**ABSTRACT**

ESKEW, DAVID DEWITT. Increasing the Cost Competitiveness of the US Textile Manufacturer Through the Attenuation of Slasher and Sized Yarn Waste. (Under the direction of Dr. Abdel-Fattah Seyam.)

Due to changing markets for US Textile manufacturers, many are running numerous styles as compared to in the past. Also, the longevity of these styles do not compare with past commodity products these same manufacturers once produced. Set lengths continue to decrease in size as customers demand shorter, more specialized orders. The amount of waste created in the warp preparation processes, while in the past commodity business was considered acceptable, has become a significant factor in lost profits.

This research works with slashing experts in the textile industry, from vendors and manufacturers, to investigate methods to reduce this inherent raw material waste in warp preparation. The areas of focus include: process engineering, innovative controls, and new technology. The process engineering focus investigates reasonable methods and procedures used throughout the industry, in turn, developing a "best practices" summary for reduction of waste in smaller slashing lots. The "best practices" compilation covers all aspects of warping and sizing that create waste and suggests ways to reduce these wastes with little, if any, capital expenditures. The innovative controls focus explores available software programs and other accessories that may offer assistance in the reduction of waste. And finally, the investigation of new technology works directly with the vendors of warping and sizing machinery to focus on what products on the horizons are available to reduce this generated warp preparation waste for smaller lot sizes.

# Increasing the Cost Competitiveness of the US Textile Manufacturer through the Attenuation of Slasher and Sized Yarn Waste

by

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## BIOGRAPHY

David DeWitt Eskew was born September 29, 1978, in Greenville, South Carolina. He graduated from Eastside High School in 1997, where he was active in Student Government and Athletics. He played both varsity golf and football for the Eagles. In August of 1997, he began his studies at Clemson University in Clemson, South Carolina, pursuing a Bachelor of Science degree in Textile Management. While at Clemson, he was involved in the IPTAY Collegiate Club, serving on the Board of Directors and IPTAY Student Advisory Board. He also served in the Student Senate, as a member of the Academic Integrity Committee. He was a member of various honor societies, as well as Kappa Sigma, a social fraternity, where he held officer positions. Upon graduation in 2001, he accepted a position as a Product and Process Improvement Specialist with Milliken & Company in Gainesville, Georgia. In August of 2004, he accepted a fellowship to the Institute of Textile Technology (ITT) at North Carolina State University in Raleigh, North Carolina. Upon receiving his Master's Degree in 2006, he will return to Milliken & Company as an Advanced Product and Process Improvement Specialist at the Sharon Plant in Abbeville, South Carolina.

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# 1. INTRODUCTION

Competitive pressures have forced successful companies to restructure and become lean enterprises [7]. As the US textile industry must adapt to ever increasing global, technological, and consumer challenges in order to survive and to prosper, company leaders must focus on efficient production, sometimes to the extent of changing entire operations and procedures. In order to meet the demands of today's customer driven market, textile companies must succeed in reducing manufacturing costs, while optimizing process capabilities, adapting to larger plant complexities, and anticipating market changes. The reduction of waste, not only raw material yarn waste, but also the waste of labor costs, time, and sizing material, will result in significant savings throughout the manufacturing process. The US textile industry is struggling to remain a cost competitive industry. However, one must realize that lost profits can be regained as long as companies are willing to change and try new ideas.

Today's textile manufacturing industry is undergoing a substantial transformation from one of mass production to one which can thrive under constant and unpredictable changes. According to a 1994 study by Kurt Salmon Associates, included in a paper by Singletary and Winchester [29], "the massive industrial transformation is caused by three macro trends: (1) globalization, (2) advancing technology, and (3) consumer emancipation (p.99)." Globalization is facilitated by international trade agreements and improvements in global manufacturing capabilities. Profitable manufacturers must continue to embrace new technology in order to meet these demands. Advancing technology in manufacturing, information, communication, and transportation has redefined quality standards and shortened supply chains, while bringing the customer closer to their product. Information technology is one of the most meaningful advances in technology lately. According to Singletary and Winchester [29], "In the modern age of information, information and knowledge are replacing capital and energy as the primary wealth-creating assets. Thus, the ability to turn information into knowledge is becoming the key source of competitive advantage (p.100)."

Technological changes are heavily influencing the marketplace, as well as the demands of the customer. In today's ever changing market, leaders must be aware of current and forthcoming complex issues. Sample turnaround time has been dramatically shortened as customers expect to receive orders within days. Many manufacturers have increased their plant complexities by running numerous styles with shorter order lengths. The longevity of current styles may not compare with commodities manufactured in the past. These changes and others have forced manufacturers to alter their processes and procedures and, in some cases, purchase new technology in order to meet customer demands.

In order to survive and gain a competitive advantage, the US textile industry must continue to adapt to market fluctuations and demands. Figure 1 below, depicts the US textile manufacturer's existence after mass production, illustrating the complexity and transformation of the market requirements and manufacturing capabilities.

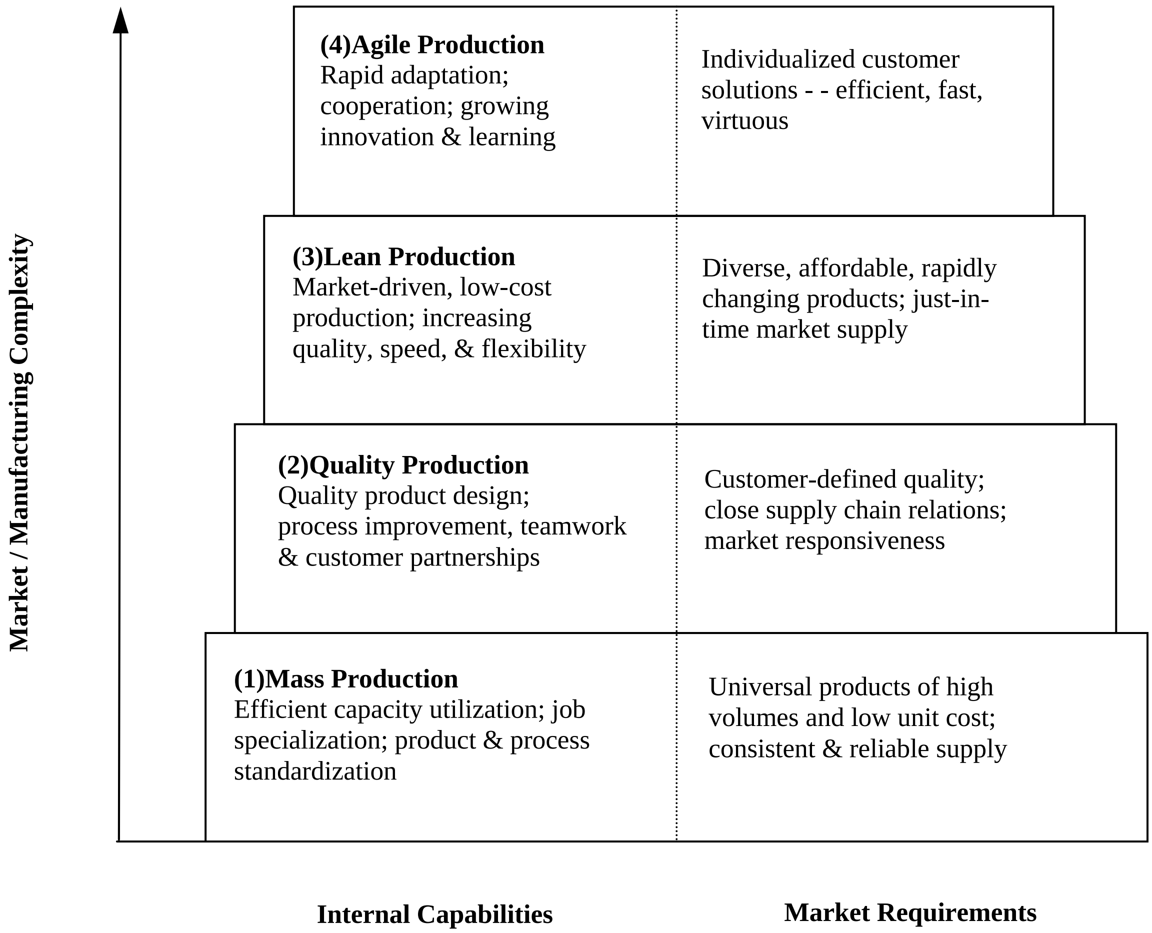


Figure 1. The essence of modern manufacturing transformation (31, p. 12)

Singletary and Winchester [31] describe this adaptation best when they state, "all textile manufacturers are transforming their traditional, mass-production systems into smaller-scale, flexible systems and processes designed to provide superior quality, responsiveness, and customer value (p.14)."  This transformation will not alone save a company; significant process and procedural improvements must be realized as well.

Due to ever-increasing competition in the textile industry, strides must be made in reducing manufacturing costs and optimizing process capabilities.  These strides must be accomplished through constant innovation and change.  Without modernization, the mass producer will continue to fall victim to the increasing competition involving speed to market, complexity issues, and market changes.

Companies that could not or did not change with the market are no longer in business. In order to compete, businesses must reduce and eliminate waste, which can be defined as anything that adds costs without adding value. Any reduction in waste directly affects profitability, due to increases in productivity, throughput, and utilization. Waste is generated in all areas of manufacturing; accordingly, the waste in each process must be attacked individually.

The amount of waste created in the warp preparation processes, while in the past commodity business was considered acceptable, has become a significant factor in lost profits for smaller lot sizes. This research investigates the raw material, time, and labor wastes accumulated in the warp preparation processes, the wastes' associated costs, and the various new available technologies, which can reduce these wastes.

# 2. LITERATURE REVIEW

## 2.1 Overview

The purpose of this section is to provide adequate background information in the field of warp preparation processes and industry terminologies. The information included in this review allows for a better understanding of the subject matter and explains why this research is valuable.

This review of literature addresses the different warping and sizing technologies which are prominent in the textile industry today. The overall core technologies have not changed considerably in the past 30 to 40 years, although faster and smaller machines, along with new advancements, have been beneficial to the changes in the industry. These advancing technologies are discussed at the end of this literature review.

## 2.2 Terminology

There are many words and phrases which are used in the textile industry and throughout this research that could be confusing to those not familiar with the industry terminology. There are also words and phrases that have different meanings even within the textile industry when referring to different processes. Table 1 allows the reader to become familiar with the terminology which is used throughout this research. The terminology of Table 1 is specific to warp preparation processes. The terminology is also limited to items which are used by the industry and not commonly found in text books.

Table 1

Glossary of terms

| | |
|---|---|
| Beam | Cylinder of metal with a circular flange on each end, on which warp yarns are wound for slashing |
| Break-out | Multiple yarn ends breaking at the same time |
| Bust rod | Smooth rounded metal stick used to separate different layers of sized warp yarns after exiting the size box and before going through the comb. Similar to leasing rods |
| Creel waste | Yarn which is left over in the creel after the set length has been reached |
| Cycling | Operator process verifying that all main areas of machine are working within specifications and that no laps have occurred |
| Delivery roll | Pulls the yarn through the slasher and across the lease rods |
| Encapsulation | Degree to which the size solution covers the outside of the yarn after going through the size box and dry cans |
| Flat stick | Long wooden bar used in leasing to separate yarn layers and check for crossed or twisted ends |
| Guide rollers | Contact rollers which support and steer yarn |
| Hard thread waste | Yarn waste which has been sized |
| Head end | Front area of the machine where the yarn is wound onto a beam |
| Lap | Occurs when a yarn end breaks and it does not unwind with the rest of the ends. The yarn begins to build upon itself traps other ends causing breaks |
| Occupancy | Amount of space between adjacent yarn ends. Also known as percent cover. 100% occupancy means ends are touching |
| Other waste | Yarn waste which is not considered to be related to creel waste or set out waste. This waste is usually caused by end breaks or defects during the sizing process |
| Penetration | Depth to which the size enters within the yarn |
| Returned warps | Loom beams which are sent back to the sizing department due to excessive defects causing runability problems in the loom |
| Set out | Largest amount of downtime of the machine involving numerous steps between the finish of one set and the start up of the next set |
| Set out waste | Waste generated between set changes which contains both hard and soft thread waste. Also called pull up or thread up waste |
| Soft thread waste | Yarn waste which has not been sized |
| Solids (%) | Concentration of the size in the sizing solution |
| Teflon® | Coating applied to the drying cans and rollers to prevent sized yarns from sticking |
| Thread up length | The distance that the yarn must travel from the creel to the head end of the machine. This is dependent upon machine configuration and machine length |
| Unavoidable waste | Yarn waste which occurs during each set out process. Thread up length and set out procedures are contributing factors |

## 2.3 Warping

The primary objective of the warping process is to provide a continuous length of yarn from individual wound yarn packages, in sheet form to a beam for the succeeding process. There are several types of warping techniques, including: ball, direct, draw, indirect (also called sectional) and sample warping. This review focuses on the three most popular process types, direct, indirect, and sample warping.

When utilizing any technique in the warping process it is important to minimize end breaks, keep a constant and uniform tension on the yarns, keep a constant yarn speed, and insure quick response braking of the warper. These factors play a large role in the quality of the warp yarns, which in turn influences the runability of that warp yarn in the succeeding process.

End breaks require knots to be tied in the yarn, causing thick spots which may pick up different amounts of size and dye in later processes. Depending on the skill level of the operator these knots may end up being three to four times the diameter of the original yarn. These knots are noticeable defects and detract from the quality of the fabric.

Constant and uniform yarn tension insures each yarn will behave in the same manner and prevent slack and crossed ends, which will cause havoc in the slashing process. The yarn should be run at the lowest possible tension in order not to over-elongate the yarns. Just enough tension should be applied to keep the yarns from entangling with one another. If a yarn is not wound at a constant speed there will be opportunity for that yarn to become slack or too tight which will cause ends to become trapped, crossed, or entangled with one another.

