method

The bending calculation is varied, but mainly based on the morphological and geometrical features of pore structures. The following are several common calculation methods:

1. Pore shape factor method: This method calculates the shape factor of the pore

by measuring the length, width and depth of the pore, and then evaluates the tortuosity. The larger the shape factor indicates that the more curved the pore is. However, this method requires obtaining detailed pore morphology data, and therefore is somewhat limited in practical applications.

2. Tortuosity method: Tortuosity is a parameter that describes the tortuous degree of the fluid flow path in a porous medium. The tortuosity can be calculated by measuring the ratio between the actual flow path and the straight path of the fluid in a porous medium. The greater the tortuosity, the more tortuous the fluid flow path in the pore, the greater the tortuosity. This method is widely used in practice, but the measurement process is relatively complicated.

3. Permeability method: permeability is an important parameter to describe the permeability properties of porous media. According to Darcys law, the permeability is inversely proportional to the flow resistance of the fluid in a porous medium. And the flow resistance is closely related to the bending degree of the pore. Therefore, the tortuosity can be assessed indirectly by measuring the permeability of the porous medium. This method is simple and easy, but it is influenced by other factors of the porous media, such as porosity, pore size distribution, etc.

4, image analysis method: With the development of computer image processing technology, image analysis method has been widely used in bending calculation. By scanning the morphology and distribution of the porous medium. Then, the images were processed and analyzed using image processing software to calculate the tortuosity. This method has high precision and intuition, but requires expensive equipment and complex image processing techniques.

As an important parameter to describe the degree of pore bending in porous media, the tortuosity is important for evaluating the transport performance and optimizing the flow of fluid in porous media. In practical application, the appropriate calculation method should be selected according to the characteristics and actual

requirements of the porous medium to obtain an accurate bending value.

3. Discussion of the relationship between porosity and tortuosity

As important physical properties, porosity and tortuosity are close between porous media. Exploring the relationship between porosity and tortuosity is important for gaining a deeper understanding of the properties of porous media and their behavior in various applications.

Porosity refers to the percentage of pore volume in the total volume of porous medium, which is an important index to evaluate the liquid storage capacity and permeability of porous medium. The higher the porosity, the stronger the liquid storage capacity of the porous media, and the better the permeability of the fluid in the porous media. However, the porosity is not the only factor determining the permeability of the porous media, and the tortuosity also has an important influence on the fluid flow.

The tortuosity is the ratio between the actual path and the straight path when the fluid flows in a porous medium. It reflects the connectivity and complexity of the pores inside the porous medium. The greater the tortuosity, the longer the fluid flow path in the porous medium, and the greater the resistance and difficulty of the fluid flow. Therefore, the tortuosity has an important influence on the permeability of the porous media.

The relationship between porosity and tortuosity is mutually complementary. The level of the porosity can affect the size of the tortuosity. In porous media with higher porosity, the connectivity between pores is better, the path of fluid flow is relatively short, and the tortuosity is smaller. However, in the porous medium with low porosity, the connectivity between the pores is poor, the fluid flow path is relatively long, and the tortuosity is larger.

Bending can in turn affect the validity and availability of porosity. In the porous medium with large tortuosity, the resistance and difficulty of fluid flow are greater,

and the fluid is difficult to penetrate into the deep layer of the porous medium, which reduces the effectiveness and availability of porosity. Therefore, the effects of both porosity and tortuosity need to be considered when evaluating porous media properties.

3. Study on the influence of circle distribution parameters on porosity

1. Change range setting of circle distribution parameters; etc

In the study of circle distribution parameters, the primary task is to clarify its variation range. This mainly includes two dimensions: distribution density and radius size. The distribution density determines the number of circles within unit area or unit volume, while the radius size determines the circle coverage and pore size. The variation of these two parameters has important effects on the properties of porosity, permeability and thermal conductivity of porous media.

Range of distribution density variation

The distribution density is the one of the most important of the circle distribution parameters. In actual porous media, the distribution density of circles is often uneven, dense in some places and sparse in some places. To comprehensively investigate the effect of this heterogeneous distribution on the properties of the porous media, we need to set a reasonable range of distribution density changes. This range should be able to cover all cases from sparse to dense distribution for comparison and analysis. When setting the range of density change, the actual structure and properties of the porous medium, as well as the research purpose and accuracy.

