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Correctieblad

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Unfired pressure vessels - Part 3: Design

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Voorbeeld
Preview

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7.5.3 Torispherical ends

7.5.3.1 Conditions of applicability

The following requirements are limited in application to ends for which all the following conditions are met:

$r \leq 0{,}2\ D_i$

$r \geq 0{,}06 D_i$

$r \geq 2e$

$e \leq 0{,}08\ D_e$

$e_a \geq 0{,}001\ D_e$

$R \leq D_e$

7.5.3.2 Design

The required thickness e shall be the greatest of e_s, e_y and e_b, where:

$$e_s = \frac{P \cdot R}{2f \cdot z - 0{,}5P} \tag{7.5-1}$$

$$e_y = \frac{\beta \cdot P\,(0{,}75R + 0{,}2D_i)}{f} \tag{7.5-2}$$

where

β is found from Figure 7.5-1 or the procedure in 7.5.3.5, replacing e by e_y.

and

$$e_b = (0{,}75R + 0{,}2D_i)\left[\frac{P}{111 f_b}\left(\frac{D_i}{r}\right)^{0{,}825}\right]^{\left(\frac{1}{1{,}5}\right)} \tag{7.5-3}$$

where

$$f_b = \frac{R_{p0{,}2/t}}{1{,}5} \tag{7.5-4}$$

except for cold spun seamless austenitic stainless steel, where:

$$f_b = \frac{1{,}6 R_{p0{,}2/t}}{1{,}5} \tag{7.5-5}$$

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At test conditions the value 1,5 in the equations for f_b shall be replaced by 1,05.

NOTE 1 For stainless steel ends that are not cold spun, f_b will be less than f.

NOTE 2 The 1,6 factor for cold spun ends takes account of strain hardening.

NOTE 3 It is not necessary to calculate e_b if $e_y > 0{,}005 D_i$.

NOTE 4 The inside height of a torispherical end is given by

$$h_i = R - \sqrt{(R - D_i/2) \cdot (R + D_i/2 - 2r)}$$

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7.5.3.3 Rating

For a given geometry P_{max} shall be the least of P_s, P_y and P_b, where:

