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KEYNOTE ADDRESS: SPUNLACE 101, THE COMPONENTS OF ESTABLISHING A PRODUCTIVE AND VERSATILE SPUNLACE PLANT

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Abstract

The Spunlace market is a recent phenomenon relative to the textile industry, with approximately 40 years since its initial start in the R&D departments of DuPont, and 20 years since it became a viable industry serviced by Engineering firms capable of supplying lines where speed, uniformity and efficiency made the fabrics applicable to the general customer applications. The lines supplied today bear little resemblance to those supplied even 10 years ago, with the machine configuration, line width and speeds all increased by an order of magnitude. The lines today are up to 4.5 meters in width and operate at 200+ meters per minute at the winder, a far cry from line widths and speeds of a decade ago. The technologies to enable this change do not lie only with the Spunlace machine where many improvements have been brought to the market, but also in carding, where a combination of doffing capabilities and wider machines which can manufacture webs which can be transferred at higher speeds without affecting the fiber orientation at wider widths, all reducing the incremental cost of production. The cost reduction criterion is critical in this very competitive market where the majority of fabrics would be considered commodity items. Thus a line today makes a line delivered 10 years ago obsolete in all but specialty applications. The purpose of this paper is to provide an insight into the general characteristics of a Spunlace line, with emphasis on the Spunlace machine, as much of the technologies for fiber preparation and web forming are well known throughout the Nonwovens Industry.

Opening and Blending

The importance of proper fiber open and blending cannot be overlooked, as the uniformity of the fiber blend ratio and degree of opening is integral to the performance of the finished fabric in its useful application by the end user. As the majority of hydroentangled fabrics are light weight (average weight is approximately 60 gsm), and are made with web forming directly feeding the Spunlace machine, Therefore the uniformity of the fiber blend and degree of opening of the fiber tufts is critical in the visual aspect as well as the technical performance of the fabric.

The majority of direct web Spunlace lines today have two or three cards in line on the same axis as the Jetlace machine. The widths and delivery speeds of these cards will in part dictate the fiber preparation format, depending upon whether the cards will always operate with the same blends or if each card is to operate with its own blends to create a composite structure.

As the production rates are quite high, in the range of 225-250 kg/meter/hour for each card on new high speed lines, the opening systems are often dedicated per card, which enables the possibility to make composite or same fiber webs from each card.

Carding

As previously stated, most lines with in-line carding have two or three cards, as this format enables the formation of 60 gsm webs at maximum speed, and allows the carding machines to doff webs well within their target range of web weight capability. The use of single card lines is not efficient as the global investment cost for a Spunlace line is quite large, and the productivity of a single card at 60 gsm cannot compete with multiple card lines where the doffing speeds are considerably higher, and the uniformity of the web is averaged over multiple cards versus a formed web from a single card, thus multiple carding lines is the industry standard.

The 60 gsm weight is the average of the wipes industry, and as wipe fabrics are considered commodity products, the incremental cost plays a tremendous role in the competitive nature of the Spunlace line, thus the higher the speed and wider the fabric at the winder, the lower the incremental cost.

The fiber orientation of the web is also important, with the target to achieve as balanced a web MD:CD ratio as possible. The whole concept of carding is to create parallel webs, something stemming from the historical fact that carding was initially based on creating slivers of fiber for the spinning industry. The carding machine used in Nonwovens uses a different principle than the flat top carding machines used in traditional textiles, as carding groups on the main cylinder use wired rollers rather than slats to comb the web. This carding format is capable of producing superior production values per meter of card, and at the same time can create webs that are not as parallel. Nevertheless, it is necessary to re-orientate the web after the doffer in order to try and balance the MD:CD ratio of the web. This is typically done with condensing rollers, placed just after the doffer of the card, which progressively rotate at slower speeds, thus having an accordion effect on the fibers as the fibers stack upon themselves due to the transfer to a cylinder with a slower surface speed. This effect pushes the fibers out of their parallel axis and into a random orientation. The net effect is an MD:CD ratio that changes from 6-9:1 to approximately 3:1 (the exact values depend on more than just the card web forming, as draft and other line influences can effect the end MD:CD values), which is a positive end result.

Another benefit of condensing the web to create a more random orientation of the web is the ability to extend the range of web weight generated by the card. This occurs as the web gains weight as the fibers are condensed, with the final web weight being a result of the card settings, gap settings, wire specifications and speed differentials for a given blend and type of fiber(s).

