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Technical parameters for the manufacture line for the semi products

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Partners

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Partners involved : Kairos, Howa Tramico

Content

Introduction

In the first part of the FLOWER project, one of the activities of the TEILLAGE VANDECANDELAERE concerns the development of processes allowing the manufacture of new semi-finished products respecting the architectural parameters defined by our industrial partners (KAIROS and HOWA-TRAMICO). During the first months of the project, the specifications for two types of reinforcements were defined to meet the needs of our partners:

- An NCF (Non Crimp Fabric) reinforcement of approximately 300 g/m², containing 100% linen rovings oriented at ±45° (see the specifications produced as part of the project with the company KAIROS)
- A fine and open grid type reinforcement of approximately 70 g/m², 100% linen, for the manufacture of stiffeners by HOWA TRAMICO.

The transformation phases to be deployed to obtain the targeted semi-finished products can be divided into two main stages:

- The transformation of flax straw into untwisted rovings: this step consists of extracting the flax fibers from the straw and transforming, following a series of mechanical shaping, the flax fibers into a unit ribbon with a controlled title (500 tex for example)
- The assembly of these ribbons, in order to obtain a homogeneous product with a constant weight. The technologies used to produce this assembly are additive manufacturing for the NCF and weaving for the open grids.

This report aims to present the technologies that will be used for the manufacture of the reinforcements, and in particular the technical parameters to be monitored in order to obtain semi-finished products that meet the specifications of our partners. First, we will present the manufacturing process for 100% linen rovings, which constitute the raw material for obtaining NCFs and open grids. Next, the assembly technologies used for the rovings will be described, as well as the first prototypes of reinforcements from the FLOWER program.

100% linen roving production line

The usual diagram for the extraction of flax fibers from straw, and their transformation into reinforcements for composite materials is carried out as shown in Figure 1. The figures presented in this diagram are provided for information only, and correspond to those of Teillage Vandecandelaère, one of the SARL DEPESTELE factories.

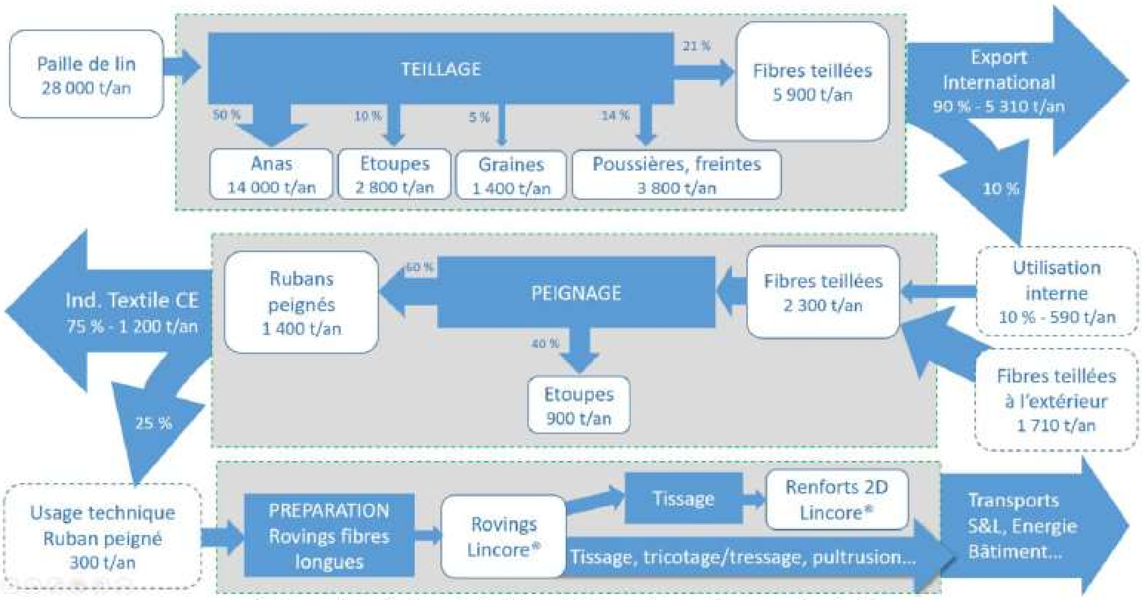


Figure 1 : schéma de la ligne de transformation usuelle du lin

The different batches of flax straw are collected from more than 600 farmers and then scutched. This operation consists of separating the different constituents of the straw: the shives (which correspond to the “wood” part of the straw and 50% of its mass), the fibers (about 30% of the straw mass), the seeds and the dust.

