Steel profile supports for vessels

Maximum permissible moments on the vessel wall due to profile support loads

DIN 28 081 Part 4

Apparatefüße; maximale Momente in die Apparatewand durch Gewichtskräfte über Apparatefüße

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Dimensions in mm

1 Scope and field of application

The moments dealt with in this standard apply to vessel supports with reinforcement pads as specified in DIN 28 081 Part 2 for vessels with cylindrical jacket operated at atmospheric pressure or at an internal pressure of 0,5 to 6 bar.

The moments given in this standard constitute the maximum additional stress on the vessel wall permissible as a function of its thickness. They have been calculated taking into account the shape of the reinforcement pad specified in DIN 28 081 Part 2.

The design of welds on the vessel shall take into account the fact that the forces to be transmitted vary with the thickness of the vessel wall.

This standard assumes predominantly static loading on the supports, the number of which around the vessel circumference is limited by the requirement for a spacing of reinforcement pads, $\hat{l}$, amounting to $2 \cdot \sqrt{(d - s_e) \cdot s_e}$. This spacing shall also apply for the distance between supports and nozzles in both the length and the circumference of the vessel.

Note 1. The boundary lines $s_o/d_1 \approx 0{,}003$ and $s_o/d_2 \approx 0{,}003$ respectively on the graphs are intended to indicate that available empirical data show that there is no risk of buckling in the range to the right of this line.

Note 2. Where, in exceptional cases, the loading on vessel supports cannot be considered to be uniformly distributed, as is assumed in this standard, manufacturer and customer shall agree on assumptions regarding the distribution of loading.

2 Diagram

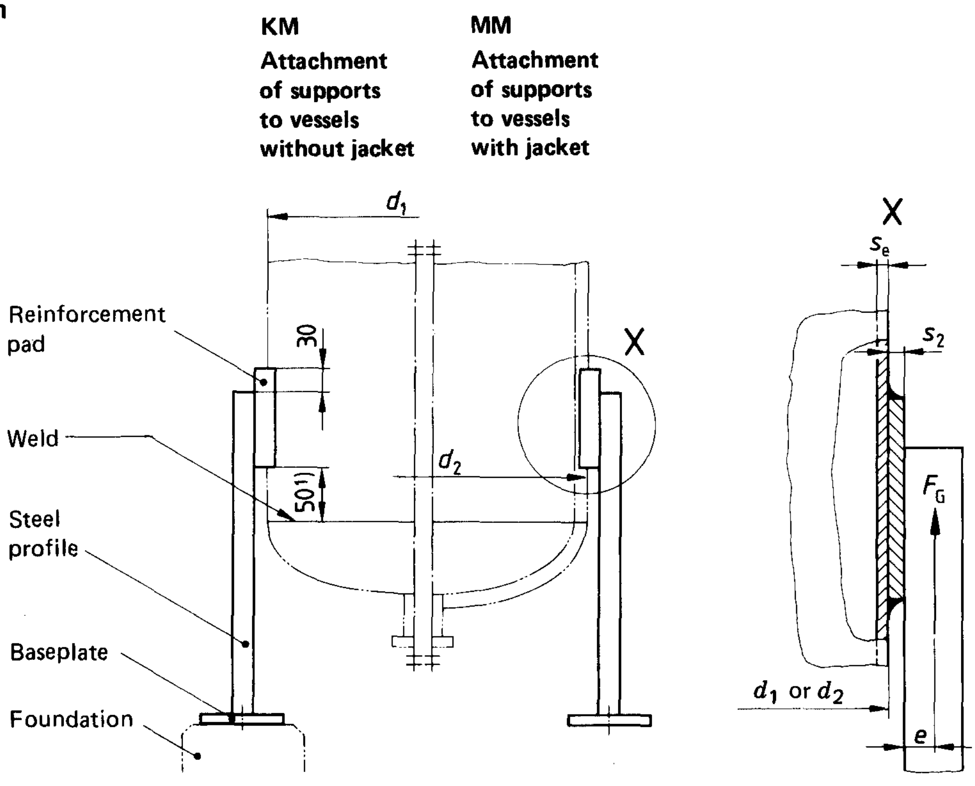

Figure 1.

