Coagulation lines for the production of filters/membranes

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Summary of the project proposal

This project is part of several initiatives that Aigle has been undertaking for some time to find applications for its proprietary textile technologies (coagulation, coating and lamination) in commercial areas, even away from more traditional supply chains and/or in existing production systems that need to be updated and developed with our technologies.

Among the various fields of activity in which Aigle is a leader, the production of coagulation and coating plants plays a very important role.

The project we are about to describe is designed and defined in accordance with basic research guidelines, viz:

- innovations
- creativity
- uncertainty
- systematic research

Idea and project

We have developed a coagulation (inversion) line with the integrated capability of using two coating systems - slot and on-cylinder doctoring. The machine combines these two systems and makes them available with virtually no equipment modification. The slot system allows low-viscosity chemicals to be coagulated with a green solvent without the use of DMF (the solvent that has always been used for the polymer coagulation process on films, fabrics). In short, the main challenge was to make the line compatible with the mechanical and hydrodynamic requirements of the new chemicals to be used for this type of processing. This applies both to the way the raw materials are treated on the line and to the triple application of chemicals on the many possible supports (textile mesh, TNT, Mylar, cotton, etc.). All of them also have the possibility of double application with supporting mylar. The line thus allows the application of specialised chemistry with different technologies, some very innovative, others more traditional, others consisting of traditional technologies used with innovative materials. This opens up very promising technical and commercial opportunities for the utilisation of these products.

Project idea and motivation, problem to be solved and overall objectives

Aigle mainly manufactures coating, coagulation, flocking and lamination equipment for the textile industry. In the past, from 1985 to 2000, Aigle has produced many lines for textile coagulation using polyurethanes dispersed in DMF. DMF is a solvent that is not very safe for either the environment or human health. In traditional coagulation systems, the water-DMF solution that remained after the coagulation process (2,500 litres/hour of solution in a three-shift plant) was then separated again into water (partially reused in the system) and DMF, which was also reused to dissolve the polyurethane. The European community has repeatedly argued in favour of not using DMF as a solvent for artificial leather and other coagulated membranes.

The research succeeded in creating a coagulation line that works with polyurethanes dissolved in alternative solvents, so-called Green Solvent.

To put this research into practice, Aigle has collaborated with major industrial companies (for confidentiality reasons, we cannot disclose the names of the companies or the specific types of products that result from this technology). In addition to using Green Solvent, the new line has been developed using mylar films to provide a coagulation/inversion process on woven polyester and nylon meshes. Therefore, part of the research has focused on how to handle the tension of a thin film (<50 microns thick) at the same time as polyester mesh, which is also very thin.

For the project, Aigle utilised its many years of experience as a manufacturer of coagulation lines with traditional solvents, and then managed to find innovative solutions to eliminate the problems encountered with new solvents and media:

- relatively lower viscosity of polymer resins
- the need to parameterise the concentration determination system, which has not been developed for solvent Green.
- a tension system with very limited tension (< 0.5 N per cm) without stretching or wrinkling must be created.
- to find an ambivalent coating technology that can handle very high viscosity ranges and the need to control the temperature regime of the compound, coagulation and wash tanks (50-90°).

Over the years, Aigle has developed various technologies focused on this area, supporting this research mainly with its own funds and partly with government funding.

First of all, coating technologies are used on metal, plastic, rubber, etc. in industries such as automotive, construction, packaging, medicine, etc.

The results of this research have enabled Aigle to offer these new solutions to various markets with great success in recent years. This has enabled Aigle to gain a significant market share in coating and laminating equipment, for example in the automotive, construction, technical textiles and other industries.

The industries in which this new technology can be applied are numerous (some of them cannot be named for confidentiality reasons), e.g. filtration (automotive industry, household appliances), medicine (tissue replacement), clean research (new materials, membranes).

In all the sectors mentioned, there is a great demand to utilise the functional advantages of the technology under investigation (increased permeability to air but not to liquids, etc.), special pressure sensitivity. All this with absolute environmental friendliness, which is an important and recognised aspect for most businesses around the world.

However, we faced a number of challenges, both at the process and technical solution level.

Problems related to the production process:

- Difficulties in using a "green solvent" in a process that mainly uses DMF
- management of transport shoots from fabric and mylar
- mechanical brittleness of the mesh support

Problems in finding the most suitable raw materials:

- difficulty in finding compatible materials of chemical compositions with treated fibres (polymers and solvents - carriers) for use in coagulation processes.

New industrial systems and the technologies used also require rationalisation of production criteria and productivity improvements, as well as the search for suitable raw materials (compounds and fabrics/films). At the same time, the continuous improvement of quality standards requires the manufacturers of these components to strive for overall quality, and thus for production systems that can increase productivity while maintaining high quality control of the semi-finished product.

The purpose of studying this plant and these technologies was to pursue and achieve these two objectives, which are in principle opposite, but which were achieved through the technical solutions proposed.

