A Review on Butane Separator Analysis

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Abstract
Methyl Ethyl Ketone (MEK) is a solvent that used in paint coatings and is, for instance, used widely in the auto industry. MEK is obtained from Butane. Butane traditionally was a waste product used in crude oil supply. Crude oil is too heavy to flow down pipelines, so Butane is injected in the pipeline to facilitate flow by making it lighter.
Traditionally, there has been no way to recapture the Butane, and was considered a cost of pushing crude oil through pipelines. With the Gas Recapture Systems process, the Butane can now be recaptured, and used again. A typical $1-3 million dollar monthly budget of Butane cost, can now recover 75% savings using, Gas Recapture Systems. This recaptured Butane can thus be utilized in producing MEK. This will be useful in preventing damage to environment. This process is termed as "Gas Recapture Process". This process of separation is unique, as this separation occurs at extremely low temperatures.
This paper presents and focuses on some Finite Element (FE) analysis of Butane separator (Pressure Vessel).

Keywords
Pressure Vessel Design, Nozzles, Stress Analysis.

This paper depicts attempt towards research work carried out in the area of static and dynamic analysis of pressure vessel. It is found that an evolutionary work/research has been done and keeps on expanding in this topic. A quite good amount of research work is found available on various areas of separator vessel analysis and optimization.

L. P. Zick et al. (1951) [1], published a paper in 1951 "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports". The purpose of this paper is to indicate the approximate stresses that exist in cylindrical vessels supported on two saddles at various locations. Knowing these stresses, it is possible to determine which vessels may be designed for internal pressure alone, and to design structurally adequate and economical stiffening for the vessels which require it. Formulas are developed to cover various conditions, and a chart is given which covers support designs for pressure vessels made of mild steel for storage of liquid weighing 42 lb.per cu. ft. In this paper an attempt has been made to produce an approximate analysis involving certain empirical assumptions which make the theoretical analysis closely approximate the test results.

In a paper1 published in 1933 Herman Schorer pointed out that a length of cylindrical shell supported by tangential end shears varying, proportionately to the sine of the central angle measured from the top of the vessel can support its own metal weight and the full contained liquid weight without circumferential bending moments in the shell. To complete this analysis, rings around the entire circumference are required at the supporting points to transfer these shears to the foundation without distorting the cylindrical shell.

Discussions of Schorer's paper by H.C. Boardman and others gave approximate solutions for the half full condition. When a ring of uniform cross section is supported on two vertical posts, the full condition governs the design of the ring if the central angle between the post intersections with the ring is less than 126°, and the half-full condition governs if this angle is more than 126°. However, the full condition governs the design of rings supported directly in or adjacent to saddles.

Mr. Boardman's discussion also pointed out that the heads may substitute for the rings provided the supports are near the heads. His unpublished paper has been used successfully since 1941 for vessels supported on saddles near the heads. His method of analysis covering supports near the heads is included in this paper in a slightly modified form.

Discussions of Mr. Schorer's paper also gave successful and semi-successful examples of unstiffened cylindrical shells supported on saddles, but an analysis is lacking. The semi-successful examples indicated that the shells had actually slumped down over the horns of the saddles while being filled with liquid, but had rounded up again when internal pressure was applied.

A. S. Tooth et al. (1989) [2], has presented the analytical approach for "The Thermal Behavior of Thin Cylindrical Shells. (Elastic Thermal Stress Analysis)". The double Fourier series thermal stress solution is presented. This is based on Sanders's linear shell theory with additional thermal loading terms. These arise due to a mid-surface temperature distribution and due to the temperature difference between the inside and outside surfaces. The thermal loading is represented by double Fourier coefficients which are determined by harmonic analysis from the temperature distributions obtained from heat transfer models, numerical techniques or measurement. The examples investigated are those analyzed in Part I (Int. d. Mech. Sci. 31,693-706, 1989) of this paper, namely, a circular hot spot in a high-temperature cylindrical reactor vessel and the solar heating of a horizontal storage vessel. The stress solutions obtained in these cases are compared with finite element results. The method is quick and easily programmable and, as an integrated package, is particularly suitable for evaluating the effect on the stress levels of possible heat transfer conditions.

