PUSHING THE LIMITS OF HEAD-BOXES AND FORMING SECTIONS

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DESIGNERS FACE MANY HURDLES IN QUEST FOR SPEED

THIS MONTH, IN OUR TECHNOLOGY SPOTLIGHT SERIES, we questioned the three major headbox manufacturers, all TAPPI sustaining members, about the challenges they face in the headbox and forming sections if they were to double paper machine speeds. Those responding included Bob Clarke and Scott Pantaleo, product manager—headboxes, for Beloit; Alex Malashenko, North American research and development manager for Valmet, and Albrecht Meinecke, vice president of R&D for Voith Sulzer.

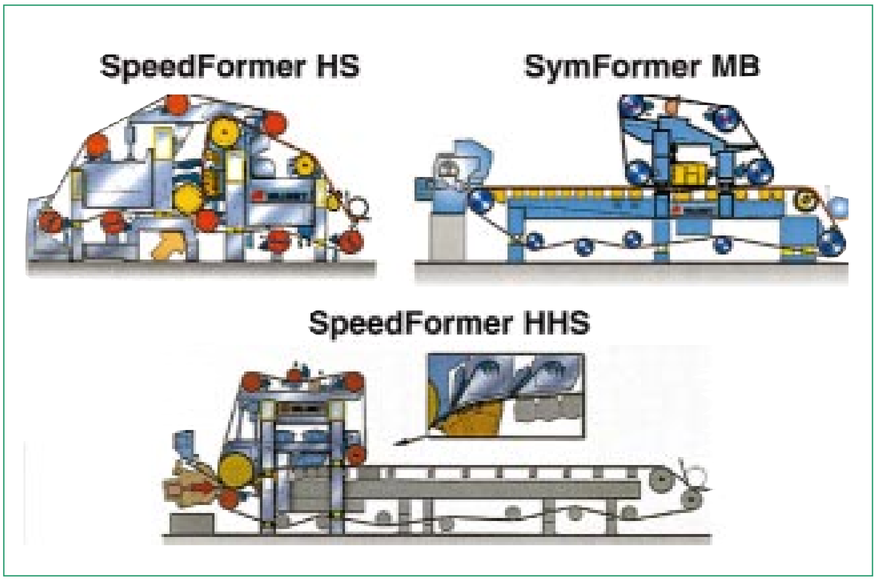
The forming section of a modern paper machine, in this case a Voith Sulzer gap former, designed to produce woodfree coated paper at 1500 m/min

TAPPI JOURNAL: *Current state-of-the-art technology for headboxes includes pressurized, high-turbulence boxes for fourdriniers with similar attributes for twin-wire formers. Are these capable of doubling capacity or will there need to be new designs?*

Beloit: First, the characterization of current headbox designs as "high turbulence" is not completely accurate. Certainly there are high turbulence portions such as the tube bank, but designs are required to deliver varying levels of turbulence at the headbox discharge. Designs are actually quite flexible in this regard.

Doubling of capacity can come from increased basis weight and /or increased machine speed. I will assume that doubling of machine speed was the intent of the question. The answer is dependent on the starting reference and will be different by grade. For example, this issue to double capacity for a board application will be much different from those related to tissue or graphic papers. A state-of-the-art newsprint machine will be designed around 6000 ft/min such that doubling capacity would require 12,000 ft/min. This will require substantial change in the entire process to achieve such speeds. All major sections of the process will be challenged and the solutions applied in various sections will impact design in other sections. Forming equipment has clearly influenced headbox design in the past and will continue to do so. Tissue machines are being designed up to 7500 ft/min today and the prospect of 15,000 ft/min will also create many challenges such that the machine for these speeds will clearly look different than what we have today. In the board grades where top speeds today are typically less than 3500 ft/min, the doubling of speed to 6000-7000 ft/min is similar to the operation already experienced for the lighter weight grades. Therefore, the headbox challenges will not be as great. Again, as in tissue and graphic papers, it is expected that forming and stock prep issues will be substantial such that headbox design may still be forced to react.

Valmet: Doubling the capacity by doubling the speed means quadrupling the internal pressure. For example, the pressures required for 1000, 2000 and 3000 m/min jets are 20, 80 and 180 psi respectively. Obviously, maintaining headbox structural integrity at higher pressures, particu-



Examples of modern forming section designs developed by Valmet for light and medium weight coated papers

larly at the slice where minutest of distortions can dramatically effect weight and orientation profiles, will not be an easy task. At some point the presently flat internal flow passages may have to be curved in some manner to better sustain high pressures. This will necessarily alter the hydrodynamics and lead to new designs. The alternative is higher consistency operation where a number of fundamental problems still remain to be resolved.