1) Reduction of the distance between the edge of the reinforcement pad and the end of the vessel (weld) to less than 50 mm is unacceptable. Any increase in this distance may be agreed between manufacturer and customer.

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3 Symbols, units

Table 1.

Symbol	Unit	Quantity
c_1, c_2	mm	Safety margins as specified in *AD-Merkblatt* (AD Instruction sheet) B0
d_1	mm	Nominal diameter of vessel
d_2	mm	Jacket diameter
e	mm	Distance between centroid axis of the support profile and the reinforcement pad (lever arm)
$\hat{l}$	mm	Clear distance between reinforcement pads
n	–	Number of supports
p_e	bar	Pressure in the vessel
s	mm	Minimum thickness of vessel wall including allowances c_1, c_2
s_e	mm	Actual vessel wall thickness
s_o	mm	Vessel wall thickness minus allowances ($s_o = s_e - c_1 - c_2$)
s_2	mm	Required reinforcement pad thickness
C	–	Coefficient
F_G	N	Loading per support (including additional loads)
G	kg	Total mass of vessel including contents and additional loads
K_Θ	N/mm²	Strength ratings at permissible operating temperature
M	Nm	Moments imposed on vessel wall $\left(F_G \cdot \frac{e + s_2}{1000}\right)$
S	–	Safety factor

4 Strength of vessel wall

The moments graphs have been based on a strength rating, K_Θ, of 177 N/mm². See subclause 7.4 for conversion to other strength parameters. The strength rating, appropriate to each permitted operating temperature is given in the relevant codes of practice (e.g. series W *AD-Merkblätter*).

5 Calculation principles

In the calculation of maximum moments, the stresses from local moments described in [1] are added to the stresses generated by internal pressure, which the user is required by the relevant codes of practice (e.g. *AD-Merkblätter*) to determine.

The method assumes that the local transmission of loads into the vessel wall is a function of the shape and dimensions of the reinforcement pad as specified in DIN 28081 Part 2.

One of the two following methods may be used to determine the stress values depending on the particular application.

a) Limit analysis (see figures 2 to 6).
This method allows for partial plastic deformation in the zone of load application, the prerequisite for employing this method being the use of sufficiently ductile materials [2], [3], [4].

b) The maximum moment given by limit analysis shall be divided by 2,17 to prevent the strength rating being exceeded, with a safety factor of approximately 1,5 (to be applied in special cases).
Stresses are thereby restricted to the elastic range, as is necessary in cases where low ductile materials (e.g. steels with strength K greater than 360 N/mm² at ambient temperature) are used or vessels are given a certain type of lining.

External pressure has not been taken into consideration in the calculation of the graphs.

6 Specification of reinforcement pad thickness

The required reinforcement pad thickness, s_2, shall be determined from the loading on each support, F_G, and the lever arm, e, using the following equation:

$$s_e \leq s_2 = C \cdot \sqrt{\frac{F_G \cdot e}{K_\Theta}} \leq 1{,}5 \cdot s_e$$

Table 2 shows factor C as a function of the reinforcement pad sizes specified in DIN 28081 Part 2. See tables 1 and 3 for e.

7 Calculation method and moments graphs

7.1 The calculation procedure described in *AD-Merkblatt* S 3/4 may be used for cases not covered in this standard.

The moments graphs have been straightened to give lower values. Calculations made for an individual case may give slightly higher results.

7.2 Use of the graphs (see figures 2 to 6)

Calculate the total mass, G, by adding the mass of the contents (volume multiplied by the maximum density of contents in service or testing) to the self weight of the vessel including the additional loads (e.g. agitator, operator platform with imposed loads, pipework and possible wind load). Divide the total mass by the number of supports selected. This then gives the loading per support, F_G.

Then calculate the minimum wall thickness, $s_o = s_e - c_1 - c_2$, from the proposed finished wall thickness.

Table 2.

Reinforcement pad dimensions, $a_2 \times b_2$	144 × 150	173 × 190	160 × 230	200 × 310	260 × 430
C, in mm $-1/2$	0,116	0,087	0,074	0,053	0,04

Table 3.

