

Finite Element based analysis of multistage tube sheet filter assembly

¹Aher Sagar Sunil, ²Prof.G.U.Tembhare, ³Mr.Vinaay Patil

¹M.Tech (Cad Cam & Automation) Student, ²Assistant Professor, ³CEO

¹Mechanical Engineering Dept Veermata Jijabai Technological Institute Mumbai, Maharashtra, India

²Mechanical Engineering Dept Veermata Jijabai Technological Institute Mumbai, Maharashtra, India

³Vaftsya CAE, Pune, Maharashtra, India

ahersagar7@gmail.com, gutembhare@vjti.org.in, info@vaftsyaecae.com

Abstract—Tube sheets are used in a medium of chemical nature i.e. some types of surfactants means surface active agents in jet fuels like sulfonates, naphthenates of sodium however over period of time they obstruct the flow of fluid so there is rise in pressure, for overall stability of vessel we can't allow to rise in pressure above certain limit value i.e. peak differential pressure, once these value is reached we have to shut down the plant and apply back pressure to clean tubes, however to speed up the process we apply multistage of the process.

Index Terms— Tube sheet, filter vessel, multistage, Mathematical model.

I. WHAT IS TUBE SHEET?

A tube sheet is a plate, sheet, or bulkhead which is perforated with a pattern of holes designed to accept pipes or tubes. These sheets are used to support and isolate tubes in heat exchangers and boilers or to support filter elements. It may be flat or circular. It should be uniform thickness

II. TYPE OF MATERIALS

- (1) Carbon Steel, Manganese Steel, Chromium Steel, Silicon Steel, Nickel Steel
- (2) Metals of resin, composites or plastic.
- (3) A cladding material as corrosion barrier and insulator.
- (4) To prevent Tube sheet from rust galvanic anode is attached to sheets.

III. EASE OF USE

By ASME, Second Div

Table A=For Allowable Stress

Table TE-1 = For Modulus of Elasticity

Table TM-1 = For Thermal expansion coefficient.

IV. MANUFACTURING

It usually constructed from a round, flattened sheet of metal.

Tube and Tube sheet are of same materials and attached with a pneumatic or hydraulic pressure roller.

At this point, tube holes can both be drilled and reamed,

To improve joint strength they are machined grooves

V. TYPES OF TUBE SHEET

- (1) U-Tube tube sheet.
- (2) Fixed tube sheets.
- (3) Floating tube sheet.

VI. TYPES OF LAYOUT

- (1) Triangular Pattern (30°)
- (2) Rotated Triangle/Equilateral Triangular Pattern (60°)
- (3) Square Pattern (90°)
- (4) Rotated Square Pattern (45°)

POSSIBLE TYPES OF CONNECTIONS IN TUBE SHEETS

The tube sheet is connected to shell and channel either by welding (integral) or bolt's (Gasketed) or a combination therefore 6 possible types of connections with the shell and channel are given below

- (1) Tube sheet integral with shell and channel.

- (2) Tube sheet integral with shell and gasketed to channel, extended as flange.
- (3) Tube sheet integral with shell and gasketed to channel, not extended as flange.
- (4) Gasketed construction on both shell and tube side.
- (5) Tube sheet gasketed on shell side and integral with channel and extended as flange.
- (6) Shell Side gasketed and tube side integral with channel and no extended as flange.

DESIGN OF TUBE SHEET

- (1) Take Elastic Modulus and allowable stress at operating temperature in case of thermal loading otherwise take at design temperature.
- (2) Use both corroded and uncorroded condition for fixed condition.
- (3) Include tube expansion depth ratio.
- (4) For chosen layout find effective dimensions and ligament efficiency.

MATHEMATICAL MODELING

For Circular Plate [Ref: Boresi and Chong 2000]

Using

$$\dots\dots\dots (1)$$

Where,

P = Lateral Pressure,

D = Flexural Rigidity,

W = Lateral Displacement.

= Invariant Vector Operator holds for all coordinate system,

h = Plate Thickness,

r = radius of circular plate.

For a plate with a is radius and h is thickness employing polar coordinate with origin at the center of plate then above equation is replaced as,

Consider the Axi-symmetric Case, in which plate loaded and supported symmetrically with respect to z axis, then above equation becomes as following equation 3 as dependency on θ vanishes,

$$\nabla^2 \nabla^2 w = \left(\frac{d^2}{dr^2} + \frac{1}{r} \frac{d}{dr} \right) \left(\frac{d^2 w}{dr^2} + \frac{1}{r} \frac{dw}{dr} \right) = \frac{P}{D} \dots\dots\dots (3)$$

The solution of above equation with $p=p_0=\text{constant}$ is as following,

$$W = \frac{p_0 r^4}{64 D} + A_1 + A_2 \ln r + B_1 r^2 + B_2 r^2 \ln r \dots\dots\dots (4)$$

Where, A_1, A_2, B_1, B_2 are constant of integration which can be determined by boundary condition at $r = a$ and the regularity equation that w (displacement), $\frac{dw}{dr}$ (Displacement rotation), M_r (Moments), V_r (Shear Force) must be finite at the center of plate origin $r = 0$ at polar coordinate system,

