

# Research on Temperature Simulation of Underground Coal Gasification Wellbore

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**Abstract:** This study aims to integrate the theoretical distribution calculation of temperature and pressure during the gasification process through the derivation of heat conduction, thermal radiation and pressure control theory in the underground coal gasification process, and analyze the temperature of the underground coal gasification process through finite element modeling. Field influencing factors and pressure changes over time. It is of great significance to obtain the relevant parameters of the gasification chamber in the underground coal gasification process.

**Keywords:** Gasification process, Finite element modeling, Underground coal.

## 1. Introduction

The progress of science and technology and society has given birth to a new scientific and technological revolution. All countries are developing their own energy utilization methods from high carbonization to low carbon and non-carbonization. Energy is an important foundation for economic and social development. China's coal energy reserves are second only to Russia and the United States. Rich coal resource reserves ensure the needs of industrial and agricultural production [1-3]. With the continuous innovation of technology, new energy technology has gradually become the focus of energy development. However, due to the relative lack of oil and natural gas resources in our country, coal accounts for far more than other resources in energy utilization [4]. According to my country's power industry statistics in 2015, coal-fired power generation accounted for 67.7% of my country's total power generation, which also led to the total installed capacity of coal power generation accounting for 58.5% of the country's total installed power generation capacity. Data released by the China National Electric Power Planning Institute in July 2021 show that China's total energy consumption has increased from 4.53 billion tons of standard coal in 2016 to 5.13 billion tons in 2021, with an average annual growth rate of more than 3%. Among them, coal The proportion increased from 2.71 billion tons in 2016 to 2.93 billion tons, with an average annual growth of more than 0.3% [5-7]. From a global perspective, China is still the world's largest coal consumer market. According to relevant forecasts, China's coal consumption is expected to account for 40% or more of the world's total by 2040. In terms of structure, coal accounted for 62.73% of total energy consumption in 2015, which dropped to 56.83% in 2020; the proportion of non-petrochemical energy increased from 12.09% to 15.86% [8]. As shown in Figure 1, my country's energy consumption changes show an increasing trend year by year. Coal is not only one of the driving forces of global economic development in China, but also the main cause of global climate warming and greenhouse gas emissions [9-11]. It can be seen that driven by national policies and high energy consumption, it is imperative to change the existing energy utilization methods [12-15].

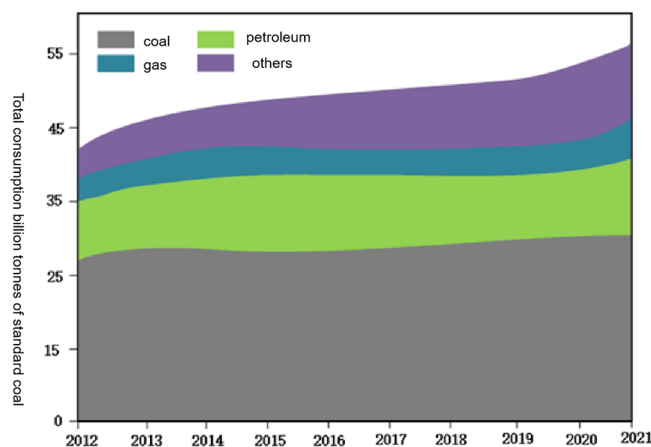


Figure 1. 1's total energy consumption trend from 2012 to 2021

China proposed at the 75th United Nations General Assembly to take strong measures in energy consumption and utilization to cope with the depletion of global non-renewable resources [16]. It is pointed out that efforts should be made to achieve carbon neutrality in 2060, and to achieve carbon neutrality, coal resources are the first to be used, and the use of coal resources is bound to change due to the proposal of carbon neutrality [17-18]. China's coal consumption accounts for a high proportion, and the proportion of major energy sources is shown in Table 1 [19]. In the context of global advocacy for low-carbon economic development, clean utilization of coal has become a key development direction. Reducing the consumption of fossil resources such as coal is a new trend in my country's energy development. With green development as the center, we should increase the role of non-fossil energy and other clean energy in social and economic development, and increase the proportion of clean energy utilization. The transformation of the world's energy structure is imperative. According to the International Energy Agency's predictions, nuclear energy, hydropower and renewable resources will dominate the energy supply in the next few decades, and the world's coal utilization is expected to slow down or even decrease [20-22]. Even so, under the influence of national conditions of various countries and the influence of external factors, fossil energy cannot be completely

replaced by other energy sources in the short term. It is still the main energy source for the development of the world economy. According to predictions from relevant departments, it is expected that by 2035 In 2015, coal's proportion in the world's energy supply will drop from 85% in 2015 to around 75% [23-25]. Because of this, how to improve coal utilization efficiency while reducing environmental pollution has become the focus of coal resource utilization in the future. At the same time, clean coal technology has emerged and has become the direction of discussion and development by researchers from various countries.

