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Design, Modification & Analysis of IndustrialAir Compressor (Type: VT4)

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Abstract—*This paper showshow important the intercooling of the air compressor is necessary for an efficient process. The meaning of air compression is to reduce a specified volume, increasingpressure. For improving the efficiency of the system,compression is done in more than one stage, and intercooler is provided between each stage. Intercooler improves the quality of air and reduces inlet air temperature in the last stage. The function of the intercooler is to cool the air as it leaves the Low-Pressure cylinder and before it enters the High-Pressure cylinder. Thisimproves the efficiency of the compressor and ensures that the temperature of the air receiver outlet valves is just right for optimumoperation of the tools connected to the compressor.Theintercooler is composed of sheet metal plate elements or tubular core.Type VT4 compressor is a Two Cylinder, Two-Stage Reciprocating Air Compressorwhichismost widely used for Industrial and Underground Mining Purpose. This paper proves that the increase in the size of intercooler increases the efficiency of the compressor and avoids heating in High-Pressure Cylinder since the intercooling is made efficient.*

Keywords—*Air Compressor, High-Pressure Cylinder, Intercooler, Low-Pressure Cylinder, Shell and Tube.*

I. INTRODUCTION

A VT4 compressor (Two Cylinder, Two Stage Reciprocating Air Compressor) is a device that converts power (usually from an electric motor, a diesel engine or a gasoline engine) into potential energy by forcing air into a smaller volume and thus increasing its pressure. The energy in the form of compressed air can be stored in the tank while the air remains pressurized. These energies can be used for a variety of applications such as utilizing the kinetic energy of the air as it is depressurized[8].

Till date, heat transfer in reciprocating compressors hasplayed a back burner role. Energy consciousness recently has shown interest and generated considerable debate, contradictory opinions about the extent of influence of heat transfer on compressor performance. The performance of the compressor is They are affected by not only heat transfer but also the design, operation and reliability.Compressed air units ranging from power values of 5 HP to over 50,000 HP is used in industrial plants throughout production and maintenance operations. Cost of a compressor is much lower than compared with its running cost, which is worth nothing. For improving efficiency, compression is done in more than one stage (in this case 2 Stage), and between each stage,an intercooler is provided.

The main limitation in the design of Industrial Air Compressor (Type VT4) is the temperature of air goes higher at the inlet port of the High-Pressure Cylinder, which results in large discharge temperature. Due to large discharge temperature, High-Pressure Cylinder of the Compressor Unit is becoming hot, which can be viewed with the naked eye and the hose between the discharge pipe and air receiver tank gets damaged regularly. Whenever temperature becomes a defining parameter in the operation of Air Compressor, multi staging is required, and the intercooler plays a vital role in increasing the efficiency of the system. In many cases, the operational pressure ratio needs to be limited depending upon the inlet temperature, to keep the discharge temperature within the limits of the working environment and to handle air temperature.

The material properties are affected by temperature, in addition to dimensional stability and integrity of the component itself. It is the matter of concern that the outlet valves which are located above the High-Pressure Cylinder become faulty. The faulty valve must be attended immediately. Serious damage can result if a compressor is operated with a broken valve or valve plate. In the Air Compressor (Type VT4), Low-Pressure Cylinder has two inlet or suction valves and two outlet or delivery valves. At the same time, High-Pressure Cylinder has one input or suction valve and one output or delivery valve. All valves are located in the respective Low Pressure and High-Pressure Cylinder Heads.

Designers have started searching for energy savings at whatever cost, since the efficiency of the compressor is approaching their limits and energy deficiencies have started looming on the horizon[2]. This is driving researchers to take another look at the effect of heat transfer on the performance and efficiency of compressors. The early stages of such effort were clouded with conflicts of opinion between differentgroups, and it is only since1980's, that the importance of the influence of heat transfer on compressor performance has been recognized[2].

