International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.05, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Modelling and Burst Pressure Analysis of Compressor Housing Using Alternate Material

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ABSTRACT

The project was aimed to find alternate material for cost iron for compressor housing which will give the best results on the basis of stress, strength & deformation. We will be finding material which will does not affect it strength criteria. We will be study of burst pressure analysis for both material and compare the stress, strain and deformation of both materials. In this project, the modeling of compressor housing is done in detailed using CAD software in CATIA V5. After that the FEA analysis is done for strength analysis.

Keywords— CAD Modelling, Burst pressure, FEA Analysis, Compressor.

I. INTRODUCTION

A compressor is a Mechanical device which increases the pressure of a gas by reducing its volume. A typical refrigeration system used in household and commercial application is composed basically by a compressor, an evaporator and a heat exchanger. The purpose of the compressor is to rise up the pressure from point 1 to point 2 in the refrigeration cycle. The compressor itself is composed by the Mechanical pump, electrical motor and an external housing enclosing the whole compressor system. In the most of refrigeration application, the working pressure in the housing lays in a very low value has not been a big concern regarding Mechanical strength. The housing thus, has an esthetical and acoustic commitment more than a structural concern. However, when dealing with high pressure refrigeration system, the safety aspects and structural reliability of the compressor housing is the most concern. In this case, the housing is subjected to internal pressure in such level that structural strength must be very well analysed, tested and evaluated. Moreover, the compressor housing is formed by three parts joined by welding. This shall be another important point of a deeply study and investigation, once it can lead to a weak point for the structure integrity.

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 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.[1]

1.1 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. 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.[1]

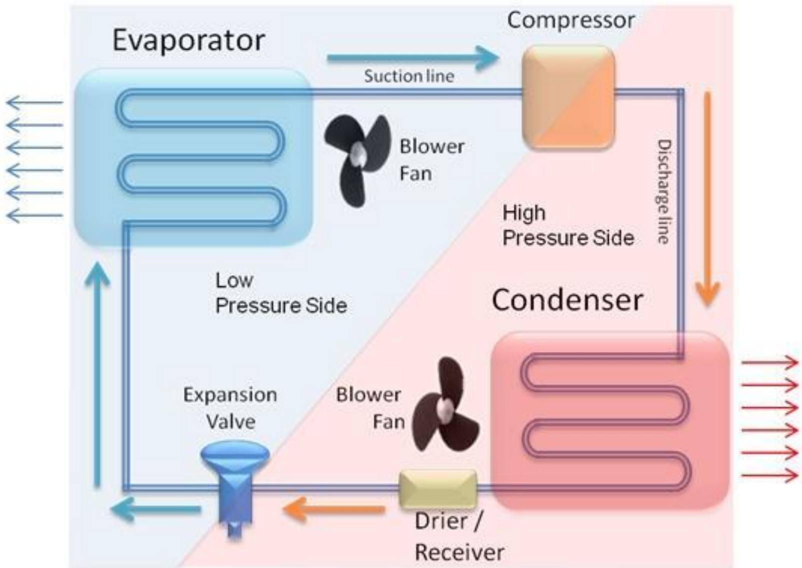

Fig 1.1 Basic Refrigeration Cycle

1.2 Parts of refrigeration system components

There are four basic components of a refrigeration system, they are:

1) Evaporator
2) Compressor
3) Condenser
4) Expansion Valve

1.Evaporator

The evaporator is used to remove unwanted heat from the product, via the liquid refrigerant. The liquid refrigerant contained within the evaporator is boiling at a low-pressure.[1]

2.Compressor

The compressor used 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 its 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.[1]

3.Condenser

The purpose of the condenser is to extract heat from the refrigerant to the outside air. The condenser is usually installed on the 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.[1]

4.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.[1]

II. PROBLEM STATEMENT

Due to constant increase in fuel cost and increased regulation seen in industry and domestic use we have to choose better alternative.The purpose of this project is to analyse the existing and alternative better material for compressor housing from that we find various stresses and burst pressure for two different material which restrict deformation. The compressor used for analysis is domestic refrigerator compressor.