**Table 1.** My country's energy consumption share from 2012 to 2021

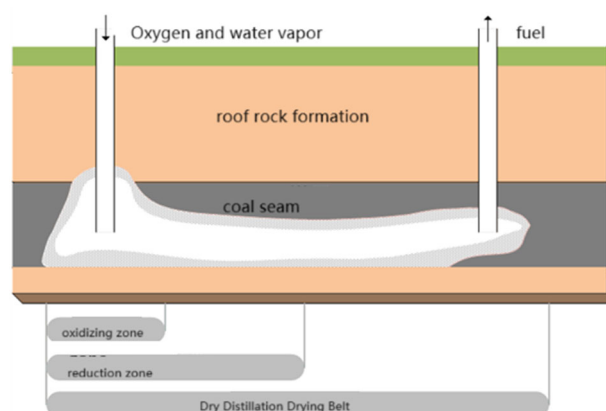
year (year)	coal	oil	natural gas	non-fossil energy
2012	69.3	17.3	3.9	9.5
2013	70.1	16.7	4.5	8.5
2014	68.6	17.1	4.7	9.6
2015	67.5	17.2	5.2	10.1
2016	65.7	17.5	5.6	11.2
2017	63.6	18.4	5.7	11.2
2018	62.1	18.6	5.9	12.0
2019	60.5	18.9	6.3	13.2
2020	59.6	19.0	7.1	13.9
2021	58.7	19.1	7.9	14.2

There are two main ways to cleanly utilize coal. One is coal post-processing technology [26]. The mined coal is subjected to advanced desulfurization, low NO<sub>x</sub> combustion technology, advanced denitrification technology, dust removal technology, CO<sub>x</sub> capture technology, Above-ground coal gasification technology (IGCC) and other treatments achieve the purpose of clean utilization. The second is underground coal gasification technology (Underground Coal Gasification, UCG) [27], which is also the mainstream clean utilization method of coal worldwide. Deep coal accounts for a large amount in my country. Reasonable use of temperature field distribution and gasification cavity parameter measurement in the underground coal gasification process is one of the important means to improve gasification recovery rate.

## 2. Basic Principles of Underground Coal Gasification

The basic principle of underground coal gasification technology is to introduce high-temperature oxygen and water vapor into the underground coal layer through an injection well, and at the same time ignite the coal through an ignition device. The coal undergoes various chemical reactions with oxygen and water vapor in the gasification chamber and produces The process of producing coalbed methane [28] is shown in Figure 2. It can be seen from the figure that the mining process requires drilling two wells, one is an injection well and the other is a gas production well. The two wells are oriented by drilling horizontal wells. Hole connectivity [27 - 29]. The ignition device that goes down the well with the coiled tubing is ignited at the bottom of the well, and oxygen and water vapor are injected at the gas injection port and ignited at the bottom of the well. At this time, a combustion zone dominated by chemical reactions such as coal combustion will be formed at the bottom of the well. According to different reactions, different temperatures and

gas group components, the reaction area in the gasification channel can be divided into a combustion area, a reduction area, and a pyrolysis drying area. In the oxidation zone, the oxidation reaction will cause the temperature of the coal seam to rise rapidly. The temperature generally reaches the temperature range of 800°C-1000°C. In the reduction zone, the temperature is generally in the range of 600-900°C, the length of the reaction zone is also 1.5-2.4 times that of the oxidation zone, and the pressure level is 0.2-0.3 MPa. After this reaction, the gas enters the pyrolysis drying zone, and the temperature is generally 200-700°C. The main reaction process is the cracking and evaporation of high-moisture coal, which also includes polycondensation and adsorption reaction processes.



**Figure 2.** Schematic diagram of underground coal gasification reaction

## 3. Simplified Model of Underground Gasifier

The design of the underground coal heat transfer model is the basis for the study of the temperature field of the entire underground coal gasifier and gasification wellbore. Reasonable design of the underground coal heat transfer process that is consistent with the real situation is of great significance to the numerical simulation of the entire model. Underground coal gasification is an extremely complex process. It includes complex flow, heat transfer, and mass transfer processes, as well as numerous chemical reactions. As the coiled tubing is withdrawn, its mass and heat transfer space changes. It is constantly changing with the movement of the flame working surface in the combustion control area and the combustion position. Facing such a complex gasification environment, establishing a reliable underground coal gasification combustion model is the most important part. The simplified model is shown in Figure 3.

In order to simulate the real heat transfer process of underground coal gasification, in the numerical simulation study, the heat transfer involved in the model was combined according to the fluid mechanics equation, energy conservation equation, rare matter value transfer, solid heat transfer, Darcy's law and turbulence solution equation. Conducted in two parts. Part One: For the formation and wellbore passage, the wellbore injection port injects oxygen and water vapor with a temperature of 100°C and a ratio of 1:1 to exchange heat with the formation through the wellbore, thereby affecting the change of the wellbore temperature. Part 2: Using the thermal radiation generated by coal combustion at the ignition point in the air-fuel zone as the heat source, the thermal radiation changes the wellbore temperature in the

special underground environment, which in turn affects the working status and lifespan of the electronic components inside the wellbore.

