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Analysis of Reciprocating Compressor Valve

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Abstract: A compressor running at even moderate speeds requires for each valve to open and close over one million times a day. It follows that valve design must bear in mind that it needs to be highly reliable and operate efficiently even in adverse conditions, such as in applications where there are liquids and debris in the gas stream.
The fundamental challenge in the design of a compressor valve lies in the opening and closing phase of the valve, where an effort is made to allow for the most desirable dynamic behavior as possible. For instance, lowering the pressure loss across the valve by increasing the flow area leads to a higher possibility of unsuitable dynamic behavior and thus decreases its lifetime.This thesis is devoted to a theoretical study of reciprocating compressor valve dynamics. The analysis of the influence of the valve parameters on its dynamic behavior is also present in this thesis.
This study has been undertaken in the compressor valve generally a flap valve and their CAD modelling with analysis of compressor valve equivalent stress, temperature and heat flux.

I. INTRODUCTION

Reciprocating compressors are among the most used types of compressors. They can be found in highly diverse fields of application, such as in the oil and gas industry or chemical industry, where these compressors are used mainly for their ability to deliver high-pressure gas. Basically, piston compressors are vital part in any process they are employed in; therefore their reliability has garnered widespread interest. As the limiting elements in the design of the reciprocating compressor, the compressor valves can be considered. They are often described as the heart of the compressor, due to the fact that should they fail, it would lead to the shutdown of the compressor and to costly downtimes. A compressor running at even moderate speeds such as 700 rpm requires for each valve to open and close over one million times a day. It follows that valve design must bear in mind that it needs to be highly reliable and operate efficiently even in adverse conditions, such as in applications where there are liquids and debris in the gas stream. The fundamental challenge in the design of a compressor valve lies in the opening and closing phase of the valve, where an effort is made to allow for the most desirable dynamic behavior as possible. For instance, lowering the pressure loss across the valve by increasing the flow area leads to a higher possibility of unsuitable dynamic behavior and thus decreases its lifetime. This thesis is devoted to a theoretical study of reciprocating compressor valve dynamics. For this purpose, a tool for the prediction of valve plate motion is developed. The main reason in developing this tool is to qualitatively assess the factors influencing the dynamic behavior. To validate the precision of this tool, the results are compared to freely accessible experimental data found in literature. However, the main goal of this study is not aimed at a quantitative estimation, since an experiment would be inevitable for the precise evaluation of the theoretical results. The analysis of the influence of the valve parameters on its dynamic behavior is also present in this Chapter.

Reciprocating compressors also widely known as piston compressors are mainly used to move air/gas at high pressure to be stored and used for different purposes. The main elements of the compressor are one or more cylinders and pistons which move within them. Automobile engines work almost the same way as reciprocating compressors do through letting the air in from one chamber, mixing it with fuel and letting the fume out from another chamber with pressure. The picture below is a schematic structure of a reciprocating compressor and its main components.

A reciprocating compressor has a piston that moves downwards thus reducing pressure in its cylinder by creating a vacuum. This difference in pressure forces the suction chamber valves open and bring gas or air in. When the cylinder goes up, it increases pressure thus forcing the gas or air out of the cylinder through a discharge chamber. Reciprocating compressors are used in a variety of industries and for different purposes. The following are the main applications of reciprocating compressors:

1) Natural gas processing and delivery
2) Chemical plants
3) Oil refineries
4) Refrigeration technology

As stated earlier, reciprocating compressors are found in almost every work setting including but not limited to diving, dental surgeries, automotive workshops, and agriculture. Pneumatic (air- powered) tools, such as drills and angle-grinders, are important in industry because they are generally lighter and safer than those with an electric motor which further highlights the significance of reciprocating compressors

A. Mechanism of Reciprocating Compressor

1) Process gas is drawn into the cylinder, compressed, contained and then released by mechanical valves that typically operate automatically by difference in pressure. Depending on system design, cylinders may have one or multiple suction and discharge valves.
2) The crankshaft is fitted with counter weights to balance dynamic forces created by the movement of the heavy pistons.
3) Suction gases are generally passed through suction strainers and separators to remove entrained particulates, moisture and liquid phase process fluid that could cause severe damage to the compressor valves and other critical components, and even threaten cylinder integrity.
4) Typically, reciprocating compressors are relatively low-speed devices, and are direct-or belt-driven by an electric motor, either with or without a variable speed drive controller.
5) Often the motor is manufactured to be integral to the compressor, and the motor shaft and compressor crankshaft are one-piece, eliminating the need for a coupling. Gearbox-type speed reducers are used in various installations.
6) Sometimes, though less commonly, they are driven by steam turbines or other sources of power such as natural gas or diesel engines. The overall design of the systemand the type of driver selected will influence lubrication of these peripheral systems.

