"MAINTENANCE AND CALIBRATION OF TWO STAGE SINGLE ACTING RECIPROCATING AIR COMPRESSOR"

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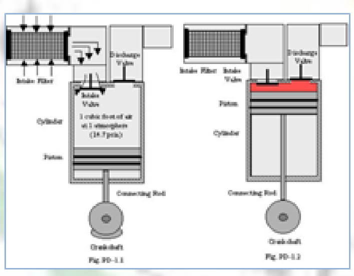
ABSTRACT

"Single acting two stage reciprocating air compressor" test rig was used for calculation of volumetric efficiency and isothermal efficiency of reciprocating air compressor.
Since the machine is used in several collages for performing experiments, this machine proves to be the best of studying About the volumetric efficiency and isothermal efficiency of single acting two stage reciprocating air compressor. The machine consist of two main components i.e. CYLENDER AND PISTON ASSEMBLY AND AIR RESERVOIR TANK. ThesThese two components plays vital role in this air compression process.
This machine is made by the company,[DATACONE ENGINEERING.PVT.LTD] which is based in [Sangli in Maharashtra state.

Air Compressor:

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed 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 the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.



Two Stage Single Acting Reciprocating Air Compressor Test Rig

TYPE ACCORDING TO DISPLACEMENT:

There are numerous methods of air compression, divided into either positive-displacement or roto-dynamic types.

Positive displacement (Reciprocating Compressor):

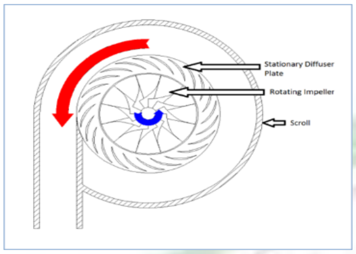
Positive displacement compressors work by forcing air into a chamber whose volume is decreased to compress the air. Once the maximum pressure is reached, a port or valve opens and air is discharged into the outlet system from the compression chamber. Common types of positive displacement compressors are

Piston-type: air compressors use this principle by pumping air into an air chamber through the use of the constant motion of pistons. They use one-way valves to guide air into a cylinder chamber, where the air is compressed. Rotary screw compressors: use positive-displacement compression by matching two helical screws that, when turned, guide air into a chamber, whose volume is decreased as the screws turn.

Vane compressors: use a slotted rotor with varied blade placement to guide air into a chamber and compress the volume. A type of compressor that delivers a fixed volume of air at high pressures

Dynamic Displacement (Rotary Pump):

Dynamic displacement air compressors include centrifugal compressors and axial compressors. In these types, a rotating component imparts its kinetic energy to the air which is eventually converted into pressure energy. These use centrifugal force generated by a spinning impeller to accelerate and then decelerate captured air, which pressurizes it.



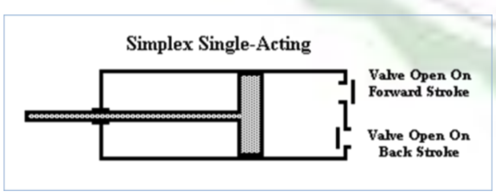
RECIPROCATING AIR COMPRESSOR:

A reciprocating compressor or piston compressor is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure.

The intake gas enters the suction manifold, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. Applications include oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. One specialty application is the blowing of plastic bottles made of polyethylene terephthalate (PET).

In the ionic liquid piston compressor many seals and bearings were removed in the design as the ionic liquid does not mix with the gas. Service life is about 10 times longer than a regular diaphragm compressor with reduced maintenance during use, energy costs are reduced by as much as 20%. The heat exchangers that are used in a normal piston compressor are removed as the heat is removed in the cylinder itself where it is generated. Almost 100% of the energy going into the process is being used with little energy wasted as reject heat.