Scope of the intervention

The development of this coagulation line opens up the possibility for Aigle to produce specialised installations in the field of advanced and innovative products.
This innovation is fully in line with the proposed sector, as it significantly changes the models used so far and allows the use and development of innovative products with a special focus on technical and structural textiles, which is also one of the most developed markets in the textile sector worldwide.
The innovation proposed in the project aims to develop a new model using coagulation techniques applied to technical textiles in the medical and industrial sectors; this makes it possible to expand the markets in which coagulation techniques can be used and thus anticipate spin-offs corresponding to the stated outcomes (diversification of supply in growing markets, creation of new concepts and products for the living environment, means of transport and design, and the medical sector).
These by-products represent, on the one hand, opportunities to occupy new market segments with high added value through specialisation of supply and, on the other hand, social challenges for which reasonable, efficient and effective solutions must be found to meet global competition.
The project fits into this context by offering a significant innovation in the technical and medical textile market, where regional manufacturing has a significant global footprint.

Benchmark trajectory in relation to the main innovative aspects of the project

The development of this model allows for an innovative product capable of replacing more traditional materials in sectors such as medicine and light industry; thanks to the characteristics of the new products coagulated with Green solvents, advantages in terms of sustainability and environmental impact can be achieved. In fact, the technical performance of breathable membranes will no longer be compromised by the low eco-factor characteristic of products made with DMF solvent.

Scientific and technological status

The term "coagulation" or "phase inversion" refers to a process in which a polymer is transferred from the liquid phase (polymer solution) to the solid phase (membrane) in a controlled manner. This phase transition can be accomplished in a variety of ways: evaporation deposition, immersion deposition, thermal deposition and solvent vapour deposition. The principle used by Aigle consists of evaporation and immersion deposition. Phase inversion allows the production of membranes varying in shape, structure and pore size using a wide range of polymers and solvents. The microporous effect is achieved by solvent migration, which, by migrating, creates micropores on the surface. Within the film, solvent migration leaves empty spaces (cells), which vary in size depending on the solution, process time and application methods, giving different results in terms of permeability to air passage. In most cases, after the process is completed, the membranes are subsequently dried in suitable ovens.

The coagulation process varies depending on the

- the substrate onwhich the film is applied,
- against the spread of chemicals
- depending on the coating technologies used.
- type of solvent used
- tank type and residence time in the coagulation tank.

Mechanical coagulation tanks are of different types

- vertical cylinder
- vertical chain
- vertical cylinder and chain
- horizontal
- horizontal and vertical

The type of tank affects two aspects of the coagulation process:

- material stress
- consistency of the film inside the tank

These two aspects are very important for cellulose, which is a fundamental variable for determining membrane permeability. In fact, cellulose is inversely proportional to tension. Therefore, in a horizontally developed tank with a conventional coil system (an arrangement of cylinders within the tank that provides maximum delay in cylinder contact with the right side where the coagulated polymer is located), tension determines the possibility of more compact or larger cellulose with a consequent higher or lower permeability. The residence time in the tank also affects the cellulose characteristics, i.e. permeability.

The chemical variables of the process are:

- polymer type
- solvent type
- solvent concentration in the polymer
- solvent concentration in the coagulation tank

The film microperforation process occurs during the evaporation phase (before immersion in the reservoir) and during the migration of solvent from the coated film into the reservoir solution liquid.

The solvent concentration naturally tends to increase with a continuous supply of solvent as the film enters the coagulation tank. To maintain a constant solvent concentration level, a special instrument, a refractometer, is used to control a valve that passes demineralised water to maintain a constant value of solvent in solution. This value usually varies between 10 and 25 %.

After coagulation, the membrane is immersed in a wash tank. Depending on the process speed and solvent concentration, one or more cascade wash tanks are used.

The membrane must come out of the washing tank with a negligible solvent content. After washing, the membrane is dried in a hot air oven.

Industries that use the coagulation process include textiles, footwear, automotive, medical, construction, geotextiles, and others.

Therefore, the evolution of coagulation aims to find and combine the

- new environmentally friendly solvents
- new chemicals
- new footholds for distribution.
- new types of media when necessary

The aim of the study was to start with a coating substrate that already has innovative intrinsic characteristics. Thus, in the past, the coating has been applied mainly on traditional cotton fabric or nonwoven fabric, whereas the study envisages the application of a coagulable polymer on mesh fabric or mylar by developing and combining new coating technologies (such as slit application) and using new chemical products, or in any case using distributed products that have not yet been used in coagulation.

The reasons why these techniques/technologies are not well developed at present are mainly due to the following factors:

- Few companies like Aigle can boast such a wealth of expertise in coagulation technology, thanks to the experience gained in various industrial plants and in laboratories on traditional coagulation lines with DMF. This know-how is essential in order to expertly analyse the most suitable technologies depending on the raw materials from which the plant will be made

- the challenge of coagulation on mylar or lightweight fabrics is to find chemistries that have adhesion and retain the desired characteristics after drying. In addition, mylar and mesh fabrics are mechanically fragile and require particularly sophisticated in-line synchronisation and tensioning systems.

