Air Cylinder Allows Ultrafine Tension Control

Mark Gaberman, Airpot Corporation, Norwalk, Connecticut
Victor Wild, Biogeneral Fiber Technology, San Diego, California

An air cylinder provides smooth operation and controls tension to less than 0.5 gram to produce special fiber sensors that are as small as 0.0013-in. diameter.

Applying tension is a very common requirement in a variety of manufacturing operations. But sometimes high precision is needed in the control of the tension. For those situations, a nearly frictionless air cylinder can actually eliminate a traditional spring-loaded tensioner and provide a level of control not possible with ordinary air cylinders. In the spooling operation at Biogeneral Fiber Technology (San Diego, CA) this has been done with repeatable control over the tension in a closed-loop system to less than 0.5 grams, with a response time constant of less than 0.1 second.

Winding operations are one example where tension is used to

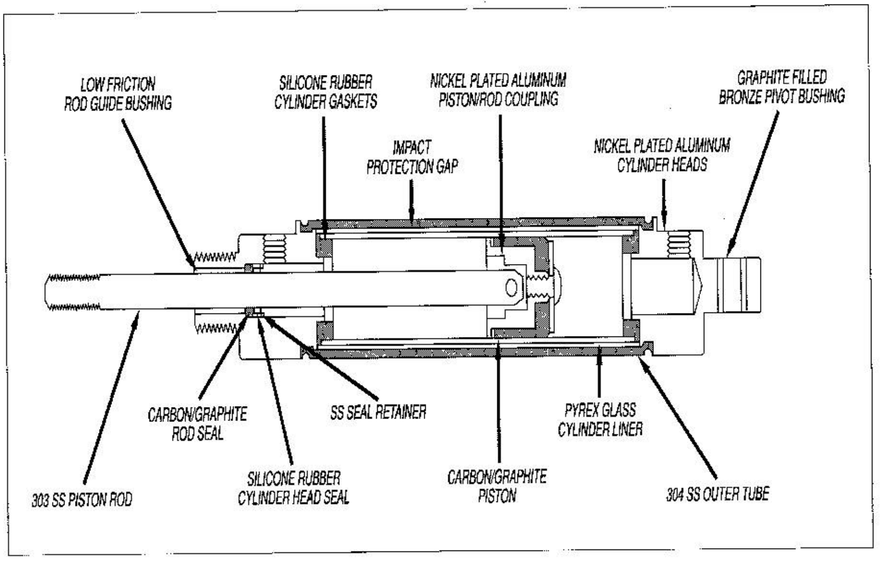

Figure 1. Cross Section of Airpel.®

control how a material is wound onto a reel. If the material is large copper cables, the tension requirements may not be that severe. But for very small diameter or fragile materials, controlling the tension is critical. Otherwise, the material can stretch, break, or be wound with uneven tension.

Biogeneral Fiber Technology manufactures nano-technology fiber sensors. These sensors consist of long strands of material with special coatings, used in medical and other high specification applications.

One of these fiber sensors, for example, consists of a 0.0013-in. diameter silver wire that is coated with a proprietary elastomer. This sensor is threaded into the human blood stream where it can monitor blood pressure, acidity, oxygenation, temperature and carbon dioxide. It is amazing technology, but very difficult to manufacture.

Biogeneral's manufacturing system involves the spinning and drawing of fiber sensors. Fiber emerging from an extruder is first drawn down by traction. A laser measures the fiber diameter and is used in a feedback loop to control the tension.

A heater is often used to align the molecular structure of the polymers to increase tensile strength and flexibility. Tension is measured after this heating process and just prior to achieving the final desired fiber diameter. Feedback from the tension measurement apparatus and another laser are again used to control tension.

Finally, the finished fiber is wound onto a series of spools, whose tension is controlled independently to customer specifications. This is done to match the end-use equipment requirements for tension consistency and payout velocity.

In most applications such as this, tension is achieved by applying force with a spring-wound dancer arm. This consists of a wheel attached to a spring, which moves up and down in response to changes in force. Variations in line speed, wheel size or fiber size all drive changes in the tension on the fiber.

The goal is to provide a constant tension on the line. The dancer arm effectively dampens variations in force to even the applied tension. Changing the overall level of tension, however, usually requires a hand adjustment of the spring loading.

For the manufacture of fibers, such as those produced by Biogeneral, much more precise control of the manufacturing process is required. In particular, the fiber tension needs to be adjustable from 5 to 150 grams with an accuracy and repeatability of 0.5 gram. To obtain this precision, and to increase the versatility of the fabrication line, Biogeneral decided it needed a computer-controlled, closed-loop feedback system to automate adjustments in tension.

First, the shaft of the dancer arm was augmented with an optical encoder to provide highly accurate positional data. Using internally developed algorithms, the position of the shaft was first used to control the driving motor speeds in a closed-loop system.