Voith Sulzer: New designs will be necessary to overcome the problems of mechanical stability and excessively high jet turbulence.

TAPPI JOURNAL: *What are the design limits of headbox technology as we push machine speeds higher and machine widths grow?*

Beloit: Machine width from a headbox design perspective is relatively easy to accommodate. There are certainly issues in geometry as forming equipment changes for width, such as larger rolls, which may affect the headbox design geometry. The headbox alone can be designed to accommodate very large widths without compromise. Speed is a completely different issue. Internal headbox pressure is proportional to the square of machine speed such that a doubling in speed results in a four times increase in pressure! Stress and deflection are critical design parameters and a tremendous pressure increase will create a significant challenge to manage these factors. Virtually all designs in use today include a free jet between the headbox and former. Managing the stability of such free jets is a speed dependent issue that will be another great challenge with increasing speed.

Valmet: Theoretically, there are no structural limits in building a pressure vessel to operate at very high flow pressures whether with flat or curved internal surfaces. In practice however, the headbox has limitations in size, geometry and weight since a headbox must produce not only a jet but conform structurally to the forming unit it serves, be fully accessible for maintenance and repair, and generally be isolated from other structures, on its own foundation. Headboxes are expensive structures and the wider they are, the more difficult and costly it becomes to maintain their dimensional tolerances and finish. At some point the shear size, weight and cost of the total installation will become prohibitive.

Voith Sulzer: One problem is simply the material used to build headboxes: stainless steel. New alloys and materials are needed. In addition, new designs will need to include more accurate means of anti-deflection.

TAPPI JOURNAL: *What are the critical limits for head box design for a high-speed machine? Control? Capacity? Turbulence as the stock exits the headbox? Maintaining stock consistency in the headbox?*

Beloit: As mentioned above, the critical issues with increasing speed will be deflection control, jet turbulence control and the changing needs driven by forming technology. It is not likely that we can simply increase speeds radically applying today's experience with headbox operating parameters, such as consistency. History has already shown us that higher consistencies have come along with higher speeds. This trend is likely to continue. The question will be the rate at which consistencies change compared to production increases. It should be noted that internal headbox hydraulic design is fundamentally the same today for both low-speed operation and high-speed operation. Internal velocities and head loss are virtually the same for a 1000 ft/min operation and a 7000 ft/min operation. The main exception to this is in the target intensity for turbulence in the discharge slice jet. As noted above, the jet turbulence must decrease with increasing speed.

Valmet: Assuming it is possible to design a structurally stable headbox to sustain very high pressures, the next problem is what to do with the increased turbulence which will be generated. Flow velocity is the most effective generator of turbulence—the higher the flow the higher the turbulence. Unfortunately, this turbulence is not always the right kind of turbulence and in many cases can lead to serious flow instabilities in the issuing jet. Even if the headbox internal flow elements were properly sized to ensure generation of useful turbulence, there still remains the much increased acceleration through the slice to contend with. New slice nozzles may have to be developed to handle this. Lastly, a jet issuing into atmosphere at 10,000 ft/min is like an explosion with an enormously high decibel level.

Voith Sulzer: Critical limits for headbox design would include accuracy of the slice under high pressure and increasingly high turbulence of the free jet.

TAPPI JOURNAL: *What other changes would impact headbox design for a very high-speed machine? Higher consistency is one obvious one, are there others?*

Valmet: High consistency is one obvious change. However, forming at high consistencies (2%-5% range) requires further study and a number of major breakthroughs before it can be extended to production of paper. Its present use is restricted to board grades with specific properties. Another change with a potential impact is new pulps such as those based on nonwood fibers, recycled fiber, increased filler and so on, in combination with the appropriate wet end chemistries used. If these pulps behave in some drastically different way compared to wood fiber pulps in a given flow regime, then different hydrodynamic principles will have to be employed for headboxes which process them.

Voith Sulzer: Higher consistencies (up to 2%) will indeed be a factor. That will require lower pressure variation at the headbox entrance or better dampening.

