Ten Years of Field Experience with Flashing Two-Phase LNG Expanders

Hans E. Kimmel
Executive Director
Research and Development
Ebara International Corporation
Sparks, Nevada, USA
Category: Developing Mid-stream Gas Value Chain
Keywords: flash gas; gas liquefaction, J-T valve, production increase

When a liquefied gas is expanded across a turbine, shaft power is generated from a near isentropic expansion. The reduction in enthalpy results in both reduced flash gas volume and increased production for a given refrigeration cycle power input, less sub cooling of the liquefied gas being required in the liquefaction process.

High pressure natural gas liquefaction processes are now employed which improve the overall efficiency of the cryogenic process. High pressure refrigerated gas is condensed followed by expansion to slightly above atmospheric pressure for storage and transportation. The expansion process inevitably generates vapour and this evaporation assists in cooling the remaining liquid. Expansion across a Joule Thomson valve with constant enthalpy generates large volume of vapour and corresponding smaller amount of liquid at the J-T valve outlet. Using a two-phase expander with a draft tube at its exit increases the amount of liquid in a near isentropic expansion process, the hydraulic energy being converted into electrical energy to reduce the enthalpy of the liquefied gas and to recover energy. There is correspondingly less vapour produced.

Most expanders installed in existing LNG plants today tolerate little or no vapour breakout inside the machine. To ensure that the LNG remains in the liquid phase at the outlet, these LNG expanders operate with a backpressure approximately 5 bar above the bubble point. The final letdown to storage pressure is therefore adiabatic, representing a lost opportunity to produce further work.

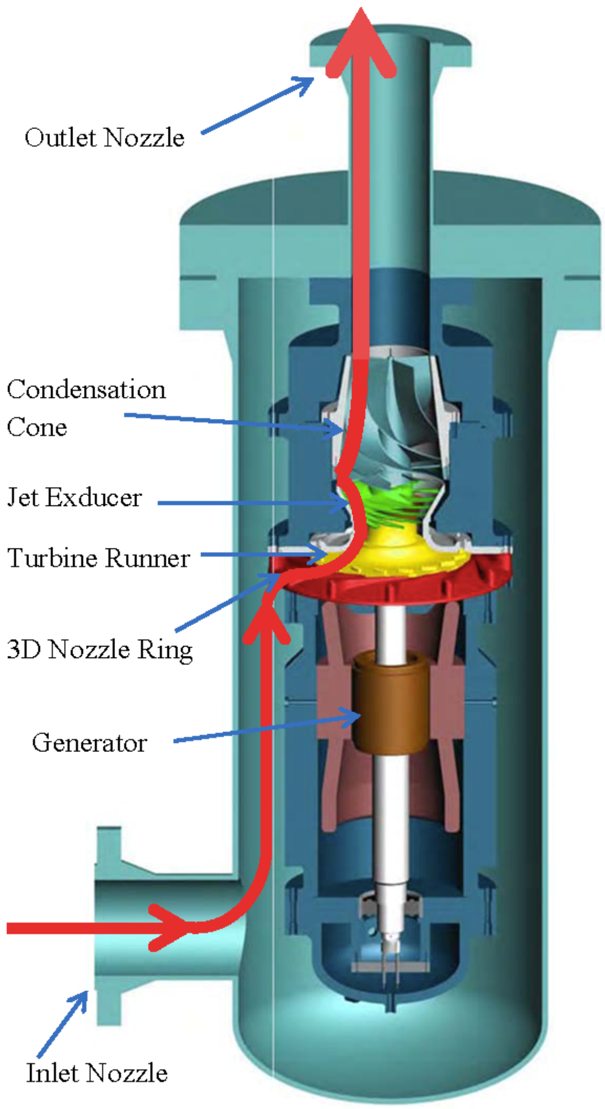
The application of liquefied gas expanders designed for two-phase flow at the outlet allows reduction of the outlet pressure to a lower level with near isentropic expansion and further reduction in enthalpy, resulting in improved plant efficiency and production increase.

Design of Two-Phase Liquefied Gas Expanders

The design of two-phase expanders is very similar to existing turbine and expander technology. The hydraulic energy of the pressurised fluid is first transformed into kinetic energy and then into mechanical shaft power, which is converted to electrical energy in an electrical generator. The electrical power is connected either directly to the power grid or via a variable frequency drive. As a result the original pressure energy is removed from the liquefied gas stream in the form of electrical energy. The enthalpy of the low pressure liquefied gas is reduced, correspondingly reducing the evolution of flash gas, giving increased liquefied gas production.