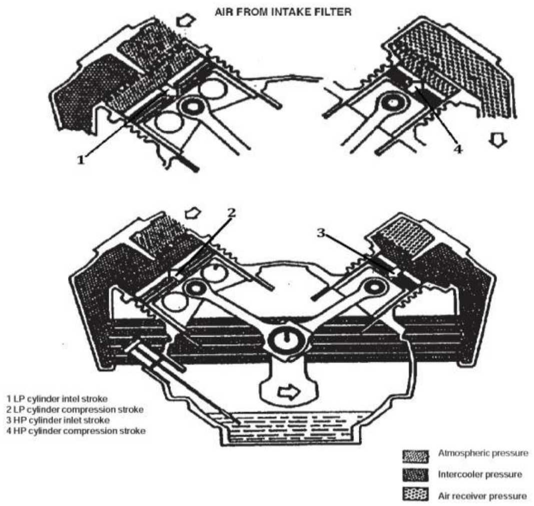

Fig.1: Front View of Compressor Element.

Larger Two-Stage Reciprocating Compressors up to 1,000 HP are commonly found in large Industrial and Underground Mining operation applications. Discharge pressures achieved from air compression can range from low pressure, i.e. 1 kg/cm^2 to very highpressure, i.e. 10 kg/cm^{2}which are used for various applications, multi-stage double-acting compressors are said to be the most efficient compressors available, and are typically larger, and more costly thanrotary units. Another famous type of Reciprocating Compressor is the swash plate compressor, which usesswashplate on which pistons are mounted on a shaft. Most multi-stage compressors use intercoolers in between each stage, which are heat exchangers that remove the heat of compression between the stages of each compression. Inter cooling of pressurized air affects the overall efficiency of the machine[2].

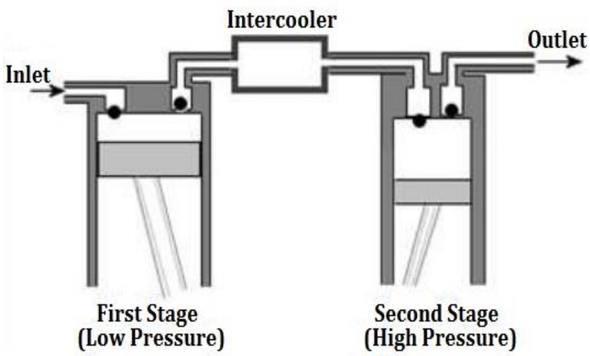

Fig.2**:**Example of an intercooler on a two-stage reciprocating aircompressor.

II. LITERATURE SURVEY

1. ShashankGurnule, RiteshBanpurkar, *"Design, Modification & Analysis of Industrial Air Compressor (Type – VT4) – A Review"*, Seventh Sense Research Group – International Journal of Mechanical Engineering, Volume: 4, Issue: 12, Page Nos. 3 – 7.

This paper presents a review of how important the intercooling of the air compressor is necessary for an efficient process. The meaning of air compression is to reduce a specified volume, increasingpressure. For improving the efficiency of the system, compression is done in more than one stage, and intercooler is provided between each stage. Intercooler improves the quality of air and reduces inlet air temperature in the last stage. The function of the intercooler is to cool the air as it leaves the Low-Pressure cylinder and before it enters the High-Pressure cylinder. This improves the efficiency of the compressor and ensures that the temperature of the air receiver outlet valves is just right for optimum operation of the tools connected to the compressor. The intercooler is composed of sheet metal plate elements or tabular core. Type VT4 compressor is a Two Cylinder, Two Stage Reciprocating Air Compressor which is most widely used for Industrial and Underground Mining Purpose. This paper highlights the various efforts of various researchers. Based on various researches, it is proposed that the change in the size of intercooler will avoid heating in High-Pressure Cylinder during long run[1].

2. Kanwar J.S Gill, Surinder Pal Singh, Gurpreet Singh & Malinder Singh, *"Designing and Fabrication of Intercooler and Control of Three-Phase Digitalized Reciprocating Air Compressor Test Rig with Automatic Control Drive Unit"*, International Conference of Advance Research and Innovation (ICARI-2015).