III. LITERATURE SURVEY

T Sai Kiran Presented in 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.[1]

ZHENG Chuan-xiang et al. Presented new modified Faupel formulae for calculating the burst pressure. According to the author formulae is derived based on bursting experiment on hundreds of mild steel pressure vessel and based on analyzing the data as Faupel formulae is having the error in the calculation. Error in the calculation is reduced after using the modified Faupel formulae and hence the value is more closely match with the experimental data.[2]

P. Xu et al. Presented a finite element model for the Al– carbon fiber/ epoxy composite laminates which is subjected to the internal pressure to find the burst pressure. Author used four theories to determine the failure properties namely maximum stress, Hoffman, Tsai–Hill and Tsai–Wu failure criteria to determine the failure properties of the composite element. They found Tsai-Wu failure criterion leads to most accurate failure pressure among all failure criterions.[3]

Amruta M. Kulkarni et al.: Calculated burst pressure of liquid petroleum gas cylinder used in household application by using twice elastic slope criteria. Authors have compared results of two design approaches which are design by experiment and design by analysis in which they consider both material and geometry nonlinearity. They performed nonlinear finite element analysis using commercial software ANSYS 14. They also suggested using Plane 42 axisymmetric elements to reduce computational time. They found mean variation between Experimental and numerical simulation to be - 0.5741% and thus establishing a strong correlation between numerical and experimental results.[4]

Usman T Murtaza et al.: Compared two different design approaches suggested by ASME for a PWR reactor pressure vessel which was made up of nuclear grade steel „SA-508 Gr.3Cl.1‟ . Authors performed FE analysis uisng ANSYS and used twice elastic slope criteria to determine the collapse load, element used for the analysis is Solid 186 i.e. higher order 3-D 20-node solid element. Maximum Stress concentration was obtained around nozzle-cylinder junction. In the end Authors suggested to not rely on theoretical design to avoid unnecessary conservatism and use design by analysis approach to predict burst pressure of pressure vessel.[5]

E.S. BarbozaNeto et al. Investigated behaviour of pressure vessel liner under burst pressure testing. They used liner with polymer blend of 95% LLDPE and 5%HDPE which is to be used in all composite carbon/epoxy compressed natural gas shell manufactured by filament winding process. Designing and failure prediction of composite laminate shell and liner were based on Tsai-Wu and Von Mises criteria respectively. Liners of different thickness were tested in hydrostatic burst pressure testing machine. FEA simulations were conducted using ABAQUS/CAE6.8 in which model was meshed by using CAX4R element type. Authors conducted preliminary simulation by using sub-laminate with different orientation and found 400 orientations to be best in regards of strength. They concluded that ideal thickness of liner which can with stand the pressure of 2-2.2 MPa lie between 15-16 mm and to withstand 20.7 MPa operating pressure liner must be used as mandrel on which carbon/epoxy are wound using filament winding process. reduce computational time. They found mean variation between Experimental and numerical simulation to be - 0.5741% and thus establishing a strong correlation between numerical and experimental results.[6]

Z. Sanal: Showed non-linear finite element analysis for two cases of pressure vessel considering both material and geometric non-linearity. Authors in first case did non-linear analysis on imperfect tubes under external pressure made of X6 CrNiTi 1810 to predict limit load. Geometric imperfections cause substantial reduction in critical buckling pressure when compared with perfect tubes and suggested to always use 1% ovality always to get accurate results. In second case authors consider pressure vessel made from strain hardened steel to simulate large stain clod-deforming process in which he found that simple elastic plastic displacement analysis yields wrong and suggested to solve such problem by using materially and geometrically non-linear analysis only.[7]

IV PROPOSED METHODOLOGY

(a)Study of Research Paper

Due to constant increase in fuel cost and increased regulation seen in industry and domestic use we have to choose better alternative. To analyse the existing and alternative better material for compressor housing from that we find various stresses and burst pressure for two different material which restrict deformation. We study few papers mentioned in literature review below.

(b)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 CATIA software.