“The old weaving adage ‘well warped is half woven’ is more valid today than ever, for the differences in individual end, warp sheet, and overall warp tension from start to finish of the warping process have a decisive effect on the quality of the fabric [25, p.57].” This quote in the International Textile Bulletin from 1994 is still applicable more than ten years later. The better quality a product has coming into a process, the better chance it has of leaving that process as a good quality product.

A constant warping speed also helps to produce a consistent, uniform build on the warp beam. This is important during the unwinding of this yarn in the succeeding process. Warping speeds vary due to types of yarn, the various twist levels in the yarn, the strength of the yarn, as well as, the tension being applied to the yarn.

Most modern warpers are equipped with electronic stop motions which stop the warper as soon as a broken end is detected. It is crucial that the braking system is fast enough to stop the warper before the end reaches the beam. The end is much harder to find and correct once it has been wound onto the beam. Today’s braking systems allow the beams to stop before one full revolution has occurred on the warp beam, in a direct system, or on the pattern drum in an indirect system.

Advancements in electronic technology have made these factors easier to control, but ensuring the quality of the warp beam is still the responsibility of the operator. Warping machines are capable of reaching well over 1000 yards per minute and are now able to stop after an end break without advancing more than one full revolution of the section beam. Warping has gained new respect in weaving plants, and is rightfully referred to sometimes, as the cornerstone of good weaving preparation.

### 2.3.1 Direct Warping

Direct warping denotes the transference of yarns from single-end yarn packages, wound packages, directly to a beam in a one step process. This means that there are an equal number of packages in the creel area as there are ends on the beam, except in the case of a magazine creel. A magazine creel connects the tail of one wound package to the beginning of a new wound package for an easy package transfer. Adanur [2] describes direct warping in two ways. It is possible to produce a loom beam straight from the wound packages in the creel. A loom beam refers to a beam that has the required number of ends for the given style and is ready to be put behind the loom to be woven. This process is especially suitable for strong yarns that do not require sizing and when the number of warp ends on the warp beam is relatively small. It is also possible to make intermediate beams called section beams. These beams only contain a section or portion of the required number of ends to be woven together. The section beams are combined later in the sizing process to produce loom beams.

Advantages of direct warping include: increased efficiencies; decreased labor requirements per warper; and increased beam yardage lengths. These advantages are the reason that direct warping is the most common warping technique among commodity type products which are of larger lot sizes and usually a single color.

The disadvantages of this technique include: increased demand of section beams; possibility of defects occurring due to unequal tensions in creel; and increased floor space for the creel area compared to other warping techniques. This is due to the large number of required yarn packages.

### 2.3.2 Indirect Warping

Indirect warping is also referred to as sectional warping, pattern warping, band warping, or drum warping. This is a two step process involving warping and beaming. The warp yarns are withdrawn from single-end yarn packages and wound onto the pattern drum in bands. The full beam is thus made from a small number of packages in the creel. Indirect warping is typically used for relatively short runs, development samples, or when there are a number of different colors of yarn to be warped together to produce stripped warps. Indirect warping can accommodate large amounts of yarn on a high capacity drum.

The bands of yarn must be added together on the pattern drum and wound onto a beam. This beam, along with others are then combined in the beaming process in order to accumulate the required number of ends needed to make the final loom beam. Indirect warping allows for more careful attention to be paid to each of the yarn ends since there are a smaller number of ends being wound at any one given time. Many mills have embraced indirect warping when quality is the determining factor above all else.

Some advantages of indirect warping include: preparing yarns from a smaller amount of packages, in return, requiring less floor space; increasing opportunity to detect yarn imperfections; decreasing waste generation; and the increasing ability to produce various ranges of warp widths. It is also convenient for orders which have frequent style changes.

Disadvantages of this technique include: increased time to wind yarns onto the final beam; double handling of yarn, during the warping and beaming phases; increased strain on the yarn as it is wound and unwound; and increased opportunity for nonparallel yarns. Indirect warpers service about fifteen to twenty percent of the weaving machines which can be serviced by a direct warper [20]. Another disadvantage of the indirect warping technology is that when an end breaks it must be threaded into the v-reed or guide reed, and the lease reed, which takes extra time and directly affects the efficiency of the machine.

#### 2.3.3 Sample Warping

Sample warping is similar to that of sectional warping, except that it is mainly for shorter order lengths. As the name indicates, it is used mostly for running samples and very short order lengths. Some of the machines can run up to approximately 800 yards. Increasing demands for greater efficiencies, better quality, and shorter production runs have shaped the technology innovations in this process. The set up time on these machines is minimal due to the small number of required packages and user friendly creels. Other advantages of this system include the small amount of floor space required, minimal waste accumulation, and the increased level of automation.

The disadvantage of sample warping relates to the limitation on order lengths. Any required yardage which exceeds the capacity of the machine must be sectional or direct warped. Figure 2 below, pictures Karl Mayer’s Gir-O-Matic Sample Warper.

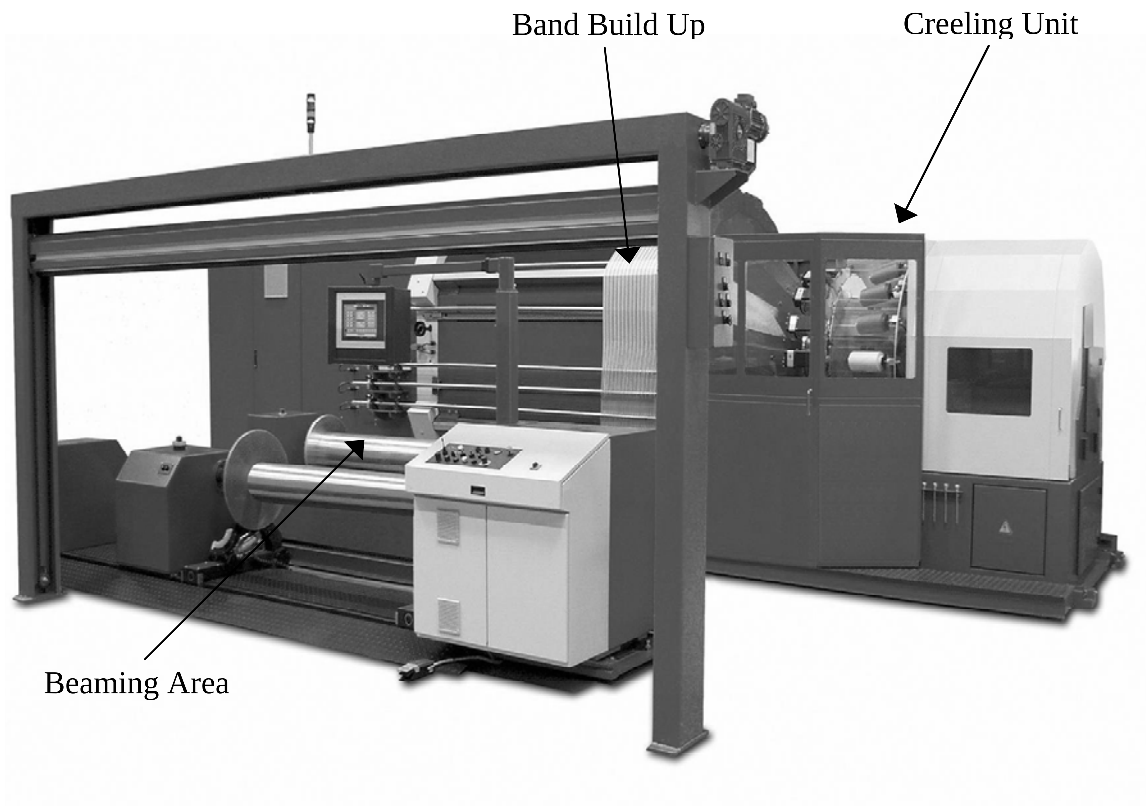


Figure 2. Karl Mayer's GOM Sample Warper (12)

**2.4 Sizing**

The sizing process, also referred to as slashing, is one of the most sophisticated processes in textile manufacturing. Although the sizing process is a key to successful weaving, it is considered to be a non-value added process in woven manufacturing because the size is applied before weaving and then removed during the finishing process. This means that any reduction in waste in this process, whether it is raw material, time, or labor waste will directly affect bottom line profits.

According to Seydel [28], "The prime function of the slashing process is to produce weavibility in the warp. This is accomplished by selecting sizing materials which are the most suitable for the yarn or filament being slashed and by applying the size properly to the warp (p.1-2)."

It is important for the size to strengthen the yarn, reduce the yarn hairiness, increase the abrasion resistance of yarns against one another and against loom parts, and reduce the fly in the weaving process. Adanur [2] agrees with these main purposes of slashing and states that the ultimate goal of sizing is to reduce or eliminate warp related stops in the weaving process. These stops or breaks can be attributed mostly to defects and to excessive tension or lack of strength in the yarn.

Selecting the correct sizing material depends upon the fiber type, the type of sizing equipment, and the end use of the yarn. It is important that all size materials adhere to the yarn and produce a protective covering or film which encapsulates the yarn and gives it added strength, but also allows for flexibility and extensibility. It must give lubricity to the yarn and also must be desized, or removed, easily. Ease of handling, slasher runability, and weavibility are also key factors in choosing a size material.

Filament yarns are sized differently than spun yarns for several reasons. Filament yarns are stronger than spun yarn as a bundle. However, individual filaments are more susceptible to breaking if they are separated from the bundle. Filament yarn packages should be handled more carefully to avoid filament breakage. The sizing process provides bundle integrity to keep the filaments held tightly together. Unlike spun yarns, filament yarns do not have protruding fibers, also called hairs; therefore surface coating to reduce hairiness is not necessary. Size must penetrate the filament bundle and act as a welding agent to keep the filaments from separating. The spun yarns, conversely, need to be fully encapsulated with size to lay down these hairs.

The sizing machine influences the amount of size pick up in several ways. The amount of size pick up, or take up, is affected by the amount of tension applied to the yarn and the length of time the yarn is exposed to the size bath. Exposure time is influenced by the length that the warp sheet is dipped into the size bath, as well as the processing speed. The squeeze roll pressure, temperature of the size bath, and the size concentration all directly affect the amount of size applied to yarns. The configuration of the drying section and its temperature impact the yarn's size encapsulation and penetration. Figure 3 below, includes several more of the factors affecting size take up.

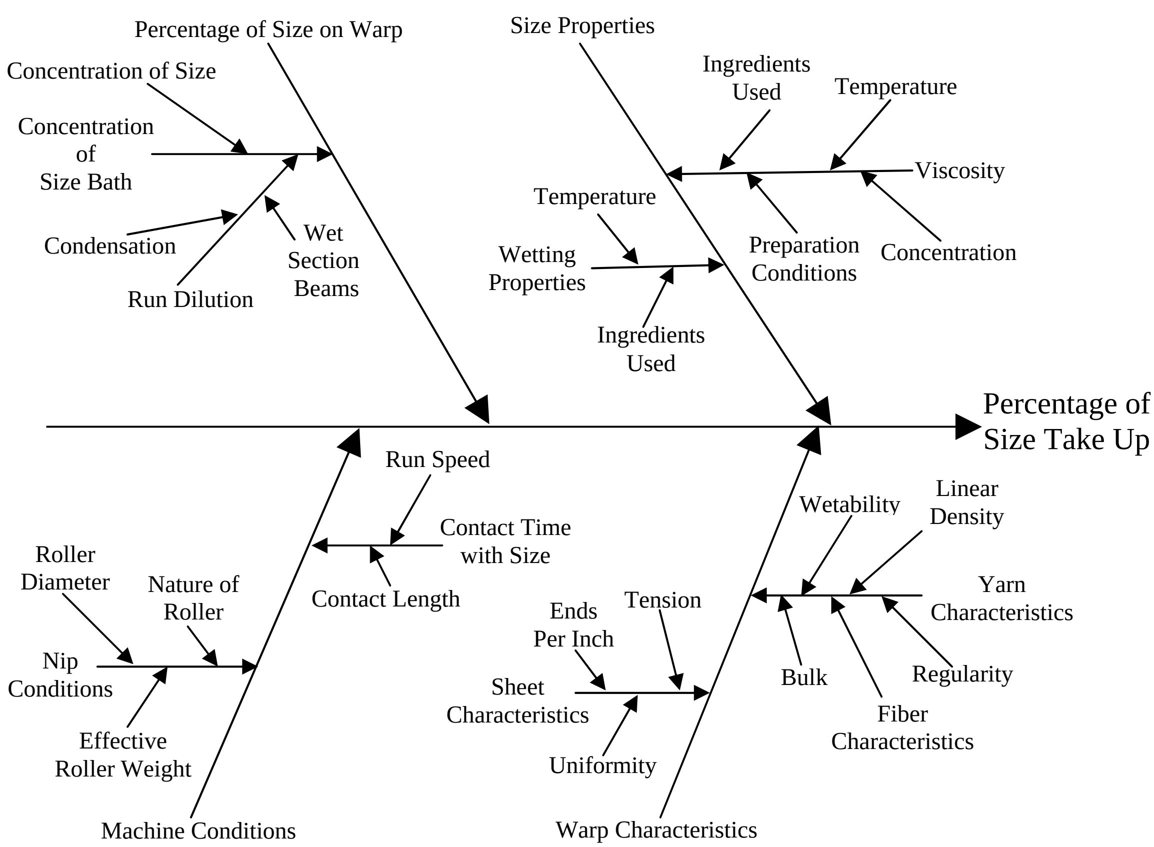


Figure 3. Cause and effect diagram for size take-up

As seen from the figure, there are numerous ways in which size take up is affected. Any combination of these factors will produce different results. It is important to note that while no one way or combination is the best, there are certain parameters which if increased or decreased too much will have an adverse effect on the yarn quality. Finding the combination of factors that works best for each individual style is unfortunately, a difficult and timely task. It has been said numerous times over the years that sizing is an art, not a science. With the great number of factors influencing how a yarn is sized, this statement will surely be quoted for years to come.