Here are a few examples that not only do not exhaust the potential of the research, but also emphasise that the scope of its application can be even wider: biomedicine, application of filtration in a wide range of industries. The opportunities for growth in this sector are significant.

In the context of modern membranes, we speak of selective permeability. This means that if two substances present in solution pass through the membrane at different rates, the permeate and retentate streams can contain large amounts of one of them, utilising precisely this difference in permeation rate. Research in this area is taking up a lot of space because the possibilities for utilising technologically advanced membranes are very large:

- desalination of water to make it drinkable
- extraction of biologically active compounds or contaminants (drugs, pesticides, heavy metals) from industrial production in the agri-food and pharmaceutical sectors,
- enzyme reactions, dialysis (artificial kidney),
- development of molecular sensors, protein crystallisation,
- extraction of substances from natural matrices, juice concentration,

As already stated, these are just a few examples, which of course do not exhaust all important potential uses and evolutionary development (technical and commercial) in the long term.

Innovations realised within the framework of the project

The subject of the study is an innovative coagulation line that, starting from traditional coagulation techniques for the production of artificial leather for clothing and upholstery using PU and DMF, comes to an innovative line that can be adapted using different chemicals to produce filters for medical applications.

We have developed a coagulation line with the integrated capability of using two coating systems - slot and on-cylinder doctoring. The machine integrates these two systems and makes them available with virtually no equipment modification. The slit system allows the use of low to very low viscosity chemicals while maintaining absolute accuracy of the coating film.

In order to meet the need for versatility and control of the production process, the line is characterised by a coagulated material tensioning system that has been specifically designed for very light fabrics suitable for the required processing and for the weaving of two overlapping materials (light fabric plus support film). The system is designed to maintain a constant material tension in the range of 0.1 to 1 N per linear cm. The coexistence of the two materials results in creases and slippage that disrupt the coagulation process. Therefore, tension control and special insertion are research elements to avoid such phenomena that are detrimental to the process. The velocity range is very high compared to similar lines, from 0.1 to 5 m/m'. To achieve this, special low friction pneumatic cylinders were used (to move the 'dancers', which are designed to control the tension of the material in order to signal the drive motor connected to them). A special converter was then used to send a very precise signal to the microprocessor, which processes it, causing the servomotor to move linearly and without jerk, even at very low speeds.

Coating tables are used in the coagulation line with three different technologies with exceptional flexibility:

- coating of doctor blades with high precision and very low coating thicknesses of up to 40-50 microns.
- coating application using tweezers in air with the possibility of polymer penetration into the coagulated tissue.
- coating with distribution slots for the use of chemicals even with low viscosity. An innovative system in this sector

Specific process monitoring and control systems (temperature, thickness, speed sensors, synchronisers, process control via PLC, etc.) were considered and applied.

The sum of technological innovations has enabled Aigle to create a coagulation line with the following characteristics:

- the use of a "green solvent" and thus bring to the market an environmentally friendly technology that does not have a negative impact on the environment.
- the use of mylar films to perform the coagulation/inversion process on woven polyester and nylon meshes to produce high-tech membranes for various applications.

Technical and economic sustainability

Aigle's decades of experience in the relevant technical and commercial sector and its existing capabilities make it optimistic about this study. The timing and cost assumptions are based on similar experiences that have already been conducted and successfully completed in previous years.
For many years Aigle has been developing, manufacturing and installing coagulation systems for a wide variety of applications.
The benchmark is always the combination of often innovative raw materials (compounds, etc.) with systems for applying these products to products of various kinds: for example, coating lines with a slit extrusion system for stretch fabrics for the production of artificial leather have recently been designed and developed.
This project is part of the Aigle product range renewal programme. In this way, an attempt is made to utilise advanced technologies in various fields to obtain installations that can be attractive because they are innovative.

It was with the previous process of coating glass fibre for wallpaper that one of the first confirmations of the market's need for technological and technical developments in this area of research was associated.

It was also assessed in which industries this research would be useful: it is already known that it could be useful in the automotive filter and white goods industries (where, in addition, there are many areas in which these coagulated membranes could be successfully used), but it is expected that there are other interested industries: for example, in products related to biochemistry, medicine, etc.

Integration with other initiatives and future developments

This project is already part of an ongoing effort to integrate coating technologies into the textile industry in order to find different innovative applications. Coating systems have already been implemented, but for non-textile fibres the research and development opportunities are still very wide and have different applications.

It is anticipated that membrane coagulation can be pursued and will open new horizons for these production technologies, as it has already been done in similar experiments.

The mechanical, functional and aesthetic properties achieved can be used in a wide variety of industries.