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Mechanical Design of Primary Air System, Meltblown Banks Machine TL02

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Abstract

The implementation of cost reduction projects within industries are one of the main objectives nowadays. Kimberly-Clark in Mexico has a special interest on cost reduction because most of its raw materials costs are affected directly by oil prices. The Tlaloc cost reduction project is one of these projects. The purpose of this work is the creation of a completely new system that consists of supplying hot air for the melt blowing process. This component is one of the fundamental systems for the implementation of the complete project. First, it is necessary to have an overview of nonwoven manufacturing techniques that go through the most common methods for a better understanding of this manufacturing area. After having a theoretical fundament, it is necessary to know the system requirements, end user needs and design standards in order to guarantee the correct system performance.

Keywords implementation, Cost reduction, Manufacturing, Performance

Introduction

As nonwovens processes and raw materials are extended, the definition is not standardized. International organizations had established their own definition. The International Standardization Organization (ISO) has this definition for Nonwovens: "A manufactured sheet, web or batt of directionally or randomly orientated fibers, bonded by friction, and/or cohesion and/or adhesion, excluding paper and products which are woven, knitted, tufted, stitch bonded incorporating binding yarns or filaments, or felted by wet-milling, whether or not additionally needled. The fibers may be natural or man-made origin. They may be staple or continuous filaments or be formed *in situ* (Albrecht, Fuchs, & Kittelmann, 2003). The European Disposables and Nonwovens Association (EDANA) and the International Nonwovens and Disposables Association (INDA) have proposed the following definition to the ISO: "A Nonwoven is a sheet of fibers, continuous filaments, or chopped yarns of any nature or origin, that have been formed into a web by any means, and bonded together by any means, with the exception of weaving or knitting (felts obtained by wet milling are not Nonwovens)" (Edana, 2008). Other definition proposed by the American Society for Testing Materials (ASTM D 1117-80)is: "A Nonwoven is a textile structure produced by the bonding oriented locking of fibers, or both, accomplished by mechanical, chemical, thermal or solvent means and combination thereof. The term does not include paper or fabrics that are woven, knitted or tufted" (Horrocks & Anand, 2000). All of these definitions have similarities but these ones are more open or exclude other materials that can be considered as Nonwovens. In common words and by these definitions, it is clear that Nonwovens materials involve any fabric or textile sheet (excluding paper) not made in traditional textile machinery as a loom. One of the most common Nonwovens classifications is made by its web formation method. Shows the three techniques for web formation and its posterior process steps in a simplified way (Figure 1).

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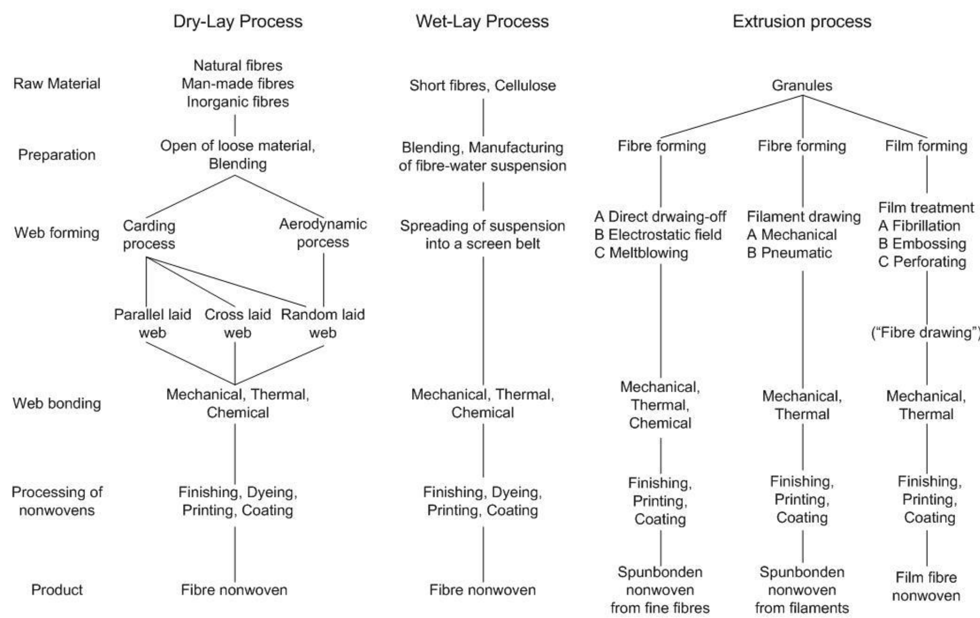

By figure 1, Nonwoven web formation processes can be divided as follows:

- Dry-Lay Process
  a. Carded
  b. Aerodynamic
- Wet-Lay Process
- Extrusion Process
  a. Cast Film
  b. Blown Film
  c. Spunlaid or Spunbond
  d. Melt blown

Extrusion Process, Spunlaid and Melt blown will be explained in detail above because they contain the fundamental of this work. Carding is a mechanical process which starts with the opening of bales of fibers which are blended and conveyed to the next stage by air transport (Figure 2). Then, they are combed into a web by a carding machine, this one is a rotating drum or series of drums covered in fine wires or teeth. The precise configuration of cards will depend on the fabric weight and fiber orientation required. The web can be parallel-laid, where most of the fibers are laid in the direction of the web travel, or they can be random-laid. Typical parallel-laid carded webs result in good tensile strength, low elongation and low tear strength in the machine direction and the reverse in the cross direction. Relative speeds and web composition can vary to produce a wide range of fabrics with different properties.

