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Modeling and Hydrostatic Analysis of Compressor Housing

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ABSTRACT

The main aim of this project is to rectify various losses of the vibration and pressure at the surrounding of the compressor that the effect of the vibration and hydrostatic pressure are more at the time of running of the compressor, these can rectifying at the time of running the compressor and identifying the high pressure at various locations and design modifications are can be done for the new design conditions.

In this project the analysis is performed on hermitically reciprocating compressor due to hydrostatic pressure in hermetic compressor is very important for product engineering. Mapping provides more realistic inputs too analytical model that simulate various compressor components. It also helps in predicting the performance changes easily, for a given change in design. The current work deals with the use of commercially available FEM codes to simulate pressure distribution in the entire compressor domain, followed by experiments to validate the simulation results. The simulations are done by using ANSYS module and the experiments are carried out by using capillaries and pressure gauges for pressure measurements. The simulation results are obtained at various locations are reported and discussed.

INTRODUCTION

Reciprocating 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, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. Applications include oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection.

OBJECTIVES OF THE PRESENT WORK

The present work deals more about the application of the results obtained by simulating a compressor model using commercially available ANSYS. For this analysis, whole compressor model is selected as the computational domain and meshed. The material and boundary conditions are applied and domain is solved by using Annoys solver to satisfy continuity, momentum and energy conservation equation. This powerful tool along with faster and robust digital computers makes it possible to predict temperature distribution in any plane across the whole domain.

LITERATURE REVIEW

INTRODUCTION

Literature review, in the present work, has been conducted from the thermodynamics and valve dynamics system point of view. A considerable quantity of work has been published in the literature for the refrigerant compressors and rotary compressors. In the published literature some work has been reported on the analysis of refrigeration rotary and reciprocating compressors with simple

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mathematical model. The work dealing with mathematical modeling and valve dynamics are alone considered in the present work.

MODEL FOR REFRIGERATION COMPRESSORS

Ed. T. W. Wu, WIT Press, Southampton, Boston, 2000. Have developed a model for fixed vane refrigerant rotary compressors which is based on a control volume for suction and pressure. The first law of thermodynamics and the law of continuity in dynamic form are used on these control volumes. The thermodynamic properties, mass flow, heat effect and compression power are calculated as a function of time or angle of rotation instead of a static average value. The developed model describes suction mass flow, pressure drop and temperature rise in suction pipe, gas leakage from pressure volume to suction volume, oil leakage from shell and shaft to suction and pressure volume, shaft torque arising from gas forces and pressure, temperature, internal energy and enthalpy from the refrigerant equations. The differential equations for the first law of thermodynamics and the law of continuity are solved numerically by a simple Euler integration. The calculated values of volumetric efficiency are validated with measurements. It was observed that the measured values are closer to the experimental values.

FUNDAMENTALS OF REFRIGERATION AND AIR-CONDITIONING

A BRIEF HISTRY OF REGRIGERATION

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space.

THE BASIC REFRIGERATION CYCLE

Refrigeration is achieved by continuously circulating, evaporating, and condensing a fixed supply of refrigerant in a closed system. Evaporation occurs at a low temperature and low pressure while condensation occurs at a higher temperature and pressure. Thus, it is possible to transfer heat from an area of low temperature to an area of high temperature.

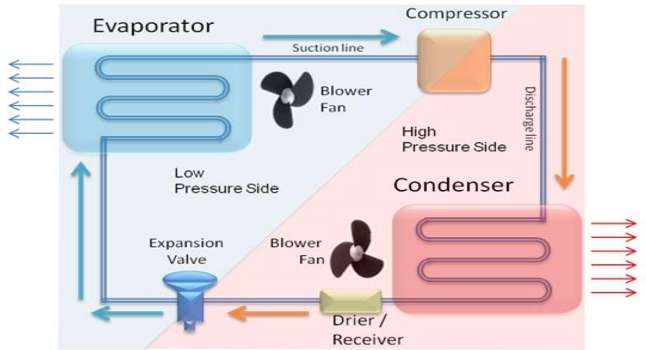

Fig-3.1 Basic refrigeration cycle

Beginning the cycle at the evaporator inlet, the low pressure liquid expands, absorbs heat, and evaporates, changing to a low pressure gas at the evaporator outlet.