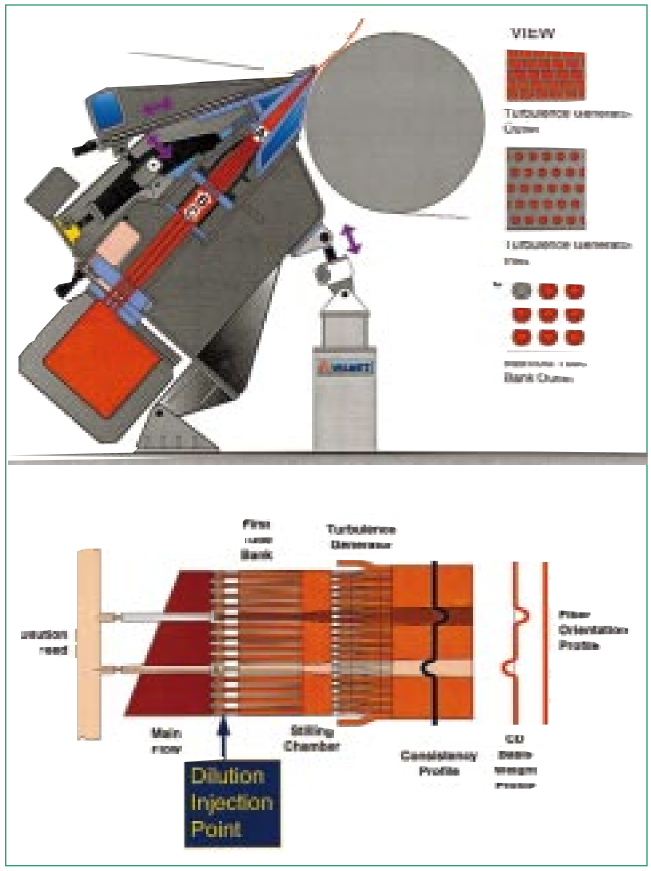
FORMING SECTION

TAPPI JOURNAL: *What are the current limits to open table fourdriniers in terms of speed? Is there enough turbulence at high speeds? What of the problems of pressure pulse? Are buildings long enough to accommodate a longer table for water drainage at high speeds?*

Beloit: In terms of the table, fourdrinier drainage is a function of both the number of blades and overall dwell time available to the sheet. However you can not drain the mat if the stock jump is so great that it's not on the table. It is well documented that drainage pulses increase with the square of the speed. At speeds over 4000 ft/min, it takes great attention to table and blade alignment to maintain control of table activity.

As we have more than enough turbulence at these speeds, the real task is to properly utilize it, keeping it under control. In this aspect, the type of macro-turbulence developed by open fourdriniers is often too much for some harder to form furnishes, actually destroying formation.

The question of length depends on what speed and weight you are referring to. However, the real question should be how effective would such a configuration be? At speeds above 4000 ft/min we would recommend twin wire forming as a way to both control the mat and induce the controlled turbulence needed for quality and productivity at higher speeds.



Valmet's "SymFlo D," an example of a newly developed headbox design using dilution control, with a detail of the flow through arrangement

Valmet: Open table fourdriniers have a number of fundamental limitations which have all but eliminated them for most paper grades produced today. A fourdrinier produces a two-sided sheet with inferior formation, usually with streaks and poor basis weight stability, all of which deteriorate with speed. For these reasons fourdriniers will be restricted to a very few specific grades and low-speed operation. The question of sufficient length in the mill to accommodate a very long fourdrinier will therefore never become an issue.

Voith Sulzer: The current limit for open table fourdriniers is now about 1200 m/min. One limiting factor is random variation of basis weight, which increases at higher speeds. Open fourdriniers simply can't handle the very high speeds. Dewatering will also be a problem and forming fabrics will have to be redesigned to handle the new demands placed on them by higher speeds.

Another concern is retention, which tends to decrease at higher speeds, although retention aids can compensate for some of that. A lot also depends on the kind of drainage forces that are involved. Drainage velocity will influence paper porosity and pinholes may become more of a problem.

TAPPI JOURNAL: *What are the current limits to twin and top-wire forming units in terms of speeds as high as 12,000 ft/min?*

Beloit: What isn't? Ceramics durability and lubrication, fabric wear resistance, structural and table alignment, speedy control response, roll balancing; everything will need to be designed to maximize up-time as the cost of being down for maintenance will rise in proportion to the machine's speed.

INITIAL ADVANCES IN TWIN WIRE GAP FORMING

As we speculate on the future development of paper machines, we should keep in mind the work that has brought us to today's technology. The 1950s through the 1970s were exciting decades for paper machine development, recalls Brian W. Attwood, owner and director of St. Anne's Paper & Paperboard, Bristol, UK, and a TAPPI Fellow.

