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**Polyethylene reinforced with short
glass fibres (PE-sGF) piping systems
for industrial applications —**

**Part 1:
General**

*Systèmes de canalisations en polyéthylène renforcé de fibres de verre
courtes (PE-sGF) pour les applications industrielles —*

Partie 1: Généralités

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 3, *Polyethylene reinforced with short glass fibres (PE-sGF) piping systems for industrial applications*.

A list of all parts in the ISO 22101 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Polyethylene reinforced with short glass fibres (PE-sGF) piping systems are pipe systems which consist of pipes produced by adding short glass fibres into high density polyethylene resins. Their physical and mechanical properties are influenced by short glass fibre orientation.

The technology of production of PE-sGF pipes is completely different from that traditionally used during PE pipes extrusion. For this reason, this document makes reference to standard inside diameter ratio (SIDR) sized pipe. To prevent the confusion, the standard dimension ratio (SDR) size pipe, commonly used for PE products, is not used in this document.

The PE-sGF system is intended to be used for general purpose liquid fluids supply (e.g. chemical plants, industrial sewerage engineering, power plants, agricultural production plants, water treatment).

For the material subject of this document, the mechanical performances are obtained on the basis of International Standards dedicated to thermoplastics. The geometrical characteristics are defined exclusively for this material in line with ISO 3 and ISO 4065.

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Polyethylene reinforced with short glass fibres (PE-sGF) piping systems for industrial applications —

Part 1: General

1 Scope

This document specifies the general aspects of short glass fibre reinforced polyethylene (PE-sGF) piping systems, manufactured by the spiral cross winding method, which are used below ground for the conveyance of liquid fluids for the following industrial and agricultural uses:

- chemical plants;
- industrial sewerage engineering;
- power engineering (cooling and general-purpose water supply);
- agricultural production plants;
- water treatment;
- small hydraulic power plants (general-purpose water supply).

In conjunction with the other parts of the ISO 22101 series, this document applies to PE-sGF pipes, fittings and their joints with each other, with other PE-sGF components, and to components from other materials intended for use under the following conditions:

- a) allowable operating pressure (PFA) up to and including 25 bar¹⁾;
- b) operating temperature of 20 °C as the reference temperature.

NOTE For other operating temperatures, guidance is given in [Annex A](#).

Other application areas differing from those listed in the scope can be permitted if the requirements of this document and/or relevant national requirements are taken into account. Drinking water applications are outside the scope of this document.

This document covers only PE-sGF using glass fibre with lengths comprised in the range between 3 mm and 5 mm.

Components conforming to any of the documents listed in the Bibliography or to national standards, as applicable, can be used with components conforming to this document, provided that they conform to the requirements for joint dimensions and to the relevant requirements of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 179-1, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 1133-1, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 1: Standard method*

ISO 1167-1, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General method*

ISO 1167-2, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 2: Preparation of pipe test pieces*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 1183-2, *Plastics — Methods for determining the density of non-cellular plastics — Part 2: Density gradient column method*

ISO 1887, *Textile glass — Determination of combustible-matter content*

ISO 1888, *Textile glass — Staple fibres or filaments — Determination of average diameter*

ISO 2078, *Textile glass — Yarns — Designation*

ISO 3344, *Reinforcement products — Determination of moisture content*

ISO 4427-1, *Plastics piping systems for water supply and for drainage and sewerage under pressure — Polyethylene (PE) — Part 1: General*

ISO 6259-1, *Thermoplastics pipes — Determination of tensile properties — Part 1: General test method*

ISO 6259-3, *Thermoplastics pipes — Determination of tensile properties — Part 3: Polyolefin pipes*

ISO 7510, *Plastics piping systems — Glass-reinforced plastics (GRP) components — Determination of the amounts of constituents*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

ISO 9969, *Thermoplastics pipes — Determination of ring stiffness*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications — Classification, designation and design coefficient*

ISO 13479, *Polyolefin pipes for the conveyance of fluids — Determination of resistance to crack propagation — Test method for slow crack growth on notched pipes*