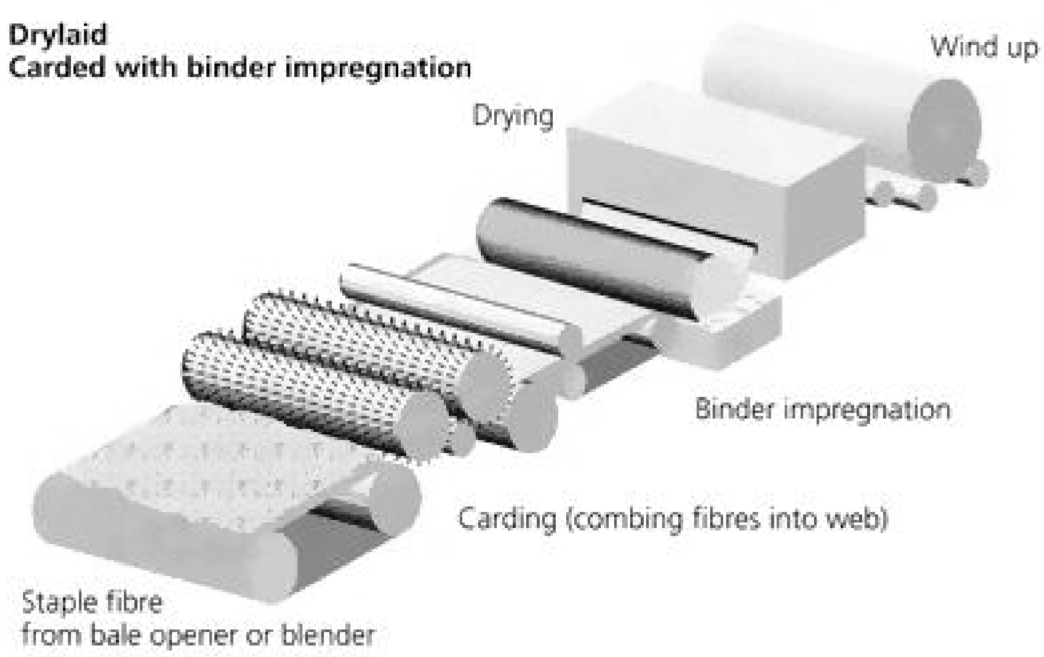

Figure 2: Drylaid Process Schematic

In Airlaying, the fibers, which can be very small, are fed into an air stream and from there to a moving belt or perforated drum, where they form a randomly oriented web (Figure 3). Compared with carded webs, Airlaid webs have a lower density, a greater softness and an absence of laminar structure. Airlaid webs offer great versatility in terms of the fibers and fiber blends that can be used.

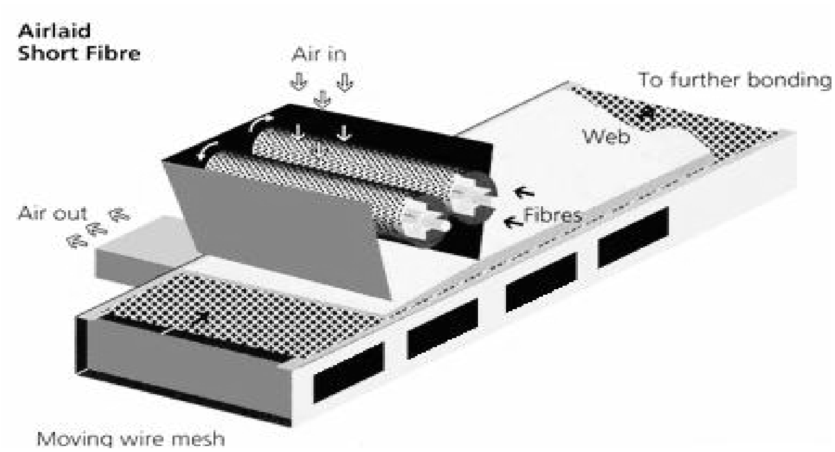

Figure 3: Airlaid Process Schematic

The principle of wetlaying is similar to paper manufacturing. The difference lies in the quantity of synthetic fibers present in a Wetlaid Nonwoven. A dilute slurry of water and fibers is deposited on a moving wire screen and drained to form a web. The web is further dewatered, consolidated, by pressing between rollers, and dried. Impregnation with binders is often included in a later stage of the process (Figure 4). The strength of the random oriented web is rather similar in all directions in the plane of the fabric. A wide range of natural, mineral, synthetic and man-made fibers of varying lengths can be used.

