Enhancement Of Performance Of The Intercooler Used In Two Stage Reciprocating Compressor

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Abstract- *Air compressor is a device that convert mechanical energy into pressure energy. Usually mechanical energy applied from an electric motor, a diesel engine or a petrol engine. Air from atmosphere enters into the compressor. It is compressed to a high pressure. Then, this high-pressure air is delivered to a storage tank (vessel or reservoir). From the storage tank, it can be sent to any desired place for any purpose through pipe lines. In a multi stage air compressor, compression of air takes place in more than one cylinder. Almost all the multistage compressor applications, air will be cooled between the stages which are also known as inter cooling. The intercooling is possible to the intercooler. An intercooler is a heat exchanger. It exchanges the heat of compressed air from the LP compressor to the circulating water before the air enters the HP compressor. Inter cooling of a compressor is necessary for an efficient process. With inter cooling; the compressor is more closely to an isothermal compression with resulting lower power requirement. In the present work, the different type of low-cost cooling medium and additives are used to enhance the performance of the intercooler (shell and tube) in two stage reciprocating air compressors. Form this process the volumetric efficiency of the compressor is increased and work requirement lowered when compared with the existing one. In this process, the main objectives were to find a viable solution to reducing the temperature of the compressed air in to the two-stage reciprocating compressor by using a low-cost cooling medium and additives in the existing intercooler. The proposed idea was to enhance the performance of the intercooler used in two stage reciprocating air compressors. During this get data for validating the possibility of proposed cooling medium.*

Keywords- air compressor, intercooler, cooling medium, analysis

I. INTRODUCTION

COMPREESED AIR:

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, the passed into the compression cylinder where gets compressed by a piston driven in a reciprocating motion through a crankshaft, and is then discharged. Applications include acid and chemical industry, agriculture, construction industry, aircraft industry, mining operations, and refrigeration plants. Intercooling of a compressor is necessary for an efficient process. It is possible to intercoolers (intercooling medium). Adding a fin to an intercooler, however, increase the surface area and can sometimes be an economical solution to heat transfer problem [1]. Adding the fins in intercoolers and intercooler material is resulting more economical problem in intercooling

II. PROPERTIES OF INTER COOLING MEDIUM

AIR: Air is a common form of coolant Air cooling uses convective airflow (positive cooling) or a forced circulation. Air is the easily available fluid so air cooling is the best way to reduce the temperature of the compressed transfers fluid can below 32°F. Specific heat capacity, viscosity and specific weight of water and ethylene glycol solution vary significantly with the percent of ethylene glycol and temperature of fluid.
INTERCOOLERS The intercooler is simply a heat exchanger in which heat of compression generated in the first stage cylinder is removed from the air before it passes to the second stage cylinder. An intercooler is any mechanical device used to cool a fluid, including liquids or gases, between stages of a multi-stage heating process, typically a heat exchanger that removes waste heat in a gas compressor.

III. FUNCTIONS OF AN INTERCOOLER

INTERCOOLER USED IN AIR COMPRESSOR PERFORMS FOLLOWING FUNCTIONS:

Atmospheric air contains moisture, and furthermore, the air may pick up oil vapor as it passes through some compressors. Cooling the air down to or below its initial temperature will remove moisture down to the dew point, improving the quality of the air.

placed in a place that as many as possible get a breath of fresh air when the car moves.

1.6.3 SHELL AND TUBE INERCOOLER

A heat exchanger such as an intercooler is a mechanical device which is used for the purpose of exchange of heats between two fluids at different temperatures. There are various types of intercoolers available in the industry, however, the Shell and Tube Type intercooler is probably the most used and widespread type of the intercooler's classification. It is used most widely in various fields such as oil refineries, thermal power plants, nuclear stations, chemical industries and much more. This high degree of acceptance is due to the comparatively large ratio of heat transfer area to volume and weight, easy cleaning methods, easily replaceable parts etc. Shell and tube type intercooler consists of a number of tubes through which one fluid flows. Another fluid flows through the shell which encloses the tubes and other supporting items like baffles, tube heade sheets, gaskets etc. The heat exchange between the two fluids takes through the wall of the tubes shell normally has a circular cross section and is commonly made by rolling a metal plate of the appropriate dimensions into a cylinder and welding the longitudinal joint ("rolled shells").