ISO 13967, *Thermoplastics fittings — Determination of ring stiffness*

ISO 15512, *Plastics — Determination of water content*

ISO 15853, *Thermoplastics materials — Preparation of tubular test pieces for the determination of the hydrostatic strength of materials used for injection moulding*

ISO 16770, *Plastics — Determination of environmental stress cracking (ESC) of polyethylene — Full-notch creep test (FNCT)*

ISO 22314, *Plastics — Glass-fibre-reinforced products — Determination of fibre length*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Terms related to geometry

3.1.1

nominal wall thickness

e_n

numerical designation of the wall thickness of a component, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres, corresponding to the minimum wall thickness, e_{\min}

3.1.2

wall thickness at any point

e

measured wall thickness at any point around the circumference of a component, rounded up to the nearest 0,1 mm

3.1.3

mean wall thickness

e_m

arithmetic mean of a number of measurements regularly spaced around the circumference of the component in the same cross-section of the component, including the measured minimum and the measured maximum values of the wall thickness

3.1.4

pipe series

S_i

dimensionless number for pipe designation in accordance with the following formula:

$$S_i = \frac{R_{\text{SID}} + 1}{2}$$

where R_{SID} is the standard inside dimension ratio (SIDR), and S_i is the pipe designation

Note 1 to entry: The relationship between the pipe series, S_i , and the standard inside dimension ratio (SIDR), is given in 3.1.5.

3.1.5

standard inside dimension ratio

SIDR

R_{SID}

ratio of the nominal inside diameter, d_i , of a pipe to its nominal wall thickness, e_n

Note 1 to entry: The standard inside dimension ratio (SIDR) and the pipe series, S_i , are related as shown in the following formula, where R_{SID} is the SIDR:

$$R_{\text{SID}} = 2S_i - 1$$

3.1.6

nominal size

DN/ID

numerical designation of the size of a component related to the inside diameter, other than a component designated by a thread size, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres

3.1.7

nominal inside diameter

d_{in}

specified inside diameter, in millimetres, assigned to a nominal size, DN/ID

3.1.8

inside diameter at any point

d_i

value of the measurement of the inside diameter through its cross-section at any point of the pipe, except the socket, rounded to the next greater 0,1 mm

3.1.9

mean inside diameter

d_{im}

value of the measurement of the inner circumference of the pipe in any cross-section, except the socket, divided by π (= 3,142), rounded to the next greater 0,1 mm

3.1.10

ring stiffness

mechanical characteristic of a pipe or fitting which is a measure of the resistance to ring deflection under an external force

Note 1 to entry: For the purposes of this document, the external force shall be determined in accordance with ISO 9969 (for pipes) and ISO 13967 (for fittings).

3.2 Terms related to material

3.2.1

virgin material

material in a form such as granules that has not been subjected to use or processing other than that required for its manufacture and to which no reprocessible or recyclable materials have been added

3.2.2

PE-sGF compound

compound (compound, short glass fibre and coupling agent) from which the pipes and fittings are produced

Note 1 to entry: This material is made by adding to the PE compound glass fibre and those additives necessary for the manufacture and end use of the products, in accordance with the requirements of the applicable part of this document.

3.2.3

short glass fibre

chopped glass fibre with a low length to diameter aspect ratio

Note 1 to entry: Short glass fibres used for the production of PE-sGF compound can be either alumina-boro-silicate glass or alumina-talco-silicate glass in the form of chopped strands.

3.2.4

coupling agent

substance used in small proportions to increase the adhesion to specific substrates

3.3 Terms related to material characteristics

3.3.1

lower confidence limit of the predicted hydrostatic strength

σ_{LPL}

quantity, with the dimensions of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength at a temperature and time.

Note 1 to entry: It is expressed in megapascals (MPa).

