Journal of Energy Storage 27 (2020) 101131

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

Stability study and optimization design of small-spacing two-well (SSTW) salt caverns for natural gas storages

Chen Jie[a,b], Lu Dan[a,b], Liu Wei[a,b,*], Fan Jinyang[a,b], Jiang Deyi[a,b], Yi Liang[a,b], Kang Yanfei[a,b]

[a] State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400044, China
[b] School of Resources and Safety Engineering, Chongqing University, Chongqing 400044, China

ARTICLE INFO

Keywords:
SSTW caverns
Natural gas storages
Stability analysis

ABSTRACT

A small-spacing two-well salt (SSTW) cavern is a relatively new type of cavern. As this type of cavern is less frequently used in underground natural gas storages, study on its stability is quite limited. To promote the application of this type of cavern and accelerate the construction of underground salt cavern gas storages, stability analysis and optimization design of this type of cavern are indispensable to the security of underground natural gas storages. In this paper, numerical calculation and parameters analysis were performed to analyze the effects of internal gas pressure and ratio of long axis to short axis (R_{LS}) on the stability of SSTW caverns. The results show that internal gas pressure has an influence on the stability of SSTW caverns and low pressure should be limited in terms of duration and magnitude. And the ratio of long axis to short axis (R_{LS}) has limited influence on the stability of a SSTW cavern by ways of volume loss rate and roof settlement. Overall, the SSTW cavern behaves similar stability state with that of a SW cavern. In addition, a flatter roof shape appears under greater Ratio value (R_{LS}) and thus a thicker roof salt rock thickness is suggested for engineering design. The most different between them are the waist displacement along short axis, therefore the pillar width close to the adjacent cavern should be a certain lengthened at this direction.

1. Introduction

To reduce carbon emissions, it is meaningful to promote the usage of clear energy, such as wind power, solar power and natural gas [1]. Natural gas is the most environment-friendly fossil fuel with the lowest CO_2 emission, it is a clean and efficient energy for industry and electric power departments compared with coal and petroleum. In recent years, the demand for natural gas is increasing significantly due to urban population growth, the gradually improved natural gas pipeline network and the implementation of pollution control policy, so the natural gas industry in China also faces enormous challenges and higher demands [2,3]. The annual consumption of natural gas will reach 620 billion m^3 in 2035 and 695 billion m^3 in 2050, respectively [4]. And the domestic natural gas production is expected to reach 300 billion m^3 in 2035 and 350 billion m^3 in 2050, respectively [4]. The consumption of natural gas in China can be seen in Fig. 1. However, the shortage of gas storages limits the quantity of natural gas that can be reserved for emergency and high-consuming period, and “gas hunger” problem may happen. Additionally, similar as the fluctuation of electricity power use [44], the demand for natural gas are changing daily, weekly and monthly which raise the necessity of carefully forecasting [45], establishing and perfecting the gas storages system so as to maintain the stability of natural gas market and meet the requirement of peak-shaving [5]. Considering the shortage of energy reserve and the increasing consumption of natural gas [6–10], it is significant to speed up the construction of underground gas storages (UGS). Rock salt is considered as the best storage medium for natural gas [11–15] due to its small porosity, low permeability and high plasticity. Underground salt cavern gas storages have been extensively used at home and abroad [16–22] and target areas selected for the construction of salt cavern UGSs main include Jintan, Huai'an in Jiangsu province and Qianjiang, Yingcheng in Hubei province. The abundance of domestic rock salt resources and the environmental friendliness of natural gas improve the feasibility of building new gas storages in China. However, domestic bedded salt mines have insoluble interlayers, different with foreign salt domes with thicker and high-grade salt [23,24]. Single well (SW) cavern-constructing technology is not adoptable for domestic salt mines. Nowadays, single-well cavern-constructing technology is the most frequently used water-solution mining method and the horizontal cross-section of a salt cavern produced by this method is circular. In recent years, the disadvantages of single-well cavern-constructing technology, which includes lengthy period of construction, frequent strings

