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Flexible Short Run Yarn and Fabric Formation

Investigators

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Relevance to NTC Mission and Goals

To improve the feasibility of producing yarns and fabrics in a short run environment which may require fabric lengths as short as one hundred yards, and to show practical means for operating in a short run environment within current mill technology.

Abstract

The shift in current markets towards smaller lots of a greater variety of products has presented challenges for textile manufacturers. To respond to a more varied customer demand within a "just in time" environment, the ability to prepare loom beams for weaving quickly will be critical. The textile processes of warping and slashing, otherwise known as weaving preparation, were examined to determine their performance in the context of a small lot, "just in time," environment. Two technological alternatives, direct and sectional warping systems, were compared. Models for both systems were created, and were coded into the SIMAN simulation language for analysis using discrete event simulation. The performance measure of interest was the average time necessary to produce a job given an input of variable length jobs. The results of the simulations showed that the distribution of job inputs as well as the level of system utilization had a large impact on the performance of the two systems. It was further seen that a bottleneck in the sectional warping system degraded its performance compared to the direct warping system. The removal of this bottleneck resulted in improved sectional warping performance, making it a good technological alternative for producing short warps.

Introduction

The Textile Marketplace

Textile plants involved in the conversion of fiber to woven fabric will increasingly be required to respond to customer demands for a greater variety of products in smaller lot sizes, and be able to respond to these demands quickly. The implementation of "just in time" and "quick response" management strategies means that textile firms will need to incorporate flexibility and speed as tools to remain competitive in an increasingly demanding market.

These processes have an inherently high level of product mix flexibility in that the number of possible products that can be produced by the same manufacturing equipment is effectively unlimited. The concern is how these processes will be affected in terms of lead time as product lots become smaller and more diverse. Longer lead times due to smaller job lots requiring more setup time is contrary to the idea of quick response. Of particular concern are the processes involved in preparing yarn packages for weaving. These processes are warping and slashing, and their output is sized loom beams.

There are two major methods of producing loom beams. These are direct and sectional warping. The direct warping method produces intermediate (or section) beams which are then consolidated into a loom beam during the slashing operation. In the sectional warping method, the warp is laid up in sections on a drum and then wound off onto a loom beam which is then processed through the slasher as before. More detailed descriptions of the two processes will be made later.

Technical Objective

The particular flexibility measure of interest was the average time necessary to process a job given a mix of variable job types. In particular, the textile processes of warping and slashing (otherwise known as weaving preparation) were studied. These processes are necessary to the production of fabric, as yarn packages must be repackaged onto beams and coated with size before they are ready to be woven into cloth at the loom. They are relatively low efficiency processes requiring a large proportion of setup time, and are therefore more susceptible to an increased time necessary to produce a unit length of warp given smaller, more variable job inputs.

The main objective of this research was to compare these two weaving preparation systems to determine if either is preferred within the context of a small lot manufacturing environment. Initially, the analysis was limited to jobs that varied in length only. A small lot, or job, was considered to be between 2,000 and 10,000 yards.

Experimental Procedure

System Models

Both the direct and sectional warping systems were modeled as a two machine flow shop as shown in Figure I.

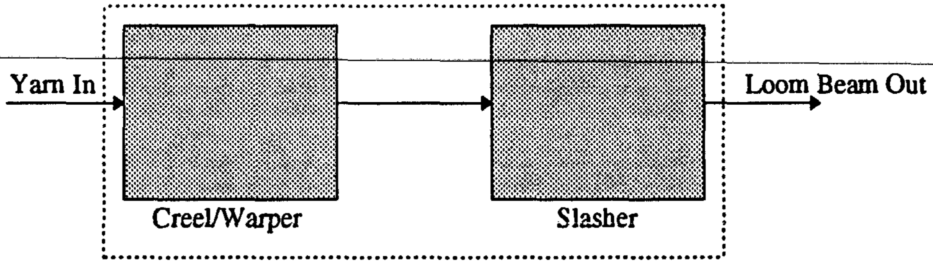

Figure I

In this model, yarn packages enter the system, are loaded onto the creel, and are then wound onto beams using either the direct or sectional warping method. The intermediate beams are then processed through the slasher where they are sized, and then exit the system as finished loom beams. As in actual textile plants, the routing is fixed with no deviation possible.