B. Types of Reciprocating Compressor

1) Single-Acting

This is the most typical air compressor in the market. They tend to be quite loud but can be relatively powerful for their size and weight. Given their portability, they can be placed close to point of use so if your needs are limited you can avoid installation of large amounts of piping and their simple design makes maintenance easier. As a rule they have a higher cost of compression than their double-acting siblings so they work best in environments where constant compressor use is not required.

2) Double-Acting

Reciprocating compressors are the most widely used compressors in almost all settings and regardless of the type, both versions of reciprocating compressors come with both single and multi-piston models, lubricated and non-lubricated, and can provide long-term and effective air compression depending on costumers’ demand.

II. AIM AND OBJECTIVE OF RESEARCH

This project was developed to study about the thermal analysis of reciprocating compressor valve. The main purposes of this project are listed below:

1) To study about the influence of temperature and pressure on flap valve located in cylinder head of reciprocating compressor.
2) To design another flap valve and take series of experiments for determining life in with comparison of earlier
3) To study about the best combination of solution for Material in manufacturing of valve plate.

III. VALVE MATERIAL AND PROPERTIES

A. Sandvik 20c Valve Material and Its Properties

Sandvik 20C is a hardened and tempered carbon steel characterized by:

1) High strength
2) High fatigue strength under bending and impact stress
3) Low level of non-metallic inclusions
4) Good wear resistance

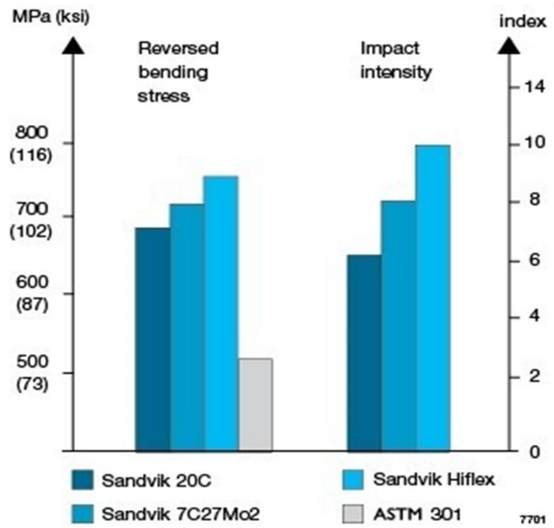
Compressor valve steel in Sandvik20C has excellent surface finish, good dimensional tolerances and good flatness.

B. Standards ASTM

1) ASTM: 1095

2) W.Nr.:1.1274
3) SS: 1870

C. Valve Types
1) Flapper valves
2) Reed valves
3) Check valveS



GRAPH 1. Comparison of fatigue properties for sandvik's flapper valve steels and standard spring steel (ASTM301)

IV. PROJECT METHODOLY

A. Specimen Flapper Valve

2 test valve specimens were prepared for the experimental work. The material valve was standard spring steel ASTM301 and Sandvik spring steel 20C.

Figure 1 Test Specimen Sandvik 20c

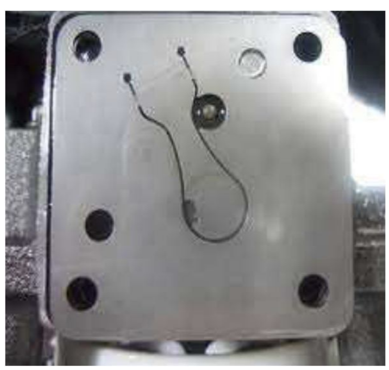


Figure 2 Test Specimen Astm301

B. Design of Valve

Desugn of Valve flap is done in siemens NX CAD software having same dimensions as that of available in market.

