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BIO-UPTAKE - Development of reinforced fibres based on biobased materials

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Foreword

This CEN Workshop Agreement (CWA 18295:2026) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid way to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the CEN Workshop “BIO-UPTAKE- Development of reinforced fibres based on recycled materials”, the secretariat of which is held by UNE consisting of representatives of interested parties on 2025-07-01, the constitution of which was supported by CEN following the public call for participation made on 2025-05-20. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

This CEN Workshop Agreement (CWA 18295:2026) is a result of the European R&I project Bio-Uptake funded by the European Union under the grant agreement number 101057049.

The general objective of the Bio-Uptake project is to ensure a sustainable uptake (increase the use by 40 %) of bioplastic composites through boosting twin green and digital transformation in the European manufacturing industry. In particular, Bio-Uptake solutions focus scientific and technological efforts on developing flexible manufacturing processes to produce biobased end-products based on the combination of intermediate formats made of natural and/or biobased synthetic fibres reinforced with biopolymers, which are easily adaptable to new market demands.

Biobased materials have demonstrated adequate performance to replace petroleum derivates in various application areas. However, due to differences in physical and thermochemical properties, a direct replacement of the currently used petroleum-based materials with newly developed biobased is not advised. To reach the full potential of biobased materials product eco-design is essential (product design, choice of materials, processability, end-of-life options, etc.).

The proposed CWAs will not define requirements related to safety aspects.

1 Scope

This document describes the method for optimizing the process for filament extrusion for biobased materials with respect to obtaining the filament properties required for their intended applications.

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.

EN ISO 2062, *Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester (ISO 2062)*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1
filament
<textile> a textile fibre of very great length considered as continuous

[SOURCE: ISO 8159:2025, 3.3]

3.2
filament yarn
yarn composed of one filament (monofilament) or more filaments (multifilament) with or without twist

[SOURCE: ISO 8159:2025, 3.16]

3.3
bicomponent filaments
filament composed of two polymers which have been extruded together to form the final filament

[SOURCE: Adapted from ISO 1968:2004, 3.4.1]

3.4
extrusion
process whereby heated or unheated plastic forced through a shaping orifice becomes one continuously formed piece

[SOURCE: ISO 472:2013, 2.356]

3.5
spinning <by extrusion>
process of forming a synthetic fibre by extruding or drawing molten or dissolved polymer material through very small openings in a metal plate (dies) and subsequent stretching

[SOURCE: ISO 1968:2004, 4.10.1]

3.6
glass transition
reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one

[SOURCE: ISO 472:2013, 2.440]

3.7
glass transition temperature
T_g
approximate midpoint of the temperature range over which the glass transition takes place

Note 1 to entry: The glass transition temperature varies significantly, depending upon the specific property and the test method and conditions selected to measure it.

[SOURCE: ISO 472:2013, 2.441]

3.8
crystallization temperature
T_c
temperature at which a polymer crystalises

3.9
degradation
irreversible process leading to a significant change in the structure of a material, typically characterized by a change of properties (e.g. integrity, molecular mass or structure, mechanical strength) and/or by fragmentation, affected by environmental conditions, proceeding over a period of time and comprising one or more steps

[SOURCE: ISO 472:2013, 2.262]

3.10
shrinkage
decrease in one or more dimensions of an object or material

[SOURCE: EN ISO 11610:2023, 4.6.3]

4 List of abbreviations

DR	melt draw ratio
DSC	differential scanning calorimetry
MFI	melt flow index
PCL	polycaprolactone (polymer)
PLA	polylactic acid (polymer)
TGA	thermogravimetric analysis
T_c	crystallization temperature
T_g	glass transition temperature
T_d	degradation temperature

T_m	melting temperature
FDY	fully drawn yarn
POY	partially oriented yarn

5 Materials

The materials used for the development of both monocomponent multifilaments and bicomponent monofilaments in Bio-Uptake are PLA (polylactic acid) and PCL (polycaprolactone).

6 Characterization of materials

Prior to initiating extrusion trials, all selected material grades shall be characterized using:

- differential scanning calorimetry (DSC),
- thermogravimetric analysis (TGA),
- melt flow index (MFI),
- and rotational rheology.

Rheological characteristics of the selected materials grades are crucial, as they provide insight into the flow behaviour of the materials under specific temperature and shear conditions. This is important for evaluating their suitability for filament yarn extrusion.

DSC and TGA analyses provided insights into the thermal properties of these materials, such as the glass transition temperature (T_g), crystallization temperature (T_c, applicable to semi-crystalline grades), melting temperature (T_m, also specific to semi-crystalline grades), and degradation temperature (T_d).

7 Filament yarn extrusion

7.1 Multifilament yarn extrusion

A general set-up for a multifilament yarn extrusion line is shown in Figure 1.