PARTS OF REFRIGERATION SYSTEM

REFRIGERATION SYSTEM COMPONENTS

There are five basic components of a refrigeration system, these are:

- Evaporator
- Compressor
- Condenser
- Expansion Valve

In order for the refrigeration cycle to operate successfully each component must be present within the refrigeration system.

Evaporator

The purpose of the evaporator is to remove unwanted heat from the product, via the liquid refrigerant. The liquid refrigerant contained within the evaporator is boiling at a low-pressure.

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Compressor

The purpose of the compressor is to draw the low-temperature, low-pressure vapor from the evaporator via the suction line. Once drawn, the vapor is compressed. When vapor is compressed it rises in temperature. Therefore, the compressor transforms the vapor from a low- temperature vapor to a high-temperature vapor, in turn increasing the pressure. The vapor is then released from the compressor in to the discharge line.

Condenser

The purpose of the condenser is to extract heat from the refrigerant to the outside air. The condenser is usually installed on the reinforced roof of the building, which enables the transfer of heat. Fans mounted above the condenser unit are used to draw air through the condenser coils.

Expansion Valve

Within the refrigeration system, the expansion valve is located at the end of the liquid line, before the evaporator. The high-pressure liquid reaches the expansion valve, having come from the condenser.

RECIPROCATING AIR CONDITIONER COMPRESSOR

The reciprocating compressor uses piston to compressor the refrigerant driven by a crankshaft in a straight line back and forth motion. This rotary motion is achieved by the use of an electric motor and the construction is quite similar to that of an automobile engine. The piston moves up and down inside a cylinder. Vapor from the suction line is moved through the intake valve as the piston move downward. As the piston moves upward, it compresses the vapor refrigerant which is then pushed through the exhaust valve into the condenser.

HERMETIC RECIPROCATING COMPRESSORS

It brings vaporous refrigerant from a low pressure level (low / suction pressure) to a high level (high / discharge pressure). There are compressors in different functional principles. There are for example scroll compressors, screw compressors, rotary compressors, turbo-compressors and reciprocating compressors. Today we are going to concentrate on reciprocating compressors and in particular on those types with hermetic design.

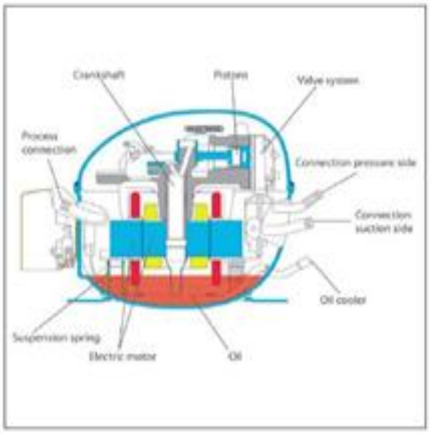

Fig-3.6 Compressor assembly parts

SOLID MODELING OF COMPRESSOR HOUSING

SELECTION OF DOMAIN

The proposed numerical simulation is carried out for hermetically sealed reciprocating compressor used for air-conditioning applications. The geometry of the compressor is modeled using UNIGRAPHICS. Because of the geometrical complexity of the domain, the model is simplified by removing unnecessary fillets, restrictions, sharp edges and sharp corners. So that it is easy to mesh the domain in preprocessing stage. Mainly the domain of interest in this simulation.

In this section the design with solid modeling of 4 different types compressor housing is explained which comprises.

GENERATION OF SOLID MODEL

The main task was to create solid model of the compressor housing according to customer's requirement. Through study of 2-D drawing is performed. After studying the details of 2D drawing, the solid model of compressor housing is generated with the help of Unigraphics software.

