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PERFORMANCE ANALYSIS AND MODIFICATION OF AIR COMPRESSOR SYSTEM

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Abstract -***Air compressors are used as versatile tool throughout the industries for a variety of purposes. They are used for various applications in manufacturing plants such as driving pneumatic tools, air operated controlling equipment's, conveying of fly ash etc.. . Air compressors are one of the major sources of energy consumption in industries. In the present scenario, the importance of energy conservation is increasing day by day. For a manufacturing plant, improving energy efficiency or replacement of less energy efficient equipment with energy efficient ones can earn significant savings. In the manufacturing plant, it was found that compressors which are running were installed in the earlier stages. Due to aging, the efficiency of compressor decreased and it resulted in huge expense. As a solution, the performance assessment of the compressors were done. Compressor with an energy efficiency less than 35% is replaced with energy efficient Compressor. Modification in the compressor air system was done to improve efficiency.***

Keywords:*Compressor, energy efficiency, Performance assessment, Modification*

1. INTRODUCTION

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine etc...) in to potential energy stored in pressurized air. By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off. The compressed air, then, is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turn on again and re-pressurize the tank. According to design and principle of operation they can be classified as positive displacement compressors and negative displacement compressors. Air compressors are used in industries for variety of applications and they consume large amount of power from a manufacturing plant. In present scenario the demand of energy efficiency is increasing day by day. Improved energy efficiency can earn significant to the plant. This motivated me to do the analysis of compressors in the manufacturing plant. Twelve compressors were analyzed. Least efficient compressor is replaced with energy efficient one. For other compressors preventive maintenance practices are suggested to improve efficiency. In manufacturing plant, compressors are running in a corrosive and high temperature conditions. So upgrading the design of the compressor unit can increase the reliability, safety and overall efficiency of the screw compressor. As a solution, modification in air compressor system was suggested to improve energy efficiency.

2. PERFORMANCE ASSESMENT PARAMETERS

The performance assessment parameters of compressors include the calculation of FAD (free air delivery), volumetric efficiency and power consumption.

2.1 CALCULATION OF FAD

The free air delivery of the compressor can be calculated by receiver filling method. The volume of the receiver is noted if mentioned on the name plate. If the receiver volume is not known it should be physically measured by pouring water from a calibrated measuring can. Dished contours cannot give correct volume when calculated analytically. The compressor is kept running on load and no load for some time so that the temperature of the compressor increases. The compressor is then stopped. The sizes of pipes up to isolations valves is measured and volume of pipe is calculated. The volume is added to the receiver volume and called 'effective receiver volume'. The valves which isolate the compressor receiver from the delivery lines are closed. Pressure gauge reading is noted. It should read zero because all the air in the receiver is drained. The compressor is started and kept on full load. This should be kept in full load mode, if controlled by an external control panel. Time taken by the compressor, in seconds to reach a cut-off pressure is recorded.

$$FAD = \frac{(\text{effective volume of receiver in liters})*60*(p_2-p_1)}{(\text{Time to reach set pressure in sec})*p_0}$$

P_0=Atmospheric pressure
P_1=Initial pressure

P_2=Final tank pressure

2.2 CALCULATION OF VOLUMETRIC EFFICIENCY

The volumetric efficiency of the compressor is calculated by the ratio of actual free air delivery of the compressor to specified free air delivery of the compressor.
Volumetric efficiency = (Actual Output of Compressor/Specified Output of compressor).

2.3 CALCULATION OF POWER CONSUMPTION

Power consumption is calculated by:
Power consumption =√3*V*I*Cosø

V = Voltage (V)

I = Current (A)

Cosø = 0.98

3. PERFORMANCE ANALYSIS OF COMPRESSORS

In the manufacturing plant, twelve compressors were taken under study. The performance parameters such as free air delivery, volumetric efficiency and power consumption were calculated:

3.1 SAMPLE CALCULATION

Location: Raw mill

Purpose: Raw mill grease spray and free jacking

K.G khosla make, three cylinder (two LP and one HP) two stage, air cooled, belt driven, oil lubricated, and electrically driven mounted compressor with start-stop regulation having the following name plate details:

Internal number: 30077

Model: 2 BC 26

Rpm: 750

FAD: 736*10^{-3} m^3/min

Actual rpm was found to be 716

Safety valve, drain cock and pressure gauge were found to be ok.

