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Optimization of Propane Compressor Capacity and Flow Rate in Refrigeration System

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Abstrak

Industri X membutuhkan gas bertekanan yang berada di unit refrigerasi sistem, berperan penting dalam kelancaran sistem operasi produksi. Hal ini dikarenakan gas propan digunakan sebagai penunjang sistem operasi utama pada pembuatan LPG. Lebih tepatnya sebagai media pendingin alat yang bernama Chiller dan Sub-Cooler. Untuk memperoleh gas propan bertekanan tersebut digunakanlah kompresor jenis pemindah positif Screw Compressor. Propane Compressor yang memiliki fungsi, yaitu untuk mensirkulasikan gas propan yang digunakan untuk mendinginkan atau menurunkan temperatur gas hidrokarbon. Mengingat pentingnya peranan kompresor sekrup Propane Compressor, perlu dilakukan optimasi untuk mengetahui kinerja dari kompresor tersebut. Langkah optimasi perlu dilakukan untuk mencari kondisi operasi yang paling efektif dan efisien. Dengan menurunkan temperature suction dan menaikkan kecepatan putaran rotor. Parameter acuan adalah pada besar kapasitas yang ditargetkan mengalami kenaikan 9%, dihasilkan perhitungan aktual 30614,40 cfm dan optimasi 30902,03 cfm. Serta laju aliran massa ditargetkan bisa mengalami kenaikan 4%, dihasilkan perhitungan aktual 627,92 lbm/min dan optimasi 654,80 lbm/min. Dengan hal tersebut bisa dihitung nilai keekonomian didapatkan hasil sebesar 26,89 lbm/min.

Keywords:
Refrigeration System,
compressor,
performance optimization

Abstract

Plant X requires pressurized gas in the refrigeration system unit, which plays an important role in the smooth operation of the production system. This is because propane gas is used as a support for the main operating system in the manufacture of LPG. More precisely as a cooling medium for tools called Chiller and Sub-Cooler. To obtain the pressurized propane gas, a screw compressor type positive displacement compressor is used. Propane Compressor C-440 A has a function, namely to circulate propane gas which is used to cool or lower the temperature of hydrocarbon gas. Considering the important role of the Propane Compressor C-440 A screw compressor, it is necessary to optimize it to determine

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the performance of the compressor. Optimization steps need to be carried out to find the most effective and efficient operating conditions. By lowering the suction temperature and increasing the rotational speed of the rotor. The reference parameter is that the targeted capacity has increased by 9%, resulting in the actual calculation of 30614.40 cfm and optimization of 30902.03 cfm. The mass flow rate is targeted to increase by 4%, resulting in an actual calculation of 627.92 lbm/min and an optimization of 654.80 lbm/min. With this, it can be calculated that the economic value is 26.89 lbm/min.

1. INTRODUCTION

Compressors are vital equipment in industrial processes and require special maintenance and operation so that their performance remains good. In Industry X, it uses a Positive Displacement Compressor, more precisely a rotary compressor type screw compressor. Which uses pure propane feed and injected lube oil as a lubricant, operates at high speeds, and produces higher output as well. Its main function is to compress/increase pressure and increase temperature, which later this refrigeration process is used to support the main process, namely as a cooling medium in Gas Chiller and SubCooler. So it has a very important role in the gas production process at the plant (Kovacevic et al., 2007).

With the following problem formulation, how to evaluate the compressor based on calculations using the parameters of inlet air pressure, inlet air temperature, and outlet air pressure. How to optimize compressor performance with calculation parameters, volumetric efficiency, capacity, mass flow rate, and power on the compressor. By lowering the suction temperature and increasing the rotation speed of the rotor (Borremans, 2019).

The hypothesis that can be determined as follows, namely Theoretical volumetric efficiency based on calculations is smaller than actual, this is influenced by the age factor of the tool. The longer the operation, the lower the volumetric efficiency. The theoretical capacity based on calculations is smaller than the actual. This capacity is influenced by the size of the volumetric efficiency. Lowering the suction temperature can increase compressor capacity by about 9% of the actual data. Increasing the rotational speed of the rotor can increase the capacity and mass flow rate by about 4% of the actual data because it strengthens the suction power of the compressor (Brown, 1997).

