Effects of Swirls on Natural Gas Flow in Supersonic Separators

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ABSTRACT

A new swirling device composed of some vanes and an ellipsoid was designed for the supersonic separator. The effects of swirls on natural gas flow were computational simulated with the Reynolds Stress model (RSM). The results show that the strong swirls result in the non-uniform radial distribution of the gas dynamic parameters. The presence of the strong swirls damages the expansion characteristics of the Laval nozzle. With moderate swirls, the low temperature (–60 °C) and strong centrifugal field (10^6 m/s^2) are obtained to condense and separate water and heavy hydrocarbons from natural gas in the supersonic separator.

KEY WORDS: Supersonic separator; swirl; swirling device; natural gas

INTRODUCTION

The concept of supersonic separation is a new technology to condensate and separate water and heavy hydrocarbons from natural gas, working on two major principles of the gas expansion and cyclone separation. The idea was first patented in 1989 by Stork Product Engineering, as the condi-cyclone, a method to remove water from air by forcing it through a tube at supersonic speed, intended for use in air conditioners (Kontt, 2000). The supersonic separator prevents the hydrate problems and eliminates the needs for inhibitor and regeneration systems due to the short residence time in the device, providing an environmentally friendly facility. As a static device, there are no rotating parts to enable high reliability and availability. Therefore it is suited for unmanned operations, especially for platforms (Okimoto, Brouwer, 2002; Liu, Liu, Feng, Gu, Yan, 2005; Betting, Epsom, 2007; Kalikmanov, Betting, Bruining, Smeulders, 2007; Wen, Cao, Wu, 2010).

Alferov, Baguirov, Feygin, Arbatov, Imayev, Dmitriev and Rezunenko (2004) and Betting, Holten and Veen (2003) proposed a method and apparatus for the separation and liquefaction of the gas mixtures, respectively. There are two structures for the supersonic separators. One is called “Twister I”, in which a swirl generation device is installed in downstream portion of the supersonic nozzle, and the other is named “Twister II” or “3-S (Super Sonic Separator) separator”, where the swirl generation device is installed in the entrance of the nozzle.

In December 2003, the first commercial offshore “Twister” had been selected by Petronas and Shell for the gas dehydration process of B11, a large gas processing platform 120 km offshore Malaysia (Brouwer, Bakker, Verschoof, Epsom, 2004). The two “Twister” gas dehydration systems had a capacity of 600 MMSCFD. Each system comprised six “Twisters” and one Hydrate Separator. The combined natural gas from the systems had a water dew point of 7°C or better at a pressure between 97 bar and 107 bar.

The comparison of the condensate recovery performance of “Twister” and a conventional Joule-Thomson (JT) System was simulated. The results showed that the “Twister” device consistently produced greater quantities of C^+ liquids than the conventional JT facilities over the whole range of compositions, feed conditions, pressure drops and upstream dehydration specifications studied. With a feed pressure of 100 bar, the improvement was typically around 0.8-1.0 tonnes/MMscf more LPG and 15-20 bbl/MMscf greater NGL recovery. With a feed pressure of 70 barg, the improvement is typically around 0.4-0.6 tonnes/MMscf more LPG and 5-10 bbl/MMscf greater NGL recovery (Schinkelshoek, Epsom, 2006).

The experimental bench with the “3S” device in Moscow provided the gas flow rate of 1.5 – 2.5 kg/s and the working pressure of up to 150 bar. The initial temperature was varied from –60°C to +20°C. The bench was equipped with special devices to specify required hydrocarbon gas mixture compositions at the “3S” separator entry.

In September 2004, an industrial complex consisting of two “3S” facilities with a combined capacity of above 400 MMSCM per year each was successfully put into pilot production at one of the gas treatment plants in Western Siberia. The initial gas pressure at the “3S” device entry was 32 bar, and the initial gas temperature was minus 30°C. The “3S” device provided extraction of components C^+ in the complex of LPG recovery (Alfyorov, Bagirov, Dmitriev, Feygin, Imayev, Lacey, 2005).

The computational fluid dynamics technique was used to study the behavior of high-pressure natural gas in supersonic nozzles by Jassim, Abdi, Muzychka (2008a, 2008b). 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 (2009). 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...