The Air Compressor Test Rig is designed to study the characteristics of a Two-Stage Reciprocating Air Compressor and the compressed airflow through flow arrangement. This unit is self-contained and fully instrumented with mild steel frame-mounted on a raised foundation, with intercooler, Air stabilizing tank and air receivers. An AC Motor drives the compressor. To provide adequate cooling to the system,the function of the intercooler is supplied with Pressure and Temperature measuring instruments at the inlet and outlet. With the introduction of an intercooler, the volumetric efficiency has been increased to 100 %.To measure the airflow rate air stabilizing tank should stabilize the flow of air, which is mandatory in this work. The actual volume of free air delivered by this compressor is 0.020 m^3/sec with a work done of 77 N-m was the result obtained during the test. Moreover, it was also found that the capacity to deliver air is about 1.02 kg/minute of thecompressor when the isothermal efficiency of the compressor is 45 %. If an intercooler is specially designed,it has a capacity of 2.049 kilojoules/kg of heat rejection[2].

3. Vijaykumar F Pipalia, Dipesh D. Shukla and Niraj C. Mehta, *"Investigation on Reciprocating Air Compressors - A Review"*, International Journal of Recent Scientific Research Vol. 6, Issue, 12, pp. 7735-7739, December 2015.

Heating is an undesirable effect of the compression process at least as far as compressors are concerned and heat transfer is nature's way of driving systems towards stability. This has not only provided food for thought for researchers trying to understand its influence and quantify its effects but also challenged designers to mitigate its impact and develop safe and efficient designs. Also, this investigation is concerned with improving the efficiency of Two-Stage Reciprocating Air Compressor by providing water cooling source, radiator coolant and ethylene glycol. The experiments with air, water and different inter coolants are performed on a Two-Stage Double Cylinder Reciprocating Compressor System[3].

4.SuprasannaRaoRavur, Subbareddy. E. V, *"Experimental Investigation to Increase the Efficiency of the Air Compressor by Changing the Coolants in Inter Cooler"*, International Journal for Research in Applied Science & Engineering Technology Volume 3 Issue IX, September 2015**.**

The compressed air usage is increasing quicklynowadays. But the efficiency of the compressor is low due to many reasons like location, elevation, length of pipelines, intercooler performance, even atmospheric conditions also affects the efficiency of the compressor, which increases the power consumption of the compressor. Inter cooling is the best method to reduce coolant. In this study, we are extending the investigating by changing the temperature of the water and the mixing of different types of coolants in the water at different proportions. The selection of the coolants depends upon their properties like miscibility, self-ignitiontemperature, boiling point and exploding range. For this investigation ethylene glycol and glycerol as coolants and a two-stage reciprocating air compressor fitted with shell and tube type heat exchanger is selected. This investigation shows the good arguments between the water, glycerol and ethylene glycol[4].

5. KuldeepTyagi&Er. Sanjeev Kumar, *"Improved Air Compression System"*, International Journal of Scientific Engineering and Applied Science, Volume 1, Issue 5, August 2015.

Intercooling of Air Compressors is necessary for increasing its efficiency. A shell and tube type of heat exchanger is particularly suitable as an intercooler between two compression stages of a compressor. A characteristic of heat exchanger design is the procedure of specifying a design, heat transfer area, pressure drops and checking whether the assumed design satisfies all requirements or not. The purpose of this research paper is to provide an easy and efficient way to design an intercooler for air compressor. This paper describes the modelling of the heat exchanger, which is based on the minimization of heat transfer area and a flow chart is provided showing the designing procedure involved[45.

6. Wadbudhe R. C., AkshayDiware, Praful kale, *"A Research Paper on Improving Performance and Development of Two-Stage Reciprocating Air Compressor"*, International Journal of Research In Science & Engineering, Volume: 3 Issue: 2 March-April 2017**.**

The Two-Stage Reciprocating Air Compressors is the most used type of compressor found in many industrial applications such as crucial machine in gas transmission pipelines, petrochemical plants, refineries, etc. Since there is a requirement ofhigh-pressure ratio, a reciprocating air compressor is commonly used in locomotives. After a certain period, unexpected failures of internal components due to miscellaneous reasons occur, which inversely affects the performance ofthe operating system.It is essential to establish the recommended clearances mentionedfor the various parts of the compressor. Compressor parts selection between repair and replacement is done based on Dimensional Measurement, whichleads to easy maintenance in an economical point of view[6].