The compressor was found to be cutting off at 7 kg/cm^2

Discharge temperature was found to be 49^0c

Maximum current drawn at the time of unloading was found to be 7.2 to 7.4 A

Receiver filling time to reach 7 kg/cm^2 from atmospheric pressure was found to be 206.5 sec

The isolation valves are very close to the receiver and the additional volume because of the pipes are negligible.

Output of the compressor = (250*60*7)/206.5=508.47* 10^{-3} m^3/min

Volumetric efficiency = (508.47/736)*100=69.08%

Power Consumption:

Full load power = 5.5 kW

Intake current = 7.3 A

Full load current = 11A

Power consumption = √3*V*I*Cosø
Power consumption = √3*415*7.3*0.98 = 5.1Kw

Table -1: Analysis Results

Compressor No:	Actual FAD (m^3/min)	Volumetric efficiency %	Power consumption (kw)
1	0.508	69.08	5.1
2	0.226	30.7	3.6
3	1.593	93.71	10.56
4	1.161	68.24	9.157
5	0.360	48.9	4.9
6	0.444	60.4	4.6
7	3.275	65.5	18.3
8	3.518	70.4	17.6
9	5.183	80.11	28.1
10	3.804	58.80	29.5
11	0.547	74.4	5.4
12	0.564	76.7	4.3

4. PREVENTIVE MAINTENANACE

The majority of compressors working in the plant have less efficiency. Due to cost problem, all compressors cannot be replaced. The compressor having an efficiency of 30.7 is to be replaced by energy efficient one .For the other compressors preventive maintenance practices can be followed in order to improve energy efficiency.

- Leakage and wastage were checked and found to be absolutely minimum. Rigorous monitoring were done by the plant

- Suction filters of the compressor in raw mill & packing plant should be changed as per the details mentioned later. The design separates and holds quiet some dust before the filter element. In case of compressors all the suction filters should be like the ones fitted on the compressor used for raw mill grease spray. The only difference between these filters and the old ones is provision of two plastic cases outside which create centrifugal action and which remove lot of dust before air reaches the filter element.
- Routine periodic maintenance of valves, cooling system, lubricating system, unloading system etc. Should be done
- Preventive maintenance should be done condition based rather than the calendar based.
- In suction filters of the compressors lot of gaps are found between the filter frames and inlet filters of compressors. As a result unfiltered air is likely to enter in to the compressors. It is recommended to clean the filters more frequently and observe the pressure drop across the suction filter.

4.1 REPLACEMENT OF COMPRESSOR

The compressor having an efficiency of 30.7% is to be replaced. Selection of new compressor is very important here. At present screw compressors are more efficient than any other compressors available. The annual energy savings that the plant can acquire is shown below:

OLD COMPRESSOR:

Discharge pressure = 9 kg/cm^2

Motor Kw = 5.5 kW/7hp

FAD =$736*10^{-3}$ m^3/min

Cut-off pressure: 6 kg/cm^2

Cut-in pressure: 5 kg/cm^2

Annual Energy cost = (Full load power (kW) *annual running hours* electricity cost/kWh) / motor efficiency

Full load power = 5.5 kW

Motor efficiency = 65.4 %

Electricity cost is 5.25 Rs /kWh

Annual energy cost = (5.5*7920*5.25) / .654 = 3,49,678 Rs

NEW COMPRESSOR:

Discharge pressure = 7 kg/cm^2

Motor Kw = 4 kW/5.5 hp

FAD = $670*10^{-3}$ m^3/min

Annual Energy cost = (Full load power (kW) *annual running hours* electricity cost/kWh) / motor efficiency

Full load power = 4 kW

Motor efficiency = 85 %

Electricity cost is 5.25 Rs /kWh

Annual energy cost = (4*7920*5.25) / .85 = 1, 95,670 Rs

Cost savings = 1,54,008 Rs

The cut-off pressure of old compressor is at $6Kg/cm^2$ but the discharge pressure is $9kg/cm^2$.So that much power can be saved. The new compressor should have discharge pressure near to the cut-off of compressor. Also the newly replaced system have better motor efficiency than the old one.

