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Design and Optimization of Air Compressor Intake Valve Body Casing using ANSYS

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Abstract - *An industrial air compressor has a wide range of applications in manufacturing and assembly. The intake valve body is a major component of an industrial air compressor that performs a variety of functions such as regulating the amount of air into the compressor for pressurization and preventing oil backflow. The intake valve of an air compressor should be strong enough to withstand high pressure exerted on walls. This strength can be increased by changing the material or optimizing the existing design. The goal of current research is to improve the strength of intake valves through design optimization and material substitution. The ANSYS FEA simulation package is used for the numerical investigation of the intake valve. The impact of design variables and MMC material on structural and thermal performance is assessed using FEA and optimization results.*

Key Words: Intake valve, FEA, Optimization, MMC

1. INTRODUCTION

1.1 Compressed Air System

In industrial buildings, compressed air systems are quite popular and frequently employed. They are used to supply compressed air to machinery, pneumatics, tools, and transportation systems. The use of compressed air varies depending on the industry. Compressed air systems are one of the most energy-intensive systems in a facility, accounting for 10% to 30% of total electricity use [1]. Thus, in order to reduce the plant's energy consumption, it's vital to understand the energy consumption of this Significant Energy Use (SEU) equipment, which is critical for compressor optimization and efficiency improvement. Figure 1.1 depicts the usual lifetime compressed air cost, with energy consumption accounting for 76% of the overall cost and installation and maintenance accounting for 12% each. Compressor system efficiency can be lowered by a variety of reasons, including equipment age, dirt, and component problems [3].

To quantify the effects, models that relate the factors to energy consumptions are required. These models are used to calculate the efficiency of each component in the system, as well as how air reacts between stages, influencing energy consumption. This will aid in the detection of system flaws, ultimately improving overall system efficiency. Another critical factor that must be investigated is the effectiveness of various energy-saving recommendations on the system. There is a difference between the amount of energy you can save and the impact on each component. [4]

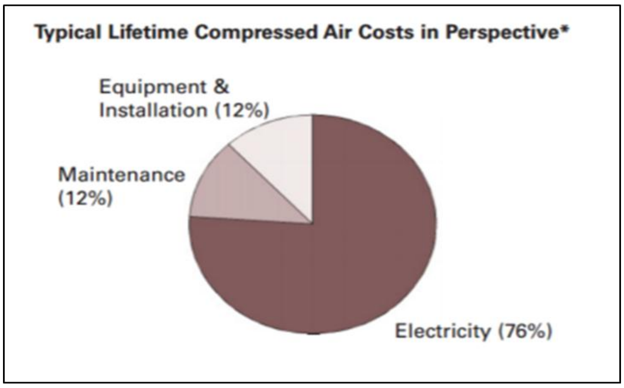


Figure 1.1 Typical Overall Cost of Compressed Air [2].

1.2 Diagram of the System

Figure 1.2 depicts a typical air compressor system. Before entering the compressor, new air is filtered. Many industrial air compressors come with a variety of components, including the compressor, motor, after cooler, and separator. After that, the air is directed into a wet receiving tank. The air is stored in the wet receiving tank, which also drains any liquid and solid particulates that the separator did not remove. It is common practice to place a filter between the receiver and the air dryer.

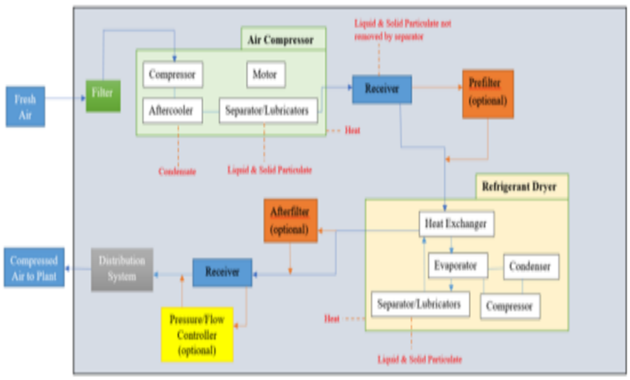


Fig. 1.2 Compressed Air System Diagram

1.3 Elements

1.3.1 Compressors of Air

The most basic component of a compressed air system is an air compressor. Air compressors come in a variety of shapes and sizes. Figure 1.3 depicts the various types of air compressors' categories and subcategories.

