SETTING UP A PROCESS CONTROL IN THE DIPPING PROCESS IN A TEXTILE COMPANY

Graduation Work for Production Engineering and Management

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Abstract
A technical textile company in Colombia has been experiencing some quality variations in their products. This creates a need to standardize the product’s quality and the best way to accomplish this is by standardizing the processes. To be able to standardize the processes it is necessary to know the different processes and the possible causes of variation. To be able to learn and understand these causes it is needed to check everything from the raw materials up to the possible variations that can come in the customer’s facilities. In this paper this is done: the raw materials are checked, along with each of the processes and their possible variations. It is also checked for the efficiency of these processes due to the age of the machines used. Furthermore a process control method is not only proposed but implemented, at least in one of the processes. The process chosen is the dipping station, which is the last stage. This process was chosen because it is the process that gives out the most information at the moment the project was done. Some sample results, as well as some graphs, are shown. The idea behind the spreadsheet presented here is that it is easily adapted to the other processes; just the variables need to be adjusted.
The conclusion gives out ideas on how to continue with the implementation of this method to the other processes and stresses the importance of continuing implementing the Statistical Process Control, which can begin with the information provided by this project. This also shows that since the fabrics can now be seen from two perspectives, the production and the quality control, these results can be compared in order to try to obtain the best possible results.
Sammanfattning
Ett tekniskt textilföretag i Colombia har haft vissa kvalitetsvariationer i sina produkter. Detta skapar ett behov av att kunna standardisera produktens kvalitet och det bästa sättet att åstadkomma detta är genom att standardisera processerna. För att kunna standardisera processerna är det nödvändigt att ha kunskap om de olika processerna och känna till möjliga orsaker till att variationer uppstår. För att kunna lära sig om och förstå dessa orsaker är det nödvändigt att kontrollera allt från råvaran till möjliga variationer som kan uppstå i kundens lokaler. I denna rapport sker detta: råvarorna kontrolleras, tillsammans med var och en av processerna och deras möjliga variationer undersöks. Även processernas effektivitet kontrolleras eftersom maskinparken är gammal.


I slutsatsen ger författaren idéer/förslag på hur man fortsätter med implementeringsarbetet av denna metod till de andra processerna. Samtidigt betonar man vikten av att fortsätta att genomföra statistisk processkontroll, en bra utgångspunkt är informationen från detta projekt. Detta visar också att eftersom tygerna nu kan studeras utifrån två perspektiv: produktion och kvalité, kan produktionen och kvalitetskontrollen jämföras i ett försök att uppnå de bästa möjliga resultaten.
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1. Introduction

This work is the compilation of a project that was done in a technical textiles manufacturing company in Colombia. The time frame for the project was the second semester of the year 2014. The time it has taken for the work to be published is mainly for the concern of confidentiality that the company wants to keep, due to the critical processes it has. Most of the processes that take place in the textile manufacture even though are known to everybody, the precise settings are considered secrets of the trade. In this company the secrecy of their processes is taken very seriously and anybody that goes in to study or work on said processes is forced to sign a confidentiality agreement.

To make an example of what is being said, the exact composition of the RFL solution, which is known to everybody is composed of Resorcinol, Formaldehyde and Latex, is a big secret amongst the technical textiles community. There are world experts that charge a lot of money not for their own formula, but to go and check and make recommendations for your own. The importance of this chemical solution is that it is responsible for the adherence of the vulcanized rubber to the fabric; this is going to be explained further in the body of the work. Since the rubbers have very different compositions depending on the cost or the function it is going to accomplish or the conditions against it has to be protected, there must be at least the same amount of different RFL compositions to achieve the best adherence to each rubber compound.

To keep in line with the secrecy this company enforces, it is not going to be discussed in any part of the work the name of the company, the people involved, the composition of the textiles, be it by brands of suppliers, customers, different materials used, brands of the machines or their components. It is going to remain a complete secret.

The structure of this work is going to be the following: in the beginning there is going to be a description of the company as a whole, its history, and the different types of products it has produced, their challenges and how the company faced them. Next there is going to be a description of the company’s situation at the time the project was started, 2014, where emphasis is made in the age of the machines, a big shortcoming for the company, the relationship it has with its suppliers and customers. There is also going to be a description of the production process, so that everybody understands what is happening to the threads and how they become a fabric. Next there will be a description of the quality control and assurance that happens at the company. This is very important because it helps dictate the relationship the company has with the customers and suppliers.

The next chapter deals with the identification of the problem and the methodology used to solve it; the problem being a way to standardize the processes and the results. Here there is going to be found a more thorough description of the possible variations that can be found in the whole process of the fabric, from the point in which it just a thread that comes from the suppliers up to the point in which it is ready to be used in the customers facilities as a finished fabric. Next there is an explanation into which process the project focused, the scope of the project. It is very important to explain the reasons for this decision, because it might not be the best decision under different circumstances.

After that, there comes a chapter where the results are going to be explained and shown. The solution that was proposed and in what the project is focused is an excel sheet where the information can be saved and that shows the results so that it is much easier to analyze and make decisions that can help improve the processes and the quality results. There are going to be some graphs to show how the results are being shown to the users and the way in that it should be used to make it much more powerful and useful.

After all of this, comes the conclusions, where the usefulness of the work sheet can be summarized and explained. The amount of information that the project gave the company is astounding and nobody knew that it could be that useful. At the end there will be an indication on how to continue the work that was started with this project, because that is all that this is: it is just a starting point, albeit a very good one, for the complex and maybe never ending process of standardization.
The whole goal of all this work was just to start laying the stones, or the bases, for the standardization of the productive process. A very important first step is to know the processes. To start this you need to know how the process behaves, what is its variance, the settings that have an influence on the results. This is the objective of this process control. To begin knowing the processes, the results, the influences.

