THINKING THIN?

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ABSTRACT

Markets drive us to ever thinner webs to reduce material costs and waste going to the landfill. The challenges for running a lighter basis weight or thinner caliper are at least as difficult for web handling as they are for web manufacturing. However, these challenges may not be as familiar as more commonly known machine limitations such as width or speed. Because they are not as familiar, they may catch us off guard. The challenges described in this paper include: wrinkling, air entrainment, tension control, roller design, problems associated with profile variations and others.

PREDICTIVE PROPERTIES

Many would have you believe their grades, processes or equipment are uniquely difficult. However, process troubles can often be anticipated by knowing key web material or physical properties. For example, slippery materials are difficult to wind without telescoping. This difficulty is shared by materials as diverse as low COF films and glossy magazine paper. Conversely, materials with a high web-to-web friction may be difficult to wind without vibration or out-round-rolls. This winding difficulty is shared by materials as diverse as tissue paper, kraft sack and nonwovens. Other predictive material properties and associated problems include: web breaks and low MD tensile strength, speed/draw control and high MD modulus, wrinkling and moisture/temperature expansion coefficients and so on.

EVER THINNER

There is one web property, however, that is continually being pushed to the limits and beyond [1]. That is the drive to ever thinner materials. There are strong economic incentives to make lighter webs as long as they can serve the same duty as heavier grades do. First, raw material costs are reduced. Second, storage, handling and transportation costs are reduced. Finally, the insult to our environment is reduced. While many associate the drive to thin with packaging grades, you will find that everywhere customers and suppliers alike are requesting and designing ever thinner versions of their products. Cardboard, car body panels, clothing, newspaper, and roofing are just a few examples of webs that have seen weight reductions in recent years.

Unfortunately, many companies have found themselves in trouble when they tried to make thinner grades. While the details vary considerably with the situation, the roots are often the same. Product developers designed grades for end use, but without regard to processing or handling. Similarly, process developers felt their job was done when they successfully extruded, coated or otherwise formed the new grade, but failed to fully consider downstream handling and converting issues. In short, neglect of web handling has caused many novel grades to struggle and even fail due to high waste or other inefficiencies.

CALIPER AND OTHER PROFILE VARIATIONS

The fussiest customer for level caliper is the winder [2]. It may complain about variations that are too small to be measured by conventional online gauging systems or test lab measurements. It will voice its complaints with defects such as caliper ridges. If the ridges are severe enough, the pressure could be as much as an order of magnitude higher there. This will increase the risk of defects such as blocking. Also, the web may be stretched into bagginess over gage bands that are a fraction of a percent larger in diameter. Abrupt variations in caliper may cause defects such as corrugations, even if they are modest in magnitude. These defects associated with caliper variations across the width are merely illustrative. The list is much longer.

Surface winders, particularly those which bear the weight of the roll on a drum such as the two-drum, have the greatest intolerance for caliper or weight variations. The winder 'difficulty curve' indicates this intolerance increases as the finished roll diameters are pushed due to increasing nip pressures [3]. This has led the paper industry to ever more sophisticated winding equipment capable of finely controlling the balance of roll weight born on the external drum nip versus the internal core nip. Even so, these winders require ever more uniform paper when diameters of fine paper are pushed to 50 inches and beyond. The same efficiency motivations for pushing roll diameter are seen in the other web industries as well. They also are experiencing the same challenges.

The large roll challenges are increased when the caliper is reduced by design. This is because the absolute variation tends to be constant so that the relative error increases. The variation may be with gap uniformity across the width of a former. In slot dies, it is very difficult measure much less achieve a 10 micro inch gap uniformity [4]. On a 0.010" gap, that is a theoretical 0.1% variation. The real error could be more and could even cause the oscillated winder a problem. However, it is difficult to measure caliper variations this small. We seldom guarantee lab test measurements of caliper to be better than 0.000,05" which is more than 1% of the thickness common paper grades [5]. This same test is used in other industries, such as film, where the web's nominal thickness is even less. Online scanners are even less accurate. As caliper is reduced by design, the relative variation and all associated problems are expected to get worse. Gage variations caused by printing ink can get acute as the base web gets thinner.

