BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING

Bachelor’s Thesis

WRAP YARN TECHNOLOGY

Fundamentals and Prototype design

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ENSISA

Table of Contents

1. PREFACE

1.1. Origins

This project was born from the idea of Mr. Artan SINOIMERI to develop a machine able to manufacture wrap yarns.

The ENSISA, one of the "École Nationale Supérieure" concerned in the *Université Haute-Alsace,* has a large reputation in the field of textile engineering. Along the years, the university has to adapt to new technologies and new tendencies. Even though the university already has numerous machines concerning the yarn development, there is still not a machine capable to develop those specific yarns called wrap yarns.

The lack of machines to create wrap yarns contributes to a lack of study about those yarns too. That is what made Mr. SINOIMERI want to investigate over that field and try to reach to have a machine able to treat wrap yarns with according to different parameters.

1.2. Motivation

Despite the fact that in the home university of the writer it is tried to give students the maximum of knowledge related to the majority of engineering fields, textile engineering is not even studied nor mentioned.

Nowadays, according to textile engineering, new technologies are being applied and new products are trying to be reached. As far as this project focuses on the field of textile engineering, it is an opportunity to open to new knowledge and inquire into this area of engineering.

1.3. Previous knowledge

As the knowledge in this field of engineering is barely existent, in order to deal with this project, some background information is needed.

First of all, it is important to understand how textile works. That is the reason why it has been studied how fibers can be converted into fabrics depending on the fabric wanted. Furthermore, it is also important to study the three basic fiber properties and other physical concepts related with yarns, such as false-twist.

Once the general knowledge about fibers has been achieved, it is indispensable to inquire into the manufacturing process and more over into the last stage of it.

2. INTRODUCTION

In textile world, nearly all types of yarns that one can imagine can be created. Some of them are easier to create, and some others have to deal with more accurate processes. Those yarns made out of fibers which are difficult to be treated are sometimes wrapped by a filament in order to give them the consistence needed to develop the yarn. These particular types of yarns are called wrap yarns.

According to that, the primordial aim of the project is to set the ideas of a future prototype able to create wrap yarns. To achieve it, it has been done a general study of the existing machines and possible alternatives.

The prototype that is being sought would have to enable the study and creation of different types of wrap yarns. For this reason, it has been tried to develop a prototype able to deal with some particular features to create different types of yarns. Those features taken into account are the following:

- The prototype should have to be able to treat all types of length fibers (long and short fibers).
- The prototype should have to be able to create yarns out of ribbon or roving.

In order to accomplish the objective of the project, first of all it has been studied what the prototype needs to have. Once the general idea of the prototype has been set, it has been discussed about how this idea could be achieved. In other words, which are the alternatives that can make the idea became into a reality. Once the brainstorming of alternatives has reached all of the possibilities, those which are more suitable are the ones that have been described and analyzed.

By now, the possibility of developing the prototype looks more achievable and more documented and studied.

Besides the main objective, there are other two more simple objectives that are also wanted to be achieved. Both objectives are related with extending the knowledge in textile engineering. On the one hand, the first aim is to get to know the fibers and their properties. On the other hand, familiarize with the manufacturing process that fibers follow to be converted into yarns and inquire into its last stage, the spinning stage.

To achieve those objectives, some books have been greatly useful. Specifically: *The Rieter Manual of Spinning;* and *Fundamentals of Spun Yarn Technology.*

3. TEXTILE FUNDAMENTALS

Textile can be described as the process by which fibers are converted into fabrics. Accordingly, fibers can follow two different processes depending on the fabrics wanted.

On the one hand, if surface fabrics are wanted, three stages can be distinguished. First of all, textile begins with single fibers. Those fibers are then processed and converted into yarns and, in closing, yarns are used to fabrics. In relation to the woven fabrics achieved, they can either be made through weaving or knitting in majority.

On the other hand, if the aim of the process is to create non-woven fabrics, then fibers do not have to be processed to create yarns because those fabrics are neither woven nor knitted. In these particular fabrics, long fibers are attached by some chemical, mechanical, heat or solvent treatment.

3.1. Fibers

As explained in the brief introduction above, fibers are the main component and first step to create yarns and afterwards fabrics. That is why a general overview of fibers and their properties are going to be given on the following pages.

The first thing one need to know about spinning fibers is that a yarn can be created with all different types of fibers. Approximately 90% of fiber consumption is processed into yarns.

The most commonly classification of fibers is whether if they are organics or inorganics. Furthermore, both groups can be more specifically classified into natural (those fibers which come from animals, plants or minerals) or manufactured fibers (artificial fibers made from petroleum).

Choosing the best fibers to produce the yarn is essential and, therefore, knowing fibers properties is a must. Fibers have vast different characteristics and properties that can help to decide which fibers are more suitable to treat. More specifically, there are three properties which predominate among the others. Those three most important properties are strength, finest and length and they will be synthetize below.

3.1.1 Fiber length

Fiber length is the first one of the three most important fiber properties. It does not only influences spinning limit and productivity, via quantity of waste and required turns of twist, but also influences in yarn properties such as yarn strength, yarn evenness or yarn hairiness.

According to this property, two types of fibers can be distinguished:

- Long fibers; such as wool with average fiber lengths ranging from 35 to 350 mm.
- Short fibers; for instance cotton, whose fibers can have an approximate length between 13 and 34 mm.

Fiber length is not only important when purchasing fibers. Very short fibers tend to cause irregularities in the drafted material and also in the yarn. As it will be explained after, fiber length is even more important after carding.

As a parameter of fiber length distributions we have the Staple diagram. This diagram shows, for a random sample taken from fibrous mass, the proportion of fibers that are greater than specified lengths. It is created by classifying the lengths of each individual fiber of the sample whether by number or by weight. There exist various Staple diagram forms depending on fibers materials.

3.1.2 Fiber fineness

Fineness is also a meaningful fiber characteristic. It determines how many fibers contain the cross-section of a yarn of a given thickness. Additional fibers in cross-section are beneficial because they provide additional strength and uniformity in the yarn.

It is interesting to know that the minimum number of fibers that cross-section needs to have is about 30; nonetheless, there are usually over 100 fibers in it.

Fiber fineness influences in yarn through, yarn strength, yarn evenness and yarn fullness. This fiber property also influences the productivity and the spinning limit.

Most fibers have random section characteristics which are difficult to measure. That is why it is not possible to determine fineness by reference to the diameter of the fibers; although there are some exceptions, like wool. Therefore, fineness is commonly specified in terms of mass to length [tex].

$$\text{tex} = \frac{\text{mass [g]}}{\text{length [km]}}$$

Even though the unit code is tex, the most commonly used unit is the dtex. Dtex is the abbreviation of decitex and it refers to the mass in grams per 10000 meters.

To have an idea of some real values, cotton fineness is approximately 1,7 dtex; wool average fineness ranges in between 2,2 up to 38 dtex; and polyesters have a fineness of about 1 to 6 dtex.

Tex is also used to measure fiber size and to calculate the diameter of a filament yarn with the next formula:

$$\text{diameter[mm]} = \sqrt{\frac{\text{Tex}}{1000 \times \text{density}\left[\frac{\text{g}}{\text{cm}^3}\right] \times 0{,}7855}}$$

Finally, it is recommendable to bear in mind that with finer fibers there are more number of fibers in a particular count of yarn to share the applied load. Finer fibers, hence, tend to produce stronger yarns.

3.1.3 Fiber strength

Last but not least, strength. It is very often a predominant characteristic and it is defined as the amount of force required to break the fibers.

In case of a single fiber, strength is commonly described as tenacity and it is expressed in terms of grams per decitex [g/dtex] or centi newton per tex [cN/tex].

According to tenacity, not all fibers are suitable for spinning due to their strength. For instance, those fibers with very low tenacity (approx. 6cN/tex) will not be adequate for textiles.

To have an idea of how strong fibers can be, some significant breaking strengths values are the followings: cotton 15-40 cN/tex, wool 12-18 cN/tex and polyester 35-60 cN/tex

Nowadays, fiber strength tests are applied to fiber bundles with HVI (High Volume Instrumentation) and conversion to physical units should be avoided because the measuring procedure is not very exact.

Another important fact to know about fiber strength is its dependence on the ambient. Fiber strength is commonly moisture-dependent and this fact has to be taken into account not only when testing but also when processing. According to cotton or linen, its strength increases with an increase of moisture. However, wool experiences the reverse effect.

It goes without saying that there is a high correlation between fiber strength and yarn strength.

3.2. From fibers to yarns

Once that the most important characteristics of fibers have been defined it is time to understand how fibers are converted into yarns.

To have a more formal definition of a yarn, we could say that a yarn is a continuous strand of twisted threads of natural or synthetic fibers, such as wool or nylon, used in the production of textiles, sewing, and with many other applications.

After reaching that definition, one has to know that yarns can be produced either by filaments or by staple fibers.

On the one hand, we can find those yarns which are made with filaments. We refer to filaments as those very long and continuous fibers. According to filament yarns, we can distinguish between monofilament yarns or multifilament yarns. The first ones are those which are made from a single fiber and are typically used for fishing line. The second ones, multifilament yarns, are those made from different fibers. These ones can be subdivided into twisted, textured or flat (which refers to only grouping together).

On the other hand, yarns can be produced by stapling fibers. As explained previously, it goes without saying that fibers can have a huge variety of lengths. Due to fiber lengths, we can subdivide this procedure into yarns produced by stapling long fibers, such as wool, or by stapling short fibers, for instance cotton. In order to know which fibers can be used in this method, fibers with the quotient $\frac{l}{d} > 600$ (l=length; d=diameter) are considered textile staple fibers. Otherwise, those fibers with a quotient under 600 are not; for example, paper cellulosic fibers.

3.3. Manufacturing process

Yarns produced by stapling fibers are going to be the subject of this thesis and so, following, it is going to be explained how this manufacturing process works.

3.3.1 Raw material

In order to convert fibers into yarns, fibers are purchased in large bales which lately will be processed. That fibrous mass is referred to as the raw material and it has a big influence in spinning.

On the one hand, raw material represents about 50-75% of the manufacturing cost of spinning. On the other hand, not every raw material has the same characteristics, the same facility of productiveness or the same quality. Therefore, choosing the suitable raw material has to be an accurate decision for yarn making.

3.3.2 Preparation: Opening and Cleaning

As it has been cited above, fibers are shipped in large bales (raw material) in order to ease their transportation. Before the manufacturing process starts, those bales have to be opened and, in the majority of the cases, they also need to be cleaned.

Opening is referred to as the breaking up of fiber mass into tufts. There exist plenty of different types of opening operations and opening devices. In relation with opening, two stages can be distinguished:

- Opening to flocks: Operation which takes place in the blowroom.
- Opening to fibers: Operation which takes place card phase.

The aim of cleaning is to eliminate the major quantity of impurities that fibers may contain. Not all fibers have the same quantity of impurities, and that is why the degree on cleaning highly depends on the type of fiber and the dust it contains. In outline, cleaning procedures can be separated into three:

1. Chemical cleaning
2. Wet cleaning
3. Mechanical cleaning

According to opening and cleaning, the degree of cleaning is linearly dependent upon the degree of opening. Moreover, each opening step should be followed immediately by a cleaning step without intervening transport because, during transportation, the surfaces can be exposed to more impurities.

3.3.3 Carding

Once the raw material is completely blended and partially cleaned it goes through the carding machine. Above all, carding should separate the flock into individual fibers and pull them into some parallel form in order to prepare the fibers to spinning. This operation is performed thanks to the huge rollers with wire teeth or hooks that the carding machine contains.

Nevertheless, this stage has other functions like cleaning or reducing neps (agglomeration of entangled fibers). Only by means of this fiber separation is it possible to eliminate the last dirt, especially the finer particles and dust. Furthermore, the carding machine also discards fibers which are too short to process.

After carding, the fibers are converted into a thicker linear structure called sliver. The sliver obtained is stored at the coiler, called also ‘can’. Multiple slivers can be combined among them as it will be explained afterwards.

3.3.4 Combing

Combing is not a compulsory process for spinning. It is used when a smoother or finer yarn is required. This process can be carried out after 2 drawing passages; and, after combing, 1 or 2 more drawing passages are also necessaries.

For those quality yarns, it is important that the quantity of neps and remnant fragments of impurity are minimized. Therefore, the process used to remove the short fiber and remnant impurities is called combing.

Expressed in other words, combing is a process by which the quantity of short fibers and remnant fragments of impurities present in a carded sliver are minimized to give a clean sliver.

Combing, accordingly, makes possible the spinning of yarns of fine counts with low irregularities and a cleaner appearance. This process also results in stronger, smoother, and more lustrous yarns.

3.3.5 Drawing

After carding, or combing if necessary, the slivers have to be transformed into a uniform strand. That strand is accomplished in the drawing stage by two different operations: doubling and drafting.

Doubling is the first operation slivers go through. It consists on placing several slivers (normally up to 8) in parallel and combining them by using a roller draft. Besides, doubling improves the irregularity and the blend of the fibers.

After doubling, fibers have to be strengthened. That fiber strength is achieved thanks to a series of rollers, rotating at different rates of speed, which elongate and stretch the slivers. Obviously, elongating the slivers produces a reduction of fineness. This operation is known as drafting.

Normally, the slivers achieved after the drawing stage are once more processed in order to improve their quality. These slivers are referred to as the ribbon.

As mentioned, the drawing stage is carried out with a series of rollers. Those rollers are called the drafting system. The most common drafting system is the one which contains three pairs of rollers rotating at different speed. The first rollers have less speed than the second ones and this gradient of speed is what makes possible a permanent elongation of the slivers. In order not to break fibers, the distance between those rollers (ratch) is also important. That distance has to be at greater than the maximum length of the fibers. Contrarily, each end of the fiber would have a different speed and that would cause a break in the fibers.

Normally, there is a relation in between the speed of both rollers depending on whether if the yarn is being made by ribbon or by roving. Afterwards, some values of these relations between roller speeds are going to be described.

3.3.6 Twisting

Once the ribbon is achieved, it can directly to go through the last stage of the manufacturing process. That is to say that it can now be spun. Nonetheless, the ribbon can pass through another stage before spinning. That stage is known as twisting.

Now that the ribbon has been formed, if wanted, its fibers can even elongate more and have an additional twist. To do so, a machine called the roving frame is used. The roving provides more strength by thinning and giving a little twist to the ribbon. Due to the name of this machine, the strands that come outside it are called the roving. Depending on the yarn wanted, the roving is less or more thinned. At the time the fibers are twisted, the roving acquires some resistance before breaking.

3.3.7 Spinning

At last, the spinning stage arrives. This stage converts either the ribbon or the roving into the specific yarns searched.

There exist a massive range of different spinning systems even though not all of them are suitable for commercial use. The four most typical technologies used in spinning for staple fibers are the following:

- Ring spinning
- Open-end spinning
- Air jet
- Wrap spinning

Choosing one or another spinning system basically depends on the fiber types that can be spun, the amount of money required and the extensive uses that can be given to the yarn.

It is also interesting to know that, once the yarns are created, it is quiet customary to twist two or more of them together to improve their properties or to overcome subsequent processing difficulties.

3.4. Spinning technologies

As mentioned above, there are four spinning techniques that predominate among the others. Hereafter it is going to be explained in broadly those four spinning technologies.

3.4.1 Ring spinning

Ring spinning is the spinning technology quintessential. What makes it useful is the great number of fabric end uses with advantageous properties obtained with it. But, despite ring spinning is the most used technology, it has a very low production speed and that is why, it does not offer the best process economics.

Ring spinning method is a process that uses roller drafting, for attenuating the fiber mass, and the motion of a guide, called traveller, that circulates freely around a ring to insert twist and simultaneously wind the formed yarn onto a bobbin. Both ring and traveler combination is a twisting and winding mechanism.

