MINIFIBERS, INC.

Ambushed on the Way to the Web

How Synthetic Fiber Processing Technology Affects the Quality of the Web

This paper was written by G.B. Keith, founder of MiniFIBERS, and presented at the TAPPI Paper Synthetics Conference in 1973. It still contains a great deal of information which is useful today.

ABSTRACT

Broad usage and a wider variety of manmade fibers available for processing web have created a fiber technology dilemma. Both the web mills and the professional webmakers have been kept busy trying fibers in new uses. Larger mills usually attract personnel with fiber expertise from the prime fiber producing industry. Smaller mills make do, using the most readily available knowledge, likely scraped together from fiber charts and/or supplier salesmen sometimes overzealous in their product claims. Results are rarely satisfactory and sometimes disastrous. Unfortunately, papermaking experts do not necessarily convert into synthetic fiber experts overnight. It follows, then, that responsible fiber suppliers not only must furnish fiber which will perform, but must also apprise the user of any possible pitfalls he may encounter when using various synthetic fibers in web. Further, the user must be trained in the art of processing synthetics, thereby being able to detect and even anticipate trouble and correct his equipment to product optimum quality web. Only then can he intelligently approach his supplier and expect to get answers to his synthetic fiber supply and performance problems.

THE FILAMENT'S LAMENT

"I am a filament. Conceived by nature, first born of spiders and insects, I made my earthly debut millions of years ago. Possessing the perfection of nature, I served my masters well, providing food, shelter, and raiment. I was copied by the ingenuity of man, reborn of chemistry and machine, and named synthetic. Inheriting the fallibility of man, I became somewhat imperfect. Alas, more rigorous demands were placed upon me. I was required to be stronger, more flexible, to mix well, feel well, absorb moisture, and withstand heat and abrasion. Since my rebirth, I have led a troubled existence. Only after I serve my useful purpose, reach the sanitary landfill, and the binder releases me, can I relax and know that I am finally free of the relentless pressures of man."

SYNTHETIC ACHIEVEMENTS

Synthetic technology deserves a rebuttal. "What's this about the perfection of nature? You can lay little claim to continuous filaments. The most your silkworm can do is about a thousand feet. We can spin a thousand miles. How accurate is your staple length? Both animal and vegetable staple lengths vary ridiculously. We can hold staple lengths to within a hundredth of an inch. Your denier variations are atrocious. Only the silkworm can come close to competing. Your animal and vegetable filaments vary so much that deniers are really ignored. We can spin synthetics to a denier tolerance of plus or minus ten percent. Finishes? Oils on your natural fibers, if present at all, vary so greatly they must be scoured off and redistributed. Our oils are often added. We can apply tailored finishes to synthetics that are not only far superior in performance to yours, but are distributed very homogenously throughout the fiber. Items like tensile strength, resistance to chemicals and temperature are no contest. We will not embarrass you further. Our point has already been made."

THE PROFESSIONAL WEBMAKER'S DECISION

As the debate on quality control rages on between the natural and synthetic fibers, the professional webmaker faces several questions: What are the demands my web must meet? Exactly what quality fiber do I require? What defect ratio is acceptable? Can I mask or overcoat? If I use a high quality, high performance fiber, can I compete economically? Or will it price me out of the market? Where can I acquire suitable fiber? And he should conclude: I must use precisely the quality of fiber that will perform adequately and is available from a number of suppliers, many of which will help me to make it perform.

SYNTHETIC FIBER VARIATIONS

Fiber quality covers the entire scale; it may range from very good to very poor. The webmaker can find whatever he requires. The synthetic manufacturing process, remarkable as it is, has inherent shortcomings that have somehow always assured this fact. Excluding a few of the exotic synthetics, there are eight separate manufacturing steps in the usual production line where foul-up may occur. Defects produced early in the process naturally compound the problems as the fiber proceeds along the production line. Trouble of this nature usually results in the fiber being discarded as waste. Manufacturers regularly expect 5 to 10 percent of the line throughput to meet this fate.