But problems were immediately apparent; the control system was unstable. The dancer arm oscillated back and forth, while the computer struggled to adjust the tension. For the most part, this was caused by the low inertial mass of the fibers, whose

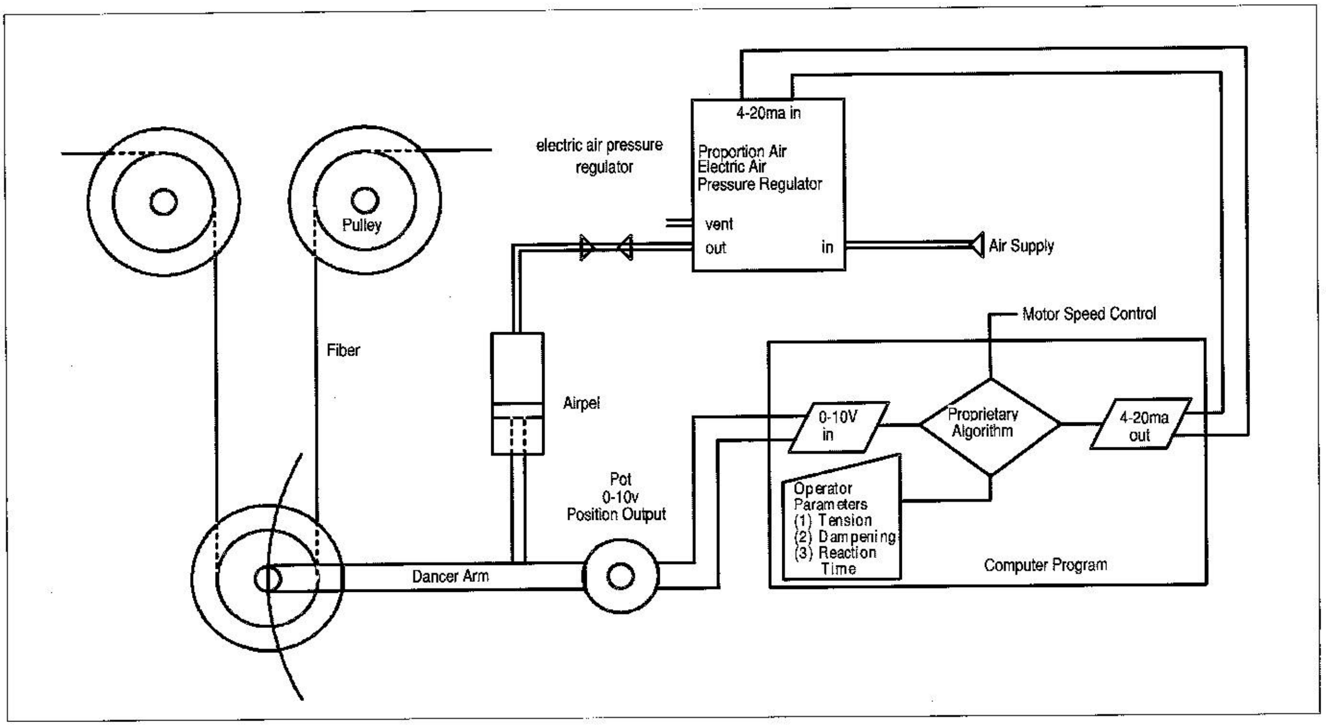

Figure 2. *Biogeneral Tension Control System.*

tension the dancer arm was trying to control. The result was uneven tension application, fiber stretching, and worse, fiber breakage.

The solution was to replace the spring with an air cylinder. An ordinary air cylinder would not do because most use elastomeric (rubber-like) seals that produce jerky and erratic motion. These devices cannot achieve the precise and repeatable force needed for this application.

The cause of the erratic motion in ordinary air cylinders is stiction, which is the tendency for a cylinder to stick in the initiation of movement, or during continuous movement. To overcome this, "anti-stiction"® technology provides an ultralow friction air cylinder, called Airpel®.

Airpel is constructed with a graphite piston, custom fitted inside a precision Pyrex® glass cylinder (*Figure 1*). The fit is designed to produce a small 0.0005-in. gap between the piston and the glass cylinder so that when pressurized, the piston is surrounded by a cushion of air. The result is an ultralow friction device with virtually no starting friction or running friction.

By eliminating stiction, Airpel allows a high degree of control over the force that the air cylinder can apply. This is exactly what was needed for control of the dancer arm.

Figure 2 shows the configuration of the Biogeneral tension control system with the Airpel cylinder replacing the spring-wound tensioner. Control of the system is similar to the spring-wound system, except that the system is now stable. Tension is controlled through a combination of motor speed control and adjustments to the cylinder air pressure.

If you found this article useful, circle 304 on the inquiry card.