International Journal of Research In Science & Engineering e-ISSN: 2394-8299
Volume: 3 Issue:1 January 2017 p-ISSN: 2394-8280

A Review on Failure Factors and Analysis of Pressure Vessel

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ABSTRACT

Pressure vessels have wide applications in thermal and nuclear power plants, in pharmaceutical industries, chemical industries and beverages and food industries, etc. The failure of pressure vessels may effect in health hazards, loss of life and damage of property.

This paper elaborates different type of failures and techniques to overcome these failures. The most important and advantageous technique is to sturdy design and analysis of pressure vessels. This papers promotes to examine different factors that are responsible for failures like fatigue life, temperature transits, forced vibrations, cyclic loading, restriction in compression and expansion, design, proper material selection, parametric analysis, etc.

Keywords*: Pressure Vessel, Failure Factors, Analysis, Pressure vessel code, etc.*

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1. INTRODUCTION

A pressure vessel is defined as a container with pressure differential between inside and outside, except for some isolated situations. Pressure vessels often have a combination of high pressures together with high temperatures, and in some cases flammable fluids or highly radioactive materials. Because of such hazardous it is imperative that the design be such that there is a no leakage can occur. With increase in demands from industrial process for higher operating pressures and higher temperature, new technologies have been developed to handle the present day specialized requirements. The material of a pressure vessel may be brittle such as cast iron, or ductile such as mild steel. Various parameters of pressure vessel are designed and checked according to the principles specified in American Society of Mechanical Engineers (A.S.M.E.) Sec. VIII and according to IBR.[1-6] Pressure vessel are designed according to ASME standards For safety purpose. The life of pressure vessel under cyclic service is related to the intensity of number of cycles. The fatigue life curves used under ASME VIII division -2 to calculate the permitted life of pressure vessel are based on a large factor of safety compared with actual cycle life curves. [7]

2. LITERATURE REVIEW

The findings various researchers in the design and analysis of pressure vessel is presented here.

The fatigue analysis of a reactor pressure vessel of System-Integrated Modular Advanced Reactor (SMART) during arbitrary transients had performed. A transient thermal analysis is performed using heat transfer coefficient based on operating environment and the results are applied to a finite element model along with the pressure to calculate he stress. The total stress intensity range and cumulative fatigue usage factor are investigated to determine the adequacy of design. In this study an analysis procedure for fatigue analysis is suggested that includes thermal and stress analysis. The reactor pressure vessel of SMART is made up of ASME SA- 508 Grade 3, Class 1. He observed that the major contribution to the fatigue usage factor is temperature variations during transients. In addition to this there is no effect of pressure loading on the fatigue factor arises inside of the vessel and the stress concentration factor is one of the most important factors affecting the fatigue usage factor. [8]

The analysis of horizontal Reactor Pressure Vessel supported on saddles using finite element analysis had been done. The pressure vessel is designed according to the rules of the ASME Code, Section VIII, Division 1 and Division 2, and analyzed according to the guidelines given in Div. 1 and Div. 2. The finite element analysis for different configurations of pressure vessel on saddle supports is done using ANSYS. The stress intensities in various cases are analyzed with considering stiffening effect. The stress distribution on various locations of saddle and vessel attachments is observed to select the optimal distance of saddle and stiffening. The operating case was considered at elevated temperature (3440) simulates the behavior of the vessel at operating condition. He concluded that the location of saddle at distance which is less than the one fourth of the vessel length with adjacent stiffener rings is the most effective one. For this configuration the optimization of thickness is done. The weight of the vessel is reduced considerably by keeping the volume of the vessel constant. 22% weight reduction is achieved for the shell alone. This shows that addition of stiffener rings helps to reduce the thickness of the shell which in turns helps in saving lot of material and cost associated with it. [9]

Finite element analysis of stresses developed in solid pressure vessels and multilayer pressure vessel had been carried out using ANSYS. Various parameters of solid pressure vessel and multilayer pressure vessel are designed and checked according to the principles specified in ASME Sec VIII Division 1. He concluded that ANSYS analysis is suitable for multilayer pressure vessels because the calculated values by using different formulas are very close to that of the values obtained from ANSYS. It is also concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions over mono block pressure vessels. [10-12]