Radius variation range

In addition to the distribution density, the radius size is also an indispensable part of the circle distribution parameters. In actual porous media, the radius size of the circle is often heterogeneous, which leads to differences in pore size and

complexity in pore structure. To investigate the effect of this size effect on the properties of porous media, we need to set a reasonable range of radius size variation. This range should be able to cover all dimensions from tiny pores to macroscopic pores in order to fully reflect the pore structure and properties of porous media.

distribution mode

Besides density and radius, the way the circles are distributed is an important factor affecting the properties of porous media. In actual porous media, the circles may be distributed in a random, uniform, cluster, etc. Different distribution modes can lead to differences in pore structure and changes in pore connectivity, which will affect the properties of permeability and thermal conductivity of porous media. Therefore, in the study of circular distribution parameters, we also need to consider different distribution modes and compare the effects on the properties of porous media.

2. Experimental design and data collection methods

sample preparation

Sample preparation is an important part of the experiment, which directly affects the accuracy and reliability of the experimental results. In order to study the parameters of porosity and tortuosity of random porous media, samples of random porous media with different circle distribution parameters are prepared. These samples should be uniform and consistent to produce representative data in the experiment.

In the preparation process, the appropriate material should be selected first. The material shall have good physical and chemical properties to ensure that the changes will not occur during the experiment. The material is processed and processed to prepare samples that meet the requirements. This involves crushing the material into the appropriate particle size and ensuring the uniformity of the

particles by screening, mixing, etc. Finally, the sample is compacted to ensure that the density and porosity distribution of the sample is uniform.

empirical method

In the experimental method, mercury pressure and nitrogen adsorption were selected to measure the porosity and tortuosity of the sample. Both methods are commonly used for measuring the pore properties of porous materials with their respective advantages and range of applicability.

Mercury pressing method is a method to calculate the pore volume and aperture distribution by measuring the amount of mercury pressed into the sample. This method has the advantages of wide measurement range and high measurement accuracy, but it requires special instruments and operation techniques. During the experiment, the pressure and the speed of mercury are controlled to ensure the accuracy of the measurement.

The nitrogen adsorption rule is a method to measure the pore size and distribution using the adsorption characteristics of nitrogen molecules on a solid surface. This method has the advantages of simple operation and high measurement accuracy, but it requires a special adsorption instrument and nitrogen gas. During the experiment, the adsorption temperature and nitrogen pressure are required to be controlled to ensure the accuracy of the measurements.

data collection

Data collection is an important part of the experiment, which directly affects the subsequent data analysis and experimental results. During the course of the experiment, various data including porosity, radius size, and distribution density are needed.

Ensure the accuracy and integrity of the data. In the course of the experiment, the operation procedures should be strictly followed, and the experimental data should be recorded. The data should be organized and analyzed. By calculating and analyzing the data, we can get the porosity and radius, and chart accordingly. These

charts can visually demonstrate the pore properties of the samples, providing strong data support for subsequent studies.

3. Results analysis and discussion

This chapter will analyze the experimental results in depth, and focus on the law of porosity change and the influencing factors, and compare the experimental results with previous studies.

We observe the porosity changes with the parameters of the circular distribution. Experimental data show that as the distribution density increases, the porosity tends to increase first and then decreases. This phenomenon can be explained by the fact that when the distribution density is small, the spacing between circles is larger and there are more gaps and hence higher porosity. However, as the distribution density increases, the overlap between the circles begins to increase, resulting in smaller voids and reduced porosity. We also find that there is also a relationship between the porosity and the radius size of the circle. When the radius of the circle increases, the porosity increases first and then decreases, but the change amplitude is small. This is probably because the increasing radius increases the overlap between the circles, but also increases the total void area, so that the porosity changes relatively little.

Besides the circular distribution parameters, other factors may have effects on porosity. For example, the effect of the media type on the porosity is very significant. Different media have different particle sizes, shapes and arrangements, all of which can affect the formation and distribution of voids. The preparation method is also an important factor affecting the porosity. Different preparation methods may lead to changes in the void structure inside the medium that can affect the porosity.

To verify the accuracy and reliability of the experimental results, we compared the experimental results with previous studies. Through comparison, we found that

our experimental results were consistent with those of previous studies, but the specific values were different. This may be due to differences in experimental conditions, experimental methods, as well as sample selection. To obtain more accurate results, we need to further improve the experimental method, improve the experimental accuracy, and expand the sample range for in-depth study.

