A Review on Skirt to Dished end Joint of Pressure Vessel

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Abstract— In pressure vessel at the junction of skirt to head (Dished end) are subjected to a combination of thermal stress and structural stress. Due to excessive temperature gradient at junction in hot operating cases can cause unpredicted high thermal stresses and high pressure cause high structural stresses which makes design of vessel critical. Then fracture of the vessel may occur as a result of cyclic operation. So motive of this paper is to reviewing different research paper on skirt to head joint and finding different causes and parameter of crack generation.

Key words: Pressure Vessel, Coke Drum, FEA, Stress, Hot Box

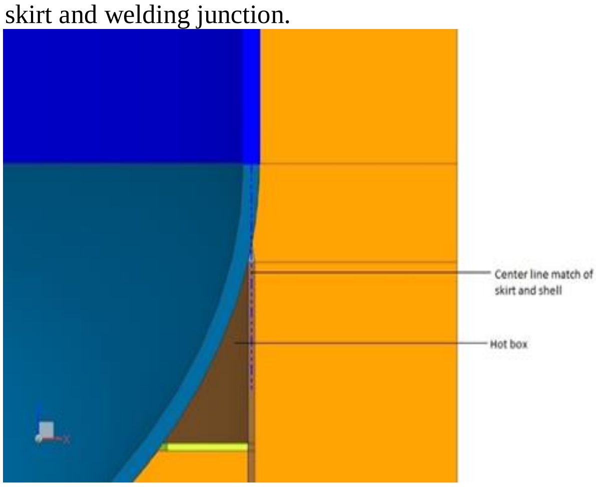
I. Introduction

Pressure vessel is a closed cylindrical vessel for storing gaseous, liquids or solid products. The stored medium is at a particular pressure and temperature. The cylindrical vessel is closed at both ends by means of dished end, which may be hemispherical, ellipsoidal and torispherical. The pressure vessels may be horizontal or vertical [1].

One of the most common methods of supporting vertical pressure vessels is by means of a rolled cylindrical or conical shell called a skirt. The skirt can be either lap, fillet, or butt welded directly to the head or shell. This method of support is attractive from the designer's standpoint because it minimizes the local stresses at the point of attachment, and the direct load is uniformly distributed over the entire circumference [2].

The critical line in the skirt support is the weld attaching the vessel to the skirt. This weld, in addition to transmitting the overall weight and overturning moments, must also resist the thermal and bending stresses due to the temperature drop in the skirt.

There are various methods of attaching skirt to the shell, center line of the shell and skirt and OD to OD coincide of skirt to shell as shown in fig. 1. There is a small air gap between the skirt to shell or skirt to head junction which named as hot box. It is used to keep low temperature gradient at skirt and welding junction.



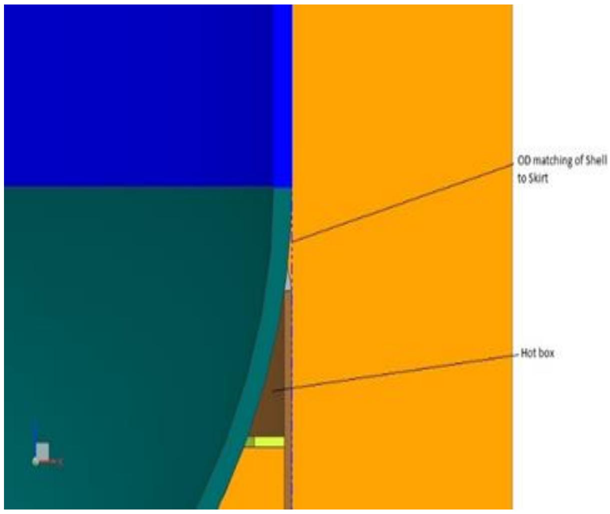


Fig. 1: Different attachment of skirt to shell with hot box.

II. Literature review

The authors had determined the factor of the performance of welded shirt supports for vertical process vessels. The importance of thermal effects is emphasized. A comprehensive analysis of local stresses with closed-form solutions is presented, permitting assessment of expected performance in service on a fatigue basis. The expected shape of skirt distortion is briefly mentioned. Suggestions and recommendations are made for design practice, control of thermal stresses, weld and fabrication detail for optimum practical quality, as dictated by service conditions. And also present numerical example to illustrate the application of the analysis. N.A.Weil et. al [3]

