Design and Analysis of Oval Shape Flange for Chiller

Dinesh M. Ugle¹ and Dr. M.J. Sheikh²

¹M. Tech Research Scholar, B.D.C.E. Sevagram, India
¹dinesh_ugle2009@rediffmail.com
²Assoc. Professor, Mechanical Dept. B.D.C.E. Sevagram, India
²mjsheikh_1971@rediffmail.com

ABSTRACT

Flange joints are very common in pressure vessel and piping systems. Flanges are primarily used where a connecting or dismantling joint is needed. These joints may include joining pipe to fittings, valves, equipment, or any other integral component within the piping system. The performance of joint is characterized mainly by its strength and sealing capability. However, recommended design procedures for bolted flange joints are available in international codes and standards. In this paper, bolted flange connections are analyzed by implementing the design method of ASME Boiler and Pressure Vessel Code. The results of a parametric study of the behavior of flanges and stresses in bolts are analyzed by varying the flange thickness, bolt preload and number of bolts, at the same time maintaining other flange dimensions constant. Theoretical results obtained using ASME design approach is compared.

Keywords— Stresses, Asme Code, Flange.

1. INTRODUCTION

Chillers find applications in industries like: chemicals, pharmaceuticals, dairies, ice production, food and beverage processing and cold storages. Industrial chillers are used for controlled cooling of products, mechanisms and factory machinery. Industrial chillers are also used in the plastic industry in injection and blow molding, metal working cutting oils, welding equipment, die-casting and machine tooling. They are also used to cool high-heat specialized items such as MRI machines and lasers, and in hospitals, hotels and campuses.

Important specifications to consider when searching for industrial chillers include the total life cycle cost, the power source, chiller IP rating, chiller cooling capacity, evaporator capacity, evaporator material, evaporator type, condenser material, condenser capacity, ambient temperature, motor fan type, noise level, internal piping materials, number of compressors, type of compressor, number of fridge circuits, coolant requirements, fluid discharge temperature, and Coefficient of performance. Ammonia as a refrigerant has zero global warming potential and therefore these absorption machines, like Lithium bromide machines, are based on an eco-friendly technology.

Chiller is a device that removes heat from liquid. This liquid (Lithium Bomider) can be used in heat exchanger to cool air or equipment as per requirement. This investigation involves the use of finite element analysis (F.E.A) to predict levels of stress and deflection of a particular flanged joint In this project tube side of equipment is oval shape, for designing this ASME SEC. VIII DIV.2 is preferred, instead of ASME SEC. VIII DIV. 1. Because this division is restricted over circular shape only. But, because of ASME SEC. VIII DIV. 2 division is expensive. The study of flange using FEA analysis. After design compare the results with ASME allowable limit.

2. PROBLEM DEFINITION

HTG (High Temperature Generator) channel shell, tubesheet, body flange and cover flange cannot be calculated to the rules
of ASME Section VIII-1 due to the complexity of the shape. Hence the guidelines of the ASME Section VIII-2 are used with the allowable stress limits of ASME Section VIII-1 and Finite Element Analysis (FEA) is done to meet the requirement of ASME Section VIII-2.

Specific objectives relating to this project include:
- Research background information relating to the assembly stresses produced when bolting two flanges together.
- Construction of parametric model finite element analysis techniques.
- Analysis of output from finite element analysis model.
- Stress linearization of stress concentrated areas.
- Calculation of Membrane, Bending & peak stresses along the thickness of highly stress concentrated zone.
- Compare above stresses with the allowable limit given by ASME.

Research Methodology relating to this project include:
- Study of sources of failure of Oval Shape flange.
- Identification of Critical design parameters.
- Design of Oval shape flange.
- Construction of Parametric Model using SOLID WORK.
- FEM analysis using SOLID WORK.