7. Pawan Kumar Gupta1, S.P.Asthana2, Neha Gupta, *"A Study Based on Design of Air CompressorIntercooler"*, International Journal of Research in aeronautical and Mechanical Engineering, Vol.1 Issue.7, November 2013, Pages: 186-203 ISSN (ONLINE): 2321-3051.

This paper presents a study on which the main objective isintercooling of air compressor, which is necessary for an efficient process. Increase in pressure is a result of the reduction of a specified volume which is also known as compression. This paper mainly discusses the reciprocating compressor, which is widely used for air compression. Compression is done in more than one stage, and between each stage,the intercooler is provided to improve the efficiency of the system[7].

8. Vishal P. Patil, Shridhar S. Jadhav, Nilesh D. Dhas, *"Performance and Analysis of Single Stage Reciprocating Air Compressor Test Rig"*, SSRG International Journal of Mechanical Engineering, Volume 2, Issue 5, May 2015, ISSN: 2348 – 8360**.**

An experimental test rig has been built to test reciprocating compressors of different size and capacity. The compressors were tested with the help of air as a working fluid.The paper provides us with much-needed information regarding the efficiency of the compressors operating under the same conditions with the same system parameters. This paper also highlights reports on the investigation carried out on the effect of pressure ratio on indicated power, isothermal efficiency of both compressors. The result shows that the indicated power is increasing as the discharge pressure increases, but the isothermal efficiency of both the compressorisdecreasing with increase in pressure ratio. Both compressor types exhibit the same general characteristics concerning system parameters. When the experiment was carried out for the constant angular speed of the compressor, no change in volumetric efficiency is observed. Besides, a comparative study was carried out for two compressors,and their differences were analyzed. To verify the model's goodness to predict the compressor performance, the study seems to be useful[8].

III. PROBLEM DEFINITION

The system under study is Industrial Air Compressor (Type: VT4). To investigate the applicability of the proposed compressor, the image of the Air Compressor (Type: VT4) is shown in the figure below:

Fig. 3: Air Compressor (Type VT4).

The fig shows Air CompressorType VT4 is a Two Cylinder, Two Stage Reciprocating Air Compressor.The High-Pressure Cylinder is getting heated up and can be viewed with the naked eye that the High-Pressure Cylinder is becoming red when it is made to run for a longer period.

IV. DESIGN CALCULATIONS AND ANALYSIS

The High-Pressure Cylinder is getting heated up due to improper working of the intercooler. Hence, the Temperature of the Intercooler is to be decreased.

By Gay-Lussac's Law which is also known as The Pressure Temperature Law states that "The Pressure of a given amount of gas held constant volume is directly proportional to the Kelvin Temperature." As the pressure goes up, the temperature goes up and vice versa.

i.e. $P \alpha T$ or $T \alpha P$

Hence, to decrease the Temperature of the Intercooler, its pressure is to be decreased.

As the formula of pressure says:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

To decrease the pressure, either force should be decreased, or area should be increased.

Let us consider the first case, i.e., force should be decreased.

To decrease the Force, Volume of Air should be decreased, and the Volume of Air can be decreased by reducing either Low-Pressure Cylinder Bore or Stroke of Piston.

1. To reduce the size of the Low-Pressure Cylinder Bore, the cylinder is to be replaced due to which the crankcase of the compressor needs to be modified. …(a)
2. To reduce the Piston Stroke, the size of the connecting rod needs to be changed, which in turn results in changing of Crankshaft of the Compressor. …(b)

Let us consider the second case, i.e., the area should be increased.

To increase the area on which the force is acting, the following parameters can be changed:

1. The diameter of tubes of intercooler can be increased, which in turn makes the existing Intercooler tubes waste for us. …(c)
2. Length of Intercooler tubes can be increased, which in turn will result in a change of complete fitting of the intercooler. …(d)
3. The number of tubes of the intercooler can be increased, which can be done easily by keeping the other parameters of compressor same. …(e)

From Statements (a), (b), (c), (d) & (e), we can conclude that Statement (e) is the most cost-effective way to achieve the objective.