$$P_s = \frac{2f \cdot z \cdot e_a}{R + 0{,}5 e_a} \qquad (7.5\text{-}6)$$

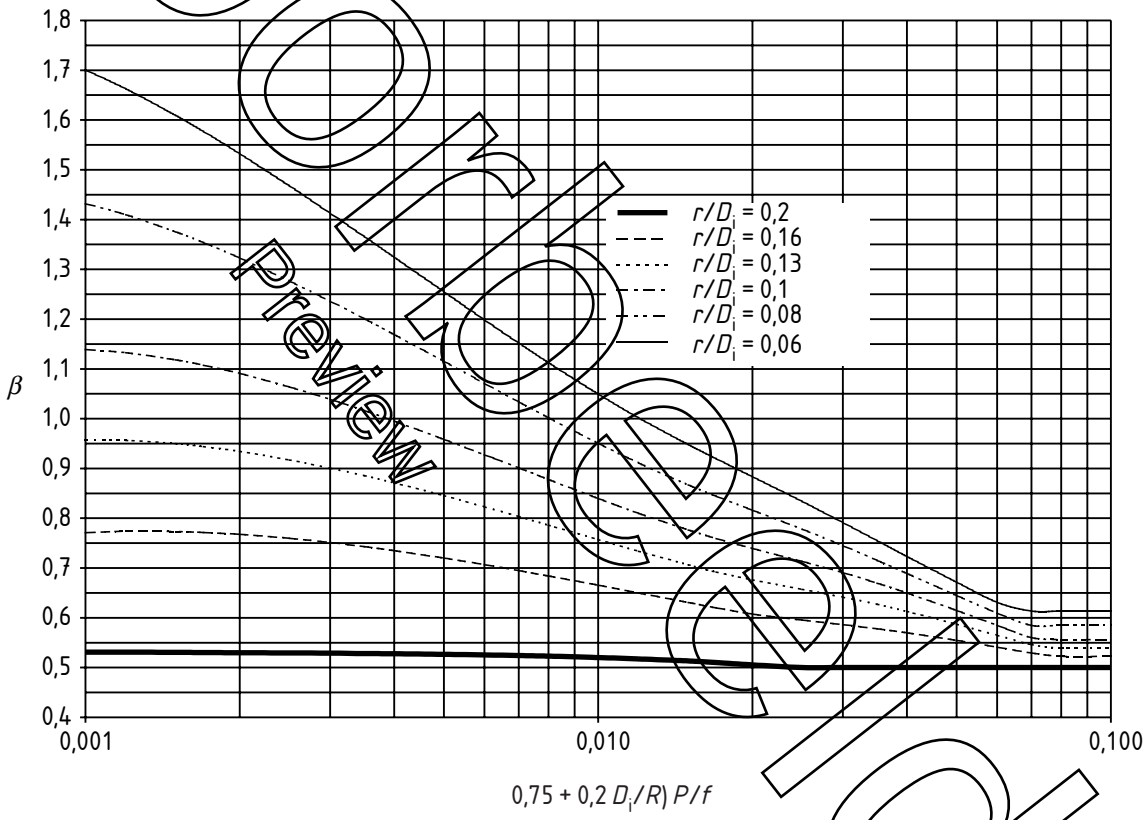

Figure 7.5-1 — Parameter β for torispherical end – Design

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$$P_y = \frac{f \cdot e_a}{\beta(0{,}75R + 0{,}2D_i)} \quad (7.5\text{-}7)$$

where

β is found from Figure 7.5-2 or the procedure in 7.5.3.5, replacing e by e_a.

$$P_b = 111 f_b \left(\frac{e_a}{0{,}75R + 0{,}2D_i} \right)^{1{,}5} \left(\frac{r}{D_i} \right)^{0{,}825} \quad (7.5\text{-}8)$$

NOTE It is not necessary to calculate P_b if $e_a > 0{,}005D_i$.

