

Melt blown technology innovations

E. KEVIN McNALLY

FOCUSING ON THE FUNDAMENTAL concerns of those operating existing melt blown equipment, J and M Laboratories concentrated on developing a novel method of spinning melt blown fibers into uniform webs while simultaneously targeting a number of desirable production/process criteria. Examples of these criteria are as follows:

- Raw material usage
- Balanced resin distribution
- Resin throughput on a per-hole basis
- Balanced air distribution
- Reduced energy consumption
- User-friendly operations
- Ease of maintenance.

In addition, using melt blown in laminating substrates is the focus of more recent developments in adhesive melt blown technology at J and M.

System designs have been based on finished product production-level requirements and polymer processing demands. These designs are currently available in the following configurations:

- Single-beam
- Multibeam
- Single-beam composites/laminates using adhesive melt blown technology (SAMAS)
- Multibeam composites/laminates using adhesive melt blown technology.

POLYMER MELT BLOWN TECHNOLOGY

The process of spinning polymer fibers via combined melt extrusion and heated impinging air streams and the controlled laydown of those fibers into flat sheet products, originally developed by Exxon Corp., has seen continued improvement by J and M Laboratories. This process, called polymer melt blown technology (PMB), is currently being made available to our industry for the purpose of forming continuous flat-web nonwoven products formed from raw polymer products such as polypropylenes, polyesters, polyethylenes, and polyamides.

This single-step method of raw resin to fibrous web formation begins with a heated screw extrusion device. The resin is sheared and step melted, and pressure is delivered via a heated flexible transfer hose to the applicator assembly. At the applicator inlet, the melt is meter distributed across the width of the applicator spray pattern via a positive displacement pump and a three-dimensionally tapered distribution cavity called a coat hanger.

Delivered to a spin pack assembly, the spinneret consists of a single row of orifices, typically 0.16 in. in diameter and with a density of 30 orifices/in., at a rate relative to the required fiber diameter. At the point of melt extrusion, heated air impinging on the full stream width draws and attenuates the fibers. The fibers will elongate and entangle and are transferred to the web-forming unit. The forming section device consists of a rotating forming belt, a vacuum box, and a source. The forming unit serves

MELT BLOWN

ABSTRACT

In recent years, the apparatuses being used for melt blown polymers have undergone tremendous technological growth. Driven by the desire to produce high-quality media at more cost-effective rates, equipment suppliers have sought continually improved process control and machining technologies. The resulting equipment has provided the end user with the following enhanced capabilities: a diversified range of processable polymers, an increase in production capacities, minimal fiber diameter spinning, a narrow fiber diameter distribution, and a cross-web basis weight uniformity within $\pm 2.5\%$; each of these capabilities has been provided at greatly reduced energy consumption rates. Equally important have been the inherent reduced maintenance requirements, significant increases in machine uptime, overall operational ease, and long-term equipment reliability, which accompany designs of this advanced magnitude.

Application:

Improvements in polymer melt blown technology assist in forming continuous flat-web nonwoven products from various raw polymer products. Adhesive melt blown technology permits bonding and laminating woven and nonwoven products.

to aid in the uniform laydown of the fibers as well as to transfer the flat web to a collection device.

Raw materials usage

In attempting to permit a wide variance of product applications, design teams have directed equipment development to allow multiple polymer usage. Polypropylenes, polyethylenes, and polyesters with various melt flows are all considered and experimented with so that the equipment can remain as polymer-independent as possible. Raw material testing is

accomplished via a desktop melt blowing unit that has been specifically designed to allow for quick melt, fiberization, and flush of our polymer candidates. Prior to the design of any melt blown equipment, client polymers are tested via this unit, and the results are analyzed. This predevelopment experimental stage aids in the correct design and manufacturing of processing equipment and precludes the opportunity for producing equipment that is incapable of fulfilling application-specific processing requirements.