Hence, the objective of this dissertation is to modify the Intercooler"Shell and Tube" type for heat transfer between two stages of compression. Therefore, let us increase 2 Nos. of Tubes in each row.

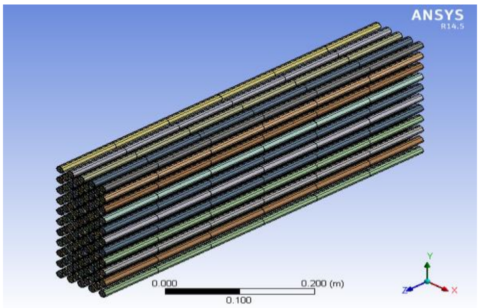

Fig. 4: Meshed Geometry of Existing Intercooler (Isometric View).

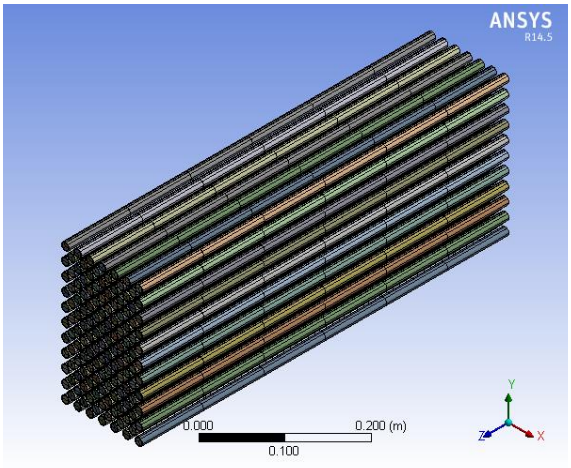

Fig. 5: Meshed Geometry of Modified Intercooler (Isometric View).

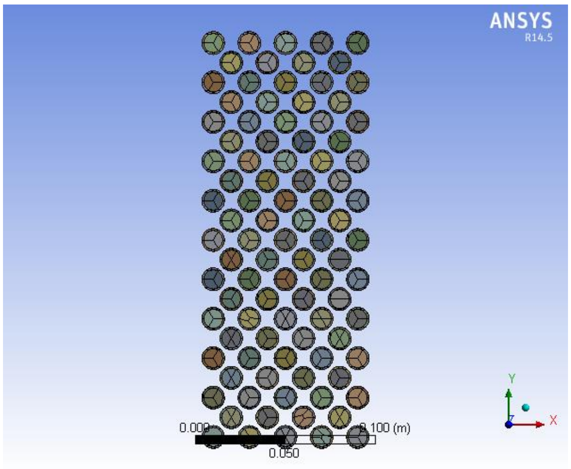

Fig. 6: Meshed Geometry of Existing Intercooler.

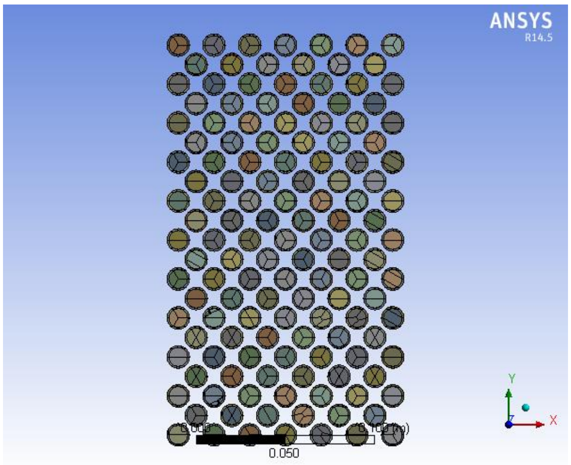

Fig. 7: Meshed Geometry of Modified Intercooler.

