Design Calculation Of Nozzle Junction Based On ASME Pressure Vessel Design Code

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Abstract—: Nozzle is a device designed to control the direction or characteristics of fluid (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe. Under different loading conditions, the stress will occur at the nozzle to head or shell junction area. Thus reliable and accurate design calculation for head or shell to nozzle junction is necessary. The calculation for nozzle design gives the information whether the design is adequate for given parameters. In this paper, design calculation of nozzle junction based on ASME pressure vessel design code is carried out for nozzle to head junction subjected to applied external load, internal pressure and moments. The equations are as per ASME Section VIII Division I. This paper gives methodize steps and format for design calculation for reinforcement of nozzle. The results are also compared with PV-Elite code.

Keywords- Reinforcement area, Nozzle shell junction, Parallel limit, Normal Limit, Layout Angle.

I. INTRODUCTION

Providing additional material in the region of the opening by thickening the shell or adding a pad material is known as reinforcement. It may be inside or outside. Generally distance is kept equal to diameter [D] from the center of the nozzle It is called boundary limit of effective Reinforcement.

1.1. Need of reinforcement

Openings in pressure vessels in the regions of shells or heads are required to serve the following purposes: Manways for letting personnel in and out of the vessel to perform, routine maintenance and repair, Holes for draining or cleaning the vessel, Handhole openings for inspecting the vessel from outside, Nozzles attached to pipes to convey the working fluid inside and outside of the vessel, For all openings, however, nozzles may not be necessary. In some cases nozzles and piping that are attached to the openings, while in other cases there could be a manway cover plate or a handhole cover plate that is welded or attached by bolts to the pad area of the opening. Nozzles or openings may be subjected to internal or external pressure, along with attachment loads coming from equipment and piping due to differential thermal expansion and other sources. From reinforcement calculation following parameters can be obtained: Wall Thicknesses required (Shell and Nozzle), Area of Reinforcement required, Area of Reinforcement available, Cross-sectional area of various welds available for reinforcement, Cross-sectional area of material added as reinforcement, Total area available Size of reinforcing pad (if required), Size of fillet welds (inside, outside and reinforcing pad fillet-if required), Maximum nozzle distance projects beyond the inner surface of the vessel wall.

II. METHODOLGY AND STEPS FOR NOZZLE DESIGN CALCULATION

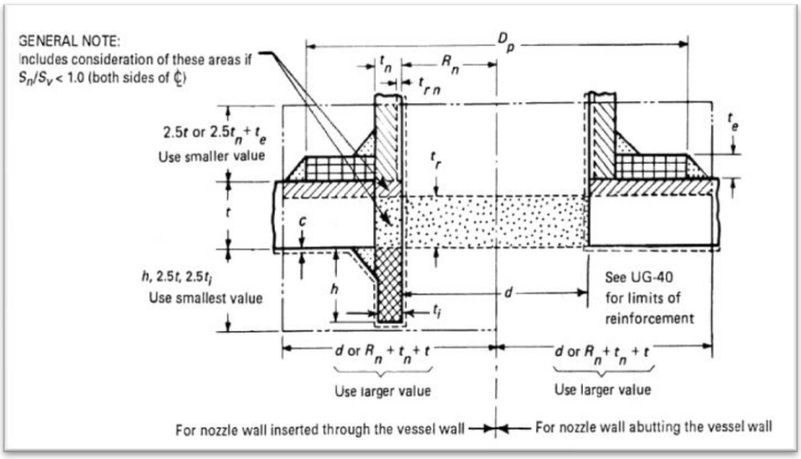

Figure 1.Reinforced nozzle

2.1 Steps for Nozzle Design Calculation

Fig1. Show the cross-sectional view of reinforced nozzle that indicates nozzle and shell thickness area, reinforcement locations and weld paths, parallel and normal limits with its equations.

1. Minimum required shell thickness is given by:

$$T_{r\,s} = (P*R)/(2*S*E-0.2*P)$$

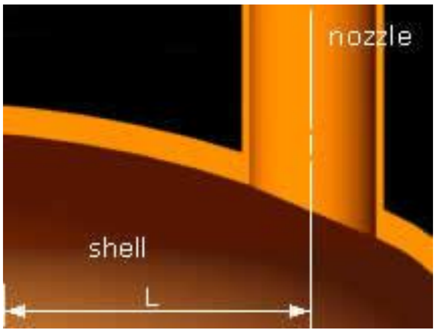

Figure 2.Nozzle Shell junction area

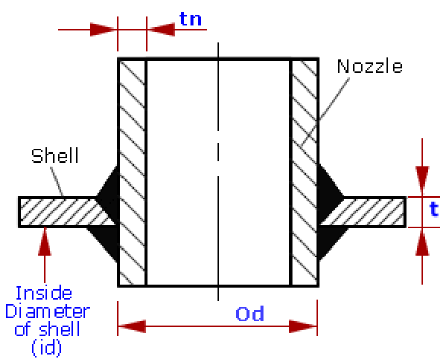

Figure 3.main parameters for reinforcement

2. Minimum required nozzle thickness is given by:

$$T_{r\,n} = R(\exp([P/(SE)] - 1)$$

3. The reinforcement area required is Ar:

$$A_r = (d * t_r * F + 2 * tn * t_r * F * (1-f_{r1}))$$

4 LIMITS:

Parallel limit:

(a) d (b) $t_n + t_s + R$ (Use greater value.)