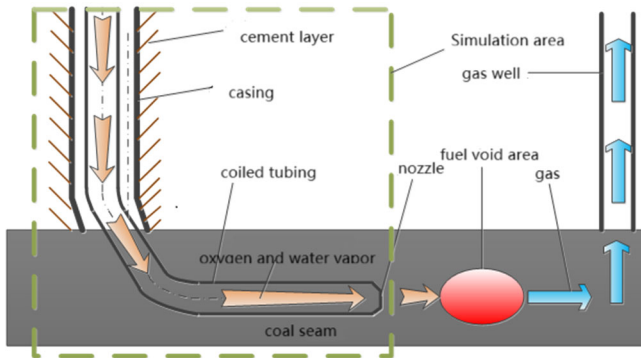


Figure 3. Simplified diagram of underground coal gasification process

## 4. Gasification Wellbore Temperature Field Simulation

### 4.1. Model establishment

Based on the simplified model of the coal underground gasifier in 3, the model is further simplified and set. According to previous research on heat transfer between the wellbore and the formation and combined with the formation depth of 1500-2000m in the selected formation in this study, the influence of the cement layer and casing on the heat transfer between the wellbore and the formation is ignored and simplified as the wellbore and Heat transfer between formations. In the horizontal direction, the combustion air zone is used as the heat source of the heat radiation generated by the gasification reaction in the coal underground gasifier,

and the main factor affecting the wellbore temperature in the coal underground gasification reaction is the combustion reaction of coal in the combustion air zone, and Simplify this simulation model. Based on the previous research results and data on the temperature field simulation of underground coal gasification, and with reference to the formation range of 1000-3000 meters in deep coal in my country, a simplified initial model of underground coal gasification was established. The gasified coal seam is Near horizontal coal seam. After reviewing the data, it was found that under ideal circumstances, for every 100m increase in formation depth, the temperature of the ladder rises by 3°C. In this study, the depth of the formation within 2000m was used as the modeling and simulation depth data. The entire formation has little impact on the temperature of the wellbore, so The study is carried out in the form of local 1500-2000m depth simulation. The equation of formation temperature changing with depth is as follows:

$$T = 45 + 0.3 (2000 - y) \quad (1)$$

In the formula, T (°C) is the formation temperature, and y (m) is the depth of the built model.

Considering that the shape of the combustion zone in conventional wellless underground coal gasification is an "elliptical ring track" and the physical field model needs to take into account fluid mechanics, combustion chemical reactions, CFD modules , etc., Comsol simulation software was used to establish the initial physics field model. The overall size of the model is: length 100m, width 500m, in which the depth and thickness of the stratum and coal seam are 460m and 40m respectively. Material selection is shown in Table 2

Table 2. Thermal conductivity and parameters of gases at normal temperature

Components	Thermal conductivity x 10 <sup>3</sup> / W/(m·K)	n
H <sub>2</sub>	172.69	0.87
CH <sub>4</sub>	30.65	1.43
CO	23.24	0.90
CO <sub>2</sub>	14.86	1.32
O <sub>2</sub>	25.84	0.89

In the finite element model, choosing the physical field that conforms to the built model determines whether the numerical simulation can produce realistic results. In this model, the application of rare substance transfer, solid heat transfer, turbulence (k- E) and Darcy's law are selected based on the previous research results and the influence of the special underground environment . Porous media are present in many natural and man-made systems, and the need for advanced porous media modeling spans many industries and application areas, such as filtration processes, pulp and paper drying, and fuel cell processes. In the single physical field of rare substance transfer, linear units are selected for discretization of the two substance concentrations. The diffusion coefficients of oxygen and water vapor are 1e-5[m<sup>2</sup>/s] and 1e-5[m<sup>2</sup>/s] respectively, and is isotropic. The velocity field of the convection field is coupled with the velocity in the turbulence field, and the concentration of both in the injection port is 1 mol/m<sup>3</sup>. The solid heat transfer module also uses the turbulent velocity field as an interface. The entire model is in a solid state, and the relationship

between formation temperature and depth is equation (3-1). The turbulence part of the physical model uses oxygen and water vapor as the main body, and the turbulence model type adopts Reynolds average simulation (R ANS). In the turbulence physics field, the input velocity is the normal cut-in velocity U<sub>0</sub> of 3m/s, the exit is static pressure and the backflow needs to be suppressed to obtain the complete turbulence model simulation effect, and the turbulence condition is to specify the turbulence length and intensity. Darcy's law runs through the entire physical model, and the permeability model attribute is isotropic to ensure that the model will not have additional attribute conflicts.

### 4.2. Model solution

In the model, before the gasifier is ignited (t<0), the initial temperature is normal temperature, set to 25 ° C, and the area around the combustion zone is insulated. There is a rock layer above the coal seam roof, and the heat radiation generated in the combustion zone of the underground gasifier can be transferred to the rock layer. The underground gasifier is

surrounded by concrete supports, and the surface and the environment exchange heat by convection heat transfer. The

basic setting parameters of the model are shown in 3.

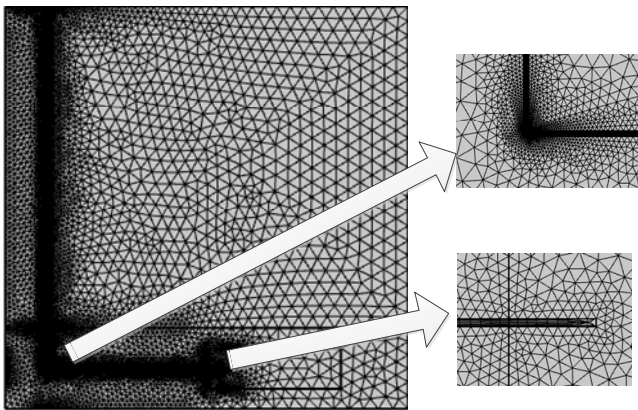
**Table 3.** Model basic parameter table

parameter	unit	Roof similar material
Internal friction angle ( $\Phi$ )	$^{\circ}$	32.18
Cohesion (c)	M p _	0.0265
Poisson's ratio (v)	1	0.024
Density ( $\rho$ )	K g/m <sup>3</sup>	1516
Linear expansion coefficient	K <sup>-1</sup>	3.4 X 10 <sup>-6</sup>

### 4.3. Grid analysis

According to the different structure of the built model and observing its characteristic structure, the finite element software C OMSOL is used to mesh it. When dividing the mesh, it should be noted that as the mesh density increases, the iteration error of the solution model will decrease, and conversely the rounding error will increase. Therefore, a method is needed to optimize the mesh. The specific method is to observe whether the simulation results of the simulation model change with the change of the number of mesh divisions during the simulation process. When the mesh division reaches a certain number, if the simulation results no longer change obviously with the change of the mesh, changes, the meshing can be stopped at this time, and the simulation results are also reliable.