Balanced resin distribution

Equal residence time with uniform heat distribution is important in maintaining a degradation-free, constant-viscosity, and application-rate resin for processing. The use of flow analysis software prior to machining the melt distribution and balancing chambers has allowed evaluation and optimization of these designs, thereby providing a smoother and more uniform melt delivery at the head's fiberization point. Previous to our modeling, a 284% difference in polymer residence time was noted and considered acceptable in an unoptimized coat hanger, which is typical of current designs. (The x axis is the distance from the center of the die, and the y axis is a time reference.) In the optimized version, we achieved and demonstrated only a 13% difference in the residence time, clearly a significant increase in the performance of the distribution chamber. In addition to uniform flow control, the strategic placement of cartridge heaters, with reduced-width control zones, has increased the uniformity of the cross-die temperature profile to within $\pm 1^\circ\text{F}$.

Resin throughput on a per-hole basis

When discussing throughput on a per-hole basis, it is important to clarify the polymer used and the fiber diameter achieved. Current capacities allow the production of high-melt-flow-rate (high-MFR) (800+) polypropylene at 1–2- μm fibers of 0.8–1.2 g/hole/min.

As fiber diameter increases, so (somewhat linearly) does the production throughput. As we approach the 10–15- μm diameters, throughputs can be on the order of 2–3 g/hole/min. These throughputs have been achieved with the addition of unique die tip geometry and the previously mentioned balanced resin and air distribution capabilities. In addition, recent innovations regarding the use of air-quenching units, applied at the die tip extrusion point, have increased throughput per fiber diameter by approximately 25%. In the past, production levels and consistencies relied on the operator's expertise to tune the machine. The use of the PLC system, detailed later, precludes this requirement.

Balanced air distribution

Air volume and air pressure requirements were of great concern during the development of the melt blown process. Due to high resin throughput capacities, airflow requirements are typically 15–20 SCFM per inch of spray pattern. In an attempt to reduce these volumes through better control, air distribution and the uniformity of the distributed air had to be enhanced. The use of flow analysis software for visualizing air distribution, baffling, and balancing allowed the design team to accommodate both of these requirements. Vector representation of volume (arrowhead size), velocity (tail length), and direction provide design direction. Prior to machining the air expansion and pressurization chambers, the distribution manifolds and balancing plenums were mathematically modeled. The resulting cavities experienced increased performance, allowing a greater equalization of pressure and airflow. This, in turn, provided a smoother, more uniform air delivery, typically $\pm 5\%$ at the head's fiberization point.

Reduced energy consumption

As in standard melt blowing, air source and heating requirements are the main concerns when analyzing

the energy consumption of a given line. These requirements involved the addition of a compressed air source: 86 psi at approximately 20 SCFM per inch of die face and an electric or gas energy source to heat the air. The recent introduction of 15-psi low-pressure blower systems and energy-efficient electric heating sources (typically 18 kW per 100 SCFM air volume) have reduced the consumption factor by as much as 50%. Typical line performance is 2 kW·h/kg of product produced. This is down from the currently available 4-kW·h/kg technologies currently on the market.