"In the early to mid-1950s, St. Anne's Board Mill (UK), using a pilot plant installed in 1951, developed the first commercial twin wire gap former (Inverform)," notes Attwood, who was heavily involved in the research. "At approximately the same time, David Webster (Canada) was working on a type of gap former now known as a twin wire roll former and Black Clawson was developing the Vertiforma, a gap former using blades. By the early 1960s, the Pulp and Paper Research Institute of Canada (PPRIC) and Time-Life were also studying twin wire forming," he continues.

"It is interesting that at a given period, three independent bodies were, unknown to each other, developing the same process. St. Anne's Board Mill filed its first twin wire forming patent in 1952. It was from this work that APM (Australia), with Walmsley/Beloit, developed the Bel Bond former. A further development, the Twinverform unit, eventually led to the development of the Bel Baie series. Walmsley, Beloit, Black Clawson and KMW were the pioneering machine manufacturers in developing this type of equipment, with later advancements added by Voith, Sulzer and Valmet.

"Following considerable development work, the process became commercial at St. Anne's in 1958. It was used to produce a wide range of paperboard products, with furnishes ranging from 100% virgin pulp to 100% recycled fiber. Further development work carried out at the pilot plant pushed newsprint formation to 3200 ft/min in 1956 and produced three-ply kraft paper at 2000 ft/min that same year.

"Among other attempts at commercializing the process during the 1950s, the most significant was at International Paper's Mobile, AL, mill, The attempt there in 1956 to follow a secondary headbox on a liner board machine with an Inverform unit, didn't succeed. The problem was the forming wires, which at that time were made of phosphor bronze construction rather than the synthetic fabrics which are now available.

"Another interesting installation was at the Reed Paper Group Aylesford (UK) mill in 1957 where an Inverform unit was installed on a fourdrinier machine producing fluting medium. The installation, which was added to improve drainage and carry out a certain degree of reforming, can be considered to be the first hybrid twin wire forming unit.

"Like many examples of pilot plant studies, there were also significant spin-offs. One that had considerable commercial importance was the development of a compact hydraulic secondary headbox which later formed the basis of the BRDA/St. Anne's pressure former, now used on countless cylinder mold machines throughout the world," Attwood concludes.

— Don Meadows

Valmet: Not all twin wire formers are the same. Those based on blades to dewater the web will run out of dewatering capacity at that speed and even if they don't, they will produce an uneven sheet at unacceptably low first pass retention levels. Formers based on roll followed by blade dewatering will be the only likely candidates to succeed to both dewater the web to a sufficient level and to produce an even web. There will be many problems to overcome at these speeds.

The main process-related problems will be the enormous amounts of water to be handled in a confined space and short time, huge amounts of air and fiber-pumped around by the forming fabrics, and transfer of web without destroying it both within the forming section and from wire to press section. The design issues will be the mechanical integrity of the equipment, reliability and safety.

Voith Sulzer: Among the limiting factors are length of the forming zone and length of the free jet before impingement. Problems can include turbulence and air entrapment at jet surfaces, as well as mist removal. There are also a number of questions involving forming fabrics: what is the maximum operating tension fabrics will withstand?How stable in cross direction (CD) will they be? What about water splashing of fabrics and the issue of cleaning?

TAPPI JOURNAL: *Will the length of the forming section be an issue with 10,000-12,000 ft/min machines? Can the fiber mat be established in half the time? Can the water be drained from the pulp slurry through the wire at very high speeds? What happens to our current suction boxes at 10,000-12,000 ft/min? Will they function?*

Beloit: Certainly, operation at these speeds will force all suppliers to review the basics of drainage from a fundamental point of view. We will need to apply the basics of the sheet formation, consolidation, and high pressure dewatering zones in new ways to maximize the production speeds a given table length can deliver. Methods will need to be developed to increase the dewatering pressures in each area to the highest level that the sheet can withstand, while eliminating wasted dwell or transfer spans that most forming configurations contain.

We have found that mats in the newer twin wire configurations can be drained in a very short fashion. The trick may be the saveall systems to contain and direct all of this water.

Regarding suction boxes, there has been a lot of publications referring to the dwell versus dewatering pressure relationship. We will either need much longer flatbox sections at traditional vacuum levels or new ways to increase the dewatering pressures across the sheet so these lengths can be minimized. Combining the function of the press with the former may be the result, but that is the topic your next article.

Valmet: Given sufficient time there is no reason why a fiber mat cannot be formed controllably into a web at 10,000-12,000 ft/min. In forming, time means length, so the ultra-high-speed formers will be based on the

Another view on the challenge of speed

Douglas Wahren, TAPPI's 1998 Gunnar Nicholson Gold Medal awardee, has worked on the theory and design of modern headboxes. His ideas on high consistency forming and impulse drying have opened new paths to the development of faster paper machines.