Analogues to the equation for rectangular plate using continuity and stress strain temperature relationship for isometric elastic plate with ν in general,

$$M_{rr} = -D \left[w_{rr} + \nu \left(\frac{w_r}{r} + \frac{w_{\theta\theta}}{r^2} \right) \right] \dots\dots\dots (5)$$

$$M_{\theta\theta} = -D \left(\frac{w_r}{r} + \frac{w_{\theta\theta}}{r^2} + \nu w_{rr} \right)$$

$$M_{rr} + M_{\theta\theta} = -D(1 + \nu) \nabla^2 w$$

$$M_{r\theta} = -D(1 - \nu) \frac{\partial}{\partial r} \left(\frac{w_{\theta}}{r} \right)$$

$$V_r = -D \left[\frac{\partial}{\partial r} (\nabla^2 w) + (1 - \nu) \frac{1}{r} \frac{\partial}{\partial r} \left(\frac{w_{\theta\theta}}{r} \right) \right] \dots\dots\dots (7)$$

$$V_{\theta} = -D \left[\frac{1}{r} \frac{\partial}{\partial \theta} (\nabla^2 w) + (1 - \nu) \frac{\partial^2}{\partial r^2} \left(\frac{w_{\theta}}{r} \right) \right]$$

$$w_r = \frac{1}{r} w_{\theta}, w_{\theta} = -w_r$$

Where, subscripts (r,) on 'w' denotes partial differentiation accordingly, for the solid plate, above equations, we conclude that for Axi-symmetric condition,

This project is analogous to a circular plate with a circular hole at the center, therefore for a circular plate with radius 'a' and central hole of radius 'b' and subjected to a uniform lateral pressure the boundary condition and using the above equations, With these coefficient the displacement and stress resultant may be computed, For example, for and the maximum displacement is,

$$w_{max} = w(b) = 0.682 \frac{p_0 a^2}{E h^2} \dots \dots \dots (8)$$

Expect for simple types of loading and shapes of plates, such as circular shape, the method of finding bending moment by solving plate equations is somewhat complicated. However, the result obtained can be reduced to table or curves of coefficient for maximum bending moment per unit width of a plate and for the maximum deflection of plate.

The bending theory of elastic plates, however, does not make any allowance for adjustment that take place when slight local yielding at portion of high stress causes a redistribution of stress.

This redistribution of stress, in turn, may result in additional strength of plate .which may often be incorporated into the design of plates, particularly plates of ductile material, we also observed that the bending theory of plates based on the above equations does not take into account the added resistance of plates resulting from direct tensile stress that accompany relatively large deflections .Circular plates of radius 'a' and central circular hole of radius r_0 are commonly used in engineering system.

For example, they occur in thrust bearing plates, steam turbines etc. Several cases of practical importance have been studied by Wahl and Lobo (1930). In all these cases, the Maximum stress is given by simple formulas of the type,

$$\sigma_{max} = k_1 \frac{p a^2}{h^2} \text{ or } \sigma_{max} = k_1 \frac{p}{h^2} \dots \dots \dots (9)$$

.....Ref. Advance Mechanics of materials by, Boreasi and Schmidt

Depending on whether the applied load is uniformly distributed over the plate or Concentrated along the edge of the central hole. Likewise, the maximum deflections are Given by simple formulas of the type

$$w_{max} = k_2 \frac{p a^4}{E h^3} \text{ or } w_{max} = k_2 \frac{p a^2}{E h^3} \dots \dots \dots (10)$$

(Ref. Advance Mechanics of materials by, Boreasi and Schmidt)

Wahl and Lobo have calculated numerical values for for several values of the Ratio and for a Poisson's ratio of

Boundary Condition:

For Fixed Edges:

At , the boundary conditions with

$$w(a) = A_1 + B_1 a^2 + \frac{P_0 a^4}{64D} = 0$$

$$w_{\theta}(a) = -w_r(a) = -2B_1 a - \frac{P_0 a^3}{15D} = 0$$

Solving equations for and we obtained the following results for circular plate with fixed edge at subjected to uniform lateral pressure P

$$w = \frac{P_0 a^4}{64D} \left[1 - \left(\frac{r}{a} \right)^2 \right]^2$$

$$M_{rr} = \frac{P_0 a^2}{16} \left[1 + \nu - (3 + \nu) \left(\frac{r}{a} \right)^2 \right]$$

$$M_{\theta\theta} = \frac{P_0 a^2}{16} \left[1 + \nu - (1 + 3\nu) \left(\frac{r}{a} \right)^2 \right]$$

Above equations summarize the bending theory of simple supported circular plates subject to uniform lateral pressure numerous solution for other types of plates, loading and boundary conditions have been presented by Marguerre and woemle have presented extensive results for orthotropic plates.

REFERENCE

- [1] Advanced finite element analysis Boresi and Chong 2000
- [2] An introduction to finite element method engineering series by J N Reddy Jan 11, 2005
- [3] A.S.M.E.Section 8 Div 2
- [4] www.efunda.com
- [5] www.thermopedia.com
- [6] Pressure vessel design concepts and principles By J Spence, A S Tooth