The cryogenic aluminium alloy liquefied gas expander assembly is mounted inside a stainless steel cryogenic alloy pressure vessel certified according to pressure vessel codes. This thermally insulated vessel protects the expander from both mechanical damage and fire, since LNG is a flammable liquid and aluminium is a flammable metal. The pressurised liquefied gas enters low in the vessel and flows upwards between vessel and expander, enters the expander nozzle ring and exits the expander and vessel at the top.

The static, non-rotating high efficiency 3D nozzle ring, with increasing vertical and horizontal cross section, achieves angular Euler momentum energy transformation with minimal losses, the rotating fluid then enters the rotating turbine runner in angular and radial direction, exiting axially in a vertical direction. The runner, being a radial inflow turbine, results in zero angular Euler momentum with no remaining rotational fluid energy at the entrance to the jet exducer. The jet exducer is a radial outflow Hero's turbine which rotates with the runner mounted on top of the runner. The flow enters with zero inlet angular momentum and generates a negative outlet angular momentum.



Two-Phase Expander

This negative outlet angular momentum increases the differential Euler momentum, increasing shaft torque and shaft power. The increasing cross section 3D exducer guide vanes are helical around the shaft. The saturated liquefied gas begins to vaporise at the inlet of the exducer, forming a two-phase liquid-vapour fluid with increasing vapour volume and increasing velocity as it progresses through the exducer. As stated by Newton's Conservation of Energy Law, the increase in fluid velocity causes a drop in the pressure which increases the liquefied gas vaporisation at any location inside the guide vanes in accordance with its thermodynamic properties. This increased vaporisation further increases the volume and thus fluid velocity, causing further pressure drop in the fluid in a continuous cycle until the final outlet pressure is reached. The described vaporisation/volume/pressure cycle is effective at any location within the helical guide vanes and repeats itself until the liquid vapour mixture exits the exducer at a high fluid velocity.

The design of the jet exducer is applicable to liquid-vapour two-phase fluids of any fraction, including single phase fluids as liquid or as vapour. Operating the expander with variable rotational speed enables the expansion of single and two-phase fluids with smooth and uninterrupted transition across all phase ratios.

At the exit of the exducer a high rotation velocity generates a large negative outlet angular momentum, increasing the shaft torque but rotational kinetic energy remains. A non-rotating condensation cone with helically shaped guide vanes having small pitch at the inlet, increasing continuously until the vanes are parallel to the shaft axis at the outlet acts like a turbine draft tube recovering this rotational kinetic energy by converting it into static pressure energy.

The condensation cone provides the fluid velocity at the outlet nozzle with all rotational fluid energy converted into pressure energy according to the conservation of energy law.

Conclusion

The utilisation of two-phase expanders enables a further reduction of enthalpy across the pressure reduction process with consequent increase in liquid produced, reduction of vapour produced and a reduction of the specific energy consumption. Variable speed two-phase expanders are able to operate with smooth and uninterrupted transition between single and two-phase at the outlet.

The benefits of two-phase expanders are available to reduce power requirements for a certain size plant or increase production from that same plant.

REFERENCES

1. Chiu, Chen-Hwa and Kimmel, H.E., ”Turbo-Expander Technology Development for LNG Plants”, *LNG-13 Conference Seoul, Korea, May 2001*
2. Euler, L.P., ”Théorie plus complette des machines qui sont mises en mouvement par la réaction de l’eau”, *Mémoires de l’académie des sciences de Berlin 10, 1756, pp.227-295*
3. Mullen, O.P. and Jacskson, D.R., “Comparison of Nozzles and Flow Straighteners”, *Pacific Northwest Laboratory, The U.S. Department of Energy, PNNL-13281, September 2000*
4. Cengel, Y.R. and Turner, R.H., “Fundamentals of Thermal-Fluid Sciences” *MacGraw Hill New York, 2005, ISBN 0-07-245426-1*
5. Cholast, K., Kociemba, A. and Heath, J. “Two-Phase Expanders Replace Joule-Thomson Valves at Nitrogen Rejection Plants” 5th World LNG Summit, Rome, December 2004
6. Cholast, K., Kociemba, A, Isalski, I., Madison, J. and Heath, J. “Two-Phase LNG Expanders” Gas Processors Association – GTL and LNG in Europe. Amsterdam, February 2005
7. Cholast, K., Isalski, W.H. and Heath, J. “Improvements in Nitrogen Rejection Unit Performance with Changing Gas Compositions.” Gas Processors Association – Annual Conference. Warsaw September 2005
8. Kimmel, H.E. and Cathery, S., ”Thermo-Fluid Dynamics and Design of Liquid-Vapour Two-Phase LNG Expanders.” Gas Processors Association –Advances in Process Equipment, Paris February 2010