SLOVENSKI STANDARD

SIST EN 13923:2006

01-marec-2006

Monofilno navite tlaļ ne posode iz FRP ï Materiali, naļ rtovanje, izdelava in preskuġanje

Filament-wound FRP pressure vessels - Materials, design, manufacturing and testing

Fadengewickelte Druckbehälter aus textilfaserverstärkten Kunststoffen - Werkstoffe, Konstruktion, Herstellung und Prüfung

Récipients sous pression en PRV par enroulement filamentaire - Matériaux, conception, fabrication et essais

Ta slovenski standard je istoveten z: EN 13923:2005

ICS:

23.020.30

SIST EN 13923:2006 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13923

November 2005

ICS 23.020.30

English Version

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This European Standard was approved by CEN on 22 September 2005.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Ref. No. EN 13923:2005: E

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Foreword

This European Standard (EN 13923:2005) has been prepared by Technical Committee CEN/TC 210 “GRP tanks and vessels”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at the latest by May 2006.

This European Standard falls under the Pressure Equipment Directive (PED) and supports essential requirements of this EC Directive.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this European Standard.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This European Standard specifies two design methods for filament wound GRP pressure vessels. In this European Standard only the winding is considered in the calculation of the strength and the stiffness of the shell.

Method A, describes the calculation of the reinforcement of the cylindrical shell and the end domes based on netting theory. The design is verified by prototype testing.

Method B, describes the calculation of the reinforcement of the cylindrical shell and the end domes based on laminate theory.

The design and manufacture of filament wound GRP pressure vessels involve a number of different materials, such as resins, thermoplastics and reinforcement fibres. It is implicit that vessels conforming to this European Standard should be made only by manufacturers and operators who are competent and suitably equipped to fulfil all requirements, using materials manufactured by competent and experienced material manufacturers.

This European Standard specifies stress and strain limits and the requirements for the acceptance testing.

1 Scope

This European Standard specifies the requirements for the design including raw materials, calculation, manufacturing including composite materials, and testing of seamless Glass Reinforced Plastic (GRP) pressure vessels with protective layer, using only multi-directional filament winding, made in a factory and for use above ground and for storage and processing of fluids.

This European Standard covers vessels subject to pressures below 20 MPa and temperatures between – 30 °C and 120 °C.

Excluded from this European Standard are transportation vessels, double wall vessels, vessels under negative pressure, vessels which are subjected to the risk of explosion or failure of which may cause an emission of radioactivity.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13121-1:2003, *GRP tanks and vessels for use above ground — Part 1: Raw materials — Specification conditions and acceptance conditions*

EN 13121-2:2003, *GRP tanks and vessels for use above ground — Part 2: Composite materials — Chemical resistance*

prEN 13121-3:2004, *GRP tanks and vessels for use above ground — Part 3: Design and work-manship*

EN ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites (ISO 527-4:1997)*

EN ISO 14129, *Fibre-reinforced plastic composites — Determination of the in-plane shear stress/shear strain response, including the in-plane shear modulus and strength, by ± 45° tension test method (ISO 14129:1997)*

EN ISO 75-2:2004, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite and long-fibre-reinforced composites (ISO 75-2:2004)*

EN ISO 75-3, *Plastics — Determination of temperature of deflection under load — Part 3: High-strength thermosetting laminates (ISO 75-3:2004)*

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

3 Terms and definitions

For the purpose of this European Standard, the following terms and definitions apply.