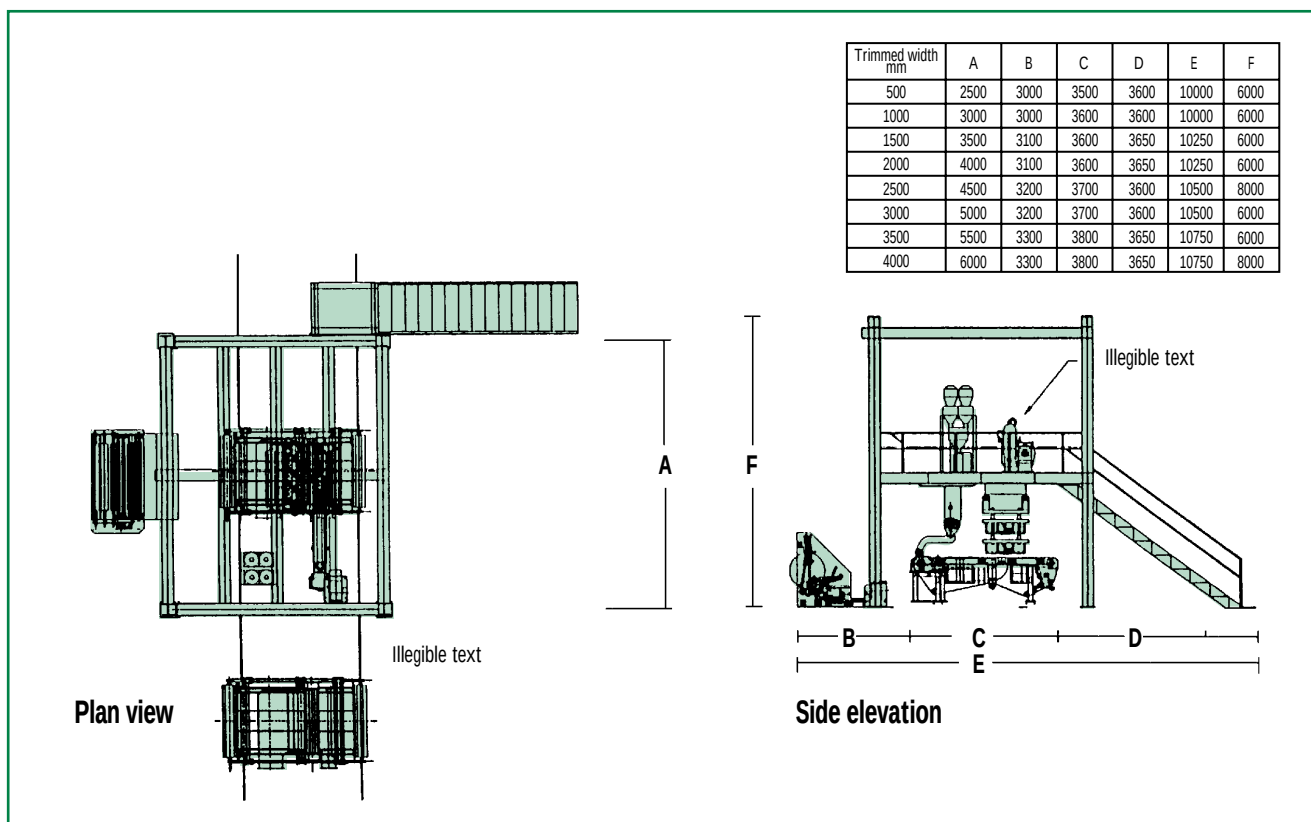
User-friendly operations

In attempting to allow maximum variance in production processes with minimal operator interface, PLCs (programmable logic controllers) were used as the control feature. During the process development phase, manual controls were used to permit ease in process tuning; however, once the variables of throughput, melt and air temperature, and air volume were determined, applications can be controlled more effectively and consistently with a PLC.

Application-specific software consisting of product-level process conditions is included in the system package. Among the design features are recipe-driven applications, real-time and historic temperature/pressure profiles, log management, on-screen troubleshooting diagnostics and system documentation, remote access via modem, and process control password protection. In the past, production relied on the expertise of the operator to make consistent product. In a 24-h, three-shift environment, three independent operators tended to produce three distinct products. The PLC system, with its one-step process, does away with this potential.

Ease of maintenance and cleaning

For ease of on-line troubleshooting, zone heating elements and sensors use quick disconnects for fast



1. Single melt blown beam

changeover. When used as recommended, the quick-change spin pack, consisting of the transfer plate, die tip, and air plates, aids in reducing downtime during die tip cleaning cycles. (An interesting note is that, when two packs are used, due to the low coefficient of expansion of the stainless steel, the second pack can be mounted cold, allowing a nearly immediate changeover.) The PLC software also assists by alarming operators for scheduled routine maintenance, and should trouble occur, it provides step-by-step troubleshooting procedures.