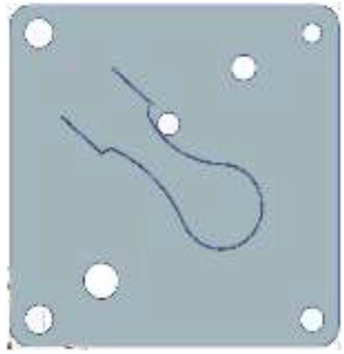


Figure 3 Flap Valve In Cad Model

V. A GENERAL OPERATION FOR ANALYSIS FACILITY

Certain steps in formulating a finite element analysis of a physical problem are common to all such analysis, whether structural, heat transfer, fluid flow, or some other problem. These steps are embodied in commercial finite element software packages (some are mentioned in the following paragraphs) and are implicitly incorporated in this text, although we do not necessarily refer to the steps explicitly. The steps are described as follows.

A. Preprocessing

The preprocessing step is, quite generally, described as defining the model and includes

1) Define the geometric domain of the problem.
2) Define the element type(s) to be used.
3) Define the material properties of the elements.
4) Define the geometric properties of the elements (length, area, and the like).
5) Define the element connectivity (mesh the model).
6) Define the physical constraints (boundary conditions).
7) Define the loadings.

The preprocessing (model definition) step is critical. In no case is there a better example of the computer-related axiom “garbage in, garbage out.”

A perfectly computed finite element solution is of absolutely no value if it corresponds to the wrong problem.

B. Solution

During the solution phase, finite element software assembles the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s). The computed values are then used by back substitution to compute additional, derived variables, such as reaction forces, element stresses, and heat flow. As it is not uncommon for a finite element model to be represented by tens of thousands of equations, special solution techniques are used to reduce data storage requirements and computation time. For static, linear problems, a wave front solver, based on Gauss elimination, is commonly used. While a complete discussion of the various algorithms is beyond the scope of this text, the interested reader will find a thorough discussion in the Bathe book.

C. Post Processing

Analysis and evaluation of the solution results is referred to as post processing. Postprocessor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution. Examples of operations that can be accomplished include:

1) Sort element stresses in order of magnitude.
2) Check equilibrium.
3) Calculate factors of safety.
4) Plot deformed structural shape.

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5) Animate dynamic model behavior.
6) Produce color-coded temperature plots.

While solution data can be manipulated many ways in post processing, the most important objective is to apply sound engineering judgment in determining whether the solution results are physically reasonable.