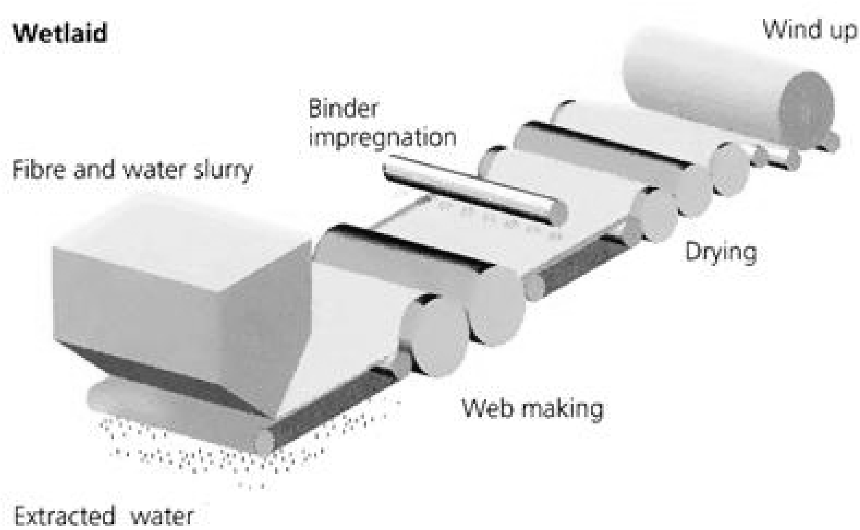

Figure 4: Wetlaid Process Schematic

Nonwovens made by Extrusion method have a common feature: the process involves converting the raw material (polymer) from solid to liquid by means of an extruder. In some cases, as Spun bond and Melt blown process, besides the Extruder, a Gear Pump is required to ensure process stability. The extruder has five distinct goals or objectives to achieve in the extrusion process that will result in a quality product if done correctly:

a. Correct polymer melt temperature, b. Uniform/constant melt temperature, c. Correct melt pressure in the die,d. Uniform/constant melt pressure in the die, e. Homogeneous, well-mixed product.

The most used in Nonwovens due to its continuous process characteristic is the screw extruder, with one or multi screws. A single screw extruder has five major equipment components (Figure 5).

a. Drive system, b. Feed system, c. Screw, barrel and heaters system, d. Head and die assembly, e. Control system.

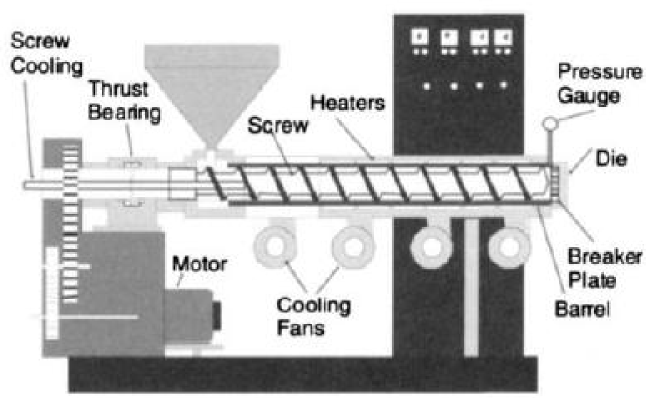

Figure 5: Single Screw Extruder

The drive system comprises the motor, gear box, bull gear and thrust bearing assembly. The feed system is the feed hoper, feed throat and screw feed section. The screw, barrel and heating system are where solid resin is conveyed forward, melted, mixed and pumped to the die. Extrudate is transported and shaped in the adapter and die, respectively. Finally, the control system controls the extruder electrical inputs and monitors the extruder feed-back. A gear pump is a positive displacement pump consisting of two gears, four bearings, internal heating, shaft seals and very precise speed control (Figure 6). Gear pumps provide consistent polymer flow, which results in more consistent product dimensions. Potential advantages associated with gear pumps include:

a. Higher product yield per pound of material from more consistent gauge control, allowing an overall reduction in the average product dimensions.

b. Increased extruder output attributed to reduced pressure flow backward into the extruder caused by die high pressure.
c. Potential increased regrind use by eliminating extruder surging from nonuniform regrinds feed.
d. Start-up time reduction as the gear pump automatically adjusts the screw aped while providing the desired constant die pressure.
e. Energy reduction as the extruder operates at lower backpressure or pressure flow. The lower pressure flow generates higher throughput at lower screw speed and lees shear heat. Lower shear heating generates lees heat that has to be removed through cooling (Giles, Wagner, & Mount, 2005).

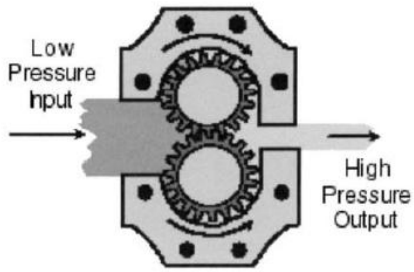

Figure 6: Gear Pump

Cast film is produced by extruding the melt from a slit die and cooling it either by contact with a chill roll or quenching in a water bath. Both processes are characterized by relatively high melt temperatures and rapid rates of film cooling (Figure 7).These ones result in films with low haze, good clarity and high gloss.