System models were developed for both the direct and sectional warping systems. The models were based on the paradigm described above, where jobs enter the system and queue behind a fixed resource. When the resource becomes available the job seizes it, and after a setup and processing delay releases the resource and moves on to the next queue. After completing all processing steps, the jobs leave the system. The job flow sequence for both systems is shown in Figure II.

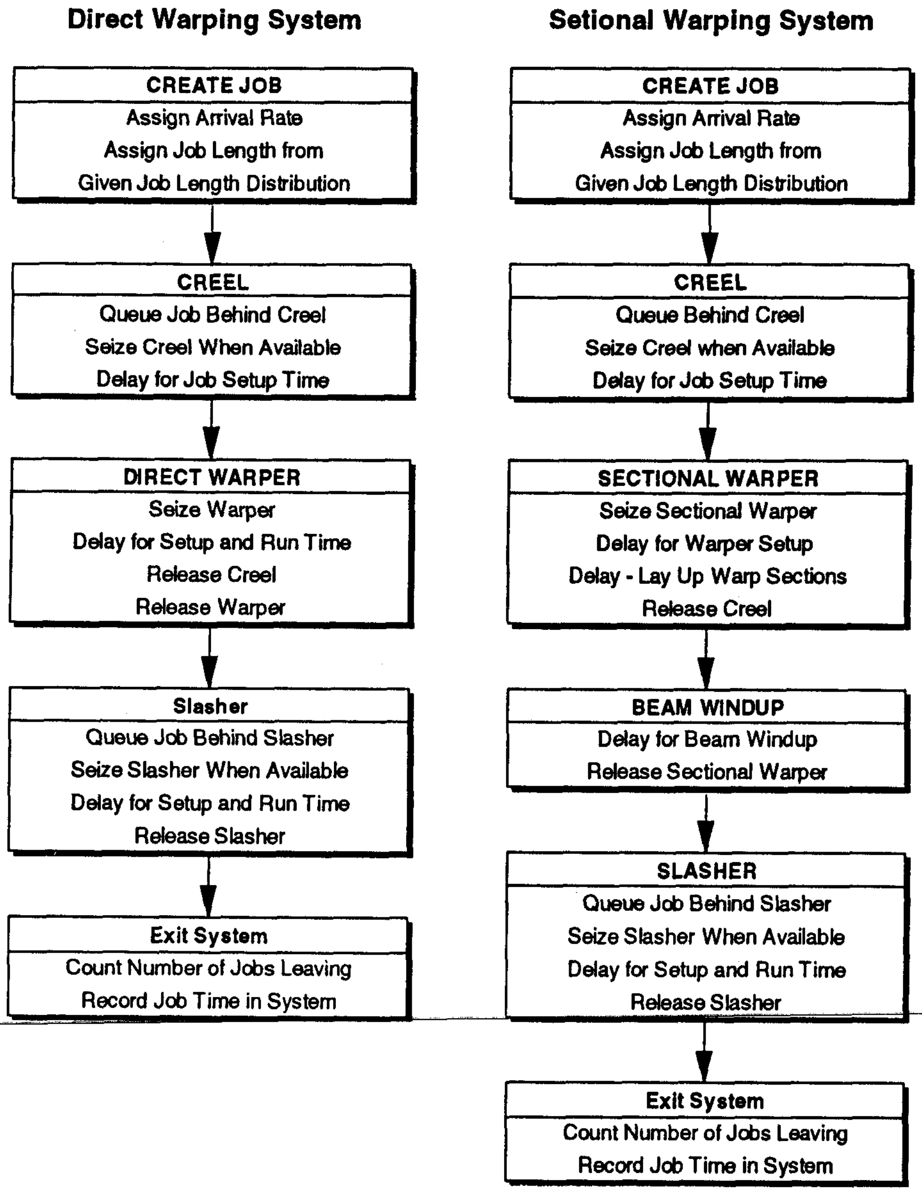

Figure II

It was assumed that the range of job lengths of interest meant that the largest possible job could be run using only a single yarn package per end, and that the beam flange diameter was sufficiently large to hold that job. For warp lengths up to 10,000 yards, this assumption was good for a wide range of common yarn counts. A uniform job arrival rate was assumed, and the system utilization was controlled from this rate. This insured that workcenter "starvation" would not occur, which was reasonable for a high utilization process. Finally, it was assumed that the time required to complete a job consisted of setup time, processing time, and queuing time. Transportation time between workcenters was not included, as these processes are typically within the same department of a single plant.