There are also some limitations, which will be explained further ahead, but in a general view are the economic situation of the company, the interest to make big investments in this and the lack of people working solely in this. These limitations, even though are evident in this work, are also noticeable in the day to day labors in the company. Hopefully this project will start to change the politics of the company and help the people that should continue with the standardization process and with the expansion of what is presented here.
2. Objective And Limitations

Objective:

The current situation of the company is briefly stated in the introduction and will be further expanded in the coming chapters. These explanations will involve dire economic situations, changes in the industry and in the company itself.

So that the objective is possible to state, the most important aspect of the current situation of the company is that is has been having a lot of variability in the quality results of all of the fabrics it produces. These variations do not mean that it produces a lot of defective fabrics, just that there is a big probability of this happening.

To narrow this variability it is needed to set up some sort of process control so that the knowledge gained throughout the processes can be used to improve not only the quality but the variation of it as well.

As of the time in which this project began, December 2013, there was no process control anywhere in the plant, meaning that the quality could not be assured but only checked in the end of each of the processes. This made the production costs to go up as well as the waste and the amount of rejected pieces of fabric.

The information that could be provided by this project could go beyond using it just for the process knowledge and be used to implement a Statistical Process Control, or give the customers answers regarding the quality and processing characteristics for their fabrics, or give a justified answer regarding claims; not only to customers but also to suppliers. Knowing your process completely will give you an insight that is unmatched.

The objectives can now be formulated in a clear and concise way:

- Set up a process control throughout the process so that the variables can be not only controlled but also monitored.
- Find the most important and critical process to use as a pilot to show the usefulness of the project.

This objectives will be further developed as the written work develops. These objectives will be faced with the limitations explained ahead.

Limitations

As will be explained in Chapter 4, the company has faced some hardships in the financial front. These financial blunders have a big effect in the interest of the company to make investments in activities that cannot be directly and speedily linked to economic gains. Since this project, although will generate savings, takes a lot of time to be completed, not a lot of money was allocated, so things had to be done with whatever was already there and alongside other activities.

Another important limitation to this project was the time constraint. The owners and board of directors were more preoccupied with the current financial situation than they were about new projects, so a short time frame was given to give proper results.

A third limitation was the personnel constraint. There was just one person working in the programming of the first iteration of the program and one other person in charge of controlling the programmer and of running all of the other parts of the project. The person in charge of programming was later let go because the program was abandoned in view of a simpler but more useful and complete spreadsheet, compiled by the same person in charge of the whole project. This small amount of people for such a big project made the advancement much more difficult and slow.
The last important limitation was the information provided by the machines. As will be exposed in the following chapters, most of the machines used were very mechanical, not electronic. This means that the machines were not set up to give all of the information required to gain understandable and sufficient knowledge regarding the processes.

To overcome all of these limitations it was decided to work and give results for just one machine. This machine gives out the most information basically because it is mostly managed by PLCs, has a software that makes extracting the information much easier and through the same machine goes through most of the fabrics produced. The machine picked will be exposed in the following chapters.
3. Literature Review

Since there are so many processes that are so specific to the company, all of the information regarding said processes is recorded in the Quality System that the company has. This information is organized in different chapters, each concerning a different stage in the whole process. There is also a division regarding the use for each of the documents. For instance, the ones used in the laboratory are called Inspection Instructions (II); the ones regarding the production process and the different machines are called Operating Instructions (OI). Since the company makes a lot of different products, there are specific set points used for each of the products, these specific points are consigned in documents called Working Pages (WP). With all of the information found here it is possible to understand the processes very well. It also helps a lot being able to observe said processes and ask the operators about them.

For the standardization of the production process as a whole some books were read and checked that talked about the Statistical Process Control (SPC), the variation of the different process and the importance to try and control as much as possible all of these changes. The SPC is an attempt to quantify and make rational the changes that can come in a process. It also helps to understand if the changes are random, or have a tendency or a periodicity. It gives a good understanding of the process as a whole.

After having all of this information it was important to find a way to make it as useful as possible. For this to be achievable, a few books concerning process intelligence were read and consulted, as well as some software that does this. The software checked were basically demo and trial versions of Zoho Reports, Splunk and Qlik. This was done so that a clearer idea could be formulated to help make the project better.

With the information written in the OI, the relevant information from each of the processes was tabulated, so that it was easier to know if it was easy to find. For this information some manuals regarding the PLCs of some machines were read. Also a manual concerning with the SCADA, the information it carries, the way in which it presents the information and the ways to extract it.

To finalize the project some forums concerning the inner workings of Microsoft Excel and its own user’s manual were read and revised. All of this to make the best use possible from the data sheet devised.

The books read and reviewed are listed in the reference section at the end of the document.
4. Current Situation

This company was founded in the late 1940’s by a Frenchman that had traveled to South America with the plan to start a new plant to weave sheep wool into worsted products. The first sale was made in 1951. In the 1970’s the company started to produce technical textiles in response to needs that the national market started having. The technical textiles division existed just as a little part of the whole company; the whole of the company’s profits came from the fabrics used in the fashion world. In the mid 1990’s the company made its first export. During the beginning of the 2000’s there begun a heavy crisis for the textile industry, causing the fashion department to start generating losses and put the company’s continuity in jeopardy. In 2007 the company decided to sell the fashion area and concentrate solely in the technical textiles. By this point in time the balance had shifted and it was the technical textiles that were supporting the company. Since the sale of the fashion department, the textile company has been growing steadily to start paying for the debts that the company had incurred to stay afloat.