There is another format of web forming called airlaid web forming, which has 2 different general formats which create webs with a more balanced MD:CD ration, but typically have limitations on kg/hr production rates and have width limitations compared with traditional carding systems. This format of web forming has 2 general ranges of weight capability, lightweight and heavy weight being the general distinction between the two general technologies.

The heavy weight technology is truly an air-laid technology and is used typically for heavier weight Spunlace fabrics, with de-makeup pads being a good example. The widths of these systems are typically narrow and operate at lower line speeds. The advantage of this format of web forming is the capability to create heavy weight webs with good isotropic behavior, which is required for de-makeup pads.

The lighter web weight technology uses traditional carding to create webs, where at the doffing phase an interjection of pneumatic principles helps to create webs that have better MD:CD ratios while keeping the web weight low. The fabrics created with this technology compete with traditional carding systems. The technology here is limited by the speeds capable on traditional carding lines which today can exceed 200 meters per minute, whereas the Pneumatic carding systems are not (yet?) capable of this rate of production.

Therefore, the majority of lines installed today still employ traditional carding systems, with only special applications using Air-laid technologies.

Spunlace Bonding

The Spunlace machine is actually a combination of systems, which are integrated to form a composite system where each component has its own role and impact on the global efficiency of the Spunlace machine. The composite elements are:

1. The Spunlace Bonding machine
2. The Auxiliary plant
3. The filtration plant

The Spunlace bonding machine is the layout of the bonding machine with a combination of cylinders, injectors and transport aprons. It is this general machine layout that receives the most attention as it is here where the web is bonded, patterned or apertured, and thus is the most visible segment of the Spunlace process. The machine layout is of course designed to meet the web width capabilities from the carding or web forming system and takes into consideration the range of fabrics desired in order to determine the number of cylinders and/or aprons required for bonding, and with this, the placement of injectors. The machine configuration therefore has some standard characteristics, which can then have elements added depending upon the project.

There is no standard machine design, although there will be a common thread of design intellect in all designs. The standard format is to employ 2 cylinders, each with 1 or 2 injectors where alternate bonding can be made to the web. Alternate bonding means that side A in bonded and then side B is bonded, with this being done through the use of 2 cylinders with a small spacing between each cylinder.

Once the web has been bonded on each side we can decide what finishing effect we wish to apply to the fabric. There are 3 general finishing possibilities (and a few unique possibilities for which we will not review here), they being:

1. make a plain fabric where no design is desired.
2. make a fabric with a design or pattern
3. make a fabric which is apertured

The use of a third cylinder or a finishing apron will dictate the finished fabric appearance, as the design of the cylinder sleeve or apron will provide the visual characteristic of the fabric. In effect, if the apron or sleeve has a pattern, and the net effect of the fabric will be a mirror image to the pattern or design of the apron or sleeve.

The number of injectors, their placement and the flow and pressure from these injectors will help determine the final fabric appearance.

Within the general scope of the Spunlace machine layout there are 3 important areas that help to make the operation of the machine efficient and successful. They are:

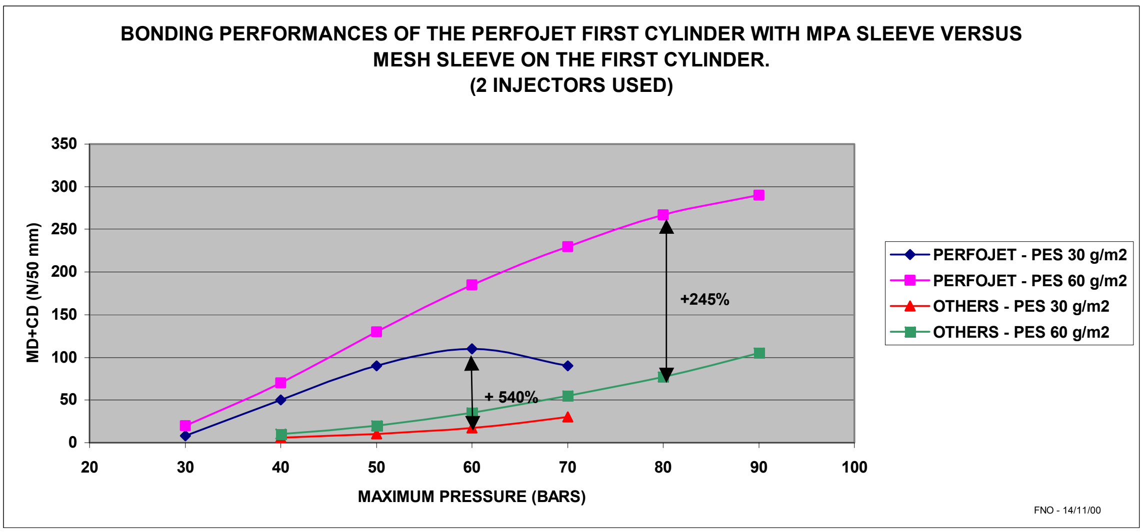
1. Primary bonding on the first cylinders
2. design of the injector body
3. efficient use of either an apron or sleeve, to create pattern or apertured fabrics