The goal to be achieved is to know the working mechanism and system of the Propane Compressor in the Refrigeration System in Industry X. Can compare compressor performance during new conditions with current operating conditions (Wang et al., 2013). Can determine the performance calculation parameters on the screw compressor to get a percentage/recap of overall efficiency data from the compressor itself. Evaluate the performance of the Propane Compressor in the Refrigeration System using the calculation parameters of volumetric efficiency, mass flow rate capacity, and power used so that it can find out whether the compressor is still working optimally or not (Hasan et al., 2009). Optimize the performance of the Propane Compressor in the Refrigeration System by lowering the suction temperature and increasing the rotation speed of the rotor. So that the compressor can work more optimally according to its operating needs (Firmansyah, 2010).

A compressor is a compressor or gas/air compressor in other words a compressor is a producer of compressed gas/air. In this industry use Positive Displacement Compressors, more precisely rotary compressor type screw compressors. This compressor compresses (adds energy) air or gas by simultaneously rotating the rotor teeth or gears that rotate in opposite directions and are interrelated (Alabdulkarem et al., 2011). These pairs of rotors rotate in unison and the direction of rotation is opposite in a fixed-height housing (casing). One of these rotors as a driver (connected directly to the driving motor) is known as a male rotor and the other as driven (driven by a male rotor) known as a female rotor whose two ends are supported by bearings. When gas enters the compressor through the suction side, it is immediately closed/blocked by a screw turn. Each gas intake is captured between the rotor gap and the casing (casing), and then the gas is transferred along the rotor groove from the inlet side to the outlet side (Giampaolo, 2010).

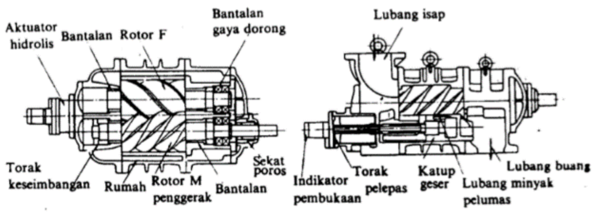

Figure 1. Compressor components

Main components of screw compressor:

a. Frame Serves to support the compressor part above the foundation. The frame must be strong to withstand all loads and vibrations caused by the compressor.
b. The casing is the outermost part of the compressor that functions as a protector of the parts inside, as well as the seat of the rotor.
c. The rotor is the main element of the screw compressor, consisting of two rotors, namely: the Convex Rotor (Male Rotor) as a driver and the Female Rotor as driven, the function of the rotor itself is as a medium to compress air (Sakomo, 2015).
d. Shaft Bearings (bearings) function to withstand axial forces due to the pressure difference between compressor discharge and suction, besides bearings also function as vibration dampers due to high rotation and also to reduce shaft wear of Male Rotor and Female Rotor due to rotational friction. This compressor uses tapered roller bearings at the discharge end to resist the axial force of the rotor (Sularso & Tahara, 2000).
e. Mechanical Seal functions to prevent leakage between the shafts that come out of the casing (shafts connected to the drive).
f. Shaft is the place or position of the rotor (thread) so that the rotor can rotate.
g. Slide valve Functions to adjust compressor capacity from 0% - 100% or vice versa. This valve is driven by an unloader valve.

The unloader valve functions to move the capacity control valve, the piston unloader moves automatically after the discharge pressure reaches ±5.9 bar, the pressure will drop to 4.4 bar, and then after ±7 seconds, the compressor will load again automatically. This valve is hydraulically driven (Hanion, 2001).

a. Balance Piston Functions to withstand axial force from the rotor (reduces load from thrust bearing).
b. Lubricating Oil Hole Serves as a place for lubricating oil to enter the compressor. Lubricating oil is used to lubricate rotors, bearings, balance pistons, and unloader valves.
c. Suction valve Serves to regulate the air entering the compressor.
d. Outlet: Serves as an air outlet after the compression process.

2. METHODS

a. Preparatory Stage

In the preparation stage, the author carried out several activities, including 1) Observing the environment and conditions of the research site. 2) Determine the subject matter to be optimized. 3) Find reference sources for writing to be evaluated. 4) Determine the variable data needed for optimization. 5) Field observation or process refinery overview. 6) Take the necessary data for calculations (Puspawan, 2014).

b. Execution Levels

At this stage of implementation, the author first conducts a literature study so that later he knows more clearly. After the author gets all the data needed for calculation, the author performs calculations using calculation parameters, volumetric efficiency, mass flow rate, and power in the compressor. By using data on inlet propane gas pressure, inlet propane gas temperature, and outgoing propane gas pressure. The results of these calculations become analytical material that will be discussed by the author based on existing theories. Until it can determine the percentage of screw compressor performance used and optimize its performance in the Refrigeration system in the Company's LPG Plant plant area X.

c. Solution Levels

At this stage, an analysis is carried out based on the results of calculations and observations that have been made at the implementation stage. After an analysis of the calculation results, the author concludes the subject matter in writing this Compulsory Working Paper and provides suggestions based on the results of the discussion with the aim of correcting the shortcomings found so that it is more optimal performance.

