Investigation of Double Screw Compressor Characteristic based on Experimental in Industry

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***Abstract*—Large-scale compressed air equipment is the only way to meet the demand for air for production facilities such as the pharmaceutical, automotive, or combustion processes industries. As one of the main driving components in the air compressor system, the double screw determines the reliability and performance of the entire compressed air system. Double screw compressors are a promising option for use in large-scale compressed air systems due to their high efficiency and reliability. The double screw profile has been specially designed to increase compression capability over a period of more than 24 hours with a range of 400 to 385 m^3 per hour. The cooling oil works well keeping the compressor temperature constant at around 100 ^{0}C, even though there are very active temperature fluctuations. On the working pressure side the compressor as a whole is constant, although there is a significant spike in the dryer pressure. The dryer pressure experienced a significant increase reaching 6.9 Bar in the sixth data collection, while the cooling oil pressure and tank pressure were the same at 6.6 Bar, and the air pressure was 6.3 Bar. The results of observing the performance of compressors during industrial operation have presented the ideal working conditions for double screw compressors reaching 58.4 kJ/kg, while the actual working conditions of compressors are 66.6 kJ/kg. Overall, the average compressor efficiency is 87.81%.**

Keywords—compressor, screw, pressure, air, temperature

I. INTRODUCTION

One of the most widely used compressors in the industrial world is the screw compressor. As the name implies, this compressor works by using a screw system. So, air enters through the inlet to a rotating screw system and compresses the air. Then, the compressed air is supplied to the air storage tank. In conclusion, the working principle of the screw compressor is to suck in, compress and expel air. Screw compressors are generally used in the manufacturing industry. This type of compressor has been widely used in several applications, such as the electric power, chemical and energy industries, mainly due to its high efficiency and safety [**1**]. The screw compressor consists of two rotors which are cast from carbon steel [**2**].

Many types of compressors have their own advantages and disadvantages and are used in various occasions. Application of twin screw compressors in combustion as a supply of oxygen from the surrounding air which is the main auxiliary unit of the fuel cell system by Li et al [**3**]. It can increase the power density and efficiency of the fuel cell and reduce the size of the fuel cell system by compressing the air.Nevertheless, air compressors already have very high parasitic power consumption, based on calculations of about 80% of the reserve power consumption of the fuel cell, and their performance level directly affects the quality characteristics of process efficiency, mutual work and fluid balance of the fuel cell system [**4**].

In the development of screw compressors over the past three decades, profile design of twin screw compressors has made great progress, whereby Stosic et al [**5**] have reported the theory of compressor performance optimization and the method of making N shape profiles. Meanwhile, researchers Spitas et al [**6**] proposed a surface discretization method of the gear profile into several involute sections to calculate the conjugate tooth shape profile. Byeon et al [**7**] and Dia et al [**8**] have developed profiles of rotor shapes for oil free range 4-6 and 3-5, respectively, after which they tested the performance of double screw applied to oil free double screw compressors.

Recently, several triggering factors have been shown to cause shaft failure in screws. As investigated by Shahrivar et al [**9**] studied shaft failure in screw compressors and found that some of the failures were due to thermal expansion. Another study was conducted by Gong et al [**10**] in which their team concluded that the crucial concentration of stress causes initiation and triggers crack propagation, thus it is designated as a priority reason for shaft failure in screw compressors. Domazet et al. [**11**] have proven that screw shaft failure is caused by fatigue that occurs in rotary bending. While research conducted by Li et al [**12**] has proven that in-service fracture of the castellated shaft and simulated that the loading impact exceeds the specified limit and the occurrence of torsional deformation is the main cause of the fracture that occurs.

Compressor performance has also been of concern to researchers such as Giuffrida [**13**] who has created a thermodynamic model of a twin-screw compressor with open drive and rotational speed which has always been a major consideration in the research of this model. Kennedy et al [**14**] have designed and built a double screw compressor model then simulated 1D geometric shapes with 3D buildings using CFD. The simulation results show a decrease in the difference between the two models as the screw compressor rotor rotational speed increases. The presence of water vapor in the compressor has attracted the interest of Tian et al [**15**] to conduct an in-depth investigation of water-injected double-screw compressors. The water flow rate must be controlled by the rotating speed of the screw rotor to ensure the saturation temperature and cool the compressor temperature to saturation. The result can increase the volumetric efficiency and efficiency of the double screw compressor.

Various research reports related to double screw compressors have been published. This shows the interest of researchers in high performance double screw compressors. This journal paper presents an analysis of the performance of

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a high-efficiency oil-injected double screw compressor. To prove high efficiency and performance, several days of observations have been made to monitor the parameters detected on the compressor.

II. Methods

The screw compressor Kobelco as seen in Figure **1** was observed for several days by recording parameters in compressor unit, such as the inlet air discharge while running and the air in the tank called loading, inlet air pressure, oil temperature, oil pressure, tank pressure, and dryer pressure.

