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Design, Modification and Analysis of Industrial Air Compressor (Type: Vt4): A Review

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ABSTRACT

This paper presents a review on how important the intercooling of air compressor is necessary for an efficient process. Basically the meaning of air compression is to reduce a specified volume, resulting in an increase in pressure. For improving efficiency of the system compression is done in more than one stage and between each stage intercooler is provided. Intercooler improves the quality of air and reduces inlet air temperature. 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 cooler is composed of sheet metal plate elements or tabular core. Type VT4 compressor is a Two Stage Reciprocating Air Compressors which is most widely used for Industrial Purpose. This paper highlights the various efforts of the various researchers. On the basis of various researches it is proposed that the change in size of intercooler will avoid heating in High Pressure Cylinder during long run.

Keywords: *Air Compressor; Reciprocating; Intercooler; etc.*

1.0 Introduction

A VT4 type 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 compressed air can be stored in the tank while the air remains pressurized. The energy 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 had assumed a back burner role. Energy consciousness recently has rekindled interest and generated considerable debate and contradictory opinions about the extent of influence of heat transfer on compressor performance. The performance of compressor is 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 comparison 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 intercooler is provided. Intercooler improves the quality of air and reduces inlet air temperature to an extent.

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, the hose between the discharge pipe and air receiver tank get damaged regularly. Whenever temperature becomes defining parameter in the operation of Air Compressor, multi staging is required and the intercooler plays a vital role in increasing efficiency of the system. In many cases, the operational pressure ratio needs to be limited depending upon the inlet temperature, in order to keep the discharge temperature within the limits of working environment and handling air temperature.

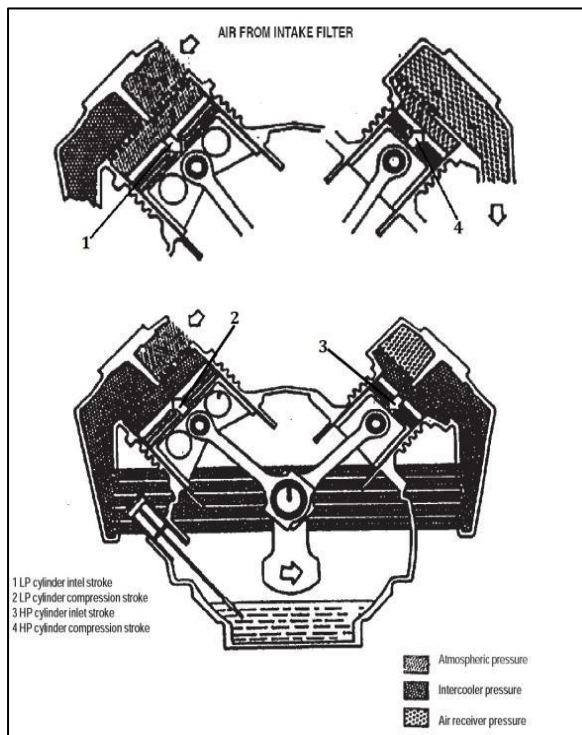
The material properties are affected by temperature, in addition to dimensional stability and integrity of the component itself. It is the matter of concern that the outlet valves which are located above

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the High Pressure Cylinder becomes faulty. The faulty valve must be attended immediately. Serious damage can result if a compressor is operated with a broken valves or valve plate. In the AIR Compressor (Type VT4), Low Pressure Cylinder has two inlet or suction valves and two outlet or delivery valves. Each 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.

Fig 1: Front View of Compressor Element

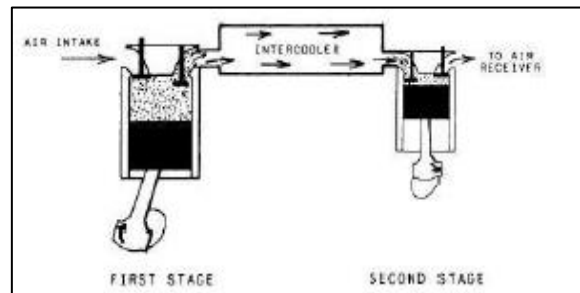


Designers have started searching for energy savings at whatever cost, since the efficiency of compressor is approaching their limits and energy deficiencies have started looming on the horizon[2]. This is driving researchers to take another look at the effect of heat transfer on the performance and efficiency of compressors. The early stages of such effort were clouded with conflicts of opinion between different groups and it is only since the 80's, that the importance of the influence of heat transfer on compressor performance has been recognized[2].

Larger Two Stage Reciprocating Compressors up to 1,000 hp are commonly found in large industrial and underground mining operation applications. Discharge pressures such as air compression can range from low pressure i.e. 1 kg/cm² to very high

pressure i.e. 10 kg/cm² is 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 than co rotary units. Another famous type of Reciprocating Compressor is the swash plate compressor, which uses swash plate 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 Air Compressor



2.0 Literature Survey

Kanwar JS Gill et al. [1] studied 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.