ADHESIVE MELT BLOWN TECHNOLOGY

The process of spinning adhesive fibers by introducing heated impinging air streams and the controlled lay-down of those fibers has been developed by J and M Laboratories. This process, called adhesive melt blown technology (AMB), is currently being made available to our industry for the purpose of bonding and laminating woven and nonwoven products. This single-step method of composite formation begins with a heated melt tank, where hot-melt ma-

terial is step melted and metered via a positive displacement gear pump. Delivered through a heated flexible transfer hose to the spray applicator assembly, the melt is then pressure distributed across the width of the applicator spray pattern. The spinneret consists of a series of orifices, typically 0.20 in. in diameter with a density of 10 orifices/in. At the point of melt extrusion, heated air impinging on the full stream width draws and attenuates the fibers. The fibers will elongate and break and are transferred to the collection substrate.

In most cases, the proper lamination technique must be determined on an application-specific basis. However, it has been found through continuing application analysis, that adhesive melt blown is the most effective method of substrate bonding. These findings have been based on the following criteria:

- Fiber size
- Fiber distribution
- Edge control
- High-speed intermittent operations
- Air consumption
- Melt consumption
- Melt add-on limitations

- Application range
- Product aesthetics
- Minimal operator interface
- Maintenance requirements
- Customer comments and satisfaction.

Fiber size

Fiber size can be easily controlled, from 20 to 200 μm , by changing the melt-to-air ratio. This can be accomplished by either increasing/decreasing the melt displacement or increasing/decreasing the air inlet volume or pressure. Of course, optimized fiber size is directly related to the adhesive used and the substrates being bonded. As previously mentioned, increased fiber diameter provides additional surface area to aid in the bond; however, excessive surface area can cause unacceptable fiber heat retention and the resulting substrate deformation. Having this inherent versatility is what makes the method of adhesive melt blowing so favorable.

Fiber distribution

If 100% coverage with consistent fiber size and distribution is key to your product's successful lamination, adhesive melt blown is the clear

method of choice. Product coverage can be consistently maintained, regardless of line speed, from 5 to 100%. This is a simple scientific function of the drawdown of the hot-melt filament, the hole density per given spinneret length, and the chosen adhesive. Unlike swirl applicators, melt blowing dies are not overly susceptible to viscosity or temperature changes, since the filament is drawn in a straight line toward the substrate. Swirl nozzles form an expanding helix that varies in size and frequency depending on process parameters, machine line speed, and die-to-collector distances.

Edge control

AMB dies will provide $\pm 1/16$ in. edge definition in the cross direction (CD) typically at a die-to-collector distance of 0.5–1.5 in. and $\pm 1/8$ in. edge definition at 1.5–3 in. Controlling this CD definition has been accomplished by extending the air-balancing plenum and air gap beyond that of the actual spray pattern. This patented design provides a twofold enhancement. The extended air curtain aids in eliminating the tendency for the fiberized melt to flair along the pattern edges. It also provides protection of the edge filaments from external air currents or disturbances.

High-speed intermittent operations

AMB dies have recently been improved regarding high-speed leading and trailing machine-direction (MD) edge definition. This control can be greatly influenced by the line speed and adhesive being used. Controlling this MD definition has been accomplished by several key design features that work together. Independently beneficial, together they can practically eliminate overspray regardless of the process attributes.

Regarding the leading edge, emphasis has been placed on reducing the adhesive surge that normally accompanies the valve opening due to die internal pressure buildup. The incorporation of internal die relief valves

configured to bypass at 15–20 psi above operating pressures with recirculation to the melt tank has eliminated this potential.

Regarding the trailing edge, a reduction in the depth (volume) of the die melt distribution cavity beyond the stem shutoff has reduced the amount of adhesive expelled at shutoff. In addition, capillary taper, previously from 1.0 mm to approximately 0.5 mm has been reduced to 0.75 mm to 0.5 mm, greatly reducing resident adhesive prior to expulsion. These items, combined with replacement of the traditional pointed shutoff stems with ball-nosed stems (providing faster displacement), has significantly improved the cleanliness of the shutoff. This, in turn, provides a sharper trailing edge definition.