RESULT AND DISCUSSION

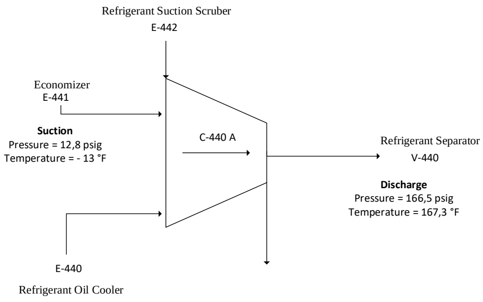

Figure 2. Compressor flow chart

So the output from the chiller will go to the Refrigerant Suction Scrubber, to capture the propane liquid that is included so that only dry propane vapor comes out to flow as a (first state) suction compressor. While the Economizer occurs a cooling process between propane and propane (cooling itself) and the output of propane steam will flow as a (second state) suction compressor.

In addition, there is *oil* injection as a lubricant derived from the *Refrigerant Oil* Cooler. The discharge gas flow will flow to the Refrigerant Separator and the oil will return to the reservoir. The specifications *of oil props* used are specific gravity 0.992, *viscosity* 64.5884 cSt, and *temperature* 50 ° C.

The feed used is pure propane purchased from Pertamina. Therefore, the compressor functions to maintain circulation so that the volume does not lose much. Because not every year a new propane feed injection is carried out. The composition of pure propane used C2=0.8%, C3=97.2%, C4=2% (this data is obtained from the supervisor's explanation). As for propane specification, in general, the freezing point is at temperature -47,2 °F, specific gravity 1,52, and density49 g/cm^3.

Evaluation Calculatio

12,8 psig = 27 psiischarge = 166,5psig = 183,3

psi°$K = \frac{Cp}{Cv}$ $K = \frac{1{,}669\ kj/(kg°\mathrm{K})}{1{,}48\ kj/(kg°\mathrm{K})}$ = 1,128

This ca be seenin the type hat ratio tableCompressibility factor= 617 Psia and Tc = 666 °R can be known from the table so that they can calculate Pr and Tr using the equation:

Sucon rebiliy f $Pr == 0{,}04$ $Tr = \frac{446{,}57}{666} = 0{,}67$

Nilai Z=0,96

caap $P = \frac{183}{6} = 0{,}30$ $Tr = \frac{626{,}97}{666} = 0{,}94$

Z value=0,87 midcap$U = \frac{\pi \times D \times N}{60} U = \frac{\pi \times 1{,}16 \times 2752}{60} = 167{,}06\ fps$3.05,19 m/min

$$VE = Ve\ desain - (Z.r.k)VE = 87{,}7 - (0{,}92 \times \frac{183{,}3}{27} x1{,}128)\% = 80{,}66\%612 \times 0{,}8566 = 30.614{,}40\ cfm$$

Mass flow rate caprate$W = Qi \times D \times Mw \times L \times U \times X \times \frac{P1}{T1} (\frac{0{,}355^3(0{,}532/0{,}355)}{2231})2752 = 0{,}0827$

Qi = 0,0827 x 87,7,67 $W = 6{,}67 \times 0{,}355 \times 44{,}09 \times 0{,}5325 \times 3055{,}19 \times 0{,}0612 \times \frac{27}{446,} = 67{,}92\ lbm/menit$

Daya

To calculate the compressor power can use the equation:

$$CHP = \frac{Qd \times \left(r\frac{k-1}{k}\right) W \times Z \times T1}{r\frac{k-1}{k} M \times \eta a \times \eta m}$$

$$CHP = \frac{0{,}0827 \times (6{,}79\frac{1{,}128-1}{1{,}128}) \times 627{,}92 \times 0{,}96 \times 446{,}57}{6{,}79\frac{1{,}128-1}{1{,}128} \times 44{,}097 \times 0{,}618 \times 0{,}80} = 1021{,}32\,HP$$

1. How to Optimize

Based on the results of the performance evaluation, optimizing compressor performance using 2 approaches, namely as follows:

a) Process Optimization

1) Lowering the Compressor Suction Temperature.

