High Performance Computing and Competitiveness

Grand Challenge Case Study

Spin Fiber Faster to Gain a Competitive Edge for U.S. Textile Manufacturing

Council on Competitiveness

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Spin faster and take market share" could be a motto for success in the U.S. textile fiber industry. Yet efforts to increase the speed of spinning fibers have been stalled for about the last 30 years because of technical problems widely considered to be intractable. In recent years, U.S. producers have continuously lost major market share as other countries have competed with the benefits of lower labor costs, lower environmental standards, and lower-valued currencies. Dramatically more capable high performance computers may offer a way for U.S. producers of synthetic fibers to gain market share. Computing innovations could substantially increase the productivity of U.S. plants by enabling them to spin fiber faster than can be imagined today.

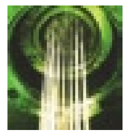

Figure 1 Courtesy of the American Fiber Manufacturing Association

U.S. Industry Faces Global Competitive Challenge

The U.S. textile industry, although still the country's largest manufacturing employer with nearly half a million workers, has remained in crisis mode since the late 1990s. Declines in the industry's employment are projected to continue throughout the next decade.[1, 2] The market share of China and the rest of the world has jumped, while U.S. textile employment and shipments have slumped badly. Since 1997, more than 250 textile plants in the United States have closed, and more than 200,000 U.S. textile workers have lost their jobs.[3] According to a recent U.S. Department of Commerce Study, "China is expected to become the 'supplier of choice' for most U.S. importers (the large apparel companies and retailers), because of its ability to make almost any type of textile and apparel product at any quality level at a competitive price."[4]

There are several reasons behind these losses to U.S. competitiveness. Essentially the same process technology is used in plants around the world. However, manufacturers outside the United States pay their workers a fraction of U.S. salaries and are able to avoid the costs of complying with the more stringent environmental standards of the United States. In some cases, these manufacturers are able to market their products at very low prices in the United States due to the steep declines in value of their currencies against the dollar that occurred in the late 1990s.[5, 3]

As an alternative to competing on wages, environmental standards, and exchange rates, U.S. textile producers may look to find a competitive edge through productivity gains driven by technological innovation, as they have in the past. Advances in high performance computing may help level the playing field and allow U.S. textile manufacturers to regain a competitive advantage—at least in some areas.

Focus on Synthetics to Regain Market Share

Synthetics, which account for more than half of all the fiber sold worldwide, are expected to dominate future growth in textiles.[6, 7] Given this area of expected strong growth, it appears particularly important to focus on ways to increase U.S. competitiveness in manufacturing synthetic fiber. Furthermore, innovation has long been the hallmark of the manufactured fiber industry, as scientists have discovered ways to create synthetic fibers with many new and highly valued applications in numerous industries.[8]

Spinning Synthetic Fiber a "Logistical Nightmare"

Nylon and other synthetic fibers, such as polyester, acrylic, polyolefin, and spandex, are produced from chemicals made from refined petroleum or natural gas. The fibers are created through an extrusion and solidification process called "melt polymer spinning." The polymer used to produce the fiber is melted into a thick viscous liquid, similar to the consistency of cold honey, and stored in large overhead vats holding approximately 100 thousand gallons each. During the extrusion process, the hot liquid is forced through tiny holes in a device called a spinneret, which resembles a bathroom showerhead.[9, 7] Figure 1 shows a spinneret in action.

The vats and spinnerets are typically mounted several stories above the floor of the production plant. As the hot liquid is forced through the nozzles of the "showerhead" spinneret, streams of polymer fall through air, cooling and solidifying into a synthetic fiber, such as nylon, as they descend. The fibers are automatically wound onto bobbins as they approach the floor. As one expert noted, it's a "logistical nightmare." If the fiber is pulled too fast onto the bobbin, it will break. People are constantly monitoring the process, grabbing the end of the fiber when it breaks and putting it onto the bobbin.[9]

Increase Spinning Speed: The Answer...and the Problem

As an industry representative noted, "The faster you can get the fiber, or thread, on the bobbin, the more money you make." Speed enables getting more fiber out per unit cost investment in the plant, and fiber-producing plants cost hundreds of millions of dollars.[9]

One of the limiting factors to spinning faster is the need to produce fiber that is uniform in color, thickness, and tensile strength. As speed in the spinning process is increased, turbulence around each stream of falling polymer increases. The nice regular stream lines get snarled and confused—they are no longer steady, but erratic. In essence, the flow gets uglier with increasing speed, and the ability to control the process and to produce uniform fibers declines.

