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An Update on Hot Melt Adhesive Fiberization

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An Update On Hot Melt Adhesive Fiberization

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Technology for fibrous application of pressure sensitive adhesives — in particular, sprayed applications of hot melt adhesives — has evolved to more efficiently adapt to the needs of the disposable sanitary product market.

In any dynamic industry, the participants, whether suppliers or manufacturers, are all interested in the future. Being the first with tomorrow's technologies and products is the key to succeeding in a rapidly changing marketplace. Before discussing sprayed applications of hot melt adhesive, especially in disposable diapers and other sanitary products, two points should be made. First, several adhesive equipment manufacturers sell heads that fiberize hot melt adhesives. Second, some of the following specific application information was gathered from published data, including patents, and commercially available products that were taken apart to determine how they were put together. By discussing specific products and applications no claims are made regarding which brand of equipment should be used for these applications.

Disposable Product Review

A 1985 sanitary napkin was a simple product consisting of a pad, a nonwoven cover and silicone release paper with garment attachment adhesive. Similar products were made all over the world, from the fastest high technology lines to slow, simple machines in emerging nations.

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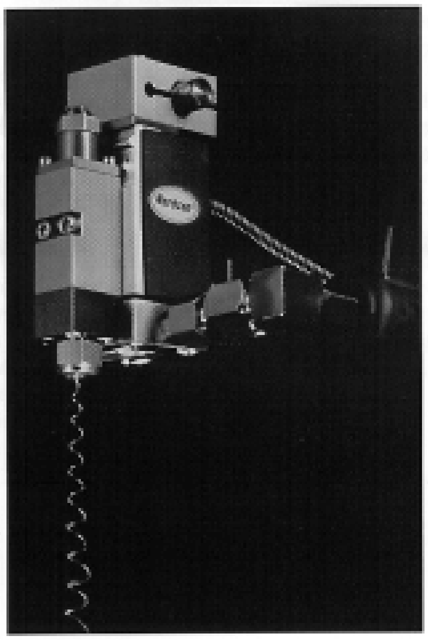


Control of adhesive spiral.

Through the first half of 1985, a shaped disposable diaper with leg elastic was considered state of the art. In some parts of the world, wingfold diapers were still the market leaders. From an adhesive point of view, a typical diaper line included one or two hot melt tanks and three hot melt heads, one applying beads or a slot coating for backsheet lamination and two application heads attaching leg elastic or putting down the wing fold dots. A diaper included about one and a half grams of hot melt adhesive and no superabsorbent powder.

Although well-suited for product assembly and other applications, the hot melt spray method proved unacceptable for the disposables market.

In the summer of 1985, the first elastic waistband diapers were introduced in the United States, and manufacturers all over the world took off on a spree of adding product features that continues to this day.

Beginnings of Hot Melt Spray

At the time these product changes were under way, disposables manufacturers began to look at methods of spraying pressure sensitive hot melt adhesives.

The first hot melt adhesive spray heads drew heavily on high-solids paint-spray technology. By the time manufacturers of disposable products began considering hot melt spray, this technology was already being successfully used in a variety of product assembly applications. Utilizing multiple sources of air, these heads stretched the fiber of adhesive and then moved it back and forth across the web in a "whipping" action.

This method produces a random adhesive deposition and, depending on the adhesive characteristics, applied coatings of up to 6-in wide from a single nozzle. Although well-suited for product assembly and other less precise applications, this method proved generally unacceptable for the disposables market.

Drawbacks included poor edge control, limited intermittent capability and substrate burn-through.

The burn-through was caused by two factors. Because the process uses low velocity, high volume air to create the spray pattern, the resulting fibers had a high residual heat content that could deform sensitive substrates. Also, as the process turned the adhesive back and forth across the web, the fiber would often stretch to the breaking point, forming adhesive droplets. These droplets had a tendency to accumulate near the edges of the adhesive pattern, and could deform the substrate in this area.

In an effort to reduce fiber size and minimize adhesive droplets, manufacturers applied polymer melt-blowing techniques to hot melt adhesives. This method produces a random deposition of very fine films and is widely used to create nonwoven webs.

In this process, adhesive is drawn through a large number of small orifice nozzles, and is formed into filaments by high volumes of high pressure air. For broad-use applications, this process failed commercially, mainly due to the excessive level of maintenance required to keep the nozzles clear and to clean overspray from production machinery.

