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Plastics and Plastic Lining Pressure Vessels - Part 3: Design

塑料及其衬里制压力容器

第 3 部分：设计

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Plastics and Plastic Lining Pressure Vessels - Part 3: Design

1 Scope

This Part of GB/T 35974 specifies design requirements for vessel pressure components.

This Part is applicable to the design of internal pressure-bearing plastics and lining pressure vessels.

2 Normative References

The following documents are indispensable to the application of this Standard. In terms of references with a specified date, only versions with a specified date are applicable to this Standard. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this Standard.

GB/T 150.1 Pressure Vessels - Part 1: General Requirements

GB/T 150.3 Pressure Vessels - Part 3: Design

GB/T 150.4 Pressure Vessels - Part 4: Fabrication, Inspection and Testing, and Acceptance

GB/T 25197-2010 Welded Static Non-pressurized Thermoplastic Tanks

GB/T 35974.2 Plastics and Plastic Lining Pressure Vessels - Part 2: Materials

HG/T 20592 Steel Pipe Flanges (PN designated)

HG 20606 Non-metallic Flat Gaskets for Use with Steel Pipe Flanges (PN designated)

HG/T 20678 Specification on Design of Steel Shell with Liner

JB/T 4712 (all parts) Vessel Supports

3 Design Guidelines

3.1 Pressure Diameter Product of Plastics Vessel

In terms of plastics vessels (lining vessels are not restricted here) designed in accordance with this Part, PD value (pressure diameter product) shall be not more than 150 MPa•mm.

4 Plastics Vessel

4.1 Minimum Thickness

The minimum thickness of the shell of plastics vessel after processing and forming, excluding the reserved thickness, shall be not less than 4 mm.

4.2 Internal Pressure Cylinder Design

4.2.1 Symbols and abbreviations

D_i---internal diameter of cylinder shell or head, expressed in (mm);

D_o---external diameter of cylinder shell or head, expressed in (mm);

p_c---calculating pressure, expressed in (MPa);

δ---calculating thickness of shell, expressed in (mm);

δ^e---effective thickness, expressed in (mm);

σ^{1t}---calculating stress of materials at design temperature, expressed in (MPa);

$[\sigma]^{1t}$---allowable stress of materials at design temperature, expressed in (MPa);

ϕ---welded joint coefficient.

4.2.2 Basic requirements

4.2.2.1 Formulas in this Part are applicable to the calculation of single-layer cylinder. In terms of cylinders which are molded in the method of winding, if the winded layers are already welded, they may be considered as single-layer cylinders.

4.2.2.2 Pipes shall be preferably selected in cylinder design.

4.2.2.3 Cylinder wall thickness of plastics vessels shall take an equivalent value as head thickness. In addition, the larger value in their calculation results shall be taken as the wall thickness of the entire plastics vessel.

4.2.3 Cylinder wall thickness

Determine cylinder wall thickness through hoop stress. In addition, when $D_o/D_i \leq 1.1$ is satisfied, calculate in accordance with Formula (2) or Formula (3).

$$\delta = \frac{p_c D_i}{2[\sigma]^{1t}\phi - 1.2 p_c} \quad \cdots\cdots (2)$$

When $D_o/D_i > 1.1$, cylinder's axial stress shall be calculated in accordance with Formula (9). σ^{1t} shall be not more than $[\sigma]^{1t}\phi$.

$$\sigma^{1t} = \frac{p_c}{4\delta_e} \times \frac{D_i^2}{\delta_e + D_i} \quad \cdots\cdots (9)$$

When $D_o/D_i > 1.1$, cylinder's hoop stress shall be calculated in accordance with Formula (10). σ^{1t} shall be not more than $[\sigma]^{1t}\phi$.

$$\sigma^{1t} = \frac{p_c}{4\delta_e} \times \frac{(2\delta_e + D_i)^2 + D_i^2}{\delta_e + D_i} \quad \cdots\cdots (10)$$

4.3 Head Design

4.3.1 Symbols and abbreviations

D_c---internal diameter of conical shell calculation, expressed in (mm);

D_i---internal diameter of cylinder shell or head, expressed in (mm);

D_{iL}---internal diameter of larger end of conical head, expressed in (mm);

D_{is}---internal diameter of smaller end of conical head, expressed in (mm);

h_i---inner surface depth of ellipsoidal head, expressed in (mm);

K---shape factor of ellipsoidal head;

M---shape factor of dished head;

p_c---calculating pressure, expressed in (MPa);

R_i---inner radius of equivalent spherical shell of dished head, expressed in (mm);

r---inner radius of the arc of conical shell larger end transition zone, or inner radius of the corner of dished head transition zone, expressed in (mm);

r_s---inner radius of the arc of conical shell smaller end transition zone, expressed in (mm);

α---semi-vertical angle of conical shell, expressed in (°);

δ---calculating thickness of ellipsoidal shaped or dished head, expressed in (mm);

δ_c---calculating thickness of conical shell, expressed in (mm);

δ_r---calculating thickness of conical shell folding edge transition section, expressed in

A_1---conversion factor of specific strength effect; please refer to Appendix C in GB/T 25197-2010;

A_{2k}---conversion factor of medium influence; please refer to Appendix C in GB/T 25197-2010;

α---welded joint thickness, expressed in (mm);

b---doubled Flange effective width, expressed in (mm);

b_D---gasket width, expressed in (mm);

C---corrosion allowance, expressed in (mm);