Modeling Delays Developed with Industrial Interaction

The delays modeled in the previous section represented tasks that needed to be completed before a job could move forward to the next workstation. The individual tasks that were defined for each workstation are listed in Table I.

Work Station	Task to be Done	Task Type	Variable Assigned	Value Used
Creel	Pull ends through stop motions (min/end)	setup	A1	0.05
	Rotate (index) creel frame (min)	setup	A2	2
Direct Warper	Pull ends through warper comb dents (min/end)	setup	B1	0.013
	Run warp onto beam - warper speed (yds/min)	processing	B2	700
	Doff beam and reload empty beam (min)	processing	B3	5
	Number of beams in set	N/A	B4	8
Sectional Warper & Beam Winding	Pull ends through lease comb (min/end)	setup	C1	0.02
	Attach ends to drum, run alignment turns, attach lease (min)	processing	C2	3
	Lay up section on drum - section warper speed (yds/min)	processing	C3	600
	Route warp sheet from drum to beam (min)	setup	C4	5
	Wind warp from drum to beam - beaming speed (yds/min)	processing	C5	300
Slasher	Replace beam in creel from previous job with beam from the current job (min)	setup	D1	10
	Pull warp through slasher using leader (min)	setup	D2	10
	Size warp - slasher speed (yds/min)	processing	D3	70

Table I

Variables were assigned to each task, and values for those variables specified. The values chosen were determined by a three step method. First, published data from textile plants and equipment manufacturers were gathered. These values were then checked in discussions with individual mills. Finally, visits were made to mills utilizing both direct and sectional warping systems to verify that these figures were reasonable. In addition to the delay variables defined above, two job attribute variables were defined:

Warplength = length of the job (yards)

Endsnumber ∝ number of ends in a job

These attributes reflect the length and width of a given job entering the system.

Using the defined task and job attribute variables, expressions were written to describe the delay time for a given job for each workstation.

Creel Delay

$$= (A1 \ast \text{Endsnumber}) + A2 \tag{1}$$

Direct Warper Delay

$$= (B1 \ast \text{Endsnumber}) + (B4 \ast (\text{Warplength} / B2 + B3)) \tag{2}$$

Sectional Warper Delay + Beam Wind-off Delay

$$= (C1 \ast \text{Endsnumber}) + (B4\ (C2 + (\text{Warplength} / C3)) \tag{3}$$

$$+$$

$$C4 + (\text{Warplength} / C5) \tag{4}$$

Slasher Delay

$$= (B4 \ast D1) + D2 + (\text{Warplength} / D3) \quad \text{(Direct Warping)} \tag{5}$$

$$= D1 + D2 + (\text{Warplength} / D3) \quad \text{(Sectional Warping)} \tag{6}$$

These delays described the setup and processing time necessary to process a job of a given length and width. The combination of the job path definitions and the delay equations provided the routing and total time required to move a job through the two weaving preparation systems.

SIMAN Simulation

The models developed for the direct and sectional warping systems were translated into SIMAN equivalents for analysis using computer generated simulation. The SIMAN simulation language was chosen for its high level of built-in functionality which allowed rapid model development, and the ability to generate and track stochastic inputs.

Simulations were run using the SIMAN model to determine the performance of both the direct and sectional warping systems given variable inputs of small lot jobs. In addition, the effect of system loading was considered, at system utilization of 90%, 95%, and 99%. The parameter measured was the average time required to complete a job. The goal was to determine whether one system showed a comparative advantage over the other within a small lot, just-in-time environment.

The experiments were run to study the effect of length variability only. In all cases, the jobs were of an equal width, which for this work was 4,032 ends per finished loom beam. Two simulation experiments were run. The first experiment was designed to explore the effect of a distribution of discrete lengths on both systems' performance. The second experiment was run using the same inputs as in the first experiment to demonstrate the effect of making a change to the sectional warping system.