First of all, the fibers pass through different pairs of rollers called drafting system, as explained above. The distance between each roller and its pair decreases as the fibers move along in order to compress the fibers. It is important to notice that drafting system only can be used when the fibers of the material to be processed have not a wide range of length.

After those rollers, there is a yarn guide called lappet, and below the lappet there is a ring with the spindle situated at its center. The lappet, the ring and the spindle are all coaxial. The traveller, made of metal, normally has the shape of the letter C and it is clipped onto the ring.

While the traveller goes around the spindle a tubular-shaped bobbin is made. The ring rail moves up and down the length of the spindle so as to wound the yarn onto the bobbin in successive layers. Therefore, the diameter of package that is being built is lower than the ring. The path followed by the yarn is consequently from the nip of the front rollers of the drafting system, through the eye of the lappet and the loop of the traveller, and onto the bobbin.

The yarn wounds onto the bobbin at the same linear speed as the front rollers are delivering the fibers. And this happens due to the rotation of the spindle that can be up to

25000 rpm. So, the traveller pull around the ring and the yarn pull through the traveller and wound onto the bobbin.

As the yarn is being created the bobbin increases in width, which means that the traveller speed has also to increase. Moreover, the traveller speed will also change with the movement of the ring rail to form successive yarn layers on the bobbin. The bobbin has commonly a conical shape because gives easy unwinding of the yarn without interference between layers.

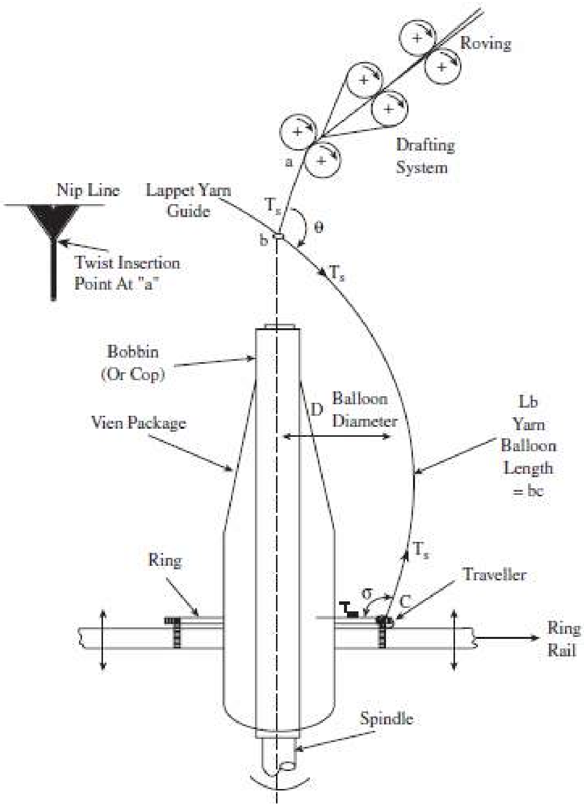

Figure 1: *Example of ring spinning system. Courtesy of Fundamentals of Spun Yarn Technology citing: Spindelfabrik Suessen Ltd.*

The advantages of ring spinning are the following:

- Offers a wide yarn fineness range.
- Allows processing most of the natural, man-made or blend fibers.
- Produces yarn with beneficial features for the most of the fabric end uses.

Otherwise, the disadvantages of this technique are:

- The speed is restricted by the frictional contact of the ring and the traveller and by the yarn tension.
- The dimension of the bobbin is restricted by the size of the ring.

3.4.2 Open-end spinning

In open end spinning systems, individual fibers are collected and twisted onto the open end of the yarn, while this one is rotating, so as to create a continuous yarn length. That yarn spun length is then wound to form a package.

In this particular system, twisting and packaging are two separate stages. Expressed in other words, the twisting action occurs simultaneously but separately from winding.

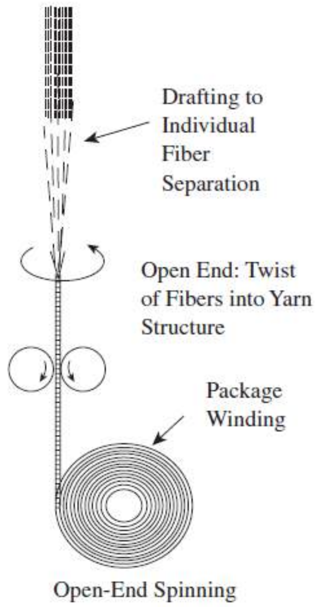

Figure 2: *Open-end spinning principles Courtesy of Fundamentals of Spun Yarn Technology.*

According to this spinning system, two commercial techniques can be distinguished: rotor spinning and friction spinning.

On the one hand, rotor spinning is more commonly used because a greater variety of yarns can be spun by this technique. In rotor spinning, fibers came in to the rotor system in the form of a sliver. Then, the feed roller and feed plate push the sliver into the opening roller. In here, the fibers are separated and afterwards conducted by the transport channel into the rotor. Thanks to the trash ejector attached to the opening roller fibers are additionally cleaned. Once the fibers reach the rotor, they are attached to the open end of the yarn. That is possible thanks to the partial vacuum in the rotor that sucks the tail end of the yarn into the rotor. The rotation of the rotor pulls the yarn end into contact with the collected fiber ribbon. At the same time the rotor rotates, the tail end is twisted and the yarn starts to create itself.

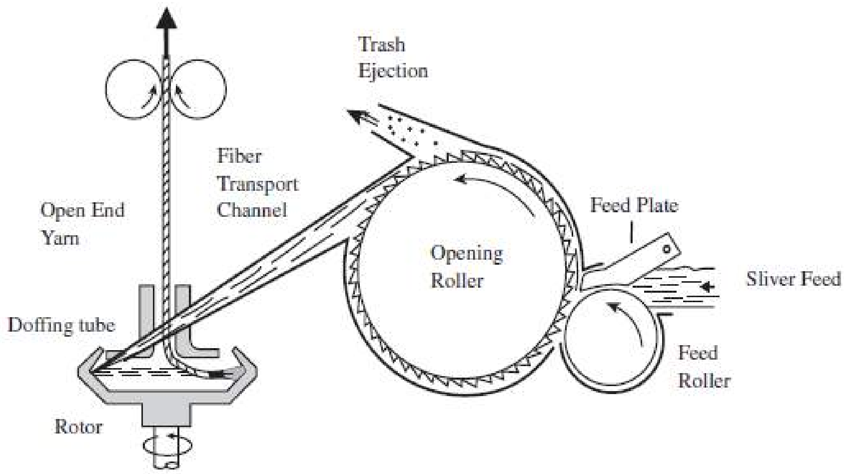

Figure 3: *Main features of a rotor spinning system Courtesy of Fundamentals of Spun Yarn Technology.*

On the other hand, friction spinning has a completely different way in which fibers are collected and twisted onto the tail end of the seed yarn. In friction spinning, the fibers are individually collected and twisted onto the yarn instead of forming a ribbon. Two rotating perforated cylindrical rollers, often referred to as the friction drums, insert the twist by frictional rolling of the yarn tail. At the same time, fibers are twisted onto the yarn tail and the yarn starts being formed.

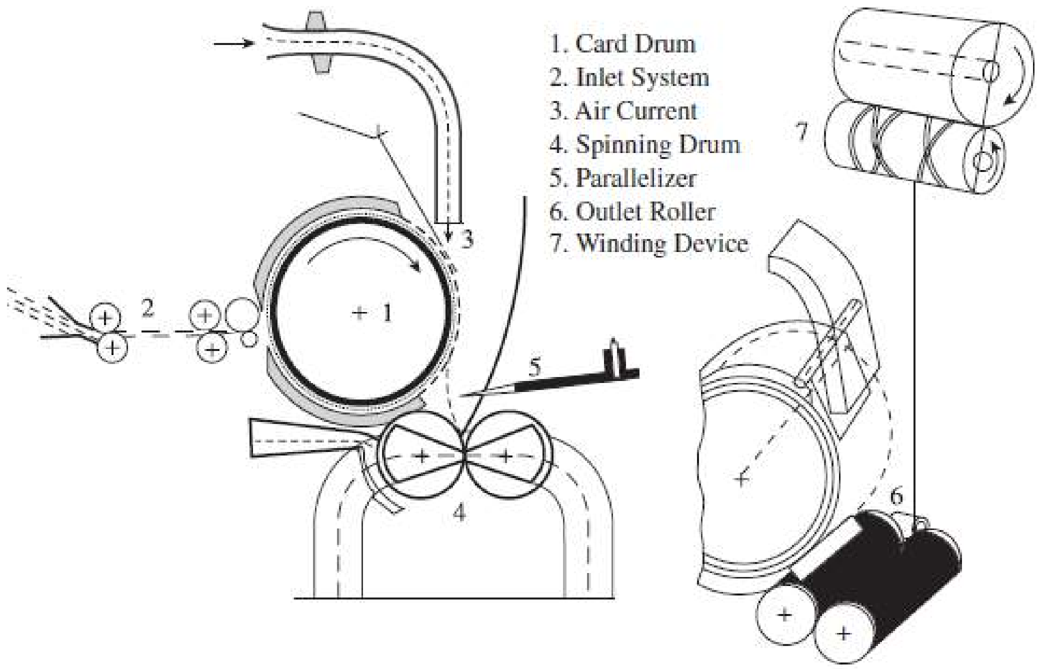

Figure 4: *Main features of open-end friction spinning system Courtesy of Fundamentals of Spun Yarn Technology citing: Fehrer AG.*

3.4.3 Air-jet spinning

Another known method is air-jet spinning which consist of surface fiber wrapping.

In air-jet spinning systems the slivers firstly pass through three pair of rollers. Afterwards, the fibers enter into two air-jets that have a central tubular channel and, inclined to this spinning channel axis there are some nozzles (generally four) by which compressed air is injected. This compressed air creates a vortex flow and it is expanded into the channel. Two velocity components can be distinguished: V1, a circular motion of the air around the channel circumference, and V2, the movement of the air to channel outlet. The mixture of these two speeds makes possible the yarn production.

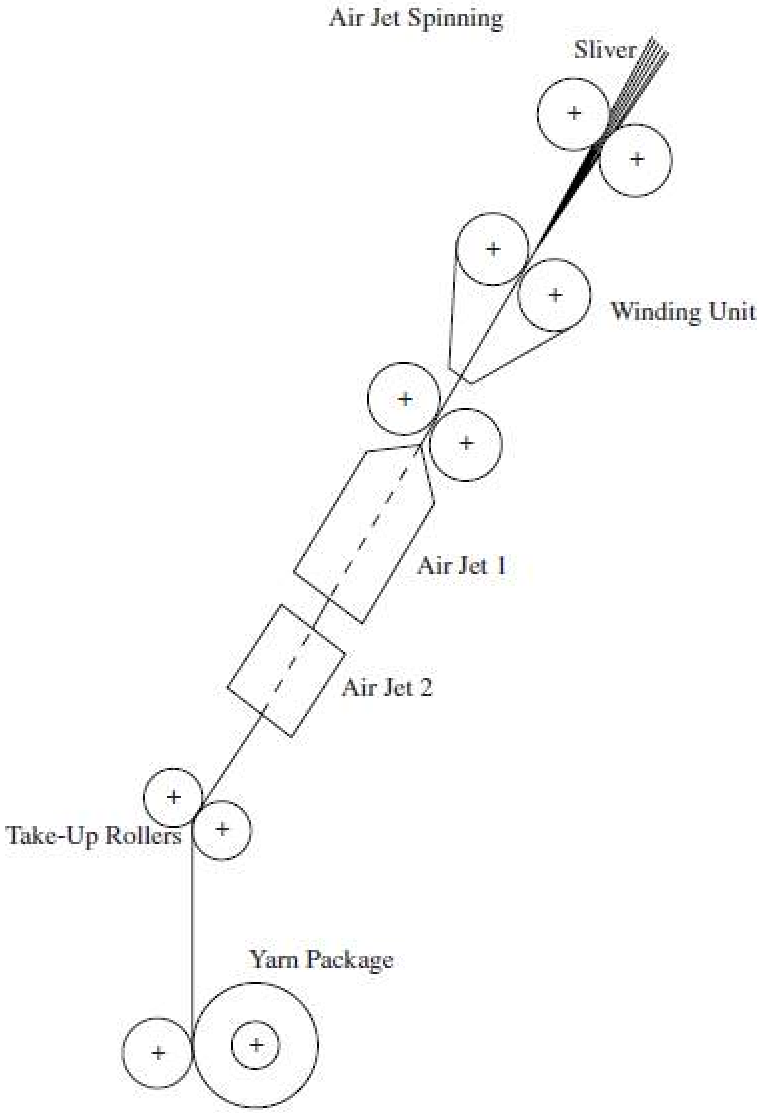

Figure 5: *Air-jet system. Courtesy of Fundamentals of Spun Yarn Technology*

3.4.4 Wrap spinning

Last but not least, wrap spinning. This particular system is the one in which the subject of the thesis will be focused.

Wrap spinning processes are those which consist in, as his own name suggests, wrapping the fibers of a yarn by continuous filament(s) in order to give the yarn more properties. A more specific definition of this particular technique should be the following:

"Wrap spinning is a process whereby a drafted ribbon of parallel fibers that constitutes the bulk of the spun yarn is wrapped by either surface fibers protruding from the ribbon or by a continuous filament or filaments so as to impart coherence and strength to the resulting yarn." [1]

Figure 6: *Wrap yarn structure. Courtesy of Wrap Spinning: Principles and Development.*

The wrap yarn technology is a process by which high quality specific yarns with a wide range of applications are achieved. Those yarns consist of two components; the first one is the staple fiber in the yarn core and the second component is a continuous-filament wound around the strand.

There exist different techniques for wrapping a filament around a core of staple but, concerning those that are suitable for commercial use, the most common technique of filament wrapping is called hollow-spindle wrap spinning.

All of the hollow spindles wrapping systems have the following features:

(1) *Roller drafting units*

(2) *Hollow spindle*

(3) Pair of delivery rollers

(4) Package build unit

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1 **LAWRENCE, Carl A. *Fundamentals of Spun Yarn Technologies.* CRC Press LLC, 2003..**

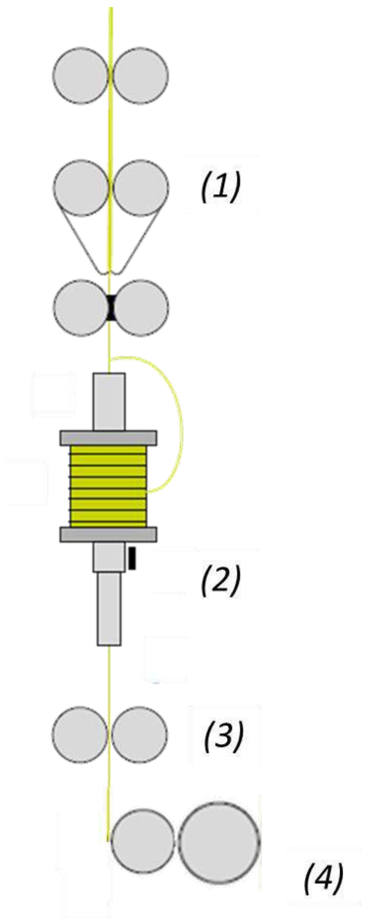


Figure 7: *Hollow spindle features*

Once known the features that this method contains, it is going to be explained how the fibers pass through all of them and create the wrap yarn.

First of all, the roving passes through a roller drafting unit. The most typical roller drafting arrangements are those which contain three, four or five rollers. Once the roving is drafted, it passes down the center of the hollow spindle and it is false-twisted by the twisting device (if necessary). That false-twisting device can either be located at the top of the spindle or at the bottom of it.