There are several ways to size yarns. The following sections describe in detail the different approaches to sizing yarns.

### 2.4.1 Direct Sizing

Direct sizing is a one step process and can also be referred to as beam to beam sizing. For cases where the warp density is high, the warp sheet is separated into two or three sheets, depending on the number of size boxes, before entering the size bath to ensure more uniform and better penetration and encapsulation of the size. It is recommended by some, to split the warp sheet after exiting the size bath by means of a splitting rod to prevent the groups of ends from becoming displaced, which may cause a stripe effect in the warp. This is known as wet splitting and is mainly due to preventing size bridges from forming. After drying, the sheets are separated by a bursting rod and again by leasing, or splitting, rods before entering the comb area where each individual end is separated and wound on the beam. Smith [32] describes an ideally sized warp as “one in which individual ends are separated from their adjacent ends in the correct order and uniformly spaced across the width of the warp (p.98).”

There are two methods of direct sizing in a one step process. The differences between the two methods include the number of beams going into the process and the method in which the beams were prepared by the warping process. After indirect warping one complete beam, containing all the required number of ends, it is possible to size this beam and produce one sized loom beam. This method, sometimes referred to as beam to beam sizing, is shown in Figure 4.

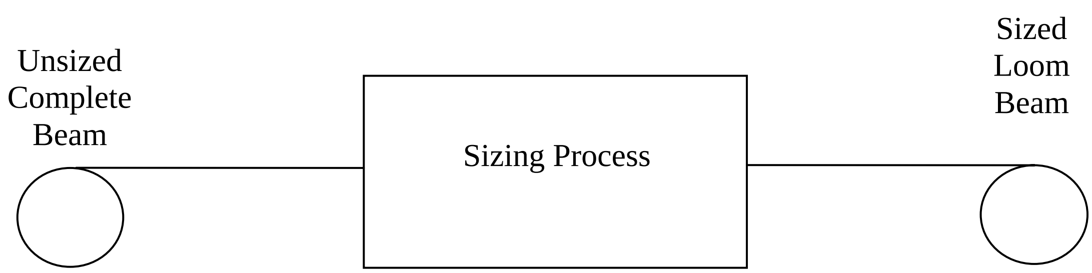


Figure 4. Direct sizing, one step process, beam to beam

It is also possible to take several unsized section beams which have been direct warped and size them to produce one sized loom beam which is ready to be inserted into the loom for weaving after drawing-in or tying-in. This method contains the total warp ends distributed equally among a predetermined number of section beams. This method is depicted in Figure 5.

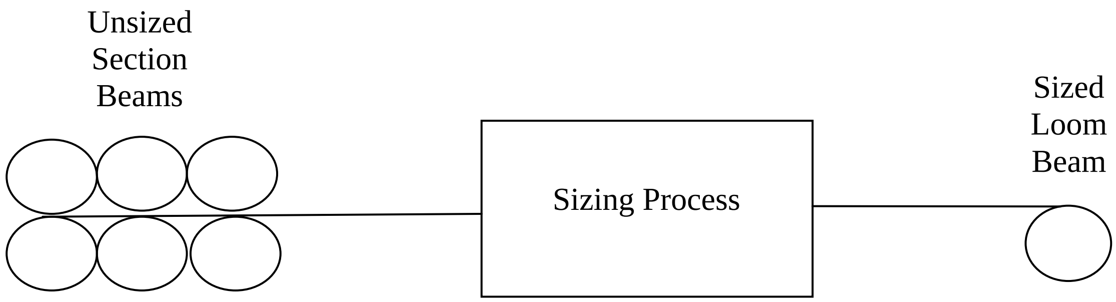


Figure 5. Direct sizing, one step process, several beams to one beam

It is imperative that all of the beams are tensioned equally; otherwise, slack ends will occur and cause stripes in the fabric. Also, unequal tensions will result in uneven runouts of the beams and excess yarn waste will remain in the creel. Tension adjustments need to be made at the end of each loom beam.

This one step method, with its individual warp sheets, results in adequate separation and order of the warp ends. The ends are brought together just before entering the size box and are separated out again using lease rods before entering the comb at the head of the slasher where the ends are laid side by side onto the loom beam.

This sizing method does require more floor space for the creel, but it is possible to get the next creel ready in a staging area before the current running creel is finished. This staging process reduces the amount of downtime significantly.

Depending on the type of creel being used the operator has full or limited access to each beam in the creel for inspection or quality related issues. There are several different types of creels, including: cluster, equi-tension, incline, and magazine. A cluster creel, shown in Figure 6, groups the beams in clusters of four, allowing the operator direct and easy access to each beam, made possible by the use of a crosswalk platform located between each cluster. The ends from the section beams run underneath the creel steered by guide rollers towards the size box area. This creel type is becoming quite popular because of the accessibility to each of the section beams.

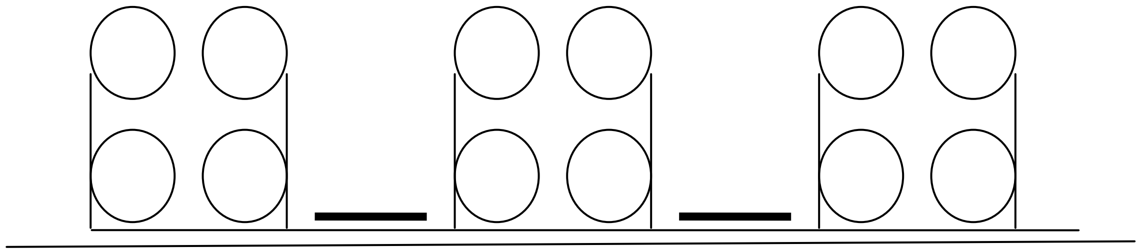

Figure 6. Cluster creel

### 2.4.2 Indirect Sizing

Indirect Sizing is a two step process, involving sizing and beaming. This process, frequently called single end sizing, is generally used for filament yarns. The phrase single end sizing originated because the yarns are sized with equal space, two or three yarn diameters, between them. This meant there is no need to split the yarns after the drying process because the size is encapsulated around each individual yarn. Since there is no cohesion between the yarn ends there will be no formation of size bridges between adjacent yarns [20].

A size bridge is an accumulation of size that joins two adjacent yarns. The two yarns once separated will break apart the size bridge, exposing unsized areas on the yarns. This causes two effects: increased hairiness of the yarns, in spun yarns only, and hard size from the size bridge which can cause end breaks or defects if woven into the fabric.

There are two methods to indirect sizing in a two step process. The first of these methods integrates the warping and sizing processes, as a sized section beam is made from a package creel. The first part of the system includes the sizing machine which sizes and winds the yarn onto a section beam with only a portion of the required number of ends for the loom beam. Since there is an integration of warping and sizing and this process mostly involves filament yarns, the sizing machine used in this method is sometimes referred to as a filament warping sizer. The second part of this system includes a beaming area which combines these section beams together to form a complete loom beam. This first indirect sizing method from a package creel is depicted in Figure 7 below.

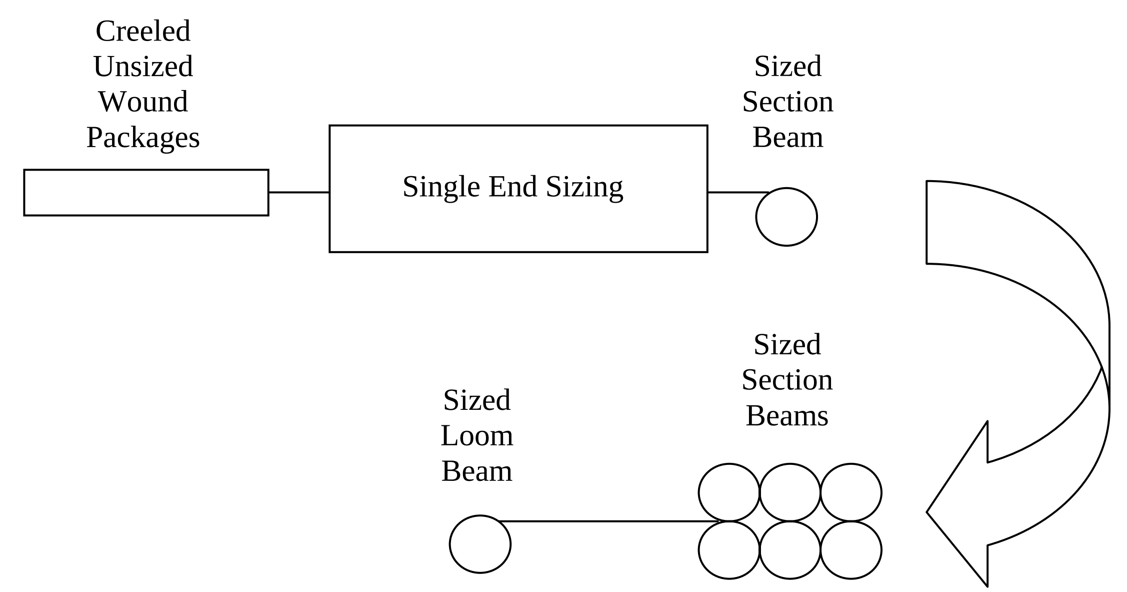


Figure 7. Indirect sizing, two step process, from a package creel

The second method of indirect sizing, called beam to beam sizing, utilizes unsized beams from direct or indirect warping and produces sized beams. The unsized beam is inserted just behind the size box area and is thread through the machine just as if the ends were coming from a package creel. Since the yarns are threaded through the machine in the same way and kept separated, this is still considered single end sizing. The sized beam, along with others, are then creeled together on a rebeamer and wound onto one loom beam. Figure 8 below, illustrates the concept of indirect sizing from beam to beam.

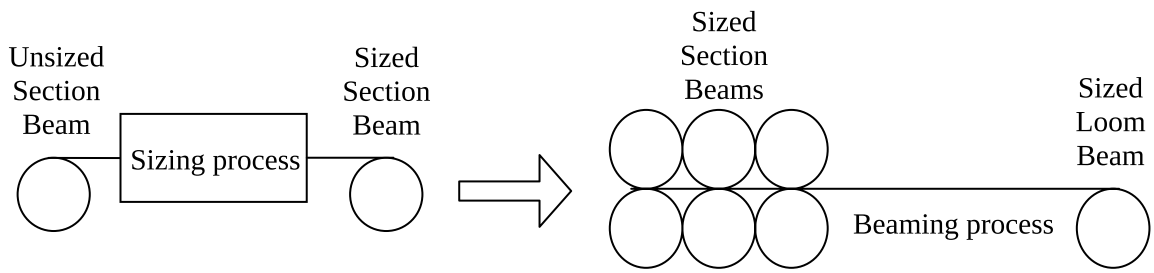


Figure 8. Indirect sizing, two step process, from beam to beam

There are several advantages of this method. Since only a portion of the required number of ends is sized at one time, there is greater spacing between the yarn ends. This spacing allows for good encapsulation of the size around each individual yarn and lessens the possibility of ends rolling or crossing over one another. Since there are fewer ends, there is not a need for multiple size boxes or lengthy drying sections. One size box is sufficient to size the ends and only a few drying cans are needed to accomplish the drying of the size and the yarns. This means that the length of the machine can be reduced, thus minimizing the thread up length waste for the machine. The smaller number of ends also means that the processing speeds can be increased without impairing the quality of the warp. Equipment costs may be decreased because there is no need for multiple size boxes and the drying section can be shorter. It is also possible to increase the flexibility in product mix, as there is the possibility of increasing or decreasing the end count or even combining multiple styles together on one loom beam.

It is the belief of some in the industry, that single end sizing machines produce higher quality sized yarns and provide gentle handling of filament yarns. This is due to the fact that each yarn is fully encapsulated with size. It is also quite difficult for the ends to become crossed and twisted in this process as the ends are drawn through multiple combs to keep the proper separation. Similar to other sizing processes, it is important to control the thread tensions during single end sizing, not to over dry the yarns, and to apply the size uniformly. Whether a sized beam is made from a creel of packages or from section beams is directly influenced by the number of package positions in the creel.

The indirect or single end sizing process does have a couple of disadvantages. If an end breaks during this process, the entire machine stops until the end is rethreaded and repaired. This also means that there is a section of yarn which remains in the drying section for an extended amount of time. This could lead to the over drying of this yarn, making it weak and brittle. This section can not be cut out and must be wound onto the loom beam with the rest of the warp. Undesirably, this section will surface in the weaving process and possibly cause numerous end breaks and loom stops. Also, afflicting this process is the sloughing off of yarn in the creel. This can cause ends to go slack and entangle with adjacent ends, causing an end break or breakout. Lastly, once the packages in the creel begin to run out there will be frequent machine stoppages.

There are other disadvantages to this system. Energy costs are typically higher in the indirect sizing process due to increased capacity utilization. A rebeamer is also now necessary to combine all of the required yarn ends and complete the beaming process. With the addition of the beaming process, there is an opportunity for extra waste to be generated. This could be in the form of incidental or process waste.

Despite these disadvantages, the advantages of this process seem to outweigh its shortcomings, as indirect, single end sizing is highly utilized in today's filament yarn processing.

### 2.4.3 Hot Melt Sizing

The technology of hot melt sizing was patented by Burlington Industries and was developed, under agreement, by West Point Foundry and Machine Company [2]. This 1960's technology was one of the first sizing technologies to provide yarn encapsulation. However, this technology is not widely used today as a sizing technique.