Historically, the reaction to the problem of turbulence has been to slow the speed of spinning. In the early days, the process would take place very slowly—inches per second—in order to maintain uniformity. Speeds of up to approximately 200 miles per hour were realized about 30 years ago. Since that time, there have been no major advances toward increasing speed. The increases that have been achieved have been incremental and based mainly on empirical trial-and-error approaches.

"Because of turbulence," an industry expert explained, "we haven't been able to improve the speed in many, many years. We haven't been able to get any better, no matter how hard we've tried. A whole generation has the mind-set that it is impossible to go any faster."[9]

Spinning Fiber Faster—A Grand Challenge

The U.S textile industry faces a significant grand challenge: Better understand the turbulence created in the spinning of synthetic fibers in order to increase the spinning speed without damaging the fibers. The problem of turbulence—the major impediment to spinning fiber faster—has been called the most difficult problem of applied mathematics. As Dr. Alexandre Chorin, a senior scientist at Lawrence Berkeley National Laboratory and a prize-winning applied mathematician noted, "The basic equations that describe turbulence are well known and simple, yet their solutions are incredibly complex, and the computing power needed to find them transcends any imaginable computer." What makes the problem so complex, he said, is that it is a multidimensional problem containing many different scales of motion that are all coupled and interacting.[10]

It is not just a mathematics problem. It is also a computational fluid dynamics problem because of the central role played by turbulence as the fluid streams through air. It is a molecular structures problem because it is necessary to know how fiber is affected at speeds of more than 200 miles per hour. It is a physical properties simulation problem because of the numerous parameters that could affect the properties of the fibers at faster extrusion rates. It is a scaling problem to uncover the relations between motions on different scales. It is also an optimization problem. For example, there might be 30 different designs for spinneret nozzles. Some might be better at speeds of 300 miles per hour, some better at 400. Without exhaustive testing, the optimal design might be missed. It is a data management problem, a computer science problem, a visual modeling problem, and a telecommunications problem because of the need to transfer high-resolution images among researchers. And it is a testing problem. Without high performance computing, the need for physical testing would be so large, costly, and time consuming as to be both impractical and uneconomic.

Successfully solving such a multidimensional problem requires development of new algorithms and models, specialized software, and dramatically more powerful computers to run the models.

Economic and Competitiveness Benefits

Slowing, or even reversing, declining market share in the textile industry is a tall order. Dramatically more powerful high performance computers may provide a technical basis to do just that.

Solving the problem of turbulence in the fiber spinning process could allow a breakthrough in process speed without jeopardizing fiber uniformity. This advance could make a real difference to an extremely important, lynchpin segment of the industry—the synthetic fiber segment. Moreover, having a ready supply of high quality, domestically produced synthetic fiber has the potential to create more responsive supply chains. Shorter times to market of time-critical products produced from synthetic fiber would provide an incentive for producers to locate in the United States and increase their ability to compete. In addition, a textile expert said, based on past experience, dramatically increasing fiber-spinning speeds would likely enable the discovery and production of fibers with new and useful properties not possible at today's spinning speeds.[9]

Faster fiber spinning would mean higher output per unit cost for U.S. producers. Assuming that no bottlenecks were encountered to offset the gains of an increased spinning rate, a 10 percent faster speed, for example, would mean 10 percent more fiber to sell without an increase in production costs. A gain in productivity would provide a competitive offset to the lower wages, lower environmental standards, and lower currency values that offshore producers have depended on to take market share from U.S.-based producers.

In the United States, labor costs in the textile industry account for an estimated 17 cents per dollar of goods shipped.[11] Labor costs in many countries are a fraction of this. An increase in spinning speed of 17 percent (i.e., 17 percent higher output), would mean a productivity gain sufficient to offset the entire labor costs of producing in the United States. A doubling in spinning speed would cut the production costs of U.S. fiber approximately in half. This reduction should make the cost structure of the U.S. producers favorable in comparison with foreign producers—sufficient even to reverse the synthetic fiber market share loss and attract other producers to locate in the United States.

What might this gain in competitiveness mean to the nation in terms of jobs, payroll, and sales? In 2000, the U.S. textile industry employed nearly a half million workers, had an annual payroll of $15 billion, and shipped nearly $80 billion of product. The entire textile complex, including raw material producers and machinery makers, employs more than 1 million U.S. workers and ships in excess of $100 billion in product each year.[3] Clearly, despite its recent problems, the industry has an enormous economic presence, particularly in the southeastern part of the country where it is concentrated. Slowing or even reversing the decline stands to generate very large benefits. Suppose we assume that faster spinning could prevent the loss of 10 percent of the textile market share, taking into account that synthetic fiber production, though extremely important, makes up only part of the textile market. This would mean preserving thousands of jobs, adding more than $1 billion to payroll, and generating approximately $8 billion in sales within the United States that otherwise would not occur.

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