Normal limit:

(a) $2{:}5 * t_s$ (b) $2{:}5 * t_n + t_e$ (Use smaller value)

5. **The reinforcement area available in the shell (up to a distance d), A_1 is given by:**

A_1=d (E_1* t_s – f * t_r) -2 * t_n (E_1 * t_s – F * t_r) * (1-f_{r1})
A_1=2 (t_s – t_n) *(E_1 * t – F*t_r) -2 * t_n (E_1 * t_s – F * t_r) * (1-f_{r1}) (Use larger value.)

6. **The reinforcement area available in nozzle wall is available in two parts A_2:**

A2=5 (t_n-t_{rn}) * f_{r2}*t_s
A2=5 (t_n-t_{rn}) * f_{r2}* t_n (Use smaller value.)

7. Area available in inward nozzle:

A_3 =5tt_j * f_{r2}
=5tit_j * f_{r2}
= 2ht_i * f_{r2} (Use smaller value.)

The total area available for reinforcement:

$$\mathbf{A_{total} = A_r + A_1 + A_2 + A_{41} + A_{43} + A_6}$$

If the available area exceeds than the required area Design is adequate.

$$\mathbf{A_r < A_{total}}$$

III. NOZZLE REINFORCEMENT CALCULATION

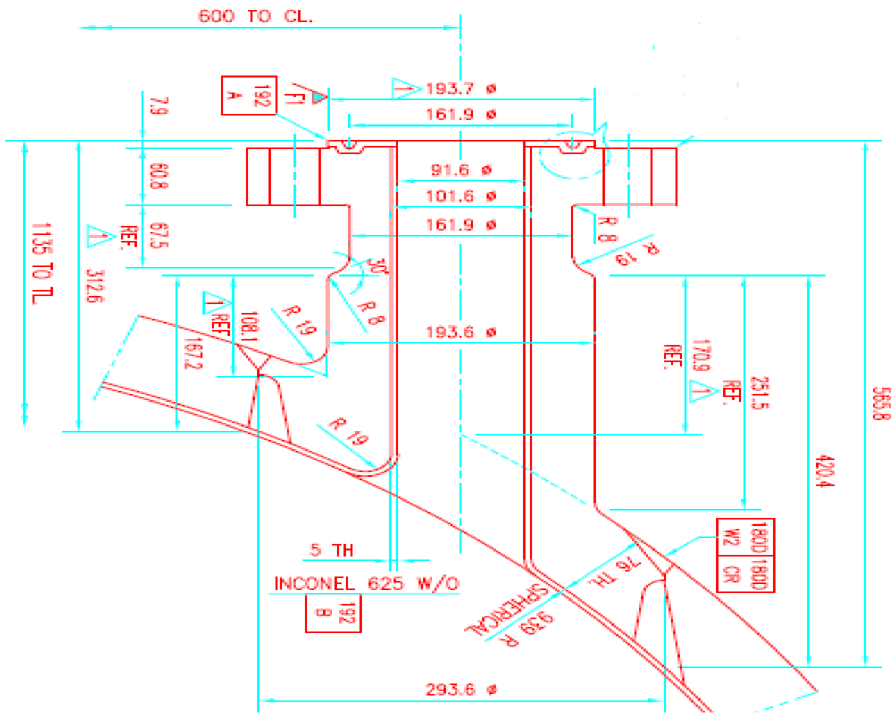

Figure 4.Geometrical Diementions

3.1 Nozzle

Dimensions of the self reinforced nozzle are shown in Fig. 4. The reinforcement calculation is carried out as per ASME guidelines and it shows that the total area available is more than the required area. The nozzle Inside Diameter (ID) is 101.6 mm and hub thickness is 46 mm. Table 2 shows the other parameters of nozzle. To determine the reinforcement requirements following parameters are given as input.

Table 1.Shell Parameters

Internal pressure (P)	15.69 *MPa*
Design temperature (Temp)	70 $^{\circ}C$
Shell Material	SA-516 ,60
Shell Allowable Stress (at design Temperature)	118 *MPa*
Shell Allowable Stress (at Ambient temperature)	118 *MPa*
Inside Diameter of Hemispherical Head D	1878 *mm*
Head Finished (Minimum) Thickness t	66 *mm*
Head Internal Corrosion Allowance C	0 *mm*
Head External Corrosion Allowance C_0	0 *mm*
Distance from Head Centerline L_1	600 *mm*
User Entered Minimum Design Metal Temperature	-29.00 $^{\circ}C$

Table 2.Nozzle Parameter

Material	SA-105
Allowable Stress at Temperature S_n	138 *MPa*
Allowable Stress At Ambient S_{na}	138 *MPa*
Diameter Basis	ID
Layout Angle	90 $^{\bullet}$
Diameter	101.6 *mm*
Hub Height of Integral Nozzle h	105 *mm.*
Height of Beveled Transition L`	9.2 *mm.*
Hub Thickness of Integral Nozzle t_n	46 *mm.*

3.2. Reinforcement calculations:

3.2.1Checking nozzle in the meridional direction:

a. Required thickness of spherical head(Internal Pressure):as per UG 37(a)

$T_{r\,s}$ = (P*R)/ (2*S*E-0.2*P) per UG-27 (d) …………(i)
= (1.61*939.0001)/ (2*12*1.00-0.2*1.61)
= 63.8624 mm.