Hot melt sizing is an integration of the warping and sizing processes. It is quite different from that of other traditional warp sizing processes. There are no size boxes or drying sections present in this process. The process begins while the yarns are still in the warping process.

A rotating, heated applicator roll, located between the warper creel and the warper, applies a molten, 100% active size to the yarn. The warp yarn is drawn over the grooves of the roll which separate the ends during the size application. The size, in the form of a solid block touching the surface of the roll, begins to melt into the grooves as the heated roll turns and the yarn passes through. The yarn, traveling at a much higher rate of surface speed than the applicator roll, has time to pick up the molten size and which then cools around the yarn before the yarn is wound onto the warper. The following diagrams depict the concept of hot melt sizing and the cross section of the applicator roll.

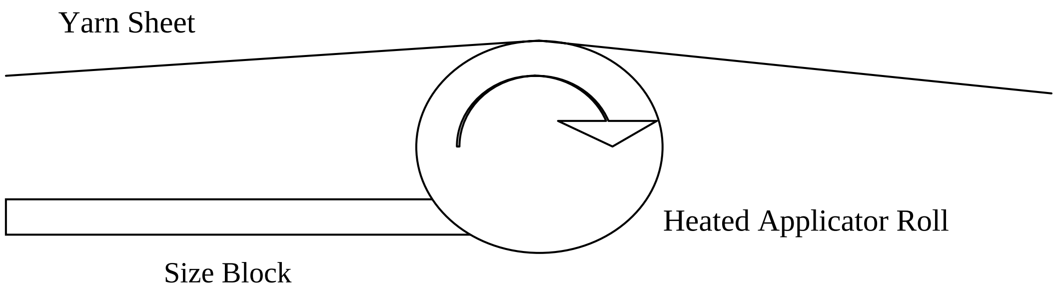


Figure 9. Concept of hot melt application (2)

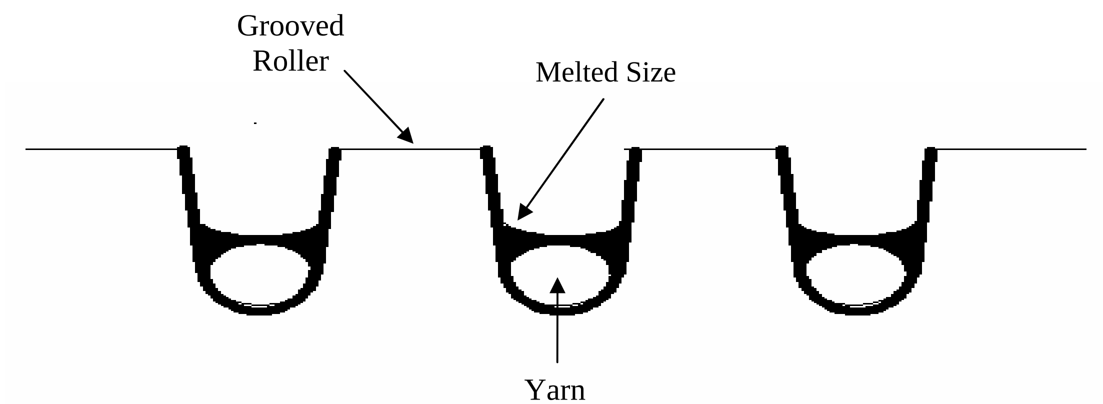


Figure 10. Cross section of hot melt applicator roll (2)

The size add-on and fiber lay are controlled mechanically by the applicator roll speed, the arc of the yarn contact in the roll groove, the applicator roll temperature, and the warp yarn speed.

The hot melt size applied to the warp yarn is not the same as polyvinyl alcohol (PVA) or a conventional wax. Cotney [2] gives the following characteristics of hot melt sizes: a melt temperature from 260° to 310°F; a relatively low melt viscosity; a rapid set-up time; suitable size properties in the areas of tensile strength and elongation; resistance to heat degradation; resistance to blocking; acceptable costs; and conventional, aqueous desizing.

Hot melt sizing presents many advantages to conventional sizing techniques. Since there is an absence of water in the yarn, drying cans and size boxes become unnecessary, resulting in far less energy (around 80% less than for aqueous sizing) being used in size cooking and heating [28]. There is no need for a cooking area or a size dumping area. The size arrives into the plant ready for use.

It is believed that there is a superior quality sizing of warp yarns because of the individualized yarns being sized separately as they travel over the grooved roll. Initial testing shows that there is a good fiber lay, with low hairiness, which results in better weaving performance. There is also a greater speed of size application, since there is no drying section. It has been determined that set-up speeds of one second or less are achievable, allowing for application speeds to equal close to that of the warper speed. Finally, hot melt sizing shows good resistance to shedding at the loom resulting from the elastic properties of available hot melt size materials [2].

The disadvantages of hot melt sizing, leading to its abandonment, include: equipment costs and increased labor costs. The equipment costs are roughly twice the cost of conventional sizing equipment. The labor costs are around ten to fifteen percent higher due to the increased time to place each end in a groove. Hot melt sizing was eventually replaced by single end sizing.

### 2.4.4 Winder Sizing

Winder sizing is the process that most people in the textile industry previously called single end sizing since one yarn end is sized at a time. The sizing winder is used to convert a single unsized, wound package into a sized wound package. More modern sizing winder machines have an individual motor driving system which controls each spindle and yarn pick up device. This allows for greater efficiencies and less downtime.

Just like any other standard sizing process, the machine consists of a supply package holder, tensioning device, size application zone, drying zone, and winding zone for the delivery sized package. Figure 11 shows one spindle of a sizing winder machine which is located in the spinning laboratory at North Carolina State University.

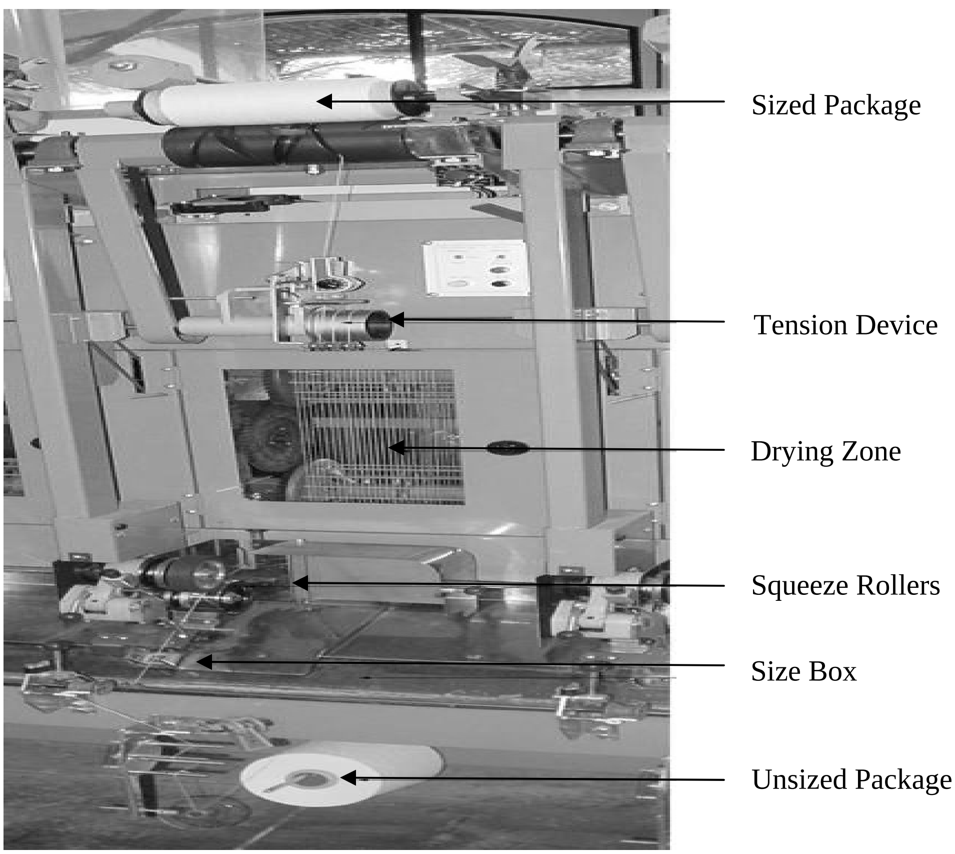


Figure 11. Picture of sizing winder

There are some immediate advantages to this process. Due to the fact that each individual yarn is sized and dried separately, the size encapsulation is maximized and the size bridges are eliminated. Consequently, the sized yarn hairiness, in the case of spun yarns, and filament breaks, in the case of continuous filament yarns, are minimized. These two factors lead to a significant reduction in warp cling, minimized fuzz ball formation, and other fabric defects occurring during weaving. Additional advantages of this process include, reduction in size solution waste, since the size box is extremely small compared to traditional sizing, and the reduction in yarn waste. There is no thread up waste like that of a direct or indirect sizing machine. While these advantages are realized, many of these machines are used only for small, short sample runs due to low productivity as compared to warp sheet sizing.

The equipment cost per unit produced is much greater than that of conventional slashing equipment and in order to be justifiable, the lot size must be much smaller. These machines typically run from 50 to 550 yards per minute, depending on fiber type and yarn diameter. Even though these processing speeds seem fast, only one yarn end is being processed at a time, creating a bottleneck in the overall production of the product. However, it is possible that the advantages of this system may outweigh the increase in costs depending on the end product and quality demands of the customer.

**2.5 Tying In**

This process links together two warp beams of the same style, just after the first beam has run out. The depleted warp beam is cut and the ends of the new warp beam are joined together with the corresponding ends of the old warp. This process is faster than that of the drawing in process because the yarns do not have to be threaded through the dropwires, heddles, and reed again.

This process is fully automated now and has the ability to tie up to 600 ends per minute. Some machines are equipped with dual knotters, one starting on the left hand side of the machine and the other on the right hand side. This reduces the tying in downtime in half. It is important that the knots are strong enough to resist slippage, but at the same time, their size must be small enough not to cause breakages during the weaving process or cause defects in the fabric. The knots must be small enough to travel through the narrow openings of the drop wires and heddles.

### 2.6 Fabric Quality

Today's more knowledgeable consumer demands a higher quality product than in the past. This desire for "top quality" has forced manufacturers to concentrate on continuous quality improvements while keeping costs low. US textile manufacturers used to be able to rely on their quality products to be in higher demand than that of the lower costing, lower quality foreign goods. This however, is no longer the case. Foreign companies have made tremendous advances in quality, in some cases, driving US textile manufacturers out of the marketplace. Singletary [12] explains this scenario best, by saying, "Today, high quality is the price for market admission, in contrast to the past when quality was a key competitive advantage (p.25)."

Fabric quality has been affected by new innovations in machines, process controlling, and electronic monitoring. Machinery manufactures' developments have allowed US textile manufacturers to stay alive in the textile industry. In order to stay competitive in the global marketplace, US manufacturers must rely on these innovations to develop smaller scale, more flexible systems and processes, while maintaining first class quality of the product.

Fabric quality is directly affected by yarn quality and, most importantly, by the warp preparation processes, including warping, slashing, and tying in. Advancements in the weaving process can not increase the productivity and quality of woven fabrics without first being supplied a quality warp. Faster weaving speeds and insertion devices have placed increased pressures on warp preparation processes. Warp yarns must be stronger and more abrasion resistant to withstand the stresses and frictional forces inherent in the weaving process. Careful attention must be paid to the warping and slashing processes to deliver the best quality warp with few to no defects.

### 2.7 Defects

A defect is a term that refers to a flaw in a textile product that detracts from performance or appearance properties. Too many defects in a textile product causes off quality concerns and usually results in downgrading of the product which does not sell at its highest premium. Defects also generate waste, as the defective area must be removed in order to maintain top quality of the textile. Defects can occur due to man, method, or machine causes. Operator error, processing variations, and faulty machinery are examples of each of these causes.

The most common defects caused in the slashing and sizing process include: crossed and twisted ends, lost ends, and hard size. Each of these defects can be eliminated if proper procedures are followed and maintained. The following sections describe these three main defects, explaining their causes, their effects on weaving, and ways to prevent them from occurring.

### 2.7.1 Crossed and Twisted Ends

Crossed and twisted ends are ends which are not properly aligned and fall into the incorrect dent in the comb. The slashing process is a frequent generator of crossed and twisted defects, but it is important to keep in mind that it is not the only cause of such defects. Crossed and twisted end defects can also arise from problems in the warping process and from improper tying in or drawing in at the loom in weaving.

There are three main types of crossed and twisted ends. These ends can be rolled, twisted, or tangled. Rolled ends occur when three or more adjacent ends are crossed over three or more adjacent ends. Twisted ends occur when one or more ends are wrapped around three or more other warp ends, bunching them together. Tangled ends happen when ends have been crossed, rolled, and twisted, resulting in a severe warp entanglement [15]. Figure 12 below, illustrates each of these crossed and twisted end types.