Spiraling the adhesive maintains good edge control, cools the adhesive, eliminates overspray and also minimizes the need for operator adjustment.

Fiberization Technology

Early in 1986, having identified the limits of both of these technologies, Nordson began a research program aimed at optimizing the spraying of hot melt adhesives for the production of disposable products. The result of that research, the Controlled Fiberization process, was introduced to the industry at the IDEA '86 trade show in Atlanta and the TAPPI 1987 Hot Melt Symposium.

The process uses a single set of air jets to spin the bead of adhesive, drawing it down into a fine fiber applied in a helix-like pattern. The spiraling action is created when the six air streams strike the adhesive stream at tangents. Typical spiral frequencies range from 1000 to 1600 spirals per second.

Spiraling the adhesive (a patented process) maintains good edge control, even in intermittent applications up to 330 m per min. The spiraling also cools the adhesive, permitting applications of hot melt on heat sensitive substrates. Since the process ideally creates a continuous spiral of infinite length, there is no overspray. In addition, the single air source minimizes the need for operator adjustment.

Commercial Applications

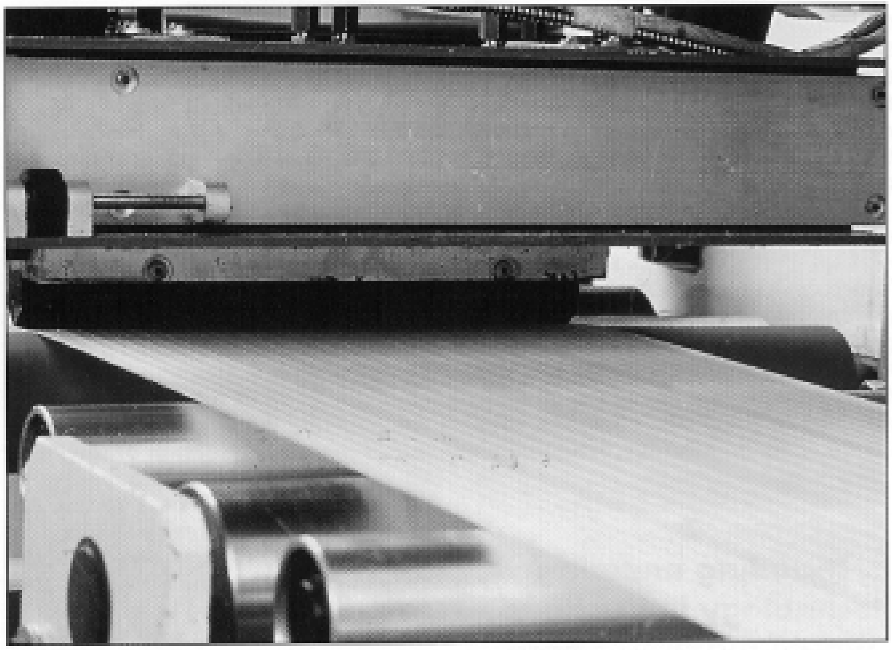
No matter how good a technology is, it will not be commercially accepted without strong application benefits. For spiral spraying of adhesive, this breakthrough came as manufacturers began changing from wide natural rubber leg elastic to a multi-strand design.

Leg Elastic Attachment. Leg elastic was one of the first features added to a disposable diaper. Starting with a single strip of natural rubber on each side of the diaper, manufacturers experimented with a variety of designs using either wider strips of rubber or multiple strips placed side-by-side. A major change occurred when the rubber strips began to be replaced by thin elastic threads.

Initially, manufacturers tried running the threads over or through a slot coating nozzle, or laying them into a bed of adhesive deposited on the poly backsheet.

None of these methods proved satisfactory for attaching stranded rubber or synthetic materials, since the heat of the nozzle and the large amount of adhesive that had to be applied combined to reduce the retraction capability of the elastic strands. Testing of spiral spray for this application first involved spraying on the poly backsheet and then laying the elastic onto the adhesive. This method provided unsatisfactory creep results, since the tack strength of the adhesive was insufficient to contain the high retractile force of the elastic.

In Europe, an adhesive company developed a patented process for spraying through the elastic strands before they made contact with the substrate. This process is now widely used throughout the world. When the adhesive spiral strikes the elastic, hot melt wraps fully around and among the strands, enabling them to bond both to the poly backsheet and to the nonwoven coverstock. The result is a product with good creep resistance.



Slot coating nozzle applying fine lines.

