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Research Article

Maintenance of an Air Compressor Used in Quarries

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Abstract: The research work investigates the maintenance of an air compressor used in quarries. The objectives of the research were achieved through the selection of a compressor. Reciprocating compressor was selected maintained as it will give the required volume of air at a very high pressure. It has capacity of 1200 m^3/hr which makes it to work with any types of pneumatic drilling machine at a very high pressure. For every 3000 hours and 6000 hours, the preventive maintenance is required.
Keywords: Maintenance, reciprocating compressor, high pressure, pneumatic drilling machine, preventive maintenance

INTRODUCTION

An air compressor is a device that converts power (usually from an electric motor, a diesel engine or a gasoline engine) into kinetic energy by compressing and pressurizing air, which, on command, can be released in quick bursts. There are numerous methods of air compression, divided into either positive-displacement or negative-displacement types [1].

Compressor is a machine that extracts air from the atmosphere and compresses it into a holding chamber. The most common use of compressed air is for the operation of pneumatic tools. Compressed air is the fluid that has been used as a source of energy in rock drilling, as much for driving the pneumatic equipment with the top hammer or down-the-hole hammer, as for flushing of cuttings when the drilling with hydraulic or rotary hammers [2].

Compressors are used to increase the pressure of air from the initial conditions (air intake) to the discharge conditions (air discharge). Compressors may be used as vacuum pumps. A vacuum pump has an intake that is below atmospheric pressure and usually compresses to no higher than atmospheric pressure. The degree of vacuum attainable is dependent upon the type of system, leakage into the system, and limitations of the equipment. The main types of air compressors are positive displacement and dynamic as shown in Figure 1.

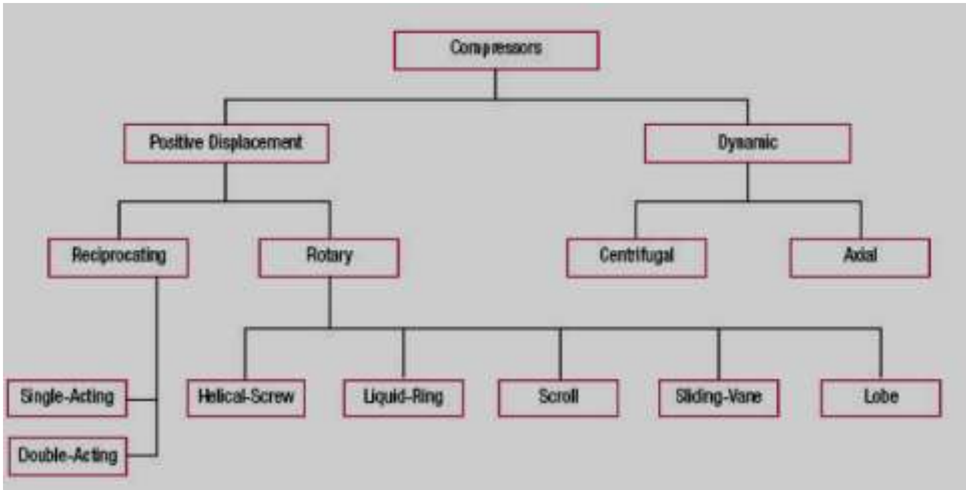

Fig-1: Types of Compressors (US DOE, 2003)

Most air compressors either are reciprocating piston type, rotary vane or rotary screw. Centrifugal compressors are common in very large applications. There are two main types of air compressor's pumps: oil-lube and oil-less. The oil-less system has more technical development, but is more expensive, louder and lasts for less time than oil-lubed pumps. The oil-less system also delivers air of better quality.

The efficiency of air compressor depends on air temperature, atmospheric pressure and relative humidity. The rating air compressor therefore depends on ambient conditions. This aspect should be taken into account if an air compressor is used in very cold weather, very wet weather or at a high altitude.

Air systems have less downtime than hydraulic systems because they have less complex controls. Less preventative maintenance is required with air, whereas hydraulic fluids must be monitored and replaced periodically. Maintenance means keeping equipment in a state of repair and efficiency. This is very important if the compressor is to be kept in good condition to achieve the required efficiency. This research work therefore looks into maintenance of air compressor used in drilling holes in mining companies.