* Corresponding author.
E-mail address: whrsmliuwei@126.com (W. Liu).

https://doi.org/10.1016/j.est.2019.101131
Received 12 March 2019; Received in revised form 9 October 2019; Accepted 2 December 2019

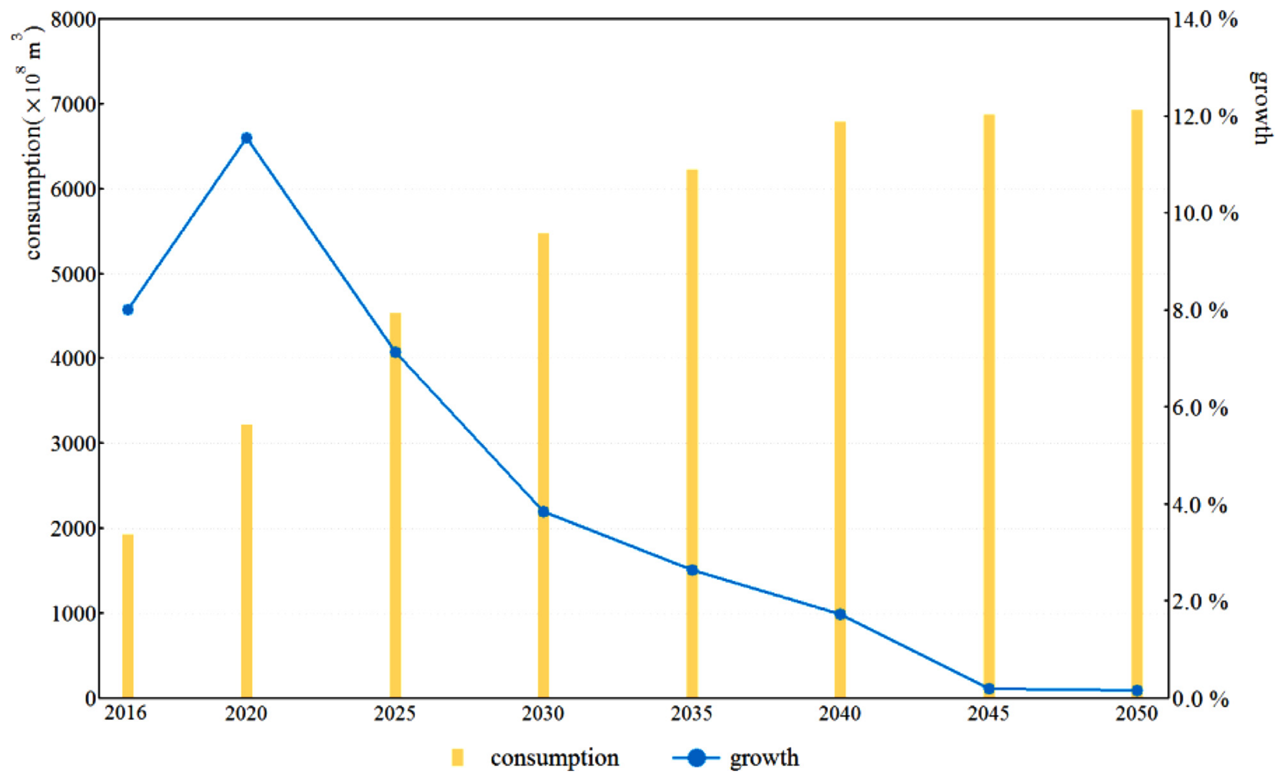

Fig. 1. The consumption of natural gas in China [4].