7.5.3.4 Exceptions

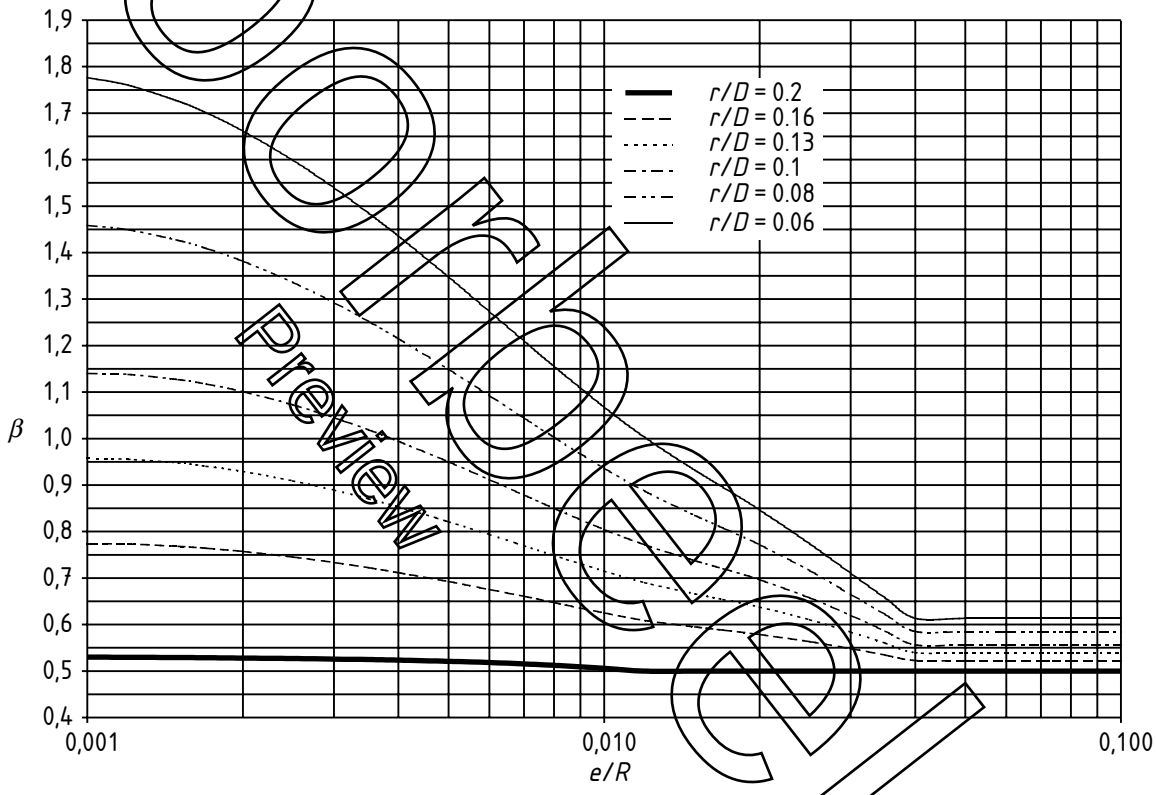

Figure 7.5-2 — Parameter β for torispherical end - rating

It is permissible to reduce the thickness of the spherical part of the end to the value e_s over a circular area that shall not come closer to the knuckle than the distance $\sqrt{R \cdot e}$, as shown in Figure 7.5-3.

Any straight cylindrical flange shall meet the requirements of 7.4.2 for a cylinder, if its length is greater than $0{,}2\sqrt{D_i \cdot e}$. When the length is equal or smaller than $0{,}2\sqrt{D_i \cdot e}$, it may be the same thickness as required for the knuckle.

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7.5.3.5 Formulae for calculation of factor β

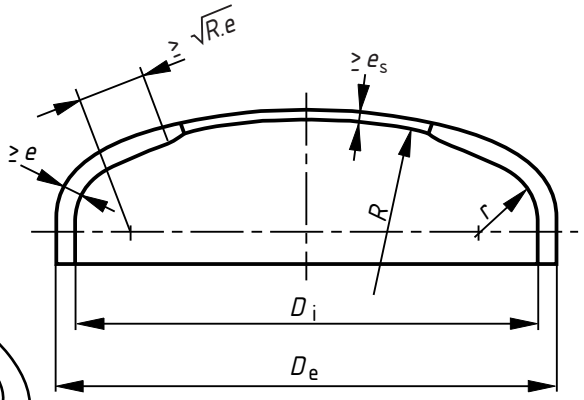

Figure 7.5-3 — Geometry of torispherical end

$$Y = \min(e/R\,;\,0{,}04) \tag{7.5-9}$$

$$Z = \log_{10}(1/Y) \tag{7.5-10}$$

$$X = r/D_i \tag{7.5-11}$$

$$N = 1{,}006 - \frac{1}{\{6{,}2 + (90 \cdot X)^2\}} \tag{7.5-12}$$

For $X = 0{,}06$

$$\beta_{0,06} = N\left(-0{,}3635Z^3 + 2{,}2124Z^2 - 3{,}2937Z + 1{,}8873\right) \tag{7.5-13}$$

For $0{,}06 < X < 0{,}1$

$$\beta = 25\left\{(0{,}1 - X)\,\beta_{0,06} + (X - 0{,}06)\,\beta_{0,1}\right\} \tag{7.5-14}$$

For $X = 0{,}1$

$$\beta_{0,1} = N\left(-0{,}1833Z^3 + 1{,}0383Z^2 - 1{,}2943Z + 0{,}837\right) \tag{7.5-15}$$

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7.6.8.2 Design

Required thicknesses e_1 and e_2 shall be determined by the following procedure:

Assume values of e_1 and e_2:

$$s = \frac{e_2}{e_1} \tag{7.6-22}$$

when $s < 1$

$$\tau = s\sqrt{\frac{s}{\cos(\alpha)}} + \sqrt{\frac{1+s^2}{2}} \tag{7.6-23}$$

when $s \geq 1$

$$\tau = 1 + \sqrt{s\left\{\frac{1+s^2}{2\cos(\alpha)}\right\}} \tag{7.6-24}$$

$$\beta_H = 0{,}4\sqrt{\frac{D_c}{e_1}} \cdot \frac{\tan(\alpha)}{\tau} + 0{,}5 \tag{7.6-25}$$

If

$$P \leq \frac{2f \cdot z \cdot e_1}{D_c \cdot \beta_H} \tag{7.6-26}$$

then e_1 and e_2 are acceptable. If not, repeat with increased values of e_1 and/or e_2.