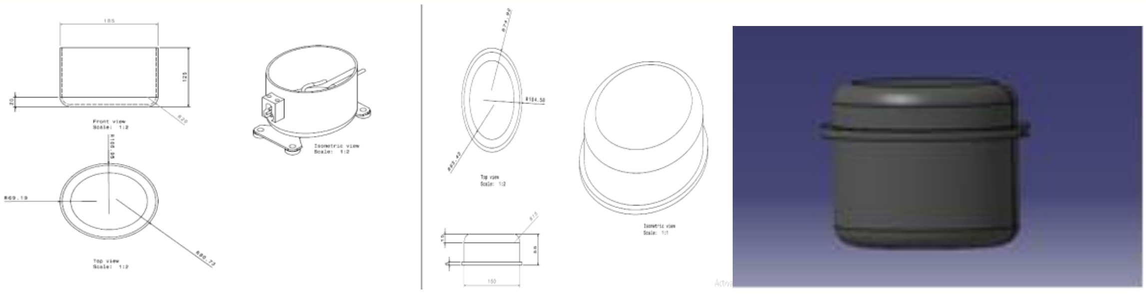

Fig 4.1. 2-D and 3-D model of compressor

(c)Selection of Material

The existing material used is cast iron which has failure of bursting and leakages for that reason we are going to use alternate material which is composite material. These gives better results compared to cast iron but weight of the alternative material increases which will increases the cost of project. We choose high strength composite material and for that material we theoretically find strength and bursting pressure of housing.

Existing Material:- Cast Iron

Country/International Organisation	Standard Designation	Brinell Hardness	C(%)	Si(%)	Mn(%)	P.Max (%)	S.Max (%)
1. India	Grade FG-220	180-220	3.3-3.6	2.4-1.8	0.6-0.8	0.35	0.15
Bending Strength Min. MPa(kgf/mm²)	FG 220 390(40)	FG 260 430(44)		FG 300 470(48)			FG 350 550(56)

Table 4.1. Cast Iron (FG 220) Properties

Alternate Material:- Composite Material(S.S. 98%, Carbon Fibre 0.8%, Kevlar 1.2%)

Property	Minimum Value (S.I.)	Maximum Value (S.I.)	Units (S.I.)
Density	7.85	8.06	Mg/m^3
Compressive Strength	205	310	MPa
Ductility	0.3	0.57	
Elastic Limit	205	310	MPa
Hardness	1700	2100	MPa
Tensile Strength	510	620	MPa

Table 4.2. Stainless Steel 304 Properties

(d) Analysis of Model

Present analysis is carried out robust, seamless, easy to use numerical tool 'ANSYS'. Solvers solve simulation using the numerical technique and we can check the results in post-processing phase. We divide our methodology for analysis in 3 phases:

1. Pre-processing

i.Geometry and mesh generation

ii.Materials properties and sections details

iii.Required Boundary conditions and loads etc.

2. Solver:

i.Details about the solver

iiNumerical techniques

3. Post-processing

i.Counter plot

ii.History plot etc.

Pre-processing:

We prepare the geometric model of compressor hosing in CATIA V5 and imported it on ANSYS workbench and tetrahydral meshing has done on compressor for more accurate results.

Fig 4.2. Geometry and mesh generation

Desired section is applied with necessary standard material properties as shown in following table

Sr. No.	Properties	Stainless Steel	Cast Iron
1	Young’s Modulus	200MPa	220MPa
2	Poisson’s Ratio	0.30	0.28
3	Tensile Ultimate Strength	460MPa	480MPa
4	Tensile Yield Strength	250MPa	270MPa
5	Compressive Yield Strength	250MPa	1640MPa
6	Density	7850kg/m³	7200kg/m³

Table 4.3. Material properties of compressor

Solver:

The solution phase deals with the solution of the problem according to the problem definations. All the tedious work of formulating and assembling of matrices are done by the computational method and finally deformation and stresses are give as output.Static Structural analysis has been used to determine the stress and deformation characteristics of compressor giving pressure(10 Bar) as input.

Post-processing:

This is very interesting part of simulation because you will get the output of your efforts and it will show whether you did good job or not. Here all results are accumulated in single paper so very few screenshot of mode shape of each condition are displayed. Finally result table would show you the exact comparison between all conditions with variable diameter.

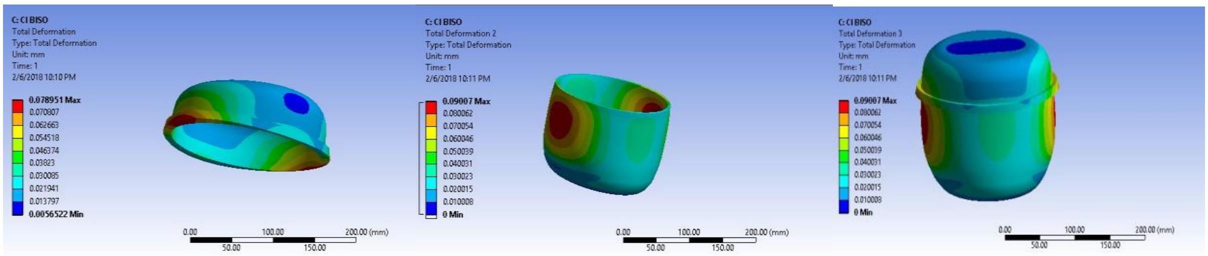

Fig 4.3. Deformation of compressor components (Cast Iron)