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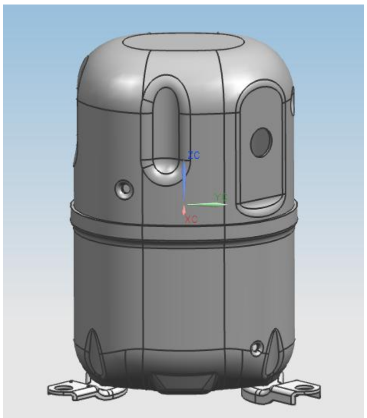

Model-1

Fig-4.1 Geometric model of compressor housings

The geometry of the compressor is modeled using UNIGRAPHICS. Because of the geometrical complexity of the domain, the model is simplified by removing unnecessary fillets, restrictions, sharp edges and sharp corners. So that it is easy to mesh the domain in preprocessing stage.

HYDROSTATIC ANALYSIS

HYDROSTATIC ANALYSIS DESCRIPTION

The proposed numerical simulation is carried out for hermetically sealed reciprocating compressor used for Air-conditioning applications. The geometry of the compressor is modeled using UG. Because of the geometrical complexity of the domain, the model is simplified by removing unnecessary fillets, restrictions, sharp edges and sharp corners. So that it is easy to mesh the domain in pre-processing stage.

Mainly the domain of interest in this simulation is Hydrostatic presser. The domain consists of compressor shell, compressor shell.

MESHING OF THE COMPRESSOR

The compressor geometry is translated from the UG to ANSYS. The domain is discredited with tetrahedral, wedge and pyramid elements. The quality of the elements is checked in terms of the equi-angle skew and the aspect ratio. The equi angle skew indicates the deviation of an element shape from its true geometrical shape.

HYDROSTATIC TEST-HERMETIC HOUSING AFTER SEAM WELD

To assure safe mechanical strength after seam weld the completed shell must be capable of withstanding for a period of one (1) minute without bursting or visible leakage, the following hydrostatic test pressures. If the welded housing of the above model withstands their respective pressure until bursting or 2100 psig, whichever occurs first? Record on hydrostatic test report from the pressure attained or the pressures at the time of rupture the location of the rupture, as well as the model of shell (housing) being tested.

TO PERFORM STRUCTURAL ANALYSIS ON HOUSING ASSEMBLY UNDER HYDEOSTATIC PRESSURE CONDITION

Model used for Analysis

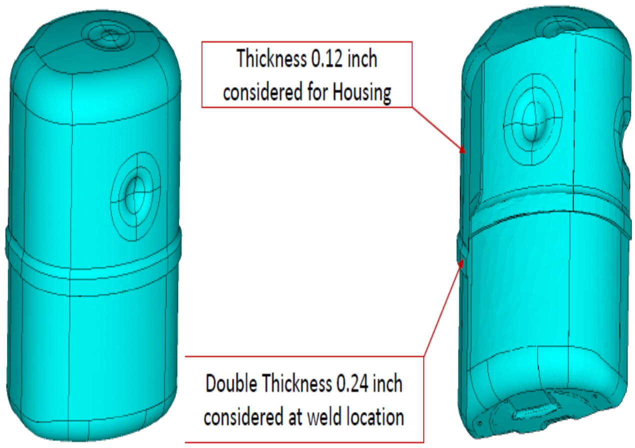

Fig-6.1 mid surface of housing

The housing mid surface is imported to ANSYS and given the thickness to the mid surface. By using shell thickness option to upper & lower housing thickness is considered as 0.12inch. For weld location the thickness is double 0.24 inch. With this shell thickness the presser is applied.

Non linear material properties

Maximum % of elongation for material SAE 1010 Steel is 29% (Max.Tensile ultimate strain is 0.29)

To observe the material nonlinearity True stress, True strain material properties are used for this analysis.