NOTE The above procedure does not provide values for e_1 and e_2 independently. Any values may be selected to suit the needs of the design, for example to obtain a favourable value of l_1 or l_2.

Provided that the requirements of 7.4.2 and 7.6.4 continue to be met, it is permissible to modify a design according to the above rule in one of the following ways:

a) Where $e_1 = e_2$ a knuckle of the same thickness may be included. l_1 and l_2 continue to be measured from the junction (i.e. the point where the centre lines of cone and cylinder meet).

b) The thickness of the cylinder may be increased near the junction and reduced further away provided that the cross-sectional area of metal provided by the cylinder within a distance l_1 from the junction is not less than $l_1\ e_1$. In addition, the thickness of the cone may be increased near the junction and reduced further away provided that the cross-sectional area of metal provided by the cone within a distance l_2 from the junction is not less than $l_2 \cdot e_2$.

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7.6.8.3 Rating

The maximum permissible pressure for a given geometry shall be:

$$P_{max} = \frac{2f \cdot z \cdot e_1}{D_c \cdot \beta_H} \qquad (7.6\text{-}27)$$

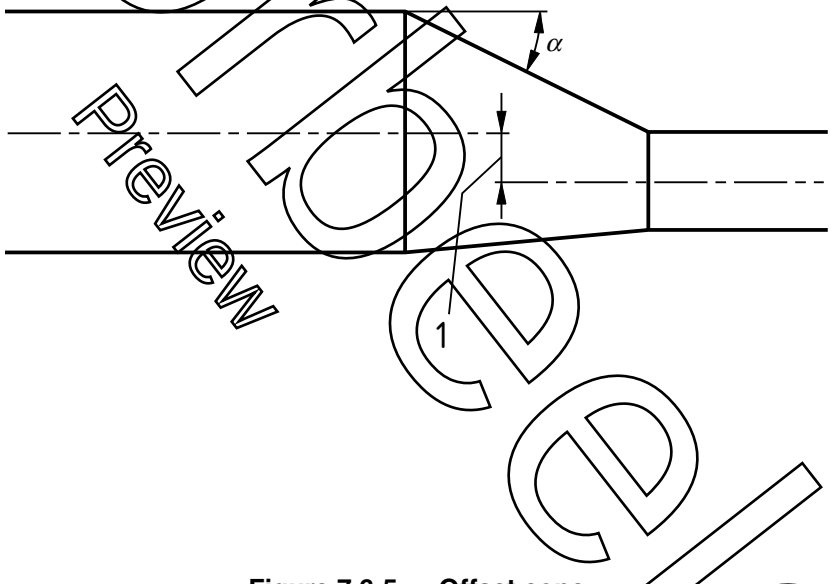
β_H is found from equations (7.6-22) to (7.6-25) using e_{1a} and e_{2a} in place of e_1 and e_2 .

NOTE 1 The procedure for finding e_{1a} and e_{2a} is as provided in the note to 7.6.6.3.

NOTE 2 Analysis thicknesses may exceed the required thickness without leading to any increase in l_1 or l_2.

7.6.9 Offset cones

This requirement applies to offset cones between two cylinders (see Figure 7.6-5). The cylinders shall have parallel centre lines offset from each other by a distance no greater than the difference of their radii. A required thickness shall be calculated in accordance with 7.6.6 for the junction at the large end. A required thickness shall be calculated in accordance with 7.6.8 for the junction at the small end. The greater of these shall apply to the whole cone. The angle (α) shall be taken as the greatest angle between cone and cylinder.



Key

1 Offset of axis

Figure 7.6-5 — Offset cone

7.7 Nozzles which encroach into the knuckle region

7.7.1 Specific symbols and abbreviations

The following symbols and abbreviations apply in addition to those in 7.5.1:

A is a parameter defined by equation (7.7-4) or (7.7-8);

A_1 is a parameter defined by equation (7.7-12) or (7.7-16);

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B is a parameter defined by equation (7.7-5) or (7.7-9);

B_1 is a parameter defined by equation (7.7-13) or (7.7-17);

β_K is the weakening factor due to presence of nozzle given by (7.7-10);

d_i is the inside diameter of the nozzle;

X is a parameter defined by equation (7.7-11) or (7.7-15);

V is a parameter defined by equation (7.7-3) or (7.7-7).