MATERIALS AND METHOD

Materials

The material used for the study is the fairly used compressor machine bought by the Department of Mineral Resources Engineering Technology, Auchi Polytechnic, Auchi from a construction company.

Selection of Compressor

The compressor used for this study was selected by using a high-level comparison of important compressor types suggested by Sustainable Energy Development Office in 2002.

Determination of Compressor Capacity

The capacity of a compressor is the full rated volume of flow of gas compressed and delivered under conditions of total temperature, total pressure, and composition prevailing at the compressor inlet. It sometimes means actual flow rate, rather than rated volume of flow. This is also called free air delivery (FAD) i.e. air at atmospheric conditions at any specific location. This term does not mean air delivered under identical or standard conditions because the altitude, barometer, and temperature may vary at different localities and at different times.

Procedure for the Determination of Compressor Capacity

(i) The compressor was isolated along with its individual receiver that are to be taken for a test from the main compressed air system by tightly closing the isolation valve or blanking it, thus closing the receiver outlet.
(ii) The water drain valve was opened and drained out water fully and empty the receiver and the pipeline.
(iii) The water trap line was tightly closed once again to start the test.
(iv) The compressor was started and the stopwatch activated.
(v) The time taken to attain the normal operational pressure P_2 (in the receiver) from initial pressure P_1 was noted.
(vi) The capacity was calculated using the Equation 1 by the Confederation of Indian Industries [5].

$$Q = \frac{P_2 - P_1}{P_0} \times \frac{V}{T} Nm^3 / Minute \qquad (1)$$

Where P_2 is the pressure after filling (kg/cm^{2}a), P_1 is the initial pressure (kg/cm^{2}a) after bleeding, P_0 is the atmosphere pressure (kg/cm^{2}a), V is the storage volume in m^3 which include receiver, after cooler, and delivery piping and T is the time taken to build up pressure to P_2 in minutes.

Determination of Compressor Efficiency

Several different measures of compressor efficiency are commonly used: volumetric efficiency, adiabatic efficiency, isothermal efficiency and mechanical efficiency. Adiabatic and isothermal efficiencies are computed as the isothermal or adiabatic power divided by the actual power consumption. The figure obtained indicates the overall efficiency of a compressor and drive motor. For the purpose of this study only volumetric efficiency was calculated using Equation 2.

$$Volumetric efficiency = \frac{FAD(m^3/\min)}{CD} \qquad (2)$$

Where FAD is the free air delivered in $(m^3/\min)$, and CD is the compressor displacement.

$$CD = ?\times D^2/_4 \times L \times S \times ?\times n$$

Where D is the Cylinder bore in metre, L is the Cylinder stroke in metre, S is the Compressor speed in rpm,? is 1 for single acting and 2 for double acting cylinders and n is the no. of cylinders.

Maintenance Process

The maintenance and troubleshooting methods adopted in the study is the one prepared by Midmark and that prepared by UNEP.

Generation of Maintenance Check List

Check list was generated for the preventive maintenance of the compressor.

Safety

The safety tips needed during and before operating the air compressor and the symbols indicating various protective dangers according to Rolair, was presented in this work [3]. The symbols were placed in the appendix.

Maintenance Cost

The cost involved in the maintenance of the purchased Air Compressor is shown in Table 1.

RESULTS AND DISCUSSION

Compressor Selection

Table 1 shows the comparison between the important compressor types.

Table 1: A High-level Comparison of Important Compressor Types [6]

Item	Reciprocating	Rotary Vane	Rotary Screw	Centrifugal
Efficiency at full Load	High	Medium - high	High	High
Efficiency at part load	High due to staging	Poor: below 60% of full load	Poor: below 60% of full load	Poor: below 60% of full load
Efficiency at no load (power as % of full load)	High (10% - 25%)	Medium (30% - 40%)	High-Poor (25% - 60%)	High-Medium (20% - 30%)
Noise level	Noisy	Quiet	Quiet-if enclosed	Quiet
Size	Large	Compact	Compact	Compact
Oil carry over	Moderate	Low-medium	Low	Low
Vibration	High	Almost none	Almost none	Almost none
Maintenance	Many wearing parts	Few wearing parts	Very few wearing parts	Sensitive to dust in air
Capacity	Low – high	Low - medium	Low - high	Medium – high
Pressure	Medium – very high	Low - medium	Medium - high	Medium – high