Basic Data required for calculation are as follows:

1. Cylinder Bore LP, D_1= 220 mm = 0.22 m
2. Cylinder Bore HP, D_2 = 130 mm = 0.13 m
3. Piston Stroke, L = 100 mm = 0.1 m
4. No. of Strokes, N = 1460 per min = 24.33 per sec
5. Density of Air, ρ_{air} = 1.225 kg/m^3
6. OD of Intercooler Tube, d_1 = 12.7 mm = 0.0127 m
7. ID of Intercooler Tube, d_2 = 10.7 mm = 0.0107 m
8. Length of Each Tube, l = 600 mm = 0.6 m
9. No. of Tubes in Existing Intercooler, N_e = 86 Nos.
10. No. of Tubes in Modified Intercooler, N_m = 124 Nos.
11. Inlet Temperature of Intercooler, T_1 = 150°C = 423 K∴ $T_{1_e} = T_{1_m} = T_1$ = 423 K

Now,

Inlet Volume of Intercooler = Volume of LP Cylinder

∴The Volume of LP Cylinder = $\frac{\pi}{4} \times D_1^2 \times L$

Where, D_1 = Cylinder bore LP

L = Piston Stroke

∴The Volume of LP Cylinder = $\frac{\pi}{4} \times 0.22^2 \times 0.1$

= 3.8 × 10^{-3} m^3 …(1)

Volume of Intercooler for 1 second = The volume of LP Cylinder for 1 second

The volume of LP Cylinder for 1 sec = Volume of LP Cylinder × No. of Strokes per sec

= 3.8 × 10^{-3} m^3 × 24.33

∴Volume of LP Cylinder for 1 sec= 92.45 × 10^{-3} m^3

Now,

Mass of Air = Volume of LPCylinder for 1 sec × Density of Air (ρ_{air})

= 92.45 × 10^{-3} m^3 × 1.225 kg/m^3

∴Mass of Air = 0.1133 kg

Now,

The force of air = Mass of Air × Gravity (g)

= 0.1133 × 9.81

∴Force of Air = 1.1115 N …(2)

Now,

Surface Area of Existing Intercooler = π × d_2× l × N_e

= π × 0.0107 m × 0.6 m × 86

∴Surface Area of Existing Intercooler = 1.74 m^2…(3)

Also,

Surface Area of Modified Intercooler = π × d_2× l × N_m

= π × 0.0107 m × 0.6 m × 124

∴Surface Area of Modified Intercooler = 2.5 m^2…(4)

Now,

Pressure in Existing Intercooler, P_e

$$= \frac{\text{Force of Air}}{\text{Surface Area of Existing Intercooler}}$$

From Equation (2) & (3),

$$P_e = \frac{1.1115 \text{ N}}{1.74 \, m^2}$$

∴ Pressure in Existing Intercooler, P_e = 0.64 N/m^2…(5)

Also,
Pressure in Modified Intercooler, $P_m = \frac{\text{Force of Air}}{\text{Surface Area of Modified Intercooler}}$

From Equation (2) & (4),

$$P_m = \frac{1.1115\ N}{2.5\ m^2}$$

∴ Pressure in Modified Intercooler, P_m = 0.45 N/m^2 …(6)

Here,
From Equation (5) & (6),
Percentage of Decrease in Pressure = $\frac{P_e - P_m}{P_e} \times 100$

$$= \frac{0.64 - 0.45}{0.64} \times 100$$

∴Percentage of Decrease in Pressure = 29.69 % …(7)

We know that the General Gas Equation is as follows:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Let us consider the Gas for One Stroke of Piston by keeping the volume constant, i.e. $V_1 = V_2$
Hence, the above equation becomes,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Let, P_1 = Pressure in LP Cylinder
P_2 = Pressure in Intercooler
T_1 = Temperature inLPCylinder
T_2 =Temperature in Intercooler

From Equation (1), For One Stroke of Piston
Volume of LP Cylinder = 3.8 × 10^{-3} m^3
Mass of Air = Volume of LPCylinder for One sec × Density of Air (ρ_{air})
= 3.8× 10^{-3} m^3 × 1.225 kg/m^3
∴ Mass of Air = 4.655 × 10^{-3} kg …(8)

Now,
Force of Air = Mass of Air × Gravity (g)
= 4.655 × 10^{-3} × 9.81
∴Force of Air = 0.0457 N …(9)