If the compressor inlet temperature is high, it can cause fluid with a fraction heavier than the fluid served by the compressor cannot be separated as a result of which the fluid enters the compressor which can cause dirt and vibration. In addition, if the compressor inlet temperature is high, the compressor outlet pressure will decrease. Lowering the compressor inlet temperature can be done by cleaning and repairing *refrigerant suction scrubbers and economizers*. The cleaning and repair are expected to make the suction ability of the *Propane Compressor* maximum.

2) Increase the rotational speed of the rotor.

With the increase in rotor speed, it will accelerate the suction and compression process of propane on the compressor. And can also enlarge the capacity reservoir inside the compressor. This can be done by observing and injecting lubricating oil into the compressor.

b) Mechanical Optimization

1) Maintenance of Supporting Equipment and Monitoring.

Maintenance of Supporting Equipment *and Monitoring Propane Compressor* C-440 A. Carrying out routine maintenance on supporting equipment and monitoring compressor performance can improve the reliability of the compressor itself.

2. Optimization Calculation

After improvements are made to the *Refrigerant Suction Scrubber and Economizer* is expected to reduce the temperature with relatively the same ability so that the combined temperature before entering *the Propane Accumulator* can be lower, which is in accordance with the capabilities of the cooler design. So after getting a lower intake temperature, it can be re-rated to determine the new capacity and flow rate. For re-rating the compressor, data with the same parameters as the actual are needed, but with lower T1 and increased N. The required data include the following:

T1 -13,1 °F downgraded to -23,8 °F = 435,87 °R

N 2752 rpm raised to 2775 pm

Compressibility Factora $Pr \;== 0{,}04 \;\; Tr \;= \frac{435{,}87}{666} = 0{,}65$

Z value=0,94

Dirgeopa $P \;= \frac{183}{6} = 0{,}30$ $\quad Tr \;= \frac{626{,}97}{666} = 0{,}94$

Nilai Z=0,87

So the average Z value obtained is 0,91

Compressor Capacity

Rotor Circumference Speed

$U \;= \frac{\pi \times 1{,}16 \times 2775}{60} = 168{,}46\,fps$ = 3080.97 m/min

Volueti $VE \;= 87{,}7 - (0{,}91 \times \frac{626{,}97}{27} x1{,}128)\% = 8{,}73\% Q \;= 1{,}16 \times 1{,}75 \times 3080{,}97 \times 0{,}0612 \times 0{,}8073 = 30902{,}03 fm$

Mass Flow Rate$\times\, ,525 \times 3080{,}97 \times 0, \frac{27}{435{,}87} = 654{,}80\, lbm/m \;(\frac{0{,}355^3(0{,}532/0{,}355)}{2231})2775 \;=\; 0{,}0834$

Qi = 0,0827 x 87,7 = 6,73

Compressor Power

$$CHP = \frac{0{,}0834 \times (6{,}79^{\frac{1{,}128-1}{1{,}128}}) \times 654{,}80 \times 0{,}94 \times 435{,}87}{6{,}79^{\frac{1{,}128-1}{1{,}128}} \times 44{,}097 \times 0{,}618 \times 0{,}80} = 1026{,}3\ HP$$

Final Recapitulation

Table 1. Data recapitulation

No	Parameter	Condition			Unit	Information
		Design	Current	Optimization		
1.	Specific Heat Ratio	1,128	1,128	1,128	...	Remain
2.	Compressibility Factor	...	0,92	0,91	...	Down 0%
3.	Rotor Circumference Speed	3552,62	3055,19	3080,97	m/min	Go on 1%
4.	Volumetric Efficiency	87,7	80,66	80,73	%	Go on 0%
5.	Compressor Capacity	33057,78	30614,40	30902,03	Cfm	Go on 9%
6.	Mass Flow Rate	982,7	627,92	654,80	IBM/min	Go on 4%
7.	Compressor Power	1534,7	1021,32	1026,38	HP	Go on 1%

d. CONCLUSION

Based on observations/optimizations that have been carried out between the design data and the results of actual operation calculations with the optimized data from the current Propane Compressor, the following conclusions can be drawn. 1) Propane Compressor capacity with design data of 33057.78 cfm resulted in an actual calculation of 30614.40 cfm and optimization of 30902.03 cfm. The result of this capacity calculation has increased by 9%, which is the main concern in terms of this optimization. 2) Propane Compressor Mass Flow Rate with design data of 982.7 lbm/min resulted in an actual calculation of 627.92 lbm/min and optimization of 654.80 lbm/min. The results of this calculation have increased by 4%, also a major concern in terms of this optimization.

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