TYPE OF RECIPROCATING COMPRESSOR:

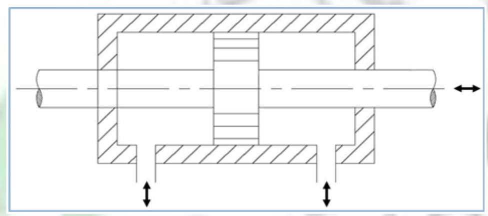


Single-acting reciprocating air compressor

A single-acting cylinder in a reciprocating engine is a cylinder in which the working fluid acts on one side of the piston only. A single-acting cylinder relies on the load, springs, other cylinders, or the momentum of a flywheel, to push the piston back in the other direction. Single-acting cylinders are found in most kinds of reciprocating engine. They are almost universal in internal combustion engines (e.g. petrol and diesel engines) and are also used in many external combustion engines such as Stirling engines and some steam engines. They are also found in pumps and hydraulic rams.

Double-acting reciprocating air compressor

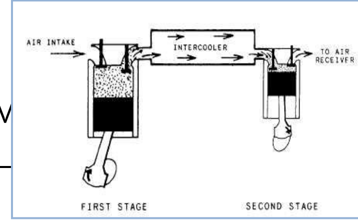
Typical horizontal steam engine with double-acting cylinder.A double-acting cylinder is a cylinder in which



the working fluid acts alternately on both sides of the piston. In order to connect the piston in a double-acting cylinder to an external mechanism, such as a crank shaft, a hole must be provided in one end of the cylinder for the piston rod, and this is fitted with a gland or "stuffing box" to prevent escape of the working fluid. Double-acting cylinders are common in steam engines but unusual in other engine types. Many hydraulic and pneumatic cylinders use them where it is needed to produce a force in both directions. A double-acting hydraulic cylinder has a port at each end, supplied with hydraulic fluid for both the retraction and extension of the piston. A double-acting cylinder is used where an external force is not available to retract the piston or where high force is required in both directions of travel.

MULTISTAGING AND WITH INTERCOOLRE IN RECEPROCATING AIR COMPRESSOR:

A multi-stage compressor is one in which there are several cylinders of different diameters. The intake of air in the first stage gets compressed and then it is passed over a cooler to achieve a temperature very close to ambient air. This cooled air is passed to the intermediate



stage where it is again getting compressed and heated. This air is again passed over a cooler to achieve a temperature as close to ambient as possible. Then this compressed air is passed to the final or the third stage of the air compressor where it is compressed to the required pressure and delivered to the air receiver after cooling sufficiently in an after-cooler.

INTERCOOLING:

An intercooler is any mechanical device used to cool a fluid, including liquids or gases, between stages of a multi-stage compression process, typically a heat exchanger that removes waste heat in a gas compressor. They are used in many applications, including air compressors, air conditioners, refrigerators, and gas turbines, and are widely known in automotive use as an air-to-air or air-to-liquid cooler for forced induction (turbocharged or supercharged) internal combustion engines to improve their volumetric efficiency by increasing intake air charge density through nearly isobaric (constant pressure) cooling.

LITERATURE SURVEY:

Review of literature of two stage single acting reciprocating air compressor

[1] Author – Ravi Shankar, Amit Suhane, Manish Vishwakarma.

Reciprocating air compressor is the most widely used type of compressor found in many industrial applications and is a crucial machine in a gas transmission pipeline, petrochemical plants, refineries, etc.

Due to high pressure ratio requirement, reciprocating air compressor is commonly used in locomotives. After a period of life unexpected failure of internal components due to miscellaneous reason occurs, which affects the operating system performance. This paper presents a case study on reciprocating air compressor. The associated problem diagnosis and effective solutions supported by appropriate strategy of maintenance for overhauling and repairing of parts due to frequent failure of parts. It is predominantly essential to establish the recommended clearance given for various parts of the compressor.

So, based on dimensional measurement of compressor based measurement of compressor parts selection of repair and replacement becomes easy and it is based for economical point of view.

[2] Author – Jenny Compressor Manufacturer

Reciprocating air compressor are manufactured in a variety of shapes, sizes and capacities. Single stage machine draw air from the atmosphere and discharges it into the receiver or storage tank and then it is used.