Flax fibers from scutching are divided into two categories:

- Tows are fibers that have broken during the process: they constitute a co-product of scutching and will be used, within the framework of FLOWER, for the manufacture of nonwovens by Ecotechnilin. They are presented in bulk in the form of parallelepiped bales
- Long fibers are those arriving at the end of the scutching line, all oriented in the same direction and rolled up in the form of a round bale.

The scutchers are adjusted so as to obtain a maximum of long fibers (and a minimum of tows), while limiting the damage to the fibers during their extraction. To do this, the **pressure of the crushers**, the **speeds of the beaters** and the **advance** of the machine are adapted to the quality of the straw supplied by the farmers. Around 10% of the long fibers are transformed into scutching tows throughout the process.

The scutched fibers are then combed: combing consists of dividing the bundles of staple fibers approximately 80 cm long (resulting from the scutching) and converting them into a continuous ribbon of approximately 35 g/m; the sheet of scutched fibers is brushed by **increasingly closer and finer points**, and advances along the axis of the machine at a certain **speed**. During the process, approximately 40% of the scutched fibers are transformed into combing tows.

It is from these combed slivers that the rovings are made, after a series of refining stages which allow both to gradually reduce the sliver count, but also to mix different batches of fibers, with the aim of guaranteeing homogeneity of the semi-finished products from one year to the next. The **number of steps** to go through and the stretching programmed in the different passages (see figure 2) to go from the raw material to the rovings depends on the expected title. In general, the lower the title targeted, the greater the number of passages and/or stretchings.

Once the roving has a compliant titer (500 tex, i.e. 0.5 g/m for example), a finishing step is undertaken using an agent **formulated in-house**. It guarantees fiber cohesion and sufficient mechanical strength to avoid any breakage during future assembly (weaving, pultrusion, filament winding, etc.). Finally, the roving is **dried** and then **reeled with constant tension** and a **predefined shearing pitch** on cylindrical mandrels so as to constitute, for all titles, 2.5 kg reels.

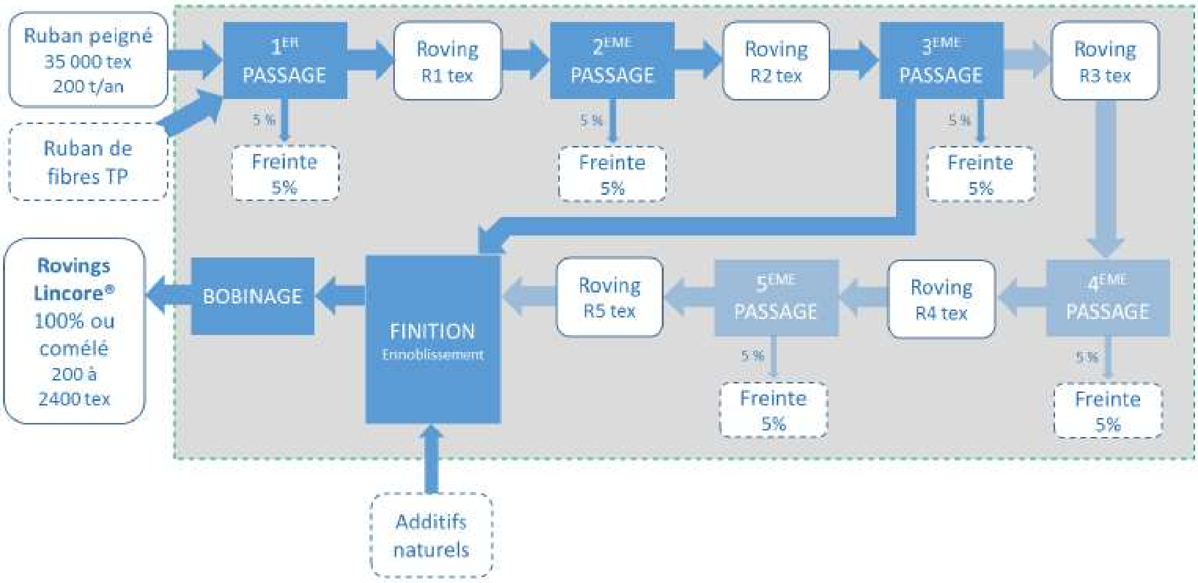


***Figure 2** : schéma de la ligne de préparation*

These bobbins are then marketed, or used internally for the production of woven reinforcements, whose weight and characteristics depend on the rovings used and the settings of the loom (weaving, texture, fiber architecture, etc.).