IV. METHODOLOGY

In this present work, shell and tube intercooler is placed between the two stage reciprocating compressors.
The manometer setup is provided to analysis the inner volume of the air entered into the LP cylinder and also 15mm dia of the orifice is provided before the cylinder to measure the volume of the air.

In the intercooler, the different type of the low cost cooling medium is used to optimize the performance.

The cooling medium is circulated through the inter cooler by using electric motor.

The inlet and outlet temperature of the compressed air in the inter cooler is measured by using thermocouple and thermostat.

The heat observed by the cooling medium from the compressed air in the intercooler is cooled by atmospheric air with the help of shower.

V. PERFORMANCE ANALYSIS OF INTERCOOLER

Experimental setup: The photographic view of the experimental setup is shown in the the Figure 3. The experiment carried out in a two-stage reciprocating air/gas compressor mounted in a V shape with two separated cylinders, as shown in the Figure.

PHOTOGRAPHIC VIEW OF TWO STAGE RECIPROCATING COMPRESSOR

In the intercooler there is constant pressure inter cooling. Here our main purpose is the measurement of drop in the temperature of the air to be cooled between the inlet and the outlet of the intercooler. Calculation of amount of heat being exchanged between the hot and cold fluid is not required.

Suppose,

T_1= Temperature of air entering the intercooler.
T_2=Temperature of air leaving intercooler when the intercooler is normal.
T_3=Temperature of air leaving intercooler when the intercooler is refrigerated.
V_1=Specific volume of air entering the intercooler.
V_2=Specific volume of air leaving intercooler when the intercooler is normal.
V_3= Specific volume of air leaving intercooler when the intercooler is refrigerated.
P_1= Pressure of air entering the intercooler.
P_2=Pressure air leaving intercooler when the intercooler is normal.
P_3=Pressure of air leaving intercooler when the intercooler is refrigerated.
We know that the general gas equation is as follows: $\frac{P1V1}{T1} = \frac{P2V2}{T2}$
But, $P_1 = P_2 = P_3$ (constant pressure intercooling)
So, $\frac{V1}{T1} = \frac{V2}{T2}$
Therefore, $\frac{T1}{T2} = \frac{V2}{V2}$

And $V2 = \frac{T2}{T1} V1 - - - (1)$ (for normal intercooler)

Similarly, $V3 = \frac{T3}{T1} V1 - -(2)$ (for refrigerated intercooler)

If V_1 V_2 and V_3 are the specific volume of air in $\frac{m3}{kg}$ entering and leaving the intercooler then the density of air at inlet and the outlet will be $\frac{1}{V1}$, $\frac{1}{V2}$ and $\frac{1}{V3}$ reciprocals of the specific volumes) in Kg/m^3.

If the air directly enters the engine cylinder (without intercooling) having swept volume v m^3, than the mass of oxygen entering the cylinder will be,

= swept volume x density x percentage of oxygen in air

$V = \frac{1}{v1} X\ 0.2$

$= \frac{0.21v}{v2}$

Then increase in the mass of oxygen entering the engine cylinder will be as follows,

$= \frac{0.21v}{v2} - \frac{0.21v}{v1}$

$= \frac{0.21v\,(v1-v2)}{v2\ v1}$

Percentage increase in the mass of oxygen entering the engine cylinder

$=\{[0.21v(v_1-v_2) / (v_1\ v_2)] \ / \ [(0.21v)/(v_1)]\} X\ 100$

$= \frac{v1-v2}{0.21v} \times 100$

$= \frac{100(v1 \frac{T2}{T1} V1)}{\frac{T2}{T1} V1}$

(From eq.1 $V2 = \frac{T2}{T1} V1$)

$= \frac{100(1\frac{T2}{T1})}{\frac{T2}{T1}}$ ....(3)

Case 2 – When the air enters the engine cylinder after refrigerated intercooling, similarly percentage increase in the mass of oxygen entering the engine cylinder.