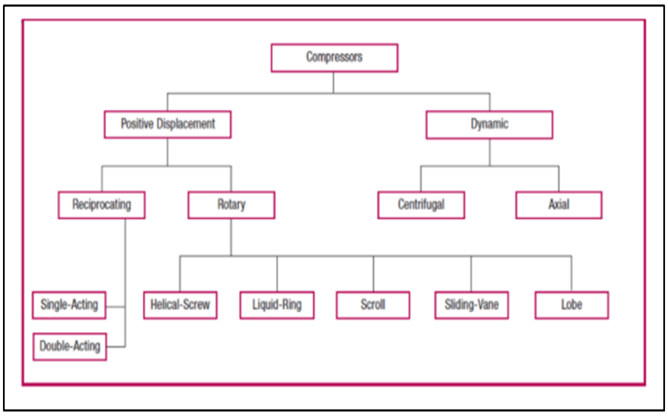


Fig.1.3. Types of Air Compressors [1]

1.3.2 Air Conditioners

Air dryers are one of the most common ways to improve air quality. Their primary function is to convert air into a form that can be used in a variety of applications. Moisture must be kept out of compressed air. Wet compressed air running through the system would harm the machines if there were no air dryers. Because of the moisture in the air, parts of the machines would rust and tear. However, excessively dry compressed air would waste energy and money.

1.4 FEA

The FEM technique is a useful tool for solving mathematical equations in a variety of engineering problems. The method was proposed in the aerospace industry as a tool for assessing anxiety in difficult jet systems. It is derived from the matrix analysis procedure used in aircraft design. In their respective fields, each researcher and practitioner has made significant progress. The main principle of finite element methodology is to break down a body or structure into smaller, finite-size components known as limited elements. ' In the initial frame and structure, the variables associated with a limited set of connections known as nodes or nodal points are investigated.

2. LITERATURE REVIEW

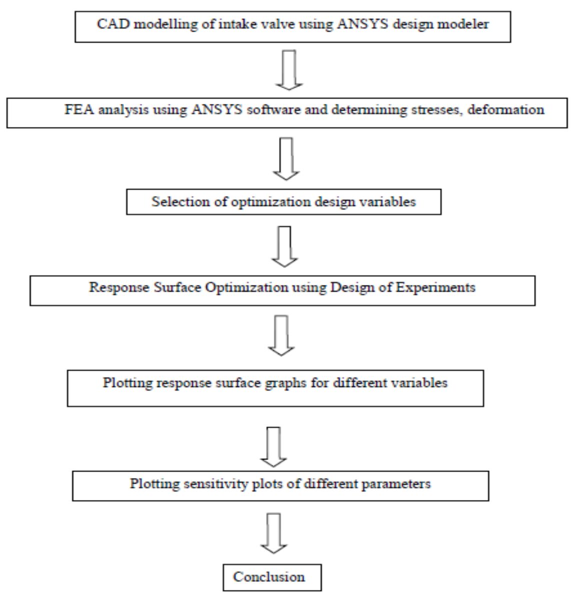
Shashank Gurnuleet. al. [8] have emphasized on the intercooling process of air compressor. The intercooling enhances the efficiency of compressor. Compression is done in more than one step to "improve the efficiency of the system," and an intercooler is given between each stage. In the final stage, the intercooler enhances air quality and lowers inlet air temperature. The intercooler's job is to cool the air before it reaches the High-Pressure cylinder after it exits the Low-Pressure cylinder. This increases compressor efficiency and guarantees that the temperature of the air receiver exit valves is just perfect for optimal operation of the compressor's tools. Sheet metal plate parts or a tabular core make up the intercooler. The Type VT4 compressor is a two-stage, two-cylinder reciprocating air compressor that is commonly used in industrial and underground mining applications. Purpose the varied efforts of numerous researchers are highlighted in this study. According to numerous studies, increasing the size of the intercooler will prevent heating in the High-Pressure Cylinder in the long term."[8]

Kanwar J.S Gillet. al. [9] Have worked on 2 stage reciprocating air compressor design. The compressor design was made of structural steel frame mounted over foundation. The unit comprised of air receivers and stabilizing tanks. During the test, the "real volume of free air provided by this compressor is 0.020 m3 /sec with a work done of 77 N-m" was discovered. Furthermore, it was discovered that when the compressor's isothermal efficiency is 45 percent, the compressor's capacity to supply air is around 1.02 kg/minute. An intercooler with a capacity of 2.049 kilojoules/kg of heat rejection can be particularly constructed."[9] .

Vijaykumar F Pipaliaet. al. [10] have worked on investigating the effect of undesirable heating on compressor functioning. The design and material modifications are suggested by the author to mitigate the heating effect and ensure efficient design development. The water cooling sources, ethylene glycol coolants are used in air compressor are investigated using experimental techniques.