Comparing the four types of compressor (reciprocating, rotary vane, rotary screw and centrifugal) as shown in Table 1, reciprocating compressor has high efficiency at full load, high efficiency at part load due to staging, high efficiency at no load 10% to 15%, large in size, moderate in oil carry over, low to high capacity and medium to very high pressure although the reciprocating compressor is noisy with high vibration and their many wearing parts to maintain. Going by these qualities, reciprocating compressor has been selected as it will give the required volume of air at a very high pressure as compare to rotary vane, rotary screw and centrifugal compressors which are not efficient under various loads.

Capacity of Selected Compressor

The estimated capacity of the selected compressor as calculated from Equation 1 is 12000 m^3/hr. It means the selected compressor can work with any type of drilling machine and at a very high pressure.

Efficiency of Selected Compressor

The estimated selected compressor efficiency using Equation 2 is 96% which is very high under various loads as compared to other types of compressor.

Maintenance of Selected Compressor

The preventive maintenance of selected compressor is presented in Table 2.

Table 2: Reciprocating Compressor Routing Maintenance

Every 8hours	Every 360hours	Every 3,000hours	Every 6,000 hours
(i) Check compressor lubricant level in crankcase and cylinder lubricator and, if necessary, add to level indicated by sight gauge. (ii) Check cylinder lubrication feed rate and adjust, as necessary. (iii) Check lubricant pressure and adjust as necessary to meet specified operating pressure. (iv) Check cylinder jacket cooling water temperatures. (v) Check capacity control operation. Observe discharge	(i) Check piston rod packing for leaks and for blow-by at gland. Repair or replace as necessary per manufacturer's manual. (ii) Inspect lubricant scraper rings for leakage. Replace as necessary per manufacturer's manual. (iii) Inspect air intake filter. Clean or replace as necessary. (iv) Drain lubricant strainer/filter sediment. (v) Lubricate unloader mechanism	(i) Perform valve inspection per manufacturer's manual. (ii) Inspect cylinder or cylinder liner, through valve port, for scoring. (iii) Change crankcase lubricant, if required. (iv) Clean crankcase breather, if provided. (v) Change lubricant filter element. (vi) Remove and clean control air filter/strainer	(i) Remove and clean crankcase lubricant strainer.

pressure gauge for proper LOAD/UNLOAD pressures. (vi) Drain control line strainer. (vii) Check operation of automatic condensate drain trap (intercooler and aftercooler). (viii) Drain condensate from discharge piping as applicable (drop leg and receiver). (ix) Check intercooler pressure on multi-stage machines, and refer to manufacturer's manual if pressure is not as specified.	per manufacturer's manual. (vi) Check motor amperes (amps) at compressor full capacity and pressure.	element. (vii) Check all safety devices for proper operation. (viii) Perform piston ring inspection on non-lubricated design. Replace as necessary per manufacturer's manual.	

The required routing maintenance required for reciprocating compressor is presented in Table 2. The lubricants in every part of compressor are always checked in every 8 hours. The lubricant pressure, cylinder jacket cooling water temperatures, capacity control operation, operation of automatic condensate drain trap and intercooler pressure on multi-stage machines are being checked every 8 hours. In every 360 hours, piston rod packing for leaks and for blow-by at gland and motor amperes at compressor full capacity and pressure are checked. The selected compressor's lubricant scraper rings is inspected for leakage and air intake filter is also inspected. For every 3000 hours and 6000 hours, the preventive maintenance that will be done on the machine is as presented in the Table 2.

The corrective maintenance which involve replacing some part of the machine like cylinder, fuel pump, lubricants and electric motor among others were replaced with new ones to put the compressor in good working condition.

Trouble Shooting

Following are the trouble shootings carried out on the selected compressor. The method adopted is the one suggested be EMGLO in 1993 [4].

(a) Compressor "Not Producing Enough Air"

1. Drain air tank a n d measure pump up time. Comp a r e with proper time for compressor model (see factory guide).
If time is O.K., compressor may be too small for application. Increasing operating pressure will exaggerate the problem.
2. Test for leaks in air lines, tank, or compressor fittings. Soap suds solution works well.
3. Clogged filter element - remove, clean or replace. Intake air must be free of contamination such as paint mist.
4 . Hot air blows out of intake. lntake valves not sealing. Remove and clean. Polish disc on fine emery cloth (#400). Replace worn parts. A complete valve plate assembly can be obtained as a factory exchange at low cost.
5. Check valve or discharge tubing clogged. Clean or replace.