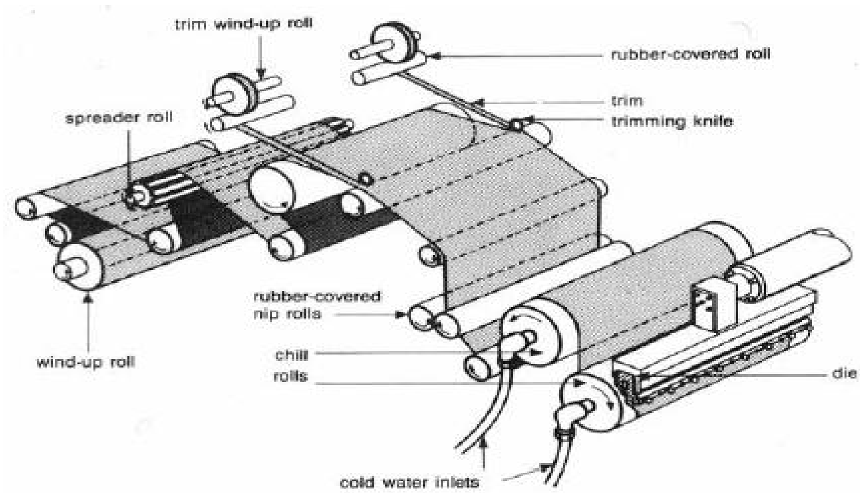

Figure 7: Cast Film Process Schematic

The blown film process involves extruding a relatively thick tube, which is expanded or blown by internal air pressure to produce a relatively thin film (Figure 8). The tube can be collapsed to form double layer lay flat film or can be slit to make one or two single-layer film webs (Maier & Calafut, 1998).

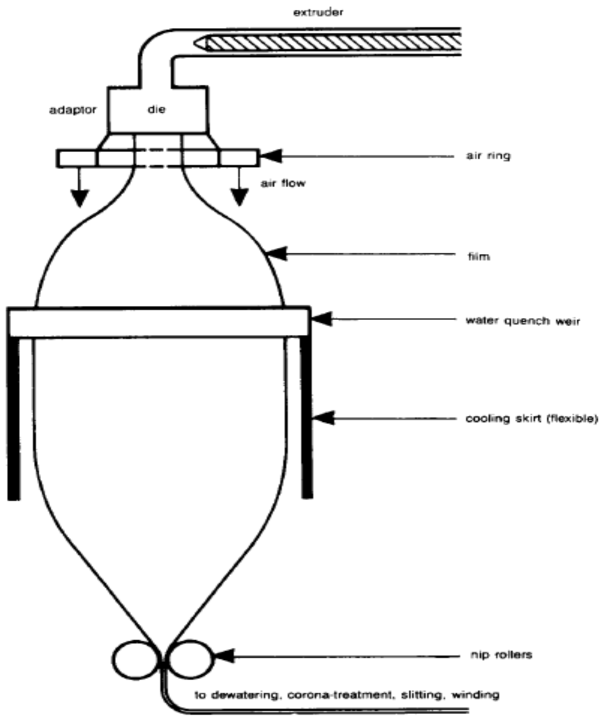

Figure 8: Blown Film Process Schematic

In this process, the polymer granules are melted and the molten polymer is extruded through spinnerets. The continuous filaments are cooled and deposited onto a conveyor to form a uniform web. Some remaining temperature can cause filaments to adhere to one another, but this cannot be regarded as the principal method of bonding. The Spun laid process (also known as Spunbond) has the advantage of giving Nonwovens greater strength, but raw material flexibility is more restricted (Figure 9).Co-extrusion of second component is used in several Spun laid processes, usually to provide extra properties or bonding capabilities.

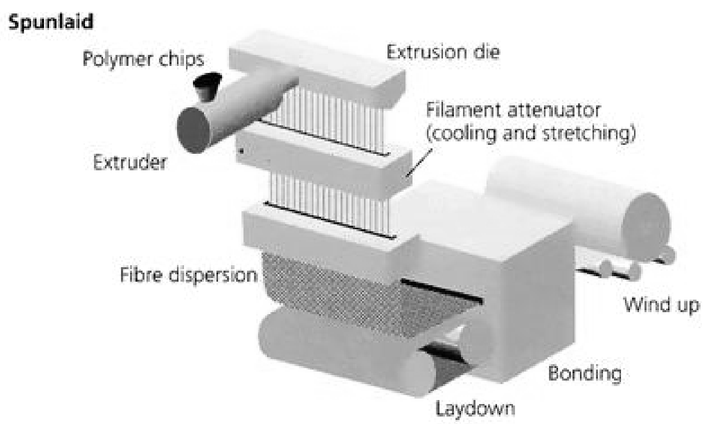

Figure 9: Spun laid Process Schematic

This process will be explained in more detail because the Primary Air System is contained within Melt Blown Process. In the melt blowing process, molten polymer (usually with a very low viscosity) is extruded from a special designed spinning die into a high temperature, high velocity blowing air stream. The emerging spun filaments are drawn down more rapidly into very fine diameters (typically several μm) by the hot air jet stream, and subsequently solidified by the turbulence of surrounding ambient air (Figure 10). This entire process from spinning to solidification takes place in milli seconds near the die exit (White & Choi, 2005).