4. Summary of the variation of porosity with circular distribution parameters

When exploring the relationship between porosity and circular distribution parameters, the influence of multiple parameters on porosity and their interaction should be carefully analyzed. This paper discusses the three key parameters of distribution density, radius size and distribution mode.

The distribution density is a parameter describing the density of the circle in the plane. With the total number of circles remains constant, the distance between the circles decreases, and the overlap and coverage is intensified. This overlap and coverage leads to a decrease of the pore space, so that the porosity decreases. However, when the distribution density is small, the distance between the circles is large and the pore space is relatively abundant, increasing the distribution density can significantly improve the porosity. Thus, there is a relationship between the distribution density and the porosity that increases first and then decreases.

Radius is an important parameter describing the circle size. With the density and way of distribution remaining constant, the larger the radius, the larger the area occupied by the circle, and the smaller the corresponding pore space. Thus presents a negative correlation between radius size and porosity. However, when the radius increases to a certain extent, the overlap and coverage between the circles begin to appear, and further increasing the radius instead leads to an increase in porosity. This is because overlap and coverage connect the originally isolated pores to each

other, creating a larger pore space. However, this effect will saturate after the radius increases to a degree, when porosity will remain stable.

Distribution refers to the way the circles are arranged in a plane. Different distribution modes can have a significant impact on the porosity. Under uniform distribution, the distances between circles are equal and the pore space is evenly distributed, so the porosity is high. However, in the case of heterogeneous distribution, the distance between the circles is unequal and the pore space distribution is uneven, leading to a decrease in porosity. When circles are distributed in aggregate form, the pore space inside the aggregated area is greatly occupied, while the pore space outside the aggregate area is relatively small, which also leads to a decrease of porosity.

Based on the above analysis, it can be seen that the porosity is affected by many factors, such as the distribution density, radius size and distribution mode. When optimizing the structural design of random porous media, we need to consider the influence law of these factors on porosity. For example, the porosity can be improved by adjusting the density and the distribution by keeping the distribution size constant, and the pore structure can be optimized by adjusting the density and distribution of the radius. Through these optimization measures, random porous media materials with higher porosity and better performance can be prepared.

4. Research on the influence of circle distribution parameters on tortuosity

1. The mechanism of tortuosity is affected by the circle distribution parameters

In porous media, tortuosity is a key physical parameter that affects the flow characteristics and transport efficiency of fluids. Tortuosity is closely related to the microstructure of porous media, in which the circle distribution parameter is one of the important factors affecting tortuosity. This section details how the circle

distribution parameters affect the tortuosity of the porous media.
The circle distribution parameters include the radius, area, and circumference of the circle, which jointly determine the circle shape and size. In porous media, the morphology and distribution of the circle distribution have a significant effect on the tortuosity. When the circle distribution is more uniform, the flow path of the fluid in the porous medium is more stable, reducing the friction and collision between the fluid and the pore wall, thus reducing the tortuosity of the medium. In this case, the fluid can pass through the porous medium faster, increasing the transmission efficiency.

The radius of the circle also has an important influence on the tortuosity. When the radius of the circle is moderate, the flow of the fluid in the circle is more smooth, reducing the rotation and vortex phenomenon of the fluid in the pore. This is beneficial to reduce the energy loss of the fluid, reduce the fluid resistance, and thus reduce the tortuosity of the porous medium. However, when the radius of the circle is too large or too small, it will adversely affect the tortuosity. When the radius is too large, the flow distance of the fluid in the pore increases, which increases the friction between the fluid and the pore wall; the fluid flow in the pore is limited, easy to form vortex and turbulence, which also increases the tortuosity.

The area and circumference of the circle distribution also have an influence on the tortuosity. When the area and circumference of the circle are moderate, the fluid flow in the pore is more uniform, reducing the friction and collision between the fluid and the pore wall. This is beneficial to reduce the resistance of the fluid and reduce the tortuosity. However, when the area and circumference of the circle are too large or too small, the fluid flow in the pore is uneven, increasing the resistance and tortuosity of the fluid.

The circle distribution parameter has important effects on the tortuosity of the porous medium. In order to reduce the tortuosity of porous medium and improve the transmission efficiency of fluid, the circle distribution parameters need to be

properly controlled reasonably. This includes adjusting the parameters such as the radius, area, and circumference of the circle to make the flow of the fluid in the channel more smooth and uniform. At the same time, it is also necessary to optimize the microstructure of the porous media to improve the porosity and connectivity of the porous medium, thus reducing the tortuosity.