5. MODIFICATION OF AIR COMPRESSOR SYSTEM

In the manufacturing plant, compressors are working at corrosive and high temperature conditions. The intake air may contain dust which in turn decrease the efficiency of the compressor. Low maintenance and continuous service are extremely important in this area. So upgrading the design of the compressor unit can increase the reliability, safety and overall efficiency of the screw compressor .The effect of intake air on compressor performance should not be underestimated. Intake air that is contaminated or hot can decrease compressor performance and result in excess energy and maintenance costs. If moisture, dust, or other contaminants are present in the intake air, such contaminants can build up on the internal components of the compressor, such as valves, impellers, rotors, and vanes. Such build-up can cause premature wear and reduce compressor capacity. When inlet air is cooler, it is also denser. As a result, mass flow and pressure capability increase with decreasing intake air temperatures. Conversely, as the temperature of intake air increases, the air density decreases and mass flow and pressure capability decrease. The resulting reduction in capacity is often addressed by operating additional compressors, thus increasing energy consumption. To prevent adverse effects from intake air quality, it is important to ensure that the location of the entry to the inlet pipe is as free as possible from ambient contaminants, such as rain, dirt, and discharge from a cooling tower. If the air is drawn from a remote location, the inlet pipe size should be increased in accordance with the manufacturer's recommendation to prevent pressure drop and reduction of mass flow. All intake air should be adequately filtered. A pressure gauge indicating pressure drop in inches of water is essential to maintain optimum compressor performance.

5.1 PLACEMENT OF PREFILTER

Compressors are sometimes installed in environments where there is a great deal of airborne dirt and dust, depending on the products manufactured by our customers. So the compressors are designed to eliminate dirt by installing filters on compressor air intakes. In good environments, these filters can operate without maintenance, until auxiliary equipment inspections are performed. However, in dusty environments, the filter quickly becomes clogged, and it is necessary to stop the compressor in order to clean the filter.

Fig -1: pre-filter

The fig. Shows the pre-filter mounted on the compressor.it is more efficient than intake air filters because it can be cleaned while the compressor is running

Fig -2: Placement of pre-filters on compressors

When an intake air filter is located at the compressor, the ambient temperature should be kept to a minimum, to prevent reduction in mass flow. This can be accomplished by locating the inlet pipe outside the room or building. When the intake air filter is located outside the building, and particularly on a roof, ambient considerations are important, but may be less important than accessibility for maintenance in inclement or winter conditions. A compressor intake air filter should be installed in, or have air brought to it from a clean, cool location. The compressor manufacturer normally supplies, or recommends, a specific grade of intake filter designed to protect the compressor. The better the filtration at the compressor inlet, the lower the maintenance at the compressor. However, the pressure drop across the intake air filter should be kept to a minimum (by size and by maintenance) to prevent and a reduction in compressor capacity. A pressure differential gauge is one of the best tools to monitor the condition of the inlet filter. If the pre-filter is installed on the compressor it removes the dust from the intake filter.it can be cleaned while the compressor is running. Additional auxiliary equipment's such as pressure gauge are not needed to measure the inlet pressure drop. Continuous and smooth air flow is provided. The air flow will be maximum at the output of the compressor.

6. CONCLUSION

Air compressors are used as versatile tool throughout the industries for a variety of purposes. At Malabar cements, air compressors are used for various applications. Air compressors are one of the major sources of energy consumption in the industry. In the present scenario, the importance of energy conservation is increasing day by day. So it is important to improve the efficiency of air compressors in the industry. As a result, I carried out the performance test of compressors at Malabar cements. It was found that majority of compressors at the plant are running at efficiencies less than 70%. Due to cost problem we cannot replace all the compressors with energy efficient ones. The compressor having an efficiency of 30.7% is replaced with screw compressors which has better performance and efficiency. The annual cost savings by installing the new compressor was also calculated. For other compressors preventive measures taken to improve efficiency were suggested. From the analysis of compressors, faults were detected and suitable remedial measures were suggested. Since the compressors are working at corrosive and high temperature conditions, design modifications are suggested in order to increase the efficiency of the compressors.

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