3.3.2

minimum required strength

MRS

$F_{r,min}$

value of the lower confidence limit σ_{LPL} at 20 °C and 50 years rounded down to the next value in the R10 series as defined in ISO 3 when σ_{LPL} is less than 20 MPa or down to the next value in the R20 series as defined in ISO 3 when σ_{LPL} is greater than or equal to 20 MPa

Note 1 to entry: The minimum required strength is expressed in megapascals (MPa).

3.3.3

design stress

σ_s

allowable stress for a given application at 20 °C that is derived from the MRS by dividing it by the design coefficient, C

Note 1 to entry: Design stress is expressed with the following formula, where $F_{r,min}$ is the minimum required strength (MRS):

$$\sigma_s = \frac{F_{r,min}}{C}$$

Note 2 to entry: Design stress is expressed in megapascals (MPa).

3.3.4

design coefficient

C

coefficient with a value greater than 1, which takes into consideration service conditions as well as properties of the components of a piping system other than those represented in the lower confidence limit

3.3.5

melt flow rate

MFR

value relating to the viscosity of the molten material at a specified temperature and load

3.3.6

sGF orientation angle

θ

angle, the value of which is provided by the extension and elongation flow of the extruder in the winding process

Note 1 to entry: The physical and mechanical properties of PE-sGF piping systems are influenced by this orientation angle.

3.4 Terms related to service conditions

3.4.1

maximum allowable pressure

PS

$\rho_{a,max}$

numerical designation used for reference purposes and related to the mechanical characteristics of the components of a piping system

Note 1 to entry: For plastic piping systems conveying fluids, PS corresponds to the allowable operating pressure (PFA) in bar, which can be sustained with water at 20 °C with a design basis of 50 years, and based on the minimum design coefficient, in accordance with the following formula:

$$\rho_{a,max} = \frac{20 \times F_{r,min}}{C \times (R_{SID} + 1)}$$

where

$\rho_{a,max}$ is the maximum allowable pressure (PS);

$F_{r,min}$ is the minimum required strength (MRS);

C is the design coefficient;

R_{SID} is the standard inside dimension ratio (SIDR).

Note 2 to entry: 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

3.4.2

hydrostatic stress

σ

stress induced in the wall of a pipe when an internal hydrostatic pressure is applied

Note 1 to entry: The hydrostatic stress, in megapascals, is related to the applied internal hydrostatic pressure, ρ , the wall thickness, e , at any point and the mean outside diameter, d_{em} , of a pipe and calculated using the following formula:

$$\sigma = \rho \times \frac{d_{em} - e}{2 \times e}$$

Note 2 to entry: This formula is applicable to pipes only.

3.4.3

allowable operating pressure

maximum hydrostatic pressure that a component is capable of withstanding in continuous service

4 Symbols and abbreviated terms

4.1 Symbols

C design coefficient

d_{em} mean outside diameter

d_i	nominal inside diameter
d_{im}	mean inside diameter
d_{in}	nominal inside diameter
d_n	nominal outside diameter
e	wall thickness (at any point)
e_m	mean wall thickness
e_{max}	maximum wall thickness (at any point)
e_{min}	minimum wall thickness (at any point)
e_n	nominal wall thickness
f_T	pressure reduction coefficient
f_A	derating factor related to the liquid fluid application type
$F_{r,min}$	minimum required strength (MRS)
R_{SID}	standard inside dimension ratio (SIDR)
T	temperature
t	time
σ	hydrostatic stress
σ_h	hoop stress
σ_{LPL}	lower confidence limit of the predicted hydrostatic strength
σ_s	design stress
ρ	internal hydrostatic pressure
$\rho_{a,max}$	maximum allowable pressure (PS)
$\rho_{o,a}$	allowable operating pressure
θ	sGF orientation angle

4.2 Abbreviated terms

OIT	oxidation induction time
PE-sGF	polyethylene reinforced with short glass fibre
PFA	allowable operating pressure

5 Material

5.1 PE compound

The polyethylene compound selected for manufacturing the extrusion compound and the inner and outer layers shall be in accordance with ISO 4427-1. The polyethylene compound shall be classified PE100 in accordance with ISO 12162.