(b) Interstage Safety Valve Leaks

1. Head gasket or high pressure inlet valve leak. Examine, clean valve or replace.
2. Defective safety valve; Replace. Do not adjust safety valve.

(c) Excessive Oil Consumption

1. Clogged air intake filter. Clean or replace.
2. Inferlor or dirty oil - see recommendations in instructions.
3. Crankcase not sealed - air leaks in. Check oil fill cap and shaft oil seal. Replace if necessary. Tighten crankcase bolts (15 Ft. Ib.)
4. Piston rings worn or sticking. Remove rin s, clean grooves. Check ring wear by pushing ring into cylinder bore. New ring end gap is approximately 0.007 to 0.017 inches. (Operation is O.K. to 0.060) Stagger ring gaps when installing.
5. Deep scratch on cylinder wall. Caused by lack of oil or dirt in oil. Hone (0.015 max. on diameter) or replace.
6. Oil in discharge air. Some oil is always present. Clean accumulation in air lines and tank. Add air line filter or clean element.
7. Compressor unloaded more than 60% with constant running control. Consider start-stop or dual control.

(d) Milky Oil in Reservoir

1. Normal result of water mixing with oil in tank or possibly in crankcase. Change oil and/or drain tank.
2. Move compressor or pipe intake to lower humidity source or cooler area. Increase intake pipe one size for every 3 feet of length - keep short.

(e) Noise, Knock or Vibration

1. Assembly-vibrating. See mounting instruction.
2. Flywheel wobbles. Cracked flywheel or bent shaft. Replace.
3. Flywheel or pulley loose. Remove, apply loctite on shaft, re-install with new key.
4. Loose or worn connecting rod or piston pin. Tighten or replace.

5. Pressure switch or magnetic starter chatter. Adjust switch for greater differential or replace.
6. Loose vee belt. Adjust tension on slotted platform.
7. Foreign matter (carbon, dirt, piece of gasket) on top o f piston. Remove cylinder head and check. To increase head clearance, add crankcase gaskets . . . not head gaskets.

(f) Runs Hot

1. Compressor operating in excess of rated discharge pressure. Reset pressure control.
2. Poor ventilation. Provide cooler location. Allow minimum *6"* flywheel clearance.
3. Incorrect rotation. Check flywheel arrow. Reverse motor.
4. Discharge valve or head gasket leak. Remove and clean valve. Replace.
5. Restriction in discharge line or check valve. Clean or replace.

(g) Compressor "Slowdown" or "Froze Up"

1. Check that supply voltage matches motor, i.e., 115 volt supply with motor connected T or 230 volts or 208 supply with 230 volt motor.
2. Measure actual voltage at the motor while the compressor is under load (starting up or at high pressure). If boltage is more than 10% below motor nameplate rating, relocate compressor closer 10 maln) witch panel and/or provide heavier wiring. Check with electric power company.
3. Vee belt slipping. Adjust tension by moving motor. (clean oil from belt and pulley).
4. Operating pressure set higher than design pressure. Reset control.
5. If flywheel cannot be turned by hand (drain tank to eliminate back pressure), check oil level. If frozen condition exists after cooling down and adding oil, disassemble compressor and replace damaged components. After compressor "run in" period, freezing is caused by lack of adequate clean lubrication.
6. Gas Engine Driven Compressors: If engine stalls during acceleration, increase engine idle speed on engine equipped with a clutch, maintain idle speed below clutch engagement speed, (approx. 1900 RPM).