Simulation Results

Initial Observations

From the construction of the system models and their underlying assumptions, the time necessary to produce a job could be explicitly stated in terms of the setup time and processing time. This was true for both direct and sectional warping systems. This quantity could be stated in terms of the delays defined for setup and processing as defined in Equations (1) through (6) in the previous section. The time required to process a job in either system could then be written as:

$$t = 0.0257\,(\text{Warplength}) + 163.75 \qquad \text{[Direct Warping]} \qquad (7)$$

$$t = 0.0309\,(\text{Warplength}) + 86.28 \qquad \text{[Sectional Warping]} \qquad (8)$$

These equations represented linear functions of the length of a given job. The intercept represented the setup time necessary for any job moving through the system. It was seen that the setup time required for the direct warping system was almost twice that of the sectional warping system. From a physical standpoint, most of this extra setup time was due to the necessity of dealing with eight separate beams as a set at both the warper and the slasher.

The processing time was a linear function of the length of a job, and was represented by the slope in Equations (7) and (8). It was seen that the slope for the direct warping system was lower than that of the sectional warping case. Again, physically this was consistent with the fact that the direct warper was modeled as running at higher speeds than the sectional warper, and holds true for actual plant operations. A plot of Equations (7) and (8) can be seen in Figure III.

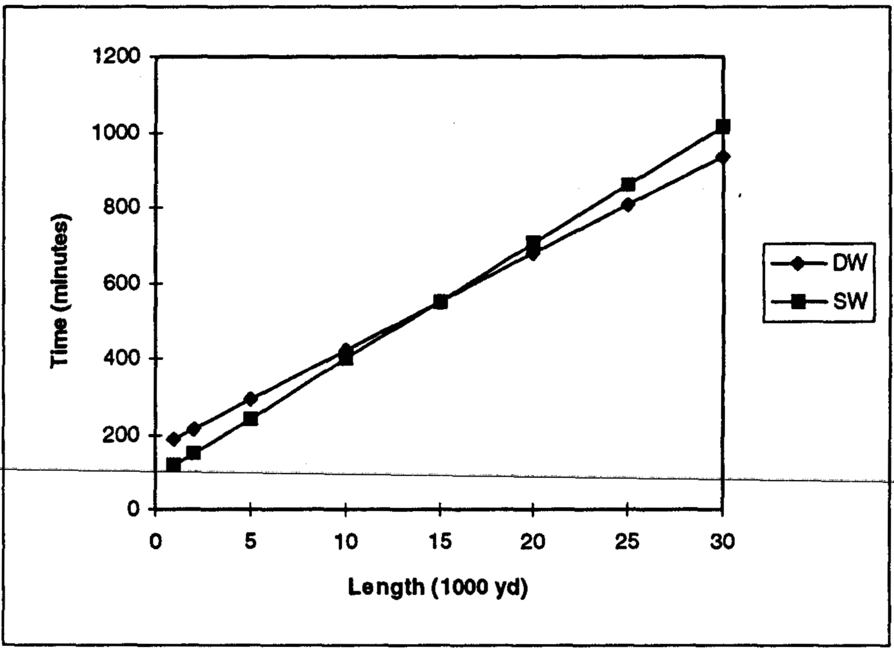

Figure III

Setting equations (7) and (8) equal and solving for Warplength revealed that the crossover point shown in Figure IV was equal to 14,898 yards. From an operational standpoint this showed that below 15,000 yards the sectional warping model was the preferred system, while the direct warping system showed better performance above 15,000 yards.

As a first cut approximation, Equations (7) and (8) suggested that the sectional warping system showed better performance in producing small lot jobs within the weaving preparation system. However, this type of analysis considered only the effect of setup and processing time.

Experiment I

Experiment I was run to characterize the response of both systems to inputs of a discrete probability distribution of 2,000, 5,000, and 10,000 yard job lengths. This type of job variability reflects the actual operating conditions in a plant. In this experiment, the mix of lengths chosen for the discrete distribution bounded the range defined for small lots. Four simulation cases were defined to cover the possible mix combinations for the three lengths. In simulation 1, increasing fractions of larger job lengths were studied. In simulation 2, increasing fractions of smaller job lengths were defined. In simulations 3 and 4, decreasing and increasing fractions of mid-range jobs were specified.

It was seen that for higher system loading the sectional warping system performance was only slightly better than that of direct warping, especially in simulations 1 and 3 where a larger fraction of 10,000 yard jobs entered the system. Figure IV shows the average job time versus each simulation for the direct and sectional warping case at 99% capacity.