2. Experimental conditions setting and data acquisition methods

The choice of experimental material is crucial for the accuracy and reproducibility of the experimental results. In the study of exploring the influence of circle distribution parameters on tortuosity, porous media as the core material of the experiment, its characteristics such as aperture size and porosity have a significant impact on the experimental results. In order to obtain more comprehensive and accurate data, various porous media with different properties were selected as experimental materials in this study. These porous media cover everything from natural rocks to synthetic materials, such as sandstone, limestone, porous ceramics, etc. These materials have different pore size sizes, porosity and pore morphology, and are able to mimic the porous media under different geological conditions.

In the material selection process, we strictly controlled the source, processing and preparation of the material, ensuring that each material is representative and well reproducible. Meanwhile, we also made detailed measurements and records of the physical properties of each material, such as density, porosity, permeability, etc., to make precise control and comparison during the experimental process.

Experimental installation is an important guarantee for experimental success. To obtain high resolution imaging and accurate measurement data, we employed advanced imaging techniques and measurement equipment. The experimental setup is mainly composed of high-resolution microscope, image acquisition system, data processing software, etc. High-resolution microscope can realize the

enlarged observation of the internal microstructure of the porous medium, the image acquisition system can capture and record the image data in real time, and the data processing software can analyze and process the image to obtain parameters such as porosity and flexosity.

During the course of the experiment, we used multiple measurements to obtain the data. We used microscopy to observe the surface of the porous media to obtain their morphological and microstructural information. Then, we used the image acquisition system to obtain images of its internal pores and channels. Finally, we processed and analyzed the image processing software to obtain parameters like porosity and tortuosity.

Data processing and analysis is an important part of the experiment. To reveal the relationship between the parameters of the circle distribution and the tortuosity, we used and analyzed mathematical statistics and model building to analyze the experimental data.

We collated and classified the experimental data to ensure their accuracy and reliability. Then, we processed and analyzed the data using statistical methods and obtained the statistical characteristics of porosity, tortuosity and other parameters. Next, we built mathematical models to describe the relationship between the parameters of the circle distribution and the tortuosity, and we verified and corrected the model using experimental data. Finally, we discuss and analyze the experimental results and draw our conclusions.

During the data processing and analysis, we adopted various methods and tools, such as SPSS and MATLAB, to ensure the accuracy and reliability of the data. Meanwhile, we also performed repeated experiments and validation of the experimental results to ensure the stability and reproducible of the results.

3. Display and interpretation of the results

In this section, we present and analyze experimental results where tortuosity is

influenced by the parameters of the circle distribution. We observe the change of tortuosity in porous media by changing the circle distribution parameters, such as radius, distribution density and the position of the circle.

The experimental results show that the circle distribution parameters significantly affect the tortuosity of the porous medium. We visually demonstrate this effect through both images and graphs. In the image, the morphological changes of the porous medium under different circle distribution parameters, and the increasing trend of the tortuosity can be clearly seen. At the same time, we also statistically and analyzed the experimental data through charts, so as to show the experimental results more intuitively.

The image shows that the tortuosity of the porous medium decreases when the radius of the circle increases. This is because as the radius of the circle increases, the channels between the pores become wider and the fluid can flow more smoothly, thus reducing the tortuosity. We also found that the tortuosity of the porous medium also decreases when the density of the circle distribution increases. This is because the increase in the density of the circular distribution increases the connectivity between the pores, and the fluid can flow more smoothly, which can also reduce the tortuosity.

The experimental results match our expectations and verify the effect of the circle distribution parameters on the tortuosity of the porous medium. The circular distribution parameters shape the flow path of the fluid by changing the morphology and distribution of the pores, thus changing the tortuosity of the porous medium.

The radius of the circle is one of the important factors affecting the tortuosity. In the porous media, the morphology and size of the pore directly influence the fluid flow. As the radius of the circle increases, the channel between the pores becomes wider and the fluids flow more smoothly, thus reducing the tortuosity. This finding has important implications for the optimized design of the porous media, which

can improve the mobility energy of the fluid by adjusting the circular radius to change the tortuosity of the porous media.

The circle distribution density also had a significant effect on the tortuosity. When the circular distribution density increases, the connectivity between the pores increases, and the fluids flow more smoothly. This finding can also be used in the optimal design of the porous media, which changes the tortuosity of the porous media by adjusting the density of the circular distribution.