The prewetting and initial bonding (primary bonding) occurs on the first cylinder for all lightweight fabric production, and the efficiency of the global bonding energy of the spunlace machine can be directly attributed to the machine design and efficiency of bonding at this primary position.

The patented design employed by Rieter Perfojet has the web passing under the first cylinder, with the web being sandwiched between the cylinder and the transport apron. The prewetting injector wets the web, and through this action, places the wet web onto the cylinder, and with the rotation of the cylinder, introduces the web to the first injector. This transfer of the web by the use of the prewetting injector eliminates stress – tension within the web, and enables the screen of this first cylinder to be designed for optimal bonding potential.

The micro-perforated sleeve (MPA) was designed to provide a flat, low open surface area support for the web, which would allow for the energy of the water needle to penetrate the web and reflect back into the web, thus providing a secondary bonding action of the same water needle. This combination of the direct water needles, and rebounding secondary energy of the water back into the fiber matrix, creates turbulence inside the web producing the hydroentanglement effect. This reflective energy provides superior bonding when compared to machines where the sleeve has mesh wire for its surface or where an apron is used to compress the web and passes around the first cylinder, and therefore becomes the support for the web at this initial bonding stage.

Rieter Perfojet used the design using an apron or belt up to the introduction of the MPA sleeve in 1996. It had been observed through hundreds of trials that almost no bonding occurs when the support of the web is a belt, as the yarns of the woven belt reflect the water needles in random directions. In other words, they deflect the energy of the water needles away from the web, and this secondary bonding potential is lost, as the water reflects away from the fibers into the vacuum of the dewatering chamber. Therefore the full bonding energy of the water needle is not fully utilized. This reduces the efficiency of the energy within the water needle, and increases the energy required for the machine in order to compensate for this loss of energy, as the water reflects off the fibers of the woven transfer apron away from the fibers within the web/batt. This compensation is measured in two forms, higher pressure energy from each injector, and/or more injectors, either of which increases the capital expenditure for the Spunlace plant and increases the incremental manufacturing costs (cost per meter^2). The use of an MPA screen at this initial bonding stage is critical in the efficiency of the energy conservation and capital investment.



As can be seen in graph, the efficiency of bonding when using the MPA sleeve is improved by 200 to 500% versus using a mesh sleeve on the first cylinder. The impact of this efficiency is the reduction of pressure energy required to achieve a desired strength or level of bonding, and this equates to lower operating pressures and fewer injectors for the machine.

The efficiency of the water needle is directly related to the design of the internal chambers within the injector body, and the elimination of turbulence as the water passes through the injector and injector strip.

The design of the Perfojet Injector allows for a uniform and turbulence free flow of water within the injector body, thus enabling a more efficient water jet created by the flow of water through the injector strip. This improvement of water flow allows the injector to operate at lower pressure while obtaining bonding efficiencies previously obtained at higher pressures. The ability to achieve better bonding at lower pressures is directly related to the coherency of the water needle. As per previous injector designs, where 2 chambers were employed, and where holes were used linking the top and bottom chambers, the ability to produce high pressures was achieved, but the turbulence within the water flow meant that the water needle produced was not uniform, which reduces the bonding efficiency of the water needle.

The speed of the water flow and the elimination of any flow vortex within the injector body must be taken onto consideration, and it is for this reason why Rieter Perfojet have opted for a single chamber single-single slot design. This design employs a single large cavity chamber reduces the speed of the water flow which in turn reduces the potential for cavitation. The water passes from the chamber to a slot that runs the full width of the injector, thus creating a uniform and constant flow of water to the injector strip.