Most of the equipment in the company is quite dated. Most of the threading machines are from the mid 1970’s and early 1980’s. The warping machines are semi-new and were built in the early 2000’s. The looms have the greatest variety in years, since there are some that come from the early 1980’s to some, the newer ones, which come from 2007. The dipping station was built in the mid 1990’s, but has undergone some modifications and renewals. It now operates through a modern PLC connected to a new computer, which manages and records the whole information regarding the machine.

4.1 Production Process

The process to manufacture a technical fabric is very similar to the one used to produce any type of fabric. The main difference is the materials used and the final dipping process. The process goes as follows:

Raw materials → Threading → Warping → Weaving → Dipping

4.1.1 Raw Materials

The raw materials used are mainly High Tenacity Polyethylene threads made in China. There are different suppliers which are chosen mainly on the cost efficiency parameter. These threads come in different titles, which represent the weight of the thread and also the resistance of the thread to rupture due to strain. This threads can be purchased with a pre-activated compound that allows the dipping solution to attach to it easier. Some samples on how the yarns come from suppliers can be seen in images 1 and 2.

Image 1: Yarn Pallet. The yarns come in the shape of bobbins. Each layer is set up on top of cardboard pieces that have a hole for each bobbin, making it easier to transport and prevents the whole pallet from coming apart. Each bobbin comes wrapped in a plastic bag to prevent it from outside pollutants.
4.1.2 Threading

The threading of the raw materials is needed for two purposes: twisting the threads in one of two different directions (s or z) and to attain a higher title by joining and twisting lower title threads. The twisting in the different directions is important so that the fabrics end up balanced. The correct way is that the threads alternate in a *szszsz* fashion. If the directions are not alternated then the fabric will look strange and will have a tendency to go in one direction.

4.1.3 Warping

The warping is a very important part of the fabrics manufacturing process. It is in this part that the tension of the fabric is controlled. The warping process consists of putting all of the threads, one beside the other, to the width of the desired final product and with the right amount of tension. This ensures that the final product will have the same tension throughout the whole width. If the tension is not the same, then the fabric will turn out with a wave pattern, where the tension is lower than the rest. The set up can be seen in image 3.
Image 4: Warp step 1. Here the threads come from the creel and each of the sections of the fabric are warped. The amount of sections, as well as the width of each of these sections depends on the required width of the finished fabric.

Image 5: Warping step 2. Here is where the full width of the fabric is warped. From here the warp goes to the looms.

4.1.4 Weaving

This is the process in which the warp threads are interweaved with the weft. The simplest kind of weave is the one that goes one above, one below, in what is called a 1:1 pattern. This is accomplished by the use of different frames, which come up or down, raising or lowering the warp threads. The weft crosses the width of the warp, and since some are up, others down, then the 1:1 weave is done. Examples of looms can be seen in images 6 and 7.

Image 6: Old Loom. This loom comes from the 1980’s or early 1990’s. This loom is mechanical, so any kind of set-up takes a lot of time. This time is consumed by the taking apart and changing of some parts and the arrangement of others.
4.1.5 Dipping Station

This is the final stage of the manufacturing process. This is the biggest difference with the production of other type of textiles. The dipping solution in which the fabrics are submerged is made from Resorcinol, Formaldehyde and Latex, that is why it is called RFL. The exact composition of those components is part of the secret of each of the companies and of the experts around the world. Everybody does it differently, to reduce costs or enhance properties. This process is the most important and critical of the textile production process. This is also the one that has the most added value. The dipping must be done with a determined speed and tension, so that the fabric does not gain too much weight by absorbing too much solution, increasing the cost of the process. After the fabrics are dipped, they go through a press that drains the excess solution. After this step, the solution must be dried. This also happens with a set speed and tension, plus a specific temperature. After the fabric comes out of the drier it needs to be completely dried, otherwise in the next step more problems could arise. The next step in this process is to activate the solution through temperature. This starts happening at around 185°C in a much longer oven than the one where the fabric is dried. This activation of the RFL is what makes it possible for the rubber to attach to the fabric.
4.2 Quality Control

There is a laboratory in the company that is in charge of checking the quality of the results of each of the processes described before. There is a minimum value that needs to be reached so that the fabric can continue the process. To reduce the amount of fabrics that do not reach this minimum, a new control has been set up at the beginning of the weaving process, so that it can be checked that the weaving is being done correctly. This controls have diminished the amount of products that do not comply in the end, but have not helped standardize the quality.

Currently, this company is pretty much the only company in Colombia that produces technical textiles in a big scale. It can even be the sole producer of conveyor belt lining and chaffer, which is used in the side of the tires. There are some other plants in the country that produce textile armor and geotextiles. In the geotextiles, what this company offers is a size that is not easily found anywhere else in Colombia. For the textile armor, the main difference is the source of the yarns, here is used a different company from the ones used anywhere else, due to the fact that there is an exclusivity contract with said company to work only with this company in Colombia for the production of armor.

Since 2007, when the company had to pretty much start over, the production has been steadily increasing. Every couple of years new looms need to be introduced and the overall efficiency of the plant need to be increased. For the years 2012, 2013 and 2014 the weight of the production has been nearing the 200 tons.
The production percentages for the years 2012 and 2013 can be seen in graph 1. The production of the company at this moment, mid 2015, is around the following percentages:

- Conveyor belt lining: 65%
- Chaffer: 20%
- Geotextiles: 10%
- Textile Armor: 5%

Graph 1: Production percentages per year

In view of this production percentages, it was decided to start the studies with the conveyor belts, due to it being the most produced, having the biggest part of the company’s income, having the highest complaints from the customers and involving the longest process of them all.