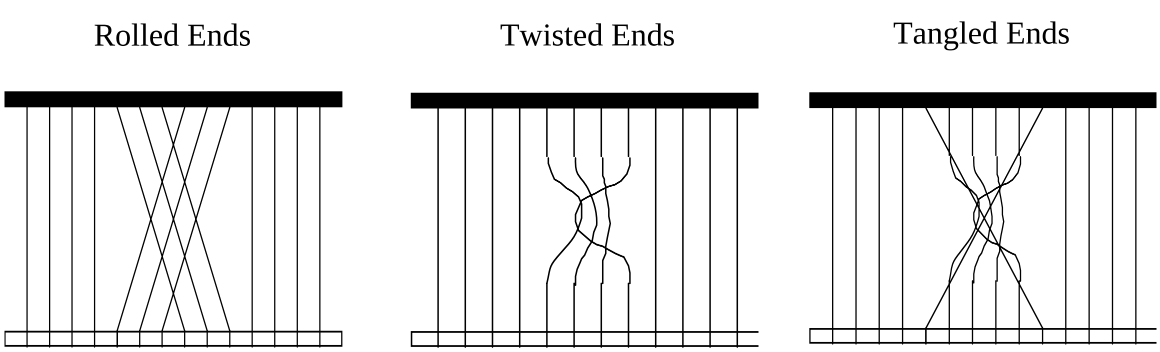


Figure 12. Crossed and twisted end defects (15, p. 4-5)

Rolled Ends

According to Leonard's findings, rolled ends account for the largest percentage of crossed end defects, totaling as much as 50% of the total warp stops in weaving [15]. Rolled ends in the selvage area can be caused by oscillating warp beam flanges or because the tape applied at slashing, keeping the warp ends straight for warp tying, is tucked under the selvage ends. To avoid this it is recommended to use the sandwich taping method. This is where one piece of tape is applied on top of the warp sheet while another is applied directly under that piece of tape on the underside of the warp sheet. It is important not to tuck the tape under selvage ends due to rolling ends. Rolled ends in the body can be related to the tape folding back on itself and sticking the ends together in a rolled or overlapping manner. Rolled ends can also be attributed to bent teeth in the comb used in slashing, especially if ends are struck in rather than counted in individually. Figure 13 illustrates how bent teeth can cause rolled ends.

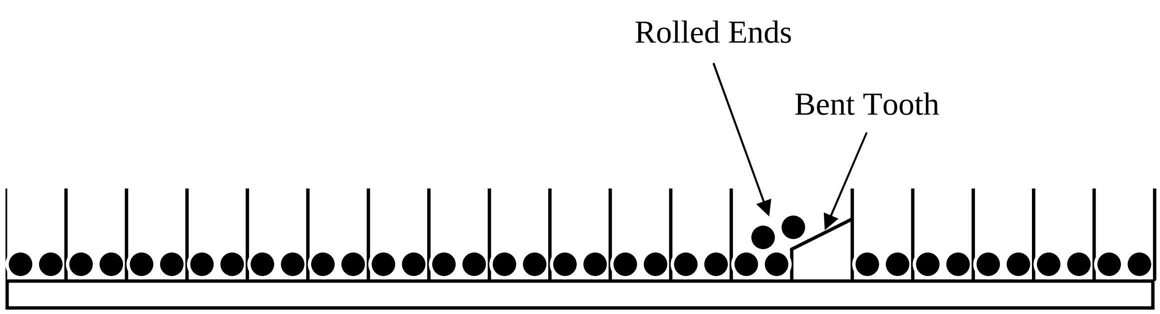


Figure 13. Rolled ends due to bent tooth in comb (15, p.6)

The best way to minimize rolled ends in slashing is to keep static under control, by maintaining humidity in spun slashing or including a static bar in filament slashing, and to have as few ends per dent in the comb as possible. Fewer ends per dent allows for comb contraction. If there are fewer ends in a dent, there is less of a possibility that they will roll over one another.

### Twisted Ends

In weaving, when an end breaks such that it must be redrawn through the dropwire and heddle, the weaver may find the end twisted around adjacent ends and repair the break without straightening the end. This type of defect greatly increases the tension on an end and the ends around which it is twisted. The end result of this will probably be another loom stop due to an end break once a weak place in the yarn runs up. It is usually better to go ahead and break this twisted yarn, untwist it from the adjacent ends, and retie it in its correct location. This will prevent the ends from breaking later due to the increased tension.

### Tangled Ends

Tangled ends occur when crossed, rolled, and twisted ends accumulate in the same area of the warp. Tangled ends are the worst type of crossed end defect because they restrict the movement of the yarn, causing excessive tension and finally an end break or multiple end breaks. This type of defect will continue to cause warp stops until it is fully corrected by the weaver. If the ends are severely tangled for an extensive amount of yardage the warp may be taken out of the loom and sent back to the slashing department to be pulled down until the ends are straightened. Proper leasing techniques and proper taping procedures will prevent rolled, twisted, and tangled ends from occurring. A little extra time and effort during these two procedures can prevent multiple loom stops in weaving and can prevent the return of a tangled warp. This extra time and effort is absolutely cost effective when compared to the cost of taking a warp out of the loom, transporting back to the slashing department, fixing the problem, and resending it to the weave room to be tied back into the loom.

Causes of Crossed Ends

There are several causes of crossed and twisted end defects. These defects can be caused by drawbacks, trapped ends, high and low selvages, slack ends, or by operator practice. All of these causes originate from the section beams in the creel, except operator practice which can originate in this area or any other area of the sizing machine.

A drawback refers to the yarn being either slack or tight when leaving the section beam and does not unwind properly. This can be caused by trapped ends, improper repair of broken ends in the warping process, inconsistent tension on the slasher, or an incorrect lap repair, on the section beam, by the slashing operator. Drawbacks can cause ends to break on the section beam, causing a beam lap and resulting in a lost end. Drawbacks can also cause ends to break and attach to neighboring ends, causing crossed and twisted ends or laps in the size boxes or on the drying cans.

Trapped ends occur when a yarn end is under a neighboring end, does not unwind properly, and causes a drawback, resulting in a lost end and a lap on the section beam, size box rollers, or dry cans. A crossed or twisted end could also result if the broken end attaches to a neighboring end, is sized, and goes into the wrong dent in the comb. Trapped ends can also be caused by an improper repair of a broken end in the warping process, an end which jumps a dent, excessive starting and stopping of the warper, or a shift in the comb on the warper while running. They can also be caused by improper beam handling or damaged beams. If a beam flange was to bump into a full section beam, the ends might be bunched together, trapping some of the ends under the adjacent ends.

High and low selvages can also cause crossed ends. High and low selvages are caused when the yarn build is off center due to a misaligned comb in the warping process, a warped beam head, a bent or worn beam journal, or the improper positioning of the press roller. This can cause ends to roll over one another and cause drawbacks or trapped ends, resulting in an end break, which will become a lost end or will cause section beam laps, size box laps, laps on the drying cans, or crossed and twisted ends if the broken end attaches to a neighboring end and enters a different dent in the comb.

Slack ends can also bring about crossed ends. If the yarn is not held at the same tension as the other yarns coming off of the section beam it can cause ends to entangle with other ends, break and result in a lost end or a breakout of multiple ends, as well as laps or crossed and twisted ends. It is important to fix slack ends as soon as they become apparent because they will continue to cause problems until they are fixed. If a slack end is not corrected and does not cause an end break, it will still cause a loom stop in weaving because the lack of tension will allow the dropwire to contact the dropwire bar and stop the loom. The only way to correct a slack end is to break the end and retie it to an adjacent end, or increase the tension on the entire section beam, thus overstretching all other ends to make up for the slack end. The latter may cause end breaks in weaving caused by exposed weak spots in the yarn due to this excessive tension.

One of the largest sources of crossed end defects is incorrect operator procedures. Creel alignment is a sure way to instigate problems in the quality of the warp. Yarn ends can catch rough edges of roller, causing the rolling and breaking of ends. If these ends break and attach to adjacent ends, get sized, and enter the wrong dent, then a crossed end defect has transpired. Inadequate tape jobs can also cause crossed ends. The ends must be kept straight coming off of the section beams and the tape must be smooth across the warp to ensure no space for ends to roll. It is important to note that improper leasing will not remove crossed and twisted ends. Conversely, proper leasing techniques will detect crossed ends needing to be repaired.

Other incorrect operator procedures could include improper repair of defects, improper laying-in of ends, moving ends in the comb after start up, inserting the wrong size loom beam, bad taping procedures, or excessive starting and stopping of slasher. Inadequate cleaning will also cause crossed end defects. Rough spots or hard size on guide rollers or bust rods can cause ends to break and attach to adjacent ends. Crossed end defects can be avoided with proper procedures set in place and operators who respect and follow those procedures.

### 2.7.2 Lost Ends

Any time an end breaks in the slashing process it will cause a lost end defect in weaving. This is due to the fact that there is tension on all of the yarn ends throughout the entire machine and the machine does not stop for a broken end. This is why awareness and responsiveness are so instrumental to the sizing of good quality warps. Since it is virtually impossible to repair a lost end defect, preventive action is the best approach to reducing lost end defects. There are many different root causes of lost ends. Discussed in this section are reasons due to laps, yarn separation, and operator practice. These three sources will cover most of the ways in which lost ends defects originate.

Causes of Lost Ends

Lost end defects can occur due to laps on the section beam, in the size box, or on the drying cans; yarn separation at the bust rod; or by improper operator practice in excessive creep time, improper end break repair, misaligning the creel, or causing a breakout.

A section beam lap occurs when an end or ends break between the creel and the size box and the end no longer unwinds from the beam while the other ends continue to unwind. This accumulation of unwound yarn will eventually trap other ends under it, creating excessive tension and eventually will cause these other ends to break as well. Section beam laps can be caused by a number of different reasons. The yarn can break due to weak yarn, rough edges on the beam head, or trapped ends. These trapped ends may happen because of rolled and trapped ends from a bent tooth on the warper comb or from high and low selvages on the beam. They may also be caused by uneven tension on the ends in warping or drawbacks or crossed ends in warping. Laps can also occur due to lost ends at the warper or loose knots tied on broken ends at the warper.

A lap in the size box can occur for several reasons as well. Too much tension between size box and drying cans can break an end or multiple ends, causing a lap to occur around the roller in the size box. Hard size accumulating in size box can also break ends in the size box. All rollers should be checked for cuts and grooves, as these will cut the yarn ends, as will, damaged or dirty rollers.

Laps in the drying section can be caused by some of the same sources as the size box laps. Cut, grooved, or dirty spots on guide rollers in drying section can break ends. This can be minimized by using Teflon® coated cans and rollers which will decrease the possibility of sized yarn sticking and forming laps. Excessive tension at exit of drying section can also cause ends to break. If the can temperatures are too high, this can cause ends to become brittle and weak enough to break and lap around the drying can.

Lost ends are also common in the leasing area near the bust rods. The bust rod can cause lost ends if the angle of separation of the yarn sheet is too large. If there is too much tension on the yarn, the yarn is separating just before the rod and excessive force is being placed on the yarn. This will cause the yarn to separate abruptly, possibly breaking the yarn ends.

Improper operator practice and procedure can also lead to lost end defects. This is true when the operator places the machine in slow or creep speed for too long of a period of time. This allows the yarn to stay in the nip point of squeeze roller in the size box longer, resulting in less size being applied. The lack of size will expose the yarn, decreasing its strength and abrasion resistance. The yarn is also in drying section longer, resulting in over dried, weak, and brittle yarn. An improper end repair may cause an end to break due to excess tension if the operator ties the broken end to a nonadjacent end. Also, if the end is not tied correctly and knot comes loose the end will break. The operator must make sure to align the creel properly to ensure that no ends run off of the guide rollers or drying cans and break. A misaligned creel can also make an end run across a damaged or burred beam end, causing the end to break. Also causing lost ends is a breakout where multiple end breaks can entangle with other ends causing all of them to break.

Again, if proper procedures are followed by the operators in warping and slashing, the amount of lost end defects can be reduced. Good communication between these two departments is also necessary. If a problem occurs in warping, the operator should notify the slashing operators to let them be aware of the problem so that they may fix it in a timely and effective manner.

### 2.7.3 Hard Size

Hard size defects include pieces of size or size-covered lint entangled into the warp or an excessive amount of size on the yarn. These hard size defects will either cause ends to break during weaving or, if woven into the fabric, cause off quality fabric, which must be cut out. There are many possible causes of hard size defects, most of which are cleaning and machinery related.

#### Causes of Hard Size

The four largest causes of hard size defects are from operator practice, opportunities in the size box, mechanical problems, and running the machine while out of specification. This section further discusses these four main causes of hard size defects.

Operator practices and procedures can cause hard size if not performed correctly. Inadequate cleaning of the slasher can cause hard size. Size or lint build up can occur under the slasher, in the size box, on the spray nozzles or jets, on the contact rollers, and on the drying cans. This build up will eventually break free and travel along with the yarn as hard size. Running the slasher in creep or slow speed, or stopping the machine for an excessive amount of time can cause hard size. Also, improperly cooking the size, in the case of spun yarn, can cause lumps of size to form in the bath.

Opportunities in the size box often lead to hard size defects. Any damaged rolls can accumulate excess size in grooves, cracks, or cuts and then release this excess size onto the yarn as it exits the size box. The squeeze roll pressure must be adequate enough to squeeze excess size from the yarn. If the size does not circulate well throughout the size box, it will coagulate and form hard size which can exit the size box with the yarn. The size jets must be working properly to prevent this from occurring. Also, in the case of spun yarn slashing, it is important to completely boil out the size box between sets as left over size will harden and linger in the box for the next set.

Mechanical problems are also attributed to the occurrence of hard size defects. Ineffective guards will not prevent size from splashing out of the box and onto the yarn. Excessive spray pressures can also spatter surplus size onto the yarn or dislodge any size build up in the box. Ineffective filtration systems will clog the lines and the size will not properly filter out, causing hard size to accumulate in the size bath. Water leaks or steam leaks can cause condensation drips on the sized yarn, which may lead to size displacement on the rollers or drying cans, which may later be dislodged.

Running the slasher within specification is important in preventing hard size defects from occurring. Too high of machine speeds will lessen the contact time the yarn is in the nip point of the squeeze roll, allowing excess size to remain on the yarn. If the temperature of the size bath is to low the size may start to coagulate. If the squeeze roll pressure is too low then excess size will be applied to the yarn. Also, too high of a percent solid concentration of size could allow too much size on the yarn. Tensions are also critical in preventing hard size, as too low of a tension will allow for there to be more surface area on the yarn, thus allowing more size to remain on the yarn. The size box level should be inspected as too low of a size level will allow size to splash and dry on the walls of the size box.