The potential for cavitation comes from water pressure and high flow rates encountering changes in flow direction and water speed within the body of the injector. Therefore, the ability to eliminate turbulence within the injector through the reduction of water speed, and the elimination of the second chamber through the use of a slot design for the transfer of water to the injector strip, together create a laminar flow of water to the injector strip.

The ability to create water needles that are uniform and free of the effects of cavitation enable the user to operate at lower pressures as the typical compensation for problems stemming from cavitation is to increase the operating pressure.

These advantages of operating at lower pressures with more uniform and coherent water needles will be realized in many ways, some of which are:

- Reduction in the number of injectors required
- Lower water flow rates through these injectors which may reduce the size of the filtration plant
- Lower power usage through the use of smaller motors which drive the high pressure pumps
- Increased life expectancy of the injector strips
- Lower capital investment resulting from these advantages.

The finishing of the fabric can be made with either an apron or sleeve, and a unique design by Rieter Perfojet enables the third cylinder to either use a sleeve (which can have a plain pattern [for example- 100 mesh wire], a pattern on the sleeve, or an aperture sleeve where the wire mesh helps to define the size of the aperture) or an apron which can incorporate the apron within its thread path.

The flexibility of having a third cylinder with multiple injectors which can operate with either sleeve or apron enables the user to operate with a wider range of possibilities whilst reducing the capital investment for the Spunlace machine. On lines without this capability, injectors would be required above both the third cylinder and the apron, thus requiring additional injectors as compared to the design where the third cylinder can utilize both formats of machine layout.

The Spunlace machine requires a system to feed and remove water as efficiently as possible. This auxiliary plant is designed to feed the return water coming from the filtration plant to the individual injectors at the desired pressure required by each injector. In addition, it is necessary to vacuum the water at each bonding site in order to improve the effectiveness of the oncoming stream of water from the injectors as well as to return the water to the auxiliary system for eventual filtration and return to the high-pressure pumps.

The global flow of water for the Spunlace plant is defined by: the number of injectors, the maximum operating pressure of each injector, and the width of the Spunlace machine. This global flow rate will then affect the size of the filtration plant (to be described later).

The layout of the Spunlace machine, the position of the injectors, and the pressures and flow expected for each injector, help to determine the number and format of placing the high pressure pumps in the auxiliary room. There are two schools of thought in the high pressure pump room, both of which are proper and function well, the difference being the possible cost and restrictions of one versus the other depending upon the characteristics of a given project.

The traditional format of high-pressure (HP) pump layout was that each injector was to be serviced by a single HP pump, the HP pump size being defined by the pressure and flow of that particular injector. If the injector had very high flow requirements, which is typical when aperturing, the injector could be serviced by multiple pumps. This is a very straightforward approach and works very effectively.

The second approach is to have fewer HP pumps, but ones with much higher flow signatures that can service multiple injectors. This approach works quite well, with valves serving as pressure/flow modulators for each injector.

As alluded to earlier, the effectiveness of the bonding is only as good as the ability to remove the water from the bonding site. Thus, there will be a vacuum box for each injector, located under the bonding zone, below the apron or sleeve. There, water is vacuumed away from the bonding zone and separated from the air via an air/water separator. The return water is then ready for filtration and subsequent usage by the HP pumps.

The filtration plant is a critical component to the efficiency of the Spunlace machine as the quality and consistency of water is the source of energy for bonding. Any buildup of spin finish, turbidity and bacteria within the return water supply will have a dramatic and damaging impact to the quality and efficiency of the Spunlace plant.

The filtration plant size is based upon the global flow rates generated by the HP pumps. There are many formats of filtration processes, and it is the proper sequence of filtration processes that help to create an efficient filtration plant.

The types of fiber(s) to be used is a key question when reviewing the filtration plant, as a plant designed to operate with only synthetic fibers will not need some of the filtration processes used when cotton or pulp fibers are foreseen. Thus the fiber mix will help to define the filtration process, and the pump room will define the flow size of the filtration plant

The filtration steps transit from coarse to fine particle entrapment, process by process. The complexity of the filtration plant being defined by the potential for pollution in the wastewater, for example, the filtration plant for synthetic fibers is simpler than a plant for pulp/tissue and/or cotton fibers fabrics, as there is not the same level of particle contamination in the water supply, nor the same particle dimensions to contend with.

The strengths of each filtration step protect the weakness of the following process. The efficiency of the filtration plant cannot be overlooked, as this efficiency has direct consequences to the efficiency of the entire Spunlace process, in both on line efficiency and consistency of fabric quality.