7.7.2 Conditions of applicability

In this sub-clause requirements are given for increasing the thickness of a dished end to compensate for nozzles which are not entirely within the central area of the head as defined in 9.7.2.4 and are therefore not covered by clause 9.

The requirements are limited in application to Kloepper and Korbbogen ends for which:

$$d_i / D_e \leq 0{,}6 \tag{7.7-1}$$

and

$$\frac{d_i}{\sqrt{e \cdot D_e}} \leq 6{,}7 \tag{7.7-2}$$

The nozzle centre line shall lie in the same plane as the centre line of the vessel. The nozzle centre line shall lie between normal to the wall of the end and parallel to the vessel centre line. The location of the nozzle shall be such that it does not cross the tangent line between knuckle and cylinder. Nozzles parallel to the vessel centre line and with outside diameter in line with the outside diameter of the vessel are included in these requirements.

The requirements of 7.7 may also be applied to ellipsoidal ends for which the aspect ratio $K \leq 2$. The thickness of such an ellipsoidal end with a nozzle intruding into the knuckle region shall be as for a Korbbogen end of the same diameter.

The increased thickness required by this clause applies to the whole knuckle region. Welded-on compensation is not permitted. The thickness of the crown may be reduced provided that the requirements of 7.5.3.4 are met and reinforcement for nozzles in the crown region meets the requirements of clause 9.

When the distance between the edge of the nozzle where it meets the knuckle and the knuckle/cylinder tan, line is less than $2{,}5\sqrt{e \cdot r}$ (measured along the surface) the validity of the method is in doubt. Unless the design is supported by special analysis or extensive experience, the design pressure shall be multiplied by two in such cases, or in a rating the allowable pressure shall be halved.

7.7.3 Design

For Kloepper type end:

$$V = \log_{10}\left(1000\frac{P}{f}\right) \tag{7.7-3}$$

$$A = \max\left(0{,}5;\ 0{,}264 + 0{,}938V - 0{,}592V^2 + 0{,}14V^3\right) \tag{7.7-4}$$

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$$B = \min\,(4{,}2;\ 4{,}9 - 2{,}165V + 0{,}151V^2) \tag{7.7-5}$$

$$\beta_k = \max\left(A + B\frac{d_i}{D_e};\ 1 + 0{,}3B\frac{d_i}{D_e} \right) \tag{7.7-6}$$

For Korbbogen type end:

$$V = \log_{10}\left(1000\frac{P}{f} \right) \tag{7.7-7}$$

$$A = 0{,}54 + 0{,}41V - 0{,}044V^3 \tag{7.7-8}$$

$$B = 7{,}77 - 4{,}53V + 0{,}744V^2 \tag{7.7-9}$$

$$\beta_k = \max\left(A + B\frac{d_i}{D_e};\ 1 + 0{,}5B\frac{d_i}{D_e} \right) \tag{7.7-10}$$

Replace P by $P\beta_k$ in equation (7.5-2) and in Figure 7.5-1 to arrive at the required thickness. The substitution shall be made before the calculation of β *in 7.5.3.5.* Equations (7.5-1) and (7.5-3) continue to apply without modification.

NOTE The graphs of Figure 7.7-1 and Figure 7.7-2 are based on the above procedure and give $\frac{e\,f}{P\,R}$ as a function of P/f and d_i/D_e.