3. DESIGN OF OVAL SHAPE FLANGE

3.1 Basic Assumptions

In order to simplify the analysis of the flanged joint, a number of assumptions were made. These assumptions are made to avoid the complexity of the problem, In a such way that it will not affect the final result.

These basic assumptions are:
- All materials for the model, blind, gasket and hub flange are assumed isotropic, i.e. materials have the same elastic properties in all directions, which is a valid approximation for steel.
- Considering self-energizing gasket.
- Modeling will be via linear static analysis.
- Stud loads will be averaged over the area where the studs are located in the circular ring.

3.2 Design Parameter

The input parameter we are considering for the design and analysis of Oval shape flange are as per the company standards and customer specification.

Tube side design pressure=1.054 MPa
Design Temperature=300 °C
Tube Side Mean metal temperature=150 °C
Shell Side Mean metal temperature=135 °C
Minimum Design Metal Temperature=−10 °C

3.3 Model Information

HTG consisting of tubesheet with tube holes, cover plate, nozzle with end cap, channel shell and main shell is modeled. The main shell is not the part of the analysis; they are modeled to transfer the forces. Parametric model are used to design a model, having similar geometry but different dimensions.

3.4 Material of Construction

The following material properties are extracted from ASME Section II Part D.

1) Channel Shell / Main Shell / Tubesheet / channel flange/ cover flange

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select the Material= SA-516 Gr 70</td>
</tr>
<tr>
<td>Design Temperature=200°C</td>
</tr>
<tr>
<td>Nominal Composition= Carbon steel</td>
</tr>
</tbody>
</table>
3.5 Design Procedure

The target load bolt-up method was used to calculate target bolt-up forces and subsequent flange stresses.

3.6 ASME Flange Design Bolt Forces

As per ASME Mandatory Appendix II, the following section details the procedure required to calculate the minimum required bolt force for a flanged joint.

The maximum of the two calculated forces, \( W_{m1} \) and \( W_{m2} \), is used to set the minimum required bolt force as set out below.

\[
W_{m1} = H + Hp \quad \text{(1)}
\]

\[
W_{m1} = (0.785G^2 + G*SP)*P \quad \text{(1)}
\]

Where,

- \( b \) is the effective gasket seating width \([\text{mm}]\);
- \( G \) is the diameter at location of gasket force \([\text{mm}]\);
- \( y \) is the gasket seating stress \([\text{mm}]\);
- \( P \) is the calculation pressure \([\text{MPa}]\) and
- \( m \) is a gasket factor.

The total cross-sectional area of bolts \( A_m \) required for both the operating conditions and gasket seating is the greater of the values for \( A_{m1} \) and \( A_{m2} \),

\[
A_{m1} = \frac{W_{m1}}{S_b} \quad \text{(4)}
\]

\[
A_{m2} = \frac{W_{m2}}{S_a} \quad \text{(5)}
\]

\[
A_m = \text{Max}(A_{m1}, A_{m2}) \quad \text{Available Cross-sectional area of the Bolts,}
\]

\[
A_b = \pi/4 * d_b^2 * n_b \quad \text{(6)}
\]

A selection of bolts to be used shall be made such that the actual total cross-sectional area of bolts \( A_b \) will not be less than \( A_m \).

Flange design bolt load,

For operating condition \( W \) [N],

\[
W = W_{m1} \quad \text{(7)}
\]

For gasket seating condition,

\[
W_g = (A_m + A_b)*S_a/2 \quad \text{(8)}
\]

4. FINITE ELEMENT ANALYSIS

4.1 General Remarks

Finite Element Method, popularly known as FEM, involves analysis of the entire structure, instead of separately considering individual elements with simplified or assumed end conditions. It thus helps in a more accurate estimate of the stresses in the members, facilitating optimum design. FEM involves idealizing the given component into a finite number of small elements, connected at nodes. FEM is an extension of...
Rayleigh-Ritz method, eliminating the difficulty of dealing with a large polynomial representing a suitable displacement field valid over the entire structure. Over each finite element, the physical process is approximated by functions of desired type and algebraic equations, which relate physical quantities at these nodes and are developed using variational approach. Assembling these element relationships in the proper way is assumed to approximately represent relationships of physical quantities of the entire structure.