3.1
manufacturer
organisation that manufactures the vessel in accordance with this European Standard

3.2
material manufacturer
organisation that manufactures the specific material (e.g. resin, glass fibre or catalyst). The material manufacturer may also be the “supplier”

3.3
purchaser
organisation or individual that purchases the vessel

3.4
supplier
organisation that supplies materials or products to the manufacturer for use in manufacturing the vessel. The supplier may be either the material manufacturer or an intermediary

3.5
pressure vessel
housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber

3.6
protective layer
chemical resistant layer (CRL) or a thermoplastic lining (TPL) in accordance with Clause 4 of EN 13121-2:2003, intended to serve as a barrier against chemical attack of the structural laminate and to prevent leakage

3.7
pressure
pressure relative to atmospheric pressure, i.e. gauge pressure. As a consequence, vacuum is designated by a negative value

3.8
maximum allowable pressure PS
maximum operating pressure for which the equipment is designed, as specified by the manufacturer. This is identical to the design pressure

3.9
maximum/minimum allowable temperature TS
maximum/minimum temperature for which the equipment is designed, as specified by the manufacturer. The maximum allowable temperature is identical to the design temperature

3.10
lamina
ply or layer of glass reinforced thermosetting resin

3.11
laminate
composite structure consisting of one or more lamina

3.12
filament winding
production technique for winding of continuous filaments of glass fibre with the specified resin system applied in a systematic manner and cured on a mandrel or other supporting structure

3.13
chemical resistant layer (CRL)
protective layer in accordance with 4.3 of EN 13121-2:2003

3.14
thermoplastic lining (TPL)
protective layer in accordance with 4.4 of EN 13121-2:2003

3.15
contact layer
layer to increase adhesion between TPL and structural laminate

3.16
hoop winding
winding for which the fibre direction is perpendicular to the rotation axis of the vessel

3.17
helical winding
winding for which the angle between the fibre direction and the rotation axis is not 0° or 90°

3.18
prototype
pressure vessel with the same diameter and end domes, manufactured with the same material and winding specifications using the same manufacturing techniques as a production vessel, but used only for testing purposes

3.19
pigment
component added to change the natural colour of the resin

4 Symbols and abbreviated terms

For the purpose of this European Standard, the symbols and abbreviated terms shall be used according to Table 1.

Table 1 — Symbols and abbreviated terms

Symbol	Term	Unit
b	width	mm
h	height	mm
m_f	fibre content by mass	—
PS	design pressure	MPa
p_{crit}	critical pressure	MPa
r	radial co-ordinate	mm
r_p	radius of polar opening	mm
t	wall thickness	mm
t_h	thickness of the helical windings	mm
t_c	thickness of the circumferential windings	mm
w_i	weight of part i of the shell	N
A	material weakening factor	—
A_1, ... A_5	partial design factors	—
C	shape factor	—
D_a	internal diameter of winding laminate	mm
E_1, E	modulus of elasticity in the fibre direction	MPa
E_2	modulus of elasticity perpendicular to the fibre direction	MPa
l	length of shell	mm
K	design factor	—
M_f	fibre reinforcement content per square meter	kg/m²
M_w	wind moment on the shell	Nmm
M_ϕ	bending moment in longitudinal direction	Nmm/mm
M_θ	bending moment in circumferential direction	Nmm/mm
N_ϕ	stress resultant in longitudinal direction	N/mm
N_θ	stress resultant in circumferential direction	N/mm
P	probability	%
R	radius of a end-dome	mm
S	safety factor	—
TSHL	Tsai-Hill criterion	—
V_f	fibre volume fraction	—
α	winding angle	°
ρ_f	density of the fibre	kg/m³
ρ_r	density of the resin	kg/m³

Table 1 (*concluded*)

σ	stress	MPa
τ	shear stress	MPa
ε	strain	%
ε_n	strain normal to the fibre direction	%
υ_{12}	Poisson's ratio	—
TS	design temperature	°C
HDT	heat deflection temperature	°C
ε_{max}	maximum allowable strain	%
ε_{lim}	strain limit	%
G	in-plane shear modulus	MPa
X_t	ultimate longitudinal tensile strength	MPa
X_c	ultimate longitudinal compressive strength	MPa
Y_t	ultimate transversal tensile strength	MPa
Y_c	ultimate transversal compressive strength	MPa
S_s	in-plane shear strength	MPa

5 General

The manufacturer shall obtain from the purchaser sufficient information to undertake the product design and construction in accordance with the requirements of this European Standard:

— vessel volume and the vessel fluid;

— maximum operating pressure including the alternating pressure;

— maximum operating temperature including the alternating temperature;

— additional data shall be supplied on any stresses occurring as a result of operation (pressures, pipe work, extremes of temperature, fluids, wind etc.), sequential filling or emptying of the vessel, the application and removal of the pressure.