Right now, the quality results of the company, although not necessarily bad, are very irregular, and the company receives some complaints from some of the clients, and it is needed to have a sound and precise answer to each of the complaints.
The quality of the conveyor belt lining is measured primarily by the adhesion results, the elongation of the fabric once it has a load, and the weight of the fabric itself, which directly influences the amount of weight the conveyor belt can carry before it ruptures.

Each of these final quality characteristics is influenced by features of the threads and yarns used, by the processes and its variables, by the pattern of the fabric and even by the rubber compound used to cover and bind the different layers of the conveyor belt lining.

Currently the Company is trying to standardize the quality of the products it produces. Right now the company is facing a dire economic situation. The earnings have not been very high, and there are some debts that need to be payed, therefore there is not much money for investment in new projects that do not give an immediate increase in the earnings of the company.

Due to these reasons, the project to influence the quality of the products, was not deemed of the utmost importance and was not given a special budget or a complete dedication to it. It was to be done at the same time as the setting up of the Process Engineering Area.

4.3 Current Quality Management and Assurance of the fabrics, specifically the conveyor belts

Right now there is no information concerning the standardization of the quality of the fabrics. All there is right now, as mentioned before, is a minimum value that needs to be achieved so that the customers will not complain and accept the fabrics. This minimum faces some complications as well: there is no universally agreed method, which includes the temperature and pressure needed for the vulcanization of the conveyor belts, the thickness of the rubber for the different types of weaves, the way to set up the tests, the way to read the results. All of this translates into a lot of differences between the suppliers and the customers if there is not an agreed method that encompasses every aspect.

The problem with just having a minimum value is that if it is exceeded greatly, or by just a tiny margin, the customer will not care, but the process can be very different in terms of the cost. This can be seen if more materials need to be used, or if the fabrics need to be re-worked.

Since there is no quality assurance in place, throughout the whole production process, the workers need to adjust the parameters for each of the fabrics from the set points, set there by the Technical Chief, who is the one that prepares and organizes the conditions under which the fabrics should be processed. Each of these modifications are made based on the experience and the knowledge of the operator. The modifications must be made to avoid some possible problems or some problem that is happening in that moment. To solve each problem, there is a lot of things that can be done, different parameters that can be moved, upwards or
downwards, and if those are moved wrongly, the problem can be worsened or if changed in conjunction with other counterparts, nothing happens.

Sometimes, even the modifications done to the set parameters are not enough to assure the minimum, so the fabrics need to be reprocessed in the dipping station, adding a thicker layer of the RFL. This has a very big increment of the cost of production, and obviously cannot be transferred to the customer. This increase in weight also affects the weight of the fabric.

Sometimes even if the minimum is met in the laboratory, when the customers check for the quality in their own labs, and the results are not met, a complaint is made. In actuality, since the conditions through which the fabrics were processed are not being taken into consideration or keeping a record of them, it is very difficult to know if a problem occurred in the manufacturing process, so if a customer does not accept the fabrics or makes a money claim, the company has to accept and pay. Although this is not very common when it happens it puts the company’s economic stability in jeopardy.

There are some customers that supply their own rubber compound for the testing of the adhesion results. This is done because the RFL can be engineered to specific mixes for the rubber characteristics. So, if it is found that with the RFL used in the company, the adhesion expected cannot be achieved, then a new RFL solution will need to be designed.

There have been also some issues with the quality of the raw materials. It was detected in the laboratory that the composition of the titles asked was not the one received. This triggered a more thorough investigation into the adhesion results comparing all of the suppliers with all of the rubber compounds used to check the quality. It was found that most suppliers have a big variability into the results. This can be a cause for the variability of the adhesion results.
5. Methodology

When there is an objective to standardize a process all of the possible sources of variability must be taken into account. When dealing with such a delicate process, that involves chemical reactions, even the weather conditions must be taken into consideration. This is not done so as to find a reason things are not working correctly but to be able to analyze future enhancements that can be done to better the process.

5.1 Variation Causes

As mentioned before, the weather has an effect on the adhesive properties of the RFL solution. This effect is caused primarily by the humidity and the ozone. The temperature also has a detrimental influence not only on the RFL properties but also in the conditions of the work force.

The presence of large amounts of ozone causes a reaction with the RFL which diminishes the effectivity of the adhesive properties of the solution. This effect increases as time goes by. To prevent this it is necessary to create a drier, cooler with less ozone environment. The climate in Dosquebradas is very humid, warm and has a very high ozone indicator.

The other sources of variability identified in the process order, were:

- Variations of the Raw Materials
- Variations in the process of threading
- Variations in the process of warping
- Variations in the process of weaving
- Variation in the process of dipping
- Variations in the storage conditions
- Variations in the transport conditions
- Variations in the customer facilities

Each of these variation causes will be described next.

5.1.1 Variations in the raw materials:

These variations come primarily in at least one of these two forms: the pre-activated coating of the threads and a different composition of the titles of the yarns. The coating is used so that the RFL solution will attach to the threads, because if there is no coating that makes the surface rougher, or porous or have some sort of branches, it will be very difficult for the solution to attach to it. This is necessary because since the threads are synthetic the surface is very smooth, and does not have spaces or places where other substances might attach.