A secondary consideration is how to handle the refuse from the filtration process, and whether secondary filtration is desired for water that may be the result of backwashing sand filters. Another consideration is whether the local costs for the water supply is inexpensive enough to flush the waste- water into the drain. It must be stated that there is always water loss, and that replenishment of fresh water into the system is a positive up to a certain extent, as this helps prevent accumulation of spin finish and bacteria.

The efficient removal of particles from the water supply is the primary focus of any filtration plan, but another element must be taken into consideration, which is the elimination and control of bacteria within the water supply. The use of water and the fibers used, provide a good environment for the development of bacteria, with a food supply for the bacteria provided by the spin finish of the synthetic fibers and/or cellulosic nature of the cotton and pulp fibers that may be used in the fabric forming process. Therefore a combination of UV and chemical biocide must be employed on a controlled basis, monitored for efficiency and effectiveness on a daily basis.

As a final filtration process, regardless of the format of the filtration plant, Rieter Perfojet has designed for a police filter to be located within the body of the injector, which has a 40-micron rating. This filter prevents the possible release of spin finish clusters and film, which can build up on the inner walls of the piping connecting the high-pressure pump and the injector, from clogging the injector strip.

The life of the injector strips is directly related to the efficiency of the filtration plant and the operating pressure in which it operates. It is not hard to imagine the impact a clogged hole in the strip has on the quality of the fabrics manufactured, nor is it difficult to comprehend the force a small particle (say 25 micron) has when it impacts the injector strip at 120 bar on its way out from the injector body. Therefore, the efficiency of filtration should never be overlooked.

As you can see, the Filtration plant efficiency directly influences the effectiveness of the Spunlace plant, and that each system is directly linked to the others, as all systems must function effectively for the complete Spunlace plant to be efficient.

Drying

The use of water as the medium for transmission of bonding energy means that we must dry the fabric. As we have stated previously, there is a de-watering slot for every injector. The purpose of these slots is to pull the water from the bonding zone, which helps improve the efficiency of the water needles. Another purpose is to minimize the thermal energy required to dry the fabric.

In addition to the de-watering slots at each injector, there is also a de-watering slot (or multiple slots), which is located at the end of the finishing apron, just prior to the transfer of the fabric to the next machine, normally the drier.

The vacuum at this position is very high, in the order of 4 meters water column. Although this is a high level of suction, the fabric is not affected due to the support of the conveying apron, and the fabric at this point in the line has considerable strength. Once again, the CFM of the conveying fabric comes into play, as a more open apron will allow a greater efficiency of water removal from the fabric.

The decision of what type of apron to use on the finishing table is dependent on the types of product being made and whether there are any injectors being used on this finishing apron. There is a trade off between the efficiency of de-watering and the need to support the fabric during final bonding by the injectors located on the finishing apron. It is for this reason why its an advantage to use a third cylinder for finishing the fabric when possible as this will enable the use of an apron on the de-watering conveyor which is optimized for the cfm necessary to remove the largest amount of water possible.

The amount of water lost by the absorption (or retention) of water into the nonwoven is less than one cubic meter per hour per card. This value is determined by the general rule of thumb, which states that for every kilo of fabric produced, one kilo of water will need to be dried. This is not an exact rule of thumb, as viscose will absorb water whilst polyester is hydrophobic, and thus the actual amount of water to be evaporated will depend upon the actual fiber blends used.

The Through Air Dryer will follow the De-watering apron and will dry the fabric prior to the slitting and winding station. There are different dryer designs using omega or s-wrap formats for the fabric path through the drying zone. The drying temperature will be in large measure be defined by the fiber types, and it is the use of both temperature and air flow rate which will determine the drying rate and speed capability for a given dryer design.

There is also the possibility that latex bonding may be desired, especially when apertured fabrics are being made, and it is often desired to use a series of can dryers after the impregnation prior to the Through Air Dryer. The reason for this arrangement is resin build-up is far easier to remove from the surface of the can dryers than the cylinder wire of the dryer, and the buildup of resin on the dryer wire will affect the positive flow of air in the dryer.

As this paper hopes to outline, the creation of a Spunlace plant depends upon all the integral components working in harmony, with each individual system providing a necessary component to the global efficiency of the process. The past few years have seen a tremendous growth of Spunlace fabric applications, and in large measure this has been possible by the technologies working not only as individual elements, but by working together in harmony.