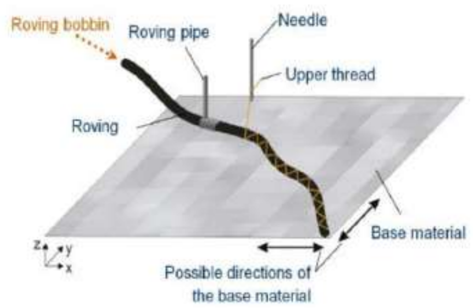
Regarding the FLOWER project, the assembly technologies envisaged to obtain the preforms expected by KAIROS and HOWA TRAMICO are different.

The NCFs will be manufactured from sewn rovings using the Optimized Fiber Placement technology with our subcontractor: it makes it possible to quickly and cost-effectively obtain made-to-measure preforms, and in particular multilayer structures with customizable angles and fiber trajectories. The fine open grids will be woven from enlarged rovings, developed within the framework of the FLOWER project, in order to offer a semi-finished product with an optimal mechanical performance/thickness ratio, for the lowest possible costs.

The rest of this deliverable presents these technologies and the associated parameters.

Assembly of the rovings in reinforcements

1. Non Crimp fabric



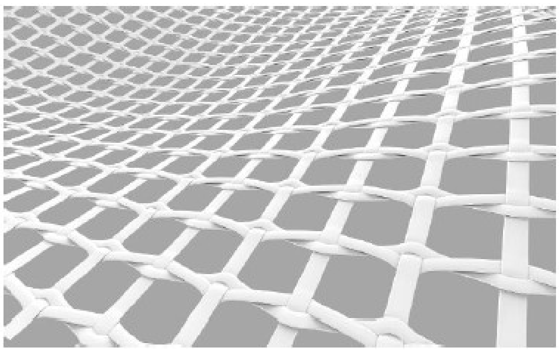
PRINCIPE DU TFP

The chosen technology is TFP (Tailored Fiber Placement, or Optimized Fiber Placement). It consists of depositing a fibrous material on a 2D support (textile, film, etc.). The assembly then constitutes a preform which can then be transformed into a composite. This method is based on robust, proven and industrialized technologies and machines. The adaptations made by our subcontractor make it possible to divide production costs by 2 to 5 compared to conventional fiber placement, and to obtain personalized and reliable multilayer preforms.

The **quantity** and **type of sewing thread** (material, title, color) is adjustable and will be optimized during the development of the reinforcements.

The disadvantage of this technology is the need to have recourse to a **support** on which the deposit will be made. The choice of this support is a crucial stage of the work, in order to preserve the mechanical properties and drapability stipulated in the KAIROS specifications. The following supports have been pre-selected for obtaining reinforcements:

- **Non-woven veil in linen or thermoplastic fibers**: their advantage is their low cost and their lightness, but they have low mechanical performance and non-optimal drapability.
- **LENO type fabric** (see opposite): light and drapable, they have correct mechanical performance but their cost is higher than nonwovens. The size of the meshes is adjustable as well as the weight of the support.
- **Oriented linen reinforcements**: the rovings can also be placed on



a woven linen reinforcement (in particular a unidirectional one), already manufactured by Teillage Vandecandelaère. This solution would make it possible to obtain a "triaxial" NCF, with a support with optimal mechanical performance in the 0° direction. The preform obtained would therefore be a 0°/-45°/45°. However, the final grammage of the preform would in this case be around 500 g/m², which nevertheless remains in line with the target of 300 g/m² to 600 g/m² defined by KAIROS. This solution is economically the most expensive.

In general, it is a question of reducing as much as possible the preponderance of the support on the NCF, in order to obtain a reinforcement with optimal mechanical performance (the ideal being to completely eliminate the latter).

Figure 3 presents the first prototypes obtained using this technology.

Figure 3 : NCF ± 45° obtenu par TFP

The orientation of the rovings perfectly follows the defined angles and the weight of the first prototypes is 300 g/m², which is in line with the specifications.

Figure 4 presents the types of support already tested: they will be characterized during the program, as planned in the project schedule.