This process works equally well with natural rubber and synthetic elastic products and permits manufacturers to attain soft, effective leg cuffs while minimizing both adhesive consumption and the amount of elastic material required. Typical adhesive usage is 0.12-0.18 g per leg cuff.

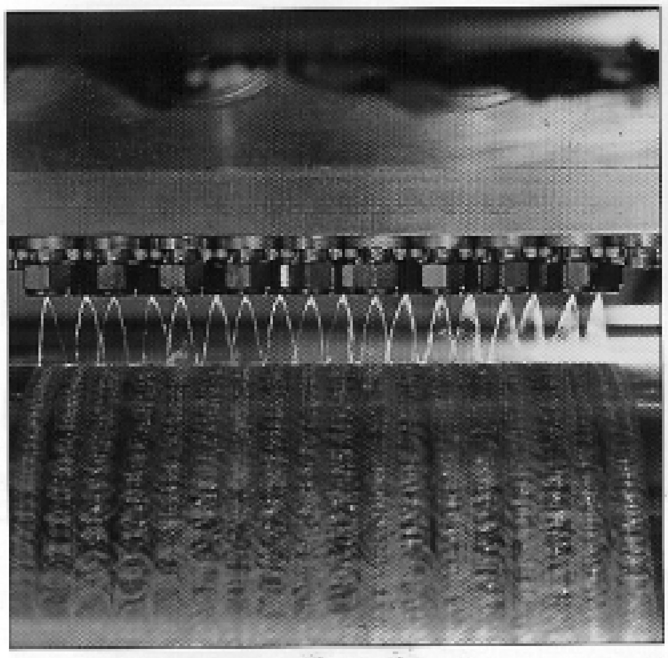
Backsheet Lamination. The greatest potential for material savings lies in the backsheet lamination application.

This application provides the primary construction bond of a disposable diaper. From 12 to 32 beads of adhesive, or a complete slot coating, were typically used. The heat content of the beads limited the ability of manufacturers to take advantage of new technologies and to reduce backsheet poly thickness.

A sprayed adhesive application provides multiple benefits, including source reduction. In this age of environmental consciousness, the cooled filament of adhesive allows manufacturers to reduce the plastic content, product weight and package size of diapers. Reduced poly thickness also provides dramatic cost savings.

Spiral spray has also allowed use of and experimentation with alternate backsheet materials, especially highly heat-sensitive materials that provide other product benefits.

At the same time, the switch to sprayed adhesive on the backsheet has improved the appearance of compression-packed products. Compression packing of diapers with finelines on the backsheet potentially increases the deformation of the diaper, resulting in a less-than desirable appearance. Sprayed lamination allows the diapers to compress flat, giving a smooth ap-



Wide lamination with a metered head.

pearance when removed from the package.

There also is some potential for significant adhesive savings without reducing the strength of the backsheet bond. This is shown in one patent in which a global manufacturer disclosed equal bond strengths at nearly 40% adhesive weight reduction where overlapping spirals replaced parallel lines.

The actual amount of adhesive savings depends on several factors, including the type of application technology selected. Adhesive savings can be maximized through the use of metered head technology for this application. Metered heads are hot melt adhesive applicators that have an individual set of metering gears for each adhesive stream.

This is contrasted with what is commonly called a "pressure-fed" head. All the nozzles on a pressure-fed head are supplied by a single gear pump, with adhesive distributed to the multiple nozzles by hydraulic pressure.

Although suitable for some applications, a pressure-fed head wide enough to accomplish backsheet lamination has so many nozzles (usually 13 to 15 for a baby diaper) that it normally requires a high level of maintenance to assure consistent patterns. The maintenance level is increased when compared to fineline applications, due to the small orifice size required to generate an optimum adhesive fiber.

Since the head relies on hydraulic pressure to distribute adhesive to the multiple nozzles, adhesive easily diverts from one area of the head to another if a nozzle becomes clogged. With metered technology, the close proximity of the metering pumps and the lack of alternative flow paths will normally quickly force the blockage from the nozzle, eliminating downtime and wasted product.

The material savings and productivity benefits are partially offset by a higher initial cost for metered technology. However, once the payback level is achieved, the cost savings greatly outweigh the higher investment.

Of all the current spiral spray applications, backsheet laminations provide manufacturers with the greatest potential benefits given material savings, environmental friendliness and machine productivity. Typical adhesive requirements range from less than 1/2 g to 0.8 g of adhesive per product for a sprayed backsheet lamination.