In addition to the circle radius and the density of the circle distribution, the center position also has some influence on the tortuosity. When the position of the center changes, the distribution and morphology of the pore will also change, which affects the flow path and tortuosity of the fluid. Therefore, the influence of the center position also needs to be considered when optimizing the design of the porous media.

4. Trend prediction of bending degree with circle distribution parameters

The prediction of the trend of tortuosity with circular distribution parameters is a crucial link in the study of porous media. By analyzing and summarizing the experimental data, we can adopt suitable prediction methods to predict the trend of tortuosity with the parameters of the circle distribution. This prediction process can not only help us to deeply understand the physical characteristics of the porous media, but also can provide an important theoretical basis and guidance for its application.

In terms of trend prediction methods, we first need to consider the accuracy and reliability of the experimental data. Through the rigorous processing and analysis of the experimental data, we can obtain more accurate circle distribution parameters and tortuosity data. Based on this method, we can adopt statistical methods such as linear regression and nonlinear fitting to predict the trend of tortuosity with the parameters of the circle distribution. Among them, the linear regression method is applicable to the data distribution is more uniform and the

trend is more obvious, while the nonlinear fitting method is applicable to the data distribution is more complex and the trend is not obvious.

Through the analysis and discussion of the prediction results, we can find that the degree and mechanism of the circle distribution parameters on the tortuosity are complex and diverse. Specifically, the increase of the circle distribution parameter may lead to an increase in tortuosity, but the speed and amplitude of the increase will be affected by many factors, such as the pore structure of porous media, particle shape, etc. There may be a nonlinear relationship between the circle distribution parameters and the tortuosity, which requires further investigation and exploration.

In practical applications, we can use the prediction results to optimize the design and preparation process of porous media. For example, when preparing porous materials, we can control the circle distribution parameters by adjusting the parameters such as the shape and size of the particles, thus achieving the precise control of the tortuosity. This will help to improve the permeability and mechanical properties of porous materials, and provide a broader space for the application of porous materials in energy, environmental protection and other fields.

Trend prediction of tortuosity with circle distribution parameters is an important task in porous media research. Through reasonable prediction methods and analysis means, we can have a deep understanding of the influence mechanism and law of circle distribution parameters on the tortuosity, and provide more reliable theoretical basis and guidance for the research and application of porous media.

5. Analysis of the combined influence of other factors

1. Temperature, pressure, and other external conditions are considered

In the development of oil and gas fields, external conditions such as temperature and pressure can significantly affect the porous medium porosity and tortuosity,

and then affect the flow of the fluid and the oil storage capacity of the reservoir. The effects of temperature and pressure on porosity and tortuosity will be discussed in detail below.

Temperature is one of the important factors affecting the porosity and tortuosity. As the temperature increases, the molecular motion in the medium accelerates and the pore space increases, leading to increased porosity. The temperature increase can also reduce the flow resistance of the fluid in the pore, making the pore structure relatively straight, thus reducing the tortuosity. This change facilitates the flow and penetration of the fluid and improves the permeability of the porous medium. However, excessively high temperatures may also lead to the thermal expansion and mineral dissolution of the reservoir rocks, thereby changing the pore structure and permeability of the porous medium.

The effect of temperature change on the porosity and tortuosity of the porous medium is complicated. Detailed thermal fluid simulations and petrophysics experiments are required to accurately assess the effect of temperature on the porous medium. By simulating the fluid flow and rock reaction at different temperatures, the changes of porous medium porosity and tortuosity can be predicted, which provides an important basis for the development scheme.

Pressure is another important factor affecting the porosity and tortuosity of the porous medium. As the pressure increases, the flow resistance of the fluid in the pore increases, making it difficult for the fluid to enter the tiny pores. At the same time, high pressure may deform the pore structure, resulting in increased tortuosity. This change will reduce the permeability of the porous medium, making it difficult to flow and mine the fluids.

In the development of oil and gas fields, the effect of pressure change on the porosity and tortuosity of the porous medium is also complicated. Detailed fluid simulations and petrophysics experiments are also required to accurately assess the effect of pressure on the porous medium. By simulating the fluid flow and rock

reaction under different pressures, the change of porosity and tortuosity can be predicted to provide the basis for the development scheme.