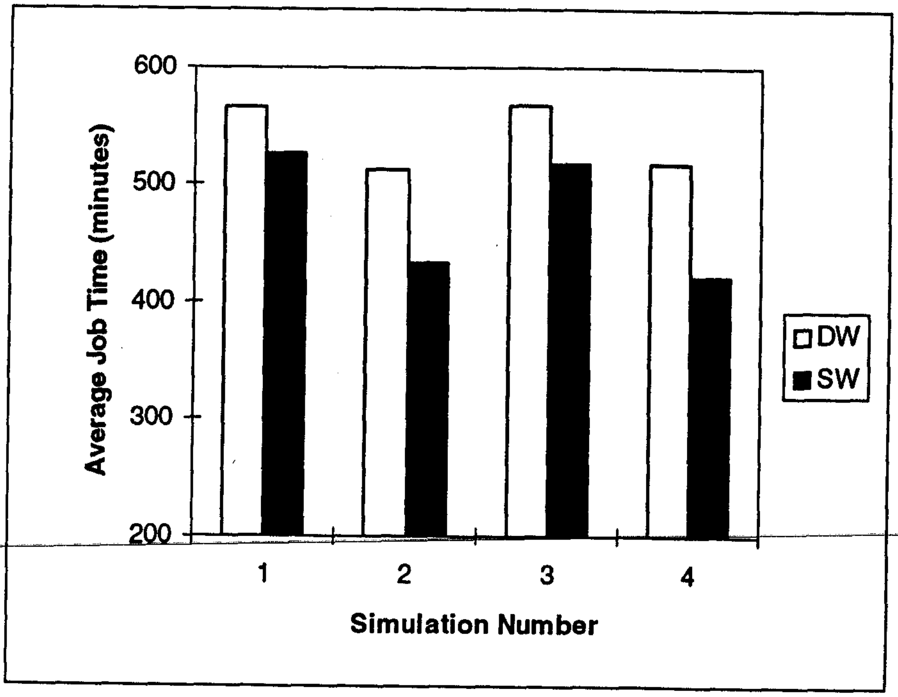

Figure IV

Although the sectional warping system did show a lower average job time, the direct warping system performance was close to the sectional warping case. This result ran counter to the results of previous analysis that showed a better system performance for the sectional warping case at job lengths below 15,000 yards. It was believed that a mix of 10,000 yard and shorter jobs would result in a significantly lower average job time for sectional warping.

That analysis was done considering setup and processing time only. As it would hold for Experiment I, the only other source of delay in moving a job through the system would be from queuing time. It was theorized that as the average job length increased, there was comparatively more queuing time in the sectional warping system than the direct warping system.

A closer inspection of the underlying model for the sectional warping system revealed the source of this added queuing time. A bottleneck was found in the beam windup processing step shown in Figure II. Above a certain length (6,660 yards for the model definitions) the time required to wind off the warp from the drum was greater than the time necessary to set up the next job on the creel. A job moving through the system above this length created queuing time in the next job at the sectional warper. Below the job length of 6,660 yards, no added queuing time was seen. Above this length, queuing time was added to the system as a linear function of the warplength. This bottleneck was seen as the cause of the degradation in performance in the sectional warping system. As a result, the sectional warping system showed only a slight comparative advantage over the direct warping system given 10,000 yard jobs and below.

Experiment II

In Experiment II the effect of removing the bottleneck revealed by Experiment I was studied. To accomplish this, the value of the beam windup speed was increased from 300 to 450 yards per minute. This change was seen as easily obtainable from an operational standpoint. The removal of this bottleneck effectively eliminated the added queuing time at the creel seen in 10,000 yard jobs within the sectional warping system. With the bottleneck removed, the simulation experiments in Experiment II were re-run for the sectional warping case. The results, compared against the Experiment II data are shown in Figure VI for the 99% loading case.

The removal of the bottleneck resulted in a time reduction of only 2.5% in terms of setup and processing time at 10,000 yards. However, by making this change the average job time for the sectional warping system decreased between 4% and 8% for simulations 1 through 4. In effect, by altering the system to remove processing time only, a side effect occurred in which queuing time was also removed from the system. This improved the performance of the sectional warping system in terms of average job time.