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 raised foundation, with intercooler, air stabilizing tank and air receivers. The compressor is driven by an AC Motor. To provide adequate cooling to the system is the function of the intercooler and is supplied with pressure and temperature measuring instruments at the inlet and outlet. With the introduction of intercooler the volumetric efficiency has been increased to 100 %. In order to measure the air flow rate air stabilizing tank should stabilize the flow of air which is mandatory in this work. Actual volume of free air delivered by this compressor is 0.020 m³/sec with a work done of 77 N-m was the result obtained during test. Moreover it was also found that the

capacity to deliver air is about 1.02 kg/minute of this compressor, when the isothermal efficiency of the compressor is 45 %. If an intercooler is specially designed it has capacity of 2.049 kilojoules/kg of heat rejection.

Vijaykumar F Pipalia et al. [2], studied 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.

Ravur et al. find the compressed air tusage is increasing quickly now a day. But the efficiency of compressor is low due to the many reasons like location, elevation, length of pipe lines, inter cooler performance, even atmosphere conditions also effects the efficiency of the compressor, which increases the power consumption of the compressor. The inter cooling is the best method to reduce the coolant. In this study we are extending the investigating by changing the temperature of the water and mixing of the different types of the coolants in water at different proportions. The selection of the coolants is depends upon their properties like miscibility, self-ignition temperature, 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 heat exchanger is selected. This investigation shows the good arguments between the water, glycerol and ethylene glycol [3]. Tyagi et al. showed 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 modeling of heat exchanger which is based on the minimization of heat

transfer area and a flow chart is provided showing the designing procedure involved[4].

The two Stage Reciprocating Air Compressors is the mostly used type of compressor found in many industrial applications such as crucial machine in gas transmission pipelines, petrochemical plants, refineries, etc. Since there is requirement of high pressure ratio, reciprocating air compressor is commonly used in locomotives. After certain period of time, unexpected failures of internal components due to miscellaneous reasons occur, which inversely affects the performance of operating system. It is essential to establish the recommended clearances mentioned for the various parts of the compressor. Compressor parts selection between repair and replacement is done on the basis of Dimensional Measurement which leads to easy maintenance in economical point of view [5].

Pawan et al. presents a study on which the main objective is to intercooling of air compressor which is necessary for an efficient process. Basically increase in pressure is a result of reduction of a specified volume which is also known as compression. This paper mainly discuss about reciprocating compressor which is widely used for air compression. Compression is done in more than one stage and between each stage intercooler is provided to improve the efficiency of the system.

Patil, used 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 provide 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 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 dischargea pressure increases, but the isothermal efficiency of both the compressor is decreasing with increase in pressure ratio. Both compressor types exhibit the same general characteristics with respect to system parameters. When the experiment was carried out for constant angular speed of compressor, no change in volumetric efficiency is observed. In addition, a comparative study was carried out for two compressors and their differences were analyzed. To verify the model's goodness with the aim of predicting the compressor performance, the study seems to be useful [7].

3.0 Problem Definition

System under study is Industrial Air Compressor (Type: VT4). In order to investigate the applicability of proposed compressor, the image of the Air Compressor (Type: VT4) is shown in the figure 3.

Fig 3: Air Compressor (Type VT4).



The fig shows Air Compressor Type VT4, the High Pressure Cylinder is getting heated up and can be viewed with the naked eye that the High Pressure Cylinder is becoming red in colour when it is made to run for longer period of time. The objective of this study is to make modification with the help of CAD in the existing model of compressor and to analyze the modified air compressor with the help of Finite Element Analysis. The main objectives were:

1. Inter Cooling of Air Compressors is necessary for achieving efficiency in the entire process. An intercooler between compression stages of a compressor can be a heat exchanger of shell and tube type particularly suitable.
2. To design and fabricate an Intercooler- "Shell and Tube" type for heat transfer between two stages of compression.

4.0 Proposed Work

The existing Air Compressor (Type: VT4) is a two stage reciprocating compressor with intercooler as the cooling medium of air. But the existing compressor (Type: VT4) is heating up too soon as compared to the other compressors. Hence, it is proposed that the intercooler of the existing compressor should be redesigned considering the

volume of flow of air and number of tubes used for the purpose of heat transfer.

The proposed work for the topic is as follows:

1. To design and fabricate an Intercooler- "Shell and Tube" type for heat transfer.
2. Design and modeling of Air Compressor (Type VT4) using CAD.
3. Perform analysis on the Existing and Modified Model by Finite Element Analysis.

First of all design and fabrication of the Intercooler is to be done by using the PTC Creo / Solid Works and on the Air Compressor (Type: VT4). After completion of design calculations and the fabrication of the Air Compressor it is to be analyzed using Finite Element Analysis Method to ensure that the modification and calculations done are feasible and will work properly after the completion. For Design & Modification: CAD. For Analysis: Finite Element Analysis Method.

5.0 Conclusions

Two Stage Reciprocating Air Compressor is gone through different intercooling processes, it can be concluded that the isothermal work required to compress the air has been reduce. So the power required to drive the reciprocating compressor has also reduced by 1-2% with respect to normal intercooling. From all the results of intercooling processes, it can be concluded that the radiator coolant intercooling and mixture of ethylene glycol with water intercooling result in better volumetric efficiency as compared to other type of intercooling. It is possible that when costs of different coolants are not considered, in operation of Two Stages Reciprocating Air Compressor can be used. In this paper we have to studied a review about Two Stage Reciprocating Air Compressor & main component which is used in air compression system i.e. intercooler. Also, we have to use very simple and time efficient algorithms for designing of intercooler for air compressor.

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