6 Materials

6.1 General

The composite materials, hereinafter referred to as "composites" are characterised by matrix materials based on thermosetting resins by the quantity and order of reinforcing fibre and by the laminating or the moulding process for the protective layer and the winding process for the structural laminate.

The components of composites hereinafter are referred to as "raw materials". Raw materials acceptance conditions and usage conditions shall be in accordance with EN 13121-1 and the exceptions or restrictions listed in 6.2.

The chemical resistance of composites shall be in accordance with EN 13121-2 and the exceptions or restrictions are listed in 6.3.

6.2 Raw materials

6.2.1 Reinforcements

In the structural laminate continuous roving in accordance with 6.6 and 9.11 of EN 13121-1:2003 shall only be used.

In the CRL chopped strand mats in accordance with 6.3 and 9.9 of EN 13121-1:2003 or chopped roving in accordance with 6.6 and 9.11 of EN 13121-1:2003 shall be used.

6.2.2 Resins

In the structural laminate UP-resins in accordance with 4.1, 4.2, 9.1 and 9.2 of EN 13121-1:2003, VE-resins in accordance with 4.1, 4.3, 9.1 and 9.2 of EN 13121-1:2003 and EP-resins in accordance with 4.1, 4.4, 9.1 and 9.3 of EN 13121-1:2003 shall be used.

6.2.3 Thermoplastic lining materials

In addition to those thermoplastic materials listed in 8.1 of EN 13121-1:2003, other thermoplastic materials may be used if they meet the requirements of workmanship and service conditions. Specifications and technological data for these materials shall be confirmed by the thermoplastic material manufacturer according to the general requirements in Clause 8 and 9.12 of EN 13121-1:2003.

The range of thickness of thermoplastic linings shall be specified by the manufacturer.

Using PE linings the minimum shear strength to the structural laminate shall be 5 N/mm^2 when tested at maximum operating temperature in accordance with D.8 of prEN 13121-3:2004. If necessary, a contact layer to the structural laminate may be used.

6.2.4 Pigments

Pigments are allowed in the structural laminate only in case of vessels designed according to method A. The amount of pigment is restricted by recommendations from the supplier or resin manufacturer.

6.3 Chemical resistance

6.3.1 Reinforcements

Type of fibre, listed in 6.2.1, shall be in accordance with A.3 of EN 13121-2:2003.

6.3.2 Resins

Resins, listed in 6.2.2, shall be used in accordance with Clause 5 of EN 13121-2:2003. EP-resins are only to be used according to 5.3, 5.5 or 5.6 of EN 13121-2:2003.

6.3.3 Thermoplastic lining material

Thermoplastic materials shall be used in accordance with Clause 5 of EN 13121-2:2003. Other thermoplastics are only to be used according to 5.4, 5.5 or 5.6 of EN 13121-2:2003.

6.4 Characteristics values for calculations

6.4.1 General

The manufacturer shall determine the required mechanical properties of all reinforcing lamina. There are four elastic constants and five strength constants that can be determined for a lamina. For design calculations only the constants E_1, E_2, G, ν_{12}, X_t, X_c, Y_t, Y_c and S_s (for definitions see Clause 4) needed shall be determined.

The mechanical properties of the individual lamina shall be used for the design calculations of the laminate according to Clause 8 and Clause 9.