Similar problems are seen with bagginess. Slight variations in thickness can cause changes in the temperature or moisture profile of the web as it is being formed. The cumulative effective of these errors, which get worse with reduced gage, is increased trouble maintaining web flatness. However, we don't need an imperfect web to cause problems. We can also have an imperfect machine.

WRINKLING

Thin webs are prone to wrinkling because the buckling resistance goes down with the cube of caliper [6]. Thus, a 40 gage film is not twice as wrinkle prone as an 80 gage film. Rather, it could be 10 times as wrinkle prone! Few process engineers and even fewer product developers, marketing directors or managers appreciate just how much harder it will be to handle even a slightly thinner material without wrinkling. Thus, the expectations and excitement of a new grade can be replaced by disappointment and frustration as waste rates remain stubbornly high.

Sometimes the wrinkles are generated by the web manufacturing process itself. For example, coating or printing on paper; oven drying, curing or metalizing of film are just a few examples of expansive processes which can generate MD trough wrinkling. I have seen many processes that were unable to run thinner grades without wrinkling because of the expansive insult of water, solvents or heat addition. We already know that not only is the thinner material less wrinkle resistant, it also has a higher relative nonuniformity. What we must now also consider is that the thin web takes on relatively more heat/moisture/solvents than thicker grades, increasing the risk of wrinkles in yet another way. This often leads to finger pointing at the raw material supplier and/or machine designer when the largest factor was the very design of the product or process itself.

Thin materials are also more demanding of certain aspects of mechanical maintenance. In particular, roller alignment and diametral precisions become much more important. For example, a thick material may take a 20 mil bulge or groove on a roller without wrinkling, while a thin material may only allow a 2 mil diametral variation. I have seen many materials that were so fussy that tails could not be conventionally taped to the cores without starting a wrinkle at the tape patches. I have seen more than a couple materials that were so fussy that the gaps or overlaps in the seams in the fiber core were enough to trigger a defect.

A generic treatment of many types of wrinkling is to use spreading devices such as concave, bowed or expander rollers [7]. However, thin materials not only need more spreading attention because they are more wrinkle prone, they are more difficult to apply spreading to. This is because most spreaders require traction to operate, which in turn requires tension, which is less on thin materials. Without tension, spreaders can't grab onto the web very effectively.

AIR ENTRAINMENT

If these challenges weren't enough, we have even more if we try to run thin webs at high speeds. Since many of our formers can run thin materials faster, we are enticed by the productivity possibilities. When we try increasing speeds, however, we may be thwarted by air entrainment between the web and roller and between the layers of the wound roll. Though both share many similarities, the resulting problems and treatments are somewhat different.

As a machine is sped up, more and more air is brought in between the web and roller. The amount of air brought in depends on several factors including speed, web tension, web bagginess and roller diameter [8]. The result is that the web will lift off the roller given enough speed. Obviously, control of tension, web path and many other factors is then lost. The treatment is to either roughen (moderate speeds) or groove (very high speeds) the roller surface. The Catch-22 is that while thin materials need more air handling treatment because their tensions are less, wider grooves will tend to make wrinkles on thin materials. (Spiral grooving does not spread as widely believed.) A starting point for maximum grooving width is no more than 10-20 times the minimum web caliper. This makes the grooves so narrow on thin grades that they resemble scratches. Not only are micro-grooves more costly to machine, they are also harder to maintain, especially in the presence of adhesives, coatings and paper dust.

Similar challenges are also found when winding thin materials. Air brought into the wound roll can cause several difficulties. First, air entrained into the roll loosens the wind. Second, the air can outgas during storage causing the roll to buckle and collapse. Third, at very high speeds the air can cause the outer layer to lift off of the roll, degrading edge quality. The most common treatment for air entrainment during winding is to use a layon or nip roller. Unfortunately, some air will still be brought into the roll. It is then possible for the air between the layers to collect behind a nip and eventually burp through the nip as a wrinkle. Thus, the same nip roll that provides the beneficial reduction of air entrainment is also responsible for the undesirable bubble behind the nip. Sometimes this can be solved with a 'burping roll' grooving pattern of the drum or layon roller. This unique groove is wide, shallow and has but a single start. The groove allows the bubble to bleed through layers underneath the nip once per revolution. Though it does let some air into the roll, the single start minimizes the amount. The tradeoff is slightly more air entrainment for a reduction of the troubles of the bubble of air which is inevitably entrained.