Now,
Surface Area of LP Cylinder = $\pi \times D_1 \times L$
= π × 0.22 m × 0.1 m
∴ Surface Area of LP Cylinder = 0.069 m^2 …(10)

Now,
Pressure in LP Cylinder = $\frac{\text{Force of Air}}{\text{Surface Area of LP Cylinder}}$

$$= \frac{0.0457}{0.069}$$

∴Pressure in LP Cylinder = 0.6623 N/m^2
∴ $P_{1_e} = P_{1_m}$ = 0.6623 N/m^2 …(11)

For Existing Intercooler, the General Gas Equation will be,

$$\frac{P_{1e}}{T_{1e}} = \frac{P_{2e}}{T_{2e}}$$

From Equation (5), $P_{2_e} = P_e$ = 0.64 N/m^2
The General Gas Equation becomes,

$$\frac{0.6623}{423} = \frac{0.64}{T_{2e}}$$

$$T_{2_e} = 408.75\ K \qquad \text{…(12)}$$

For Modified Intercooler, the General Gas Equation will be,

$$\frac{P_{1m}}{T_{1m}} = \frac{P_{2m}}{T_{2m}}$$

From Equation (6), $P_{2_m} = P_m$ = 0.45 N/m^2
The General Gas Equation becomes,

$$\frac{0.6623}{423} = \frac{0.45}{T_{2m}}$$

$$T_{2_m} = 287.41\ K \qquad \text{…(13)}$$

From Equation (12) & (13),
Percentage of Decrease in Temperature = $\frac{T_{2e} - T_{2m}}{T_{2e}} \times 100$

$$= \frac{408.75 - 287.41}{408.75} \times 100$$

∴Percentage of Decrease in Temperature = 29.69 % …(14)

From Equation (7) & (14),

Percentage of Decrease in pressure = Percentage of Decrease in temperature

Hence, Gay-Lussac's Law is proved which is also known as The Pressure Temperature Law, which states that "The Pressure of a given amount of gas held constant volume is directly proportional to the Kelvin Temperature." As the pressure goes up, the temperature goes up and vice versa.
i.e. P α T or T α P

In this case, When the Pressure of Intercooler is decreased; the temperature of the intercooler is decreased.

Now, let us have a look atthe Analysis part of dissertation:

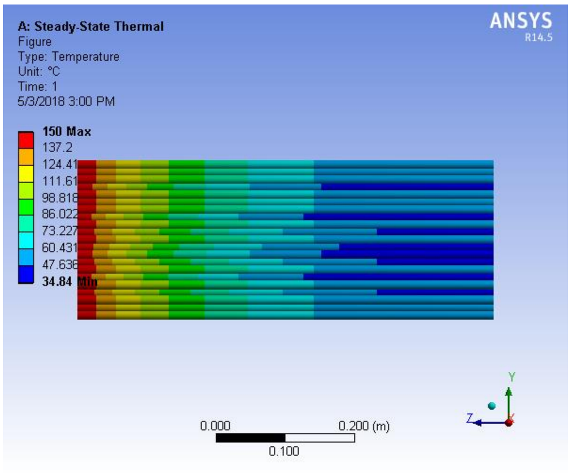

Fig.8: Temperature Distribution Result in Existing Intercooler

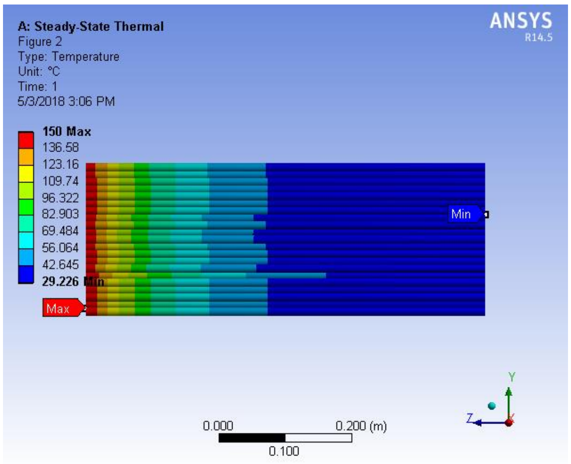

Fig. 9: Temperature Distribution Result in Modified Intercooler

Here,
From Figure 8 & 9,

$$\text{Percentage of Decrease in Temperature} = \frac{T_e - T_m}{T_e} \times 100 = \frac{34.84 - 29.226}{34.84} \times 100$$