When dividing the mesh in this article, the entire model is first divided conventionally, and then the model is solved. According to the results of the model simulation, the meshing detail is gradually increased until it is compared with the calculation result of the previous meshing. , if the difference between the two calculation results is within 3%, it can be considered that the number of divisions is reliable. If it continues to increase, the reliability of the results can also be improved, but the required calculation time and calculation amount will double. Therefore, There is no need to proceed with subsequent meshing. Jin Guo made many comparisons and verifications and found that when the grid size was determined to be 0.001m, the number of grids in the simulation model reached 64099, and the calculation error was about 3%. Therefore, this meshing indicator was selected for subsequent parameterization. Solving lays the foundation.



**Figure 4.** Mesh division diagram

### 4.4. Boundary condition settings

Regarding the wellbore temperature field distribution and combustion zone expansion boundary conditions during the underground coal gasification process, the boundary

conditions are constraints on the physical calculation process. According to the basic structural characteristics of the gasifier in the underground coal gasification process in this study, and combined with previous experience in simulating temperature distribution in the combustion air zone and wellbore, there are mainly the following boundary conditions in this simulation [ 52 ] .

(1) Injection port boundary conditions: For the inlet boundary conditions, we set the ratio of oxygen and water vapor in the injection wellhead gas components to 1:1, and set the injection flow rate, temperature and pressure. The actual coal underground process The above two parameters during the gasification process can be measured with the gas flow meter and gas component analysis instrument provided by the system.

(2) Outlet boundary conditions: The outlet boundary conditions are tentatively set as the concentration gradient is zero, the outlet is subject to radiation from the chemical reaction in the fuel air zone, and the ambient temperature is set to normal temperature. If there is no thermal radiation, the temperature gradient is naturally zero. In this study, coal combustion in the combustion air zone has strong thermal radiation to the wellbore outlet, so the concentration gradient was chosen to be zero.

(3) Stratum (rock layer) boundary conditions: The stratum is mainly rock, ignoring the influence of other materials, and the rock layer boundary conditions are more complex. According to previous research, the rock layer boundary conditions are usually simplified to adiabatic and non-mass transfer boundary conditions. .

Of course, in the underground gasification process of coal, the rock layer is thermally conductive and there are gaps, so even if there is sediment on the ceiling, it can pass through the gas part, and boundary displacement conditions must be considered. During the simulation process, these complex influencing factors were ignored and attributed to adiabatic or third type boundary conditions [ 30 ] .

The boundary balance equation for heat exchange at the inlet boundary is as follows:

$$\left( \sum_{i=1}^n f_i h_i \right)_{y=0^-} = \left( \sum_{i=1}^n j_i h_i \right)_{y=0^+} - \left( k \frac{\partial T}{\partial y} \right)_{y=0^+} \quad (2)$$

The temperature and flow velocity of the inlet boundary in the equation are known, and the gradient of its inlet position and temperature is obtained from the intermediate calculation results. When the temperature gradient at the inlet drops to zero, then  $y=0^-$  (inlet air temperature) is the same as  $y=0^+$  (inlet temperature).

The boundary balance equation of heat exchange at the outlet boundary is as follows:

$$-K \frac{\partial T}{\partial y} = S(T^4 - T_\infty^4) \quad (3)$$

For the outlet, assuming there is radiation heat transfer at the outlet (which can be ignored when the temperature is low), the coefficient S includes the emissivity, Stefan-Boltzmann constant and shape factor. When radiation is assumed to be negligible, the equation simplifies to a temperature gradient of zero.

The centerline boundary condition equation is as follows:

$$\frac{dF}{dx} = 0 \quad (4)$$

For the center line, it is a condition of symmetry on both sides, so the gradient of any parameter is zero, and F represents any parameter, including temperature and component concentration.

Rock layer boundary condition equation:

(1) For the boundary equation of adiabatic rock layers,  $\frac{dT}{dz} = 0$  the heat flow is zero;

(2) If it is assumed that there is heat exchange with the rock layer boundary, there are two situations. One is considered to be a constant (known) temperature of the boundary rock layer, which is the third type of boundary condition with finite thermal conductivity based on the Nusselt coefficient. Another assumption is that the temperature of the rock formation changes, and it is necessary to assume that there is a certain relationship between the thermal conductivity and the flowing medium.

The inlet boundary mass transfer equation is as follows:

$$f_i = j_i \quad (5)$$

That is, the flow rate at the inlet is known, and is measured by a flow meter and a flue gas analyzer during the actual underground coal gasification process.

arrive.