Although there are problems to contend with in order to be able to produce paper at up to 4000 m/min, Wahren does not see any basic limitations in the forming section that would prevent that from happening.

By-in-large, the know-how exists to be able to handle problems of water and mist, Wahren said. Pressures in the headbox get to be fairly high, he noted, but that too can be managed and the forming section itself shouldn't have to grow much.

An absolute necessity will be to eliminate open draws well into the dryer section, he suggested. "There are reasonably well working attempts at it now," Wahren said. But, as open draws are eliminated, the press section will need to be modified to be able to dry the sheet at higher speeds.

"I think the sheet structure might actually change for the better," Wahren said. One reason for that would be better dispersion during forming, although some retention may be lost. And, because of the faster pressing, it may be possible to get two dense outside surfaces, with less denseness in the middle. That could equate to better bending stiffness for the basis weight, a prime concern in printing papers.

Of course, the issue isn't simply being able to make paper at faster speeds, it also has to be dried and wound into rolls (topics for future issues of *TAPPI JOURNAL*). The degree of automation will have to increase and more precise methods for measurement will have to be incorporated into the process, Wahren indicated.

— Don Meadows

presently known technology but with a longer forming path. There may be surprises uncovered in the behavior of draining slurries at high speeds which will require new resolutions to draining and forming a web. Most likely, the suction boxes will only be used for web transfer purposes, or not at all. The same is true of suction rolls.

Voith Sulzer: The length of the forming section itself is not an issue. Sheet formation in half the time is possible. Current suction box designs, however, are not suitable for very high speeds.

TAPPI JOURNAL: *Are current wires useable at double current machine speeds? If not, what will need to change?*

Beloit: Fabric life is a function of its material of construction and the percentage of time that it is being dragged over a wear surface. Higher speeds and longer forming zones both imply that materials with a greater wear resistance and a greater tension strength will be needed to support the prolonged operating up-time and increased drive tensions that fabrics on these formers will demand.

Valmet: This remains to be seen. Obviously drainage, cleanliness and windage will become major problems to be resolved. Guiding and generally keeping the fabrics safely on the machine will be another. Centrifugal forces will become much more prominent from point of view of tensioning of the fabrics and from point of view of added dewatering forces which these will provide.

Voith Sulzer: No, current wire designs would not work at twice today's speeds. They will need to hold up to higher maximum tension and have more cross direction stability. They will also need to splash water less and resist wear better. A further requirement is better uniformity in drainage resistance.

TAPPI JOURNAL: *What wire guidance problems could occur at 10,000—12,000 ft/min?*

Beloit: Response. Both over- and under-response of a guide at these speeds drive a fabric off a forming loop in seconds. Soft response guide systems as used today will need to be replaced with smart positive responding units. Additionally, special attention to roll alignment and cover uniformity will be critical.

Valmet: Wire guiding for 10,000—12,000 ft/min operation will have to be much more accurate and with a much faster response than at present. Safety will be another aspect to be addressed. A fabric running off the machine at these speeds would cause major harm both to the operator and to the equipment, therefore a new fail-safe system would be required to ensure this never happens.

Voith Sulzer: A suitable control system should be able to manage potential guidance problems.

TAPPI JOURNAL: *Will current couch roll technology work at these speeds? Can rolls drive the wires at these speeds, or will direct wire drive be needed?*

Beloit: You are already seeing the gradual elimination of the traditional couch roll from conventional forming configurations. High vacuum flatboxes can do the same job as the couch while both saving energy and reducing capital investment required. Any roll with a high degree of wrap could be used to drive the fabric. The former of the future will need to be designed to support this need.

You will likely see suction rolls become an integral part of the forming section where low vacuums and high flows rates are required.

Valmet: A couch is generally an expensive and an inefficient dewatering component in the former. The higher the speed, the more ineffective it becomes because of the diminishing dwell time for dewatering to occur and because a large portion of installed vacuum capacity is simply used to evacuate air from the holes and in the process, to create noise. It will therefore inevitably be replaced by something cheaper and more effective, not to dewater the web, but to transfer it onto the right wire at point of separation. There should be no difficulties in driving the wires through the rolls provided their path geometry excludes runs which produce differential displacement between wires and adversely affect both web quality and wire life.

Voith Sulzer: Current technology has been proven at up to 2200 m/min on tissue machines. Some modifications will be necessary, but rolls can drive the wires. TJ

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