VI. ANALYSIS RESULTS

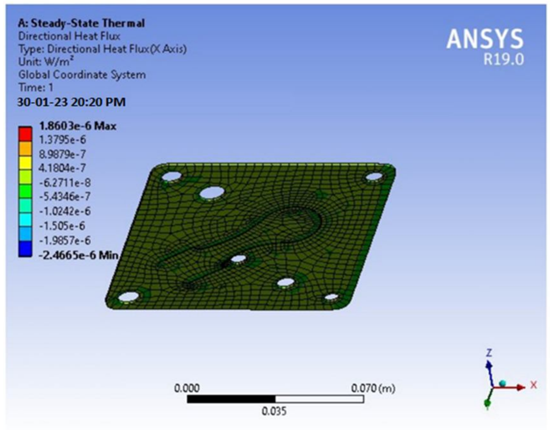

Figure 4. Directional heat flux

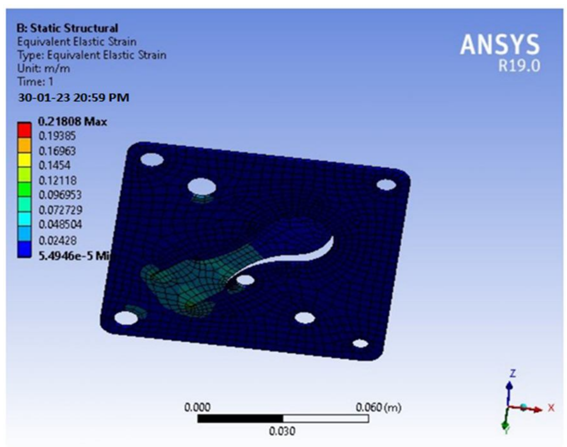

Figure 5. Equivalent elastic strain

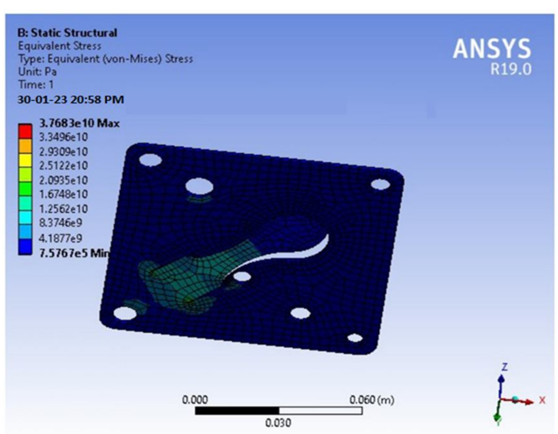

Figure 6. Equivalent stress

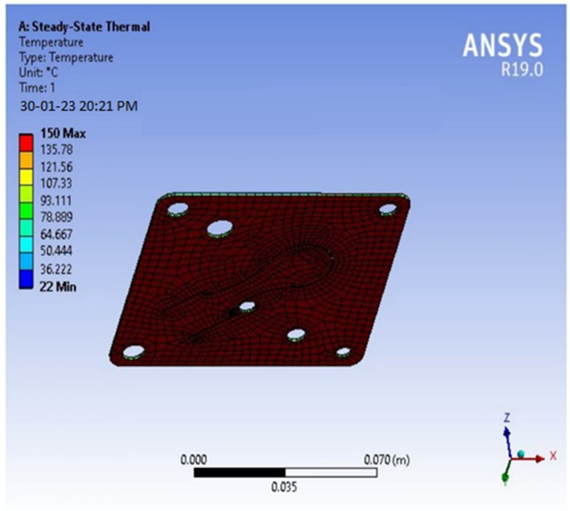

Figure 7. Temperature

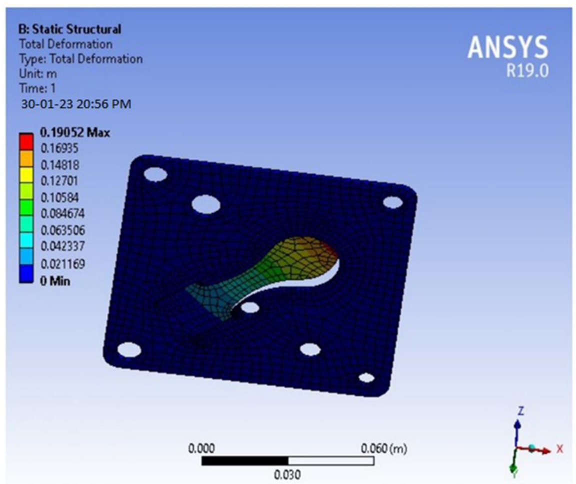

Figure 8. Total deformation

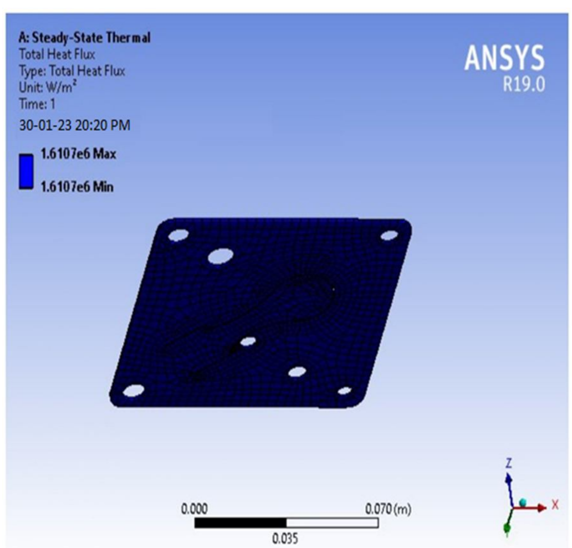

Figure 9. Total heat flux

VII. CONCLUSION

This thesis has presented for optimization best suited material for flap valves of reciprocating compressor. As shown in this study, method provides a systematic and efficient methodology for determining optimal parameters with far less work than would be required for most optimization techniques. The confirmation experiments were conducted to verify the optimal parameters. It has been shown that Total deformation can be significantly improved in Flap valve materials using the optimum level of parameters.