The investigated LCF behavior can provide reference for pressure vessel life assessment and fracture mechanisms analysis .In this current work, the strain controlled low cycle fatigue behavior of the 20MnMoNi55 reactor pressure vessel steel at room temperature is presented. Irrespective of applied loading condition, the 20MnMoNi55 steel shows cyclic softening characteristic, i.e. decrease in stress amplitude with number of cycles for strain controlled low cycle fatigue. The cyclic stress–strain response and the low cycle fatigue (LCF) behavior of 20MnMoNi55 pressure vessel steel were studied. Analysis of stabilized hysteresis loops at various strain amplitudes showed that the material exhibited a non-Masing behavior. Furthermore, analysis of stabilized hysteresis loops showed that the steel exhibits non-Masing behavior. Decrease in the linear portion of the hysteresis loop (cyclic yield stress) is responsible for cyclic softening of steel. [13]

A life prediction method for the CFRP composite hydrogen storage vessel under cyclic fatigue loading and high temperature conditions was proposed based on the integration of micromechanics of failure (MMF) and time-temperature superposition principle (TTSP) method. Finally, a life prediction procedure using the constituent master curves is described and applied in the MATLAB software to predict the long-term fatigue life of the composite vessel. Then, the fatigue tests of unidirectional CFRP laminates were performed at various temperatures, and the matrix fatigue master curves were constructed accordingly by using the micro mechanical calculation and time-temperature shift factors. The predicted fatigue life of the CFRP composite vessel correlates well with the experiment results, which demonstrates the validity of the proposed MMF based fatigue life prediction strategy. The time-temperature effect of the viscoelastic material is considered by the stiffness and fatigue master curves of the matrix, and the cyclic effect is handled by parameters such as the loading frequency and stress ratio. This paper proposes a micromechanics-based procedure to predict long-term life of the cylindrical laminates under cyclic fatigue loading and high temperature conditions. Then, the MMF is used to calculate the constituent strength from ply strength at various temperatures, and the matrix fatigue master curves are constructed accordingly by using TTSP. A simplified elastic solution is first presented to analyze the stress of cylindrical laminates subjected to internal pressure based on the classical laminate theory. As a first step, the elastic solution of the cylindrical laminates subjected to internal pressure is obtained based on the classical laminate theory. [14]

Fatigue life of stationary hydrogen storage vessel constructed of the practical materials of low alloy steels was analyzed based on fracture mechanics in hydrogen and air of 45, 85 and 105 MPa using cylindrical model with inside diameter of 150, 250 and 350 mm. The design fatigue life data of the model materials under the conditions of Di, pressure, ultimate tensile strength, KIH, fatigue crack growth rate and regulations in both hydrogen and air were proposed quantitatively for materials selection and development for stationary hydrogen storage vessel. [15]

The study of structural integrity of a type III hydrogen pressure vessel under impact loading by using finite element analysis, with a user subroutine for determining the material failure in each failure mode had proposed. The fibers, which play a major part in load transfer, remained intact, the pressure vessel can be used even after the impact, but repetitive pressurization may cause crack propagation inducing fatigue failure of the composite layers. The impact loading condition including the auto frettage pressure and service pressure was successfully imposed on the finite element model of the pressure vessel. [16]

The paper discusses the issue of the modelling of strains and stresses resulting from heating and cooling processes of the components in power plants. It is readily apparent from the stress versus time graphs that under unsteady operating conditions, components analyzed in the paper, especially in the case of boiler restarts, may operate with transient thermal stresses which sometimes reach values higher than a yield point. One of the main conclusions from the research concerns the necessity of using the time-dependent heat transfer coefficients in problems of heat transfer modelling. Only in such a case can we obtain a correspondence between the temperature measurements and modelling. The local temperature measurement offers the possibility of validation of the models, and should be used together with the modelling for the assessment of actual damage conditions. This might suggest that more intensive damage could be accumulated near point A compared with point B. This is in agreement with the observations of the processes of internal surface cracking during the operation of the components. In such circumstances a more destructive process could take place not as a result of the hoop stresses near point B, but as a result of axial stresses near point A. This phenomenon is quite unexpected when the mechanical loading character is taken into consideration. [17]