5.2 Short glass fibres

The short glass fibres used in the production of the extrusion compound shall be type E-glass in accordance with ISO 2078.

The short glass fibres used in the production shall have the properties specified in [Table 1](#).

Table 1 — Properties of the short glass fibre used in the extrusion compound

Characteristics	Requirements	Test parameters		Test method
		Parameter	Value	
Short glass-fibre filament diameter	from 12 µm to 15 µm	Number of test pieces	25	ISO 1888
Short glass-fibre chopped strand length ^a	(4 ± 1) mm	Number of test pieces	3	ISO 22314
Short glass-fibre loss in ignition	from 0,4 % to 0,6 %	Test temperature	625 °C	ISO 1887
Short glass-fibre moisture content	≤ 0,10 %	Test temperature	105 °C	ISO 3344

^a The values indicated in this table are referring to the glass fibre lengths before the compounding.

5.3 Coupling agent

The coupling agent shall be an anhydride modified polyethylene and shall conform to [Table 2](#).

Table 2 — Properties of the coupling agent used in the extrusion compound

Characteristics	Requirements	Test parameters		Test method
		Parameter	Value	
Melt flow rate	10 ≤ MFR ≤ 14 g/10 min	Temperature	190 °C	ISO 1133-1
MFR		Load	2,16 kg	
Density	≥ 940 kg/m ³	Test temperature	23 °C	ISO 1183-1
Moisture content	≤ 0,03 %	Test temperature	110 °C	ISO 15512

5.4 PE-sGF compound

The PE-sGF compound from which the pipes and fittings are manufactured shall be made by adding to the polyethylene compound short glass fibre and only those additives necessary for the manufacture and end use of the products, conforming to the requirements of the applicable parts of [Table 3](#).

Short glass fibre and all additives added in the PE compound shall be uniformly dispersed. The PE-sGF compound shall be evaluated by the pipe manufacturers with test specimens taken from sample of a pipe, DN/ID 200. The test methods in [Table 3](#) apply.

The PE-sGF compound shall only be made from virgin materials and the use of recycled material is not allowed.

NOTE Additional information about the PE-sGF production process is reported in [Annex B](#).

Table 3 — Characteristics of the PE-sGF compound in the form of pipe

Characteristics	Requirements ^a	Test parameters		Test method
		Parameter	Value	
Compound density	from 1,02 kg/m ³ to 1,09 kg/m ³	Test temperature	23 °C	ISO 1183-1 or ISO 1183-2
Glass-fibre content (in weight)	(20 ± 1) %	Temperature	550 °C	ISO 7510
Oxidation induction time ^b	≥ 20 min	Number of test pieces	3	ISO 11357-6
		Test temperature	210 °C ^c	
		Test atmosphere	Oxygen	
Charpy impact strength ^d	≥ 19,6 kJ/m ²	Test temperature	23 °C	ISO 179-1
		Number of test pieces	5	
		Notch	A	
		Specimen	Edgewise	
		Direction	Longitudinal	
Tensile strength in circumferential direction ^{d,e,f}	≥ 40 MPa	Test temperature	23 °C	ISO 527-1
		Shape of type	Type 1	
		Tensile speed	50 mm/min	
Tensile strength in longitudinal direction ^{d,e}	≥ 24 MPa	Test temperature	23 °C	ISO 527-1
		Shape of type	Type 1	
		Tensile speed	50 mm/min	
Elongation at break for longitudinal direction ^{d,e}	≥ 4 %	Test temperature	23 °C	ISO 6259-1
		Shape of type	Type 1	ISO 6259-3
		Tensile speed	50 mm/min	
Full notch creep test ^g (FNCT)	No failure	Test temperature	80 °C	ISO 16770
		Test period	1 000 h	
		Number of test pieces	3	
		Stress level	4 MPa	
<p>^a Conformity to these requirements shall be proved by the PE-sGF compound manufacturer.</p> <p>^b Oxidation induction time (OIT) shall be measured on each layer.</p> <p>^c Test may be carried out at 200 °C providing that there is a clear correlation with the results at 210 °C. In case of dispute, the reference temperature shall be 210 °C.</p> <p>^d This test is necessary to ensure homogeneity of the material for inner and outer layer and correct fibre orientation. Different values of the relevant parameters are an indication that the compounding has not been carried out properly.</p> <p>^e Thickness may be reduced by machining. Machine the strip after it has been flattened under the following conditions, temperature (120-140) °C, duration of heating time (3 hours), flattening pressure (1-6) MPa.</p> <p>^f Test specimen may be pressed at 110 °C by compression machine.</p> <p>^g The size of the pipe shall be 200 mm DN/ID.</p> <p>^h The test pressure is obtained by $\rho = \frac{2 \times \sigma}{R_{SID} + 1}$</p>				