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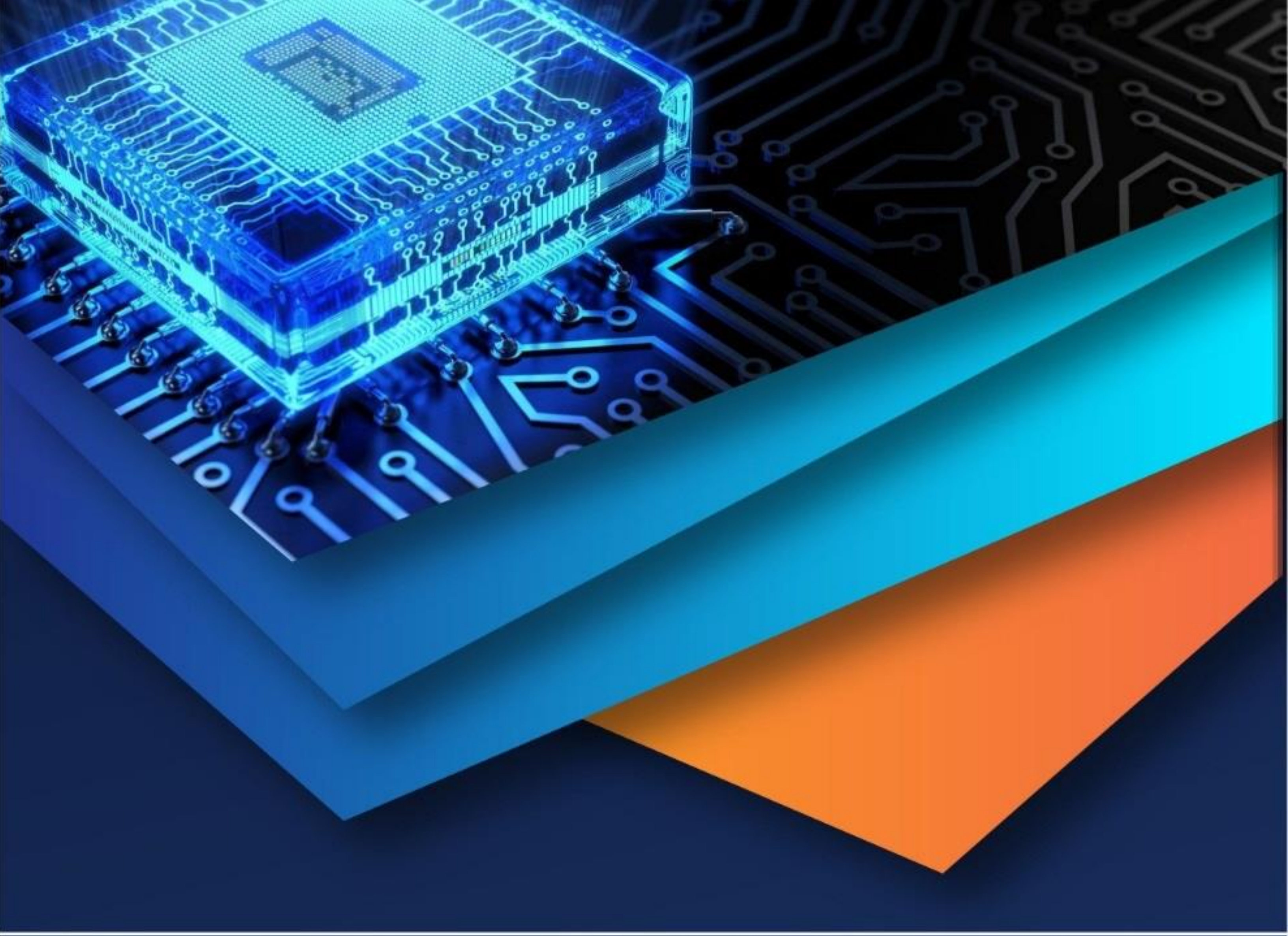

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