C_1---constant of welding technique;

d_a---external diameter of Flange, expressed in (mm);

d_D---average diameter of gasket, expressed in (mm);

d_i---internal diameter of Flange pipe, expressed in (mm);

d_K---bolt root diameter, expressed in (mm);

d_L---bolt hole diameter, expressed in (mm);

d_1---internal diameter of loose Flange, expressed in (mm);

d_t---center diameter of Flange bolt hole, expressed in (mm);

d_2---average diameter of contact torus of Flange and loose Flange ring, expressed in (mm);

d_3---the sum of d_1 and two times of Flange chamfered curvature radius; please refer to Figure 10; expressed in (mm);

d'_L---reduced bolt hole diameter, expressed in (mm);

f_1---welding groove depth, expressed in (mm);

h_D---gasket thickness, expressed in (mm);

h_F---Flange thickness, expressed in (mm);

K---creep strength at design temperature and designed service life; please refer to Appendix C in GB/T 25197-2010; expressed in (MPa);

K_D---deformation resistance of gasket materials, expressed in (MPa);

K_{F1}---allowable yield stress of compression gasket materials (metal), expressed in

(MPa);

K_{Schr}---allowable yield stress of bolt materials, expressed in (MPa);

K'---creep strength under test conditions (temperature and time), expressed in (MPa);

k_o---gasket's eigenvalues under installation conditions, expressed in (mm);

k_1---gasket's eigenvalues under operating conditions, expressed in (mm);

L_a---Flange neck height, expressed in (mm);

l---lever arm of bolt force, expressed in (mm);

n---number of bolts;

P_{DV}---installation force, expressed in (N);

P_{SB}---bolt force under operating conditions, expressed in (N);

P_{SO}---bolt force under installation conditions, expressed in (N);

P'_{SB}---bolt force under test pressure, expressed in (N);

p---operating pressure, expressed in (MPa);

S---safety factor;

S_M---safety factor of metal under operating conditions;

S'_M---safety factory of metal under test and installation conditions;

t---wall thickness of tank body, expressed in (mm);

V---damping coefficient;

W---take the maximum value of W_1, W_2 and W_3, expressed in (mm^3);

W_1, W_2 and W_3---Flange's flexural modulus, expressed in (mm^3);

y_1, y_2---force arm acting on O-shaped ring, expressed in (mm);

β---chamfering, expressed in (°).

4.4.2 Basic requirements

The selection of Flange structural type shall guarantee airtightness. Loose Flange structural type should be selected.

Sealing elements shall adopt an entire gasket or O-shaped gasket. In the selection of

4.5.1 Symbols and abbreviations

A---reinforced cross-sectional area needed for opening weakening, expressed in (mm^2);

A_e---reinforcement area, expressed in (mm^2);

A_1---shell's effective thickness minus surplus area excluding calculating thickness, expressed in (mm^2);

A_2---connecting pipe's effective thickness minus surplus area excluding calculating thickness, expressed in (mm^2);

A_3---cross-sectional area of welding materials, expressed in (mm^2);

A_4---additional reinforcement area within effective reinforcement range, expressed in (mm^2);

B---effective width of reinforcement, expressed in (mm);

C_2---reserved thickness, expressed in (mm);

D_i---internal diameter of cylinder, expressed in (mm);

d---mid-diameter of connecting pipe, expressed in (mm);

d_o---external diameter of connecting pipe, expressed in (mm);

d_{op}---opening diameter, expressed in (mm);

h_1---effective reinforcement height of outreached connecting pipe, expressed in (mm);

δ---calculating thickness of shell's opening, expressed in (mm);

δ_e---effective thickness of shell's opening, expressed in (mm);

δ_n---nominal thickness of shell's opening, expressed in (mm);

δ_{nt}---nominal thickness of connecting pipe, expressed in (mm);

δ_{et}---effective thickness of connecting pipe, expressed in (mm);

δ_t---calculating thickness of connecting pipe, expressed in (mm).

4.5.2 Basic requirements

4.5.2.1 Principle

This stipulation is applicable to the opening and its reinforcement calculation of plastics vessel. The method of opening and reinforcement calculation shall comply with area equalization method.

4.5.2.2 Application scope of area equalization method

Area equalization method is applicable to shell's round opening under the effect of pressure. The scope of application is as follows:

a) When cylinder's internal diameter $D_i \leq$ 1,000 mm, opening's maximum diameter $d_{op} \leq D_i/3$. When cylinder's internal diameter $D_i >$ 1,000 mm, opening's maximum diameter $d_{op} \leq D_i/3$; in addition, $d_{op} \leq$ 450 mm;

b) The maximum diameter of convex head opening $d_{op} \leq D_i/3$;

c) The maximum diameter of conical head opening $d_{op} \leq D_i/3$; D_i is conical shell's internal diameter in the center of the opening;

d) The spacing (spacing on curved surface shall be calculated by arc length) of two opening centers on the shell shall be not less than the sum of the diameter of the two openings;

e) In terms of opening on ellipsoidal head, opening range shall not exceed 80% of the diameter of the ellipsoidal head center;

f) In terms of opening on dished head, opening range shall not exceed the spherical part of the dished head.

4.5.2.3 Welded joints near openings

Openings on the vessel shall avoid vessel's welded joints. When openings are close to vessel's welded joints, it shall be guaranteed that welded joints shall not manifest any excessive defects within the $2d_{op}$ range of opening center.

4.5.3 Reinforcement structural type and reinforcement material

4.5.3.1 Reinforcement ring

Please refer to Table 3 for the welded structure of reinforcement ring, connecting pipe and shell.

Table 3 -- Welded Structure of Reinforcement Ring, Connecting Pipe and Shell

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