$= \frac{100(1\frac{T2}{T1})}{\frac{T2}{T1}}$ ....(4)

VI. FINAL CALCULATIONS

1. Actual Volume

$V_{act} = C_d \times a \times \sqrt{2gh}$

$H = \frac{Density\ of\ Water\ x\ Difference\ in\ Manometer}{Density\ of\ Air}$

C_d = coefficient of discharge

2. Theoretical Volume

$V_{the} = \frac{\pi}{4} \times D^2 \times L \times \frac{N}{60}$

Where,

D = Diameter N = Speed in rpm

Volumetric Efficiency = $\frac{V_{act}}{V_{the}}$

Where,

v_{act} = Actual Volume

v_{the} = Theoretical Volume

VALITATIONS

Calculation 1: A without cooling medium in the intercooler

The reading observed from the experiments at the constant pressure, 49.05N/m^2

Observation data of without cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.3	7.9	2.9	690	2.2×10^{-3}	3.98×10^{-3}	57.1

Actual Volume:

$V_{act} = C_d \times a \times \sqrt{2gh}$

$H = \frac{Density\ of\ Water\ x\ Difference\ in\ Manometer}{Density\ of\ Air}$

$= \frac{1000 \times 2.9 \times 10-2}{1.18}$

=24.57m

$V_{act} = 0.6 \times 1.7 \times 10^{-4} \times \sqrt{2x9.81x24.57}$

$= 2.276 \times 10^{-3}\ m^3$

Theoretical Volume:

$V_{the} = \frac{\pi}{4} \times D^2 \times L \times \frac{N}{60}$

$= \frac{\pi}{4} \times 0.07^2 \times .0.90 \times \frac{690}{60}$

$= 3.983 \times 10^{-3}\ m^3$

Volumetric Efficiency $= \frac{V_{act}}{V_{the}}$

$= \frac{2.276 \times 10-3}{3.983x10-3}$

Volumetric Efficiency = 57.1%

Calculation 2:

Water used as a cooling medium in the Intercooler The reading observed from the experiments as the constant pressure, 49.05 N/m^2.

Observation data of water as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.4	8.3	3.1	690	$2.35x10^{-3}$	$3.98x10^{-3}$	59.09

Actual Volume:

$V_{act} = C_d$ x a x $\sqrt{2gh}$

$$H = \frac{Density\ of\ Water\ x\ Difference\ in\ Manometer}{Density\ of\ Air}$$

$$= \frac{1000\ x\ 3.1x\ 10-2}{1.18}$$

=26.67m

V_{act}= 0.6 x 1.7 x 10^{-4} x$\sqrt{(2x9.81x26.67)}$

= 2.354 x 10^{-3} m^3

We Know That:

V_{the}= 3.983 x 10^{-3} m^3

Volumetric Efficiency = $\frac{V_{act}}{V_{the}}$

$$= \frac{2.354\ x\ 10-3}{3.983\ x\ 10-3}$$

Volumetric Efficiency =59.09%.

Calculation 3:

Water + Al_2 O_3 used as a cooling medium in the Intercoolers

The reading observed from the experiments as the constant pressure, 49.05 N/m^2

Observation data of Water + Al_2 O_3 used as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.3	8	3.3	690	2.428 $x10^{-3}$	3.983 $x10^{-3}$	60.95

Actual Volume:

$V_{act} = C_d$ x a x $\sqrt{2gh}$

$$H = \frac{Density\ of\ Water\ x\ Difference\ in\ Manometer}{Density\ of\ Air}$$

$$= \frac{1000\ x\ 3.3\ x\ 10-2}{1.18}$$

=27.96m

V_{act} = 0.6 x 1.7 x 10^{-4} x$\sqrt{(2x9.81x27.961)}$

= 2.428 x 10^{-3} m^3

We Know That:

V_{the} = 3.983 x 10^{-3} m^3

Volumetric Efficiency = $\frac{V_{act}}{V_{the}}$

$$= \frac{2.428x\ 10-3}{3.983\ x\ 10-3}$$

Volumetric Efficiency =60.95%

Calculation 4:

Ethylene Glycol +Water used as a cooling medium in the Intercooler

The reading observed from the experiments as the constant pressure, 49.05 N/m^2.