Generation Check List

The check list generated in this study is as written below:

(i) Find and fix current compressed air leaks and try to prevent the same. Check for leaks and pressure losses throughout the system regularly (monthly).
(ii) Avoid the improper, yet common practice of cracking drains in an effort to insure moisture free performance at a particular point-of- use.
(iii) Regulate all point-of- use operations at the lowest possible pressure using a quality regulator.
(iv) Eliminate the use of air hoists, and air motors.
(v) Shut off the air supply to "off- line" production equipment.
(vi) Isolate single users of high pressure air.
(vii) Monitor pressure drops in piping systems.
(viii) Evaluate your need for modulating compressors.
(ix) Use high efficiency motors in place of standard motors.
(x) Consider multiple staged compressors.
(xi) Lower the output pressure as far as possible.
(xii) Use waste heat off the compressor to help the rest of the plant save energy.
(xiii) Avoid delivering higher pressure to the entire plant just to meet the requirements of one user.
(xiv) Understand multiple compressor system controls.
(xv) Utilize intermediate controls/expanders/high quality back pressure regulators.
(xvi) Understand the requirements for clean- up equipment.
(xvii) Use the drying technology that gives you the maximum allowable pressure dew point.
(xviii) Choose "best in class" products for all compressor parts in case of replacements.
(xix) Monitor the differential pressure across the air filter. Excessive pressure drop in filters also wastes energy.
(xx) Use cool outside air for the compressor intake.
(xxi) Adopt a systematic preventive maintenance strategy for your compressor.
(xxii) Impart training and create awareness among employees for efficient operation andmaintenance of compressor systems.
(xxiii) Ensure the entire system is monitored by good housekeeping practices.
(xxiv) Ensure condensation can be removed swiftly from the distribution network, or does notoccur.
(xxv) Check that receivers are sized to store air for short heavy demands.

Safety

Safety symbols are used to alert you to potentially hazardous situations during operation of air compressor. The following definitions describe the level of severity for each signal word.

DANGER: Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

WARNING: Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION: Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury or damage to the air compressor.

All this warning should be taken care off during the operation of compressor.

Maintenance

The costs involved in purchasing and putting the compressor to other is presented in Table 3.

Table-3: Cost of Purchasing and Maintenance of Air Compressor

S/N	DESCRIPTION OF ITEMS	COST ₦ : K
1.	Air Compressor	240,000:00
2.	4 No set of Rings	22,000:00
3.	1 No top Gasket	10,000:00
4.	1 No oil Filter	1,000:00
5.	4 set of Valves	4,000:00
6.	2 No fuel Filter	1,000:00
7.	1 set of connecting Rod Metal	8,000:00
8.	Bank Charges on cash transaction	675:00
9.	Recharge Cards	800:00
10.	PMS (Petrol)	2,000:00
11.	20 Litres of AGO (Diesel)	3,100:00
12.	19 Litres of Lubricant (Engine Oil)	8,250:00
13.	Files	400:00
14.	2No empty Gallon	850:00
15.	Bottom filter	300:00
16.	Bottom packing	600:00
17.	Menco packing	400:00
18.	Oil seal	400:00
19.	Battery terminal head	200:00
20.	Repair of Injector	7,000:00
21.	Grinding of Top Cylinder	2,700:00
22.	Servicing / Welding of Kick Starter	800:00
23.	workmanship	20,000:00
24.	Feeding (Mechanics)	10,000:00
25.	Transportation (Mechanics)	20,000.:00
26.	2 No (100 Amps each)Car batteries	30,000:00
27.	1 No top packing	1,250:00
28.	1 No screw driver	50:00
29.	Project Representative expenditure	10,085:00
30.	Online browsing	1000:00
31.	7 yards of PVC carpet	1,750:00
32.	Auto Kick	4,000:00
33.	3 pieces of Air compartment Big piston rings	35,000:00
34.	4 pieces of Air compartment Small piston rings	30,000:00
35.	Air compartment bearing	10,000:00
36.	Air compartment big Sleeves	85,000:00
	TOTAL	**572,610:00**

CONCLUSIONS

Based on the results of this study, the following conclusions were made:

1. Before the selection of the bought compressor various types of compressor were compared and the one that has the highest quality was selected which is reciprocating compressor.
2. The efficiency and capacity of the selected compressor were determined to be 96% and 12000 m^3/hr respectively.
3. Preventive maintenance used on the compressor was listed and a trouble shooting method suggested by EMGLO in 1993 was adopted which has assisted in putting the compressor in good order.
4. Check list for the preventive maintenance was also generated.
5. The overall cost used for purchasing and repair of the compressor is ₦ 572,610:00 which is smaller than the cost of obtaining a new compressor.

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