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Influence of coal types on overlying strata movement and deformation in underground coal gasification without shaft and prediction method of surface subsidence

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ABSTRACT

Under the action of high temperature, the mechanical properties of coal will change significantly. After gasification, different types of coal will form different surrounding rock mechanical characteristics, which may have different impacts on the movement characteristic of combustion space areas overlying strata and surface. Without considering the influence of coal types or degree of coalification, the actual underground coal gasification (UCG) projects may have issues, such as instability of surrounding rocks in the combustion space zones, damage to surface buildings and structures. At present, the surface subsidence prediction method for UCG and underground gasifier design haven't considered the effects of different coal types. Therefore, this paper studies the influence of coal types on the movement characteristics of the combustion space area overlying strata and surface through field measurement, theoretical analysis and numerical simulation. The research results are as follows: 1) The principle of the mechanical property change of different types of coal is different after UCG; 2) Different types of coal have an effect on the surrounding rock movement and deformation around combustion space area, the vertical stress distribution of coal pillar and the surface subsidence. The strong-caking coal underground gasification is more useful for controlling overlying strata movement in the combustion space area and reducing the surface subsidence; 3) The prediction method of surface subsidence for UCG without shaft is proposed and the method is applied to the Ulanqab UCG industrial experiment field; 4) Suggestions for the design of gasifiers and isolated coal pillars considering the impacts of different coal types are proposed. The research results have important guiding significance and practical value for underground gasifier and isolated coal pillar design, surface subsidence prediction and UCG industrialization development.

1. Introduction

Underground coal gasification (UCG) is a method that controlled burns of the underground coal resources. It is a process of producing combustible gas or feed gas through the thermal effect and chemical effect of coal. Its nature is to extract effective components from coal on site and leave solid waste such as ashes in the ground. It is called the second generation mining method, because it realizes green mining of coal resources in the real sense (Zamzow, 2010; Khadse et al., 2007; Shafirovich and Varma 2009; Bhutto et al., 2013; Yang et al., 2008; Perkins and Sahajwalla 2005, 2008); Prabu and Jayanti, 2011, 2012; Daggupati et al., 2011; Stańczyk et al., 2011, 2012; Eftekhari et al., 2012; Chen et al., 2014). In 1868, the German scientist Sir William Siemens first proposed the concept of UCG (Siemens, 1868). After more than 150 years of efforts by scholars, UCG technology has been basically formed to meet the demands of industrialization and large-scale production. UCG can be divided into UCG with shaft and UCG without shaft. The application of UCG shaftless technology in industrial testing includes the controlled retraction and injection point (CRIP) in US (Shafirovich et al., 2008), εUCG™ technology in Canada (Shafirovich et al., 2008), and ŝtrip mining-surface miningĝasifier controlled retraction injection point in China (Li et al., 2016). The most widely used UCG technology with shaft is UCG technology characterized with l̈ong channel, large cross-section and two stagesïn China (Liang et al., 2013). In general, the UCG development has maintained sound momentum. Existing UCG technology can meet the demands of industrialization and large-scale production. Thus, the development of UCG has

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important practical and long-term significance for the coal revolution, also conforming to the world's coal fluidization and energy structure of low-carbon adjustment.

No significant surface subsidence was observed in the completed UCG industrial experiments, such as the Chinchilla project in Australia (Yu, 2009), the UCG project in Angren (Shafirovich et al., 2008), the Majuba UCG project in South Africa (Shafirovich et al., 2008), the Ulanqab UCG mining experimental project in China (Li et al., 2016), and Huating UCG project in China (Xin, 2014). This is because their experimental scales are relatively small and the widths of the isolated coal pillars are larger, thus ensuring the stability of gasifiers and surrounding rocks in the combustion space area. With the extension and application of UCG experiments, the resource recovery, the gasifier surrounding rock instability, strata movement and surface subsidence, will become bottlenecks restricting the development of UCG.

The ultimate goal of the study of strata and surface movement characteristics is to realize surface subsidence prediction caused by UCG. Meanwhile, surface subsidence prediction can forecast and evaluate the environmental influence of UCG mining projects, and provide evaluations and design basis for gasification under buildings, water bodies and railways, surface subsidence control and comprehensive treatment of surface subsidence areas. However, rare researches have been conducted on the prediction method of surface subsidence caused by UCG. On the basis of the surface subsidence prediction method of strip mining, the former work has established the prediction method of surface subsidence based on stochastic medium theory, and investigated the selection of prediction parameters (Li et al., 2016), which is conducive to the UCG popularization and application.

However, the above described method only considers the mechanical properties changes of the overlying strata and the sizes of the combustion space area, but hasn't considered the change characteristic of coal's mechanical properties before and after gasification. In fact, there are many different coal types and the corresponding mechanical properties before and after gasification vary greatly, which will greatly affect the movement characteristic of the overlying strata and surface during the UCG process. Due to the lack of related researches, this paper analyzed the principle of the mechanical property change of different coal type before and after experiment of UCG without shaft based on field drilling data and coal's pyrolysis characteristics. Then the numerical simulation method was utilized to research the influence of coal types on the movement characteristics of the combustion space area overlying strata and surface. Finally, the design suggestions for gasifier and isolated coal pillar considering the impact of different coal types were proposed. The findings in this work have important theoretical and practical significance for investigation the strata movement and control in different coal's UCG industrialization and large-scale production.

2. Mechanical properties change characteristic of different coal types after gasification

In order to study the influence of coal types on the movement characteristic of the combustion space area overlying strata and surface, it is necessary to grasp mechanical properties changes of different types of coal before and after gasification, which is mainly analyzed in this section combining coal's pyrolysis characteristics. Next, based on the field drilling data of the UCG experimental area and physical simulation methods, this section further verifies the analysis results.

Table 1
Caking and coking properties of different types of coal.

Coal type	Anthracite coal	Bituminous coal										Lignite coal
Coal type	Anthracite coal	Meagre coal	Meager lean coal	Lean coal	Coking coal	Fat coal	1/3 coking coal	Gas-fat coal	Gas coal	1/2 medium caking coal	Weakly caking coal	on-caking coal	Long flame coal	Lignite coal
Caking property	N	N	Weakly	Medium	Strong	Strong	Strong	Strong	N	Medium	Weakly	N	N	N
Coke or not	N	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	N