THE SYNTHETIC PROCESS

Synthetic fiber has its beginning with **chemistry**; after a media is developed, it is **filtered** under pressure; it is then **extruded** into continuous filaments; the filaments are allowed to **solidify**; they are then **stretched**; a **finishing** solution is now applied; the bundle of filaments is then **crimped**, or given a zigzag kink; the final step before packaging and shipping is **cutting** the fiber bundle into staple lengths.

Each manufacturing step deserves separate treatment. What happens to produce poor performing fiber? How does it affect the web? How can the user pinpoint the problem?

Chemistry: Poor chemistry of the spinning media usually manifests itself in lowered physical properties of the fiber. Tensile strength suffers, along with resistance to temperature or perhaps chemicals. Extremely poor chemistry almost guarantees that the fiber will never see the light of day. It simply will not spin, sometimes even degrading in the extrusion system. The slightly off-spec media produces the fiber that demands our closest vigilance. The web will be weak, may show dark fibers, will not withstand normal heat or chemicals, and may bond poorly. Should the user become suspicious of any synthetic which fails to perform within reasonable parameters in the areas mentioned above, he should immediately resort to physical and chemical testing to pinpoint the difficulty. Requesting a small skein of uncut tow for testing is good insurance while establishing a fiber supply program. Fiber suppliers will not object to furnishing such a test sample with each shipment.

Filtration: The filtration principle is well known in the art of fiber production. The spinning media is simply pumped through a screen, sand, or other mesh-like pack to break up the media and screen out the impurities. As the filter packs with impurities and approaches clogging, the pumping pressures peak. Eventually, the near-clogged filter must be replaced with a new pack. Improper filtration of the spin media most often results in broken filaments. This is caused by small particles of impurities passing through the filter and clogging, or passing on through, the spinnerette hole. This leaves a nick in the filament; it simply pulls in two when stretched later on in the manufacturing process. Stubby, oversized filaments, sometimes discontinuous, result from failure to change the filter pack soon enough. Pressures build and the spinning process stutters. Increased pressure, accompanied by temperature buildup, causes brittle, weak, discolored filaments to emerge from the spinnerette. The professional webmaker who encounters the above fiber defects will find himself producing weak, scabby, discolored web. Visual inspection, both with the naked eye and by magnification, will usually be sufficient to determine the origin of the problem. The fiber should never have been shipped; proper grading would have placed it in an inferior quality category in the plant of the producer.

Extrusion: Extrusion takes place in a crude sort of way when toothpaste is squeezed from a tube. A spinnerette is a precision machined cup or plate, usually with multiple, minute holes through which the spin media is pumped to form filaments. A spider has six holes in his spinnerette; man copied his equipment, adding hundreds of holes. To form good filaments, spinnerette holes must be very accurate in size, the outlet edges must be square, and the surfaces must be smooth. Prolonged usage can cause the holes to wear, enlarge in diameter, and produce larger filaments. The most common foul-ups at the extrusion head are broken filaments, link sausage filaments, hollow filaments, oversize filaments, Siamese twin filaments, coiled filaments, and blobs of unspun media. They appear in web as scabs, dumbbells, slick spots, or slit-like openings. Visual inspection of the furnish fiber is sufficient to detect most of these imperfections, and their use should end after a hand sheet is made. Your purchasing agent has probably saved some money and bought sheer trouble.

Solidification: Hot melt synthetics are allowed to solidify in air with controlled flow. This usually takes place in a vertical stovepipe. The filaments are held apart when soft, but collected together after hardening. Cool air is wafted slowly across the spinnerette face to initiate this process. In the wet spinning process, the filaments are encouraged to coagulate or solidify in a controlled chemistry liquid bath. The spinnerette is immersed. In either system, Siamese twin filaments, flabby filaments, tubular filaments, knobby filaments, broken filaments, or cross-fused filaments may result. Web malformations appear as shiners, scabs, dumbbells, and harsh spots. Visual inspection of the fiber is usually sufficient to forewarn of impending trouble. Siamese twin filaments, however, have regularly been mistaken for filaments of quadruple denier, even when viewed under a microscope. They were simply seen as one filament of double diameter when, in reality, they were two regular sized filaments securely welded together. A cross-section of such a formation would be viewed as a perfect figure 8. They had touched and adhered before solidifying.