Mounted on the hollow spindle unit there is a bobbin that contains the continuous-filament that is going to be wounded around the ribbon. This wounding around the fiber sliver is possible thanks to the rapid movement of the bobbin and, as the ribbon is untwisted, the rotation of the pin false-twister makes possible the union of the ribbon and the filament. It has to be noticed that the filament does not receive the false twist because the bobbin rotates with the spindle.

Once the filament is completely wound around the ribbon, the yarn is finally produced. Then, the delivery rollers conduct the final yarn into a package build unit in order to store it and ease its distribution.

All the characteristics and little details of this process are going to be described on the following part of the thesis while proposing the different ideas for the prototype.

4. PROTOTYPE

Once seen all the concepts and general terms about textile, it is time to try to develop the prototype we are looking for.

As explained in the intro, there are several aspects that have to be taken into consideration. In any case, the most important characteristic that the prototype has to deal with is that it has to be capable to treat whether long or short fibers and roving or ribbon. Those characteristics will add some important properties to bear in mind in some of the structures of the prototype when discussing the possible alternatives.

In order to obtain the wrap yarn desired the prototype should have to be formed by the following main structures:

- Drafting unit
- Hollow spindle unit
- Storage unit

As can be seen, the structures that will contain the prototype are nearly the same as all other hollow spindle wrapping systems have. That is because we are not looking for a new innovative type of machine to treat fibers, but for a prototype to develop different types of wrap yarns based on existing machines.

Hereafter, it is going to be explained in detail each of the parts that the prototype may contain by giving distinct alternatives with some advantages and disadvantages for the prototype.

4.1. Drafting Unit

4.1.1 Principles

The drafting unit, as it has been already explained, consists of a series of rollers that attenuate the fiber mass.

This particular structure is the one that has to deal with the features of treating long or short fibers and ribbon or roving. Those features added the following two aspects to the prototype drafting unit:

- Changeability in the distances between rollers.
- Changeability in the speeds relations between each pair of rollers.

Those aspects will have to be considered at all times when discussing the possible alternatives.

Accordingly with the aspects mentioned above, in order to treat long and short fibers the distance between each pair of roller will have to be changeable for not breaking the fibers. If a fiber is pinched at the same time by different rollers it will break due to the difference of speed of each roller that will be transmitted to the fiber.

Moreover, the input material may be presented in two ways, ribbon or roving, and that particular characteristic demands a changeability in roller speeds.

Hereafter, the alternatives about the drafting unit will be exposed. To make the prototype simpler, the drafting units chosen will have 3 pairs of rollers. All proposals, no matter the length of the fiber and its type, will have to deal with certain parameters established. For instance, the output speed of the treated material, the speed production, will have to be of **100 m/min**. In order to obtain the input speed as well as the one from the middle roller to settle the drafting unit properties, it will be taken into account the following parameters:

	Ribbon	Roving
$\frac{V_{mdl}}{V_{in}}$	1,5	1,5
$\frac{V_{out}}{V_{in}}$	150	50

The rotational speeds of each pair of roller can be known by using the followings equations:

$$W_{in}(rpm) = \frac{V_{in}\,(m/_{min})}{\pi \cdot D(m)} \quad \text{(Eq. 4.1)}$$

$$W_{mdl}(rpm) = \frac{V_{mdl}\,(m/_{min})}{\pi \cdot D(m)} \quad \text{(Eq. 4.2)}$$

$$W_{out}(rpm) = \frac{V_{out}\,(m/_{min})}{\pi \cdot D(m)} \quad \text{(Eq. 4.3)}$$

With the equations mentioned above along with the parameters, it is displayed down below the value of each speed:

	Ribbon	Roving
V_{in} *(m/min)*	0,667	2
V_{mdl} *(m/min)*	1	3
V_{out} *(m/min)*	100	100
W_{in} *(rpm)*	7,074	21,221
W_{mdl} *(rpm)*	10,610	31,831
W_{out} *(rpm)*	1061,033	1061,033

To ease the comprehension of the equations mentioned, a simple schematic is shown below:

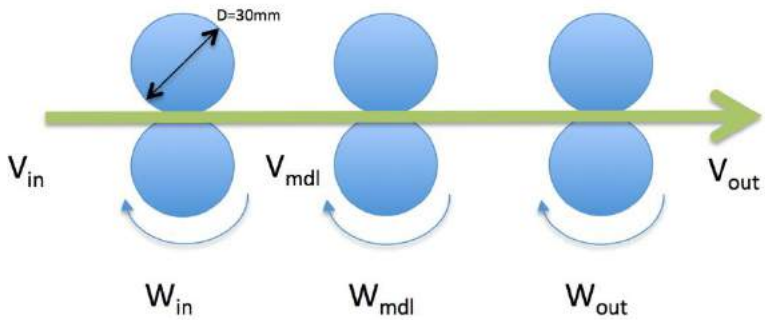


Figure 8: *Drafting unit scheme with corresponding speeds abbreviations*

4.1.2 Alternative 1

The first alternative taken into account in order to develop the drafting system is to command the variations of rotation speeds with mechanical transmissions. These types of mechanisms are used in industrial machines and so, it is interesting to see if they are suitable for the prototype.

In this particular alternative, one only engine is needed. Therefore, to amortize the economics, the engine that could be used could be the one from *Schneider Electrics®* that is already at the university (**BSH0551P31F2A**). The brushless technology of this engine and its characteristics make it suitable for this prototype.

This particular motor (Product chip at section 7.2) turns at a nominal rotational speed of 8000rpm. As explained before, the maximum rotation speed is the one concerning the last cylinder of the drafting unit which, within the example, ranges in values close to 1000rpm. To achieve this rotational speed at the last cylinder with an engine of these characteristics, it is needed to include a reducer (**GBX060008K**) and also a drive (**LXM32AU60N4** or **LXM32MU60N4**) to command the speed to desired values. Both the reducer and the drive have been chosen from *Schneider Electrics®* catalogue according to the compatibilities with the engine.

As known, reducing the rotation speed provokes an augment in the engine torque. The efforts present in the drafting unit commonly are not high, so there will not be any problem when applying this reducer. Consequently, the engine will have enough torque as to make the drafting unit function.

Once the last cylinder speed is achieved, the two remaining speeds will be commanded, as mentioned, by mechanical transmissions, specifically with gears. Lots of combinations of gears can be used in order to achieve the gear ratio we are looking for. Following, it is shown a scheme of the combination of gears which is thought to be the most suitable with the corresponding gear ratios:

Ribbon: $\frac{Z_{mdl}}{Z_{in}} = 1.5$; $\frac{Z_{out}}{Z_{mdl}} = 100$ Roving: $\frac{Z_{mdl}}{Z_{in}} = 1.5$; $\frac{Z_{out}}{Z_{mdl}} = 33.33$

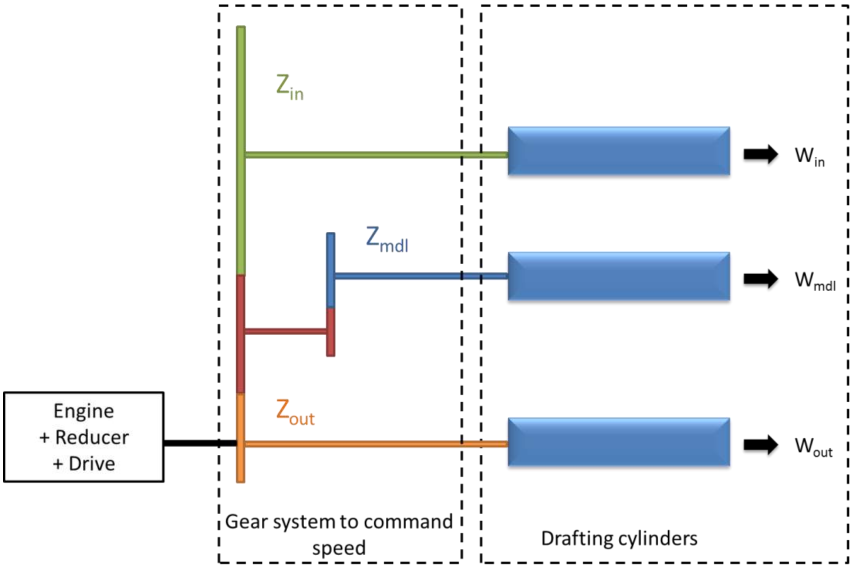


Figure 9: *Mechanical transmission scheme*

The reason why it is thought that this combination would be the most suitable is because it contains the less number of gears to make all the cylinders rotate at the appropriate speed and in the same direction. In other words, less space is needed and that makes the drafting system handier. Of course, the diagram shown above is only an approximation of what the gear system would look like. If this alternative would be suitable, it would be necessary to discuss about the number of tooth each gear should have and also about their radius, all of them according to the gear ratio specified above.

The advantages of this alternative are the outrageous number of possible gears combinations. We can use several different gears with different tooth numbers and radius. Furthermore, we could use standard market gears or even try to create our own gears with a 3D printer. However, creating 3D printed gears can be not useful in account of the weakness of the materials used nowadays in this technology.

Nonetheless, there also exist some disadvantages. Using mechanical transmissions will not allow altering easily from long fibers to short fibers because changing distances between the drafting cylinders will have to deal with removing the gears involved with others more suitable. That is to say, change the gears for others with bigger or lower radius in order to increase or decrease the distance between rollers. Moreover, the speeds relation between the cylinders also varies depending if the yarn will be made from ribbon or roving. That fact will cause again a need of changing the gears so that they conform to the new gear ratios and that would take more time and also more gears and calculations. At last, including mechanical transmissions to the drafting unit will make it heavier and more voluminous.

In order to try to overcome the disadvantages that this alternative presents, it has been opted to study another alternative.

4.1.3 Alternative 2

This second proposal consists of three independent motors, one for each pair of rollers. The engines chosen for this alternative will be the same as the one mentioned in the first alternative, due to the accessibility to them.

The three engines will have a nominal rotational speed of 8000rpm and with the presence of a drive and a reducer the desired speed will be achieved.

The fact that the movement of each pair of roller is carried out by a different engine involves that the speeds of the pairs of rollers are not physically related. Thereby, it will be easier to change the distance between the rollers in order to treat different lengths of fibers, as in the first alterative it was necessary to bear in mind the gears ratios.

Moreover, unlike the first proposal, changing the speeds of the rollers will not have to deal with changing gears and thinking about its ratios, but only with manipulating the drivers. This fact implies an ease in speed changeability.

The combination of the engine, the reducer, and the drive could be commanded by a computer. Thanks to numerical control, the desired speed could be introduced in the computer and this way the rollers would be able to change their rotational speed.

As in the first alternative, a representative schematic of this second alternative is the following:

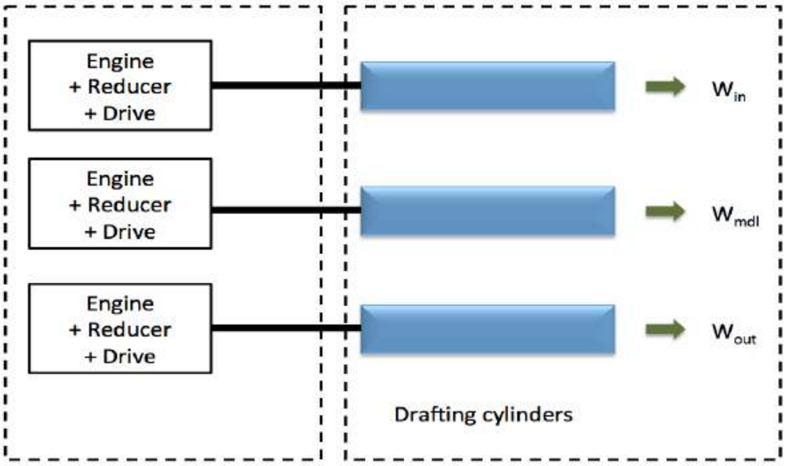


Figure 10: *Engines transmission scheme*

4.1.4 Alternative 3

In case it is not possible to obtain a drafting unit with variable distances between the rollers, the two alternatives above could not be used to spin both long and short fibers. To resolve this problem, a third alternative is proposed. More than an alternative, it is an implementation applicable to both of the previous two alternatives.

That implementation consists of acquiring two different drafting arrangements instead of only one. Each of those two drafting units will have an individual purpose: one will be used to spin short fibers and the other will be used for long fibers.

The problem that presents this alternative appears when trying to give the speed to the rollers of both drafting arrangements.

The simplest way to do so will be to treat both drafting units per separate, that is to say, to make them function with any of the two alternatives mentioned before but with no correlation between them. But, in order to economize, it is better to see if there is a way to connect both drafting arrangements with only one power system.

To achieve this aim, a research has been done and it has been found that the best way to relate both drafting arrangements is with the system called universal joint or Cardan joint; which allows joining two non-collinear axes. Its objective is to transmit the rotational movement of one shaft to the other despite the non-collinearity. The main problem that appears with this joint is that, by its configuration, the shaft at which it is given the transmission does not rotate with a constant speed. However, if two Cardan joints are placed in series and the first shaft and the last one are parallel, these differences in rotation speed are canceled and both the last and the first shafts rotate at a regular and equal speed. Thanks to the parallelism of the rollers from both drafting units, this particular concept is the most suitable to be applied in order to relate the rotation speeds of both drafting units by only the use of one driving mechanism.

On the next page, a scheme of this mechanism is shown:

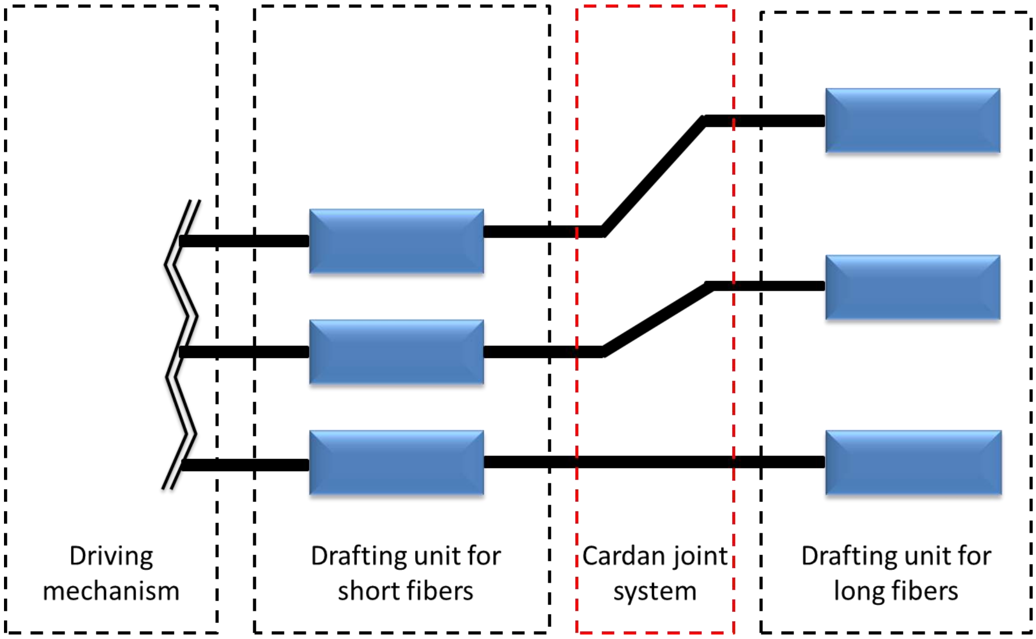


Figure 11: *Cardan joint mechanism scheme*

As the scheme shows, only two Cardan joints mechanisms are needed because the lasts cylinders will be collinear.