You-Hong Liu et al. (2004) [3], has observed "Limit Pressure and Design Criterion of Cylindrical Pressure Vessels with Nozzles". Limit pressures and corresponding maximum local embrane Stress Concentration Factors (SCF) are assessed for two orthogonally intersecting thin-walled cylindrical shells subjected to internal pressure. The plastic collapse pressures obtained by 3D FEM are in good agreement with test results presented by previous authors. The local membrane SCF at the intersections of two cylindrical shells subjected to the limit pressure load is calculated by elastic thin shell theoretical solutions presented by Xue and Hwang.

Donald Mackenzie et al. (2008) [4], has proposed "Design by analysis of Ductile Failure and Buckling in Torispherical Pressure Vessel Heads". Thin shell Torispherical pressure vessel heads are known to exhibit complex elastic–plastic deformation and buckling behaviour under static pressure. In pressure vessel Design by Analysis, the designer is required to assess both of these behaviour modes when specifying the allowable static load. The EN and ASME boiler and pressure vessel codes permit the use of inelastic analysis in design by analysis, known as the direct route in the EN Code. In this paper, plastic collapse or gross plastic deformation loads are evaluated for two sample Torispherical heads by 2D and 3D FEA based on an elastic-perfectly plastic material model. Small

and large deformation effects are considered in the 2D analyses and the effect of geometry and load perturbations are
Considered in the 3D analysis. The plastic load is determined by applying the ASME twice elastic slope criterion of plastic collapse and an alternative plastic criterion, the Plastic Work Curvature criterion. The formation of the gross plastic deformation mechanism in the models is considered in relation to the elastic–plastic buckling response of the vessels. It is concluded that in both cases, design is limited by formation of an ax symmetric gross plastic deformation in the knuckle of the vessels prior to formation of non-axisymmetric buckling modes.

Shafique M.A Khan et al. (2010) [5], presented "Stress distributions in a horizontal pressure vessel and the saddle supports". This paper presents analysis results of stress distributions in a horizontal pressure vessel and the saddle supports. The results are obtained from a 3D finite element analysis. A quarter of the pressure vessel is modeled with realistic details of saddle supports. In addition to presenting the stress distribution in the pressure vessel, the results provide details of stress distribution in different parts of the saddle separately, i.e. wear, web, flange and base plates. The effect of changing the load and various geometric parameters is investigated and recommendations are made for the optimal values of ratio of the distance of support from the end of the vessel to the length of the vessel and ratio of the length of the vessel to the radius of the vessel for minimum stresses both in the pressure vessel and the saddle structure. Physical reasons for favoring of a particular value of ratio of the distance of support from the end of the vessel to the length of the vessel are also outlined.

L. Xue et al. (2010) [6], has suggested "Parametric FEA Study of Burst Pressure of Cylindrical Shell Intersections". An elastic-plastic large deflection analysis method was used to determine the burst pressure and fracture location of hillside cylindrical shell intersections by use of nonlinear finite element analysis. To verify the accuracy of the finite element results, experimental burst tests were carried out by pressurizing test vessels with nozzles to burst. Based on the agreement between the numerical simulations and experimental results of Wang et al. (2009, "Burst Pressure of Pressurized Cylinders with the Hillside Nozzle," ASME J. Pressure Vessel Technol., 131(4), p. 041204), a parametric study is now carried out. Its purpose is to develop a Correlation equation by investigating the relationship between various geometric parameters (d /D, D/T, and t /T) and the burst pressure. Forty-seven configurations, which are deemed to cover most of the practical cases, are chosen to perform this study. In addition, four different materials are employed to verify that the proposed equation can be employed for different materials. The results show that the proposed equation resulting from the parametric analysis can be employed to predict the static burst pressure of cylindrical shell intersections for a wide range of geometric ratios.