A detailed thermo-mechanical stress analysis for reactor pressure vessel of Tarapur Atomic Power station-1 and 2 had done. A complete evaluation of temperature and resulting stress distribution across the vessel wall thickness, in a non-steady state is obtained using a numerical model. In this model the temperature of the inside surface is considered to change according to various transient, viz., reactor startup, shutdown and emergency condition. He concluded that the most stressed location in RPV wall is clad-vessel interface and the governing transient is emergency shutdown condition. The results have been used for structural integrity assessment of reactor pressure vessel. He also studied for re-circulation nozzle for its structural integrity assessment to preclude the possibilities of crack initiation or propogation. For this he used finite element analysis and validated with analytical solutions. The analysis reveals that the flaw that governs the operability is the axial flaw during shutdown condition. [18]

The new Part will cover methods used to estimate the time to crack initiation using a strain-life approach and will be written as a multi-tiered approach covering screening, current design code methods, and advanced methods that take into account the latest in technology. The advanced methods will include next generation versions for the fatigue assessment of welded joints, the Master S-N Curve Method as described in WRC 523, and the Verity Fatigue Assessment Method developed by Battelle. The advanced methods will also include a new smooth-bar fatigue assessment method that incorporates a multi-axial fatigue criterion with a critical plane approach. Part 14 covering the strain-life approach to fatigue is a new part in the third edition of API 579-1/ASME FFS-1.The four methods described that utilize strain-life techniques based on smooth bar and welded joint fatigue curves will be included in Part 14.These methods include the legacy ASME techniques that have been updated to include more modern cycle counting methods and a new critical plane approach based on the Brown-Miller strain-life equation, a rain flow cycle counting method with multiple channels, and an incremental multi axial Neuber plasticity correction using the nonlinear kinematic-hardening model of Chaboche. [19]

The behavior of weld defects in pressure equipment was investigated. They focus specially on the lack of penetration in longitudinal welds of small cylindrical vessels subjected to stress cycle on a pressure vessel during its life. For this they used the technique of Acoustic emission (AE) monitoring. During first stage –no accurate emission localizes in lack of penetration defect. This is the stage of stress concentration and deformation of shell around defective weld. During second stage – acoustic signals appear. Located initially at center of defects and then to the ends. This stage indicates propagation of damage has reached this area and next step is failure of structure. During third stage – high amplitude and energy of signals recorded and located in center of defect of lack of penetration – due to remaining failure. AE has shown that vessel failure is caused by change in lack of penetration defects instead of cracks at the ends. The letter affects only the distribution of stresses around the defects. [20]

The failure behavior of pressure vessels during high pressure of hydraulic loading has been experimentally investigated. He studied pressure vessel manufactured by two different procedures i.e. spin forming and tungsten gas welding process and other is blow forming and solid-state diffusion bonding process. He studied titanium tanks manufactured by two different methods. The attitude control tanks were spin formed and TIG welded, while the valve driving tank was diffusion bonded and blow formed. These tanks were hydraulically loaded and deformation behavior and AE signals were analyzed. He analyzed the effect of forming method. The result shows that the pressurization rate and the acoustic emission signal increasing rate provide a similar tendency for a vessel of integrity, while the signal increasing rate is much higher than the pressurization rate for a vessel with defects. It is clear that the acoustic emission response of the vessel to the pressure loading can be successfully applied to predict the structural integrity and failure behavior of the vessels manufactured with both methods. [21]

3. CONCLUSION

Pressure vessel related to accidents might never be fully eliminated; however, we can work towards reducing the risk and likelihood of accidents occurring. For this purpose, the use of standards and code specified by many countries may be used. Such as ASME BPV Code, IBR, etc. are widely used for designing of pressure vessel. Also FEA is a great tool to shows it's important for analysis of pressure vessel.

From the immense literature review it has been observed that fatigue contributes to approximately 90% of all mechanical service failures. So the fatigue analysis of pressure vessel is very important which reduces the risk of failures.