Stretching: Drafting or drawing of fiber orients the molecules along the filament. It increases its tensile strength, decreases its elasticity, and generally hardens the filament. Fiber that is stretched, then permitted to relax or recover some of its extension, performs better in most situations. It does not shrink upon calendaring as much as fiber that is not relaxed. In some production process, the term “heat set” is applied to this procedure. Increasing strength by drawing is not all gain. Softness or hand of the web deteriorates somewhat with the use of the harder, stronger fiber. Since the stretching process is usually accomplished by passing the continuous band of fiber over two sets of differentially driven rolls while heated, numerous defects abound in this processing step. Filaments break and do not get stretched. Previously broken filaments leave a trailing end segment and an entering end segment unstretched, hence grossly oversize. Rolls overheat and bands of filaments are welded together as a strap. Filaments insulated from the heat source by other filaments remain colder; they do not stretch or relax properly. Slack segments of two result and play havoc at the cutting machine, causing foldbacks and long staple. Uneven heating of the band causes uneven shrinkage at the calendaring rolls. Some filaments do not carry their fair share of the load, and more fiber must go into the furnish to achieve the desired web properties. The webmaker can detect poorly stretched fiber by harsh feel of the web, lack of web strength, slicks, dumbbells, and scabs. The fiber, inspected visually, will exhibit longs, harsh strips, oversized filaments, and a generally harsh feel. A hand sheet test is not always necessary. The user can usually tell from experience if the fiber will perform.

Finishing: Finish is applied first as a very light oil, to assist in transporting the filaments over the guides. This usually occurs after solidification. It permits the filament to proceed to subsequent processing steps without abuse. Later, this oil is a nemesis. It must either be scoured off or overcoated. It may also interfere with the performance of the binder. Gloves just naturally slip off an oily hand easier than a dry one! Most users require an anti-stat finish if the fiber is to be used in a dry lay system, a dispersant finish if used in a wet lay system. Dispersants and anti-stats are usually applied to the fiber bundle by immersing in a bath, spraying on in a booth, or rolling on with rolls. In all systems, even application is difficult. The outer filaments get the most finish and insulate the inner ones from it. Users often attempt to correct the finish foul-up by mixing chemical additives in the furnish. This is not always satisfactory; besides, they increase the cost of the product. And alas, chemical composition of manufacturers’ finishes is one of the most zealously guarded secrets of the art. Why not? Before the finish was applied, it was simply polyester, or nylon, or acrylic. Now it has a trademark! The user can easily detect his finish problem: The fiber simply will not disperse, static adherence or bridging will occur, or his binder will not give the desired physical properties to the web. He has one of two options: Experiment with chemicals in the furnish, or go back to the supplier with the problem. As a footnote, it seems somewhat sad to comment that all users who are striving for a 100% fiber web must, as of now, settle for less. They can only get a predominantly fiber web with a small percentage of residual finish.

Crimping: Crimping, or kinking, of fiber is accomplished by either of two methods: It may be done chemically, particularly with the cellulosics, or it may be done mechanically by use of a stuffing-box machine. The apparatus simply folds the fiber back and forth upon itself into a pressure chamber. The latter process is used most widely. The product is improved somewhat by the application of moisture or steam to the fiber prior to its entry into the chamber. Kinking of the filaments imparts some desirable characteristics to the end product. It adds bulk, softness, hand and lateral resistance, particularly to dry lay web. Wet lay, for the most part, uses straight or uncrimped fiber. Slippage of the stuffing rolls on the tow may result in harsh, fused fiber. Spots of uncrimped fiber may also result from the slippage. Crimp may vary greatly in magnitude, or it may occur only in one plane. In this case, it is termed “primary crimp.” The best results are obtained if the crimp action occurs in two or more planes. This is termed “secondary crimp.” The professional webmaker can recognize poor crimp by lack of bulk in the finished web, obvious zigzag lines (primary crimp) on the web surface, or slick spots from harsh crimp passing under the calendaring roll. Visual inspection of the fiber is usually sufficient. Excessive defects in the web can only be corrected by demanding higher quality fiber from the supplier.