J. Michael Rotter et al. (2011) [7], has observed "Buckling of Thin Cylindrical Shells under Locally Elevated Compressive Stresses". Thin cylindrical shells used in engineering applications are often susceptible to failure by elastic buckling. Most experimental and theoretical research on shell buckling relates only to simple and relatively uniform stress states, but many practical load cases involve stresses that vary significantly throughout the structure. The buckling strength of an imperfect shell under relatively uniform compressive stresses is often much lower than that under locally high stresses, so the lack of information and the need for conservatism have led standards and guides to indicate that the designer should use the buckling stress for a uniform stress state even when the peak stress is rather local. However, this concept leads to the use of much thicker walls than is necessary to resist buckling, so many knowledgeable designers use very simple ideas to produce safe but unverified designs. Unfortunately, very few scientific studies of shell buckling under locally elevated compressive stresses have ever been undertaken. The most critical case is that of the cylinder in which locally high axial compressive stresses develop extending over an area that may be comparable with the characteristic size of a buckle. This paper explores the buckling strength of an elastic cylinder in which a locally high axial membrane stress state is produced far from the boundaries (which can elevate the buckling strength further) and adjacent to a serious geometric imperfection. Care is taken to ensure that the stress state is as simple as possible, with local bending and the effects of internal pressurization eliminated. The study includes explorations of different geometries, different localizations of the loading, and different imperfection amplitudes. The results show an interesting distinction between narrower and wider zones of elevated stresses. The study is a necessary precursor to the development of a complete design rule for shell buckling strength under conditions of locally varying axial compressive stress.

Sotiria Houliara et al. (2011) [8], has presented "Buckling of Thin-Walled Long Steel Cylinders Subjected to Bending". The present paper investigates structural response and buckling of long un stiffened thin walled cylindrical steel shells, subjected to bending moments, with particular emphasis on stability design. The cylinder response is characterized by cross-sectional ovalization, followed by buckling (bifurcation instability), which occurs on the compression side of the cylinder wall. Using a nonlinear finite element technique, the bifurcation moment is calculated, the post buckling response is determined, and the imperfection sensitivity with respect to the governing buckling mode is examined. The results show that the buckling moment capacity is affected by cross-sectional ovalization. It is also shown that buckling of bent elastic long cylinders can be described quite accurately through a simple analytical model that considers the ovalized prebuckling configuration and results in very useful closed-form expressions. Using this analytical solution, the incorporation of the ovalization effects in the design of thin-walled cylinders under bending is thoroughly examined and discussed, considering the framework of the provisions of the new European Standard EN1993-1-6.

J. M. Alegre et al. (2011) [9], has presented "Stress Intensity Factor Equations for Internal Semi-Elliptical Cracks in Pressurized Cylinders". In order to calculate the fatigue life of cylinders subjected to internal pressure using the fracture mechanics approach, the stress intensity factors (SIFs) for internal semi-elliptical cracks are needed. Nowadays, the most accurate procedure for fatigue life calculation consists in starting from a postulated internal semi-elliptical crack and updating the flaw aspect ratio during the crack propagation. In this sense, assuming a semi-elliptical shape during crack propagation, SIFs both at the deepest crack point and at the surface point must be calculated in order to update the crack aspect ratio through its fatigue propagation. This continuous crack shape updating cannot be done using the conventional tabulated solutions, as those provided in the main design codes and SIF handbooks. This paper presents a number of closed-form equations, which very accurately fit the tabulated results in ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, to calculate the SIF for internal semi-elliptical cracks in cylinders subjected to internal pressure. These equations can be used to avoid the use of the tabulated solutions, and, as a consequence, an automatic numerical integration of the propagation law can be done.

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R.C. Carbonari et al. (2011) [10], has carried out "Design of pressure vessels using shape optimization: An integrated approach". Previous papers related to the optimization of pressure vessels have considered the optimization of the nozzle independently from the dished end. This approach generates problems such as thickness variation from nozzle to dished end (coupling cylindrical region) and, as a consequence, it reduces the optimality of the final result which may also be influenced by the boundary conditions. Thus, this work discusses shape optimization of axisymmetric pressure vessels considering an integrated approach in which the entire pressure vessel model is used in conjunction with a multi-objective function that aims to minimize the von-Mises mechanical stress from nozzle to head. Representative examples are examined and solutions obtained for the entire vessel considering temperature and pressure loading. It is noteworthy that different shapes from the usual ones are obtained. Even though such different shapes may not be profitable considering present manufacturing processes, they may be competitive for future manufacturing technologies, and contribute to a better understanding of the actual influence of shape in the behavior of pressure vessels.

By carrying out above literature review it is found that the vessel that is oriented vertically, there is a chance of bending. When the height of vessel is so large the above problem becomes critical. So in such cases it is necessary to carry out dynamic analysis of vessel in addition to structure analysis.

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