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Rules for Optimum Bonding

Advancements in fiber application technology minimize waste and refine product features.

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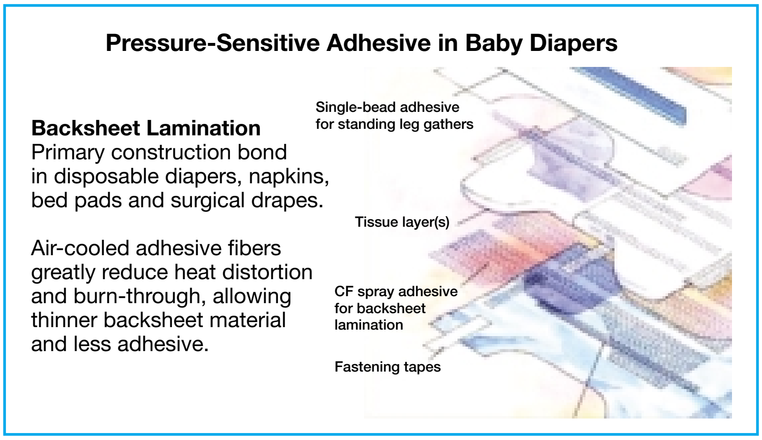
ADHESIVE FIBERS, applied by non-contact spray, are used throughout disposable non-woven products to enhance performance and save raw materials. Advancements in fiber application technology minimize waste by reducing variability and improving accuracy, which can help refine product features. Improved control and flexibility of adhesive fiber processes are driving bonding optimization. Basic rules and approaches influence the level of bonding improvements attainable.

Manufacturers of disposable products are producing better products more efficiently and economically. This trend translates directly into requirements for improved adhesive application performance.

While the conditions for optimum bonding differ for each application, adherence to basic rules will typically deliver favorable results. These rules are supported by theory, data and experience. The three rules for optimum bonding include larger fibers form stronger bonds; fiber crossings reinforce bonds for higher bond strength; and lower variability minimizes waste.



Rule 1: Larger Fibers Form Stronger Bonds

At a given add-on, there is a compromise between fiber size and coverage. Larger fiber size yields lower coverage density, but delivers stronger bonds. This is because larger fibers:

- hold more heat for more open timeor better flow at the same open time;
- bridge the gaps between substrates, or within a non-woven substrate;
- and flow out more at the nip, creating more bond area.

These characteristics are strongly related. Since a larger fiber has less relative surface area, it retains more heat. Consequently, the adhesive viscosity is lower on first contact with the substrate, and when the substrates are nipped. Low viscosity allows the adhesive to better flow into the substrate. Hotter adhesive has lower surface tension for better wetting of the substrate.

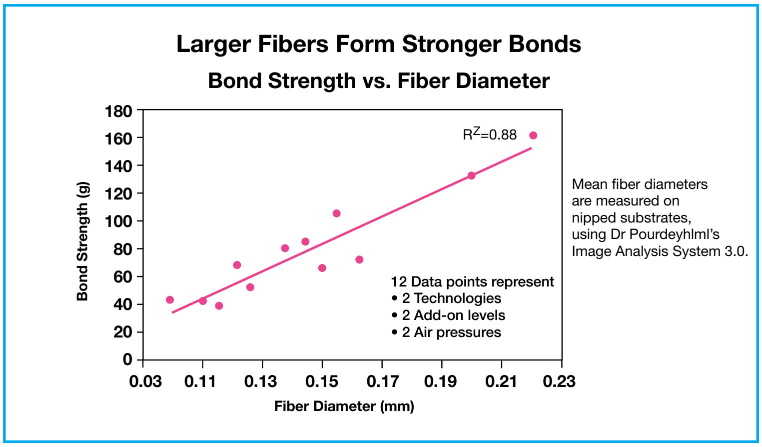


Figure 1: Bond strength vs. fiber diameter

Additionally, realistic nip pressures cannot compress the adhesive below a certain thickness range. If a fiber is only a little larger than this thickness, adhesive flow will be limited in the nip. If the fiber is significantly larger, the flow will be increased, resulting in much better nipped substrate bonding.

The rule of larger fibers forming stronger bonds can be shown in lamination by comparing technologies. Figure 1 shows that larger fibers are strongly correlated with stronger bonds. The data represents three add-on levels, with the highest representing the low end of current commercial practice.

The add-on levels are repeated with two spray technologies and two process air pressures, so the correlation holds across many conditions.

The rule that larger fibers form stronger bonds is also supported by broadly comparing large-fiber technologies to fine-fiber technologies. In Figure 2, four technologies are compared. Sixty samples were collected from each process over a wide range of operating conditions.

The specific operating conditions were repeated for each technology in a designed experiment. The average of all 60 points were compared. Clearly, the large fiber technology produces the strongest bonds, followed by the medium technologies. Fine fibers form the weakest bonds.