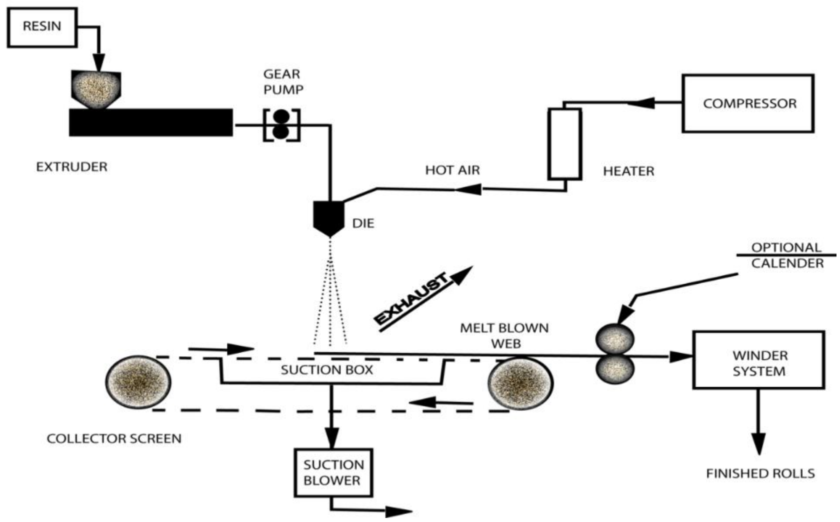

Figure 10: Melt blown Process Schematic

The die assembly is the most important element of the Melt Blown process. It has three distinct components; polymer-feed distribution, die nosepiece and air manifolds (Dahiya, Kamath, Hegde, Kotra, & Rong, 2004).

1. Feed distribution: The Feed Distribution in a melt blown die is more critical than in a film or sheeting die for two reasons. First, the melt-blown die usually has no mechanical adjustments to compensate for variations in polymer flow across the die width. Second, the process is often operated in a temperature range where thermal breakdown of polymers proceeds rapidly. The feed distribution is usually designed in such a way that the polymer distribution is less dependent on the shear properties of the polymer. This feature allows the melt blowing of widely different polymeric materials with one distribution system. The feed distribution balances both the flow and the residence time across the width of the die.

2. Die Nosepiece: From the feed distribution channel the polymer melt goes directly to the die nosepiece. The web uniformity hinges largely on the design and fabrication of the nosepiece. Therefore, the die nosepiece in the melt blowing process requires very tight tolerances, which have made their fabrication very costly. The die nosepiece is a wide, hollow, and tapered piece of metal having several hundred orifices or holes across the width (Figure 11). The polymer melt is extruded from these holes to form filament strands, which are subsequently attenuated by hot air to form fine fibers. In a die's nosepiece, smaller orifices are usually employed compared to those generally used in either fiber spinning or Spun bond processes.

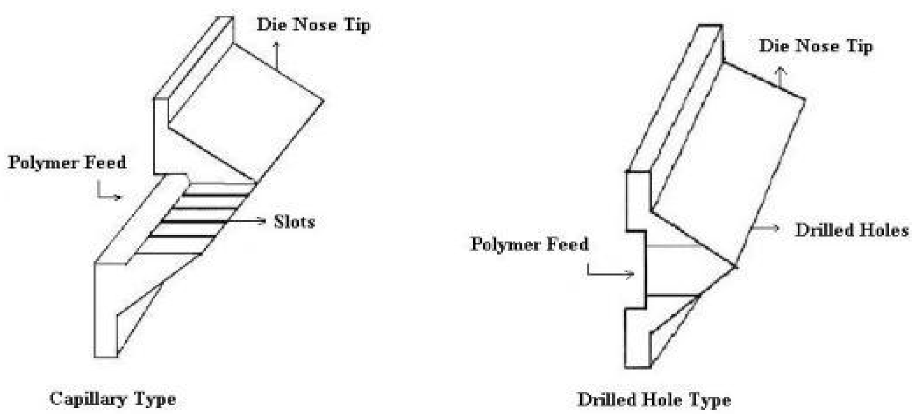

Figure 11: Melt blown Die Nose Tip

3. Air Manifolds: The air manifolds supply the high velocity hot air (also called as primary air) through the slots on the top and bottom sides of the die nosepiece. (Figure 12). The high velocity air is generated using an air compressor. The compressed air is passed through a heat exchange unit such as an electrical or gas heated furnace, to heat the air to desired processing temperatures. Typical air temperatures range from 230°C to 360°C at velocities of 0.5 to 0.8 the speed of sound.

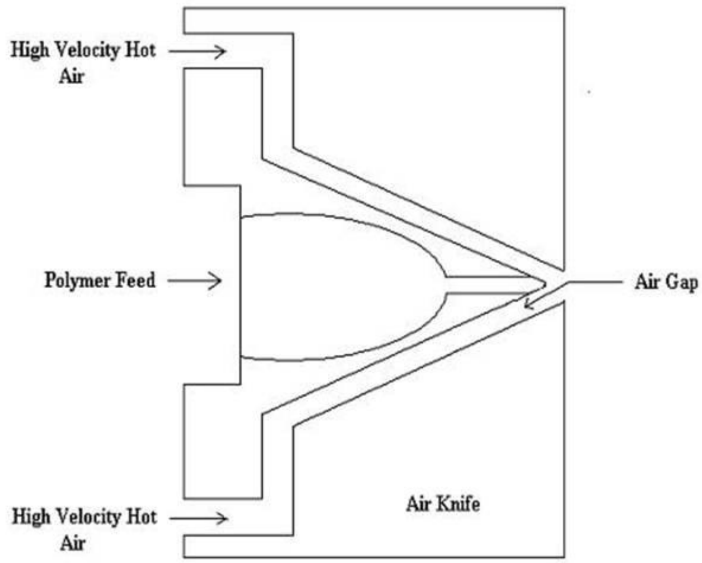

Figure 12: Meltblown die Section

This Melt blown process review shows how Primary Air interacts within process and the importance of this system to assure a correct polymer blowing.