Fig. 1. Kobelco compressor

When air or gas enters the compressor through the suction side, this intake air or gas will immediately be closed/sealed by the rotating screw. Any air or gas intake is captured between the rotor gap and the housing (casing), then the air or gas is transferred along the rotor groove from the inlet side to the outlet side. In a screw compressor the volume of air or gas decreases as the air or gas is pushed or moved towards the outlet. This reduction in volume causes the air or gas pressure to rise.

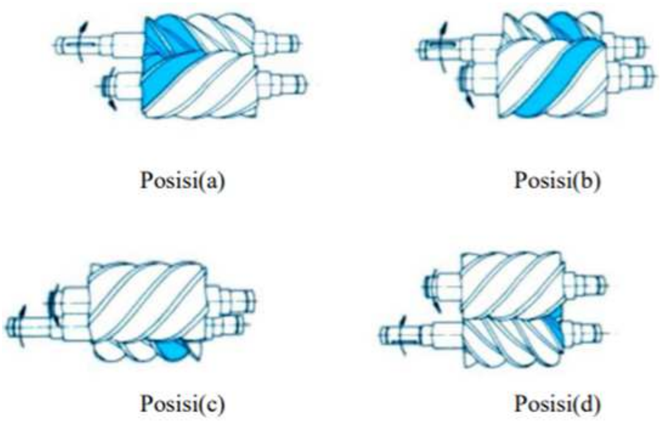

Fig. 2. Double screw compressor

In Figure **2**, the compression step of the screw compressor is explained, where at position (a) air is fully sucked through the suction hole into the groove chamber. Suction will be completed after the groove space is completely covered by the housing wall (casing) this step is called the final suction step. Whereas position (b) shows the middle of the compression process where the volume of air or gas in the groove space is already in the middle, this step is called the initial compression step, continued at position (c) shows the end of compression where the confined air or gas has reached the outlet, step this is called the final compression stroke. Position (d) the air or gas trapped in the groove has been partially removed until only a portion remains to be completed, this step is called the release step. Because the suction, compression, and discharge processes are carried out continuously, the flow is more stable than a reciprocating compressor.

III. Results and Discussion

Double screw compressors with a specific pressure of 0.8 Mpa used in the industry have been analyzed in a few days and produce data as in table **1**.

TABLE 1. Operational Data.

Compressor					Ptank (Bar)	Pdryer (Bar)
Hourmeter (H)		Pair (Bar)	Toil (°C)	Poil (Bar)		
Running	Loading					
4916	4514	7	85.7	7.2	7,2	7
16767	16394	6.4	98.5	6.7	6.6	6.4
16771	16398	6.3	103.1	6.7	6.6	6.5
16772	16399	6.4	100.2	6.7	6.6	6.4
16774	16401	6.4	109.4	6.7	6.6	6.4
16784	16411	6.3	43.4	6.6	6.6	6.9
16786	16413	6.4	96.7	6.7	6.6	6.4
16790	16417	6.3	99.9	6.6	6.5	6.3
16791	16418	6.3	91.7	6.6	6.6	6.4
16793	16420	6.3	99.5	6.7	6.6	6.4
16797	16424	6.2	95	6.5	6.4	6.1

A. *Compressor oil*

The oil in an air compressor not only lubricates the moving parts, it also cools the parts so the motor doesn't overheat, and acts as a sealing agent during compression. The oil in an air compressor not only lubricates the moving parts, it also cools the parts so the motor does not overheat, and acts as a sealing agent during compression. The condition of the compressor oil can be monitored with fluctuations up and down from 43.4 ^{0}C to 109.4 ^{0}C, while the operating pressure was a downward trend starting from 7 Bar down to 6.2 Bar, but overall there is a trend of stable usage and evenly distributed in a few days data retrieval as shown in Figure **2**.

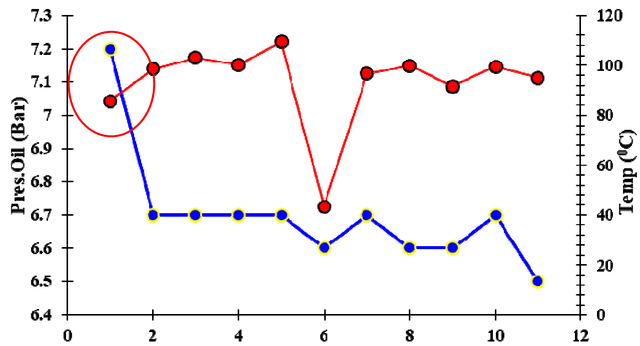

Fig. 3. Oil compressor operational data (Pressure & Temperature)

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In Figure **3**, when the data was collected for the first time, the pressure was read to be large enough to reach 7 bar, marked with a red circle, at which time the compressor unit was operating for the first time so that the pressure being pursued to supply air reached operating pressure. There was a decrease in oil temperature around 60 ^{0}C from 109.4 ^{0}C to 43.4 ^{0}C, this was due to the addition of compressor cooling oil so that the temperature dropped.