Support type	L 60 × 6	L 80 × 8	U 100	IPB 100	IPB 140	IPB 200
e	18,6	24,7	34,5	50	70	100

The maximum permissible moment acting on the vessel wall for each support can be read from the appropriate graphs for the specified pressure p_e in the vessel as a function of the ratio of vessel wall thickness to vessel diameter (s_o/d_1 or s_o/d_2), interpolation between the graphs being permitted.

Once the lever arm to be applied ($e + s_2$) has been determined, the actual moment resulting for F_G can be compared with the maximum permissible moment.

Note. The distance between the centroid axis of the support profile and the vessel wall has been taken as the lever arm for the examples below (see subclauses 7.3 and 7.4), this being a conservative assumption. Further studies (stress analysis and/or strain measurements) would be necessary to determine a more realistic value.

7.3 Examples

Given:

$d_1 = 1600$ mm $\quad s_e = 12$ mm

$p_e = 6$ bar $\quad c_1 = 0{,}5$ mm

$c_2 = 1$ mm

Vessel support complying with DIN 28081 Part 2 for vessel diameter $d_1 = 1600$ mm, made from RSt 37-2 steel complying with DIN 17100. Vessel made from material H II complying with DIN 17155 with a strength rating, K_Θ, of 177 N/mm². Reinforcement pad made from either material.

$s_o = s_e - c_1 - c_2 = 10{,}5$ mm rounded to $s_o = 10$ mm.

$$F_G = \frac{M \cdot 1000}{(e + s_2)} \left[\frac{\text{Nm}}{\text{m}}\right]$$

$$s_o/d_1 = \frac{10}{1600} = 0{,}625 \cdot 10^{-2}$$

Sought:

$M_{max} = ?$ Nm $\quad F_G = ?$ N

a) Stress analysis using the limit analysis method and figure 6.

$M_{max} = 7300$ Nm

based on lever arm e taken from table 3 corresponding to the profile specified in DIN 28081 Part 2, s_2 as specified in clause 6, but at least the thickness specified in DIN 28081 Part 2.

$(e + s_2) = 50 + 10 = 60$ mm

(see note to subclause 7.2 in this respect)

$$F_{G\,max} = \frac{7300}{0{,}06} = 121\,666 \text{ N per support}$$

b) Stress analysis with a safety factor of approximately 1,5

$$M_{max} = \frac{7300 \text{ Nm}}{2{,}17} = 3364 \text{ Nm}$$

$$F_G = \frac{M_{max}}{(e + s_2)} = \frac{3364}{0{,}06} = 56\,067 \text{ N}$$

(maximum moment determined by limit analysis divided by 2,17, as specified in subclause 5 b))

7.4 The example below, which applies for both the limit analysis method and the safety factor method, may be followed in order to calculate values for other strength ratings K'_Θ on the basis of the moments graphs.

Given:

$d_1 = 2000$ mm $\quad s_o = 8$ mm

$p_e = 6$ bar $\quad K'_\Theta = 338$ N/mm²

Limit analysis

Vessel support complying with DIN 28081 Part 2 for vessel nominal diameter $d_1 = 2000$ mm, made from RSt 37-2 material complying with DIN 17100.

Reinforcement pad material identical with vessel material.

Sought:

$M_{max} = ?$ Nm

Determination of hypothetical pressure $p'_e = 6 \cdot \dfrac{K_\Theta}{K'_\Theta}$

gives $p'_e = 6 \cdot \dfrac{177}{338} = 3{,}14$ bar,

thus, according to figure 5, for 3,2 bar (moments graph 12)

and $s_o/d_1 = \dfrac{8}{2000} = 0{,}4 \cdot 10^{-2}$: $M'_{max} = 8$ kNm

and, according to figure 4 for 1,6 bar (moments graph 12)

and $s_o/d_1 = \dfrac{8}{2000} = 0{,}4 \cdot 10^{-2}$: $M'_{max} = 9$ kNm.

Interpolation for 3,14 bar gives

$$M'_{max} = 8000 + \left(\frac{9000 - 8000}{3{,}2 - 1{,}6}\right) \cdot (3{,}2 - 3{,}14) = 8037{,}5 \approx 8037 \text{ Nm}$$

from which follows

$$M_{max} = 8037 \cdot \frac{338}{177} = 15\,347 \text{ Nm.}$$