The outlet boundary mass transfer equation is as follows:

$$\frac{dc_i}{dy} = 0 \quad (6)$$

For the outlet boundary, it is assumed that there is no potential difference in the component concentrations.

The centerline boundary condition equation is as follows:

$$\frac{dF}{dx} = 0 \quad (7)$$

For the center line, it is a condition of symmetry on both sides, so for any parameter, its gradient along the x direction is zero. F represents any parameter, including temperature and component concentration.

The rock boundary condition equation is as follows:

(1) For the non-mass transfer rock layer boundary equation, it is  $\frac{dy_i}{dz} = 0$ .

(2) There is partial mass transfer phenomenon, and it is assumed that the mass transfer is related to the properties of heat transfer.

Mechanical boundary conditions:

The bottom and sides of the model adopt displacement boundary conditions, which limit horizontal displacement and

allow vertical displacement; the top

Stress boundary conditions are adopted, considering that the actual burial depth of the coal seam is 1900m, so it is also necessary to apply stress boundary conditions on the top of the model.

A load of 5.5MPa is applied, and a horizontal initial stress of 2.2~2.8MPa is applied from top to bottom inside the model.

Yield criterion [ 31 ] :

The stress combination that begins to produce plastic deformation is called the yield condition. For a scalar function called the yield function number, suppose

$$f = 0 \quad (8)$$

This value was simulated using the Drucker-Bragg yield criterion, which is a modification of the Coulomb-Moir yield criterion

Unlike the Coulomb-Moore criterion, which takes into account the influence of intermediate principal stresses and the influence of hydrostatic pressure on plastic analysis, the Drucker-Bragg yield criterion is more convenient. Experts in rock mechanics at home and abroad admit that the Coulomb-Mohr yield criterion and the Drucker-Bragg yield criterion agree well with rock failure conditions [31], and their yield function can be expressed as:

$$f = \alpha I_1 + J_2^{1/2} - S \quad (9)$$

$$I_1 = \sigma_1 \sigma_2 + \sigma_1 \sigma_3 + \sigma_2 \sigma_3 \quad (10)$$

$$J_2 = \frac{1}{6} [(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2] \quad (11)$$

$$\text{In the formula } \alpha = \frac{\sin \varphi}{(9 + 3 \sin^2 \varphi)^{1/2}}, S = \frac{3C \cos \varphi}{(9 + 3 \sin^2 \varphi)^{1/2}};$$

C is the cohesion force and the  $\varphi$  internal friction angle,  $I_1$  represents the first invariant of stress,  $J_2$  represents the second invariant of the stress deviator tensor, which  $\sigma_1$ 、 $\sigma_2$ 、 $\sigma_3$  respectively represent the first principal stress, the second principal stress and the third principal stress [ 31 ] .

#### 4.5. Analysis of the impact of temperature simulation results

After the calculation settings are completed, the simulation is started in Comsol using the known conditions and the set physical field boundary conditions. When the iteration residual reaches the convergence limit, the calculation ends. After the calculation was completed, the calculation details were found to be 55,856 degrees of freedom and 142,320 internal nodes in the model. Since the heat transfer in the wellbore and the thermal radiation in the fuel space zone during the underground coal gasification process are weakly coupled problems, the simulation process was solved by indirect coupling . method. First, you need to set up the temperature field by setting the thermal boundary, then calculate the corresponding stress of the temperature field, perform a parameter sweep, and then calculate the results in different modes.

### 4.5.1. Temperature changes with time

Taking the wellbore local model simulation as one of the model setting conditions, within the 2000m stratum range, the stratum and coal seam range of 1740m-1900m with a depth of 160m and a width of 100m is used as the research object. Due to factors such as calculation time and huge amount of calculation, the entire reaction time of this model is set to 10 hours. As shown in Figure 3, the figure shows the expansion of the fuel space zone and the wellbore temperature distribution at different times. The formation temperature gradient is calculated according to Formula 3-1: as the depth increases from 1740m to 1900m, the formation temperature gradually increases from 52.2°C to 57°C. Based on this, the temperature field in this depth range was selected to study the temperature evolution rules of underground coal gasification in both vertical and horizontal directions. In the figure, when the reaction proceeds to 1 hour, you can see that coal combustion in the combustion air zone has begun to take shape. According to the set space size, it can be measured that the coal gasification reaction has advanced 2m. When the reaction proceeds to 4 hours, The set coal area of 5m\*10m is about half gasified. When the reaction proceeds to the 8th hour, the reaction zone continues to expand forward, with an expansion distance of 8.5 m . When the reaction proceeds to the 10th hour, the set Some of the coal is burned and gasified. At the same time, during the integrated gasification process, it can be seen that the temperature of the injection well bore pipe also increases due to thermal radiation generated by reactions such as combustion in the fuel space zone.