It is possible to prevent hard size defects from occurring, but it requires properly followed work instructions and attention to detail. The effects of hard size defects at weaving are impeding. If the hard size makes it through the dropwires and heddle without causing a break in the warp yarn, it may prevent the filling yarn from passing through the warp shed, resulting in a filling loom stop, or worse a thin spot in the fabric where the filling yarn is missing. If the hard size is woven into the fabric, it will either be burrowed out in inspection, creating holes and weak spots in the fabric, or during desizing, it will be fully removed, also causing a hole in the fabric. These areas will then have to be cut out, resulting in two fabric rolls of non-standard warp lengths. This creates a problem, as most customers specify and demand exact roll lengths.

### 2.8 Waste Sources

Eliminating waste sometimes first, involves finding waste. Many sources of waste are difficult to identify, especially to those who work closest to the process. When eliminating waste it is important to fight the root causes or sources rather than to fight the symptoms of the waste. There are two main categories of waste: resource or system related, and loss or variation [7]. Resource or system related wastes can be clearly attributed to a specific resource, such as a machine or operator. System related waste cannot be attributed to a specific resource, but it is known to be caused by some part or by a whole process. This is usually the most difficult category of waste to eliminate because it is seen as a normal or necessary part of the process. Losses and variations relate to resources not being fully utilized, which lead to deviations from the expected value of those resources.

There are six big losses in three specific areas according to De Smet [7]. There are downtime losses, speed losses, and quality losses. Downtime losses include equipment failure and setup. Equipment failure relates to machine breakdowns, which are infrequent but have a long duration. Setup includes the process from the end of one production run to the start up of the next run. The amount of time a machine is not running directly affects its efficiency and productivity, consequently, impinging on profitability. Downtime losses can be reduced by implementing standardized work instructions and encouraging teamwork among operators. All downtime losses should be documented for cause and length of time to ensure proper record keeping.

Speed losses include idling time or minor stoppages, and reduced speed. These losses have a low per unit cost, although high frequency can become problematic. Idling time and minor stoppages relate to yarn end breaks, operator relief, or machine malfunctions. These stoppages are usually short in duration, but can be detrimental if frequent in nature. Reduced speed constitutes a loss, in that full capacity utilization is not being met. Speed losses should also be properly documented for cause and length of time. These reports allow for measurement and control of the process.

De Smet [7] also describes quality losses, including defects and reduced yield. Losses caused by defective products or time and energy of reworking defective material can be costly to the manufacturer. Defects can cause off-quality products which sometimes must be completely wasted, nullifying all of the time, energy, and money that went in to making the product. This is why it is critical to properly train all operators, constantly monitor and improve their performance, and demand excellence in their work ethic. Reduced yield, another quality loss, refers to the loss of material at the start up of a machine or process. Proper start up is crucial in all areas of manufacturing in order to reduce and control waste generation. Standard operating procedures can help to consistently start and stop machines in the same manner each time, thus reducing variation in the product.

Losses from raw material waste are generated throughout all of the warp preparation processes. Waste is accumulated due to processing conditions and by incidental error caused by either the machine or the operator. Processing conditions can be altered in order to reduce or even eliminate this waste accumulation. Waste generated by incidental error can be eliminated by proper training and implementation of preventive measures to ensure correct settings and procedures are being followed at all times.

As mentioned earlier, it is important to detect and eliminate waste which is not obvious or easily seen. This waste is sometimes referred to as invisible waste. Robinson and Schroeder [22] suggest that waste can be invisible for two reasons: knowledge based and perspective based. The first of these, knowledge based invisible waste, arises due to the fact that a person knows of no way to eliminate it, making it become a normal part of the process.  The second reason for invisible waste, perspective based, is visible only when the process is viewed from a different perspective.

Knowledge based invisible waste is usually never directly attacked.  The root causes of the waste are not accurately identified and solutions are not formulated to reduce this waste.  This typically leads to the waste becoming a “necessary” counterpart to the process, which is not literal.

Perspective based invisible waste is often overlooked because it is a part of the everyday process and is never questioned by those close to it.  In order to reduce or eliminate this type of waste it is best to bring in someone who knows little about the process so that they can view it from an outside perspective, asking the easy and hard questions about how the waste is generated.  Most often this type of waste is identified and attacked after many questions of “why”.

Throughout the warp preparation processes there are both invisible and visible waste sources.  Most of the waste generated in the warping department is visible creel waste.  This consists of yarn remaining on the packages in the creel once the set is complete.  Most often, this yarn waste is run onto a waste beam at the end of the set and is then cut off.  It is crucial to the reduction of this waste that all packages are properly metered in the winding process.  This will ensure that the packages are of the same length.

Waste is generated in several areas of the sizing process.  Waste is accumulated in the creel area when the section beams begin to run out.  This creel waste is in the form of soft thread or unsized yarn.  Since this yarn has not been run through the slasher and has not been coated with size, this yarn waste has a different cost value than that of yarn which has been sized. Waste can occur all throughout the slasher if a defect is detected and must be removed. Waste also occurs when two sets are joined together, and is referred to as set out waste. However, some of the waste caused from the set out procedure is unavoidable waste. One example of this unavoidable waste is the amount of yarn needed to thread up the machine. Unless good quality yarn can be replaced by other means, this thread up yarn will be wasted.

Other waste is due to improper procedure and operator or machine error. Waste is also generated when the warp is taken out of the weaving loom due to defects and runability problems. The beam is usually sent back to the preparation department and must be pulled down until the defect is no longer visible. It is also possible that the warp may be wasted completely if the defect is consistent throughout the entire length of the warp or if there is only a small amount of yarn left on the beam. Due to the large time requirement for tying in a warp into the loom, most weave rooms do not accept beams containing less than 500 yards, unless the price of the fabric heavily outweighs the time and energy of retying the warp. Examples of other accumulated waste are proportional to the order size length, in that, as the order length size increases there is a greater possibility for defects and operator or machine related errors to occur. Figure 14 illustrates some of the possible sources of hard and soft thread waste.

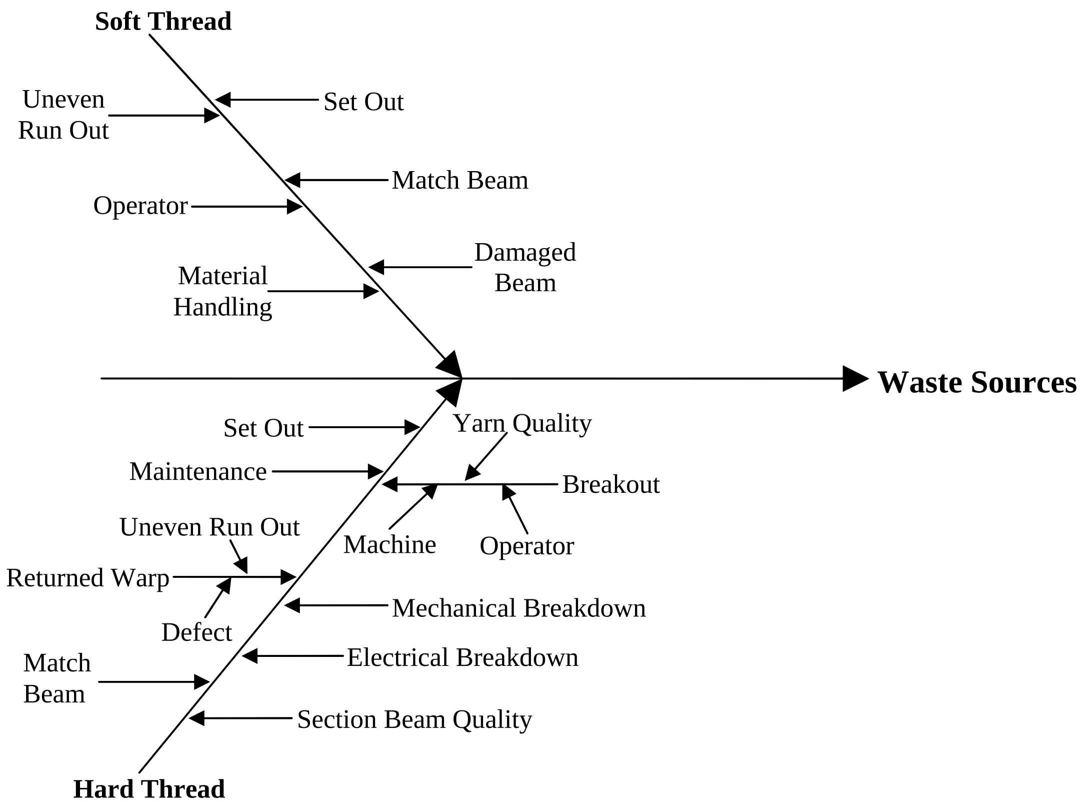


Figure 14. Soft and hard thread waste sources

Whether the waste is caused by human error or machine, there are ways in which to reduce this loss, some of which are included in the results of this research. When attacking waste related issues, companies should strive to constantly improve and never settle for modest gains. This will ensure that they are gaining maximum throughput and reaching full utilization of their resources.

### 2.9 Technology Advances

This section describes and discusses the latest warp preparation technologies and advancements therein, over the past ten years. Every four years machinery manufacturers come together to showcase their new technological advances at the International Textile

Machinery Exhibition (ITMA) which is held in different European cities. The last of these exhibition shows was in 2003, in Birmingham, England. During these shows the machine manufacturers reveal their latest developments to the textile industry, in hopes that these machines will help to lower the manufacturer's costs, increase their production capabilities, offer increased flexibility, and ultimately, provide better service to the end customers.

The warp preparation equipment in this section includes: sample warping machines, sectional warping machines, direct warping machines, single end sizing machines, conventional filament sizing and spun slashing machines, sizing winder machines, and tying in machines, as well as, electronics and software for the warp preparation processes. Each section describes the new advancements showcased by some of the participating companies in the past two ITMA shows.

Sample Warper

CCI Tech [5], a company based out of Taiwan, specializes in providing sampling solutions to the textile industry. They have a ring warper, which is similar to a sectional warper. It makes warp beams for sampling or of small quantities of yarn to be woven on normal sized looms. It has a working width of 2250 mm and is equipped with either stationary or rotational creels. There is no available warp length capability for this ring warper. CCI Tech has also developed a sampling warper that produces warp beams at a maximum length of three meters and width of twenty inches. Combined with this sampling warper they also have designed a sizing winder unit to size the warp yarns. These sizing winders and sampling warpers produce sample warps to be run on their sampling loom, which is intended for weaving samples and new product developments. There are no available processing speeds for CCI Tech's sampling warper or sizing winder.

Karl Mayer [12] has been producing sample warpers for over ten years, showcasing its best seller, the Gir-o-matic (GOM), in 2003. This innovative sample warper has met the increasing market demands for greater efficiency, better quality, and shorter production runs. The GOM offers several advantages including reduction in: set up and production times, operator labor, yarn inventory, and floor space requirement. It can also accompany up to seven leasing sections. The GOM is equipped with a fully automatic leasing unit, up to sixteen packages of creel capacity with full yarn delivery flexibility, and a pre-beamer option for uninterrupted production. Table 2 organizes the technical data on the Karl Mayer GOM.

Table 2

Karl Mayer GOM sample warper technical data

| | |
|---|---|
| Warping Length | 700 meters |
| Warping Speed | 1200 meters/minute |
| Leasing Speed | 1000 meters/minute |
| Color Change Speed | 1000 meters/minute |
| Number of Creel Positions | 16 wound packages |
| Pre Beaming Speed | 60 meters/minute |
| Beaming Speed | 30 meters/minute |

Suzuki [36], a Japanese company, also provides equipment technology for short warp processing. They offer two NAS series sample warpers which have maximum warp lengths of 63 meters and 90 meters, respectively. Each of these machines can hold up to nine wraps. The difference in these machines is their drum circumference, one measuring seven meters and the other ten meters. The NAS-Super series holds up to 40 wraps, offering lengths of up to 280 meters and 400 meters. These machines are fully automated, so once the preparation has been done, the machine carries out the job with no human intervention until the completion of the warp. The NAS-Super can warp at speeds up to 1500 meters per minute. Table 3 and Table 4 illustrate the technical data for the NAS and NAS-Super series sample warpers.

Table 3

Suzuki NAS series sample warper technical data (10m circumference drum)

| | |
|---|---|
| Warping Length | 90 meters |
| Warping Speed | 900 meters/minute |
| Leasing Speed | 900 meters/minute |
| Color Change Speed | 900 meters/minute |
| Number of Creel Positions | 10 wound packages |

Table 4

Suzuki NAS-Super series sample warper technical data (10m circumference drum)

| | |
|---|---|
| Warping Length | 600 meters |
| Warping Speed | 1500 meters/minute |
| Leasing Speed | 1500 meters/minute |
| Color Change Speed | 1500 meters/minute |
| Number of Creel Positions | 20 wound packages |

Sectional Warper

Benninger's Ben-Tronic sectional warping machine [3] provides constant thread tension, outstanding warp quality, and production flexibility. The Ben-Tronic is equipped with ten leasing sections and is capable of running 800 meters per minute. With the reversal of the winding direction, high level of reliability, outstanding ergonomics, and symbol-prompted controls, this machine facilitates a safe and efficient operation. Benninger offers several creel models depending on the area of applications, package type and size of the process material, and space conditions in order to satisfy different customer requirements. The Ben-Matic automatic sectional warper has utilized Ben-Tronic's technology and automated the leasing and section changes, making it more beneficial and desirable. Table 5 includes the technical data on Benninger's Ben-Matic automatic sectional warper.

