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Performance Analysis of a Helium Turbo-expander for Cryogenic Applications with a Process Modeling Tool: Aspen HYSYS

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Abstract

Cryogenic system refers to interacting group of components involving low temperature. Cryogenic engineering deals with the development and improvement of low temperature techniques, processes, and equipment. They are applicable to helium refrigerators and various liquefiers. Nowadays, the energy crisis has forced the need to recover the energy which is normally wasted in other industrial processes. Reduction of gas pressure is one of such process in which there is a high loss of energy. To prevent such high wastage of energy, Turbo-expander which is the heart for the production of low temperature by reducing the pressure to a low value, has been introduced in the industries. Turbo-expanders are used in almost every segments of the oil and gas industry to produce Cryogenic refrigeration. Before implementation of such a critical component in the plant, it is necessary to carry out the performance analysis of turbo-expander.

In this paper, a process simulator called Aspen HYSYS is used for the analysis of Helium turbo-expander (Helium gas is taken as a process sample gas) and detailed observation is carried out for checking the performance of helium turbo-expander at various adiabatic efficiencies. The results provide useful indications on the selection of turbo-expander to obtain required output at various efficiencies with variation in temperature. Keeping the constraints of the plant in mind, this analysis can thus result in the design of an efficient productive plant

Keywords: Aspen HYSYS; Cryogenic; Helium; Performance analysis; Turbo-expander

Introduction

Aspen HYSYS is a powerful and innovative engineering tool especially designed for the chemical and gas industries. Cryogenics is an important area for the gas industries, where you have to deal with extremely low temperature. This process modeling tool helps in avoiding production delays by giving an analysis of the performance of various equipment that are to be placed in the processing plant.

Performance analysis of various equipment like compressor, expander, control valves, distillation column, that plays a keen role in a Cryogenic plant can all be analyzed for its performance by this process modeling tool. Such analysis gives a clear idea about the selection of equipment and thus production costs can be reduced which leads to the profitability of the organization [1-4].

Turbo-Expander

The expansion turbine or the turbo-expander is one of the important component of most cryogenic system. Since the turbo-expander plays the role of the main cold generator, its properties – reliability and working efficiency, to a great extent, affect the cost effectiveness parameters of the entire cryogenic plant.

Turbo-expander is a machine, which continuously converts kinetic energy into mechanical energy. This is done by expanding the high pressure gas from upstream to a lower pressure downstream through the expander. The high pressure gas causes the radial expander to rotate. Rotation is transmitted to the shaft, which is supported by a set of bearings. The energy transmitted to the shaft can be used to drive a compressor (i.e., wastage of energy can be prevented). Figure 1 show a helium turbo-expander, that is, helium gas is used as a process sample gas [5-8].

Analysis of Helium Turbo-expander with Aspen HYSYS

Analysis of helium turbo-expander is carried out with the process

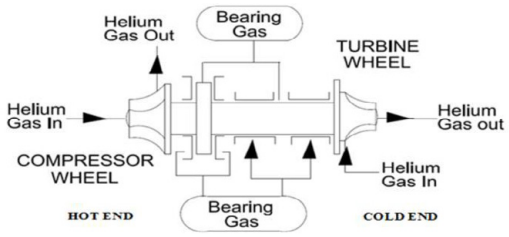

Figure 1: Helium turbo-expander.

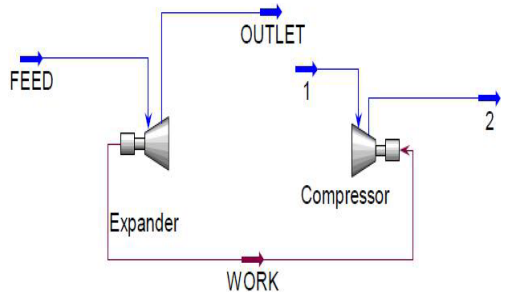

Figure 2: Modeling helium turbo-expander in Aspen HYSYS.

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Material Streams					
		Feed	Outlet	1	2
Vapour fraction		1	1	1	1
Temperature	K	35	23.63	35	46.06
Pressure	bar	13.5	5	13.5	22.98
Molar flow	Kg/mole/hr	107.9	107.9	107.9	107.9
Mass flow	g/s	120	120	120	120
Liquid volume flow	m^3/h	3.482	3.482	3.482	3.482
Heat flow	Kw	21.74	14.51	21.74	28.97

Table 1: Material streams of turbo-expander in Aspen HYSYS.