The differences attributed to the coating are basically caused by different amounts of it being applied to the threads. This basically means that the length of the “branches” to which the RFL is supposed to attach varies, and in this way can modify the adhesion properties of the fabric.

The composition is also very important. The basic title is the 1100 dTex. This means that 10,000 meters of thread will weigh 1100 grams. The yarns used to weave the conveyor belts in this particular company go from 3300 dTex to 8800 dTex, although the most common is 5500 dTex. All of these different titles can be achieved in different ways. The threads can be produced from ranges of 440 dTex to 2220 dTex, making a vast amount of possible compositions to attain higher numbers like 3300 dTex, 4400 dTex or 5500 dTex. The ideal composition is to have the largest amount of threads possible, so that the surface area to be covered with the RFL is the highest possible without the fabric gaining too much weight. For the heavy weight conveyor belts produced in this company, the idea is that each of these higher titles are composed of various 1100 dTex threads. It has been proven that this is not always what the suppliers send, so the company has to make it through with whatever it gets. This is a huge variation for the finished product, because it is like producing
with a different material each time, and the process and characteristics and parameters are arranged for the best possible raw materials.

5.1.2 Variations in the process of threading

Most of the variations in the threading process come from the fact that the equipment is quite old, as mentioned before, so all of its settings are adjusted mechanically, not electronically, so there are variations that cannot be controlled; also since the machines were manufactured in a different time, the variations allowed then were bigger than the ones allowed now. Nowadays quality has become much more strict, so the processes need to be much more precise so that the final products comply with the requirements of the customers and the market.

Here the variations are mostly the amount of twists per inch, the tension of the bobbins and the size of the bobbins, as a consequence of said tension.

5.1.3 Variations in the process of warping

The warping process involves much more variables than the threading. Here is where the tension of at least 250 bobbins, depending on the width of the fabric. This tension is of the utmost importance because any difference in the tension will create, in the weaving process, waves in the fabric, which not only look bad but will not respond accordingly to the requirements of the customer. The ideal set-up is that each thread has its own tension controller in the two steps: the unwrapping of the bobbins themselves and the warping itself. The tension of the unwrapping is supposed to be around 20% of the tension desired for the fabric. The current setup of the machine only checks for the tension, at both steps, in just one of the threads.

Here, even though the variation possibilities are less in quantity are much more important, because these cause defects in the final fabric.

The variations that occur here are mainly due to the difference in tension and the amount of knots due to bobbins that are smaller so need a new one to be attached so that the length of the fabric can be done.

5.1.4 Variations in the process of weaving

The problem with the weaving is very similar, in causes, to the problem in the threading. This means that most of the looms are very old so all of the parameters need to be adjusted mechanically. This causes that each of the fabrics made have a slightly different setting. In the past this might not be a substantial difference, but now that the customers expect their fabrics to be exactly the same each time, and that the variabilities have been diminishing to almost nothing, the age of the looms is evidencing.

This difference in setting, although not noticeable by a person may cause a difference in the tightness of the weave, a difference in the tension of the fabric, wavy appearance of the fabric, especially in the edges.

5.1.5 Variations in the process of dipping

The process of dipping is probably the most complex of all the processes involved in the manufacture of the technical textiles. This complexity is made because of all the variables involved, which were mentioned before. These variables are the temperature, the tension, the speed of the fabric. The temperature needs to be controlled in two different parts of the process, the tension in three. This creates a lot of places where variations and differences in the fabric can appear. To this you also have to add the differences that may appear when mixing the RFL solution.

All of the variations here will have a direct impact in the laboratory and in determining the quality of the fabrics.
5.1.6 Variations in the storage conditions

The storage conditions suffer from the same climate variations that are part of the city in which the fabrics are produced, all of this because the storage space does not have a controlled environment, as it would be very costly.

The variations come primarily from the weather: heat, humidity and ozone presence.

5.1.7 Variations in the transport conditions

Since most of the customers are abroad, most of the fabrics need to be shipped by boat. This means that they need to be loaded in containers that need to be transported to the docks. This creates possible variations also due to the weather.

In here the customs management must also be included. The customs need to open the container to check for possible smuggled contraband or narcotics. This means they need to manipulate the rolls of fabric, the packaging and may damage something.

The variations come primarily from the weather conditions, which are the heat, the high humidity and the presence of ozone. Some variations may come also from the customs and the way they handle the products.

5.1.8 Variations in the customer facilities

These variations, even though after the production process is complete, are important, nonetheless. The importance of these possible variations resides in that you need to know the conditions in which your product is going to be handled, so that you can make recommendations on how it should be handled.

The causes for variations are the heat, humidity, ozone and the handling of the rolls.

Some of the possible variations come from the weather and some happen outside of the plant. Controlling these variations fall out of the company’s control. The most that can be done about this is to issue recommendations on how to handle the product. For the other causes of variations a different process needs to be done, which is what is going to be explained next.

5.2 Further Review of Process Related Causes of Variation

In view of the restrictions that were mentioned in Chapter 3, and the possible causes of variation that were exposed before, what was done was the following:

- Review the instructions of each of the processes done to make the fabrics.
- Review the influences each of the different thread compositions and suppliers had on the adhesion results.
- Review each of the machines involved in each of the steps involved in the making of the fabrics.
- Review the variables involved in each of the processes, see the effects each of those had on the next step and the possible effects this might have in the adhesion results. The only place where this is really possible and feasible is in the last stage of the process, the dipping of the fabrics.

The findings of each of these steps are described next.