What if Stronger Bonds are Not the Main Goal?

There are several reasons that optimum bond strength may not be targeted:

- Finer fibers minimize heat distortion; finer fibers reduce bleed-through;
- higher density coverage may have preferred appearance or hand;
- and higher frequency may be preferred at higher line speeds.

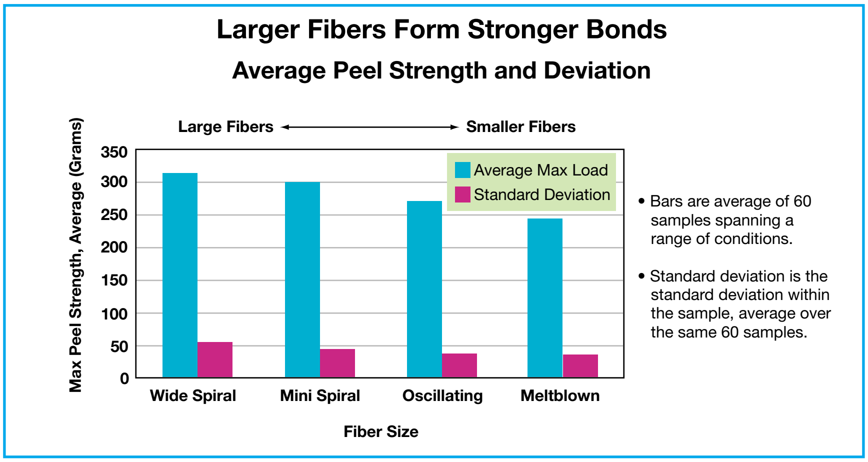


Figure 2: Average peel strength and deviation

Figure 3: Fiber characteristics

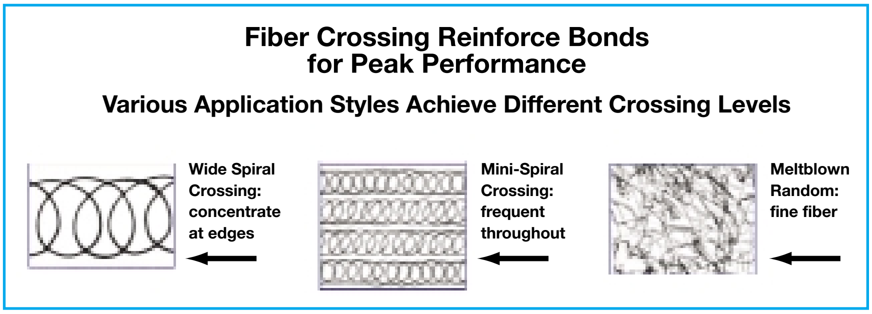


Figure 4: Application and crossing levels

These characteristics are often desirable with very thin substrates. The photographs in Figure 3 illustrate relatively large and fine fibers, and their characteristics.

Rule 2: Fiber Crossings Reinforce Bonds for Peak Performance

It is useful to consider some examples of reinforcement in other materials. The best analogy for adhesive fibers comes from fabric material called rip-stop parachute nylon. In this fabric, heavier threads (or fibers) are woven in at regular intervals. If the fine fibers start to tear, the heavier fiber stops the rip. Another example is impact-modified plastics, which have a relatively brittle matrix. Reinforcing filler particles are added for improved impact strength.

Reinforcement technologies are effective because they take more energy to initiate a failure than to propagate it. In an adhesive bond, strand-crossing points act as double-thickness fibers. As an adhesive fiber bond begins to fail, single fibers tear out. When the tears hit a crossing-point, they are stopped and a new failure point must be initiated. This dissipates energy, requiring an overall higher force for failure.

Crossing Characteristics of Lamination Technologies

Various application technologies achieve different crossing levels as demonstrated in Figure 4.

Referring back to Figure 2, the mini-spiral and oscillating patterns produce similar fiber size, but the mini-spiral shows higher bond strength due to the increased number of crossing reinforcement points. The wide spiral shows higher standard deviation due to the concentration of crossing points at the edges.

Rule 3: Lower Variability Minimizes Waste

Optimum bond strength in the lab is only valuable if it translates into savings for the production process. Modern production processes must produce high-quality prod-