Coke Drums are critical equipment in refineries due to variable temperature and pressure. This paper provides discussions on the modeling, analysis, and monitoring of hot box designs. Hot box is critical part of vessel designs in catalytic crackers and delayed coke drums. In coke drum cycles, the sudden heating of the vessel generates significant bending stresses in the skirt, and radiation heat transfer causes a greater area of skirt to be heated when compared to conduction alone. This heat must be removed during the cooling transient or the hot expanded skirt will be pulled by the contracting vessel, resulting in large bending stresses. It is the experiences of the authors that failures to calculate the transient temperatures in the components often underestimate fatigue stresses. Some of the important elements associated with modeling thermal stresses in hot boxes include using appropriate boundary conditions, radiation and convection conditions, pressure end loads, and conductivities for the insulation materials. This paper emphasizes the importance of performing detailed sensitivity analyses when unknown thermal or mechanical loading conditions exist and discusses the importance of making field measurements to enhance modeling assumptions. Chris Alexander et. al [4]

Fatigue analysis is performed for a full-penetration weld joint, welded from both sides, connecting a cylindrical vessel to a flat head. It is subjected to a repeated transient cycle of ambient temperature inside the vessel. No pressure is cycled. Finite element heat transfer and elastic stress analyses are performed, and stress ranges are calculated. The allowable number of cycles for cyclic service is obtained by two structural stress methods. One is a method proposed for the ASME Boiler and Pressure Vessel code and the other is in the European Standard for unfired pressure vessels. It is found that for the same geometry and loading the former would permit 136,000 or 36,000 cycles while the latter would permit 8,000 cycles. The results of this paper indicate a discrepancy between the number of cycles permitted for a specific weld joint by the European Standard EN 13445 and the structural stress method of Dong and Hong that has been proposed for the ASME B&PV Code, Section VIII. Arturs Kalnins [5]

This paper describes the considerations employed in the finite element analysis of a relatively short support skirt on a hydrocarbon reactor vessel. The analysis is accomplished in accordance with ASME Section VIII alternate rules in conjunction with the guidelines outlined in WRC Bulletin 429. This provides a sound basis for the classification of the calculated stress intensities. The support skirt is capable of sustaining the deadweight load, wind loads, overturning moments from external piping loads, and friction between the skirt base plate and concrete foundation. The skirt design also employs a hot-box arrangement whereby the primary mode of heat transfer is by radiation. A discussion of the two-part analysis is included and details the interaction between the heat transfer analysis and the subsequent structural analysis. The heat transfer finite element analysis is utilized to determine the temperatures throughout the bottom of the vessel shell and head, as well as the integrally attached support skirt. Of prime importance during the analysis is the axial thermal gradient present in the skirt from the base plate up to and slightly beyond the skirt-to-shell junction. While the geometry of the subject vessel and skirt is best described as axisymmetric, the imposed loadings are a mixture of axisymmetric and non-axisymmetric. This combination lends itself to the judicious selection and utilization of the harmonic finite element and properly chosen Fourier series representation of the applied loads. Comparison of the thermally induced axial stress gradient results from the FEA to those obtained by the closed form beam-on-elastic-foundation are also tendered. Dennis K. Williams et. al [6]

Welds play an important role in the life of these vessels. Cracking and bulging occurrences in the coke drums, most often at the weld areas. Thermo-mechanical fatigue is the most common cause for cracking in coke drums. With use of number of models and methods for estimating the thermo-mechanical fatigue life of engineering components subjected to thermal and mechanical loads can be determined. In this work, focus is placed on comparing some of the commonly used methods including API 579 methods, Creep-fatigue crack initiation using R5 Volume 2/3 and Non-linear isothermal fatigue analysis using maximum shear strain amplitude with Morrow mean stress correction. In this study, a Finite Element (FEA) model is used to estimate the cyclic stresses and strains for the skirt-to-bottom head attachment weld. The model includes details of the geometry, material properties, boundary conditions, and loads. The results of this work indicate that the predictions of the number of cycles to crack initiation are not significantly different between various crack initiation methods, but they are significantly different when compared with the structural stress method. Thus, the thermo mechanical fatigue algorithm selection should be based on the assessment goals and service conditions. The parametric analysis showed that the life of the drum is strongly influenced by the switch temperature and quench rates with lower switch temperatures and faster quench rates negatively impacting the life of the drum. Jorge A. Penso et.al [7]

The author describes a comparison of fatigue strength of three metals base metal, weld metal and heat affected zone provided by the low cycle fatigue test for SA-387 Gr.11 materials. A skirt to shell attachment of a coke drum experience severe thermal cyclic stresses, which cause failures due to low cycle fatigue. The attachment of skirt by a weld build-up is most commonly used. Due to the integral skirt attachment with a large inner radius allows reducing stress concentration compared with the weld build-up design. This advantage can be confirmed easily by FEA. The fatigue design curve from ASME Section VIII is based on fatigue tests for the base metal. Accordingly, the integral skirt attachment is more resistant to cracking than its welded counterpart from a fatigue strength viewpoint. And concluded that the base metal has the greatest fatigue strength among these metals. Its fatigue strength is twice as long as the weld metal and three times as long as HAZ which means the integral design has three times as long fatigue strength as the weld build-up design. Yasuhiko SASAKI et. al [8]