2. Description of the multicomponent gas competitive adsorption phenomenon

When exploring the behavior of multicomponent gas in random porous media, the competitive adsorption phenomenon is an important factor that cannot be ignored. When multiple gases exist in the same pore system, they compete with each other to occupy the adsorption position of the pore. This competition is not only dependent on the physical properties of each gas, such as molecular size, shape, polarity, etc., but also affected by various factors such as temperature, pressure, and pore structure.

There are significant differences in the adsorption capacity of different gases in the pores during competitive adsorption. This results in some gases being able to occupy favorable positions in the pore more efficiently, thus hindering the access of others. This difference in the adsorption capacity is mainly derived from the interaction force between the gas and the pore surface. When the attraction between the gas molecule and the pore surface is strong, the adsorption amount of the gas in the pore will increase. Conversely, when the attraction is weak, the adsorption volume decreases.

The effect of the competitive adsorption phenomenon on the porosity and tortuosity is also significant. Because the different gases in the pore, their occupation of the pore space will be different. When some gases occupy more positions in the pore, the pore space will decrease, thus reducing the porosity. The gas adsorbed on the pore wall also makes the pore structure more complex and curved. These changes will affect the diffusion and permeability properties of the gas, and then affect the overall performance of the porous media.

The phenomenon of competitive adsorption of a multicomponent gas in a random

porous medium is a complex and important process. It not only affects the distribution and adsorption capacity of the gas in the pores, but also changes the pore structure and tortuosity of the porous media. In order to understand this phenomenon deeply, in-depth experimental research and theoretical analysis are needed. By exploring the competitive adsorption rules of different gases in the pores, it can provide a more accurate guidance for the preparation and application of porous materials.

3. Model modification suggestions under the action of comprehensive factors

When exploring the porosity and tortuosity problems of a random porous medium, it is not enough to only consider the physical characteristics of the medium itself. To characterize these properties more accurately, we need to introduce more parameters, including external conditions and internal factors. External conditions such as temperature and pressure, they have significant effects on the porosity and tortuosity of the porous medium. For example, increasing temperature causes thermal expansion of the dielectric material, changing the size and shape of the pore, and increasing pressure presses the pore, resulting in a decrease in porosity. Internal factors include multi-component gas competitive adsorption, which will affect the distribution and diffusion of gas in the pore, and then affect the measurement of porosity and tortuosity.

To introduce these new parameters into the model, we can adopt a combination of experimental studies and theoretical analysis. Through experiments, we can observe the variation of porosity and tortuosity of porous media at different temperatures and pressures, and the influence of multicomponent gas competitive adsorption on the pore structure. Then, we can use these experimental data to correct the original model, so that it can better reflect the actual situation.

After introducing the new parameters, we need to correct the original model

formula. This correction procedure should be based on experimental data and theoretical analysis to ensure that the corrected model can more accurately describe the porosity and tortuosity of random porous media. The modified model formula should be able to reflect the influence of external conditions such as temperature and pressure on porosity and tortuosity, as well as the influence of internal factors such as multi-component gas competitive adsorption on the pore structure.

In the process of correcting the model formula, we need to conduct a lot of computations and simulations to verify the accuracy and applicability of the model. We can use advanced computer technology and numerical simulation methods to simulate and verify the modified model to ensure its good results in practical applications.

To verify the accuracy and applicability of the modified model, we can select some specific cases for our analysis. These cases should be representative and able to cover different external conditions and internal factors in order to test the performance of the model comprehensively.

For example, we can select a porous rock sample for analysis to measure its porosity and tortuosity at different temperatures and pressures, and its adsorption characteristics under different gas compositions. We then compared these experimental data with the corrected model to assess the accuracy and applicability of the model. Through such case analysis, we can better understand which factors affect the porosity and tortuosity of random porous media, and how these factors affect the permeability and gas storage capacity of porous media.

6. Conclusion and Outlook

1. Review of the main research findings

In the field of random porous media, porosity and tortuosity properties are key

factors determining the overall performance of the media.

This study provides a comprehensive analysis of the porosity and tortuosity of random porous media. By employing advanced experimental techniques and computational methods, we find that porosity and tortuosity have significant effects on the permeability, heat transfer and electrical conductivity of the medium. Specifically, the porosity determines the storage capacity of the fluid in the medium, while the tortuosity affects the path of the fluid flow in the medium. Therefore, an accurate description of the porosity and tortuosity properties of random porous media is crucial to predict the overall performance of the media.