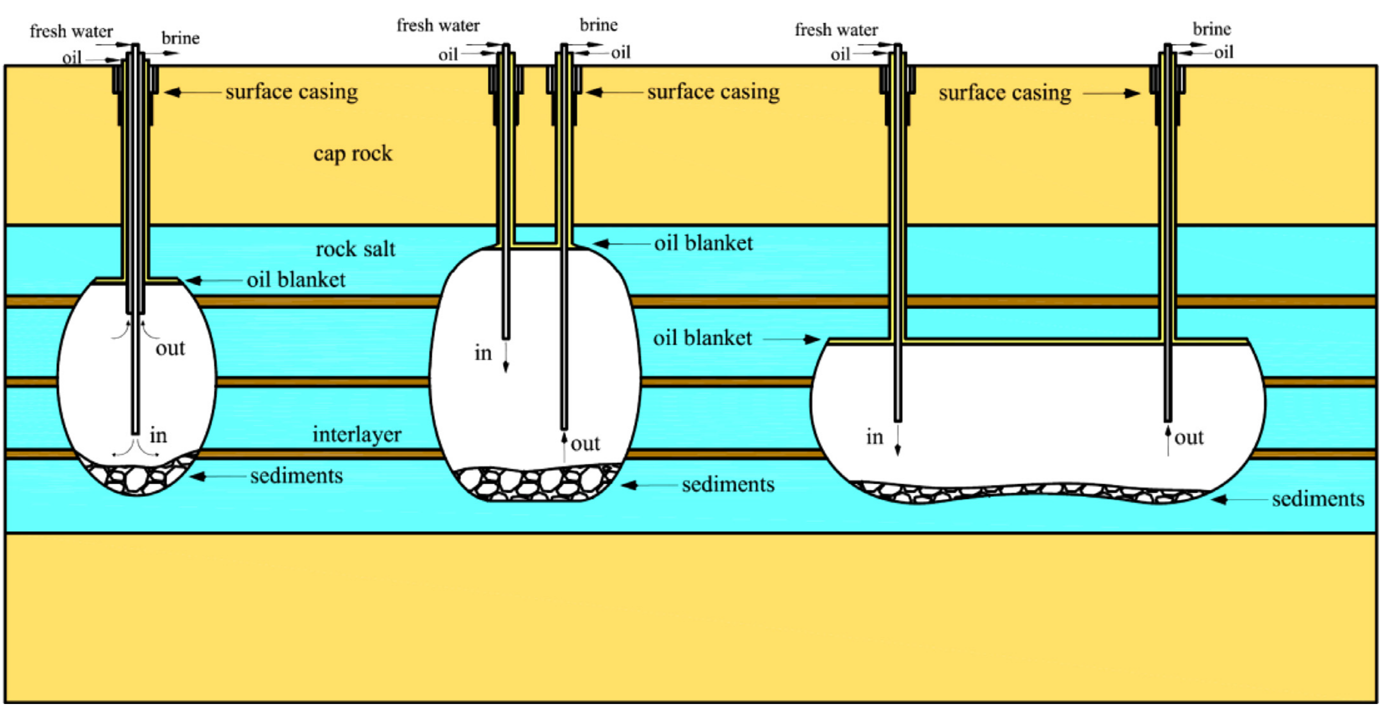

Fig. 2. Sketch map of constructing process of a SW cavern, a SSTW cavern and a horizontal cavern.

accidents, irregular cavern shape and low operating efficiency [24], are constantly emerging. The conception of small-spacing two-well (SSTW) caverns was put forward first in Poland [25]. This type of cavern is composed of a two-well system with an elliptical horizontal cross-section, and the "small space" means the space between two boreholes is smaller than a horizontal cavern with bigger space in between. A SSTW cavern has a height bigger than its diameter, and thus the cavern is still vertical which differentiate it from a horizontal cavern. A Sketch map of constructing process of a SW (single-well) cavern, a SSTW cavern and a horizontal cavern is given in Fig. 2. The constructing process of a SSTW cavern was introduced in [26] and laboratory cavern-constructing test has been carried out by Yi et al. [27]. This type of cavern can reduce string accidents, improve the construction rate, create bigger cavern volume and add flexibility for operation. The difficulties of building SSTW caverns under present circumstances were analyzed and key issues of this cavern-constructing technology were concluded as the