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Investigating the effect of fracture–matrix interaction in underground gas storage process at condensate naturally fractured reservoirs

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A B S T R A C T

Depleted oil and gas reservoirs are used for underground gas storage. Accurate prediction of fractured reservoir efficiency during storage period is of great importance due to complex phase behavior of fluids and existence of fractures. The reservoir model should be representative of the reservoir behavior, the interaction between fracture and matrix and it should be capable of exact prediction of reservoir deliverability.

Despite comprehensive studies performed on fractured reservoirs, the effect of fracture–matrix interaction on underground gas storage capacity and reservoir injectivity is not yet investigated. In this paper, the role of fracture on storage capacity and fluid distribution is determined by investigating the behavior of a fractured gas condensate reservoir using different models during gas storage. The single-porosity compositional model of a real reservoir is constructed and validated. The reservoir is simulated using dual-porosity and dual-permeability models and reservoir performance is compared for different storage periods.

The primary objective of this study is to determine the fracture influence on fractured reservoir simulation, as compared to matrix in underground gas storage. The water production, gas invasion in the reservoir during injection, condensate production, and relative permeability which are known to have high impact on the gas behavior are all affected by the changes in the system used for model construction. The results of this study show that although petrophysical properties, the volume of gas in place, and reservoir pressure drop are the same during reservoir depletion, different storage capacities and injectivity are predicted in gas storage periods. Fractures result in wider spread of injected gas (improvement of injected gas invasion) in the field and gas movement is easier during injection and production periods, mainly owing to the absence of water in fractures.

1. Introduction

Gas storage is a beneficial economic method to compensate the imbalance between supply and demand and is currently considered as an important part of gas chain. Storage reservoirs are stores that provide an easy supply of gas during the peak of consumption in cold periods of the year. The natural gas of pipeline is injected to the underground storage reservoir during low consumption periods. When demand surpasses the supply capacity of the pipeline, the storage reservoir starts to produce as a complementarity. The global increase of gas demand has made the storage development and optimum utilization of available reserves an economic-engineering priority (Xiao et al., 2006).

Fig. 1 shows the relationship between supply and demand in gas storage. The role of gas injection is developing globally. Although the primary purpose was energy supply in the peak of consumption and optimization of transferring network, nowadays, some other specific objectives are dominated. In fact, the volume of imported and transferred gas between producer and consumer is increasing gradually. Another role of gas storage is to guaranty sustainable supply. In addition to the mentioned objectives, gas storage is performed in some countries due to commercial reasons by industry shareholders, such as storing when the natural gas price is low and then its distribution and trading when natural gas price is high (Bolelli, 1992).

There are two different methods of storage, namely, conventional gas storage and unconventional gas storage. Conventional gas storage takes place by injecting gas to a depleted reservoir and

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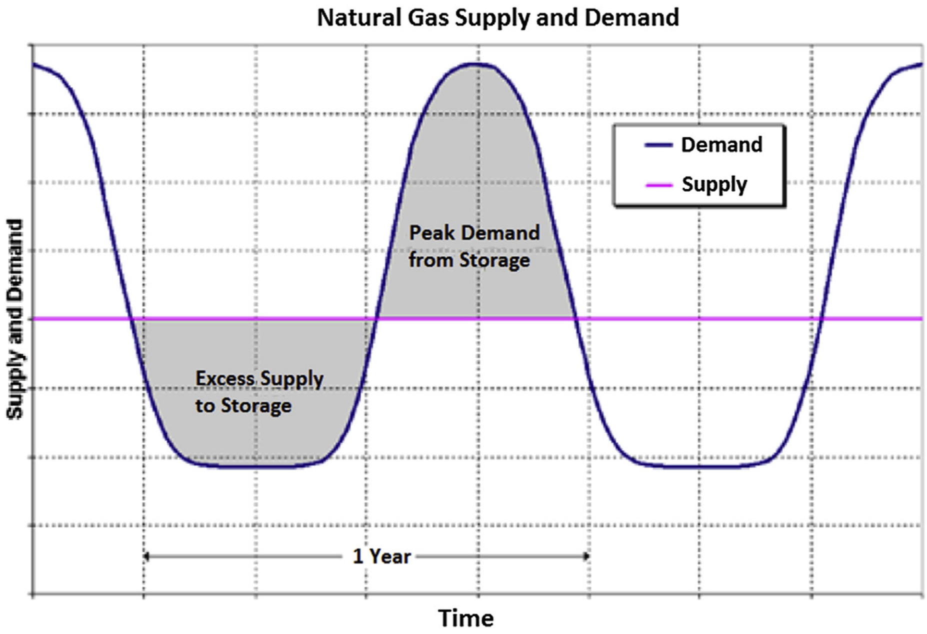