Because of highly fluctuating temperature causes the thermal fatigue in coke drums which plays a very crucial role in failure of coke drums. In this paper, a coke drum is subjected to pressure temperature reversal with each cycle of 48 hours duration. Temperature and pressure varies from 338 to 738 K and 0 to 0.404 MPa, respectively. The material was 1.25Cr-0.5Mo used. This coke drum is at higher temperature of 738 K for 24 hours in one full cycle. The skirt to shell and cone junction is a critical portion of coke drum because it is highly susceptible to fatigue at higher temperature. ASME Section VIII is used for the fatigue life evaluation in the present case. Nonlinear transient thermal analysis is coupled with the elastic-plastic structural analysis for calculation of stresses and strains. The effect on fatigue life has been studied with variation in inside crotch radius. It has been found that fatigue life at skirt to cone junction is increasing with increase in crotch radius. But, this increase in crotch radius is adversely effects on slot tip where the life is drastically reducing. M Sohel M Panwala et. al [9]

The major typical location of failure due to thermal fatigue in coke drums is the shell to skirt junction area. This paper focuses on temperature and stress characteristics and also the thermal fatigue life of the junction area. The main objective was to explore effect of the switching temperature on thermal fatigue life of the junction area. Four coke drums, currently in service have been considered in the analyses, named drums A, B, C, and D, identical in dimensions and with an operating cycle period of 48 h. Operational temperatures and strains have been measured and collected every minute. The number of measured cycles of coke drum A, B, C, and D were 52, 53, 53, and 54 cycles, respectively.

Thus, a total of 212 cycles have been analyzed. The operational temperatures and strains were examined. Finite Element Method (FEM) analyses have been performed on the selected cycles in order to find the most severe location in the junction area. The strain history and FEM results were used to assess thermal fatigue life. The number of cycle to fracture versus switching temperature for the coke drums was then plotted. The results show that the switching temperature strongly affects the number of cycle to fracture wherein shorter injection times result in shorter thermal fatigue lives. These results can be used to provide the necessary information to operate coke drums safely in order to extend their useful lives. Masaaki Oka et. al [10]

In pressure vessel due to high pressure and temperature loading there is possibility to generation of cracks/failure at skirt dished end joint. Vessel is design as per ASME standard and analyzed by finite element method (FEM). After analyzing with different case studies it should be concluded that skirt to dished end joint is part of pressure vessel in which maximum cracks are developed. The analysis for skirt to dished end joint of pressure vessel is by FEM which can give information to reduce the stresses by considering different parameter. It also that decreased by changing the weld size of the skirt to dished end joint. This can increase the life of pressure vessel. Kiran Parmar et. al [11]

Skirt to dished end junction in vertical pressure vessel is one of such critical junction which is often subjected to different loads. These loadings include internal pressure inside vessel, wind & seismic shear force and moments, operating weight of vessel& thermal stresses in the welds near the junction. This paper re-presents guidelines in structural analysis for skirt to dished end junction. Analysis is carried out in compliance with ASME Section VIII. After analyzing it is known that various stresses encountered in the skirt to dished junction which makes its design critical. It can be concluded that stress and other parameters are also decreased by changing weld size of skirt to dished end junction. Sagar P. Tiwatane et. al [12]

In pressure vessels excessive temperature gradient near the junction of skirt to head in hot operating cases, can cause unpredicted high thermal stresses. Then fracture of the vessel may occur as a result of cyclic operation. This paper demonstrated the profit of hot box over vessel without hot box according to Simulation. Providing an air pocket (hot box) in crotch space is an economical, applicable and easy mounting method in order to reduce the intensity of thermal stresses, due to which, radiation due to temperature difference between the wall of pocket, will absorb heat near the hot wall and release it near the cold wall then the skirt wall conducts heat to the earth as a fin. It has been seen that radiation has important effect on heat transfer in this triangular cavity and thereby heat conduction in skirt is the most important parameter to keep convection in steady state condition. The analysis is accomplished in accordance with ASME section VIII. This provides sound basis for classification of calculated stress intensities. By providing small air pocket at the shell and skirt junction the temperature stress and overall stress concentration can reduce considerable. The reduction in peak stress is almost around 30% as compared to without hot box. The alternative stress becomes lower and hence fatigue life of the component is increases. Sagar M. Sawant et. al [13]