Figure 4 : supports pour NCF ±45°. A gauche : tissu de type LENO, à droite : voile non-tissé PP

2. Fine open grids

Reinforcements for HOWA TRAMICO must meet the following criteria:

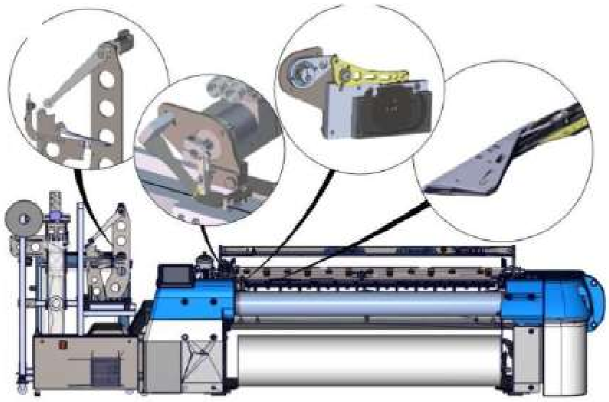
- Lightness: the surface mass of the reinforcements must be lower than that of the glass mats currently used for the manufacture of the stiffeners. The target is around 70 gsm. The minimum title of the rovings manufactured by Teillage Vandecandelaère being 300 tex (with a standard production of 500 tex rovings), the only solution to achieve such light grammages is to use preforms of the open grid type, which make it possible to offer optimal reinforcement in two directions while maintaining a low surface mass.
- Mechanical resistance: the grids must make it possible to obtain mechanical performance equivalent to that measured with current materials, while lightening the stiffener.
- Fineness: the reinforcements, used as sandwich structure skins, must remain invisible on the final part. It is therefore important to produce the thinnest possible flat grids, with enough fibers to guarantee the expected mechanical performance.

To do this, an enlarged roving was developed by Teillage Vandecandealère. This is a 500 tex roving, whose fibers were opened ("spread tow") during the manufacturing process during the finishing stage, presented in chapter 1. This modification of the manufacturing process made it possible to go from an average width of 3 mm to an average width of 5 mm, equivalently, while maintaining good coverage (no voids in the structure of the rovings).

The assembly of these grid rovings is made by weaving. The disadvantage of current weaving machines is that when inserting the weft, the beating of the reed tends to compress the weft yarn and greatly reduce its width. The tests carried out on our looms confirm this fact, and few differences were measured on the width of the standard rovings and the rovings widened after weaving.

This is the reason why our company has invested in a new loom for the FLOWER project: this loom has weft insertion technology, as well as specific lances and grippers to maintain the width of the rovings during their weaving. In addition, the system of heddles used for the integration of the warp limits the deformations of the rovings and these therefore retain their integrity throughout the weaving (see figure 5).

The only supplier capable of supplying this type of loom at acceptable costs is the company PANTER, where we were able to carry out prototyping tests on closed reinforcements.



The trials made it possible to test different yarns and textures, and a very promising result was obtained with 1.7 threads per cm. The closed reinforcement obtained has a surface weight of 170 g/m² (see figure 6), which makes it a 100% linen closed reinforcement among the lightest on the market.

Figure 6 : renfort 100% lin à 170 g/m², obtenu par tissage à plat (métier PANTER)

By modifying the texture and the picking to 0.7 yarn per centimeter in the warp and in the weft, without any other modification compared to the tests carried out at our supplier, we will therefore obtain with the same rovings a flat open grid of 70 g/m², of very low thickness.

The loom was ordered on February 5, 2019 and will be delivered in May 2019. Upon receipt, the first grids will be produced and then characterized by the partners of the FLOWER project.

Conclusion and perspectives

This deliverable presents the implementation technologies for the manufacture of the reinforcements developed and studied within the framework of the FLOWER project. First, the different stages of the manufacturing process for 100% linen rovings were described, as well as the associated parameters. From these rovings, and taking into account the specifications of the partners, two new semi-products were designed: an NCF from our standard rovings, and a light and thin grid made up of widened ribbons specially manufactured for the needs of FLOWER. The assembly of these new semi-finished products has been studied and the associated parameters have been described.

Several reinforcement prototypes were then manufactured:

- NCFs at ±45° manufactured by TFP on different supports (non-woven and LENO)
- Lightweight fabrics obtained from 500 tex rovings expanded and woven at the loom supplier, whose investment was made as part of the FLOWER project.

In the rest of the project, larger quantities of NCF will be manufactured and characterized, in order to validate their adequacy with the expectations of KAIROS. As soon as the PANTER equipment is received, the first grid prototypes will be woven and then characterized.