5.2.1 Process Instructions

The instructions of each of the processes, even though had all the information required, were not very clear and were not being used to operate or check for doubts. It was the experience of each of the operators what proves to be of the utmost importance. If by any chance the operator did not know what to do, he asked the Supervisor, not check or read the OI. The real use of the Operation Instructions is for them to be used as a
reference manual, it should not be just to comply with a Quality Management System. This was happening at the company.

Another of the problems found with the instructions was that it was written by various people along the way, with different styles and different scholastic processes. For the instructions to be useful it is needed that they are written in a clear and concise manner. This need to be concise does not trump over the need to have as much information about the process as possible, but the information can be added as an annex. It is also important to give clear, step by step instructions. These instructions could and should be also used as a training guide for new employees. They should be written in a way that if somebody knows nothing of the process, after reading them, should be able to do the whole process. Again, this was not the case.

Another problem with the instructions was that they were not written by the people that were going to use them but by the Quality Department some years ago. This poses two problems, the first is that there have been some changes in the process and even though those have been added to the instructions, have not been added in a cohesive manner. Just additions here and there; second the language used might not be the clearest possible and can confuse the users.

To solve all of these problems it is necessary for the instructions to be written again by mixed discipline committee. This committee should be composed of operators, the quality department, the supervisor and the person in charge of process engineering.

5.2.2 Thread Compositions and Suppliers

As discussed before, the different suppliers have a different adhesion value. This happens not only because of the composition but also because of the different pre activated compound they use on their own fibers. This compound causes an effect in two ways, the first is obviously the quality, but the amount used is also very important. If too little is used, it will have almost no effect at all; if too much is used, the cost will go up, and there will not be an additional boost to the adhesion.

Table 1: Average of the different suppliers and customers. The customers are labeled A, B and C. The suppliers are numbered 1, 2 and 3. The customers have their own rubber compound and those results are compared to the results obtained with the company's own rubber.

<table>
<thead>
<tr>
<th></th>
<th>Own Rubber</th>
<th>Rubber A</th>
<th>1 Own</th>
<th>A1</th>
<th>2 Own</th>
<th>A2</th>
<th>3 Own</th>
<th>A3</th>
<th>Everything</th>
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<tbody>
<tr>
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<td>-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
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</tr>
<tr>
<td>C</td>
<td>-</td>
<td>70.24</td>
<td>-</td>
<td>66.54</td>
<td>-</td>
<td>75.63</td>
<td>-</td>
<td>73.08</td>
<td>70.24</td>
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</table>
Table 2: Standard Deviation of the different suppliers and customers

<table>
<thead>
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<th>2 Own</th>
<th>A2</th>
<th>3 Own</th>
<th>A3</th>
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</thead>
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<td>-</td>
<td>0.6</td>
<td>-</td>
<td>0.6</td>
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This table shows the difference of the different suppliers, labeled 1, 2 and 3, with the different rubber compounds from the customers, in a sample type of fabric, EP160, which is one of the most common. This data come from the year 2013. The customers have been labeled A, B and C. The difference in the compositions is very difficult to check, because since this does not happen a lot, the times it does happen, those threads are dispersed amongst the lots of threads that make up the fabric.

5.2.3 Machines and Information Provided by them

Since most of the machines are very old and mechanical, almost none have any sort of PLC that can give out the information for the processes. There are only 4 looms, both warping machines and the dipping station that could be able to give out the information concerning the process.

Out of all of these machines it is only the dipping station that has any sort of program to analyze the process. The other machines will need a way to translate the information into a usable form. This will require some sort of different software. Some quotations for this software were presented by some companies.

Even though there was not any budget for the software, at least now the company knows the next steps it has to take in order to keep on standardizing and improving the process.

5.2.4 Variables and their effect in the subsequent process

Of the different variables and sources of variations discussed in section 4.1, the variables that have the most impact in the next process are:

- Tension from the warping
- Tension from the looms
- Tension in the dipping station
- Temperature in the drying part of the dipping
- Speed of the dipping process
- RFL solution

These variables were chosen because there has been some evidence in the laboratory regarding some quality defects that can be traced to at least one of these variables being off target. For instance, if the tension is not right, some parts of the fabric become looser; if there is not enough tension and speed in the process, then the fabric gains too much weight and may become unusable; if the temperature and speed is not right in the drying oven, then the fabric does not dry properly and a defect called freckles appears at the end of the activation oven, these freckles are spots of wet fabric that dry too fast and do not penetrate the fabric, son in...
that precise spot there is no adhesion; the RFL solution is also important because if it is not mixed properly, then it will not work and there will be no adhesion, which is the importance of the dipping station.

After checking all of these variables, defects and effects, it was decided, to focus the project in just the final stage of the production process. In section 4.1.5 it is clearly shown that the dipping part is the most important and complex part of the process. This decision was also based on the fact that the dipping station is important because if it is not mixed properly, then it will not work and there will be no adhesion, which is the importance of the dipping station.

This decision was made in an attempt to try and show, in the least amount of time possible, the beneficial possibilities that arise after an organized and efficient way of storing and sorting all of the information obtained from a process.

This decision might seem really wrong, due to the fact that it is the last stage of the manufacturing process, and the smartest way to start standardizing is from the beginning of the process and go on from there. The importance of what was done here is that with this the whole impact of the sheet can be shown, and the customers can be answered with facts, not opinions.

Also, this will give a lot of insights into the process itself. This is going to help people understand the importance of the variations that happen earlier in the process and might push the board into investing in upgrading the equipment and into the software necessary to obtain the information from the other processes.