Table 5

Benninger's Ben-Matic sectional warper technical data

| | |
|---|---|
| Warping Length | 9000 meters |
| Warping Speed | 800 meters/minute |
| Warping Width | 3800 mm |
| Leasing Sections | 10 |
| Beaming Speed | 300 meters/minute |

Karl Mayer's Rob-o-matic (ROB) automatic sectional warping machine [12] offers warp lengths of up to 8000 meters, making it suitable for sample and short production runs. It is suitable for all ranges of yarns and fitted with new electronic systems and more accurate and faster positioning motors. Karl Mayer's ROB incorporates the leasing and separating cords during the warping process, increasing the production efficiency and eliminating this work later on in the beaming process. The operator manually sets the leases for the first section and ties the warp ends onto the pattern drum. The machine then automatically sheds and leases the warp and it is ready to run without further operator intervention. The ROB is equipped with an integrated laser for optimum band build up. Since the ROB runs one continuous warp band, once the correct yardage has been run the top layer is cut to create the yarn sheet's end. The yarn sheet is then manually wrapped around the final warp beam for wind up. The lease cords are removed and the warp is beamed. Table 6 further describes the technical data associated with the Karl Mayer ROB sectional warper.

Table 6

Karl Mayer ROB sectional warper technical data

| | |
|---|---|
| Warping Length | 8000 meters |
| Warping Speed | 800 meters/minute |
| Warping Width | 3600 mm |
| Leasing Sections | 7 |
| Beaming Speed | 300 meters/minute |

Suzuki's K7A Auto-warper [36] is equipped with automated leasing and band matching capability, eight sizing leases, and endless warping technology by cut-lease. The K7A Auto-warper allows warping speeds up to 600 meters per minute and allows from 38 to 6144 meters in warp length, depending on yarn count and number of ends. After manually taking care of the first section, the K7A carries out the remainder of the job automatically. Table 7 describes some of the technical data on the K7A Auto-warper.

Table 7

Suzuki K7A Auto-warper technical data

| | |
|---|---|
| Warping Length | 6100 meters |
| Warping Speed | 600 meters/minute |
| Warping Width | 2250 mm |
| Leasing Sections | 8 |
| Beaming Speed | 60 meters/minute |

Before automation was introduced to sectional warping, fewer, wider bands were desired to reduce the amount of manual labor involved in leasing and transferring bands on the pattern drum.  Now that the leasing and separating actions are completed automatically, more, smaller width bands are preferred.  This allows for a smaller creel capacity, decreasing the amount of floor space and inventory required.

Direct Warper

Benninger's Ben-Direct [3] is a direct warping machine which features throughput speeds of up to 1200 meters per minute and useful widths of up to 2800 mm. It has toothed tapers to ensure exact beam centering and drive and hydraulically operated disk brakes for quick stopping after end breaks.  It also features precision thread guidance, electronic length measuring, an automatic moving widescreen, and an indirect-acting press system to produce perfectly cylindrical winding.

Karl Mayer's direct beamer series ZM-SP 1800 [12] is capable of running warping speeds of up to 1200 meters per minute, with a working width of 2800 mm.  It is also equipped with an automatic cutting and knotting device for the creel.  At the end of a set, the cutter goes through and cuts all of the package ends leaving them hanging in the creel.  Then, after the new creel has been loaded, the knotting unit travels by and knots each end in the creel to the end on the new package.  This eliminates the need for rethreading the machine at each set out, saving time and money.

Single End Sizing Machine

Karl Mayer's Fil-o-matic single end sizing machine [12] features a constant unwinding tension throughout the entire process by means of a motor drive system and a load cell. It has the potential to run at speeds of up to 500 meters per minute and has a working width of 1800 mm. There is also a laser stop device which automatically stops the machine when an end break is detected. Its touch screen monitors allow for user-friendly, easy to control set ups.

Toyoda's Filamaster Express 610 high speed single end sizer [38] for filament yarn can reach speeds of up to 610 meters per minute. It has dual, large capacity drying chambers and a six sheet divided drying system. The temperature control system provides efficient drying while maintaining high yarn quality even during the high speed operations. Its equal pressure (EP) roller system gives custom sizing and high speed operation while consuming less energy. The EP roller squeezes the center and the edges of the warp sheet uniformly, preventing irregular sizing. The monitoring system, including a touch screen, is designed to improve the ease of operation. The head end is also equipped with an automatic taping device, eliminating this manual task previously done by the operator.

Tsudakoma Corporation's KSH500 single end sizing machine [39] features accurate and precise tension control through its advanced electronics technologies. It also features a computer control system which monitors and manages the sizing machine. It allows for quick and easy data collection and communication. The multi-section drive system allows for increased complexities. It is equipped with a two step temperature control system for more accurate drying. It can run up to 1800 ends and can reach speeds of up to 500 meters per minute. It also has a working width of up to 2000 mm.

Direct Filament Sizing Machine

Benninger's Ben-Sizetec [3] uses advanced control and regulating technology to keep all sizing parameters constant and optimal. The automatic monitoring of the machine conditions allows for high reproducibility and high quality warps. The flexible squeeze rollers enable uniform sizing across the width of the warp. The control and regulatory technology mentioned earlier monitor the tension and stretch parameters ensuring proper stretch is applied to the yarns, leaving a high residual elongation in the warp for the weaving process.

Karl Mayer's Size-o-matic [12] has an operator terminal which can control the entire machine. The working parameters for the machine are included as pictures on the touch screen for easy-to-recognize and easy-to-use convenience. It has a working width of up to 2800 mm and can reach speeds up to 150 meters per minute, depending on yarn type and diameter.

Toyoda-Kawamoto's Filament Escort filament yarn sizer [13] achieves high quality sizing and beaming at high productivity, up to 180 meters per minute. It features an even sizing system, where the even-press system equally squeezes the liquid size of high-density warp yarns. The machine is also equipped with wet dividing rods and a hot air drying chamber, ensuring uniform and consistent drying across the warp sheet. It can dry numerous sheets of warp yarns equally and efficiently, claiming savings of up to 40 percent in energy consumption.

Direct Spun Slasher

Ira Griffin [10] slashing systems offer precise tension control with electronic load sensing and pneumatic brakes. The cluster creel allows for easy operator access to all beams using walkways between the four beam clusters. The ILG-2 size box features a vertical exit path for the yarn. This vertical yarn path from the size box is the shortest and most stress-free route to the dry cans, producing a perfect exit from the nip point to aid in the reduction of hairiness. It is also equipped with operator walkways for easy access to cut laps or make end repairs in the size box area. The heavy-duty, DJG remote winding head end has enhanced comb access and beam diameter capacity of up to 1250 mm. This remote head end is equipped with an operator walkway which gives easy comb access. Also, included is a user-friendly touch screen process control system for monitoring of the entire machine. Ira Griffin systems also emphasize pre-drying rather than final drying to reduce hairiness.

Sucker-Muller- Hacoba [35] boasts their new Wetsize SC size box which is compact and integrates the prewetting and sizing techniques. The size box consists of three rollers, each of which allows for double immersion and squeezing. The prewetting technique permits the use of higher viscosity size solutions, without increasing size consumption. The prewetting soaks the inside core of the yarn while the size adheres to the outer surface. The Wetsize sizing process is controlled by the Telecoll system which holds the size take-up reproducibly constant.

Sizing Winder

Yamada [42] offers their YS-6 sizing winder as an option for sizing small order sets. This YS-6 sizing winder links the sizing, drying, and winding processes together into one machine, dramatically improving efficiency, quality, and floor space utilization. This machine also greatly reduces, or even eliminates, the wastes usually generated in the sizing process. The YS-6 individually drives each spindle and is capable of running at 400 meters per minute. These machines are equipped with banks of four spindles and can accommodate as many as 20 spindles per machine.

Kaji Seisakusho Company, subsidiary of Izumi International, [11] offers their KS-7 Uni-Sizer coating machine as a sizing winder. The KS-7 is ideal for producing a variety of fabrics in high complexity, small lot sizes. The KS-7 can wind up to a 1.2 kilogram package at up to 550 meters per minute. Each spindle is individually driven for maximum processing efficiency.

Tying In Machine

Knotex has a new dialogue guided program on its TS-2 machine, which can tie all types of yarn materials from the finest of silks to coarse cotton. It can tie at rates of up to 600 knots per minute. An electronic repeats selector also allows the operator to select the number of picking attempts to better adapt to the yarn type. The machine stops and waits for operator assistance after the predetermined number of attempts. The TS-2 promotes gentle and reliable thread handling, even on different counts within the same warp [8].

Zellweger’s Warplink system provides constant tension of all the ends across the warp by a plastic welding device. This replaces the tying in operation of each individual yarn end.  Zellweger estimates that this reduces the total downtime for tying in a warp by twenty minutes [8].

Software and Electronics

The latest advancements in the warp preparation processes have been software and electronic upgrades to already existing systems.  The advancements made include: on-line and potable instrumentation, tension controlled braking systems; new stored program control SPS; touch-screen machine set point monitoring; network connections; real time diagnostics of off-quality potential; yarn end break detecting systems; slasher tension and stretch controls; consistent add-on level controls; and increased production speeds.

Today's textile market is one that demands multi-styling and high complexity. Process instrumentation has made it possible to maintain style-based control over the warping and sizing processes.  One of the most important advances in this sector is the ability for the warp preparation equipment to store all of the settings for each of the individual styles run.  There are several advantages to this advancement.  Processing a particular style in a unique and consistent manner is now possible.  Optimum settings for tension, stretch, wet pick-up, size add-on, moisture retention, and temperatures can be achieved for each individual style.  Style-based control ensures that each beam of a set is processed in exactly the same manner as the others, reducing variability between production runs.  The automatic loading of settings also reduces a large portion of the set up time for a new set.  Operators, in the past, had to find the paperwork for the next set, clear out the old set data, and enter in the new data.  Now the computer aided systems store all of this information on the machine.  This is very useful for high complexity plants that run many different styles with frequent style change.

The real time diagnostics, yarn end break detectors, tension and stretch controls, and squeeze roll pressure sensors all play a role in reducing the chances for defects to occur during the sizing process.  Digital set point monitoring allows for speeds and efficiencies to be optimized, while energy and sizing material losses are minimized.  Real time monitoring of the wet pick-up and size add-on provide an accurate measurement system to monitor and control these parameters.  Network connections from the machine allow for real time and historical data to e processed and analyzed based on developing trends or statistical quality control charts.  Through all of these advancements, operators are making better and more-timely decisions, contributing to the reduction of generated waste in the warp preparation processes.

## 3. RESEARCH OBJECTIVE

The main goal of this research is to make it possible for US textile manufacturers to gain a competitive advantage in the marketplace by lowering costs in the warp preparation processes. This research on the reduction of waste allows manufacturers to cut costs and increase throughput, thus increasing their competitive advantage. Waste has a direct effect on the profitability of a company. Reducing the amount of waste generated in any process should be a constant objective.

This research works with slashing experts in the textile industry, including vendors and manufacturers, to investigate methods to reduce this inherent raw material waste in the slashing process. The area of focus is on new equipment, innovative controls, and process engineering, which all have the ability to bring about reduced manufacturing costs.

The investigation of new equipment involves discussions with machinery manufacturers of warping and slashing machinery focusing on what products will soon be available to aid in reducing waste for smaller lot sizes. It also includes financial reasoning for the purchase of new machinery. The focus on innovative controls looks into software and mechanical apparatuses that may be available to support in the reduction of waste. Finally, the process engineering segment of this research investigates reasonable methods and procedures to develop a “best practices” summary for reduction of waste in smaller order size lots. The “best practices” investigation includes aspects of warping and sizing which reduce or eliminate waste with little, if any, capital expenditures.

The value of this research relies heavily on industry support in the form of process access and information sharing.  The support of vendors of alternative warping and slashing solutions is also required.  Included in this study are recommendations and an economic analysis of potential slasher and sized yarn waste reduction solutions.

The results of this investigation can be used by US textile manufacturers to gain an understanding of: where waste is being generated in the warp preparation processes, how order lengths and style complexities affect waste accumulation, and what the most beneficial machinery setups for certain selected cases may be.

The value of this research not only benefits the textile industry, but all work related operations, as it provides a methodology for identifying and attacking waste drivers.  The waste drivers may not, and in most cases will not, be the same, although the methodology used to find and fix these problems or opportunities will be effective in achieving desired results.

# 4. METHODOLOGY

## 4.1 Overview

During the research, industry participation and cooperation was sought, well received, and complimentary to meeting the objectives and reaching the goals of this research. This research consists of three phases. The first phase involves an initial understanding of the warp preparation processes and technologies presently operating in the textile industry in the US and Europe. The second phase involves in-plant process mapping, time studies, material utilization and waste analyses, and trials. The third phase involves a solution evaluation through operational procedures and technology modifications.

## 4.2 Phase One

The first phase includes secondary research conducted in the field of study, initial interviews, and plant visits with US manufacturers and machine vendors. The secondary research consists of reviews of past theses, dissertations, studies, papers, and reports on the warp preparation processes, order length and complexity issues, and new and existing machinery. The research also investigates the way in which manufacturers are constantly evolving to meet the demands of the textile market and its consumers.

Today, consumers are less aware of how their products get to the retailer and from where those products are made and assembled. Price and quality now seem to be much more important than whose economy is being strengthened. It is of little concern to the consumer how manufacturers operate, as long as the products they sell do not increase in price or decrease in quality.

In order to stay competitive, American textile manufactures must constantly innovate, all the while cut and control costs. Being innovative not only applies to creating new products, but also altering processes and procedures in order to produce better and more efficient results. However, before altering processes and procedures it is important to benchmark other operations and processes in order to understand what practices and procedures work and which ones do not.