An example of what could look like the Cardan joint system can be appreciated in the next figure:

Figure 12: *Cardan Joint*

This implementation will have to deal with the problem of changing from spinning short fibers to spin long fibers. To solve this problem, two options can be taken into account.

On the one hand, the prototype could contain a rail system as to enable the movement of the hollow spindle unit. This way, we could be able to change from spinning long fibers to spin short fibers by moving the hollow spindle structure. In this option, it is assumed that only one hollow spindle structure is going to be used and that both short and long fibers are not going to be spun at the same time.

On the other hand, instead of having one only hollow spindle unit and a movement system, two fixed hollow spindle units can be used. One would be used for treating short fibers and the other one for long fibers. This alternative will enable, if necessary, to treat both long and short fibers at the same time. More details of this particular option are clarified in section 4.2.2.

As explained, with this implementation both drafting units will be functioning at the same time even though, possibly, only one of them will have a purpose. From an energetic point of view, that implementation would not be considered as suitable because it implies a loss of energy. That is certain, but it is reminded that it is a prototype what is being tried to achieve, and not a fully operable industrial machine. That is the reason why that energy loss does not include any impediment.

4.2. Hollow Spindle Unit

4.2.1 Principles

As we have been discussing throughout the project, the aim of it is to achieve those wrap yarns wanted. Now, it is time to settle the parameters of the hollow spindle unit.

According to that, the ribbon or the roving coming from the drafting unit would have to be wrapped by a filament. That filament will be stored around a bobbin and, as the fiber strand passes through the center of that bobbin, the filament will wrap it thanks to the rotation speed given to the bobbin.

In general terms, combining the rotation speed of the bobbin with the vertical speed of the fiber strand will be the key of the wrapping yarn. More rotation speed with less vertical speed will produce a much wrapped yarn and vice versa. In order to measure if the yarn is more or less wrapped the next formula will be applied:

$$Amount\ of\ wrapping = \frac{Wbobbin}{Vout}\left[\frac{rev\ of\ bobbin}{m\ of\ yarn}\right] \qquad \text{(Eq. 4.4)}$$

For the purpose of giving a certain rotation speed to the bobbin another engine is needed. Again, the engine that is already at the University is suitable for this purpose. But, as mentioned before, when looking for a much wrapped yarn, it is more convenient to accomplish a high bobbin rotation speed. As the engine provides a speed of 8000rpm it would be suitable to include a system to augment and vary that speed. To obtain this augmentation of speed, a gears system can be used. This system should be as simple as possible. That is why only two toothed wheels are going to be used. In order to make the prototype as much trustworthy to the existent machines, those gears will be not directly physically connected but connected by a toothed belt. As usual, an additional gear will be also included to maintain the contact and tense the belt. The fact of connecting both toothed wheels with a belt also contributes to an ease to vary the speed by changing those gears and a diminution of lubrication to the system.

According to the following equation, whatever desired rotation speed of the bobbin can be obtained depending on the teeth of the gears:

$$W_{engine} Z_{engine} = W_{bobbin} Z_{bobbin} \quad \text{(Eq. 4.5)}$$

It is important to remark that, in order to let the yarn pass through the gear attached to the bobbin, this one has to contain a hole on its center.

4.2.2 Two Hollow Spindle alternative

After describing the mechanisms of a single hollow spindle, we can get back to the alternative of having two different hollow spindles. If this idea would be put into practice, both hollow spindle units would be subjected to the same characteristics mentioned above. For instance, both of them will turn thanks to the same double sided toothed belt which will transmit the rotation movement. That is to say that both units will be turning equally and at the same time.

According to this alternative, three possible ways of spinning can be distinguished:

- The prototype only treats short fibers.
- The prototype only treats long fibers.
- The prototype treats both short and long fibers.

If both short and long fibers are being treated at the same time, apparently does not imply any problem. The difficulties appear with the first two options. When only one hollow spindle is treating fibers and the other one is not, as mentioned, both of them will be turning. That means that while one unit will be working, the other unit will be heating itself and supporting useless efforts, as well as implying an energetic loose. Moreover, having elements turning around us is a danger.

In order to solve these problems, it has been thought of attaching a mechanism so as to stop the hollow spindle unit that is not being used. First of all, to maintain the contact between the gear and the belt as to keep the hollow spindles rotate, a pair of plain cylinders will be used. So, if we only want to treat one type of fibers, we would be capable of removing the cylinders so that the contact between the gear of the non-wanted hollow spindle and the belt would be lost. Without contact, there is not movement and the prototype becomes safer. In addition, to reduce the speed quicker, the mechanism will also contain a brake synchronized with the cylinders. This means that when the cylinders are exercising pressure to the belt, the brake does not have any function; it does not touch the hollow spindle. Otherwise, at the same time the cylinders lose contact with the belt, the brake approaches to the hollow spindle and stops it.

A top view schematic of how the whole hollow spindle unit would look like with this alternative is shown below:

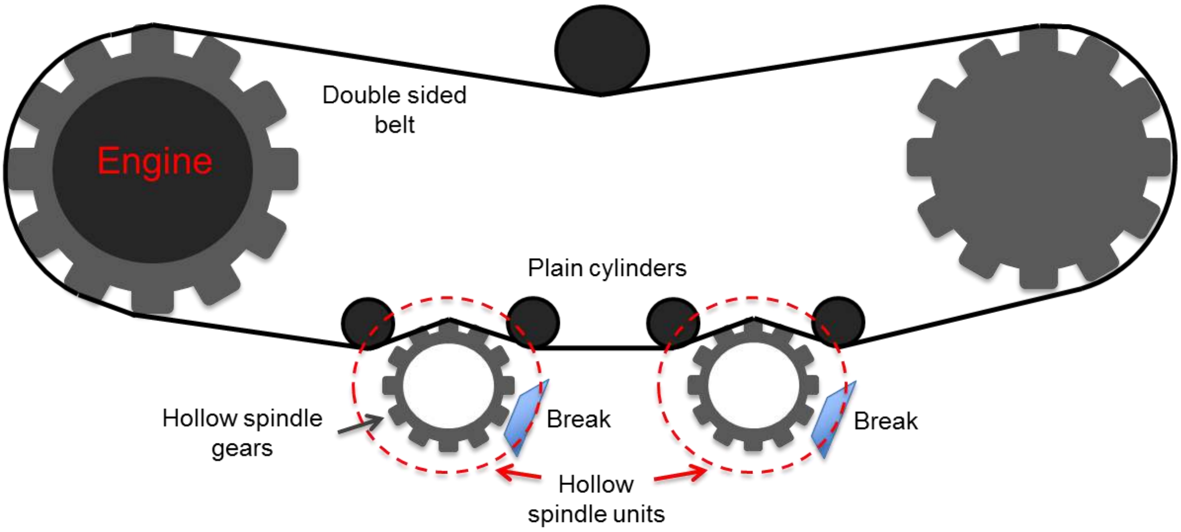


Figure 13: *Top view schematic of two hollow spindle units alternative*

4.2.3 Numerical example

Once the ideas of the wrapping unit have been settle, it is given a numerical example of how one can achieve all the values wanted concerning this unit.

The rotation speed of the engine it has been said that it is 8000rpm. According to the numbers presented at the beginning of this chapter, the production speed is about 100m/min. Imagine that for the desired yarn an amount of wrapping of 300 revolutions of filament per meter of yarn is wanted. According to this numbers, the following features can be obtained:

- Rotation speed of the bobbin:
  When knowing the amount of wrapping wanted and the speed production we can obtain which is the appropriate rotation speed of the bobbin. By using (Eq.4.4) and isolating the unknown variable we obtain:

$$W_{bobbin} = V_{out} \times \text{Amount of wrapping} = 100\,\frac{m}{min} \times 300\,\frac{rev}{m} = 30000\ rpm$$

  This way, in order to achieve the wrap yarn wanted, the bobbin should have a rotation speed of 30000 rpm.

- Number of teeth of the gears:
  Once we know the rotation speed of the bobbin, by using and developing (Eq.4.5) we obtain the gear ratio of the teeth wheels.

$$\frac{Z_{engine}}{Z_{bobbin}} = \frac{W_{engine}}{W_{bobbin}} = \frac{30000\ rpm}{8000\ rpm} = 3.75$$

  With this gear ratio we obtain the following combinations of teeth wheels:

Z_{bobbin}	Z_{engine}
16	60
20	75
24	90
28	105
32	120
36	135

Z_{bobbin}	Z_{engine}
40	150
44	165
48	180
52	195
56	210
60	225

  After achieving these tables, the only thing left is to decide which pair of wheels are more easily reachable for us and attach them to the prototype.

- Pitch:

  Additionally, thanks to the amount of wrapping, we can also calculate the distance between each revolution of the wrapping filament as:

$$\text{Pitch} = \frac{1000\ \text{mm}}{\text{Amount of wrapping}} = \frac{1000\ \text{mm}}{300\,\frac{\text{rev}}{\text{m}}} = 3.33\ \text{mm}$$

With this example as a pattern, we are able to achieve all the details needed in order to achieve other types of yarns.

4.2.4 Twisting element

As commented along the pages above, some short fibers present difficulties when treated. In order to overcome those difficulties, providing a false-twist is a must. As explained in the ANNEX 7.1, applying a false-twist to fibers gives them a torsion which will help its treatment. Therefore, the bobbin would have to contain some sort of a false-twist mechanism. In addition, this false-twist applied is not contradictorily with long fibers so, it will be suitable for both long and short fibers.

When applying the false-twist two alternatives can be discussed: above or below the bobbin. But, the closer to the end of the drafting unit will occur the false-twist, the better. In order to give the appropriate time to make the false torsion disappear before storing the finished yarn, it is preferred to apply the false-twist above the bobbin.

Once decided that it is better to place the false-twist above the bobbin, it is time to determine how it is going to be applied. As explained in the ANNEX 7.1, false twist can be either applied by the filament that will wrap the ribbon or the roving, or by mechanisms specially designed for this purpose. Hereafter, three possibilities are presented (two with an external twisting element; and the other one with the filament acting like a twisting element):

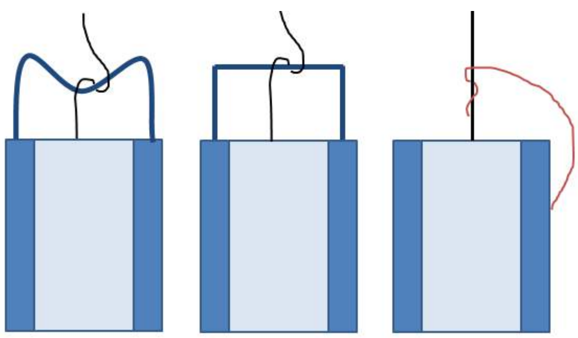


Figure 14: *Schematic of 3 possible false twist alternatives*

As it can be seen in section 5.2, those three possibilities shown above are quite similar to the ones used in real enterprises.

Another possible option is the false-twist mechanism used in the machine ParfiL by the Suessen Company shown below:

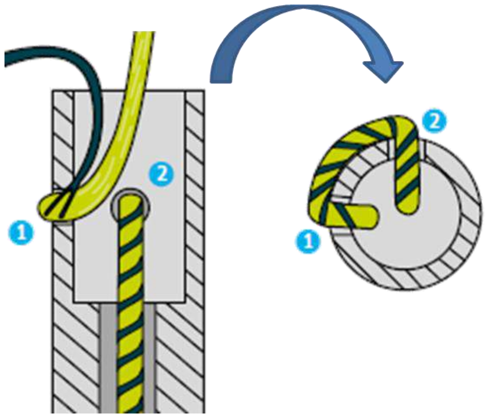


Figure 15: *ParafiL false-twist system (courtesy of The Rieter Manual of Spinning)*

After all, and as a conclusion, even though thinking that the best option is to place the twisting element at the top of the bobbin, the optimum alternative is to have a removable twisting element. This way we could be able to attach or remove the twisting element depending on the fibers requirements. If the fibers treated need a false-twist, the false-twist element will be attached to the bobbin. Whereas, if the fibers treated do not request any false-twist principle, we could be able to remove it and treat them without a twisting element.

4.3. Storage unit

Once the yarn has been produced it is now time to store it. The final yarn originating from the hollow spindle unit passes through two delivery rollers and afterwards it gets stored around a storage bobbin. In order to storage the final yarn around the bobbin, two main procedures are afterwards going to be proposed.

4.3.1 Principles

Before explaining these two procedures, some general information has to be clarified.

The first thing that it is important to notice is that the yarn has to have the same speed during all the process. Otherwise, the tension forces developed owing to the speed differences would end up with the yarn break. That is the reason why the bobbin has to rotate at nearly the same speed as the last drafting cylinder. But, it is not the storage bobbin at which the rotation speed is going to be given by the engine. In fact, a complementary bobbin is going to be attached at the storage unit and it is that bobbin the one that is going to receive directly the rotation speed.

The use of both bobbins is essential. When wrapping the yarn around a bobbin the diameter of this particular bobbin increases with the layers. Nevertheless, the production speed desired at all times is constant. So, if the yarn would be directly wrapped around the storage bobbin, the rotational speed of it would have to decrease continuously. That is the reason why the constant rotational speed is transmitted to the complementary bobbin. The storage bobbin, hence, rotates thanks to the friction with the complementary bobbin.

According to the idea that two bobbins in contact are going to be needed, it is time to focus on the speed. If, for instance, we focus on a single point of the yarn between the two bobbins, this point is going to have a speed itemized in two components: one vertical component and another one horizontal. The combination of both components ends with the real speed (V_y).

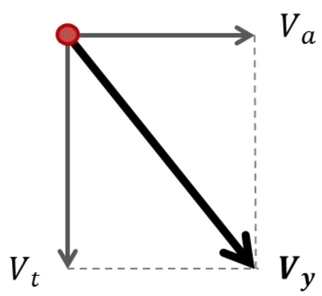


Figure 16: *Speeds diagram*

The first component makes reference to a tangential speed (V_t) proportioned by the rotation. This speed can be calculated multiplying pi per diameter (d) per rotation speed (n):

$$V_t = \pi \cdot d_c \cdot n_c = \pi \cdot d_b \cdot n_b \qquad \text{(Eq. 4.6)}$$

As the rotation speed of the storage bobbin (b) is not constant, it is the rotation speed of the complementary bobbin (c) the one that is more suitable to use.

The horizontal component of the speed refers to the speed given to the yarn when moving along the bobbin in order to get stored around it. Although this axial speed (V_a) can sometimes be disregard, it can be calculated as:

$$V_a = pitch_c \cdot n_c \qquad \text{(Eq. 4.7)}$$

The mathematical combination of both equations, (Eq. 4.6) and (Eq. 4.7), gives us the real speed of the winding. In fact, we can refer to this winding speed as the speed of the yarn (V_y):

$$V_y = \sqrt{V_t^2 + V_a^2} \qquad \text{(Eq. 4.8)}$$

This particular speed is the one that would have to be constant and equal to the production speed in order to not break the yarn. This way, the yarn will not be once stretch and other times slackened.

Although we are able to achieve a winding speed equal to the production speed, as the yarn gets stored along the bobbin some tension forces will appear. For instance, when the yarn is getting stored at the edge of the bobbin, the tension at which it is being subjected is higher than when it gets stored at the center of the bobbin.

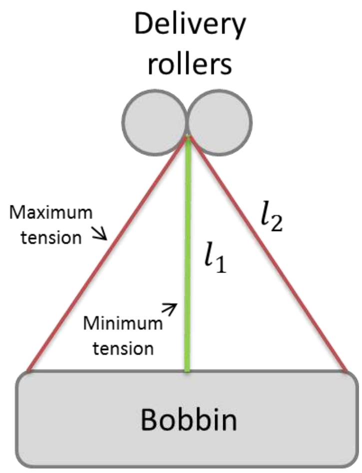


Figure 17: *Yarn efforts when storing*

Despite that these inequality of tensions does not imply a problem, it will be tried to decrease it. Minimum differences between tensions are better than higher differences.