Elastic Waistbands. One of the earliest product features to incorporate spiral sprayed adhesive was elastic waistbands. Early waistband attachment methods included ultrasonic bonding, slot coatings on foamed elastic materials and finelines on heat-activated elastics. As in the case with leg bands, slot coatings for waistband attachment reduce the retractile capability of the elastic. The appearance of the waistband on the finished product may also be less attractive than desired.

The addition of standing leg gathers to diapers was implemented using spiral spray technology, and several methods of manufacturing this feature are available.

By combining a uniform application of lines on the one side with a sprayed application on the other, an attractive waistband can be produced. The most uniform waist gather can be accomplished by putting the lines on the backsheet and spraying the nonwoven. However, combining lines on the nonwoven with a sprayed backsheet also will provide attractive results. This application requires about 2/3 g of adhesive per diaper.

Core Stabilization. Although not immediately evident to consumers, core stabilization applications for spiral sprayed adhesive have played a key role in manufacturers' abilities to reduce pad weights.

As pads became thinner, they became more likely to separate during shipment or after the initial wetting, especially in the case of tri-folded products, which generate twice the stress locations on the pad as diapers folded in half. Core stabilization also is required for diapers using unbleached fluff or other short fiber fluff pulp materials.

A variety of application methods are used. In most cases, adhesive is applied to the tissue on both sides of the pad, as well as between the tissue and the nonwoven coverstock. A very small amount of adhesive is commonly used for this application, in the range of 0.1 g per pad. These low weights can be applied using several different processes, since pattern uniformity and integrity are not really critical on internal applications, where the sole function of the adhesive is to provide some stability to the pad structure of the product. This application also is suitable to meltblown technology.

In-Line Frontal Tape Production. An application that has been exclusively tested but is in limited commercial use is the in-line coating of frontal tape with spiral spray. Currently, pre-adhesive applied tapes or tapes made in-line with full coatings or lines are used. Spiral spray provides some potential for reducing tape thickness and adhesive consumption while maintaining tape integrity and edge control. An adhesive company evaluation found that significant savings were possible with in-line sprayed coating of the tape.

Standing Leg Gathers. With so many proven applications worldwide, the addition of standing leg gathers to diapers was implemented using spiral spray technology. At least three methods of manufacturing this feature are on the market today, and a maximum of eight adhesive applications are required.

In the first, the leg cuffs are created and then added to the top of the nonwoven. In this method, the elastic is attached to the cuff, the cuff held together for its full length, attached to the nonwoven and tacked down at the ends of the diaper. Normally, the elastic attachment application, which also may accomplish the cuff seal and end tack down are done with spiral spray. Beads are commonly used to attach the cuff to the nonwoven.

A second implementation creates the cover and cuff structure from three separate pieces of nonwoven. Elastic is attached to the side sections, which are folded and attached to the center section. The ends are then tacked down to the diaper.

The third method actually involves two steps. The topsheet is an extra wide sheet of nonwoven. The elastic is attached to the flat sheet with a sprayed application that also will seal the sides of the cuff together. Two pleats are then pulled into the nonwoven, creating the cuff around the elastic. Once the nonwoven is joined to the rest of the diaper, the ends are tacked down. This method eliminates the need for two applications that attach the cuff to the diaper.

The interest in finer fibers and greater uniformity in adhesive distribution has led to a re-evaluation of melt-blow technology for spraying PSAs.

Fluff-Free Napkin Core. The core stabilization applications discussed earlier also apply to current designs of sanitary napkins. As fluff cores have become thinner or, in some cases, disappeared entirely, adhesive applications have been added to provide stability and to fix superabsorbent powders in place.

Finer Fiber Requirements

Even with the acceptance of spiral spray, there continue to be requirements and requests for finer adhesive fibers and more uniform coatings. With any geometric spray process, there will be some areas of greater and lesser coating weights. With spiral spray, the heavier areas are those where individual patterns overlap or where the spirals themselves cross each other. These areas of unequal distribution can be minimized by controlling the overlap, generally by one-third on each side.

This interest in finer fibers and a greater uniformity in adhesive distribution has led to a re-evaluation of melt-blown technology for spraying pressure sensitive adhesives.

Re-evaluating Melt-Blown Technology. As mentioned earlier, melt blowing of pressure sensitive adhesives was first implemented in 1986. At that time, it was adopted by disposables manufacturers for internal applications such as core stabilization.