Methodology

The project involved the installation of four Aerzen VML60 new compressors and two air heaters as principal new equipment. When the machine was designed, it was done thinking in the addition of one third bank of Spun bond material located between Bank1 and Bank 3. This planned bank would not need any new compressor because the existing equipment is able to supply the amount of compressed air for this kind of process. But as Melt blown process needs larger amounts of air at higher pressure than Spun bond process, the existing compressors will not work for this application. This is the reason for the need of four new compressors Aerzen VML60 (Figure 13), two for Bank 2A and two for Bank 2B.

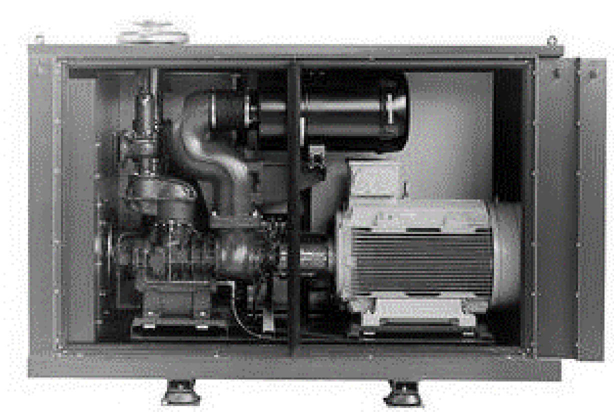

Figure 13: Aerzen VML60 Compressor

Each compressor needed an area of twelve square meters for its correct operation. In total, the four compressors needed an area of forty eight square meters. A new compressor area was needed, due to the current facility did not have enough space to accommodate them.

The main objective of this paper is to determine the best location for this new equipment; a multidisciplinary group was conformed including representatives from Projects, Production and Maintenance departments. The future compressor area was defined from this meeting, located next to an existing unloading railcars room (Figure 14).

Figure 14: New Compressor Area

The construction of this new compressors area was responsibility of the civil area of the Projects Department. The design of this area was done considering the compressors weight and needed working area. Regarding air heaters location, it was defined taking the process stability as main factor. The Melt blown process is very sensitive to temperature changes. It was decided that the best location for air heaters should be as close as possible to the application to avoid temperature fluctuation, being the third mezzanine the closest area to the application point (Figure 15), in this case die body.

Figure 15: Air Heaters Area

The reliability is one of the most desired characteristics in a continuous process. The instrumentation equipment has as main objective the control and stability of processes. As its name describes, a Process & Instrumentation Diagram shows the components of a process and its control instruments. These instruments can be on/off valves, automatic or manual valves, proportional valves, pressure, temperature or flow sensors/transmitters etc. For the Primary Air System and after a meeting within Mechanical and Electrical Areas the P& ID was furnished taking as basis the following process requirements:

a. The system should be able to control the air pressure automatically by mean of a given set point.
b. The system should be able to control the air temperature automatically by mean of a given set point

c. The system should provide mechanical isolation for equipment maintenance
d. The system should be able to feed 2A Bank with 2B Bank compressors and vice versa
e. The system should be able to control air flow automatically
f. The system should have an auxiliary inlet in case of compressors failure

This P&ID shows the entire system in a simplified way including the instrumentation needed such as mechanical valves (VM), automatic valves (VA), and pressure and temperature transmitters (Figure 17). A brief description of this diagram is: Each die body is feed by two compressors named 2A1 and 2A2 for thedie 2A, and 2B1 and 2B2 for die 2B respectively. Each compressor has a pressure transmitter at its outlet for pressure control. The air flow is controlled in each compressor outlet by a proportional valve tagged as VAC. The isolation mechanical valve is tagged as VMC and it isolates the compressor from de entire pressurized system for its maintenance. The by-pass section is represented by VMB-2A, VMB-2B mechanical valves and VBA-BP, VPA-2A and VPA-2Bautomatic on/off valves. After the by-pass section, there is an electric heater with temperature transmitters at its inlet and outlet and a pressure transmitter at its outlet. For the auxiliary compressor connection, an auxiliary inlet is controlled by a valve VMA-IN. In a normal operation, all valves are opened excluding the valve VBA-BP. If one bank is stopped (2A) and the other bank presents a failure in its compressors (2B) theby-pass section should close valve VPA-2A and open valve VBA-BP. This array diverts the airflow from compressors 2B to the bank 2A. This operation can be done vice versa. With the definition of the system instrumentation, the piping design was able to get started.