Table 3 (continued)

Characteristics	Requirements ^a	Test parameters		Test method
		Parameter	Value	
Resistance to slow crack growth ^{d,g,h}	No failure during test period	Test temperature	80 °C	ISO 13479
		Number of test pieces	3	
		Test period	500 h	
		Type of test	Water-in-water	
		Hydrostatic stress	9,2 MPa	
^a Conformity to these requirements shall be proved by the PE-sGF compound manufacturer. ^b Oxidation induction time (OIT) shall be measured on each layer. ^c Test may be carried out at 200 °C providing that there is a clear correlation with the results at 210 °C. In case of dispute, the reference temperature shall be 210 °C. ^d This test is necessary to ensure homogeneity of the material for inner and outer layer and correct fibre orientation. Different values of the relevant parameters are an indication that the compounding has not been carried out properly. ^e Thickness may be reduced by machining. Machine the strip after it has been flattened under the following conditions, temperature (120-140) °C, duration of heating time (3 hours), flattening pressure (1-6) MPa. ^f Test specimen may be pressed at 110 °C by compression machine. ^g The size of the pipe shall be 200 mm DN/ID. ^h The test pressure is obtained by $\rho = \frac{2 \times \sigma}{R_{SID} + 1}$				

5.5 Colour

The colour of the extrusion compound shall be black.

The carbon black used in the production of black compound shall have an average particle size of 10 nm to 25 nm.

5.6 Designation and classification

PE-sGF compounds shall be designated by the pipes type (PE-sGF) and the level of minimum required strength (MRS).

The MRS determination is preferably carried out on DN/ID 200 mm. The smallest dimension of the manufactured range is considered to have the lowest strength in circumferential direction.

Such strength is evaluated considering the smallest angle of the spiral cross winding extruded method.

NOTE 1 Additional information on the relationship between the spiral winding angle and item characteristics can be found in [Annex B](#).

For the purpose of this document, the MRS value and PE-sGF compound classification are derived from the σ_{LPL} value, in accordance with [Annex C](#).

The designation is PE-sGF 200.

The classification of the PE-sGF compound as described in [Annex C](#) shall be demonstrated by the pipe manufacturer on their own pipes.

NOTE 2 Where fittings are manufactured from the same PE-sGF compound as the pipe, then the material classification is the same as for the pipe.

5.7 Design coefficient and design stress

The overall design coefficient, C , shall be greater than or equal to 1,6. Higher design coefficients may be agreed between the manufacturer and the purchaser.

The maximum value for the design stress, σ_s , shall be 12,5 MPa for PE-sGF 200, at the reference temperature of 20 °C.

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Annex A (informative)

Pressure reduction coefficient

A.1 General

This annex is provided for reference only. Whenever operating temperatures are higher than 20 °C, reference should always be made to ISO 13761.

When a PE-sGF piping system is to be operated at a continuous constant temperature between 20 °C and 50 °C, a pressure reduction coefficient as given in [Table A.1](#) may be applicable for PE-sGF.

Table A.1 — Pressure reduction coefficient for PE-sGF

Temperature ^{a,b} °C	Coefficient
20	1,00
30	0,85
40	0,73
50	0,63
^a For other temperatures between each step, interpolation is permitted. ^b For higher temperatures, consult the compound manufacturer.	