Cutting: It seems ironic that, after all our laborious efforts to keep the filaments continuous, we would now want to use them in short lengths and face the many problems of accurately cutting the fiber bundle. It becomes even more distressing when we consider that no shipment of fiber has ever left a dock that did not contain longs. There are simply more longs or fewer longs. It is easier to understand when we face facts. A 40,000 lb. truckload of fine denier, quarter-inch polyester contains over 17 trillion separate pieces of fiber! Each piece has had several chances to become a long filament. We are dealing with a geometric progression of ever-increasing, staggering proportions. That fiber can be processed to perform at all is remarkable and a credit to the ingenuity of the producers.

The problems of cutting fiber (with emphasis on the shorter flocking fibers) have been discussed to some length in previous TAPPI papers. Since that time, however, rather significant advances in fiber cutting machinery have eliminated many problems that formerly plagued the art. Generally speaking, most previous machines clung tenaciously to the knife-anvil system of cutting. This method, replete with feed rolls, anvil, and a reel of rotating blades; or an anvil and single guillotine blade, by mechanical nature inherits at least three defect-producing capabilities: First, adjustment of the blade to the anvil simply cannot be made close enough to avoid skipping a few filaments and permitting multiple lengths. Secondly, the speed with which the blade passes the anvil, in the manner of striking a flint, generates heat and causes fusing of most types of fibers. Thirdly, since no one pushes with a rope, control of the filaments is lost between the feed roll nip point and the cutting point, and the fiber is not held taut but is free to flutter around. At least a portion of such a feed bundle is cut at random.

Recent machines operate on the principle of winding the fiber around a reel of sharp knife edges. A roller pushes the cut fiber between the knives. This eliminates all three provoking problems. Incoming fiber forces the cut fiber past the knives, removing the need for close adjustment of knife to anvil. The fiber is moving with the knives; there is no impact, so heat of fusion is not produced. The fiber band is wrapped under tension; full control is maintained on the filaments until they are cut. Obviously, fiber performance has shown marked improvement with the advent and usage of this equipment to enhance the art of cutting.

Despite the best efforts and improved equipment of the fiber cutters, somehow, poorly cut fiber still seems to find its way to the furnish. It can usually be detected beforehand by making hand sheets. Very poorly cut fiber can be detected by visual examination. Fused fiber will feel harsh to the touch, longs may be spotted, or logs – which will form daisies in the web – are easily found. Whether a fiber will perform or not is dependent upon the number and type of defects that the end use of the web will permit. Some products demand few or no defects; others will allow more. Usually, several hand sheets will be required on a fiber that has borderline quality of cut. Sometimes a staple run is necessary to get an accurate defect count. If the fiber is found to be unsatisfactory, ask the supplier to correct the problem. If he cannot or does not, a new source of supply is the only answer. More fiber run through the same processing line will most likely perform as before.

It is most important at this juncture to emphasize that the webmaker must ensure that his equipment is in proper adjustment, and that his chemistry and other parameters are correct. Also, his communication with the supplier must remain open. If either of these facets of the operation is not diligently pursued, the entire project may terminate in failure, resemble a conspiracy rather than a cooperative venture, and result in no new product but loss of effort and capital.

SUMMARY

Synthetic fiber technology has broadened the horizons of the professional webmaker's field with new and improved performance fibers. The remarkable synthetic production process, including chemistry, filtration, extrusion, solidification, stretching, finishing, crimping, and cutting of fibers, is not perfect. The user can procure a wide variety of fibers to fulfill his needs, ranging from very high performance to very low performance. Costs vary greatly. The webmaker must keep abreast of developments with the suppliers to be able to select the correct type and quality of fiber to keep him economically competitive. Lines of communication between the supplier and the user must be opened, and kept open. The user needs constantly to know what fibers are available and the uses they will fulfill; the supplier needs to know what the demands are on his products, and how he can help to improve their performance. The time has come for relationships of trust to be developed between supplier and user. Proprietary information must be protected, but general knowledge disguised as proprietary has impeded the progress of the webmaking boom much too long.