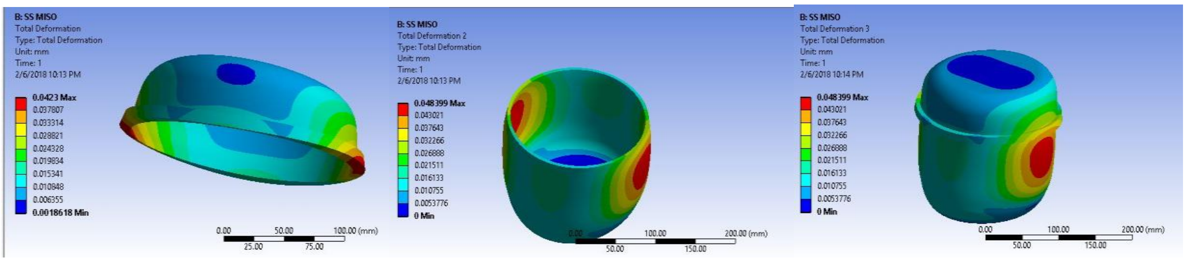

Fig 4.4. Deformation of compressor components (Stainless Steel)

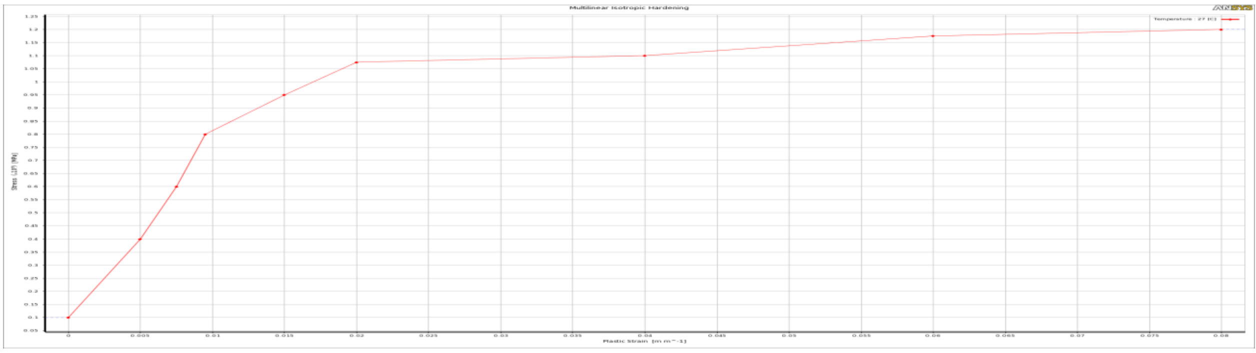

Fig 4.5. Stress vs Plastic strain curve of composite material

Components	Housing Top	Housing Bottom	Compressor Housing	S.I. Unit
Deformation (Cast Iron)	0.078951	0.09007	0.09007	mm
Deformation(Stainless Steel)	0.0423	0.048399	0.048399	mm

Table 4.4. Comparison of deformation of both materials

Components	Housing Top	Housing Bottom	Compressor Housing	S.I. Unit
Stress(Cast Iron)	43.484	81.721	81.721	MPa
Stress(Stainless Steel)	43.548	78.874	78.874	MPa

Table 4.5. Comparison of stresses of both materials

V.CALCULATIONS

Parameters	Calculated Value	S.I. Unit
Yield Strength	37.04	MPa
Elastic Strength	0.0001852	MPa
Tensile Strength	66.66	MPa
Burst Pressure	18.75	Bar
Allowable Stress	206(S.S) 146(C.I)	MPa

Table 5.1. Calculations of compressor housing

VI. CONCLUSION

Study is made on the compressor of refrigeration system. The housing assembly is done by using CATIA V5. The shell housing is analysed in ANSYS 16. In this project, we analyse the housing of compressor of domestic refrigerator for two different material. With reference to previews compressor housing of cast iron, we analyse it for modelling & burst pressure analysis for Stainless Steel. We can say from results that the deformation in Stainless Steel in less than Cast Iron.

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