The skirt support structure of hydrogenation reactor works in the conditions of high temperature and high pressure. There is not only high mechanical stress but also high temperature difference stress in this zone. In this paper, temperature field analysis and structural analysis on the local structure of skirt hot box is carried out as shown in fig. 2 and 3. The stress classification method and direct route method are used to calculate the skirt support structure of hydrogenation reactor. The calculation results are compared. Results of these two analysis and design methods are both meet with the requirements of relevant standards. Stress classification method is an engineering approximation. The analysis is simple, mature, low computation cost. But there are some difficulties in correct stress classification. The direct route method avoids the problems caused by stress classification, the results are more reasonable. But the analysis method is more complex and high requirements for designers. It is suitable for complex and important pressure equipment. The direct route method is more advanced after a reasonable comparison. It represents the future trends of pressure vessel analysis and design methods. Jianhua PAN et. al [14].

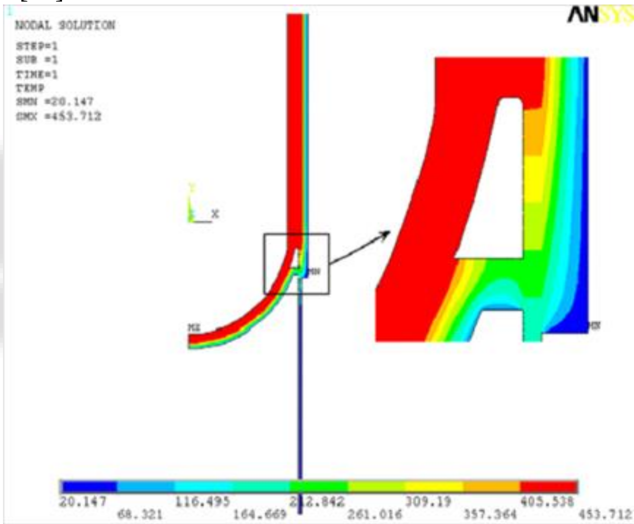


Fig. 2: Results of steady state temperature [14].

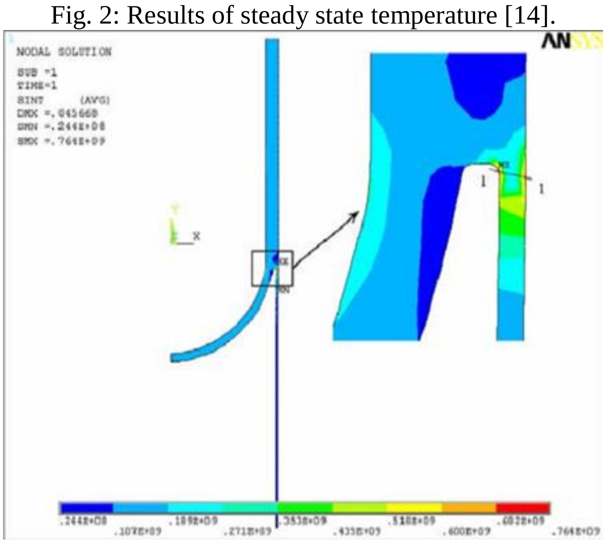


Fig. 3: Results of steady state structural stress [14].

Since thermal cycling is most severe near the bottom of the coke drum, where temperatures can reach up to very high, the skirt and other attachment welds are just as prone to cracking and premature structural failure as the vessel wall. The purpose of author is to determine a hot box junction geometry which will minimize thermal gradient stresses and improve fatigue life. The process flow of coke drum along with the temperature gradient due to coking process and the effect of thermal stresses on the skirt shell junction. In this work comparative analysis of hot box is done by analytical and FEA. Finite element analysis is used to evaluate the thermal and stress profiles for the cold and hot conditions. Study demonstrates that by modifying the dimensions of the hot box such as length, will affects the fatigue life of coke drum. This appears to be due to the longer hot-box length, which results in a more gradual thermal gradient and also moves the gradient lower on the skirt away from the welded connection. It is observed that by modifying the dimensions of the hot box, alternating equivalent stresses decreases. Reducing the length by 190mm minimizes 28% of fatigue life. From the detail fatigue analysis, it is observed that hot box length is one of the most important factor which affects the life of coke drum. Nirmal Pravin Chandra et. al [15]

III. CONCLUSION

After reviewing above papers it can be concluded that due cyclic pressure loading and high temperature leads to cracking at the skirt to dished end joint and on skirt also. There are not any specific equation is available for determination of stress and temperature at the junction so evaluation is done by FEA and with use of stress linearization method only.

By varying welding radius at junction leads to stress reduction. With the provision of hot box at junction result in to less stress generation and higher fatigue life of vessel or coke drum. Length of the hot box is the critical parameter for hot box design and it is to be found out by Thermo structural FEA.

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