5.3 Solution Description

After the SCADA variables were all obtained, it was needed to formulate some sort of way to analyze such a large amount of data in a fast and comprehensible way. What was decided was that a spreadsheet should be constructed. The most important part of the spreadsheet was that it could handle a lot of information, graph the behavior of the different variables and also help with the Statistical Process Control.

The SCADA records the behavior of the sensors connected to the PLC every time interval that is user defined. This means that it can provide information every second, minute, hour, etcetera. This gives an edge to the process knowledge and allows graphs to be constructed.

As was mentioned before, there are a lot of variables that need to be controlled. Each of these variables need to be compared alone, so that it can be comprehended correctly. It is also important that the variables be correlated to each other, to analyze if one variable affects any of the others.

Each of these variables is controlled by different sensors:

- The speed is measured in 4 places
- The drying temperature is controlled by 6 sensors
- The pressure of the draining rolls in one place
- The speed of the dryers is controlled in two parts
- The activation temperature is controlled by 5 sensors
- There are three different tensions and each of these is controlled in one place

All of these sensors is controlled by a set point, except for the drying temperature in which all six sensors are controlled by just one set point. This gives a lot of liberty for the processing.
Each of these groups of variables are graphed separately so that the whole process can be seen. The time frame selected is one data set each minute, to try and be as precise as possible but without carrying too much information that might overload the system or the capacity of Microsoft Excel.

Also a simple statistics analysis tool was programmed inside the spreadsheet, so that it is possible to know the maximum value, the minimum, the average, and the variability of each set of data.

A very interesting feature that was included into the SCADA was the possibility to introduce the item number being processed, so that the analysis can be done for each individual roll. Also, the reference for the type of product being processed is also introduced, so the set points and their ranges that are introduced in the Working Pages (WP) can be checked against the ones used to process the roll. This will allow the person checking the results to look for any anomaly. If any of the values go out of the expected range, then there will be a problem.
Results

After the solution being explained in the previous chapter, here the results are going to be presented. Here the final look of the spreadsheet will be shown, as well as the information that can be extracted from the SCADA, and the graphs that can be shown. Some examples will also be shown, to help illustrate the usefulness and the scope of information that can be extracted from this.

Graph 2: Sample of data obtained from SCADA software. To see better see Annex 1.

The information that is extractable from the SCADA software is stored in a database that is kept by the software itself. The only way to access this database is through the SCADA, but it can be downloaded as a Microsoft Excel file. Each of the sets of data are paired with a time stamp, so that it is possible to match the different sets of data. It also allows to extract only the information you want, not always the whole database.

The size of the database is fixed, and is rewritten every couple of months. To prevent any information from being lost, the extraction of information was done twice a week. The other idea behind doing this twice a week was to have the information as fresh as possible so that any changes needed could be made fast enough.

Graph 3: Sample of the worksheet. It is not necessary to view the information. This is just to show how the spreadsheet displays the information in the Data sheet. To view better see Annex 2.
The pages are the following:

- The data page
- Temperature of the drying station
- Temperature of the activation part
- The tensions, showing both parts active at the moment
- The straining pressure
- The speed of the fabric

6.1 Data Page

In this page the data obtained from the SCADA in introduced. The columns are the following:

- Date and time
- Date
- Time
- Roll Number
- Drying Set Point
- Drying Sensor 2
- Activation Set Point 1
- Activation Sensor 1
- Activation Set Point 2
- Activation Sensor 2
- Activation Set Point 3
- Activation Sensor 3
- Activation Set Point 4
- Activation Sensor 4
- Activation Set Point 5
- Activation Sensor 5
- Tension Set Point 1
- Tension Sensor 1
- Tension Set Point 3
- Tension Sensor 3
- Fan 1
- Fan 2
- Suction
- Strain Set Point
- Strain Sensor
- High Speed Set Point
- Low Speed Set Point
- Speed Roll 1
- Speed Roll 2
- Speed Activation Oven
- Speed Roll 3
- Fabric Reference

With all of these variables having a record every minute, it is obvious that the amount of information is huge. It can easily go to at least 4300 registers. With all this information a way to find a way to show the information required. For these filters have been introduced to the page that allows information to be filtered by the roll number, the date, the time or the reference. This way allows the relevant information to be shown and graphed.
6.2 Drying Temperatures

Graph 4: Graph of the Drying temperatures and simple statistics. See Annex 3.

This graph shows the process for a sample roll number. It can be seen, minute by minute the behavior of the drying oven temperature, compared to the set point. Because the variable being measured here is temperature, there are going to be some small variations, what is important here is that the temperature does not fall too low or rise too high.

The simple statistics shown illustrates the behavior from a mathematical perspective rather than a visual one. Here you can see the maximum value, the minimum, the standard deviation, the range the values have and the average value. This can complement the analysis from a different perspective.

6.3 Activation Temperatures

Graph 5: Graph of the Activation temperatures and simple statistics. See Annex 4.

This graph shows the process for a sample roll number. It can be seen, minute by minute the behavior of the activation oven temperature, compared to the set points. Here, since there are 5 fields each has its own set point and sensor. The idea behind this is that each field can be set to a different temperature to avoid a big temperature shock to the fabrics. In this company this is not usually done. Because the variable being measured here is temperature, there are going to be some small variations, what is important here is that the temperature does not fall too low or rise too high.

The simple statistics shown illustrates the behavior from a mathematical perspective rather than a visual one. Here you can see the maximum value, the minimum, the standard deviation, the range the values have and the average value. This can complement the analysis from a different perspective.
6.4 Fabric Tensions

<table>
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<tr>
<td>2022</td>
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<td>626</td>
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<td>626</td>
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</table>

Graph 6: Graph showing the tensions and the simple statistics. See Annex 5.