Two stage compressor bring the air of two intermediate pressure in one employed. The unit is defined as multistaging. Multistaging compressor produce higher discharge pressure like all the other machines. the compressor also brakes down after certain amount of its life to prevent breakdown. Properly also use compressor and obey all the instruction regarding use of the compressor the maintenance can be done in different ways to make the machine working.

[3] Author - Navedtra

Air compressor range from small reciprocating brake units to system that are so large they required their own trailer. You will need to understand how air compressor function before you can become a component trouble shooter. This chapter gives you the foundation to recognize problem and repair them.

To gain the knowledge to identify the faults first study about the compressor. We needs to study different methods for different type of compressor.

Trouble shooting techniques are developed through experience and all are used to do it little different however, there are basic steps that we all should take. The best way to talk with to person working on the compressor. Check all regulatory device, check for something loose. The finally based on your knowledge think of various kinds of problems. After identification of problem use suitable methods to repair it.

IDENTIFICATION OF FAULTS:

1) Bearings makes too noise while performing practical.
2) High amount of vibrations in compressor and whole testing rig.
3) 'Screaming' sound, especially when compressor starts up.
4) Oil leakage in reciprocating compressor.
5) Cooling fan cover is damaged and it makes too noise.
6) Some of the valves are jammed.
7) Air leakage has been occurred in compressor.

8) Temperature measuring instrument is working with error.

METHODOLOGY:

Proper lubrication if possible or replacement of bearings is required.

1) Testing rig requires some support structure.
2) Belt is too loose .Tighten belt or replace with new one.
3) Replace the oil seals.
4) Repair the fan cover or replace if required.
5) Lubrication or replacement of old valves is required.
6) It requires providing seal between joints.
7) Replace the temperature measuring instrument.

MAINTENANCE:

1. Calibration of all the Pressure Gauges after the identification of problems we firstly took pressure gauges out for calibration.
2. Drilling of Hole on Pulley perpendicular to the axis of the shaft and perform Internal Threading on it and Fillet new oil.

Fig. Motor pulley before maintenance

Fig. Motor pulley after maintenance.

3. We changed the old not working starter with a new

one.

Fig. Obsolete (Not Working) 3 Phase Induction Motor Starter.

Fig. New (In Working) 3 Phase Induction Motor Starter

4. We brought sealing paste and applied it to all the

leakages in order to restore the leakages.

Fig. Gasket Sealing Paste on Oil Leakages

5. The 'O' ring of motor loading device is changed with new device

6. Working Accumulator after Changing of Hydraulic Oil and 'O' Ring.
Replacing Old 'O' Ring with New One.

7. We lubricated all the valves and moving parts in the compressor.

8. We changed the hydraulic oil in the compressor with new oil.
9. We changed all the gaskets for tight sealing.

CALCULATIONS:

The calculation given below are the readings taken after the Maintenance of "Two Stage Single acting Reciprocating Air Compressor".

Because, The last maintenance is done on .Test rig is before 5 to 6 years that's why the Test rig is not safe to use before maintenance and because of the Test Rig is not in use .

The test rig was not working properly before our maintenance and it is working now.

The calculation of our new reading are:-

Specification of Test Rig

There are two cylinder HP and LP cylinder compressor Specifications.

(1)Compressor Specification

*Bore of low pressure (L.P.) cylinder DLP = 100mm

*Bore of High pressure (H.P) cylinder DHP = 80mm

*Stroke of LP cylinder LLP = 89mm

*Rated speed = 1140 Rpm

*Maximum working pressure = 10 Kg/cm2

*Air Receiver capacity = 800×140 m3

Compressor capacity = 17.5Kg/cm2

No. of acting (A) = 1

(2)Motor specification:-

Power = 7.5 HP

Phase = 3

Rated speed = 1440 Rpm.