Since oil also acts as a sealant, it's another reason why you should keep up with oil changes and changes. Lack of oil can cause air leaks, meaning your compressor won't be performing as well as it should. Also, less oil leads to more wear and tear, you need to find out more why changing your oil regularly is so important.

B. Compressor operating pressure

The critical parameter of the air compressor is the pressure, which is set using the pressure switch on an ordinary air compressor. KOBELCO VS37A-H screw compressor has a maximum allowable pressure of 0.85 Mpa. The pressure data is presented in graphical form in Figure **4**.

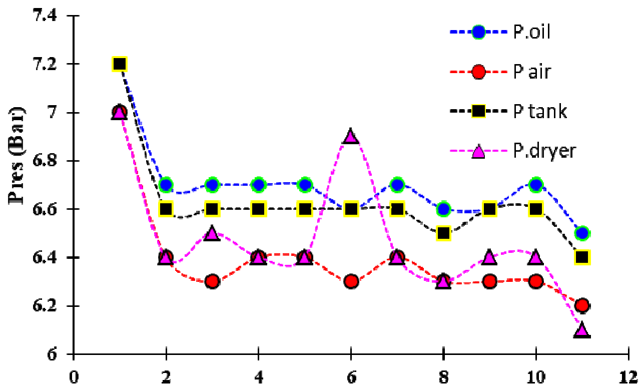

Fig. 4. All pressure in compressor operational

In general, the trend of compressor operating pressure decreases sharply at the start of operation, followed by a uniform operating pressure for all types of pressure. Dryer pressure has experienced a very significant surge reaching 6.9 Bar on the sixth data collection during operation compared to other pressures. The cooling oil pressure and tank pressure are the same at 6.6 Bar, and the air pressure is at 6.3 Bar.

C. Debit input air and operational air

The two-screw compressor is a type that can work 24 hours without stopping and is used for high air flow requirements. The advantage of a screw air compressor is that the air produced does not contain much water vapor, because the system of this air compressor uses screws, namely two threads that rotate to each other in pumping air, this type of air compressor also does not make noise.

When the compressor is operating, it has been set how much discharge is needed so that in Figure **5**, the graph shows a fluctuating movement resembling a uniform wave between 400 to 385 m cubic per hour.

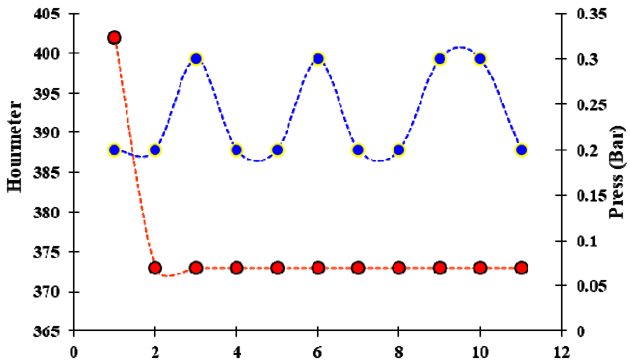

Fig. 5. Example of a figure caption. (style: figure caption)

D. Efficiency compressor

The power required by the compressor is not only for the gas compression process, but also for overcoming mechanical constraints, friction, airflow aerodynamic resistance constraints on valves and pipelines, gas leaks, cooling processes, and others. These constraints will reduce the power of the compressor shaft. But to determine how much influence each of these constraints is very difficult. In theory, the calculation of the power required for multilevel compression process is as follows:

Compressor Working Conditions Ideal

Wcs = h2s – h1

= 359 kj/kg – 300,6 kj/kg

= 58,4 kj/kg

Actual Compressor Working Conditions

Wc = h2 – h1

= 367 kj/kg – 300,6 kj/kg

= 66,5 kj/kg

Compressor Efficiency

$$\eta c = \frac{Wcs}{Wc} x100\%$$

$$\eta c = \frac{58{,}4}{66{,}5} x100\%$$

= 0,8781 x 100%

= 87,81 %

From the results of these calculations, the ideal compressor working conditions are 58.4 kj/kg, while the actual compressor working conditions are 66.5 kj/kg and the air compression process with the double screw compressor type produces an efficiency of 87.81%.

IV. Conclusion

This study realized the high efficiency and reliable operation of the observed oil-injected double-screw compressor, by adopting several analytical activities to solve some of the operating problems in the industry as follows:

(1) The profile is specifically designed to reduce noise and increase compression capability over a long period of time (more than 24 hours) with a range of 400 to 385 m cubic per hour.

(2) Cooling oil works well keeping the compressor temperature constant at around 100 ^{0}C, even though there are very active temperature fluctuations.

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(3) Overall compressor operating pressure is constant, despite significant spikes in drier pressure.

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