In order to try to minimize the inequity of tensions, increase the distance between the delivery rollers and the bobbins is the best option. This can be demonstrated with the following approach:

$$\Delta L = l_2 - l_1 \qquad \text{(Eq. 4.9)}$$

$$\Delta Tension = \frac{\Delta L}{l_1} \cdot E_{young} \qquad \text{(Eq. 4.10)}$$

As we can see in (Eq. 4.10), when we increase distance, the numerator and the Young Modulus of the yarn remain constant contrarily to the denominator that increases; and so, as we were looking for, the inequity of tensions present in the yarn decrease.

Taking into account the general terms of the storage unit described above, the two procedures of storing units are going to be presented.

4.3.2 Procedure 1

This storage process consists on a complementary bobbin provided with rails that permits to guide the yarn to get stored around the storage bobbin.

Once the yarn has been manufactured, it is conducted to that specific bobbin in order to make it pass through its rails. The yarn follows the rails thanks to the rotation movement of the bobbin around its own axis and it gets stored around the storage bobbin. As explained above, is this specific bobbin the one that rotates thanks to the engine.

In order to economize the prototype, the same engine of the drafting system could be used to also provide the rotation of the storage unit. To provide that rotation speed, two toothed wheels interconnected by a toothed belt are going to be attached. One toothed wheel will be placed at the last drafting cylinder, and the other one at the complementary bobbin. The toothed belt will be used because it is the best way to enable the transmission of movement without contact.

As explained before, the horizontal speed component cannot always be disregard, and so the rotation speed of the last cylinder and the rotation speed of the bobbin have to be different in order to not break the yarn. According to this, there will have to be a gear ratio between the cylinder and the bobbin in order to decrease the speed. This gear ratio could be changed as desired by changing the gears attached to the complementary bobbin.

The yarn that follows the rail of the bobbin is not storage around it. Attached to the bobbin with rails there is a storage bobbin where the yarn is stored along it in a distributed way, thanks to the rail bobbin that places the yarn each turn in a different place. Once the first layer of yarn around the storage bobbin is finished, the next layer is started and so on. The storage bobbin also turns around its axis; but now, it rotates thanks to friction with the other bobbin, not thanks to another engine.

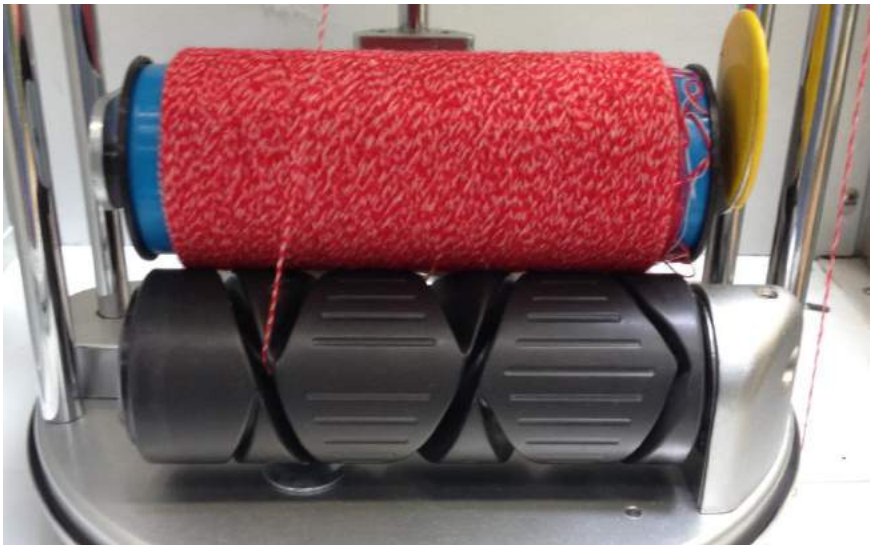


Figure 18: *Storage unit procedure 1*

According to the storage principles, in order to increase the distance between the delivery rollers and the bobbins with the aim of lightening the tension variations, the following mechanism with a metallic bar seems appropriate:

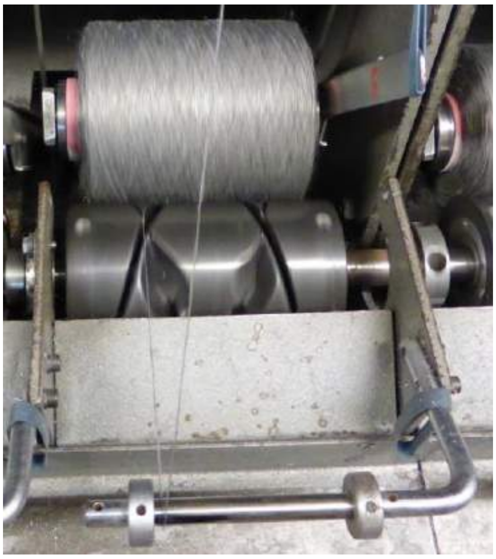


Figure 19: *Enterprise storage unit*

4.3.3 Procedure 2

In this second alternative the function of the railed bobbin will be replaced by a smooth bobbin and a guide; but never forgetting the idea that when wrapping the yarn around the bobbin the diameter increases and thus it cannot be directly done.

As in the first procedure, the smooth bobbin, which replaces the bobbin with rails, will also receive the rotational movement from the engine of the drafting system with the aid of a toothed belt and the gears. The storage bobbin will once more rotate thanks to the friction between both bobbins.

In this second procedure, once the yarn leaves the hollow spindle and the delivery rollers, it passes through a guide which is in charge of distributing the yarn along the first bobbin by moving horizontally from one side to the other. So, when one layer is completed the next one will be started. The guide is used then as a connection between the hollow spindle and the bobbin where the yarn is stored.

This second procedure would also have to contain the same mechanism as the first alternative in order to decrease de inequity of tensions while winding.

It is important to notice that by this procedure we would be able to command the axial speed because this one is exactly the speed of the guide. By commanding the guide speed, the yarn speed of the storage unit (V_y) would be more accurate. That is the reason why this second alternative is commonly known as accuracy winding.

A picture of what this mechanism would look like is shown below:

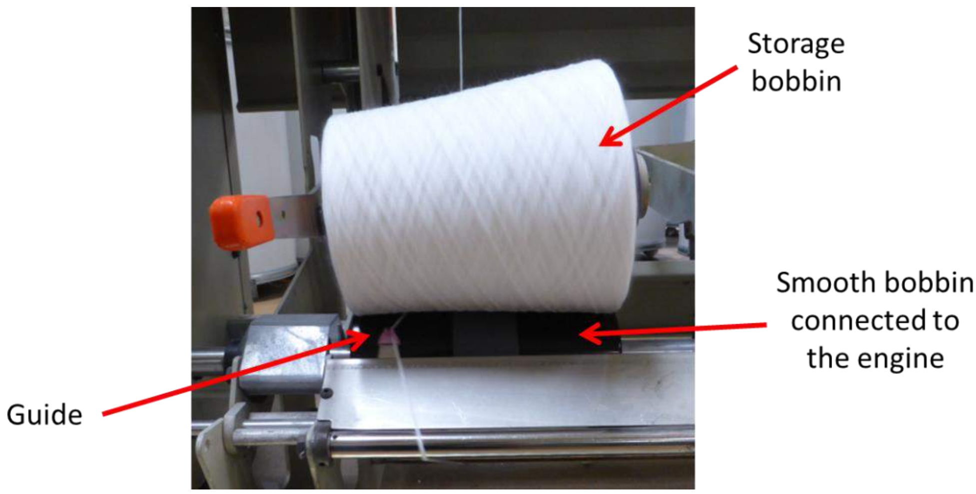


Figure 20: *Storage unit procedure 2*

5. Enterprises

An essential part of this project is to know what type of mechanisms or machines are used by real enterprises. It is remind that the aim of the project is not to create a new wrap yarn machine but to develop a prototype by gathering different parts of existing machines. That is the reason why knowing what type of machines are the enterprises using is a must.

To acquire this knowledge, two enterprises which develop yarns of the characteristics wanted have been contacted and visited. Those two enterprises are: *Schappe Techniques* and *Bergère de France*.

5.1. Schappe Techniques

Schappe Techniques is an enterprise with a known reputation for the spinning of the latest generation of advanced technical fibers. The technical yarns developed by this enterprise have numerous applications in nowadays industrial fields such as composites, individual protection, packing, glass industry or technical sewing threads.

In order to achieve those wrap yarns, Schappe Techniques uses the ParafiL wrap spinning system by the Suessen Company. The machine that we could be able to see and analyze treated some sort of metallic fibers. The nature of these fibers (its thickness) explains the no presence of false-twist. Moreover, metallic fibers are abrasive and the efforts between the fibers and the twisting element could end breaking that element.

Due to the confidentiality of the enterprise, not much information could be extracted. However, some photographs of the Schappe Techniques system are shown below and commented according to what has been studied.

The picture on the next page shows the complete Suessen ParafiL system used to develop the wrapp yarns of the enterprise.

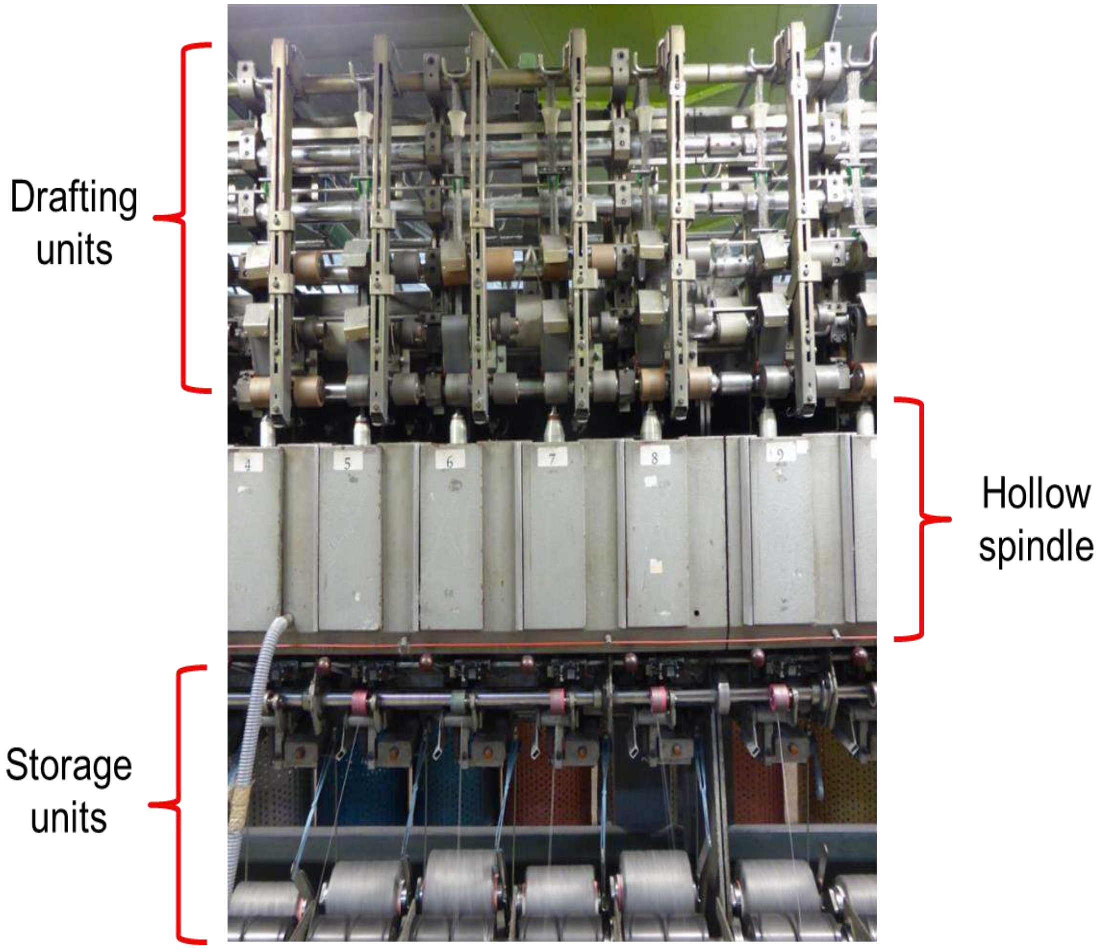


Figure 21: *Suessen ParafiL system used in Schappe Techniques*

As it can be observed in the picture, we can rapidly distinguish the 3 major components of a hollow spindle system studied in the thesis and that the prototype should have.

At the top, there is a drafting unit which is in charge of elongating the fibers; the hollow spindle unit, where the filament stored around the turning bobbin wraps the fiber mass; and, finally, at the bottom, the storage unit; where the wrap yarn manufactured is there stored.

The drafting unit used in this machine had the possibility of changing distances between the rollers. That enabled the machine to have more uses. That is to say that the machine was able to treat different types of fibers depending on their length. That specific characteristic is one of the ones we are looking for and accords to alternative proposed.

The next picture shows the end of the drafting unit and the top of the hollow spindle.

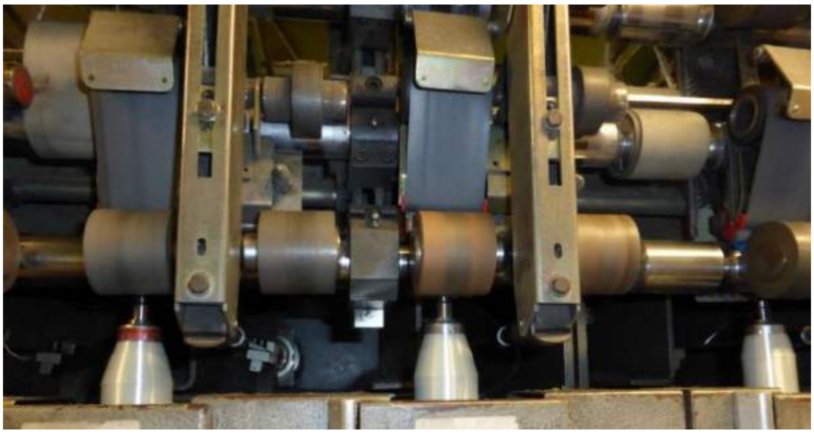


Figure 22: *Drafting unit and hollow spindle at Schappe Techniques*

If we peer on the picture, we can be able to see how the filament is getting off the bobbin and getting wrapped around the fibers. Furthermore, if we could be able to see the top-end of the hollow spindle, we could appreciate that there is not twisting element. As explained before, the thickness and cohesion of the fibers along with their abrasive properties make the presence of a twisting element unnecessary. Nonetheless, according to the characteristics of some of the fibers that out prototype is wanted to manufacture, the presence of a twisting element is going to be crucial.

On the occasion of the visit, we received two twisting elements normally used in the ParafiL system. Those twisting elements were the same as the ones shown and described in section 4.2.4.

Last but not least, the storage unit. As observed in the next photograph, the alternative they use to store the yarn is the same as the first one described on the prototype explanation. Furthermore, it also includes a metallic bar as to increase the distance between the delivery rollers and the bobbins.