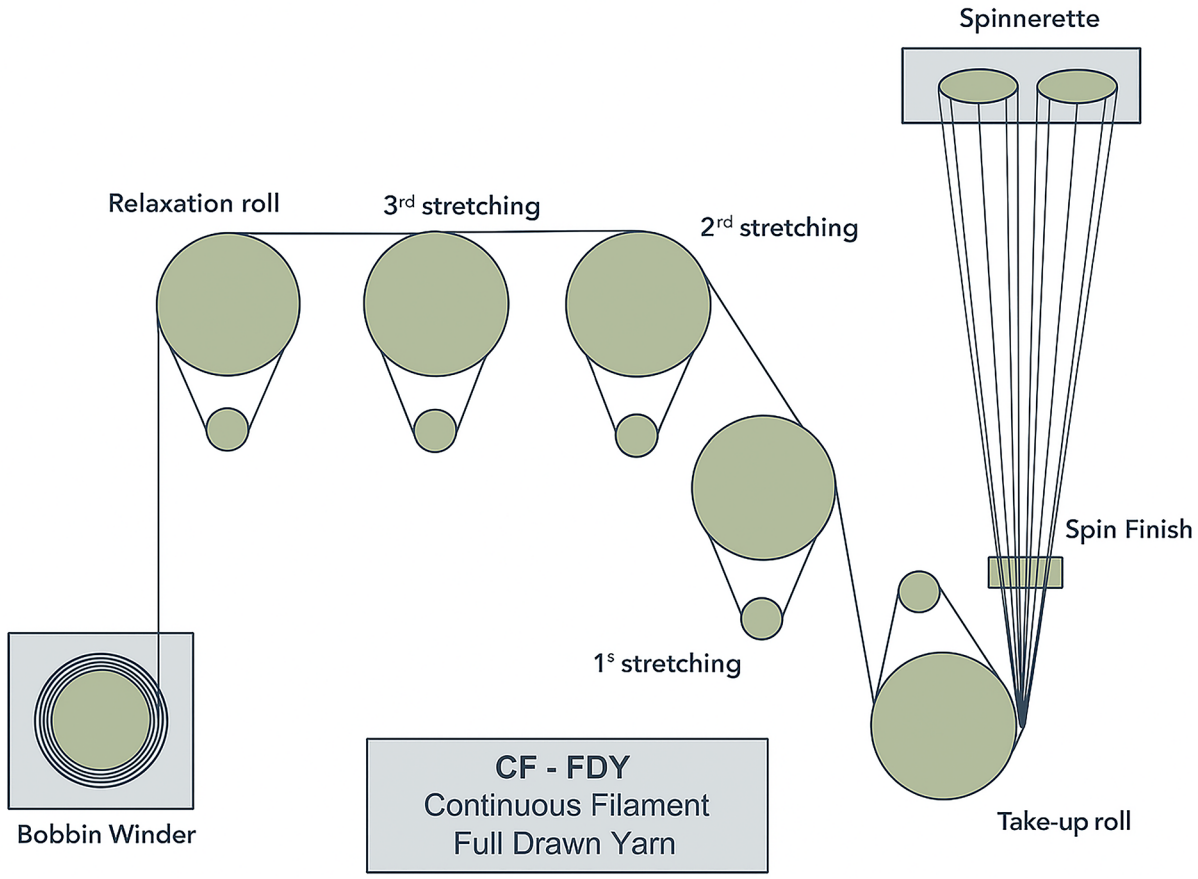

Figure 1 — Multifilament extrusion line

A multifilament yarn extrusion process requiring a minimum of 7 kg to10 kg of material per trial.

In general, a multifilament production process relies on air cooling of the polymer melt, achieving a high melt draw ratio (DR) with a relatively lower cold DR. The yarn is stretched across multiple heated godets, with stretching typically performed in two or three stages. Resulting filament diameters generally range from 20 µm to 50 µm. This multifilament technology allows for significantly higher production speeds—up to 3 000 m/min—compared to the monofilament extrusion process, which operates at a maximum of 200 m/min.

Another type of yarn produced in mulitiflament extrusion is POY (see Figure 2). In contrast to FDY, described above, POY undergoes only an initial melt draw before winding, resulting in lower mechanical properties. However, POY is intended for further stretching in a second step, which can enhance its mechanical properties beyond those of FDY. The drawback of POY production is that it requires a two-step process, increasing operational costs.