∴Percentage of Decrease in Temperature = 16 % …(15)

From Equation (7), (14) & (15),
When the Pressure of Intercooler is decreased by 29.69%, the temperature is decreased by 16%. The change in temperature values is due to actual ambient conditions.

V. CONCLUSION

Two-Stage Reciprocating Air Compressor is gone through different intercooling processes, and it can be concluded that more the surface area of intercooling more will be depression in temperature of the air which will directly result in improving the efficiency of the Air Compressor. From all the results of intercooling processes, it can be concluded that the radiator intercooling with an increase in the size of intercooler results in better volumetric efficiency as compared to another type of intercooling. In operation of Two Stages Reciprocating Air Compressor,it is possible that when costs of different parameters are considered, the method adopted by us can be used for improvement in its overall efficiency.

In this paper, we have studied about Two Stage Reciprocating Air Compressor and one of its main component which is used in an air compression system, i.e. intercooler. Also, we have used very simple and time-efficient algorithms for designing of Intercooler for Air Compressor.

REFERENCES

[1] Shashank Gurnule, Ritesh Banpurkar, "Design, Modification & Analysis of Industrial Air Compressor (Type – VT4) – A Review", SSRG International Journal of Mechanical Engineering (SSRG - IJME), V4(12), Page Nos. 3 – 7 December 2017. ISSN: 2348 – 8360.

[2] Kanwar J.S Gill, Surinder Pal Singh, Gurpreet Singh &Malinder Singh, *"Designing and Fabrication of Intercooler and Control of Three-Phase Digitalized Reciprocating Air Compressor Test Rig with Automatic Control Drive Unit"*, International Conference of Advance Research and Innovation (ICARI-2015).

[3] Vijaykumar F Pipalia, Dipesh D. Shukla and Niraj C. Mehta, *"Investigation on Reciprocating Air Compressors - A Review"*, International Journal of Recent Scientific Research Vol. 6, Issue, 12, pp. 7735-7739, December 2015.

[4] SuprasannaRaoRavur, Subbareddy. E. V, *"Experimental Investigation to Increase the Efficiency of the Air Compressor by Changing the Coolants in Inter Cooler"*, International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume 3 Issue IX, September 2015.

[5] KuldeepTyagi&Er. Sanjeev Kumar, *"Improved Air Compression System"*, International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-5, August 2015.

[6] Wadbudhe R. C., AkshayDiware, Praful kale, *"A Research Paper on Improving Performance and Development of Two-Stage Reciprocating Air Compressor"*, International Journal of Research In Science & Engineering, Volume: 3 Issue: 2 March-April 2017.

[7] Pawan Kumar Gupta1, S.P.Asthana2, Neha Gupta, *"A Study Based on Design of Air Compressor Intercooler"*, International Journal of Research in Aeronautical and Mechanical Engineering, Vol.1 Issue.7, November 2013, Pages: 186-203 ISSN (ONLINE): 2321-3051.

[8] Vishal P. Patil, Shridhar S. Jadhav, Nilesh D. Dhas, *"Performance and Analysis of Single Stage Reciprocating Air Compressor Test Rig"*, SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume 2 Issue 5–May 2015, ISSN: 2348 – 8360.

[9] VijayendraPatil,AashishAgrawal. "In-Cylinder Combustion Analysis of DI Diesel Using Experimental and CFD Approach", International Journal of Engineering Trends and Technology (IJETT), V14(5),249-254 Aug 2014.

[10] Prof. DrV.S.OddvarPetter, "An Alternative DSFB Fuel for Pure Diesel Four Stroke Engine" SSRG International Journal of Industrial Engineering 3.1 (2016): 8-10.