Fig. 1. Natural gas supply and demand in all over the world (Soroush and Alizadeh, 2008).

producing from it at high demand season. This method also includes gas storage in depleted oil reservoirs and aquifers. Unconventional gas storage includes storage in coal mines, salt caverns, mined caverns, earth strata with artificial cap-rock, and storing in steel pipes (Coats, 1966).

The most effective method for gas storage is it's storage in porous media. In fact, the cheaper alternative for gas storage to supply gas in winter, is to use depleted reservoirs, introducing this method as the most common method in the world (Katz and Tek, 1981).

The most common type of underground storage operation takes place in shallow depleted gas and oil reservoirs with high deliverability. The candidate reservoir should include a suitable cap-rock with appropriate closure, high capacity of production, high deliverability and also weak aquifer drive. In porous media, in spite of the injection period, production period is relatively short-lived in range of a couple of weeks or days in which the reservoir should be capable of transferring fluid from reservoir to the transport pipelines. Although base gas varies for different reservoirs, about 50% of the base gas is rendered necessary in practice (i.e. the same amount of working gas and base gas should be used) (Xiao et al., 2006).

In 2013, the total volume of stored gas by different methods was reported to be 8.2 TSCF. About 4.4 and 3.8 TSCF of this volume are base gas and cushion gas, respectively. Only about 500 BSCF of stored gas are stored in salt caverns. According to the EIA annual report in 2010, about 3.3 TSCF gas was injected to the reservoirs and was then produced in production season. In recent years, development of some other methods has diminished the contribution of depleted reservoirs in gas storage from 79% to 65%. Due to the fact that gas reservoirs have proved their capabilities for gas storage, they have more contribution in gas storage than depleted oil reservoirs, such that about 80% of working gas is available in facilities of gas storage in depleted gas reservoirs (https://www.ferc.gov/).

The advantage of gas storage in depleted reservoirs is that they are usually available in close vicinity of the pipelines. The available field includes some wells and usable facilities that reduce the costs of turning reservoir to a storage one and geological studies are performed before. It is generally believed that previous presence of hydrocarbons in the reservoir indicates the lower risk of gas leakage compared to aquifers. Aquifers are the most expensive means for natural gas storage. First, the structural description of the reservoir is not well-defined and thus, a significant amount of expenditure and time should be allocated for this and second, for development of a natural aquifer, it is necessary to develop all the corresponding sub-structures (Xiao et al., 2006; Bolelli, 1992; Coats, 1966).

Table 1
Comparison between conventional and unconventional gas storage.

Type/factors	Type of storage			
	Conventional gas storage		Unconventional gas storage	
	Depleted reservoir	Aquifer	Salt cavity	LNG
Main usage	Seasonal strategic	Seasonal strategic	Multi cycle	Peak shaving support
Advantages	Low cost Large capacity	Large capacity	High rate low cushion gas	Very high rate
Disadvantages	Low rate High cushion gas	High cost Time consuming Potential environmental objections	Low capacity High cost Brine disposal	High cost Low capacity Safety exposure
Working capacity mcm	500	500	500	32
Deliverability mcm/d	7	5	24	5
Cushion gas	55%	60%	20%	5–10%