Required thickness of nozzle wall:

(Here nozzle radius (50.8) and nozzle thickness (30.15) so $T_n > R_n$ so use Appendix 1-2(a)(1))

$T_{r\,n}$ = R (exp ([P/ (SE)] - 1) per Appendix 1-2 (a)(1) …………(ii)
= 50.800(exp ([1.61/ (14.06*1.00]-1)
= 6.1639 mm.

b. Here, hub height=105 mm and hub thickness=46 mm

If h > (2:5 * hub thickness) use UG: 40 fig(e-2)
If h < (2:5 * hub thickness) use UG: 40 fig(e-1)
Here, using UG: 40 fig (e-1)

c. Limits:

Parallel limit:

(a) d =323.8 mm

(b) $t_n + t_s + R = 161.9$ mm .... (iii)

Normal limit:

(a) 2:5* t_s= 2:5* 66 = 165 mm

(b) 2:5 *t_n+ t_e= 2:5 * (30.15) + t_e= 102.828 mm ....(iv)

$$t_e = \frac{\text{Hub Thickness-Neck Thickness}}{\cos 30} \quad \text{...........(v)}$$

$$= \frac{4630{:}50}{\cos 30}$$

$$= 27.4530$$

So,

Parallel Limit: 323.8 mm. For parallel limit consider larger value.

Normal Limit: 102.828 mm. For normal limit consider smaller value.

d. Weld strength reduction factor:

$f_{r1} = 1$ or $f_{r1} = \frac{S_n}{S_a} = 1.16$ Where , S_n =14.06 and S_a=14.02

f_{r2} =1 or f_{r2} =1.16

$f_{r3}= f_{r2} = 1$ (use minimum values) .... (vi)

e. To calculate the opening chord length at mid surface of the required shell thickness procedure is as follows:(use Appendix-L,L7.7)

$R_m = R_s + t_{rs2} = \frac{939 + 63.740}{2} = 970.87$ ....(vii)

Calculation of area:

A_r = (d * t_r * F + 2 * tn * t_r* F * (1-f_{r1})) UG-37(c) .... (viii)

= (129.4663 * 63.8624 * 1.0 + 2 * 46.0000 * 63.8340 * 1.0 * (1-1))

= 8254.566 mm^2

Reinforcement areas per figure UG-37.1

Area available in shell (A_1): A_1= 229:616 mm^2 or

A_1= 434.598 mm^2 (use large values)

Area available in nozzle outward (A_2):

If A_2 upper side should smaller than A_2 inside use UG 37(b)

If not less than 0.5 require reinforcement each side opening So A_2 on inside should not greater than A_2 upside.

Therefore , A_2 = 5890.77 mm^2

Area available in inward + outward weld (A41+ A43) or (A4+ A5):

= $(leg^2 * f_{r2}) = 0$ …………(viiii)

Area (A41+ A43) will not consider because welds vary from fillet to butt type weld.

Area available in Hub section A_6:

A_6= (2 * [min (Tlnp.h0.. Hub height (h))] * (Hub thickness - t n) * fr2 (3:23)) ………(x)
= (2 * [min (102.8, 400, 105)] * (46 - 30.15) * 1
= 3269.04 mm^2

$\mathbf{A_r}$ = Area required = **8254.566** mm^2
$\mathbf{A_1}$ **=** Area required in shell = **434.5986** mm^2
$\mathbf{A_2}$ **=** Area required in nozzle wall = **5890.77** mm^2
$\mathbf{A_{41}+ A_{43}}$ =Area required in weld = **0** mm^2
$\mathbf{A_6}$ = Area required in Hub = **3269.04** mm^2

$\mathbf{A_{total} = A_r + A_{1+} A_{2+} A_{41} + A_{43+} A_6}$
= 9594:408 mm^2

Ar= 8254 mm^2
Here, $\mathbf{A_r < A_{total}}$

This condition indicates that for the given design parameters required area is less than the total area. Hence, there is no need to add any extra amount of material. **So, opening is adequately Reinforced.** If the required area is more than te total area then the reinforcement pad is required.

IV. CONCLUSION

The above mentioned detailed Calculation is carried out to determine the requirement of the reinforcement pad for the given loading condition as per ASME Section VIII, Div. I. This calculation steps simplifies the reinforcement calculation. The calculation result suggests that there is no need for providing reinforcement pad and hence self reinforced nozzle is used. If condition is $\mathbf{A_r > A_{total}}$ than only additional reinforcement would be required.

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