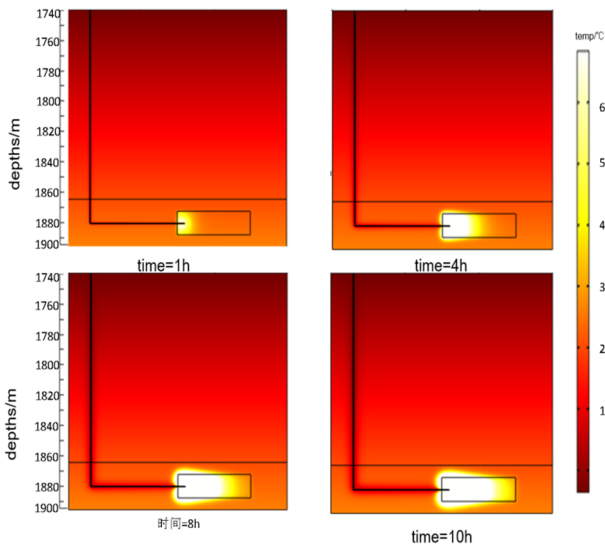


Figure 5. Distribution of reaction cross-section temperature in underground coal gasification chamber with 1

The heat source distance is the main factor affecting the temperature distribution of underground coal gasification wellbore. In order to obtain the specific temperature change of the wellbore, the distance between the temperature measurement point and the wellbore outlet is set to M. According to previous research on the temperature field , this paper adopts the method of trial mining points and sets the place where M = 2 m as the temperature collection point, and we get Figure 5 shows the data graph of temperature changes over time. It can be seen from the graph that as the reaction continues and the fuel space zone expands, the temperature at the temperature measurement point changes with time. In the first 2.5 hours of reaction time, because the ignition point is

close to the wellbore, the forward expansion distance of the reaction is short, and the space in the fuel space is small, the temperature here increases from 0°C to 323°C relatively quickly, with the highest temperature rise. The speed reached 129.2°C/h. When the reaction time exceeds 2.5 hours, as the combustion control zone expands and the reaction moves forward, the temperature increase at this point tends to be slow, and the temperature of the local wellbore slowly rises with the increase of time until the set fuel air zone. When all reactions were completed, the highest heat transfer rate reached 24.3°C/h. At this time, the temperature at the temperature measurement point reached the highest point of 505.8°C and the temperature curve approached the level. It can be seen that during the underground coal gasification process, the temperature of the wellbore rises quickly at the beginning. When the combustion zone expands to a certain distance, the wellbore temperature gradually increases slowly until the reaction is completed, and the reaction repeats after the wellbore gas outlet retreats.

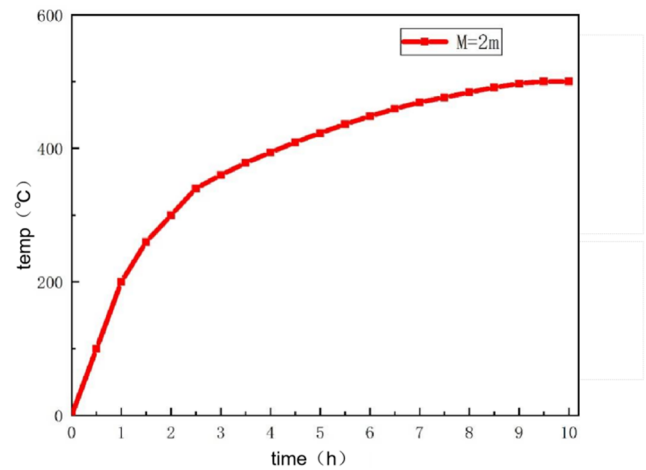
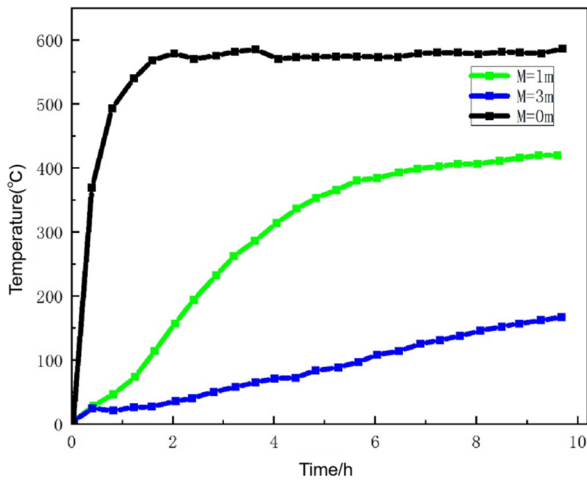


Figure 6. Temperature change at the distance M=2m from the temperature measurement point

### 4.5.2. Temperature changes with distance

The effect of thermal radiation on temperature points varies with distance. Traditional underground coal gasification process temperature measurement systems and methods focus on the high accuracy, high efficiency, low cost, and convenience of temperature measurement in the underground coal gasification zone, not to mention that the range measurement may also vary greatly. In this article, the temperature observation point distances of the heat sources are set to 0m, 1m, and 3m in this model. The temperature variation curves observed at different distances with time are shown in Figure 7. It can be seen from Figure 5 that at temperature measurement points that are different from the combustion point of the gasification chamber, the temperature changes with time. The farther away from the heat source, the smaller the temperature rise and the smaller the rise speed. When the coal in the underground combustion zone begins to undergo a chemical reaction after ignition, at the M = 0m observation point, when the reaction proceeds to the first hour, the temperature rises rapidly to around 568°C and fluctuates until the reaction is completed. The temperature of the wellbore at the temperature measurement point 1m away from the heat source slowly increased as the reaction progressed. When the reaction progressed to the 5th hour, the temperature increase rate gradually decreased and the temperature became