TENSION CONTROL

The primary task of any machine's drive is to control tension. However, thin materials present an extra challenge for the drive system in two ways. First, the absolute tension is lower. Second, the tension range and tolerances may be tighter. A general guideline for many web materials is that tension should be between 10% and 25% of the MD tensile strength. However, the appropriate tension for very light materials may be between 5% and 10% of strength. Note how both the value and range are reduced. Now imagine holding these low tensions to within a tolerance of 10% of the setpoint. You will quickly appreciate that a drive may have to effectively hold tension excursions to less than 1% of an already low tensile strength. This may be just a couple of pounds on a wide machine, to just a few ounces on a narrow machine.

Many older machines and even some new ones do not have the mechanical and control finesse to be able to hold low tensions consistently. These tension control shortcomings may be the result of conscious design choices for an originally specified purpose. Sometimes, however, the shortcomings stem from lack attention to detail during the design process. An example here is oversized pneumatic devices, such as unwind brakes which result in low control pressures, or oversized motors which result in low armature currents. Another example would be to use an excessive number of overly large idler rollers which would cause large inertial tension upsets during speed changes. Unfortunately, it can be difficult, often to the point of impracticality, to rebuild a machine to handle low tensions properly. At the very least the drive controls may need rework or upgrading, if not the mechanicals as well.

ROLLER DESIGN

Rollers are the building blocks of web machinery. There are many criteria for sizing rollers, some of which are tension sensitive. If tensions are reduced, then tension component of deflection is also reduced, perhaps allowing the roller diameter to be reduced one size. When tensions are reduced, the relative effect of inertia increases. This means greater challenges in changing speeds gracefully. When tensions are reduced, the relative effect of bearing drag increases. This means greater challenges in maintaining tension at any speed. Thus, the primary mechanical difference between heavy and light web machines is in the rollers. As web thickness and thus tensions decrease, the rollers become more delicate. Bearing friction may need to be reduced by, for example, changing from grease to oil lubrication. On heavy webs, we can over design rollers without causing tension issues for the web. As webs get more delicate, the window between too big and too small gets much narrower.

LET THE WEB TELL YOU

The results of running a thin web on a brutish machine depend on the circumstances. If the web is brittle, such as paper, you might expect an increase in web breaks. However, even a ductile material will break if the drive allows the web to momentarily go slack. If the material is stretchy, an increase in tension wrinkling might result. If the process involves lamination, you might expect that curl and flatness might be more inconsistent. Printing registration tolerances may degrade. Guiding and wound roll edge quality may suffer. Tension control is vital for web processing and handling and no where is tension control more challenged than on thin grades. Increased waste at the winder due to bagginess, blocking, corrugations and ridges may be clues to a machine at the edge of its envelope.

We are obliged to make a good effort when we run a thin material on our old machine. If we are successful, the range of the equipment has been extended. This will allow a wider range of products to be made and markets to be served. If we are not successful, it is possible that a modest rebuild might be all it takes. In all cases the web will let us know when our efforts fall short. It will break, bend or jump. It will be flighty and erratic. If it doesn't end up in the waste bin, it will let you know via a call from the customer.

Changes, whether they be of lifestyle or web process, can be desirable in the long term. However, we must be prepared for the difficulties that these changes cause in the short term. To improve our chances of success, we should arm ourselves with as much knowledge as possible. We should expect a period of difficulty where new problems must be solved before the benefits are seen. Losing a few pounds of web basis weight or a few points of gage can be just difficult as taking a few pounds or inches off of one's middle. However, the result can be just as rewarding.

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