Air consumption

One of the fundamental arguments against adhesive melt blowing has been air consumption and the continued heating of that high-volume air. Due to improved designs of the die's internal air distribution and balancing channels and the resulting die's exit-to-substrate fiber entrainment, the current process requires very low volumes of airflow and pressure to achieve an optimal fiber attenuation. Today's technology provides production-ready dies requiring process air of less than 1 SCFM per inch of die spray pattern at pressures of 10–20 psi. This precise distribution and optimization of airflow has allowed low-volume, low-pressure air to produce the required fiber diameters in the range of 20–200 μm .

Melt consumption

Discontinuous fiberization, providing millions of contact points, produces a high degree of bond strength. This total use of adhesive for the purpose of bonding only aids in reducing overall glue usage for equal peel strength when compared to slot-style applicators. The same can be said of swirl applicators. In all instances where these applicators are wider than one nozzle

application, any overlap in adhesive laydown between spray zones could be considered as wasted glue. Melt blowing can inherently eliminate the overlapping of the fibers as dictated by the process control of the application, thereby successfully controlling the level of adhesive usage vs. peel strength.

Melt add-on limitations

Slot-coating devices are typically limited to a minimum of 14 g/m² add-on weight due to internal gun designs and the associated adhesive flow characteristics. Furthermore, swirl assemblies cannot produce the continuous swirl filament at levels below 10 g/nozzle/min. However, adhesive melt blowing can effectively fiberize at levels of 0.08 g/hole/min, a significant advantage considering its abilities of enhanced bond strength and the reduced raw materials that it implies.

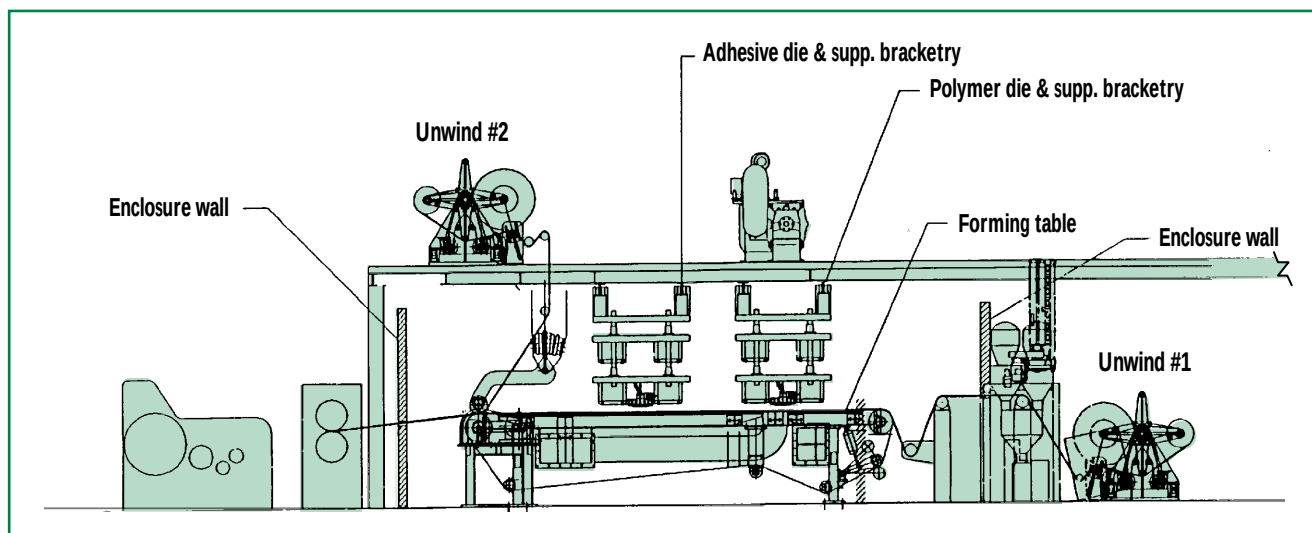
Application range

Virtually all lamination requirements can be accomplished uniformly using melt blown technology. Unlike swirl and coating methods, the consistency of melt blowing laydown is not limited to maximum or minimum add-on weights, substrate widths, or line speeds. Many industries have taken advantage of the new hot-melt blowing technology. Systems are in use for the following applications:

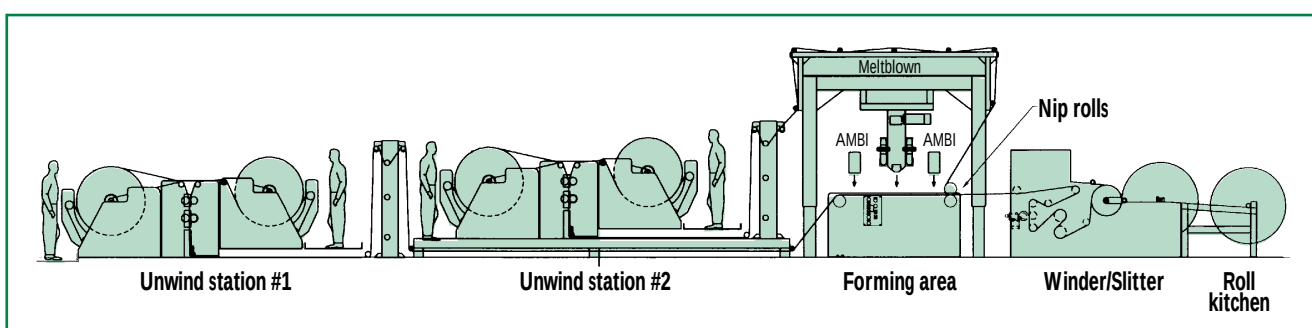
- Baby diaper construction and elastics
- Feminine napkin core stabilization and adhesive strip
- Industrial filter material lamination
- Filter mask lamination
- Surgical drape/gown lamination
- Wide-web paper, film, textiles, and nonwovens laminations
- Perishable products packaging.

Product aesthetics

Due to the randomness of the melt blowing fiberization technique, visual properties of the laydown are excellent. Unlike swirl nozzles, 100% pattern coverage is achievable and to-



2. Multibeam configuration



3. Composite/laminate melt blown line

tally controllable. In some aspects of the nonwovens industry, where the hot-melt filaments provide a functioning product layer, only melt blowing can provide the correct filament structure. Light films and foils are not distorted by large swirls but are gently joined by millions of invisible bond points. As previously mentioned, consistent, controlled laydown and reduced levels of adhesive for bonding aid in maintaining the original hand of the two substrates as well as limiting the effect that the adhesive can have on product breathability and filtration. (The opposite can also be stated: Adhesive melt blown can be used to aid in the hand, providing increased integrity, and increase the filtration efficiency i.e., act as an additional filtering media or even a barrier layer, of the composite product.)

Minimal operator interface

The reduction of operator involvement has been a prime concern. Current-generation grid-melt systems, featuring touch-screen graphics, network interfacing, and modem accessi-

bility, have permitted remote system analysis, startup, and troubleshooting. Reduced-cavity die distribution channels, recessed air plates, and hydraulic discharge features have reduced cleanup so that it can be done during standard maintenance downtime. Line speed tach-following adhesive melt and airflow ramping functions have allowed the splice and run-speed mode to be preset and provide the capability of constant add-on weight regardless of line speed.

Maintenance requirements

In the industry's early attempts to develop production-capable adhesive melt blown lines, maintenance (for die cleanliness, orifice clogging, and melt degradation) proved to be a hindrance to process acceptability. Recent design modifications have provided the solutions to these concerns.

Melt degradation has been virtually eliminated by progressive melt temperatures, the slow elevation of melt temperature as the melt moves toward the applicator, continual recirculation of melt (which reduces the opportuni-

ty of extended application temperature residence times), and the continued advancements in adhesive properties of glue thermal stability.