REFERENCES

[1] Mayer H.,Stark H.L., Ambrose S., '' Review of fatigue Design Procedure for Pressure Vessels'', International Journal of Pressure Vessel and Piping ,77,2000, pp. 775-781

[2] Kulkarni Aniket A., Jatkar Keshav H., ''A review on optimization of Finite Element Modelling for Structural Analysis of Pressure Vessel'', International Journal of Engineering Trends and Technology, Vol. 12, Number 1,Jun 2014, pp. 20-22

[3] Gupta Shyam R, Vora Chetan P. , ''A review Paper on Pressure Vessel Design and Analysis'', International Journal of Engineering Research And Technology, Vol. 3, Issue 3, March 2014, pp.295-300

[4] Panchigar Chirag H.,Parekh Vijay, '' A Review on Design and Analysis of Pressure Vessel'', Afro-Asian International Conference on Science ,Engineering and Technology,2015, pp. 19-21

[5] Dubal Sumit V.,Gajjal S.Y., Patil V.G., ''Review on stresses in Cylindrical Pressure Vessel and its Design as per ASME Code'' International Journal of Engineering Trends and Technology, Vol. 11, Number 6, May 2014, pp. 300-305

[6] Umbarkar Bhagyashri B., Mishra Hredeya, '' A review on Design and Analysis of Pressure Vessel'' ,IJARIIE, Vol 1,Issue 5, 2015, pp. 348-353

[7] D. Sunil Kumar, B. Suhas, ''Design and Evaluation of Pressure Vessel as per ASME Section VIII Division 2,Vol.5, Issue 10,Octomber2016,pp. 17989-18002

[8] Jhung Myung Jo, '' Fatigue Analysis of Reactor Pressure Vessel for SMART'' Nuclear Engineering and Technology, Vol.44, No.06, August 2012, pp. 683-688

[9] M. Adithya, PatnaikM. M. M., ''Finite Element Analysis of Horizontal Reactor Pressure Vessel Supported on Saddles'' International Journal of Innovative Research in Science, Engineering and Technology ,Vol. 2, Issue 7, July 2013 pp. 3213-3220

[10] Praneeth Bandarupalli, Rao T.B.S., ''Finite Element Analysis of Pressure Vessel and Piping Design'', International Journal of Engineering Trends and Technology,Volume3,Issue5- 2012, pp. 567-570

[11] Raparla Siva Krishna, Seshaiah T., ''Design and analysis of Multilayer High Pressure Vessel s'', International Journal of Engineering Research and Applications, Vol. 2, Issue 1, Jan-Feb 2012, pp. 355-361

[12] Palekar Ameya, Kompelli Prasad , '' Study and Design of Shell of Multi Wall Pressure Vessel'' , International Journal of Technical Research and Applications ,Vol. 4,Issue 3, May-June,2016, pp. 436-443

[13] Sarkar Apu, '' Low cycle fatigue behavior of a ferritic reactor pressure vessel steel '', Journal of Nuclear Materials, 462, 2015, pp. 273-279

[14] Wang Liang, '' Prediction of Long-term fatigue life of CFRP composite hydrogen storage vessel based on micromechanics of failure, Composites Part B 97,2016,pp. 274-281

[15] Zhou Chilou ,Li Zhiyuan, ''Effect of Inside Diameter on design fatigue of stationary hydrogen Vessel based on Fracture mechanics'' International Journal of Hydrogen Energy XXX,2014, pp. 1-9

[16] Han Min-Gu, '' Failure analysis of a Type III hydrogen Pressure Vessel under impact loading induced by free fall'', Composite Structures, 127,2015, pp. 288-297

[17] Okrajni Jerzy, '' Description of the Thermo-Mechanical fatigue of thick-walled pressure vessels'', 20th European Conference on Fracture (ECF20), Procedia Materials Science ,3,2014, pp. 918-923

[18] Chaudhry V. ,''Thermo-Mechanical Transient Analysis of Reactor Pressure Vessel'',1st International Conference on Structural Integrity,ICONS-2014, Procedia Engineering , 86,2014, pp. 809-817

[19] Osage David A. , '' Fatigue Assessment for In-Service Components- A New Part for API 579-1/ASME FFS-1 Fitness-For-Service'' 6th Fatigue Design Conference,Fatigue Design,2015, Procedia Engineering 133(2015), pp. 320-347

[20] Laksimi A. , '' AE of Damage Evolution in Pressure Vessel under Cyclic Loading'', 30th European Conference on Acoustic Emission Testing & 7th International Conference on Acoustic Emission University of Granada, September 2012

[21] Lee Ho-Sung, '' A Study on Failure Characteristic of Spherical Pressure Vessel'', Journal of Materials Processing Technology 164-165,2005,pp. 882-888