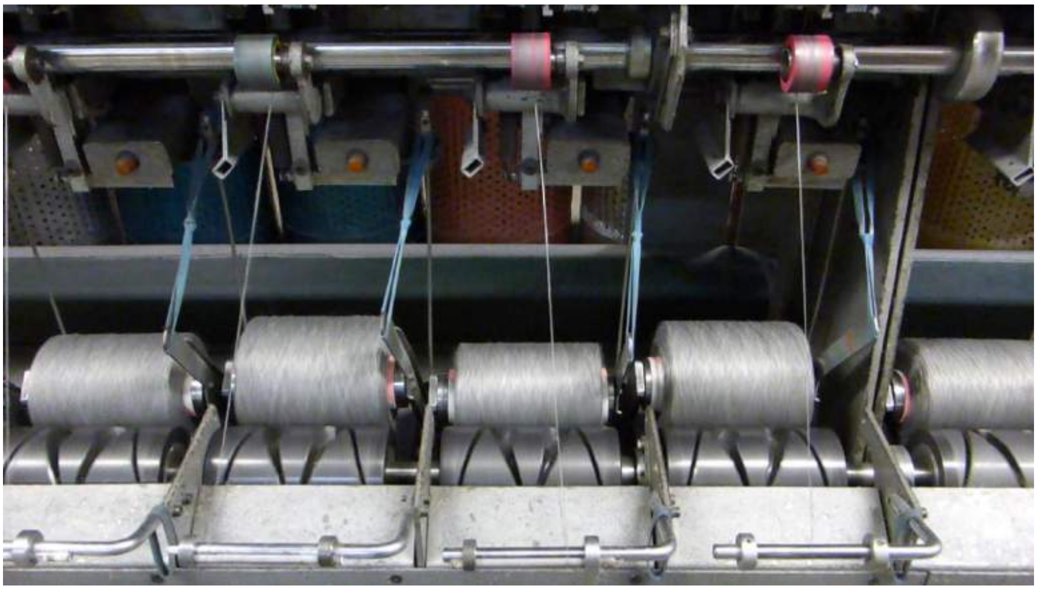


Figure 23: *Schappe techniques storage unit*

5.2. Bergère de France

Contrary to *Schappe Techniques*, the enterprise *Bergère de France* is known for treating common fibers but not technical. *Bergère de France* manufactures a large amount of different types of yarns adequate for all kinds of clothes and accessories. Among all their yarns, there is one named “fil fantaisie” that is manufactured using a hollow spindle system. This concrete yarn is the one in which the visit has been focused.

In order to manufacture this “fil fantaisie”, Bergère de France utilizes four types of machines. Once more, all of them also contained the 3 basic components of the hollow spindle system. But, despite all of them used the same system and principles, each one had something in particular that distinguish it from the others. Following, some of these characteristics are described and shown in pictures.

Concerning the drafting unit, the most relevant fact seen among those machines is that one machine was able to create a yarn mixing two different fibers. That machine counted with two drafting units which processed fibers at the same time. Those fibers where conducted to the same point in order to develop the yarn core. This way, yarns made of fiber mixture were able to be made. Despite in the prototype only one type of fiber at a time is going to be manufactured, it is interesting to know that a different type of yarn can also be reached by using a mixture of two different fibers. A picture of this mechanism explained is shown below:

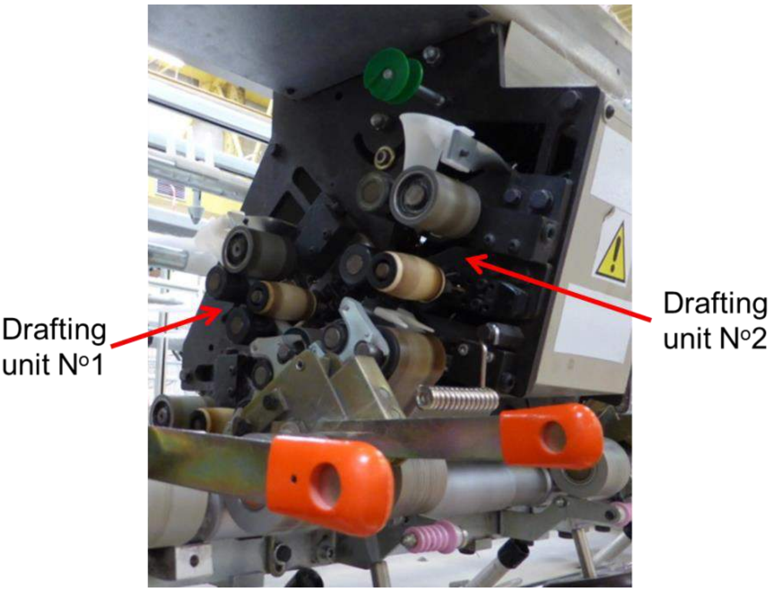


Figure 24: *Mechanism able to mix fibers*

What refers to the hollow spindle unit, not surprising things were observed. All of them comprise a bobbin with the filament in charge of wrapping the yarn. But, contrarily to the machine seen at Schappe Techniques, the wrapping units from Bergère had twisting elements. Those twisting elements had different shapes but all of them did the same job. Furthermore, all of them were placed at the bottom of the hollow spindle unit which contradicts the reasoning made in the prototype explanation where it has been opted for placing it at the top better than at the bottom.

The pictures below show some of the twisting elements mentioned:

Figure 25: *Different type of twisting elements at Bergère de France*

About the storage arrangements seen, both of the procedures mentioned when describing the prototype were used. Some machines used the bobbin with rails and others the plain bobbin with the yarn guide. This confirms that both of the alternatives proposed are the most suitable due to their use in industrial productions.

Equally to the storage units in the machines of Schappe Techniques, some of the machines in Bergère de France also contained a metallic bar to decrease the yarn tension stresses. Another one, in order to solve this problem by increasing the distance, it had the storage unit placed above the drafting unit. This way, the yarn makes a long way until the storage unit and the differences in the tension stresses are decreased.

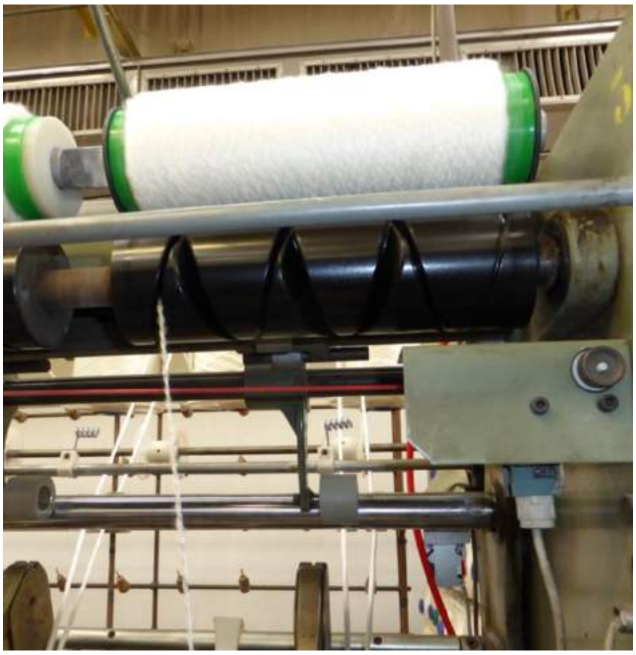


Figure 26: *Storage unit placed above the wrap spinning system*

Finally, one of the machines had a complete automatized functionality. An intelligent screen enabled to change productions, speeds, detect mistakes in the yarn and other characteristics. That would be considered as the last stage of the prototype. Once the prototype is fully operable, a possible implementation could be to try to automatize everything by an intelligent screen such as that one.

6. CONCLUSIONS

Above all, it is important to remark that this thesis enables the possibility to continue investigating and trying to reach new alternatives and knowledge. Furthermore, any decision has been taken among all the alternatives proposed to let to the possible future developer of the prototype more variety of options.

However, by now it is possible to highlight some conclusions concerning the future prototype.

First of all, it can be concluded that the wrap yarn prototype must have to contain three main features: the drafting unit, the hollow spindle and the storage unit. Those three features are primordial to develop the prototype even though the numerous different alternatives that can be taken into account; like the ones studied and also the ones not studied.

Furthermore, all the features proposed to be included to the prototype at the beginning of the project have been successfully achieved in every single alternative of it. All the different mechanisms proposed are able to deal with those features; which means that regardless of which alternative is going to be later developed, there can be no doubt that the features sought will be taken into account.

In addition, most of the procedures proposed for the prototype are nearly identical to those mechanisms used in nowadays industrial machines. That enables to reinforce the goal of finally achieve to develop the prototype.

In other words, as explained in the introduction, at the beginning of the project the prototype seemed non-achievable. Once the research has been done and the main ideas of the prototype have been settled and studied, it can be concluded that, by now, the prototype has become an achievable reality. Furthermore, hopefully in a near future, this prototype could become real and fully operable.

Concerning the other educational objectives mentioned, knowledge in textile engineering has been fully enlarged. The textile introduction done at the beginning of this thesis allows obtaining a general overview of the process at which fibers are subjected in order to be converted into yarns. Moreover, general physical concepts and characteristics have also been comprehended.

7. ANNEX

7.1. False Twist

There are some stages related with the yarn producing that need to be false-twisted.

Apply a twist to a fiber strand increases the fiber tenacity and gives them cohesion. That cohesion is, above all, significant in short fibers because, without it, fibers tend to separate and the fiber mass would break regularly. In the field of long fibers, this twist in not that important by reason of the own length of the fibers that make them stabilize and do not break.

Even though a twist is needed to give some cohesion to fibers, the torque provided by that twist is not useful and so, it is need to make it disappear. That is the reason why the false-twist method is applied.

This particular method consists on the following:

When a ribbon is nipped by two extremes and a twist, by angular speed W [rev/min], is applied in some point in between those two extremes, it appears a torque in both sides of the point where the twist is applied (one part of the ribbon twists in one way and the other twists in the opposite way). If the ribbon has no speed, i.e. it is static, the torsion maintains itself. This torsion is referred to as stable torsion. But, if the ribbon is given a certain speed, the torsion of the inferior part of the ribbon (B) is going to disappear after passing a certain time (virtual torsion), whereas the superior part of the ribbon (A) is going to maintain the torsion (stable torsion).

Thus, the non-needed torsion (T_B) disappears while the needed torsion (T_A) is maintained.

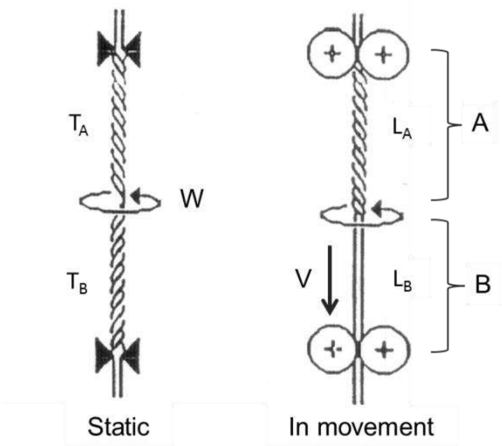
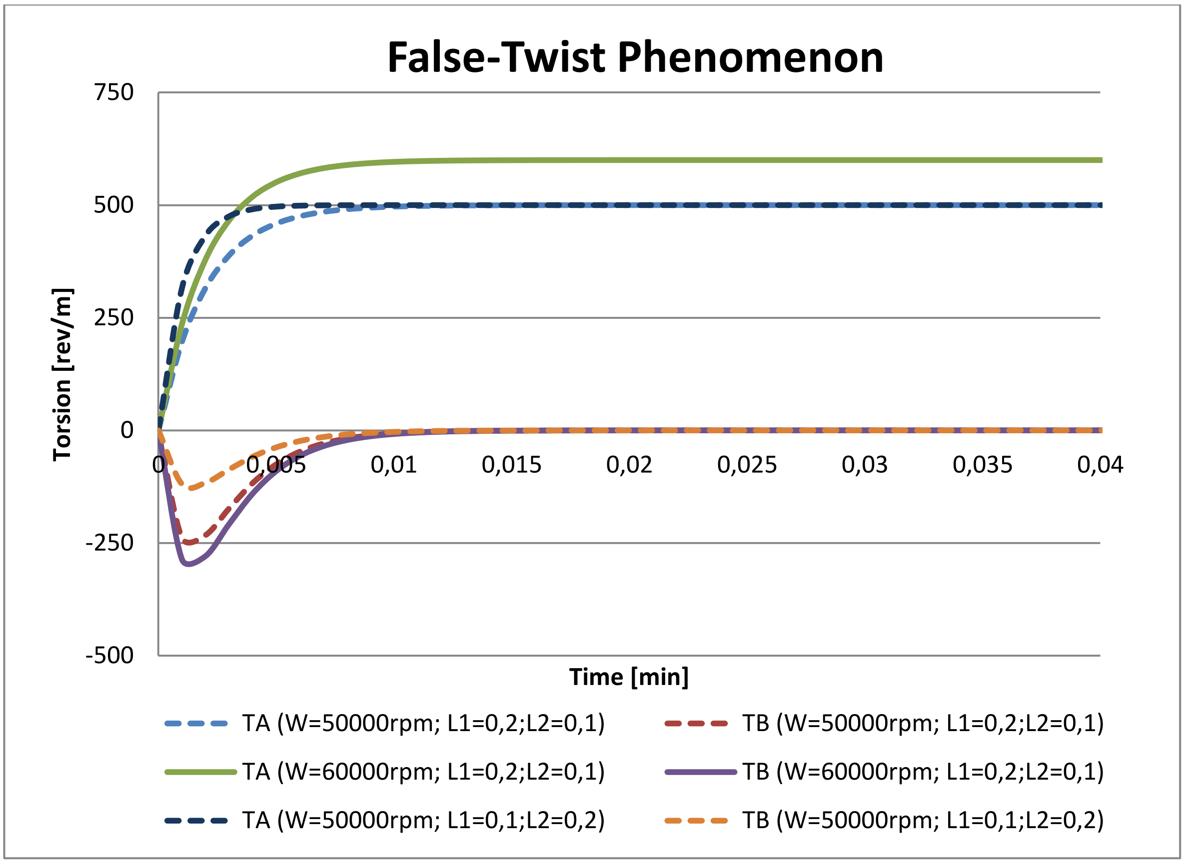


Figure 27: *False-twist concepts*

The next formulas with the corresponding graphic corroborate that phenomenon:

$$T_A\left[\frac{rev}{m}\right] = \frac{W}{V}\cdot\left(1 - e^{\frac{-V}{L_A}\cdot t}\right)$$

$$T_B\left[\frac{rev}{m}\right] = \frac{W}{V}\cdot\frac{L_A}{L_A - L_B}\cdot\left(e^{-\frac{V}{L_B}\cdot t} - e^{-\frac{V}{L_A}\cdot t}\right)$$



According to the graphic shown above we can obtain the following conclusions:

- When increasing the rotation speed (W), both the torsion applied at the top of the yarn (T_A) and at the bottom of it (T_B) increases in absolute value.
- With the same rotation speed (W), if the superior part of the yarn (A) is shorter than the inferior part (B), the maximum T_A is achieved faster and the non-needed torsion (T_B) disappears faster too. So, the shortest the part A is, the better; in order to be sure that the non-needed torsion disappears before storing the yarn.

There exist different ways by which the false twist method can be applied. It can be the filament itself that exerts a pressure to the ribbon, and that pressure is the responsible of applying the twist along the ribbon and producing the false twist; or also other mechanisms specially designed for this purpose.

