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Original Research Paper

Evaluation of natural gas dehydration in supersonic swirling separators applying the Discrete Particle Method

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ABSTRACT

The natural gas flow fields and particles separation characteristics were numerically calculated with the *RNG* $k-\varepsilon$ turbulence model and Discrete Particle Method (DPM) in the supersonic swirling separator. An experimental system was set up for testing the separation efficiency of three new designed separators with wet air. The numerical results showed that the new annular nozzle not only expanded the natural gas to supersonic velocity with resulting in low temperature (−72 °C), but also strengthened the swirling flow with the centrifugal field of 640 000*g* (*g* is the acceleration of gravity), both of which created good conditions for natural gas dehydration. Under the strong swirling flow field, most particles collided with the walls or entered into the liquid-collection space directly, while only few particles escaped together with the gas flow. The separation efficiency reached over 95%, when the length of the cyclone separation section was about 10 times of the diameter of the wall at throat. The experimental results indicated that the water can be efficiently removed from the wet air. The numerical results were in good agreements with the experimental findings, which demonstrated that the Discrete Particle Method (DPM) was accurate and stable enough to evaluate the dehydration characteristics of the supersonic swirling separator.

1. Introduction

The demand for natural gas has motivated the oil and gas industry to discover natural gas reservoirs in remote areas. However, in the process of producing and transporting natural gas, the presence of water in natural gas can cause corrosion, excessive pressure drop, hydrate, the decrease of its heating value and the reduction in gas transmission efficiency. The possibility of pipeline obstruction due to the formation of hydrate is one of the most serious problems in the gas industry. Therefore, it is important to assure that water is removed as the gas is transported from the wellhead to a processing facility.

Supersonic swirling separators have been introduced to treat the problems in natural gas for offshore applications [1,2]. Alferov et al. [3] and Betting et al. [4] proposed a method and apparatus for the separation and liquefaction of the gas mixtures, respectively. Alferov et al. [5] introduced a technological process for supersonic separator and compared the effectiveness of the 3-S separator, Joule–Thomson valve, and turbo-expander in extracting C_3+ from natural gas. Liu et al. [6] described a supersonic swirling dehydration system for natural gas and the indoor experiment was carried out to test the unit performance. The effects of the temperature, flow rate and pressure loss ratio on the dehydration characteristics were analyzed. The key components of Twister separator and hydrocarbon recovery were investigated by Betting and Epsom [7]. Jiang et al. [8] developed a mathematical model to investigate the one-dimensional transonic flow of two-component gas mixture with spontaneous condensation. The mixing flow field of the nitrogen and water vapor is numerical simulated in a supersonic separator.

The computational fluid dynamics technique was used to study the behavior of high-pressure natural gas in supersonic nozzles by Jassim et al. [9,10]. The effects of real gas and nozzle geometry on the natural gas flow behavior in the nozzle were discussed. The influences of vorticity on the performance of the nozzles and shock wave positions were studied. Shock wave with reasonable strength was beneficial to the particles separation. Selective dehydration of high-pressure natural gas through supersonic nozzles was investigated by Karimi and Abdi [11]. A computational model linked to MATLAB and HYSYS package was presented to predict the effect of different parameters such as the inlet pressure, inlet temperature and flow rate on the behavior of the working fluid. However, few researchers focused on the characteristics and separation efficiency of the liquid particles in the supersonic swirling separator.

In the two-phase flow models, the governing equations of continuous phase are generally written in Eulerian form, whereas,

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