Experiment II showed that there are relevant operating parameters that need to be addressed when judging the response of a system to a given range of inputs. In this case, attempting to reduce the average job time of the sectional warping system by reducing creel setup time would have failed. The bottleneck was further downstream in the system, and attention needed to be focused on reducing the time for that process.

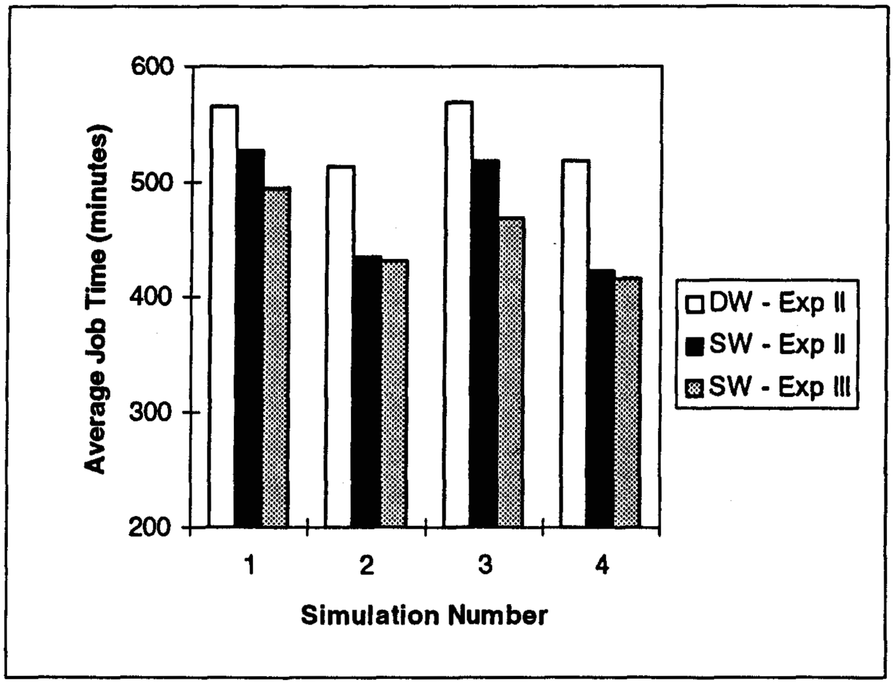

Figure VI

Conclusions

The methodology utilized revealed that any attempt to quantify performance must be made from a system instead of a machine perspective. Analysis of the machine parameters of setup and processing time suggested that the sectional warping system was the preferred system for small lot manufacturing up to 10,000 yard jobs. Analysis of the systems using discrete event simulation however, showed that bottlenecks inherent in the sectional warping system degraded its performance advantage in relation to the direct warping system. It was seen that the length distribution of the job inputs to the system had a major effect on the performance of the systems. Inputs with large fractions of 10,000 yard jobs particularly affected the performance of the sectional warping system. By making changes to operational parameters, the performance of the system could be improved beyond the gains made in processing time only. The removal of a bottleneck in the sectional warping system and the consequent improvement in performance suggested that the system was made more flexible in processing the range of inputs defined as small lot jobs, thus gaining a comparative advantage over the direct warping system.

Future Work

System Modeling

Work has already begun to relax some of the current assumptions and add decision making ability to the system models. Job sequencing rules will then be evaluated to determine how jobs can be ordered coming into the system for improved performance. With algorithms for sequencing jobs developed, these systems can be optimized for a particular set of inputs. To aid in the development of these expanded models, an undergraduate student from the Chemical Engineering department who is conversant in SIMAN code has been retained to help build the expanded simulation models.

A plant will be identified where a virtual model of the weaving preparation processes can be implemented. The performance of this specific physical system will be evaluated for the current job mix as well as for a set of small lot job inputs. Areas where the system can be improved to reduce the time necessary to produce jobs will be identified.

Short Run Line

Work is almost complete on the small lot line for evaluation of short run methodologies. A 96 end Hacoba creel has been installed, and beaming capability is in place. In addition, various looms are available, including; projectile, rapier, and air-jet types.

Education Achievements

The graduate student assigned to this project has completed the requirements for the masters degree program and has been awarded a Masters of Science in Textile Engineering degree. He is continuing on to pursue a Ph.D.