Internally caused orifice clogging due to adhesive degradation, charring, or foreign contaminants has been eliminated by introducing filtration systems and release coatings (for reduced side wall friction and to limit buildup) that are strategically placed prior to both the transfer hose and die balancing chamber. In addition, AMB dies have relatively large orifices, typically 0.020–0.040-in.-diam. (compared to 0.016–0.018-in.-diam. of swirl applicators), further reducing the opportunity for hole clogging. Environmental or external causes of orifice and air gap clogging due to adhesive runoff or fluff in the air have been virtually eliminated by both the concept of recessed air gaps and air plates set back from the die tip, reducing the opportunity for melt to flow up into the air passage and clog the chamber and hydraulic discharge feature, and independent firing of the solenoids to force

KEYWORDS

Man made fibers, melt blowing, melt blown fibers, product development, synthetic fibers, technology.

purge orifice blockage. With AMB technology, up to 20% of the orifices can be disabled with little or no effect on pattern coverage. Compare this to a single swirl orifice clogging, which results in a full swirl pattern failure.

EQUIPMENT SPECIFICS

Available in several configurations, the technology is based on the following generalities that are constant with standard melt blown equipment.

The polymer is introduced into an extrusion device, where it is heated, sheared, and transferred via pressure control to the application head manifold; here, it is balanced across the width of the spray pattern. The application head consists of the distribution manifold, the transfer plate, the die tip, and a set of fixed-gap air plates. The die tip features a single-row, multiorifice spray arrangement with holes set typically at 30 orifices/in., and each orifice is 0.015 in. in diameter. As the resin is metered or pressure forced out these orifices, heated air impinges on the stream, causing the melt to attenuate. By manipulating the die tip geometry and the variance of the air gap, a relatively high level of attenuation is achievable with low levels of air volume, typically 15–20 SCFM per inch of spray pattern. This fiberized material is then collected on a conveyor, where it is formed into flat web and wound into rolled goods or is transferred downstream for further processing. The following configurations are available as complete systems or key components in 0.1–4.0 m widths.

Single-beam configuration

The single-beam design permits manufacture of melt blown web as a stand-alone product in rolled goods form or as suitable for downstream convert-

ing. A single melt blown beam (see Fig. 1), extrusion device, air source and heating unit, and collection equipment are needed to produce flat-web melt blown media. In the case of wide-web production, it becomes more difficult to coat hanger-balance the pressurized resins. To alleviate this condition, this design can be enhanced by adding zoned metering pumps mounted on the die distribution manifold. In addition, by allowing airflow to remain constant and by independently controlling the displacement rate of each pump, multifiber diameter zones can be created in the cross-machine direction of the web. This style of flat sheet can then be converted downstream to produce density gradient-style filter media. The single-beam configuration can also be designed to permit direct mounting into an existing melt blown line for increased production levels, higher filtration efficiencies, or enhancement of lower-quality products that are already being produced.

Multibeam configuration

The multibeam configuration (see Fig. 2) again features an extrusion device, air source and heating, and collection equipment. This design is desirable because of the higher production levels that are achievable. Beams are configured in series, and production is limited only by the number of beams that are used. By the addition of head-mounted displacement pumps, wide-web basis weight uniformities are increased, and both cross-machine-direction and machine-direction density gradient products can be manufactured. This permits a wide variance of filter media applications.

In-line composites/laminates (SAMAS)

Both the single-beam and multibeam configurations can be further developed to allow the production of composite products, i.e., those that the fibers from all beams involved entangle during the attenuation process, and the production of laminate products, i.e., those products that are formed in

layers with no migration of fibers. A composite/laminate melt blown line (substrate-adhesive-melt blown-adhesive-substrate, known as SAMAS) (see Fig. 3) allows the introduction of films, spunbonds, and existing rolled melt blown webs and the enhancement of various attributes of these products. Rolled goods are unwound and conveyed to the fiberization module, where they can be lightly oversprayed with the melt blown. In some applications, adhesive melt blown technology or the fiberization of hot melts through the melt blown process is used in combination with the melt blown heads to achieve a greater bond between substrates. The composite or laminate is then nipped or s-wrapped, depending on the loft desired, and transferred downstream for converting or collection. TJ

McNally is Asia-Pacific regional manager for J and M Laboratories, Inc., 12 J&M Dr., Dawsonville, GA 30534.

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