Modeling and Burst Pressure Analysis of Compressor Housing Using Different Materials

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Abstract- *The project was aimed to find alternate material for cost iron for compressor housing because of weight. 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 and strain of both materials. In this project, the modeling of compressor housing is done in detailed using modeling software. After that the FEA analysis is done for strength analysis. The stresses & deformation obtained for this compressor housing.*

Keywords- Modeling, Burst pressure, Analysis, Compressor.

I. INTRODUCTION

A compressor is a mechanical device that 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 propose of the compressor is to raise 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.

A brief history of refrigeration

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.

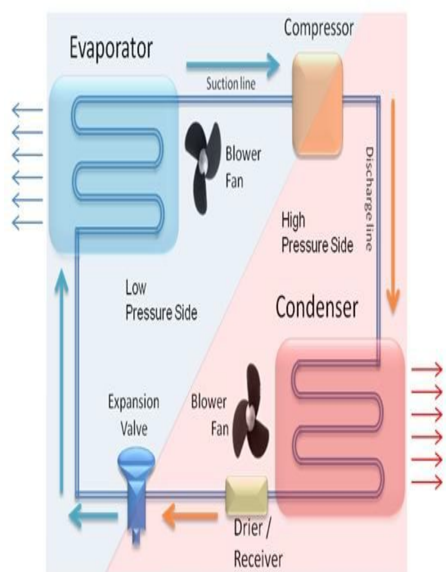

Fig 1 Basic Refrigeration Cycle

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 components

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

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

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.

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.

II. PROBLEM STATEMENT

Due to the constant increase in fuel cost and increased regulations seen in the industry, a trend has been noted in the downsizing of engines, resulting in an increase in the demand of turbochargers, better material used for components like compressor, pressure vessels, etc. to improve efficiency & reduce weight.

The purpose of this project is to analyze the material used for compressor housing that results in maximum efficiency & burst pressure readings for two different material. The compressor used for analysis is domestic refrigerator compressor.

III. LITERATURE SURVEY

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.

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.

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.

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.

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.

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.

A.Th. Diamantoudis et al.: Did a comparative study for design by formula and design by analysis for a cylinder to nozzle intersection by using finite element techniques. Materials they used in their study were ductile P355 steel alloy and high strength steel alloy P500QT. They concluded that design by analysis approach leads to much conservative design parameters.

IV. PROPOSED METHODOLOGY:

(a)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 modelled 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 pre-processing stage. Mainly the domain of interest in this simulation. In this section, the design with solid modelling of 4 different types compressor housing is explained which comprises.

(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. The geometry of the compressor is modelled 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 pre-processing stage.

(c)Material and method

Material for the vessel was 20R (1020) which has defined yield of 285 MPa and ultimate limit of 400 MPa with strain at rupture of 28% is considered for analysis. Ramberg—Osgood equation is used to describe the non-linear relationship between stress and strain. It is especially useful for metals that harden with plastic deformation. Original form of Ramberg—Osgood equation can be written

$$\varepsilon = \frac{\sigma}{E} + 0.002\left(\frac{\sigma}{\sigma y}\right)^n$$

where ε and are total strain and stress respectively is Young's Modulus of the material. Estimation of parameter n is proposed to simplify the definition of material. Although there were numerous approached to estimate this parameter, the following equation is widely accepted.

$$n = \frac{\ln\left(\frac{e_{us}}{0.002}\right)}{ln\left(\frac{\sigma_U}{\sigma_Y}\right)}$$

Whereas is uniform strain at max load, i.e. at U. Y are U yield stress and ultimate stress of material respectively.

V. CONCLUSION:

The following conclusions were drawn from the above investigation:

Study is made on the compressor of refrigeration system. The housing assembly is done by using CATIA V5. The solid, 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, we analyse it for modelling & burst pressure analysis for stainless steel.

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