(3) Other specification:-

Diameter of orifice d =15mm =0.015m

Diameter of motor pulley D2 = 125mm = 0.125

Diameter of compressor Pulley D2 = 280 =0.28m

Coefficient of discharge of orifice Cd = 0.54

Observation:

Sr. No.	Particular	Notation	Unit	Reading
1	Intake pressure(gauge)	$P_{1(gauge)}$	Kg/cm^2	1.01325
2	Inter cooler /Intermediate pressure gauge	$P_{2(gauge)}$	Kg/cm^2	1.8
3	Delivery Pressure (gauge)	$P_{3(gauge)}$	Kg/cm^2	4.6
4	Intake Temperature	t_1 $T_1 = t_1+273$	℃ °K	33 306
5	Temperature before Intercooler	t_2 $T_2 = t_2+273$	℃ °K	59 332
6	Temperature after Intercooler	t_3 $T_3 = t_3+273$	℃ °K	52 325
7	Deliver Temperature	t_4 $T_4 = t_4+273$	℃ °K	65 338
8	Motor Speed	N_1	rpm	1148
9	Manometer Reading	h_1 h_2	mm mm	206 54

Calculation:

A Calculation for volumetric efficiency

1. Compressor speed:

As belt drive is used, $D_1 \times N_1 = D_2 \times N_2$

Compressor speed, $N_2 = (D_1 \times N_1)/ D_2$

$= (0.125 \times 1448)/0.28$

$N_2 = 646.428$rpm

(Note: Compressor is directly coupled to motor, the speed of motor is the speed of compressor.)

2. Density of air:

Using characteristic gas equation,

$P_1 \times V_1 = m_a \times R_a \times T_1$

Where m_a= mass of air

R_a= characteristic gas constant=287 J/kg°K

$m_a = (P_1 \times V_1)/ (R_a \times T_1)$

Now, density of air= $\rho_a = m_a / V_1$

$= P_1/ (R_a \times T_1)$,

Where P_1 is in N/m^2

$= P_1/ [R_a \times (t_1+273)]$

$\rho_a = (1.0132 \times 10^5)/ [(287 \times 33)+273]$

$= 1.1536\ kg/m^3$

3. Water Manometric head:

$h_w = h_1 - h_2 = 206-54$

$h_w = 152$ mm of water

$h_w = 0.152$ m of water

4. Air ahead causing the flow of air:

$h_a = h_w \times (\rho_w /\rho_a)$, where r_w = density of water

$= (0.152 \times 1000)/1.1536$

$=131.76$ m of air.

5. Actual volume of free air delivered:

Area of orifice, $a= \pi/4 \times d^2$

$= \pi/4 \times (0.015)^2$

$= 1.76 \times 10^{-4}\ m^2$

Actual volume of free air delivered, $V_a = C_d \times a \times \sqrt{2gha}$ m^3/s

$= 0.64 \times 1.76 \times 10^{-4} \times \sqrt{2.98 * 131.76}$

$V_a = 5.727 \times 10^{-3}\ m^3/s$

6. Mass of air supplied:

$m_a = \rho_a \times V_a$

$= 1.1535 \times 5.727 \times 10^{-3}$

$= 6.606 \times 10^{-3}$ kg/sec

7. Theoretical volume of air delivered:

Volume of low pressure cylinder=

$V_{LP} = (\pi/4)\ D_{LP}^2 \times L_1 m^3/cycle$

$= (\pi/4) \times (0.1)^2 \times (0.089)$

$=6.99 \times 10^{-4} m^3/cycle$

Theoretical volume of air delivered at intake condition

$V_{th} = V_{LP} \times (A \times N_2/60)\ m^3/sec$

8. Volumetric efficiency:

Volumetric efficiency = (actual volume of free air delivered)/ (theoretical volume of air delivered)

η_{vol} =(V_a/ V_{th}) ×100

= [(5.727 ×10^{-3})/(7.53×10^{-3})] ×100

η_{vol} = 79.05 %

A. calculation for isothermal efficiency:
1. index of compression:

Compression follows the polytrophic process i.e. PV^n=C

a) value of compression index 'n' for 1st stage compression-

	READING-1	READING-2	READING-3	READING-4	READING-5
η_{vol}	76.05 %	77.26%	78.29%	77.97%	80.01 %
η_{iso}	93.71 %	92.6%	91.17%	94.02%	93.09 %
N	1.033	1.102	1.026	1.007	1.002
W_{iso}	876.93 J/s	889.94 J/s	823.23 J/s	836.23 J/s	888.27 J/s