Applicable, higher factors and hence higher pressures may be applied.

The continuous allowable operating pressure (PFA, $\rho_{o,a}$) is derived from the following formula:

$$\rho_{o,a} = f_T \times f_A \times \rho_{a,max} \quad (A.1)$$

where

f_T is the coefficient according to [Table A.1](#);

f_A is the derating factor related to the liquid fluid application type (for the conveyance of water, the maximum value of f_A is 1);

$\rho_{a,max}$ is the maximum allowable pressure.

Annex B (informative)

PE-sGF winding process

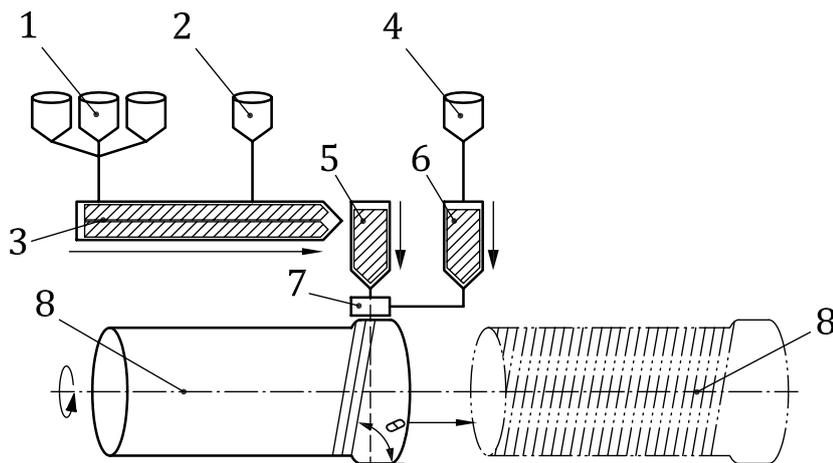
B.1 Principle

This annex summarizes the manner of producing PE-sGF compound from which the pipes and fittings are manufactured, using [Figure B.1](#) as an illustration.

PE-sGF provides improved strength, in comparison to the corresponding thermoplastic material and based on the improved circumferential strength, good chemical resistance and low weight. PE-sGF pipes and fittings combine the well known properties of PE100 polyethylene with the significant characteristics of short glass fibres. The inner and outer layer of unfilled PE100 provide a smooth inner bore for fluid flow and an outer surface for fusion bonding.

Manufacturing of PE-sGF pipe is done using a system as schematically presented in [Figure B.1](#). The PE-sGF compound is manufactured by using the gravimetric dosing system (1), the polyethylene compound and coupling agent are melted in the main twin extruder (3) with short glass fibre from a suitable source (2) close to the end of (3). The PE-sGF compound is then processed in a single extruder (5), then passes into die head (7) from which the PE-sGF compound flows out in the form of a strip that is helically wound on a mandrel (8) moving axially. In the die head (7), non-glass filled polyethylene layers (inside and outside) that are extruded (6) from the dedicated hopper (4) are added to the PE-sGF compound core. The mandrel (8), sized based on required DN/ID, is rotated and moved axially to obtain the defined short glass fibre orientation.

The physical and mechanical properties are influenced by the orientation, θ , of the short glass fibres. The lowest orientation angle is obtained at the minimum diameter, 200 DN/ID mm.



Key

- 1 hoppers containing PE compound and coupling agent
- 2 hopper containing sGF
- 3 main twin extruder
- 4 hopper for PE for non-glass filled layer
- 5 single extruder
- 6 single extruder
- 7 extruder die head
- 8 mandrel
- θ sGF orientation angle

Figure B.1 — PE-sGF winding method

B.2 Relationship between glass fibre orientation and mechanical features

For additional information purposes, [Figure B.2](#) shows, as an example, a graph demonstrating the relationship between tensile strength (circumferential and longitudinal) and the helical angle of glass fibres obtained by laboratory tests. ^[3]