Elevating Production Efficiency, Part 2

Spaghetti with Rubber Bands

Workhardening: You don't need an electron microsope to observe polymer reorientation - a platter of pasta will do. Under stress, some bonds between noodlelike polymer chains break and mesh begins to elongate. Additional new bonds form between now-more-parallel polymers, creating a stronger mesh strand.

Last time I introduced three concepts that affect our ability to get and hold—to *stabilize*—mesh tension: elongation, retensioning and workhardening. You'll recall we established a mesh-tension goal, to obtain and stabilize high tension, but turned right around and stated flatly that mesh is, by nature, *unstable*.

This month, we'll demonstrate how the three concepts just mentioned help resolve that contradictory state of affairs. But first, I've got to define some terms: What do we mean by stable? And why is mesh unstable?

Don Newman, president of Stretch Devices, is one of the industry's leading advocates of on-press production efficiency—primarily via the virtues of elevated screen tension. Here is the continuation of his comprehensive analysis of the subject, stripped of scientific jargon and mathematical formulae and revealed as a set of simple concepts.

Let's take the last first. Mesh is unstable for two reasons. For one thing, it's elastic. We can illustrate this using something that arrives at your door everyday with your newspaper: a rubber band. If I stretch my rubber band out and let it go, it appears to snap back to its original shape. Mesh behaves in similar, but less exaggerated fashion. If stretched on a retensionable frame or stretching machine, it lengthens, but when pressure is released it appears to shrink back to original size. We call such dimensional recovery *memory*, because each object appears to remember it's original shape. Traditional thinking about mesh has assumed that mesh instability is due to its elastic properties alone. If we stretch our rubber band just enough to keep it from sagging, it is, of course, easily bent out of line or deflected. If we pull the band taut, you know what happens. It offers resistance to our downward pressure. This is the classic argument for high-tension screens: those more tightly strung exhibit less screen deflection when the squeegee displaces the mesh. As a result, there is far less image distortion.

While there is nothing wrong with that argument (I intend to expand on it in a later installment), it's not the whole story behind mesh instability.

A Slight Case of Amnesia

On more careful examination, we see that our rubber band's memory is not as perfect as we thought. Lay the rubber band out and measure its length. Now stretch it over an object large enough to highly tension the band, and leave it for a while. Later, when it's removed, your second measurement will reveal the band is now longer. (Ours lengthened by a full quarter inch.)

We may observe the relationship between screen tension and elongation by making two marks on a piece of mesh prior to stretching it. A tension meter placed on the mesh after tensioning will show the tension level falling as the mesh, like the rubber band, begins to relax. The marks will grow farther apart as the tension on the mesh drops. (Mesh, in fact. Elongates approximately 1/64 inch per foot, per 7-Newton tension drop.)

When mesh "loses its memory" or elongates, increase in the stencil size is not just the temporary sort we observe when it is deflected by the squeegee, but permanent. And as the pencil marks grow farther apart, so do the elements of our stencil image.

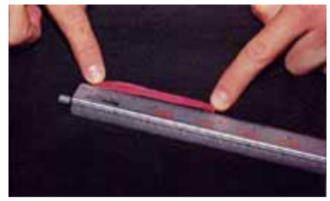
So to answer our first question, high tension alone isn't enough. Mesh is stable only when elongation has (for all practical purposes) been defeated, creating an image area as rigid and unchanging as possible.

Unfortunately, mesh elongation is a much tougher nut to crack in practical terms. If, for example, we took an N300 mesh and cranked the tension up to 50 Newtons immediately, the elongation that would occur afterward as the mesh relaxed would create severe miss-registration problems during printing. That doesn't mean you can't tension N300 mesh to 50 newtons, it just means you have to do it *properly*. But before we can properly put elongation in check, we've got to explore why it happens. As in last month's installment, we'll find our answers at the filament level.

Under a powerful microscope, what appears to us a solid, cylindrical object—the mesh filament—is actually a collection of millions of molecules arranged in chain-like structures called polymers. In a piece of new mesh. these are randomly (or only partially) oriented to one another, resembling a plate of spaghetti. The polymer chains are bonded to one another where they intersect. Those bonds give the mesh what strength it has and, in simple terms, that strength is limited by the number of bond sites between chains.

When we stretch the mesh, it's like taking a fork and pulling the spaghetti from opposite ends. What happens? First, the intersections between the spaghetti strands are disturbed. In like manner, by stretching mesh. We begin to break bonds between the polymer chains. The mesh is actually coming apart at the seams—some of the bonds between polymer chains begin to disengage and the strand or filament begins to grow in length. The net result is a larger piece of mesh, overall, and explains why we experience that typical drop in tension after initial stretching.