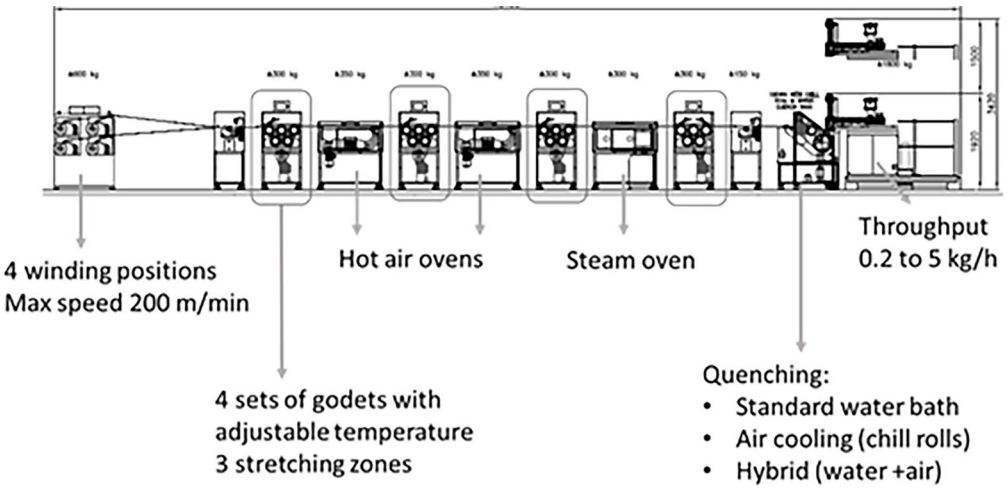

Figure 2 — Multifilament extrusion POY process

7.2 Monofilament yarn extrusion

A general set-up of a monofilament yarn extrusion line is shown in Figure 3.

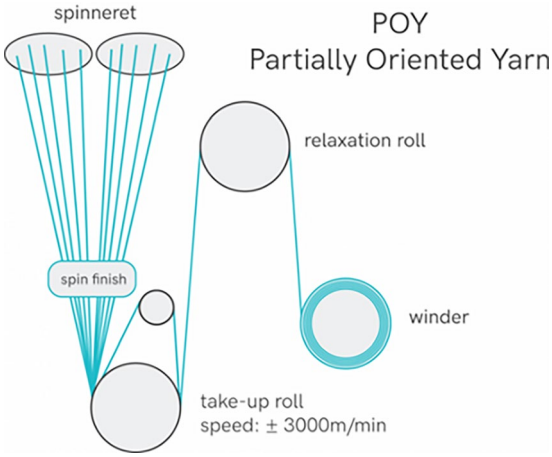

Figure 3 — Monofilament extrusion line

A monofilament yarn extrusion process requires a minimum of 3 kg to 5 kg of material per trial.

In general, a monofilament yarn extrusion line includes two independent single-screw extruders with an L/D ratio of 30, enabling the fabrication of multicomponent structures such as bicomponent filaments or tapes. After extrusion, the filaments pass through a water bath, cooling them below their glass transition temperature (T_g). This is followed by three sets of ovens and heated godet rolls, where the filaments undergo stretching to align the polymer chains, forming crystalline structures that enhance mechanical properties. To minimize shrinkage and excessive tension, a relaxation step is applied at the final set of rolls before the filaments are wound onto bobbins.

Another use of the monofilament extrusion line is to use it for a 2^{nd} step drawing process. In this case the extruder and quenching unit is not used, and the POY yarns are used just before the spin finish application and stretched by three sets of ovens and heated godet rolls. In this way the filaments undergo stretching to align the polymer chains, forming crystalline structures that enhance mechanical properties. To minimize shrinkage and excessive tension, a relaxation step is applied at the final set of rolls before the filaments are wound onto bobbins.

The reason we perform this 2nd step stretching method is mainly to decrease the shrinkage of the PLA filaments significantly, so the further processing of them into composites is easier, but also the mechanical properties of the PLA yarns are significantly higher.

8 Texting of filaments

8.1 Mechanical properties of filaments

Tenacity, elongation, and modulus shall be tested in accordance with EN ISO 2062.

8.2 Titer of the filaments

The titer of the filaments is measured to ensure consistency in linear density.

The titer of polymer filaments is determined by cutting a defined length of filament, weighing it with high precision, and normalizing the mass to its length. The result is expressed in tex, defined as the mass in grams per 1 000 meters of filament.

8.3 Shrinkage of filaments

As the shrinkage is an important factor during the further processing into composites also this is determined at 100 °C for 30 min and at 150 °C for 2 min (internal standard).

The shrinkage of a polymer filaments is determined by measuring the change in length of a defined filament sample after exposure to specific thermal or environmental conditions. The initial length is recorded, the filament is treated under controlled conditions, and the final length is measured. Shrinkage is then expressed as the relative decrease in length, usually in percentage. This is an important measurement for the further processing of these filaments.

Annex A
(informative)

Recommended values

Shrinkage 100 °C: 1 % to 8 %.

Shrinkage 150 °C: 2 % to 10 %.

It should also be noted that tenacity, elongation and modulus can be broad in range as this is just about the processing of the yarns and will therefore be very application dependant.

Bibliography

[1] EN ISO 11610:2023, *Protective clothing — Vocabulary (ISO 11610:2023)*

[2] ISO 472:2013, *Plastics — Vocabulary*

[3] ISO 1968:2004, *Fibre ropes and cordage — Vocabulary*

[4] ISO 8159:2025, *Textiles — Morphology of fibres and yarns — Vocabulary*