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Finite Element Model

The housing assembly is meshed by using element - 4 node shell 181. With this element we had meshed in hex-mapped mesh. This gives more accrues result
Element used –**4 NodedSHELL181**
No. of Nodes –**230027**
No. of Elements –**230229**

Fig-6.2 Meshed model

Boundary Conditions

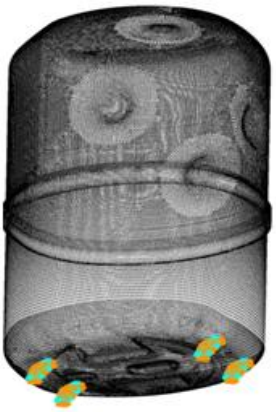

Fig-6.3 Displacement

Fig-6.4 Pressure

The Housing fixed at mounting locations there are four mounting stands so there is a four fixed supports and Internal Pressure is applied on faces Load of housing.

Table-6.2 Internal pressure applied on faces Load

Load Case	Internal Pressure applied on Housing (PSI)
1	500
2	1000
3	1500
4	2000
5	2200

The internal pressure applied to the face of the housing gradually in five steps 500 to 2200.

Table 6.3 Von Mises Stress and Strain Results

Load	Internal Pressure applied on Housing (PSI)	Total Mechanical Strain (%)	Elastic vonMises Strain (%)	Plastic vonMises Strain (%)	vonMises Stress (KSI)
1	500	11.6	0.215	11.4	48.42
2	1000	40.8	0.262	40.5	54.13
3	1500	61.1	0.272	60.9	63.08
4	2000	73.9	0.275	73.6	73.45
5	2100	75.7	0.276	75.4	71.89

Max strain is observed at the nodes which are fixed. From load case 2 onwards the max strain location is observed at connecting region of both the top and bottom housing and the strain values are in the range of 9% to 25% for load case 2 & 3, 40% to %)% for load case 4 & 5.

Von Mises Total Mechanical strain

1st Location

Maximum Strain occurring at constrained locations

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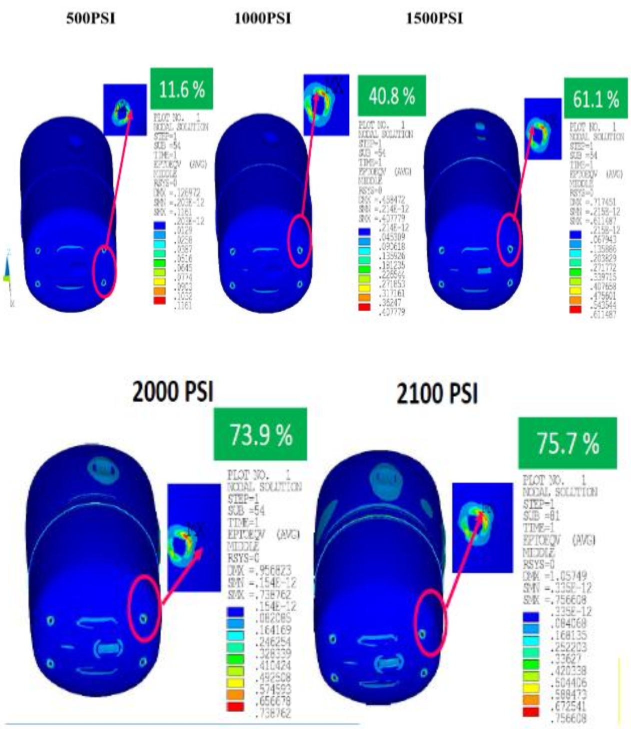

Von Mises Total Mechanical strain 2nd Location

After removing at constrained location, maximum strain has shifted towards flange region Simulation is going on to check at what pressure Strain is exceeding 29%