Once the location of new equipment and instrumentation requirements were defined, the rest of the system could be designed. This design should consider the process conditions to ensure the correct selection of auxiliary equipment (instrumentation) and installation materials. These conditions were:

- Fluid high temperature; air coming out from compressors is at.
- Heat radiation; piping reaches high temperatures representing a burn hazard for operators 300° Fahrenheit , system should be able to handle these temperatures and heat loose is undesirable. Air should be heated up to 500° Fahrenheit and heat loose increases energy consumption.
- Rust proof system. Primary Air is applied directly to the product that is used on hygienic products; no rust on piping is permitted.

The design of pipe routing was done under the Kimberly-Clark Corporation Construction Specification for Aboveground Piping number 16KT4520-059-001. This specification applies for valves, piping materials, piping insulation and piping supports. As it was shown on the P&ID, an array of mechanical and automatic valves was developed for the process control. Kimberly-Clark Corporation has defined the valves for this application as follows: 3" thru 16", Class 150, high performance butterfly valve, tapped lugged flange, cast type 316 stainless steel body and disc, tight shut-off, double dead end service, lugged-wafer type with tapped holes to accommodate through-stud or cap screw bolting, non-lubricated bearings, reinforced Teflon seat and seals, faced and drilled to Class 150 ASME/ANSI B15.5, face to face dimension shall be in accordance with MSS SP-68. The materials for body and disc should be Type 316 stainless steel conforming to ASTM A351 or ASTM A744 Grade CF8M. The materials for the shaft should be Type 316 stainless steel or 17-4PH stainless steel (Kimberly-Clark Corporation, 2007). These specifications were given to valve suppliers having a positive response from one of the current equipment, Bray Vales of Mexico. They proposed their 40 Series Valves with different optional accessories to accomplish P&ID and construction specification requirements.

A mechanical butterfly valve isolates the compressor with an enclosed gear operator. A pneumatic actuator proportional butterfly valve for controlling the air flow, having a positioner module with valve position electronic feedback. A pneumatic actuator butterfly valve for the by-pass opening/closing. The presence of rust in the Primary Air System is not permitted. This statement is the guide for pipe material selection. All the carbon steel based material pipes were discarded for this purpose. Kimberly-Clark Corporation states that all the used piping for this application will be welded Type 304Lstainless steel conforming to ASTM A312, Grade TP 304L. Eight inches nominal diameter pipe wall thickness will be the Schedule 10S (Kimberly-Clark Corporation, 2010). The entire pipe fitting was specified under the same schedule and material description. In order to avoid heat transfer to the ambient or facilities and none desired safety and energy cost implications, it was needed to insulate all the pipe run, and all the supporting accessories should be constructed with low heat transfer rates. Kimberly-Clark Corporation regulated the insulation specification: the mineral fiber with a density of eight pounds per cubic foot and two inches thickness protected with a jacketing fabricated from a flat aluminum sheet 0.024 inch thick.

Pipe supports should provide thermal insulation and it was specified to be fabricated with a heavy density calcium silicate segment with equal thickness as pipe insulation(Kimberly-Clark Corporation, 2011). Piping Technologies, a company from Houston Texas and that had provided these supports in last projects, supplied the supports used on this project(Figure 16).

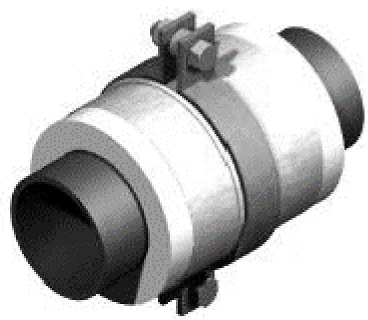

Figure 16: Insulated Pipe Support Schematic

A site survey was conducted to avoid these problems. The survey consisted in check the electrical and mechanical drawings contained in electronic file against what is installed physically. This file includes building, electrical and mechanical drawings showing how the facilities were build and the existing operating systems. These drawings were taken as a reference to perform site survey. It was done on site by mean of a measuring tape and electronically by mean of AutoCAD software (Figure 17).

Figure 17: Existing Pipe Lines and Wire Trays

The pipe routing design was planned to be as straight as possible. This was done thinking in eliminate unnecessary money spending of material such as straight pipe sections or elbows, making installation simplest and reducing pressure drop caused by longer pipe routing. As can be appreciated in the general pipe arrangement, there was a straight pipe section of 117 feet approximately between 0C and 1A building axis. This section exceeds one hundred feet with the potential of piping failure due to pipe thermal expansion. This pipe expansion amount was calculated taking the Thermal Expansion Coefficient of stainless steel at 300° F as 2.61 per 100 feet (American BOA Inc., 2010). The calculation done with these values is: 1.17 x 2.61 in = 3.0537 in. The obtained pipe thermal expansion length was 3.05in. This expansion was absorbed by an expansion joint calculated by a local vendor. The vendor proposed a double spiral with a rigid intermediate section (Figure 18). This stainless steel expansion joints have a 3.50in axial compression capability.

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Figure 18: Expansion Joint

After the piping expansion problem was resolved, the system was subdivided in three areas: compressors area, railcar area and machine area. This subdivision made the design easier to handle. Each drawing section has a Bill of Materials describing materials, equipment, its quantities and dependent or reference drawings. These drawings were used to install entire system.

Results

After the design was complete and materials delivered, system installation could be started. The installation was performed by a contractor. This contractor had wide experience in machinery and auxiliary industrial systems. The contractor followed the installation drawings and the KCM installation leader resolved any doubt to avoid misunderstandings. The installation began from de railcar area, while compressor area was being constructed (Figure 19).