In the study, we performed a detailed analysis of the circle distribution parameters. The circle distribution parameters are important parameters for describing the size and shape of the pores in a random porous medium. Through a thorough analysis of the circle distribution parameters, we found its significant advantages in describing the porosity and tortuosity. Specifically, the circular distribution parameters enable a more accurate description of the pore size and shape, thus revealing the influence of the pores on fluid flow and heat transfer. At the same time, the circle distribution parameter can also effectively reflect the heterogeneous and anisotropy properties of the media, providing a more accurate basis for the prediction of the media performance.

Based on the above findings, we propose specific suggestions and directions for the optimization of random porous media. We should improve the permeability and heat transfer properties of the medium by adjusting the porosity and tortuosity properties of the medium. Specifically, the effective regulation of the porosity and tortuosity can be achieved by changing the particle size, shape and arrangement of the medium. We should also consider the heterogeneity and anisotropic properties of the medium, and adopt more refined models and algorithms to describe the microstructure of the medium. This will help us to predict the overall performance of the media more accurately and provide a more reliable basis for practical

applications.

2. Analysis of the existing problems and limitations

When exploring the research results and their limitations related to random porous media, we must face up to the main problems facing the current research and its inherent challenges.

The difficulty of data acquisition and processing is a major obstacle in random porous media studies. The structure of such media is complex and irregular, making data acquisition and processing extremely difficult. Traditional data collection methods often fail to meet the requirements of precision and depth of research, while high-precision and high-resolution data acquisition equipment is often expensive and complicated to operate. Due to the characteristics of random porous media, the data collection process is prone to various interference and errors, such as noise, instrument error, etc., which further increase the difficulty and accuracy of data processing. Therefore, how to effectively obtain and process data from random porous media is an important topic in the current study.

There are still some shortcomings in the completeness of this study. Although we have conducted some exploration of the application of the circle distribution parameters in random porous media, many questions remain to be solved. For example, the application of circle distribution parameter is relatively limited and is mainly limited to certain types of porous media and flow conditions. Our depth of the circle distribution parameters is not enough, and our understanding of the internal physical mechanisms and influencing factors is lacking. These limitations all affected the breadth and depth of the study, preventing us from having a comprehensive understanding of the properties and behavior of random porous media.

There are still some limitations in the practical application of this study. Although we propose some optimization suggestions and solutions, these suggestions are

based on theoretical analysis and experimental simulation, and their effect in practical application needs to be further verified. Due to the complexity and variability of practical applications, our recommendations may not be fully adapted to all practical situations. Therefore, in practical application, we need to combine the actual situation for specific analysis, and adjust and optimize according to the actual needs.

3. Future research direction and trend prediction

Further study of data acquisition and processing is indispensable in the future direction of randomized and porous media research. At present, although some progress has been made in data acquisition and processing technologies, some challenges remain. For example, the accuracy and reliability of data acquisition equipment still need to be improved, especially in extreme environments or complex porous media, and the acquisition of data still faces great difficulties. The accuracy and efficiency of data processing methods also need to be further improved to better extract useful information from massive amounts of data. To address these challenges, future research will focus more on innovation in data acquisition and processing technologies, and develop more efficient and accurate data acquisition equipment and data processing algorithms to improve the accuracy and reliability of research.

The application range of the circle distribution parameter in the random porous media also needs to be expanded urgently. At present, the circle distribution parameters are mainly used to describe the characteristics of porosity and tortuosity, but in practice, other characteristics of porous media, such as permeability and thermal conductivity, also have an important impact on its performance. Therefore, future studies will aim to extend the circle distribution parameters to the description of more properties for a more comprehensive characterization of the porous media. Mathematical models of circle distribution

parameters also need to be further improved and optimized to better accommodate the characteristics and application scenarios of different porous media.

In-depth research combined with practical applications is an important trend for future studies on random porous media. At present, most of the studies on random porous media remain at the theoretical level and lack the support of practical application. In order to better apply the research results to the actual production, the future research will pay more attention to the cooperation with the industry, in-depth understanding of the actual needs and problems, and put forward more targeted optimization suggestions and application schemes. For example, in the process of oil and gas exploration and development, geological characteristics and logging data can be combined to build more accurate random porous medium models to improve the efficiency of porous medium identification and development. In the field of environmental protection, the stochastic porous medium model can be used to simulate the migration and diffusion process of pollutants to provide scientific basis for environmental governance.

7. References

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