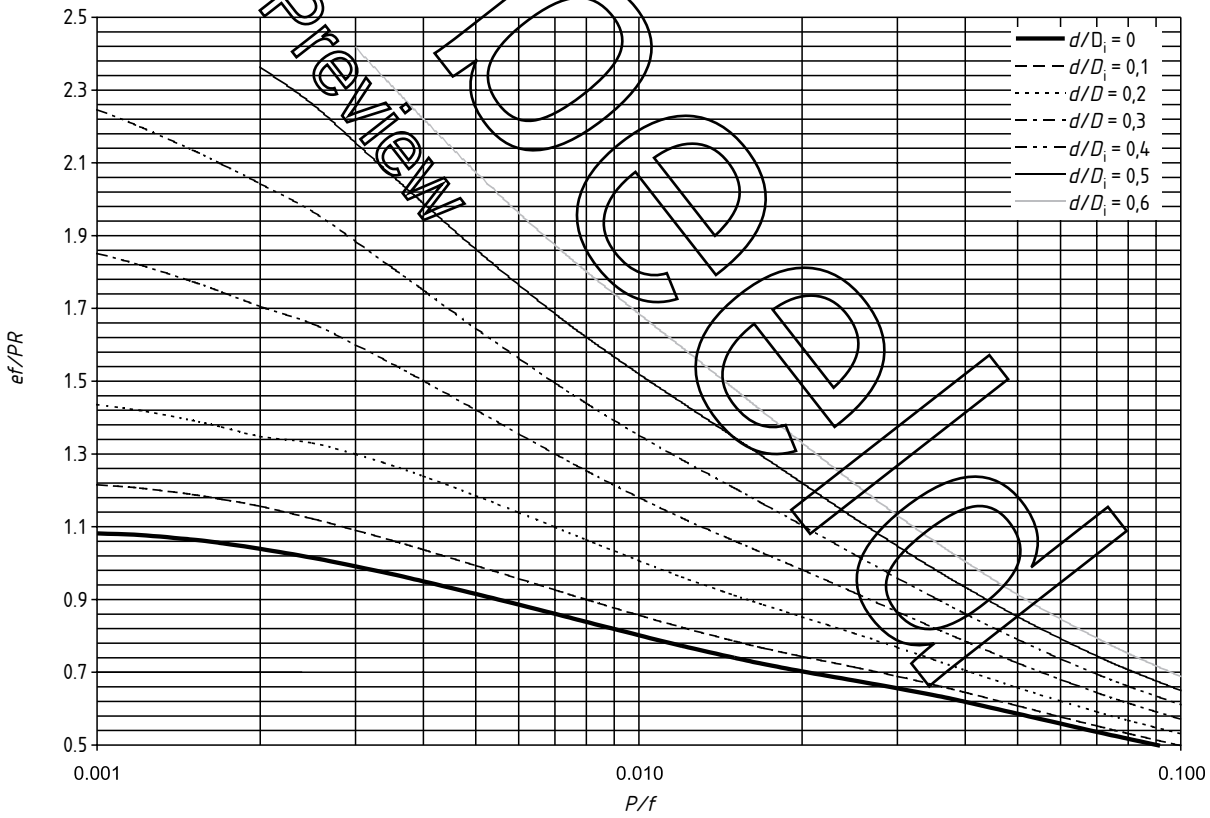

Figure 7.7-1 — Design ratio for Kloepper ends

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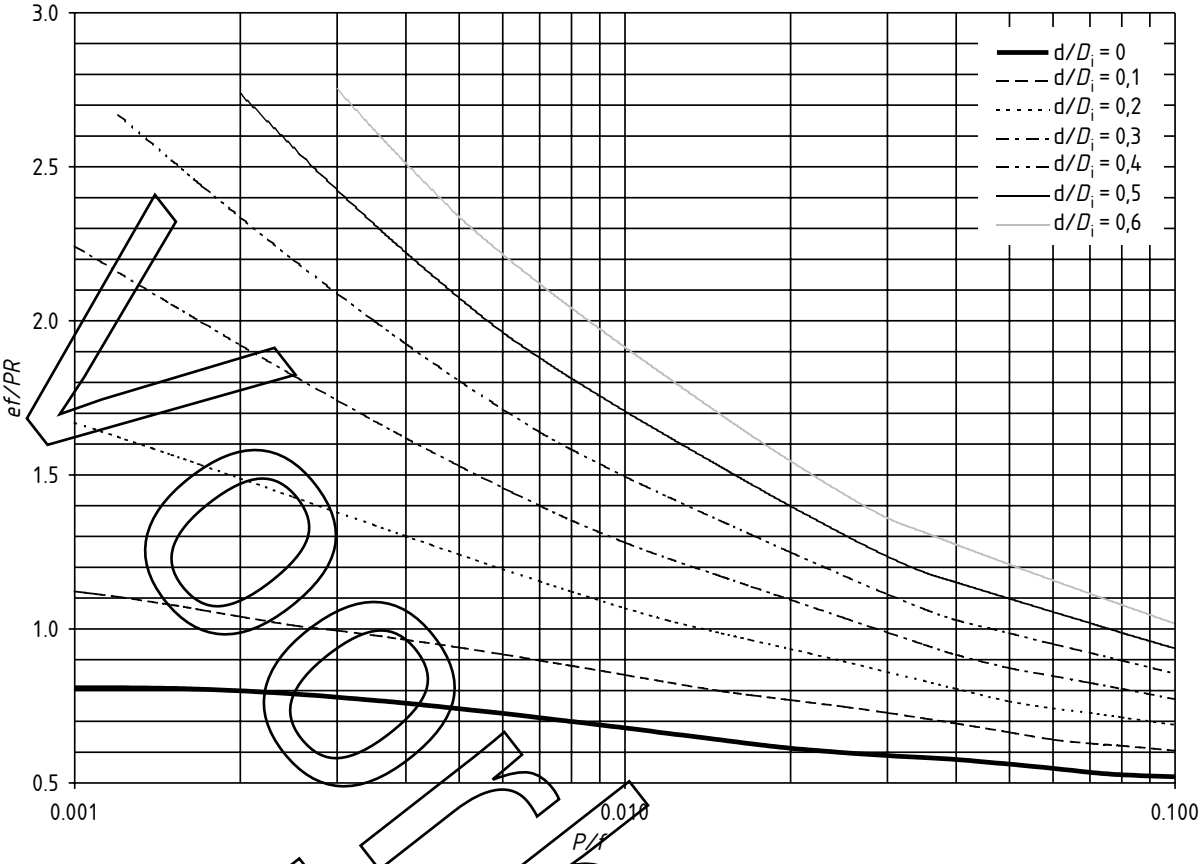

Figure 7.7-2 — Design ratio for Korbbogen end

7.7.4 Rating

To determine the maximum permissible pressure corresponding to a given geometry (rating) a trial and error procedure may be adopted. Alternatively the following procedure provides an approximate and always conservative estimate of β_k.

For Kloepper type end:

$$X = \log_{10}\left(1000\,\frac{e_a}{D_e}\right) \qquad (7.7\text{-}11)$$

$$A_1 = 1{,}07\ \max(0{,}71 - X;\ 0{,}19X + 0{,}45) \qquad (7.7\text{-}12)$$

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$$B_1 = 1{,}02\left\{\min\left((3+5X);\frac{1}{0{,}241+0{,}116\left(X-0{,}26\right)^3}\right)\right\} \quad (7.7\text{-}13)$$

$$\beta_k = \max\left(A_1 + B_1\frac{d_i}{D_e};\ 1+0{,}3B_1\frac{d_i}{D_e}\right) \quad (7.7\text{-}14)$$

For Korbbogen type end:

$$X = \log_{10}\left(1000\frac{e_a}{D_e}\right) \quad (7.7\text{-}15)$$

$$A_1 = \frac{1}{1{,}136 + 0{,}0053\left(\frac{D_e}{d_i}\right)^{0{,}8}} \quad (7.7\text{-}16)$$

$$B_1 = (8{,}87 - 4{,}35X + 0{,}19X^3) \quad (7.7\text{-}17)$$

$$\beta_k = \max\left\{(1+0{,}1\frac{d_i}{D_e})\left(A_1 + B_1\frac{d_i}{D_e}\right);\ (1+1{,}1\frac{d_i}{D_e})\left(1+0{,}5B_1\frac{d_i}{D_e}\right)\right\} \quad (7.7\text{-}18)$$

Replace β by $\beta \cdot \beta_k$ in equation (7.5-7). Equations (7.5-6) and (7.5-8) continue to apply without modification.

7.7.5 Multiple nozzles which encroach into the knuckle region

The requirements for multiple nozzles in clause 9 apply also to nozzles designed to these requirements if the ligament between adjacent nozzles is entirely within the central area defined in 9.7.4. If the connecting line between adjacent nozzles is not entirely within the central area, the ligament shall not be less than half the sum of the nozzle bores.

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