7.2. BSH0551P21A2A

Fiche produit
Caractéristiques

BSH0551P21A2A

servo-moteur CA BSH - 0,5N.m-8000tr/mn

- arbre non taraudé - sans frein - IP65

Principale

Statut commercial	Commercialisé
Type de produit ou de composant	Moteur autopiloté
Nom abrégé d'appareil	BSH
Vitesse mécanique maximum	9000 Tr/mn
Couple continu à l'arrêt	0.5 N.m pour LXM32.U60N4 1.5 Aà 480 V triphasé 0.5 N.m pour LXM32.U60N4 1.5 Aà 400 V triphasé 0.5 N.m pour LXM15LU60N4à 230 V triphasé 0.5 N.m pour LXM15LD13M3à 230 V monophasé
Couple crête à l'arrêt	1.5 N.m pour LXM32.U60N4 1.5 Aà 480 V triphasé 1.5 N.m pour LXM32.U60N4 1.5 Aà 400 V triphasé 1.4 N.m pour LXM15LU60N4à 230 V triphasé 1.4 N.m pour LXM15LD13M3à 230 V monophasé
Puissance de sortie nominale	300 W pour LXM32.U60N4 1.5 Aà 480 V triphasé 300 W pour LXM32.U60N4 1.5 Aà 400 V triphasé 170 W pour LXM15LU60N4à 230 V triphasé 170 W pour LXM15LD13M3à 230 V monophasé
Couple nominal	0.48 N.m pour LXM32.U60N4 1.5 Aà 480 V triphasé 0.48 N.m pour LXM32.U60N4 1.5 Aà 400 V triphasé 0.46 N.m pour LXM15LU60N4à 230 V triphasé 0.46 N.m pour LXM15LD13M3à 230 V monophasé
Vitesse nominale	6000 tr/mn pour LXM32.U60N4 1.5 Aà 480 V triphasé 6000 tr/min pour LXM32.U60N4 1.5 Aà 400 V triphasé 4000 tr/mn pour LXM15LU60N4à 230 V triphasé 4000 tr/min pour LXM15LD13M3à 230 V monophasé
Compatibilité produit	LXM32.U60N4à 480 V triphasé LXM32.U60N4à 400 V triphasé LXM15LU60N4à 230 V triphasé LXM15LD13M3à 230 V monophasé
Extrémité d'arbre	Inexploité
Degré de protection IP	IP67 (avec kit IP67) IP65 (standard)
Résolution du retour vitesse	131 072 points/tour
Frein de parking	Sans
Support de montage	Bride conforme à la norme internationale
Raccordement électrique	Connecteurs orientables à angle droit

Complémentaires

Compatibilité de gamme	Lexium 15 Lexium 32
[Us] tension d'alimentation	480 V
Nombre de phases réseau	Triphasé
Courant continu à l'arrêt	0.73 A
Puissance continue maximum	0.45 W
Courant maximal Irms	2.9 A pour LXM32.U60N4 3.5 A pour LXM15LU60N4 3.5 A pour LXM15LD13M3
Courant permanent maximum	2.9 A

Fréquence de commutation	8 kHz
Second arbre	Sans avec deuxième extrémité d'arbre
Diamètre de l'axe	9 mm
Longueur de l'axe	20 mm
Type de retour	Single turn SinCos Hiperface
Taille bride moteur	55 mm
Nombre de taille moteur	1
Constante de couple	0.7 N.m/Aà 120 °C
Constante de fem arrière	40 V/krpmà 120 °C
Nombre de pôles de moteur	6
Inertie du rotor	0.059 kg.cm²
Résistance du stator	41.8 Ohmà 20 °C
Inductance du stator	71.5 mHà 20 °C
Constante de temps électrique du stator	1.09 msà 20 °C
Force radiale maximale Fr	340 Nà 1000 Tr/mn 270 Nà 2000 Tr/mn 240 Nà 3000 Tr/mn 220 Nà 4000 Tr/mn 200 Nà 5000 Tr/mn 190 Nà 6000 Tr/mn 180 Nà 7000 Tr/mn 170 Nà 8000 Tr/mn
Force axiale maximale Fa	0,2 x Fr
Type de refroidissement	Convection naturelle
Longueur	132.5 mm
Diamètre de collier de centrage	40 mm
Profondeur de collier de centrage	2 mm
Nombre de trous de fixation	4
Diamêtre des trous de fixation	5.5 mm
Diamêtre des trous de fixation	63 mm
Masse du produit	1.2 kg

Caractéristiques environnementales

Statut environnemental	Produit Green Premium
RoHS (code date: AnnéeSemaine)	Compliant - since 1018 - Schneider Electric declaration of conformit Déclaration de conformité Schneider Electric
REACh	Reference not containing SVHC above the threshold
Profil environnemental du produit	Disponible Télécharger Profil Environnemental Produit
Instruction fin de vie du produit	Pas d'opération de recyclage spécifiques

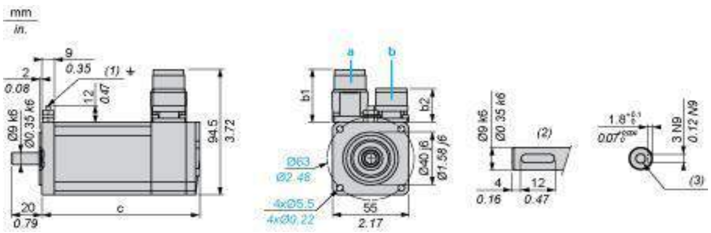
Garantie contractuelle

Période	18 mois

Dimensions Drawings

Servo Motors Dimensions

Example with Straight Connectors



a: Power supply for servo motor brake
b: Power supply for servo motor encoder
(1) M4 screw
(2) Shaft end, keyed slot (optional)
(3) For screw M3 x 9 mm/M3 x 0.35 in.

Dimensions in mm

Straight connectors		Rotatable angled connectors		c (without brake)	c (with brake)
b	b1	b	b1		
39.5	25.5	39.5	39.5	132.5	159

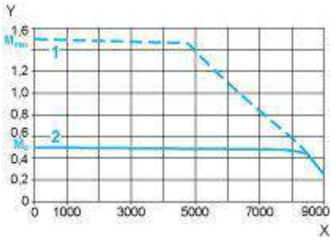
Dimensions in in.

Straight connectors		Rotatable angled connectors		c (without brake)	c (with brake)
b	b1	b	b1		
1.55	1.00	1.55	1.55	5.21	6.25

400 V 3-Phase Supply Voltage

Torque/Speed Curves

Servo motor with LXM32•U60N4 servo drive

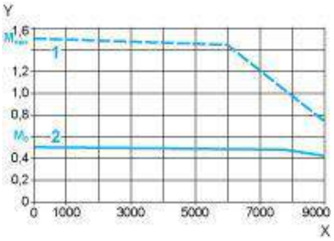


X Speed in rpm
Y Torque in
Nm 1 Peak torque
2 Continuous torque

480 V 3-Phase Supply Voltage

Torque/Speed Curves

Servo motor with LXM32•U60N4 servo drive



X Speed in rpm
Y Torque in
Nm 1 Peak torque
2 Continuous torque

7.3. GBX060008K

Fiche Produit
Caractéristiques

GBX060008K

réducteur planétaire droit GBX - Ø 60 mm - réduction 8:1 < 10 arc.min - 18 N.m

Principale

Statut commercial	Commercialisé
Compatibilité de gamme	Lexium ILA Lexium ILS Lexium SD3 Lexium 32 Lexium 28
Type de produit ou de composant	Réducteur planétaire
Type de réducteur	Denture droite
Nom abrégé d'appareil	GBX
Compatibilité produit	BCH2 (60 mm, 2 taille moteur) BCH2 (60 mm, 1 taille moteur) ILS (57 mm, 3 taille moteur) ILS (57 mm, 2 taille moteur) ILS (57 mm, 1 taille moteur) ILA (57 mm, 2 taille moteur) ILA (57 mm, 1 taille moteur) BRS3 BSH (70 mm, 1 taille moteur) BSH (55 mm, 3 taille moteur) BSH (55 mm, 2 taille moteur) BSH (55 mm, 1 taille moteur) BMH (70 mm, 1 taille moteur)
Diamétre externe réducteur	60 mm
Ratio réducteur	8:1

Complémentaires

Jeu de torsion	< 10 arc.min
Rigidité de torsion	2.3 N.m/arcmin
Couleur du logement	Noir
Matière du boîtier	Aluminium anodisé noir
Matière de l'axe	C 45
Information complémentaire	Lubrifié pendant toute la durée de vie
Durée de vie en heures	30000 Hà 100 Tr/mnà 30 °C
Position de montage	Toutes positions
Rendement	96 %
Force radiale maximale Fr	340 Nà 100 Tr/mn, force appliquée à mi-distance de l'arbre de sortie pendant 30 000 heures à 30 °C
Force axiale maximale Fa	450 Nà 100 Tr/mn, pendant 30000 heures à 30 °C
Monent d'inertie	0.065 kg.cm²
Couple de sortie continu	18 N.mà 100 Tr/mnà 30 °C
Couple de sortie maximal	29 N.mà 100 Tr/mnà 30 °C
Masse du produit	0.9 kg

Environnement

Intensité du signal sonore	58 dBà 1 m, sans charge
Degré de protection IP	IP54 sur arbre de sortie
Température ambiante de fonctionnement	-25...90 °C

Caractéristiques environnementales

Statut environnemental	Produit Green Premium
RoHS (code date: AnnéeSemaine)	Compliant - since 1129 - Schneider Electric declaration of conformity Déclaration de conformité Schneider Electric
REACh	Reference not containing SVHC above the threshold
Profil environnemental du produit	Disponible Télécharger Profil Environnemental Produit
Instruction fin de vie du produit	Pas d'opération de recyclage spécifiques

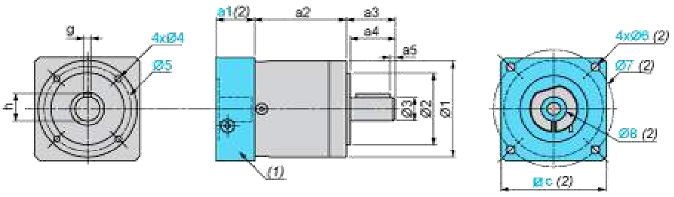
Garantie contractuelle

Période	18 mois

Fiche Produit
Dimensions Drawings

GBX060008K
réducteur planétaire droit GBX - Ø 60 mm - réduction 8:1 < 10 arc.min - 18 N.m

Dimensions with Servo Motor Adaptation Kit



(1) GBK adaptation kit
(2) GBK adaptation kit related dimensions a1, c, Ø6, Ø7, Ø8 depend on the gearbox and servo motor combination
Ø8 shaft end adaptor in case motor shaft diameter is smaller than gearbox input coupling diameter

Values in mm

a2	a3	a4	a5	h	g	Ø1	Ø2	Ø3	Ø4	Ø5
55	35	30	2.5	16	5	60	40 h7	14 h7	M5 x 8	52

Values in in.

a2	a3	a4	a5	h	g	Ø1	Ø2	Ø3	Ø4	Ø5
2.16	1.38	1.18	0.10	063	0.19	2.36	1.57 h7	0.55 h7	M5 x 0.31	2.05

7.4. LXM32AU62N4

Fiche produit

Caractéristiques

LXM32AU60N4

LXM32A INTERFACE CAN RJ45 6A RMS CRETE 3PH 480V

Principale

Statut commercial	Commercialisé
Gamme de produits	Lexium 32
Type de produit ou de composant	Servo variateur pour commande de mouvement
Nom abrégé d'appareil	LXM32A
Format du lecteur	Livre
Nombre de phases réseau	Triphasé
[Us] tension d'alimentation	380...480 V (- 15...10 %) 200...240 V (- 15...10 %)
Limites de la tension d'alimentation	170...264 V 323...528 V
Fréquence d'alimentation	50/60 Hz (- 5...5 %)
Fréquence du réseau	47,5...63 Hz
Filtre CEM	Intégré
Courant de sortie permanent	1.8 A (f = 8 kHz)
Courant de sortie de crête 3s	6 A pour 5 s
Alimentation continue	800 Wà 400 V 400 Wà 230 V
Puissance nominale	0.4 kWà 400 V (f = 8 kHz) 0.35 kWà 230 V (f = 8 kHz)
Courant de ligne	1.8 A, THDI of 187 %à 380 V, without line choke 1.2 A, THDI of 201 %à 480 V, without line choke 1.6 A, THDI of 116 %à 480 V, with external line choke de 2 mH 1.9 A, THDI of 106 %à 380 V, with external line choke de 2 mH

Complémentaires

Fréquence de commutation	8 kHz
Catégorie de surtension	III
Courant de fuite	< 30 mA
Tension de sortie	<= power supply voltage
Isolation électrique	Entre alimentation et contrôle
Type de câble	Câble IEC monobrin (pour θ = 50 °C) matériau conducteur: cuivre 90°C ,matériau isolant des fils: XLPE/EPR
Raccordement électrique	Bornier câble 5 mm² AWG 10 (CN10) Bornier câble 5 mm² AWG 10 (CN1) Bornier câble 3 mm² AWG 12 (CN8)
Couple de serrage	0.7 N.m (CN10) 0.7 N.m (CN1) 0.5 N.m (CN8)
Nombre entrées TOR	4 logique 2 sécurité 1 capture
Type d'entrée TOR	Sécurité (complément de STO_A, complément de STO_B) Logique (DI) Capture (capuchon)
Durée d'échantillonnage	0.25 ms (DI) pour numérique
Tension entrées TOR	24 V c.c. pour sécurité 24 V c.c. pour logique

Logique d'entrée numérique	Positif ou négatif (DI) à l'état 0: < 5 V à l'état 1: > 15 V conformément à EN/IEC 61131-2 type 1 Positif (DI) à l'état 0: > 19 V à l'état 1: < 9 V conformément à EN/IEC 61131-2 type 1 Positif (complément de STO_A, complément de STO_B) à l'état 0: < 5 V à l'état 1: > 15 V conformément à EN/IEC 61131-2 type 1
Temps de réponse	<= 5 ms (complément de STO_A, complément de STO_B)
Nombre sorties TOR	2
Type de sortie TOR	Logique (DO) 24 V DC
Tension de sortie TOR	<= 30 V DC
Logique sortie TOR	Positif ou négatif (DO) conformément à EN/IEC 61131-2
Durée des rebonds de contact	0.25 µs...1.5 ms (DI) 2 µs (capuchon) <= 1 ms (complément de STO_A, complément de STO_B)
Courant de freinage	50 mA
Temps de réponse de la sortie	250 µs (DO) numérique
Type de signal de commande	Retour codeur servo-moteur
Type de protection	Contre les courts-circuits :signal de sorties Contre l'inversion de polarité :signal d'entrée
Fonction de sécurité	STO (safe torque off), intégré
Niveau de sécurité	PL = e conformément à ISO 13849-1 SIL 3 conformément à EN/IEC 61508
Interface de communication	Intégré Modbus Intégré CANopen Intégré CANmotion
Type de connecteur	RJ45 (repère CN7) :Modbus RJ45 (repères CN4 ou CN5) :CANopen RJ45 (repères CN4 ou CN5) :CANmotion
Méthode d'accès	Esclave
Interface physique	RS485 multipoint à 2 fils Modbus
Vitesse de transmission	9600, 19200, 38400 bps pour une longueur de bus de <= 40 m Modbus 500 kbps pour une longueur de bus de <= 100 m CANopen, CANmotion 50 kbps pour une longueur de bus de <= 1000 m CANopen, CANmotion 250 kbps pour une longueur de bus de <= 250 m CANopen, CANmotion 125 kbps pour une longueur de bus de <= 500 m CANopen, CANmotion 1 Mbps pour une longueur de bus de <= 4 m CANopen, CANmotion
Nombre d'adresses	1...247 Modbus 1...127 CANopen, CANmotion
Service communication	Sync CANmotion Mode positionnement, vitesse, couple et prise d"origine CANopen Mode positionnement CANmotion Garde de notes, battement de cœur CANopen Déclenchement selon événement/temps, demande à distance, sync cyclique/acyclique CANopen Urgence CANopen, CANmotion Affichage d"erreurs sur terminal intégré Modbus Entraînement d"équipement et commande de mouvement CANopen CANopen, CANmotion 4 PDO mappés configurables CANopen 2 SDO émetteurs CANopen 2 SDO récepteurs CANopen 2 PDO conformes à la norme DSP 402 CANmotion 1 SDO en transmission CANmotion 1 SDO en réception CANmotion
LED d'état	1 LED RUN 1 LED erreur 1 LED (rouge) tension dans le servo-variateur
Fonction de signalisation	Affichage des défauts in 7 segments
Marquage	CE
Position de montage	Vertical +/- 10 degree
Compatibilité produit	Servo motor BSH (55 mm, 2 motor stacks) Servo motor BSH (55 mm, 1 motor stacks) Servo motor BSH (55 mm, 3 motor stacks) Servo motor BMH (70 mm, 1 motor stacks)
Largeur	48 mm Hauteur 270 mm