6.4.2 Test specimen

Test specimen for filament wound laminate shall be made from a unidirectional wound flat panel made according to Annex A. The test specimen shall be made from the same materials as determined in the production specification. The flat test specimen shall have a representative thickness, the curved test specimen shall have a representative thickness to diameter ratio. The fibre content of the test specimen shall be as specified in Clause 8 and Clause 9 with a tolerance of + 0 % and – 10 %. Winding patterns shall be achieved to within ± 5° of the specified angle. The number of test specimen shall be in accordance with the value of the partial design factor for dispersion (see 7.2.2).

6.4.3 Elastic properties

6.4.3.1 E_1-modulus

The E_1-modulus for a filament wound laminate shall be determined either by performing an uniaxial tensile test according to EN ISO 527-4 on a flat test panel according to Annex A. The Poisson ratio ν_{12} shall be determined from the same test, from the measurement of longitudinal and transverse strains.

6.4.3.2 E_2-modulus

The E_2-modulus for a filament wound laminate shall be determined by performing a uniaxial tensile test according to EN ISO 527-4 on a test panel according to Annex A.

6.4.3.3 G-modulus

The shear modulus G for a filament wound laminate shall be determined by performing a shear test according to EN ISO 14129.

6.4.4 Strength properties

6.4.4.1 The longitudinal strength

The longitudinal strength X for a filament wound laminate shall be determined by performing a uniaxial tensile test according to EN ISO 527-4 on a test panel according to Annex A.

6.4.4.2 The transverse strength

The transverse strength Y for a filament wound laminate shall be determined either by performing a uniaxial tensile test according to EN ISO 527-4 on a test panel according to Annex A.

6.4.4.3 The shear strength

The shear strength S_s for a filament wound laminate shall be determined by a shear test according to EN 14129 on a flat test panel.

6.4.5 Test report

The results of the tests in accordance with 6.4.3 and 6.4.4 shall be documented in a report which shall become a part of the "Design documentation", as described in Clause 10.

7 Design

7.1 General

This European Standard contains two methods for the design of filament wound GRP pressure vessels.

The thickness of the vessel parts designed by method A shall be determined by the calculation method given in Clause 8 and the design shall be confirmed by prototype testing according to 8.3.

The thickness of the vessel parts designed by method B shall be determined by the calculation method given in 9.1.

Filament wound pressure vessels shall be designed so that any developing distortions and changes in material properties do not impair the safety of the component part, not even during long-term stressing. This shall be approved in tests according to Clause 6 and Clause 12.

The design shall take into account the maximum difference in fluid pressure which can occur under the service conditions as specified in the design specification, between the inside and the outside of the vessel wall or between two chambers.

The protective layer shall not be included in the determination of the required wall thickness. However, the weight of the protective layer shall be taken into account when determining loading other than pressure. The protective layer shall be designed so that it extends completely through all openings in the vessel.

7.2 The design factor

7.2.1 General

The allowable stresses in each layer of the load-bearing material are derived from the characteristic values for elasticity and strength, the material-independent safety factor S and the partial design factors to account for the influence of inhomogeneities and dispersion (A_1), chemical environment (A_2), design temperature versus heat resistance (A_3) and long term behaviour (A_5). The protective layer shall be ignored in strength calculations. The design factor K shall be determined from the Equation (1).

$$K = S \times A_1 \times A_2 \times A_3 \times A_4 \times A_5 \quad (1)$$

The safety factor S shall be 2,0.

The partial design factors A_1 to A_5 in Table 2 apply only if it can be demonstrated that the requirements according to 6.4 and the conditions given in 7.2.2 to 7.2.6 are strictly observed.

The partial design factors A_1 to A_5 may be reduced if justified by long-term tests on representative material samples or by strain measurements or by long-term pressure tests on representative vessel samples and if such a reduction is confirmed by material quality specifications. The product of two or more partial design factors can be determined by one test.

The design factor K shall not be less than 4,0.