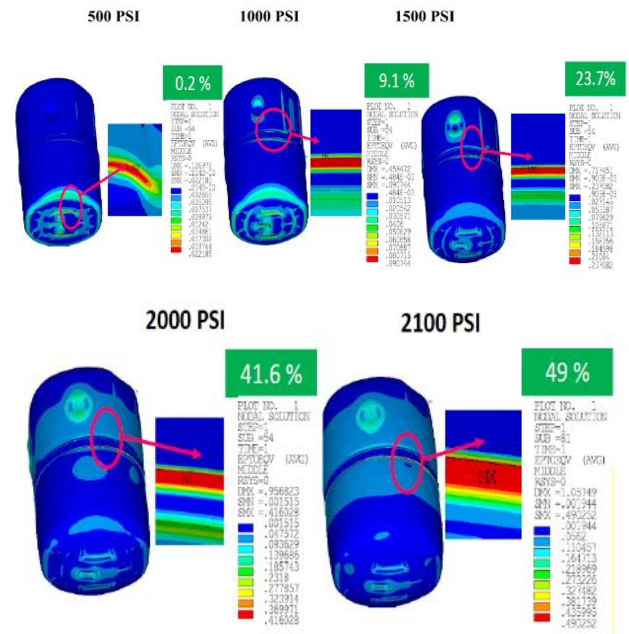

Fig -6.5 Von Mises Total Mechanical strain

Internal Pressure 2200 PSI

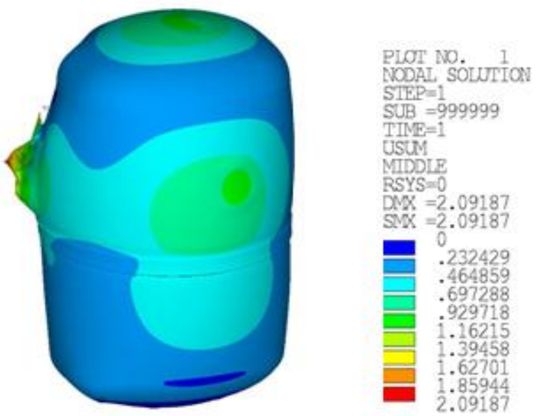

Fig- 6.6 Internal Pressure 2200 PSI

Observations

From the results it is observed that

- From 500 PSI itself material is in plastic zone and same can be observed in elastic strain. Where it is not showing any strain.
- All the maximum strain locations are at constrained regions, so we have taken next strain locations to see the physical effect of load. [1st location may not be in our regular testing. Second will be realistic]
- Deformations at maximum pressure of 2000 PSI are 1.06 inch and after this pressure, elements are getting highly distorted and facing convergence issues.
- In general housings are withstanding up to 1800 PSI in hydrostat testing conducted at TI labs

HYDROSTATIC TEST

The hydrostatic test done on the compressor housing assembly this test is done at hydrostatic compressor testing room.

- We should mount the compressor housing in the work bench and we should fix it tightly.
- There will be two valves one is discharge and suction valve for this test we close both the valves.
- To the process tube we connect the pressured fuel pipe.

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- From this pipe we get the pressurized water to the housing.
- By using pressure gage we should fixe the pressure slowly step by step.
- At the pressure 2200psi the housing will get crack.

Fig-7.1 Hydrostatic test

The pressure in the system to be gradually increased to 1800 PSIG and maintained for one minute.

TABLE 7.1 Hydrostatic test

S,NO	Machine/Mode	Pressure(psi) During 1Minute	Max Value Reached PSI	Bust Location	Result
1	AW2	1800	2000	Top of terminal vertically	ok
2	AW2	1800	2000	Top of terminal vertically	ok

CONCLUSION

The following conclusions were drawn from the above investigation:

- Study is made on the compressor of Air conditioning system.
- The housing assembly is done by using UG NX8.
- The solid, shell housing is analyzed in ANSYS 16.

As per costumer requirement we design the compressor. With reference to previews compressor housing we make some modifications. The changes like thickness, shapes, height, and volume. Four models have been done by changing those parameters by using UG NX8.

Then for all housings model analysis is done to find that which is the best housing that withstands the frequency by using ANSYS workbench 16.

For selected housing among all hydrostatic analysis is done in ANSYS APDL 16 to mid surface of the housing.

The hydrostatic test done to the housing and then find its stability. The compressor assembly is done as per customer requirement.

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