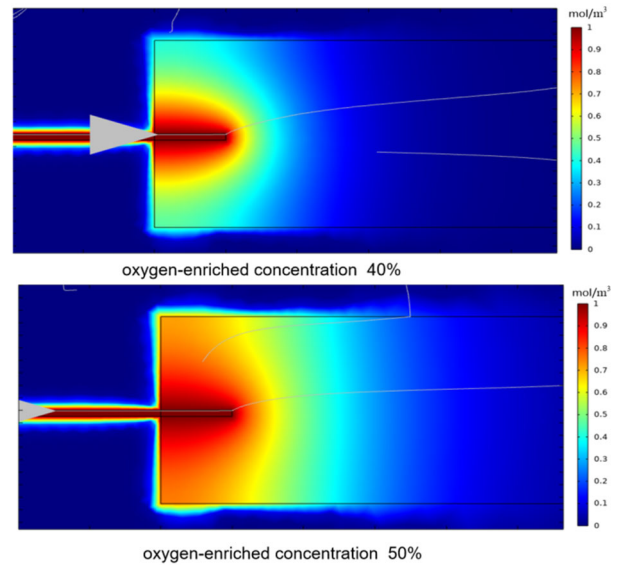
stable, fluctuating around 405°C. When M=3m, the temperature at the wellbore temperature measurement point slowly increases with time until the reaction is completed. The temperature at the temperature measurement point at this time is 188.5°C. At the same time, the temperature increase rate within this interval is 18.85°C/h. It can be seen that This temperature rise rate is the lowest and the temperature resistance decreases rapidly with distance. The temperature limit of conventional electronic components is 175°C. The electronic components in the wellbore at this distance are fully satisfied by airgel insulation materials and ensure that the electronic components work below 175°C. On the one hand, the use of electronic components is extended. life, on the other hand, through distance optimization, electronic components have better measurement results and working environment.



**Figure 7.** Temperature data of different temperature measurement point distances changing with time

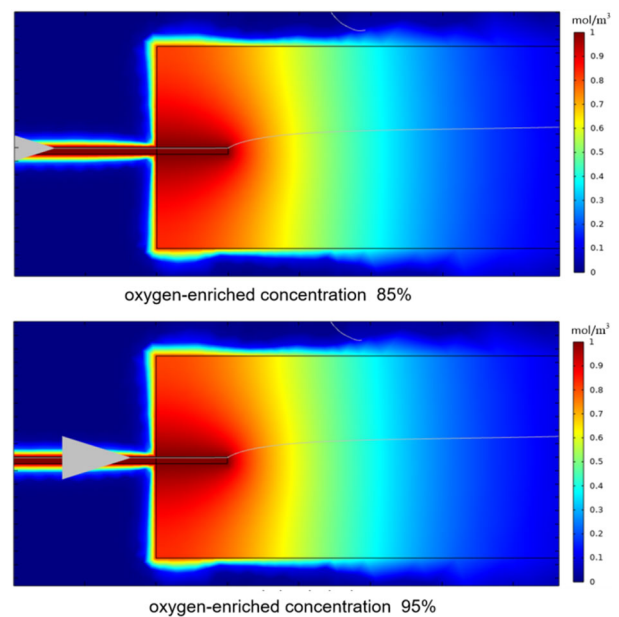
#### 4.5.3. Evolution of temperature field by concentration

Changes in the gas concentration in the injection well during the underground coal gasification process will change the distribution of the temperature field in the underground coal gasification process. Therefore, the concentration is also one of the factors that affects the temperature field in the underground coal gasification process. The concentration of oxygen in the injection well gas has a significant impact on the entire gasification process. The gasification process has the greatest impact. Reasonably setting the proportion of oxygen and other gases in the injection well gas plays an important role in determining the temperature field of underground coal gasification and producing gas. In this article, based on previous research on concentration, we first set the oxygen content to 40% and 50%, and obtained the distribution map as shown in Figure 8. From the figure, we can see that as the injection well When the oxygen concentration increases from 40% to 50%, the area of the coal underground gasification temperature field extends to both sides of the gasification channel axially, and the area increases. This result occurs because the increase in oxygen increases the speed and efficiency of the combustion reaction during underground coal gasification. Therefore, as the reaction accelerates, the temperature field will also show a distribution as shown in the figure.



**Figure 8.** Effect of concentration on the evolution of temperature field

As shown in the figure, when the oxygen-rich ratio of oxygen increases to 85%, the temperature field area of the underground coal gasification process further increases, and the forward expansion range also increases. When the oxygen concentration increases to 95%, the change in the temperature field area is almost negligible. The reason for this phenomenon is that with the increase in oxygen concentration, although the speed and efficiency of the combustion reaction in the underground coal gasification process are accelerated, Because the proportion of water vapor is relatively small, it slows down subsequent reduction and other reaction types. Therefore, the more oxygen introduced, the better. A reasonable allocation of the proportion of oxygen and water vapor has a certain impact on the underground coal gasification recovery rate. important influence.