3. METHODOLOGY

4.1 Methodology Flow Chart



3 Coupled Field Analysis using P100/6061 Al MMC

The coupled field analysis is conducted on intake valve using P100/6061 Al MMC material. The total deformation, equivalent stress and safety factor are determined. The maximum deformation obtained from the analysis is .00469mm at the top free end of the intake valve as represented in red color.

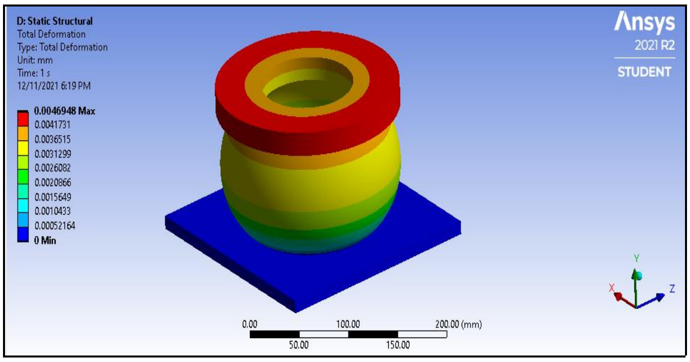


Figure 5.22Total deformation usingP100/6061Al MMC

The maximum equivalent stress is obtained at the contact region between bottom support and cylindrical region with magnitude of 9.77MPa.

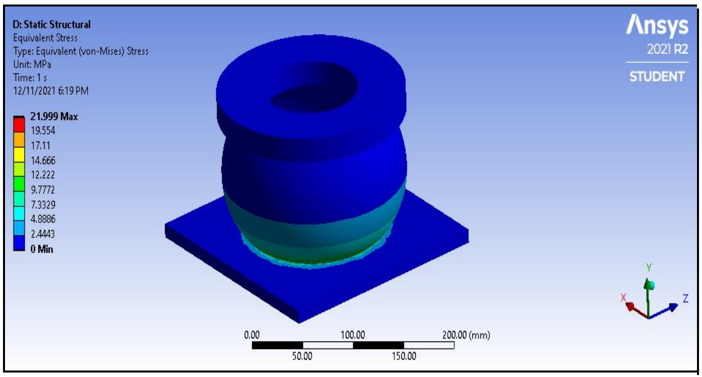


Figure 5.23Equivalent stress usingP100/6061Al MMC The safety factor plot is generated using Al MMC material. The safety factor is high with use ofP100/6061Al MMC material with magnitude of 12.546.

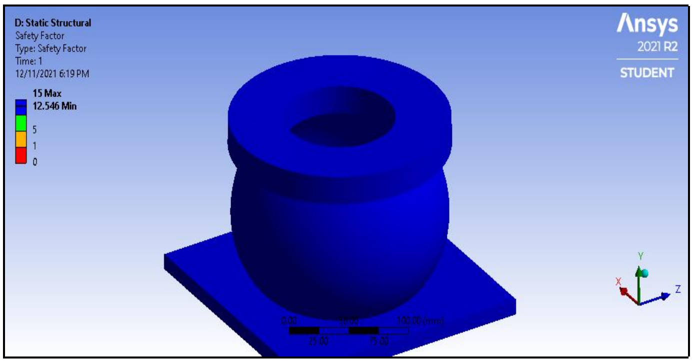


Figure 5.24 Safety factor usingP100/6061 Al MMC

6.1 CONCLUSION AND FUTURE APPLICATIONS

The FEA is a useful tool for determining the structural and thermal properties of a compressor's intake valve. The critical areas of high stress and the safety factor are identified. To generate dimensions, the optimization variables are chosen and Taguchi design of experiments is used.

1. According to coupled field analysis, heat flow is greatest at the edge region, with a magnitude of.00138W/mm2. The heat flux decreases until it reaches.000614 W/mm2.

2. The topmost region of the intake valve exhibits the greatest deformation. The coupled field analysis yielded a maximum deformation of.221mm.

3. The equivalent stress is greatest at the point where the base and circular geometry meet. The analysis yielded the maximum equivalent stress .

4. The outer dia has a sensitivity percentage of 77.369 for total deformation, while the inner dia has a sensitivity percentage of 26.873. As a result, the outer dia has a larger effect on total deformation and the inner dia has a smaller effect on total deformation.

5. The outer dia has a sensitivity percentage of 65.125 for equivalent stress, while the inner dia has a sensitivity percentage of 67.678. As a result, the inner dia has a greater effect on total deformation and the outer dia has a lesser effect.

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