4.2 Constrains for shell flange

The Tube sheet, bolt & back side of shell is constrained in all the directions as shown in figure given below.

4.3 Pressure

Internal pressure of 1.054 MPa is applied all over the channel area including the channel flange, tubesheet & nozzle.

Vacuum is applied over the shell and shell side of the tubesheet

<table>
<thead>
<tr>
<th>Mesh type</th>
<th>Mesh Using Solid Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesh Used</td>
<td>Standard mesh using parabolic tetrahedral solid elements defined by four corner nodes, six mid side nodes and six edges</td>
</tr>
<tr>
<td>Element size</td>
<td>45 mm</td>
</tr>
<tr>
<td>Mesh quality</td>
<td>High</td>
</tr>
<tr>
<td>Total nodes</td>
<td>81651</td>
</tr>
<tr>
<td>Total elements</td>
<td>42025</td>
</tr>
</tbody>
</table>
4.5 Mesh convergence

For the optimum selection of the mesh size and plotting of the results, deflection convergence is established and the percentage variation is kept under 10%. Details are as follows –

Table-III Mesh Check for Shell Flange

<table>
<thead>
<tr>
<th>Description</th>
<th>Mesh</th>
<th>Nodes</th>
<th>Elements</th>
<th>Maximum Deflection mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot Run</td>
<td>45</td>
<td>81651</td>
<td>42025</td>
<td>0.1038</td>
</tr>
<tr>
<td>Check Run</td>
<td>35</td>
<td>92167</td>
<td>47700</td>
<td>0.1125</td>
</tr>
<tr>
<td>Percentage Variation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.38 %</td>
</tr>
</tbody>
</table>

As the maximum variation in less than 10% the convergence is achieved and the results will be plotted with the mesh size 45 (Plot Run).

4.6 Result

Stress Plot give stresses at various portion. Color represent intensity of stress variation.

Table-04 Stress Comparison

<table>
<thead>
<tr>
<th>Von Mises stress</th>
<th>Software output</th>
<th>Manually calculated</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane Stress</td>
<td>27.11 MPa</td>
<td>26.57 MPa</td>
<td>2.03</td>
</tr>
<tr>
<td>Bending Stress</td>
<td>103.63 MPa</td>
<td>106.40 MPa</td>
<td>2.60</td>
</tr>
</tbody>
</table>

As the maximum variation of stresses less than 10%, Convergence is achieved. Now the final stage i.e. checking with allowable limit. As the stresses obtain is less then allowable value of stresses as per ASME Section VIII-2 and allowable stress limit allowed for ASME Section VIII-1.

5. CONCLUSIONS

Bolted flange connections are analyzed by implementing the design method for gasketed bolted flanged connections as per ASME Boiler and Pressure Vessel Code and results were validated with finite element analysis results. It is concluded from this investigation that the maximum stresses developed on flange are at middle part of the bolt and it is within the
acceptable limit specifying by ASME. Firstly, mesh convergence is done using deflection analysis, as maximum deformation in both the analysis is less than 10% hence, convergence is achieved.

From the Finite element analysis the maximum stresses are reported in shell flange of 5N model, but the stresses are within acceptable limit specified by ASME. The lowest values of stresses are reported in 2K model. Stress results obtained from the F.E.A. analysis indicated the flanged joint is within acceptable levels. It was attempted to compare the F.E.A. results with that of the target load bolt-up method. Stress results obtained from the F.E.A. analysis indicated the flanged joint is within acceptable levels. It was attempt to compare F.E.A. result with the stresses obtain as a output from stress linearization method. Result gave output stresses within the acceptable limit specify by ASME.

REFERENCES