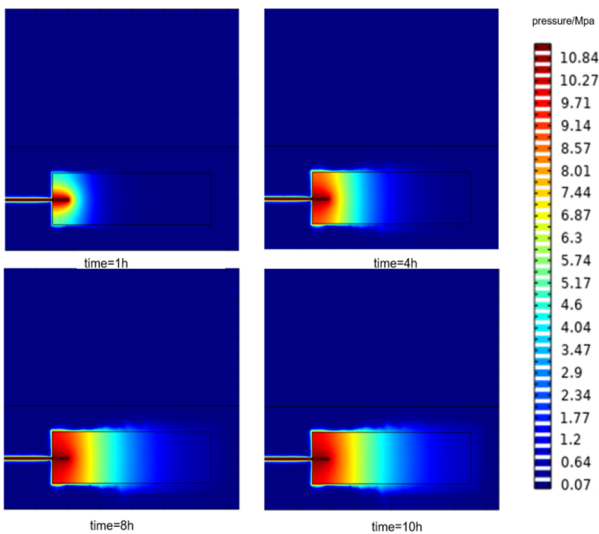


**Figure 9.** Oxygen enrichment 85% and 95% concentration chart

#### 4.6. Pressure changes with time

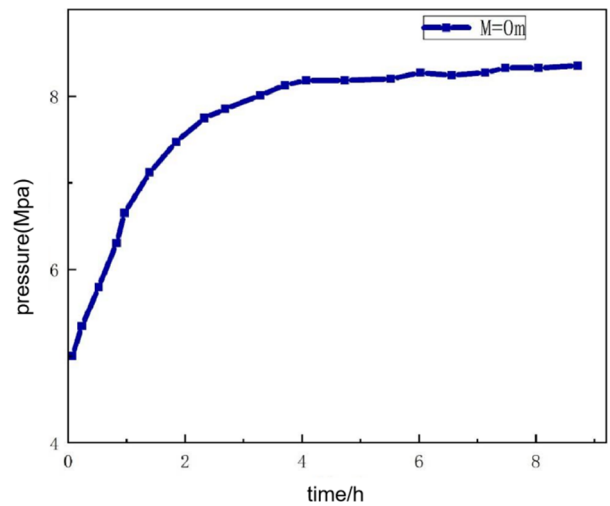
Pressure measurement in underground coal gasifiers is crucial to improving underground coal gasification efficiency

and improving coalbed methane recovery. Whether during the drilling design process or after it is put into production, it can be said that the gasification chamber pressure must be accurately measured at all stages of underground coal gasification operations, so as to assist the ground in reducing production risks and improving surface coalbed methane recovery. From the perspective of gasification reaction, the gas pressure in the gasification channel has a slight impact on the calorific value of the gas during the gasification process. According to previous research, it is found that both combustion and reduction in the underground coal gasification reaction are a kind of expansion. reaction, so as the chemical reaction in the fuel air zone continues to proceed, the pressure in the fuel air zone also increases rapidly. According to various data settings in the temperature simulation model, the pressure at the outlet of the coal underground wellbore is set to 5 MPa. As the reaction proceeds, the pressure in the wellbore and its gasification chamber continues to increase, as shown in Figure 10. The figure can be It can be seen that as the reaction time progresses, the fuel void zone continues to expand forward, and at the same time, the pressure in the fuel void zone continues to increase. By observing the pressure distribution cloud data gradient of the simulation results, we can roughly judge that the pressure of the entire fuel space zone is in the range of 3.5 MPa -8.5 MPa .



**Figure 10.** Distribution of pressure changes over time in underground coal gasifiers

In order to obtain the changes in wellbore pressure during the entire reaction process,  $M=0$  m is set as the pressure measurement point, and the pressure change curve with time is obtained as shown in Figure 10. From the figure, we can see that when the initial pressure is 5 In the case of M pa, the pressure at this pressure observation point continues to increase with time. When the reaction is within the first 3 hours, the pressure increases here quickly. As the reaction proceeds, the pressure increases slowly to supercharge. The rate is 0, and the pressure value fluctuates around 8.4 MPa until the reaction proceeds to the 10th hour. According to this rule, the pressure will gradually decrease with the change of reaction time and the tendency of the fuel air zone to advance the reaction. This The pressure value can also be used as an indicator of the safe pressure range, which will play a certain role in the subsequent underground coal gasifier reaction.



**Figure 11.** Wellbore outlet pressure changes over time

## 5. Conclusion

This chapter first hypothesizes the various conditions required for this study through the investigation and analysis of previous models, and simplifies the underground coal gasification model based on the assumed conditions. Then, through the establishment of geometric models, materials Settings, physical field model selection and coupling between various physical fields, as well as the most important boundary conditions and initial value settings, the simulation simulates the relationship between the temperature of the underground coal gasification wellbore changing with time and the temperature changing with distance. The main results are as follows:

(1) According to the boundary conditions, the reaction time was set to 10 hours, and the temperature field expansion distribution and temperature changes at different temperature measurement points under different reaction times were obtained. According to the simulation results, when the distance between the temperature measurement points is 3m, the temperature of the wellbore temperature measurement point is completely consistent with the normal operating temperature of the downhole measurement device.

(2) Set different injection well oxygen concentrations to simulate the evolution of the temperature field under different concentrations. The data shows that when the oxygen concentration is 85% and below, the temperature field area increases as the oxygen concentration increases, but when the oxygen concentration reaches 95% and beyond, the temperature field area no longer increases because of the water The lower proportion of steam reduces the rate of reactions such as reduction and pyrolysis.

(3) Based on the results of numerical simulation, the distribution of the pressure field was also studied. The simulation results showed that the evolution of the pressure length changes with the increase of the temperature field in a proportional relationship. At the same time, set the pressure measurement point at the outlet  $M=0$  . The data at this point shows that the pressure continues to increase as the reaction proceeds and tends to level off. However, if the reaction continues, the pressure field will also occur as the temperature field moves forward. With similar changes, the pressure change curve will gradually decrease until the reaction is completely completed.

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