As time passed, manufacturers found that melt-blown technology has several disadvantages. First, the very fine adhesive fibers, although desirable from a product perspective, had a tendency to become entrained in the air carried along by the web. These fibers of pressure sensitive adhesive would then attach themselves to the machine, causing maintenance problems and accelerating wear of bearings and motor shafts.

Above: Diapers have become thinner over the past eight years (right to left: 1985, 1992, 1993). Right: Control Coat permits edge control and intermittent capability.

Second, the many small nozzles required to melt blow an adhesive created an unacceptable level of required maintenance in a high-fluff environment. Very small orifice diameters and 10-25 nozzles per in were used. Also, the volume and velocity of air required by this process had a tendency to disrupt nonporous webs and to blow adhesive fibers through porous webs. Finally, the combination of small fibers and high volumes of air limited the melt-blown process to continuous applications. Technology was not available to permit a clean cut-on and cut-off for intermittent patterns.

Most of the melt-blown heads put online in the mid 1980s were eventually replaced by other technologies. Late in the 1980s, melt-blown technology for PSAs was again commercialized, with several improvements. This technology, licensed from Exxon, has been refined to improve edge control, reduce overspray and increase intermittent capability.

Although accepted for some niche applications, this technology has yet to find wide application for the manufacture of diapers and sanitary napkins. The shortcomings identified earlier continue to limit acceptance.

The Control Coat System

With manufacturers still interested in increasing pattern uniformity and reducing fiber size, and the limitations of melt-blown technology well known, a new type of spray technology has been developed. Called the "Control Coat System," these heads minimize fiber size and produce uniform coatings with good edge control and intermittent capability. The effect is actually closer to a slot coating than a typical sprayed adhesive coating.

The head combines elements of both slot coating and melt-blown heads. Adhesive is distributed to the desired pattern width through internal channeling. As the adhesive is extruded from the nozzle, heated air impinges on the adhesive from both sides, stretching the adhesive and breaking it into very fine fibers. The design of the air channel allows the fiberizing air to entrain the fibers, controlling their placement as they are carried to the web.

By virtue of this design, overspray is eliminated, edge definition is optimized and small fiber size is maintained. Timed control of the fiberizing air also permits intermittent applications with good pattern cut-off and cut-on. Here, the timing sequence ensures that the fibers remain entrained in the filtering air until they are placed on the substrate. This technology, when compared to melt blowing, also reduces air and maintenance requirements.

Including metering technology in the head would maximize both pattern uniformity and adhesive savings, and increase maximum width capability.

The head is designed for use of low-volume, high-velocity fiberizing air. Fiberizing air passage design eliminates disruption of the web and permits application on porous substrates. The design also eliminates the many small nozzles required for melt blowing. By extruding the film of adhesive through a narrow slot and including a filter in the head, nozzle plugging is reduced, even in high fluff environments.

Early testing found this technology to be potentially well suited for narrow-web applications such as pad stabilization in both diapers and sanitary napkins. In diapers, stripes of adhesive along the sides of the pad would provide stability while keeping adhesive out of the center section of the pad. This would allow some engineering of the pad to reduce thickness without inhibiting any of the designed absorbency. In sanitary napkins, this technology is ideal for bonding the pad to the poly liner, for internal bonding of the pad or for positioning superabsorbent powder in the product.

Potential diaper applications also include bonding one side of the elastic waistband to the diaper and in-line coating of frontal tape. In either case, this technology permits a non-contact, uniform coating with PSA. Bond strength can be maximized while minimizing adhesive use.

As discussed with the spiral spray application on a diaper backsheet, including metering pumps in the head would maximize both pattern uniformity and adhesive savings. Metering technology also increases the maximum width capability of this process.

It also may permit the in-line manufacture of diaper backsheets using a thin polyethylene combined with a nonwoven on the outside of the product. Outside the disposables market, this technology has been tested in applications as diverse as bookbinding and sealing the necks and corks of wine bottles.

Summary

Technology for fibrous applications of PSAs have quickly progressed:

- from modifications of other devices to technology specifically designed to apply adhesives to disposable products;
- from equipment difficult to operate and maintain to equipment designed to apply adhesives to disposable products;
- from a technology unknown on high speed disposables production lines to the standard technology for diaper and sanitary napkin production.

Looking to the future, opportunities will continue to improve disposable products through technologies that make it possible to add new product features and pay back investments in a reasonable time, through material savings and productivity improvements.

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