Measurable memory loss: Beore and after (below) shots confirm permanet elongation.



Becoming "*forgetful*": Highly stressed over time, both rubber band and mesh filament relax or elongate and become incapable of full recovery to size.

Key word is "*tends*": Like the rubber band, the individual mesh filament tends to recover its original shape and size when deflected.

Self-repair Feature

We would also have a considerably weaker piece of mesh were it not for the fact that the mesh has a remarkable ability to heal itself and, in fact, to get stronger. As we apply increasing force to the mesh during stretching, energy is created sufficient to break these molecular bonds between the polymer chains. When we stop increasing the force, that same energy is available to fuel the creation of new bonds. Experimentation has shown that in as little as ten minutes (though up to one hour is preferable), polymer chains within tensioned mesh can re-bond. This allows us to retension the mesh (this month's second concept) without weakening it. As a result, the retensionable frame has, in the last decade, gained wider acceptance as a means to raise tension to higher levels.

And indeed, that understanding is correct as far as it goes. But that's not the whole story. Endless retensionings of the mesh, in fact, do relatively little toward our stability goal until we begin *printing* with the mesh. We can demonstrate why by applying our fork once more to our plate of spaghetti. Notice that the individual noodles begin to reorient in the direction of the applied force. This directionalization is similar to what happens when we begin to work the mesh with the squeegee. The continuous stressing of the mesh as it deflects with each pass of the squeegee results in our third concept, *workhardening*. Under stress the polymers become increasingly reoriented in a more parallel fashion and, as they do, our molecule chains not only can replace broken bonds with new bonds, but actually form *additional* bonds. The result is a stronger mesh, because filament strength increases with the total number of bond sites. And a stronger filament better resists elongation even at much higher tensions.

Workhardening, to a small degree, occurs during retensioning. But it is the stress of printing that primarily accomplishes it, in conjunction with an occasional retensioning between print runs. That's why, in practice, I recommend that after as few as one to three retensionings, the mesh should be coated, exposed and used in production. But care should be taken to avoid jobs that require extremely close-tolerance registration during the first one or two print runs, because the mesh does continue to elongate somewhat during the process of workhardening.

Like Fine Wine

Polymer reorientation and additional bonding continue as you print, improving the fabric as it ages. As mesh is reclaimed, retensioned and then used on press *repeatedly*, tension loss during even the lengthiest print runs can be reduced to as little as 1 N/cm, bringing extraordinarily fine butt-registration or process work within the reach of most printers. In the process, we draw very near that goal we set last month, to turn our mesh variable into reliable constant.

In my lectures, it's often at this point that someone asks: *If we keep retensioning do we get to the point where there is no change?* If they mean no *further elongation*, the answer is no. Truth is, a "constant" represents a theoretical ideal. And, like most things in the "perfect" category, constant tension (*absolutely* no change) is a practical impossibility. But that's in no way a piece of bad news. For screen-printing purposes, at higher tensions the variation represented by the loss of a Newton or two rarely makes a visible difference in a printed image. So *practically* speaking, the answer to that question is: *we're already there*.

Next time, I'll detail the role of elevate tension in the mesh-stabilization process, explain practical steps to attain it, and pose the ultimate high-tension question: "How high is high enough?"

Making it Measurable

When you make a trip to the shoe store, you could, of course, just start trying shoes on in hopes of finding a couple that fit. But for buying shoes—and tensioning screens—such a hit-and-miss process isn't very efficient. Shoe people have developed a handy device (incidentally, can anyone name this device?) that measures feet, based on an arbitrary standard—a list of shoe sizes corresponding to incremental increasing lengths. The tension meter is to mesh tension what that device is to shoes. Its arbitrary numerical standard is Newtons per centimeter (N/cm). And yes, it's named for that famous early science pioneer. Sir Isaac, whose observation of falling apples prompted his discovery of gravity.

The now-familiar device measures mesh deflection over a centimeter of length, with its numerical N/cm designation corresponding approximately to the number of pounds of force per linear foot of mesh at the screen frame perimeter listed in the following chart.

Forceful statement: A screen tensioned to 50 N/cm easily holds the weight of a grown person.

N/cm =	lbs. per linear foot
3.5 =	25
7 =	50
14 =	100
28 =	200
56 =	400

Thus, mesh mounted on a frame two feet wide and three feet long and tensioned to 56 N/cm would be subjected to 2+3 total feet X 400 lbs. per foot, for a total of 2000 ft./lbs. of force. To put what the tension meter tells us in proper perspective, one N/cm does little more than overcome gravity's attempt to make the mesh sag, but because force doubles as the number of N/cm doubles, a 50 N/cm screen easily supports the weight of a grown person.