Environnement

Compatibilité électromagnétique	CEM rayonnéeà category C3 conformément à EN/IEC 61800-3 CEM rayonnéeà class A group 2 conformément à EN 55011 Test d'immunité des transitoires rapides/salves électriquesà level 4 conformément à EN/IEC 61000-4-4 Test d'immunité aux ondes de choc 1,2/50 µsà niveau 3 conformément à EN/IEC 61000-4-5 Susceptibilité aux champs électromagnétiquesà niveau 3 conformément à EN/IEC 61000-4-3 Test d'immunité de décharge électrostatiqueà niveau 3 conformément à EN/IEC 61000-4-2 Tests CEM réalisésà environments 1 and 2 conformément à EN/IEC 61800-3 Tests CEM réalisésà category C2 conformément à EN/IEC 61800-3 Tests CEM réalisésà environment 2 category C3 conformément à EN/IEC 61800-3 Tests CEM réalisésà class A group 2 conformément à EN 55011 Tests CEM réalisésà groupe 1, classe A conformément à EN 55011
Normes	EN/IEC 61800-3 EN/IEC 61800-5-1
Certifications du produit	CSA RoHS TÜV UL
Degré de protection IP	IP20 conformément à EN/IEC 61800-5-1 IP20 conformément à EN/IEC 60529
Tenue aux vibrations	1,5 mm crête-à-crête (f = 3...13 Hz) conformément à EN/IEC 60068-2-6 1 gn (f = 13...150 Hz) conformément à EN/IEC 60068-2-6
Tenue aux chocs mécaniques	15 gn pour 11 ms conformément à EN/IEC 60028-2-27
Niveau de pollution	2 conformément à EN/IEC 61800-5-1
Caractéristique d'environnement	Classes 3C1 conformément à IEC 60721-3-3
Humidité relative	Classe 3K3 (5 à 85 %) sans condensation conformément à IEC 60721-3-3
Température de fonctionnement	0...50 °C conformément à UL
Température ambiante pour stockage	-25...70 °C
Type de refroidissement	Convection naturelle
Altitude de fonctionnement	> 1000...3000 m Avec conditions <= 1000 m sans facteur de déclassement

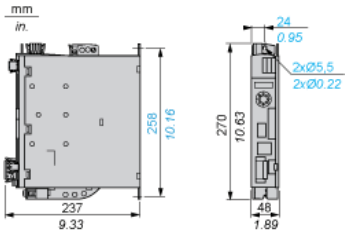
Caractéristiques environnementales

Statut environnemental	Produit non Green Premium
RoHS (code date: AnnéeSemaine)	Compliant - since 0930 - Schneider Electric declaration of conformity Déclaration de conformité Schneider Electric
REACh	Reference not containing SVHC above the threshold
Profil environnemental du produit	Disponible Télécharger Profil Environnemental Produit

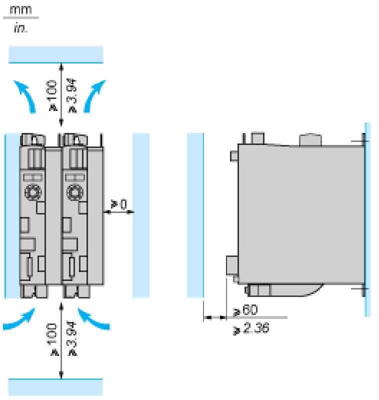
Garantie contractuelle

Période	18 mois

Dimensions



Mounting Recommendations



LXM32•U45M2, •U90M2 and LXM32•U60N4 servo drives are cooled by natural convection. LXM32•D18M2, •D30M2, LXM32 •D12N4, •D18N4, •D30N4 and •D72N4servo drives have an integrated fan.

When installing the servo drive in the enclosure, follow the instructions below with regard to the temperature and protection index:

- Provide sufficient cooling of the servo drive
- Do not mount the servo drive near heat sources
- Do not mount the servo drive on flammable materials
- Do not heat the servo drive cooling air by currents of hot air from other equipment and components, for example from an external braking resistor
- Mount the servo drive vertically (± 10%)
- If the servo drive is used above its thermal limits, control stops due to overtemperature

NOTE: For cables that are connected via the underside of the servo drive, a free space ≥ 200 mm/7.87 in. is required under the unit to comply with the bending radius of the connection cables.

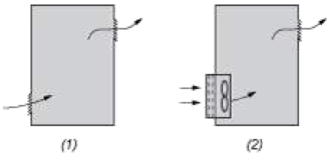
Ambient temperature	Mounting distances	Instructions to be followed
0°C…+ 50°C	d ≥ 0 mm	–
+ 50°C…+ 60°C	d ≥ 0 mm	Reduce the output current by 2.2% per °C above 50°C

NOTE: Do not use insulated enclosures, as they have a poor level of conductivity.

Recommendations for Mounting in an Enclosure

To ensure good air circulation in the servo drive:

- Fit ventilation grilles on the enclosure.
- Ensure that ventilation is adequate, otherwise install a forced ventilation unit with a filter.



(1) Natural convection
(2) Forced ventilation

- Any apertures and/or fans must provide a flow rate at least equal to that of the servo drive fans (refer to characteristics).
- Use special filters with IP 54 protection.

Mounting in Metal Enclosure (IP 54 Degree of Protection)

The servo drive must be mounted in a dust and damp proof enclosure in certain environmental conditions, such as dust, corrosive gases, high humidity with risk of condensation and dripping water, splashing liquid, etc. In these cases, Lexium 32 servo drives can be installed in an enclosure where the internal temperature must not exceed 60°C.

7.5. LXM32MU62N4

Fiche produit
Caractéristiques

LXM32MU60N4
LXM32 MODULAR 6A RMS CRETE 3PH 480V

Principale

Statut commercial	Commercialisé
Gamme de produits	Lexium 32
Type de produit ou de composant	Servo variateur pour commande de mouvement
Nom abrégé d'appareil	LXM32M
Format du lecteur	Livre
Nombre de phases ré-seau	Triphasé
[Us] tension d'alimenta-tion	380...480 V (- 15...10 %) 200...240 V (- 15...10 %)
Limites de la tension d'alimentation	170...264 V 323...528 V
Fréquence d'alimenta-tion	50/60 Hz (- 5...5 %)
Fréquence du réseau	47,5...63 Hz
Filtre CEM	Intégré
Courant de sortie per-manent	1.5 A (f = 8 kHz)
Courant de sortie de crête 3s	6 A pour 5 s
Alimentation continue	800 Wà 400 V 400 Wà 230 V
Puissance nominale	0.4 kWà 400 V (f = 8 kHz) 0.35 kWà 230 V (f = 8 kHz)
Courant de ligne	1.8 A, THDI of 187 %à 380 V, without line choke 1.2 A, THDI of 201 %à 480 V, without line choke 1.6 A, THDI of 116 %à 480 V, with external line choke de 2 mH 1.9 A, THDI of 106 %à 380 V, with external line choke de 2 mH

Complémentaires

Fréquence de commutation	8 kHz
Catégorie de surtension	III
Courant de fuite	< 30 mA
Tension de sortie	<= power supply voltage
Isolation électrique	Entre alimentation et contrôle
Type de câble	Câble IEC monobrin (pour θ = 50 °C) matériau conducteur: cuivre 90°C ,matériau isolant des fils: XLPE/EPR
Raccordement électrique	Bornier câble 5 mm² AWG 10 (CN10) Bornier câble 5 mm² AWG 10 (CN1) Bornier câble 3 mm² AWG 12 (CN8)
Couple de serrage	0.7 N.m (CN10) 0.7 N.m (CN1) 0.5 N.m (CN8)
Nombre entrées TOR	4 logique 2 sécurité 2 capture
Type d'entrée TOR	Sécurité (complément de STO_A, complément de STO_B) Logique (DI) Capture (capuchon)
Durée d'échantillonnage	0.25 ms 0.25 ms (DI) pour numérique

Tension entrées TOR	24 V c.c. pour sécurité 24 V c.c. pour logique 24 V c.c. pour capture
Logique d'entrée numérique	Positif ou négatif (DI) à l'état 0: < 5 V à l'état 1: > 15 V conformément à EN/IEC 61131-2 type 1 Positif (DI) à l'état 0: > 19 V à l'état 1: < 9 V conformément à EN/IEC 61131-2 type 1 Positif (complément de STO_A, complément de STO_B) à l'état 0: < 5 V à l'état 1: > 15 V conformément à EN/IEC 61131-2 type 1
Temps de réponse	<= 5 ms (complément de STO_A, complément de STO_B)
Nombre sorties TOR	3
Type de sortie TOR	Logique (DO) 24 V DC
Tension de sortie TOR	<= 30 V DC
Logique sortie TOR	Positif ou négatif (DO) conformément à EN/IEC 61131-2
Durée des rebonds de contact	0.25 µs...1.5 ms (DI) 2 µs (capuchon) <= 1 ms (complément de STO_A, complément de STO_B)
Courant de freinage	50 mA
Temps de réponse de la sortie	250 µs (DO) numérique
Type de signal de commande	Retour codeur servo-moteur Impulsion/Direction (P/D), A/B, CW/CCW :RS422 (f = <= 1000 kHz) (longueur de câble: 100 m) Impulsion/Direction (P/D), A/B, CW/CCW :Liaison 5 V, 24 V (push-pull) (f = <= 200 kHz) (longueur de câble: 10 m) Impulsion/Direction (P/D), A/B, CW/CCW :Liaison 5 V, 24 V (collecteur ouvert) (f = <= 10 kHz) (longueur de câble: 1 m) Sortie avec train d''impulsion (PTO) :RS422 (f = <= 500 kHz) (longueur de câble: 100 m)
Type de protection	Contre les courts-circuits :signal de sorties Contre l'inversion de polarité :signal d'entrée
Fonction de sécurité	SOS (safe operating stop), avec carte de sécurité eSM séparée SLS (safe limited speed), avec carte de sécurité eSM séparée SS2 (safe stop 2), avec carte de sécurité eSM séparée SS1 (safe stop 1), avec carte de sécurité eSM séparée STO (safe torque off), intégré
Niveau de sécurité	PL = e conformément à ISO 13849-1 SIL 3 conformément à EN/IEC 61508
Interface de communication	Avec carte de communication séparée I/O Avec carte de communication séparée DeviceNet Avec carte de communication séparée Profibus Avec carte de communication séparée EtherCAT Avec carte de communication séparée Ethernet/IP Avec carte de communication séparée CANmotion Avec carte de communication séparée CANopen Intégré Modbus
Type de connecteur	RJ45 (repère CN7) :Modbus
Interface physique	RS485 multipoint à 2 fils Modbus
Vitesse de transmission	9600, 19200, 38400 bps pour une longueur de bus de <= 40 m Modbus
Nombre d'adresses	1...247 Modbus
LED d'état	1 LED (rouge) tension dans le servo-variateur
Fonction de signalisation	Affichage des défauts in 7 segments
Marquage	CE
Position de montage	Vertical +/- 10 degree
Compatibilité produit	Servo motor BSH (55 mm, 2 motor stacks) Servo motor BSH (55 mm, 1 motor stacks) Servo motor BSH (55 mm, 3 motor stacks) Servo motor BMH (70 mm, 1 motor stacks)
Largeur	68 mm
Hauteur	270 mm
Profondeur	237 mm
Masse du produit	1.8 kg

Environnement

Compatibilité électromagnétique	CEM rayonnéeà category C3 conformément à EN/IEC 61800-3 CEM rayonnéeà class A group 2 conformément à EN 55011 Test d'immunité des transitoires rapides/salves électriquesà level 4 conformément à EN/IEC 61000-4-4 Test d'immunité aux ondes de choc 1,2/50 µsà niveau 3 conformément à EN/IEC 61000-4-5 Susceptibilité aux champs électromagnétiquesà niveau 3 conformément à EN/IEC 61000-4-3 Test d'immunité de décharge électrostatiqueà niveau 3 conformément à EN/IEC 61000-4-2 Tests CEM réalisésà environments 1 and 2 conformément à EN/IEC 61800-3 Tests CEM réalisésà category C2 conformément à EN/IEC 61800-3 Tests CEM réalisésà environment 2 category C3 conformément à EN/IEC 61800-3 Tests CEM réalisésà class A group 2 conformément à EN 55011 Tests CEM réalisésà groupe 1, classe A conformément à EN 55011
Normes	EN/IEC 61800-3 EN/IEC 61800-5-1
Certifications du produit	CSA RoHS TÜV UL
Degré de protection IP	IP20 conformément à EN/IEC 61800-5-1 IP20 conformément à EN/IEC 60529
Tenue aux vibrations	1,5 mm crête-à-crête (f = 3...13 Hz) conformément à EN/IEC 60068-2-6 1 gn (f = 13...150 Hz) conformément à EN/IEC 60068-2-6
Tenue aux chocs mécaniques	15 gn pour 11 ms conformément à EN/IEC 60028-2-27
Niveau de pollution	2 conformément à EN/IEC 61800-5-1
Caractéristique d'environnement	Classes 3C1 conformément à IEC 60721-3-3
Humidité relative	Classe 3K3 (5 à 85 %) sans condensation conformément à IEC 60721-3-3
Température de fonctionnement	0...50 °C conformément à UL
Température ambiante pour stockage	-25...70 °C
Type de refroidissement	Convection naturelle
Altitude de fonctionnement	> 1000...3000 m Avec conditions <= 1000 m sans facteur de déclassement

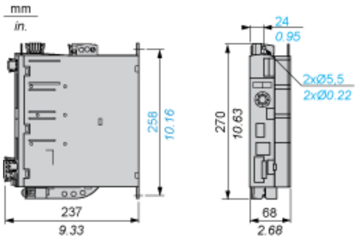
Caractéristiques environnementales

Statut environnemental	Produit non Green Premium
RoHS (code date: AnnéeSemaine)	Compliant - since 0930 - Schneider Electric declaration of conformity Déclaration de conformité Schneider Electric
REACh	Reference not containing SVHC above the threshold
Profil environnemental du produit	Disponible Télécharger Profil Environnemental Produit

Garantie contractuelle

Période	18 mois

Dimensions



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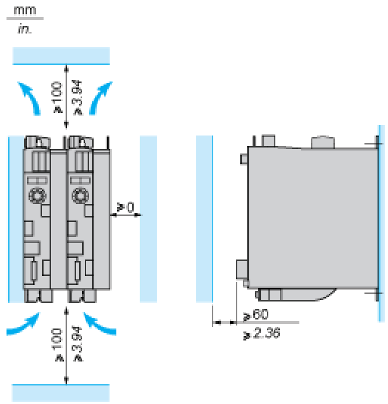

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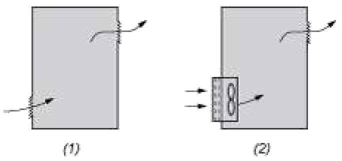

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8. Bibliography

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