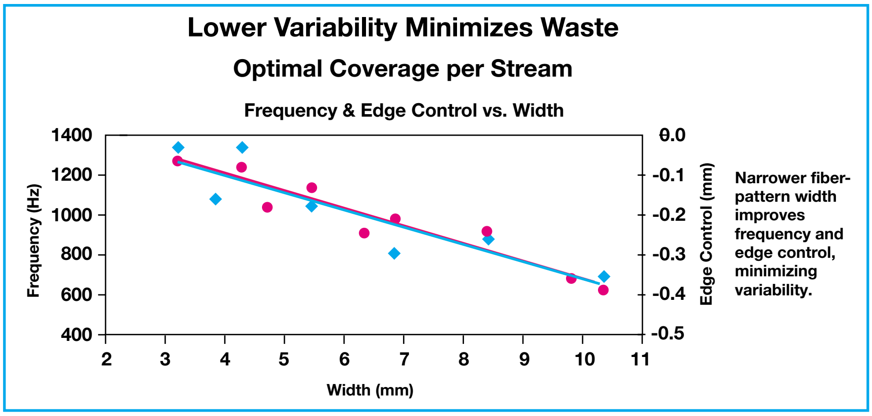


Figure 5: Frequency and edge control vs. width

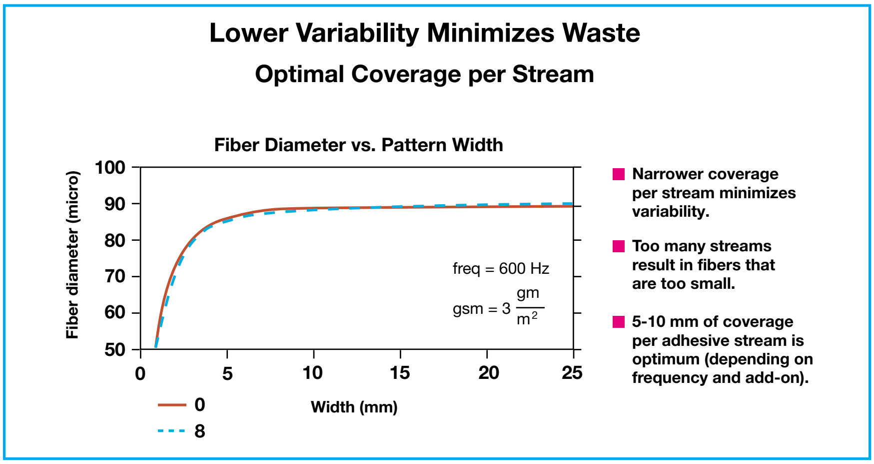


Figure 6: Fiber diameter vs. pattern width

uct with minimum waste. Six Sigma is one approach to this requirement, where sigma is the standard deviation, a measure of variability. In Six Sigma, the process is operated at least three sigma above the minimum required level (6 refers to +3). The minimum required level is determined in the lab.

The production process must be designed to minimize the variability, sigma. Two key concepts relate what has been presented about strong bonds to minimized variability.

Unbroken fibers maximize control over the fiber: Unbroken fibers minimize contamination since the adhesive fiber remains attached to both the substrate and the nozzle. Only intermittent application provides an opportunity for contamination.

Processes that create unbroken fibers are more repeatable and provide more uniform fiber size and predictable placement of the fiber on the substrate.

Table 1: Industry Trends and Requirements

Trend	Requirement
Higher line speeds	Higher frequency
Better process control	Lower variability
Lower cost materials	Less thermal distortion
Less adhesive	Superior process control
Increased machine uptime	Modern equipment

There is an optimal range of coverage width per stream: While unbroken fibers help control adhesive placement, coverage width per stream determines variability in edge control. Coverage width per stream can also be viewed as streams per inch (25 mm). In general, the narrower the area an adhesive fiber is expected to cover, the less it will deviate from this path.

Alternatively, edge control is roughly a constant percentage of the width, so a narrower width results in proportionally better edge control, as illustrated in Figure 5. Figure 5 also shows that narrower patterns achieve higher loop frequency, a benefit on today's fast lines.

Note in Figure 6, however, that a narrower width results in smaller fibers, and thus lower bond strength. Remarkably, Figure 6 is not a linear relationship like the edge control in Figure 5; therefore, 5 to 10 mm (or 3 to 5 fibers per 25 mm) represents on optimum range, depending on frequency and add-on.

Beyond these two key points, there are many practical ways to reduce variability and waste. Any time a small change in conditions can cause larger changes in adhesion, waste is likely to result. In adhesive application processes, consider the following issues:

- adhesive sensitivity;
- sensitivity to horizontal or vertical application;
- and sensitivity to process parameters.

Conclusion

The non-wovens market will continue to become more competitive. Consolidation within the industry, combined with global economic changes and population adjustments, are forcing manufacturers to seek production equipment that can meet demands for faster line speeds, superior products and cost management. Equipment and technology that have the ability to precisely dispense adhesive, optimize bonding performance and reduce adhesive consumption will provide manufacturers with significant advantages over competition.

Research and development continues to refine the manufacture of non-woven and disposable products. Recent advancements in non-contact adhesive deposition allow manufacturers to realize significant cost savings and help produce superior-quality products.

Extensive testing has demonstrated that larger fibers form stronger bonds; fiber crossings reinforce bonds for higher bond strength; and lower variability minimizes waste. When followed, these three rules for optimum bonding have proved beneficial in improving the manufacturing process. AA

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