Energy streams		
Variable	**Unit**	**Work**
Heat flow	Kw	7.227

Table 2: Energy/work output stream of turbo-expander in Aspen HYSYS.

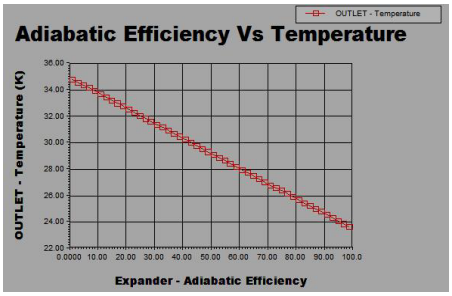

Figure 3: Adiabatic efficiency vs. outlet temperature of turbo-expander in Aspen HYSYS.

modeling tool called Aspen HYSYS. This tool helps in analyzing the important parameters of turbo-expander like temperature, pressure, heat flow, work done and mainly the optimum efficiency of turbo-expander can be analyzed. Hence, we can wisely choose the efficiency of turbo-expander for getting the optimum productivity.

Figure 2 shows the model of turbo-expander, where the sample gas is taken as helium and the work output is used to drive a compressor.

Table 1 shows the values of various parameters used and obtained from modeling of helium turbo-expander.

Table 2 shows the energy obtained from the helium expander. This energy which was else wasted can be used to drive a compressor. This is carried out in Aspen HYSYS, which can be observed in Figure 2.

Adiabatic Efficiency of Helium Turbo-expander with Aspen HYSYS

The efficiency of turbo-expander plays the major role while selecting or purchasing procedure. Efficiency of an expander is the maximum expansion it can provide by reducing the temperature in the most efficient way. Aspen HYSYS is a platform where you can easily choose the parameter on which you are supposed to do expansion and can observe its behaviour.

Figure 3 shows the graph for adiabatic efficiency vs. outlet temperature. It is observed that with increased efficiency of expander, we can get more reduction in the temperature which is a very important point while dealing with cryogenics.

It is observed from the graph the we can get approximately 23K

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CANADA

Case Name: F:\ASPENTECH\ASPEN HYSYS 2006\CASES\TURBOEXPANDER.HSC
Unit Set: NewUser
Date/Time: Thu Jan 19 21:26:14 2017

Workbook: Case (Main)

Material Streams

Fluid Pkg: All

Name		FEED	OUTLET	1	2	
Vapour Fraction		1.0000 *	1.0000	1.0000 *	1.0000	
Temperature	(K)	35.00 *	23.63	35.00 *	46.06	
Pressure	(bar)	13.50 *	5.000 *	13.50 *	22.98	
Molar Flow	(kgmole/h)	107.9	107.9	107.9	107.9	
Mass Flow	(g/s)	120.0 *	120.0	120.0 *	120.0	
Liquid Volume Flow	(m3/h)	3.482	3.482	3.482	3.482	
Heat Flow	(kW)	21.74	14.51	21.74	28.97	

Compositions

Fluid Pkg: All

Name	FEED	OUTLET	1	2	
Comp Mole Frac (Helium)	1.0000 *	1.0000	1.0000 *	1.0000	

Energy Streams

Fluid Pkg: All

Name		WORK				
Heat Flow	(kW)	7.227				

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Expander	Expander	FEED	OUTLET WORK	No	500.0 *
Compressor	Compressor	1 WORK	2	No	500.0 *

Figure 4: Overall report of the modeling plant generated in Aspen HYSYS.

of temperature at the outlet of expander with the 100% efficiency ideally. So, practically we can choose the optimum efficiency required for the plant.

Thus, it is seen that the helium gas is expanded from a temperature of 35K to 23K approximately, which is quite a good expansion ideally. Similarly, we can analyze the expander and can get the optimum required efficiency of expander which can help us in the costing of the device and hence the overall plant.

Now, at last we can have the overall details of the modeling we have carried out in Aspen HYSYS. Figure 4 below shows the overall details of the plant.

Conclusion

The analysis of the turbo-expander plant is carried out with the simulation tool Aspen HYSYS. The result obtained plays an important role in performing experiments with the actual hardware before its actual implementation in the plant. The optimum adiabatic efficiency can be obtained with variation in the outlet temperature of expander. Thus, Aspen HYSYS as a process modeling simulation tool, proves to be very useful in deciding the productivity and thus the profitability of the plant efficiently.

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