This graph shows the process for a sample roll number. It can be seen, minute by minute the behavior of the tensions, compared to the set points. Here, since there are 2 different tensions, each has its own set point and sensor. This two tensions are measured in two different points of the process. The first one, called Z1 is measured as the fabric goes into the drying oven; the other one, called Z3 is measured as the fabric goes into the activation oven. The tensions serve two purposes, first that the fabric does not soak up too much solution and the second that the fabric does not shrink with the temperature. If any of these sensors sense that the fabric is not having the adequate tension, the results can be very bad, either in weight or in length.

The simple statistics shown illustrates the behavior from a mathematical perspective rather than a visual one. Here you can see the maximum value, the minimum, the standard deviation, the range the values have and the average value. This can complement the analysis from a different perspective.

6.5 Straining Pressures

<table>
<thead>
<tr>
<th></th>
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<th>P2</th>
<th>P3</th>
<th>P4</th>
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</table>

Graph 7: Graph showing the straining pressure and the simple statistics. See Annex 6.

This graph shows the process for a sample roll number. It can be seen, minute by minute the behavior of the straining pressure, compared to the set point. The pressure is controlled by a set point and sensor. The pressure is usually higher due to the fact that the pressure set is for the pressure that the two rollers exercise on each other, as there is a fabric going in between them, it naturally goes up. The objective of straining the fabric is so that it does not take up too much RFL solution and get too heavy.
The simple statistics shown illustrates the behavior from a mathematical perspective rather than a visual one. Here you can see the maximum value, the minimum, the standard deviation, the range the values have and the average value. This can complement the analysis from a different perspective.

6.6 Speeds

Graph 8: Graph showing the speeds and the simple statistics. See Annex 7.

This graph shows the process for a sample roll number. It can be seen, minute by minute the behavior of the speeds, compared to the set points. Here, since there are 2 different tensions that change the length of the roll, the speeds need to adjust themselves at each point of the process. The important part is that the linear velocity of the rollers is the same so that the whole fabric moves at the same speed, regardless of the tension. The first speed is measured at the beginning, before the fabric is dipped, the second after the fabric is dried, the third is inside the activating oven, the last is after the fabric is activated and is in the process of cooling down.

The simple statistics shown illustrates the behavior from a mathematical perspective rather than a visual one. Here you can see the maximum value, the minimum, the standard deviation, the range the values have and the average value. This can complement the analysis from a different perspective.

6.7 Other variables

The other variables, even though are extracted from the SCADA are not used in the graphs mainly because they are just set points and have no sensors to monitor them, so it is pointless to do a statistic or a graph of them.
7. Conclusions

- The process control scheme was introduced successfully into the company.
- The most important and value adding process was identified.
- The knowledge of the processes has increased dramatically not only with the conclusions of this project but also with the steps taken to do it.
- The responses to the customers for their claims can now be done with certainty, knowing that if anything went wrong with the process it can be evaluated before the fabric reaches the client.
- Now it is possible to show the suppliers if there is anything wrong with their raw materials. It can also be compared amongst the other suppliers so that the quality can be comparatively shown.
- The process to standardize not only the processes but the variables has been started. It is now possible to check each of the fabric’s processing conditions with the quality results, so that they can be graphed and analyzed to provide the best settings to obtain the best results. Or maybe try and get the minimum values with the lowest possible cost. What this means is that the results end up being linked, in a graph, to the processing variables, allowing an easy look at the process.
- Now that the variables and quality results is being measured and controlled, the quality can start to be standardized. Even though there are a lot of variables, not all affect the quality in the same way, so the variables can be chosen so that the best information can be obtained.
- Since now there are a lot of variables, levels and quality results, there is enough information to begin the Statistical Process Control (SPC). This is very important, because it is the gateway to the standardization of the processes, the quality, the cost of production and everything else related to the production of the conveyor belt fabrics.
- The model constructed for the specific process of the dipping of the conveyor belts can be easily converted into a solution for all the processes involved. It only needs that each of the processes gives it enough reliable and sufficient information so that it can graph, against time, the whole process, for each of the different items.
- Even though this is a good first step towards the standardization, it is just the first step. It still remains to be done the continuation to the other processes so that there is much more information to be analyzed and a lot more can be done.
- Also, it is essential to continue the SPC, because this is a very helpful tool. Also there are some customers that are asking for some information only available through the SPC. Right now there is some sort of SPC being done, but just in the laboratory and just for the fabrics that reach the minimum and are accepted. This is most of the time going to give a nice result, but it is not useful when trying to fix a problem or if you are trying to understand the real process.
8. Reference

ÁLVAREZ BORREGO, Josué. Control Estadístico de Procesos. Publisher and year unknown.


SIEMENS. Siemens Simatic WinCC V7.0 Manuals. SIEMENS AG. 2008.

Here all of the information is not showed, this is just a sample of how the information is presented and organized.

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<tr>
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<th>S</th>
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</tbody>
</table>
Here is how the drying temperatures are displayed. Here also appears some simple statistics that help analyze the time interval.
Features are displayed. Here also appears some simple statistics that help analyze the time interval.
Here is how the fabric tensions are displayed. Here also appears some simple statistics that help analyze the time interval.
Here is how the straining pressure is displayed. Here also appears some simple statistics that help analyze the time interval.
Here is how the speeds are displayed. Here also appears some simple statistics that help analyze the time interval.