Figure 19: Pipe Installation at Railcar Area

After the installation of piping at railcar area, the contractor started installation of system at machine area (Figure 20). This area was where the probability of interferences could appear, but with the conducted survey and double check by the contractor, the planed pipe routing could be rigged up without any interference with any existing pipe line, duct or electrical cable tray.

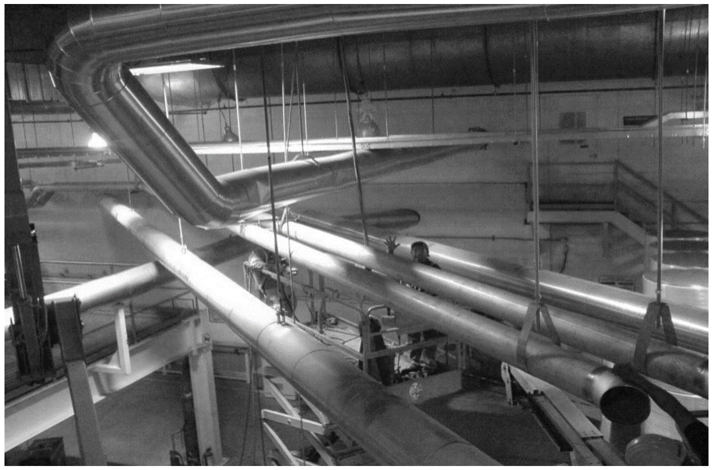

Figure 20: Pipe Installation at Machine Area

Once new area construction is finished, the compressors were received, unloaded and placed on its final position. After the compressors were in position, they were connected to the already installed lines (Figure 21).

Figure 21: Compressors Connection

KCM has safety procedures regarding working at elevated heights, soldering, grinding or any kind of hot work. During the installation of Primary Air System this kind of works had to be done. Most of the installation was necessary to work at heights above 1.80 meters. This height is considered as the limit for working without any personal protection equipment. When is necessary to work above this height, an Elevated Height Work Permit (Figure 22).

Figure 22: Working at Elevated Height

This permit is a check list of work executant physical and mental condition, equipment to be used (ladders, hydraulic platforms, scaffolds), personal protection equipment condition (safety glasses, gloves, hard hat, harness) and area safety conditions. This permit has to be signed by the contractor supervisor; the preventer who is in charge of keep safe conditions during the activity and the KCM operative responsible who is leading the installation (Figure 23).

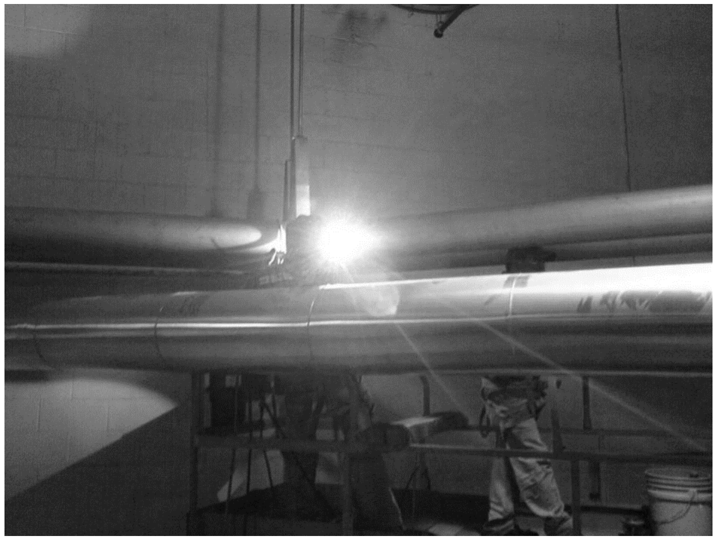

Figure 23: Hot work at Elevated Height

The Hot Work Permit is a check list (as the Elevated Work Permit) of executant and surrounding area conditions to be maintained during the execution of a hot work. A hot work involves the generation of heat, an open flame or sparks. This permit emphasizes the attention to be paid to the fire risk and to the fire protection equipment. These permits helped to minimize the possibility of an accident or incident due to high risk activities performed during project installation. Thanks to contractor safety commitment and safety procedures there was not any accident or incident during project execution,

Conclusion

The Nonwoven materials area is parts of the manufacturing technics with a huge develop technology history, being a fundamental part of this work the study of the principles of nonwoven making and its different methods. The procurement and execution of this project permitted to realize the efficiency of having a good planning, the effectiveness of multidisciplinary working groups and the importance of safety procedures and statements during high risk works. Besides the functionality, this project demanded the union between an efficient system design and the appearance of the equipment in relation with its environment. This good appearance was one of the main goals of compressors area (Figure 24).

Figure 24: Finished Compressors Area

One of the main concerns of this project was the closest installation of air heaters. This could be accomplished with the proposed design without any important interference or misalignment, being possible the correct heaters installation (Figure 25).


Figure 25: Installation of Air Heaters

Summarizing, the proposed design was implanted successfully without any major modification or mistake. The system could not be tested due to the integration with complete machine was planned to be performed later.

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