We know for compression process 1-2,

$T_1 /T_2 = (P_1/ P_2)^{(n-1)/n}$

I.e. 306/332= [$(1.0132)^{(n-1)/n}$]/1.8

0.92 = $0.5628^{(n-1)/n}$

n= 1.1637

b) $T_2/T_3=(P_2/P_3)^{(n-1)/n}$

325/353= $(1.8/4.6)^{(n-1)/n}$

log0.97= (n-1)/n log (0.39)

n=1.033

2. Actual work done

a) work done in compressing air in low pressure(LP) cylinder is

W_{LP}=[n/(n-1)] ×{$P_1V_1[(P_2/P_1)]^{(n-1)/n}$-1} J/s

=[n/(n-1)] ×{$m_aR_aT_1[(P_2/P_1)]^{(n-1)/n}$-1} J/s

=[1.179/(1.179-1)] ×{6.6×10^{-3}×287×306 $[1.8/1.01]^{(1.17-1)/1.17}$

=349.39 J/s

b) work done in compressing air in high pressure (HP) cylinder

W_{HP}= [n/(n-1)] ×{$P_2V_2[(P_3/P_2)]^{(n-1)/n}$-1} J/s

= [n/(n-1)] ×{$m_aR_aT_2[(P_3/P_2)]^{(n-1)/n}$-1} J/s

= [1.033/(1.033-1)] ×{6.6×10^{-3}×287×325 × $[4.6/1.8]^{(1.033-1)/1.033}$

= 586.35 J/s

c) Actual work done or indicated work

W_{ind}= W_{LP}+ W_{HP}

= 3.49.39+586.35

W_{ind}= 935.74 J/s OR W=0.93574 KW

3. Isothermal work:

$W_{iso}=P_1V_1[\log_e(P_3/ P_1)]$ J/s

= $m_aR_aT_1[\log_e(P_3/ P_1)]$ J/s

= 6.6×10^{-3}×287×306[$\log_e$(4.6/1.01)]

W_{iso} = 876.93 J/s OR W=0.87693 KW

4. Isothermal efficiency:

η_{iso} = (isothermal work/ indicated work) ×100

= (0.87693/0.93557) ×100

η_{iso} = 93.71%

RESULT OF CALCULATION:

1. Volumetric efficiency of this air compressor = 76.05%
2. Isothermal efficiency of this air compressor = 93.71%

Similarly we took 4 more readings to find mean values.

Mean Calculation:

1) Mean Volumetric efficiency of this air compressor = 79.91%
2) Mean Isothermal efficiency of this air compressor = 92.98%

COSTING:

Costing for Maintenance of Two Stage Single Acting Reciprocating Air Compressor

Sr. No	Type of Maintenance	Cost in Rs.
1.	Calibration of All Three Pressure Gauges	3000
2.	The Starter of The Compressor.	2200
3.	Drilling Of Hole On Pully perpendicular To The Axis of The Shaft And Perform Internal Threading on It And Fillet Welding.	1100
4.	Replacement Of Old Gaskets With New One.	400
5.	Gasket Paste To Block Minor Leakages	200
6.	Hydraulic Oil Replaced With New One	500
7.	'O' Ring of Motor Loading Device	100
8.	Travelling And Other Expenses	500
	Total Cost	8000

CONCLUSION:

As we have stated in our thesis we believe that we have successfully completed our work on the compressor.

And we conclude that our project "**MAINTENANCE AND CALIBRATION OF TWO STAGE SINGLE ACTING RECEPROCATING AIR COMPRESSOR**" finished.

We have properly replace and recalibrate all the damage parts and instruments respectively. As our experimental data states that the compressor is fully operational.

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