Observation data of Ethylene Glycol + Water as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.3	7.9	3.4	690	$2.468x10^{-3}$	$3.983x10^{-3}$	61.9

Actual Volume:

$V_{act} = C_d$ x a x $\sqrt{2gh}$

$$H = \frac{Density\ of\ Water\ x\ Difference\ in\ Manometer}{Density\ of\ Air}$$

$$= \frac{1000\ x\ 3.4x10-2}{1.18} = 28.81m$$

V_{act} = 0.61 x 1.7 x 10^{-4} x$\sqrt{2x9.81x28.81}$

= 2.465 x 10^{-3} m^3

We Know That:

V_{the} = 2.465x 10^{-3} m^3

Volumetric Efficiency = $\frac{V_{act}}{V_{the}}$

$$= \frac{2.464\ x\ 10-2}{3.983\ x\ 10-3}$$

Volumetric Efficiency =61.9%

Calculation 5:

CUO +Water used as a cooling medium in the Intercooler

The reading observed from the experiments as the constant pressure, 49.05 N/m^2.

Table 4.2.5 Observation data of CUO + Water as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.4	7.5	3.9	690	2.640 x10^{-3}	3.983x 10^{-3}	66.28

Actual Volume:

$V_{act} = C_d \text{ x a x } \sqrt{2gh}$

$H = \frac{\text{Density of Water x Difference in Manometer}}{\text{Density of Air}}$

$= \frac{1000 \text{ x } 3.9 \text{x} 10-2}{1.18} = 33.05\text{m}$

$V_{act} = 0.61 \text{ x } 1.7 \text{ x } 10^{-4} \text{ x} \sqrt{2\text{x}9.81\text{x}33.05}$

$= 2.640\text{x } 10^{-3} \text{ m}^3$

We Know That:

$V_{the} = 2.640\text{x } 10^{-3} \text{ m}^3$

Volumetric Efficiency $= \frac{V_{act}}{V_{the}}$

$= \frac{2.640 \text{ x } 10-2}{3.983 \text{ x } 10-3}$

Volumetric Efficiency =66.28%

Calculation 6:

Ethylene Glycol +CUO +Water used as a cooling medium in the Intercooler

The reading observed from the experiments as the constant pressure, 49.05 N/m^2.

Observation data of Ethylene Glycol + CUO + Water as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.4	7.1	4.2	690	2.789 x10^{-3}	3.983 x10^{-3}	70.02

Actual Volume:

$V_{act} = C_d \text{ x a x } \sqrt{2gh}$

$H = \frac{\text{Density of Water x Difference in Manometer}}{\text{Density of Air}}$

$= \frac{1000 \text{ x } 4.2\text{x } 10-2}{1.18} = 36.44\text{m}$

$V_{act} = 0.61 \text{ x } 1.7 \text{ x } 10^{-4} \text{ x} \sqrt{2\text{x}9.81\text{x}36.44}$

$= 2.789 \text{ x } 10^{-3} \text{ m}^3$

We Know That:

$V_{the} = 2.789\text{x } 10^{-3} \text{ m}^3$

Volumetric Efficiency $= \frac{V_{act}}{V_{the}}$

$= \frac{2.789 \text{ x } 10-2}{3.983 \text{ x } 10-3}$

Volumetric Efficiency =70.02%

Calculation 7: Ethylene Glycol +CUO +alumina used as a cooling medium in the Intercooler

The reading observed from the experiments as the constant pressure, 49.05 N/m^2.

Observation data of Ethylene Glycol + cuo + alumina as a cooling medium

Manometer Readings			Speed	Actual Volume	Theoretical Volume	Volumetric Efficiency
h1	h2	H	Rpm	m^3	m^3	%
11.6	7.1	4.5	690	2.903 x10^{-3}	3.983 x10^{-3}	72.88

Actual Volume:

$V_{act} = C_d \text{ x a x } \sqrt{2gh}$

$H = \frac{\text{Density of Water x Difference in Manometer}}{\text{Density of Air}}$

$= \frac{1000 \text{ x } 4.5\text{x } 10-2}{1.18} = 38.13\text{m}$

$V_{act} = 0.61 \text{ x } 1.7 \text{ x } 10^{-4} \text{ x} \sqrt{2\text{x}9.81\text{x}38.13}$

$= 2.903 \times 10^{-3}\ m^3$

We Know That:

$V_{the} = 2.903 \times 10^{-3}\ m^3$

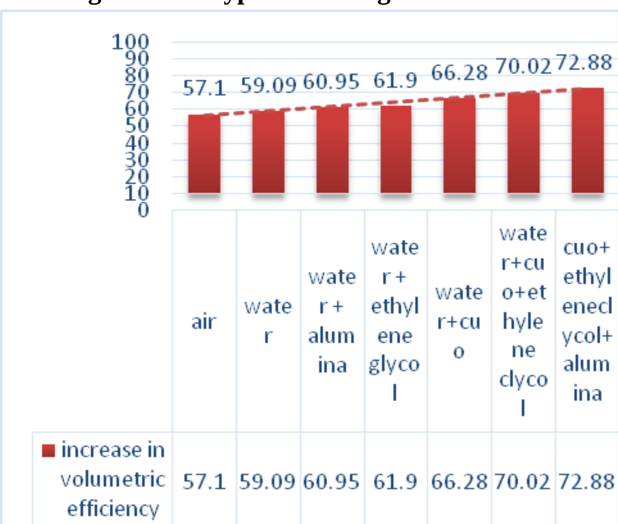
$$\text{Volumetric Efficiency} = \frac{V_{act}}{V_{the}}$$

$$= \frac{2.9035 \times 10-2}{2.983 \times 10-3}$$

Volumetric Efficiency =72.88%.

VII. RESULTS AND DISCUSSION

Volumetric Efficiency Vs Cooling Medium shows the increase of the volumetric efficiency of the compressor when using different types of cooling med



VIII. CONCLUSION

The intercoolers provided between low pressure and high-pressure cylinder fist well. The efficiency of the air compressor has been increased by using low cost cooling medium. There happens to be saving in electric energy, and a high temperature drop is established between low pressure cylinder and intercooler nears perfect intercooling. After analyzing the data and determining the difference in intercooler's outlet fluid temperature through testing the different type of cooling medium proves to acceptable. From the analyzing data of different cooling medium such as air, water, water+$A1_2O_3$, water+ ethylene glycol used the intercooler represented the display a trend of decreasing outlet temperature of compressed air from the intercooler. In the trail-1 there was addition of the cooling additive' air only flows into the intercooler, the outlet temperature of the compressed air from the inter cooler is reduced from 80^0 C to 42^0 C at constant pressure of 5 kgf/cm^2. In the trail-2 the water is used as cooling medium in the inter cooler which reduce the temperature of the compressed air from 80^0 C to 39^0C at constant pressure of 5 kgf/cm^2. In the trail-3 the addive $A1_2O_3$ is added to the water to increase the cooling effect. From this, temperature of compressed air is reduced from 80^0 C to 38^0C at constant pressure of 5kgf/cm^2. The trail-4, ethylene glycol is added to the water to increase the performance of the intercooler. While using this additive the temperature of compressed air will be reduced from 80^0 C to 37^0C. when cuo is added to the water and allowed to pass through the intercooler for 25 minutes at constant pressure of 5kgf/cm^2 the temperature reduced to 36.5^0C.

again water+cuo+ethylene glycol mixed fluid is allowed to pass though the intercooler the temperature reduced to 36^0C .finally water+cuo+alumina mixed fluid is allowed to pass though the intercooler the temperature reduced to 35^0C This reduction of temperature shows the intercooler nearly enhanced as perfect intercooler which increase the volumetric efficiency of the compressor. If the volumetric efficiency of the compressor increased, the working efficiency of the compressor will also increase. Thus the performance of two stage reciprocating compressor is increased .

REFERENCES

[1] Nagakishore.S, prof.M. Bhagvanthrao, "thermal analysis on a finned tube heat exchanger of a two stage air compressor, IJRAST, vol.2, issue.V, 2014

[2] Mr. Pawankumargupta, "A study based on design of air compressor intercooler performance" – 2009

[3] Mr. Vijay f. Pipalia, "Experimental investigation of overall efficiency of two stage reciprocating air compressor by way of intercooling", IJARSET, 2010, vol 03.

[4] Pawn Kumar gupta, "Minimiation of heat transfer area of an air compressor intercooler using MATLAB", (IJRAME) vol.1 issue. 8 2013.Pp 20-45.

[5] Vinod Kumar, smasher, "Technique and processes for performance improvement of gas and steam turbine power plant", (IJETAE), vol.4, issue 1, 2014.

[6] Caniere H. Willockx A, Dick E, and De Paepe M, "Efficiency calculations of air-cooled gas turbine with intercooling" HEFAT2007 paper number: CH3