The initial interviews conducted in this phase of the research are face- to- face or over the phone, depending on proximity and availability. Follow up correspondence is conducted by the two earlier mentioned methods and by e-mail. These initial interviews help to identify whether or not the identified company would aid in, and benefit from, the successful completion of this research.

### 4.3 Phase Two

The second phase of the research involves more in-depth plant visits and interviews. This phase focuses on process mapping, time studies, waste analyses, cost studies, and process complexities within the plants. These visits typically last three to four days depending on the equipment and data analyzed. Visits and interviews are conducted with both manufacturers and machine vendors.

During the visits the processes are first mapped out, detailing the machinery configurations of the slashing and sizing equipment. The machinery configuration is important to note because of its direct correlation to waste accumulated during thread up of the machine.  The thread up length varies depending on the length of the creel, the number of size boxes and drying section configuration, as well as, the length of the machine itself.

Time studies are conducted in order to follow the process flow and identify where time and labor wastes are occurring.  These time studies are focused on set outs in the warping and slashing processes.  The set out process, also sometimes referred to as change out, is the most time consuming and labor intense activity in the slashing process.  In order to fully understand the set out process, time studies are conducted to identify the necessary tasks involved in changing slashing sets.  Several tasks must be completed when performing a set out, including: cleaning, tying in the new set to the end of the previous set, threading up the machine, verifying correct set information, and cutting off waste from the previous set.

Each of these duties, and others, must be carried out each time a new set is to be run.  It is important that these duties are done in an orderly and timely fashion to reduce the amount of downtime of the machine and loss of production.  Several of the tasks to be completed during set outs can be performed by more than one person and in some cases can be carried out simultaneously.  Complete lists of set out duties can be found in the appendix.

Through communication with the machine operators and technicians it is possible to then identify the areas of the process in which the generation of waste is most likely to occur.  These areas are noted and categorized as to the amount of waste and the reason for its accumulation.  Further investigating these sources and amasses of waste through waste databases and waste records; it is possible to analyze the factors contributing to the generation of waste.

In order to accomplish a thorough waste analysis on a plant, there are certain requirements that must be met. There must be full access to data records and histories. Those records must also be accurate and complete. If the records are not accurate or complete there is not any reason to try and make sense of them. As mentioned earlier, there are different kinds of waste and those kinds of waste can be caused by different sources. It is important that all types of waste be kept separate, as well as, each source of generated waste. This allows for a more complete and meaningful analysis. Given that there is full access to complete and accurate records, it is possible to draw good conclusions from a waste analysis.

These waste analyses vary from case study to case study, as some companies do a much better job of tracking waste than others. In the cases where little to no tracking is evident, overall waste percentages are reported.

Order length and style complexity information is obtained for each of the case studies. These numbers are useful in comparing the cases, as well as depicting how the textile industry has changed over the years. No longer are companies producing long runs and only specializing in a few different styles. Companies are now faced with producing much smaller order lengths and a higher demand of numerous different styles. Complexity issues have become a growing concern for many companies who want to continue to compete for business here in the US and abroad. Supply chain logistics must be carefully mapped out and special care must be taken in planning what styles to run and when.

## 4.4 Phase Three

The third and final phase of the research suggests recommendations for optimization of the warp preparation processes, as well as, methods for waste reduction. Technology evaluations and operational procedures are compared and contrasted, cost analyses are presented, and any new process or machinery designs as emerging technologies are discussed.

Machinery manufacturer, Karl Mayer's support during this phase of the research provided technological assistance and offered full access to their manufacturing facilities and customers, in the US and abroad (Germany, Austria, and Italy).

# 5. RESULTS AND DISCUSSION

## 5.1 Overview

The objective of this research is to investigate methods to reduce waste being generated in the warp preparation processes. Through the comparison of ten participating plants, represented as case studies, it is possible to identify where waste is being accumulated, what the largest sources of that waste are, and what factors may be contributing to this waste generation.

Also included in this section are comparisons between the case studies, identifying some of the waste opportunities these companies are facing, average order length sizes, and average plant complexities; best practices on waste reduction, currently being used in the industry (case study plants, as well as other participating companies); measures for defect prevention; comparisons between technologies; and emerging technologies, which may become more prevalent in the near future.

## 5.2 Case Studies

The ten plants involved in this data collection and analysis are coded to protect their individual rights and processing conditions. Each plant is given a case study letter in random order, the only stipulation being that the filament plants are kept together as case studies "A" through "E" and the staple, spun plants are grouped "F" through "J".

To best categorize each plant the following information is obtained: order length sizes, including the minimum, median, maximum, and most commonly run; the warp style complexities, including how many styles they run and what percentage of total production their most common styles make up; machine configurations, including thread up length of the machine; waste analyses, including what percentage of waste was generated from warping and slashing; and time studies on the set out procedures between sets. In some cases this information is incomplete due to inaccurate record keeping or not provided for reasons of competition.

### 5.2.1 Case Study A

Order Lengths

This plant is a filament yarn processing plant with order lengths ranging from 5,000 yards to 150,000 yards depending on style and customer requirement. Table 8 below, includes the breakdown of their set order lengths.

Table 8

Case study A: set size order lengths, in yards

| | |
|---|---|
| Minimum | 5,000 |
| Median | 78,000 |
| Maximum | 150,000 |
| Most Common | 75,000 |

Plant Complexities

Plant A has a fairly large complexity of warp styles running. They are currently running 75 different styles, while their two largest styles make up 25% of the total production. This means that 73 other styles account for three-quarters of their production.

### Machine Configurations

The machine configuration on this conventional filament slasher is unique in that it is multi platform slasher. It has two platforms, where each of the slashing elements is located. The top and bottom warp sheets, also referred to as sheds, come together at the head end in the front comb, just before they are wound onto the loom beam.

The double-deck incline creel, which is used primarily for filament yarns, allows for a direct path of yarn from each section beam to the size box. This helps in lowering the thread up length of the machine, thus reducing yarn waste. The largest vertical separation of yarn is from the beam closest to the size box. The beam farthest from the size box enters the size box with the least amount of vertical spacing.

The yarn from each of the section beams is pulled into the back hook reed which keeps each adjacent end separated from the next. This prevents any ends from becoming crossed or twisted and also ensures the ends do not jump out of line for any reason. The ends are then guided into the size box where the size is applied to the yarns.

After exiting the size box, the yarn is again separated by the use of lease rods. These lease rods have cooled water circulating through them in order to cool the size around the yarn as it leaves the size box.

The yarn then passes through the predrying and into the final drying section which includes two steam drying cans. The yarn contacts the dry cans, which are usually kept at a higher temperature than the predrying oven for final drying. The two warp sheets, top and bottom, are still separated at this point. The separation of the two sheets allows for better encapsulation of the size as it dries around the yarn. This is because of the greater space of yarn separation. The size is able to fully encapsulate the yarn ends without forming a size bridge between adjacent yarns.

Once exiting the drying section, the yarn reaches the leasing section, where the yarn is again separated into same number of sheets as there were in the creel area. After the yarn has been separated into the various warp sheets, the individual ends again must be separated from the adjacent ends. The front hook reed, or comb, located on the head end of the machine makes sure that each individual end is inline and not crossed or twisted. This allows the warp to be wound correctly onto the loom beam. This process is easily followed with the help of the Figure 15 below.

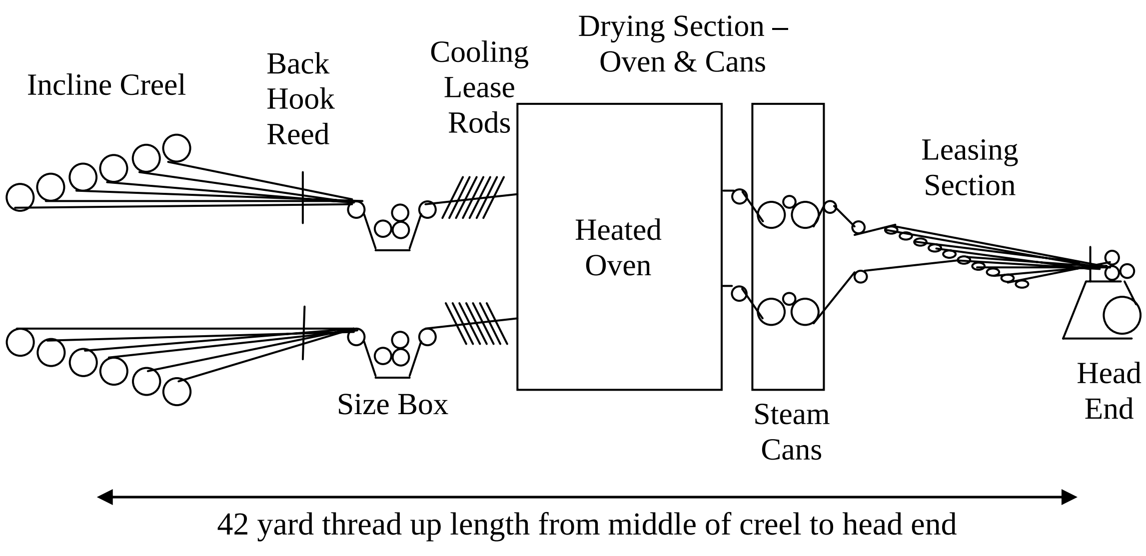


Figure 15. Two platform direct filament slasher setup used in Plant A

Time Studies

Four time studies are conducted in this plant. Two different styles are followed through both the warping and the slashing processes. The time studies noted the time it took to creel in the set, the time to lay the ends in the comb, the actual run time, and the stop time, including time for doffing and time for machine stops.

There are several important notes to mention here. The creeling time includes all set out duties other than laying-in the ends into the comb on the head end. The stop times do not take into account downtime for operator breaks or shift changes.

The first set tracked is a style consisting of a 70 Denier yarn, of an approximately normal order length, and includes approximately 1075 yarn ends per section beam. This same set is then followed through the slashing process. The time study results are included in Table 9 and Table 10.

Table 9

Time study 1 on warping (70 denier, 78,000 yards, 1075 ends)

| | |
|---|---|
| Creeling | 372 minutes (4 people) |
| Laying In | 22 minutes (1 person) |
| Run Time | 108 minutes |
| Stop Time | |
| Doffing | 35 minutes |
| Stops | 27 minutes |
| **Total Time** | **564 minutes** |

It is important to note that there are four people being utilized in the creeling procedure. This teamwork minimizes downtime and increases the efficiency and productivity of the machine and process.

Table 10

<u>Time study 2 on filament slashing (70 denier, 78,000 yards, 1075 ends/beam)</u>

| | |
|---|---|
| Creeling | 137 minutes (2 people) |
| Laying In | 35 minutes (2 people) |
| Run Time | 1620 minutes |
| Stop Time | |
| Doffing | 35 minutes |
| Stops | 41 minutes |
| **Total Time** | **1868 minutes** |

The second set tracked is a style consisting of a 2 x 70 Denier yarn, of a minimum order length, and includes approximately 800 yarn ends per section beam. Again, this set is followed through the slashing process. Again, in this time study on warping there are four people participating in the creeling procedure to reduce the amount of downtime of the machine, preparing it for the next set. The time study results for this set are included in Table 11 and Table 12.

Table 11

<u>Time study 3 on warping (2x70 denier, 5,000 yards, 800 ends)</u>

| | |
|---|---|
| Creeling | 281 minutes (4 people) |
| Laying In | 17 minutes (1 person) |
| Run Time | 16 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 33 minutes |
| **Total Time** | **387 minutes** |

Table 12

<u>Time study 4 on filament slashing (2x70 denier, 5,000 yards, 800 ends/beam)</u>

| | |
|---|---|
| Creeling | 112 minutes (2 people) |
| Laying In | 27 minutes (2 people) |
| Run Time | 175 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 23 minutes |
| **Total Time** | **377 minutes** |

Waste Analyses

Plant A does a good job of recording waste generated in each of the warp preparation processes.  They also do a good job of keeping these waste types and sources separated.  The problem is that these waste numbers are only recorded and never tracked. If an abnormally large amount of waste is recorded then management gets involved and finds out why the problem occurred.  Unfortunately, after a talk with the operator and a manager's awareness signature, there is no preventive action to keep this waste opportunity from occurring again.

This is not uncommon among plants which, in the past, have run large runs with small complexity issues.  This however is not the case of many manufacturing facilities still in business today.  Performance tracking is a must.

Since the records on waste generated are not being logged into a database and being tracked, it is impossible to know the exact waste numbers for each of the processes. But, through some general calculations of total waste pounds and total pounds produced, it is possible to estimate the amount of waste generated as a percent of total throughput pounds.  In the warping process it is estimated that three percent of the total throughput in warping is being wasted.  It is also estimated that one percent of the total throughput in slashing is being wasted.  And based on data collected from three months of returned warps from the weave room to the slashing department due to defects or runability problems, another 0.014% of the total throughput in slashing is being wasted.

Waste Opportunities

There are several areas in which this plant can work on improving their waste in the warp preparation processes. Yarn performance variation and runability issues are created due to the fact that there are approximately fifteen different yarn package suppliers.

Some of the yarn purchased from suppliers is unmetered yarn, which means that all of the packages are not the same length. This presents a problem with runouts and increased downtime. As more packages begin to run out, there is more labor and time spent on recreeling a new package in for the remainder of the run. This also creates a problem for the creelers at the end of the set because now they must decide whether to waste the remaining yarn left on the spindle or repackage it for reuse in another set at a later time. In most cases, the operator wastes more yarn than put forth the extra effort of repackaging, resulting in higher waste accumulation.

Through conversation with operators and management, there is also a concern of variation in tension and stretch throughout the slasher. This causes concern as too high tensions will result in excessive yarn breaks either in slashing or in weaving. Conversely, too low of tension will cause slack ends and opportunity for crossed and twisted ends to occur, which will result in end breaks in weaving.

There also seems to be little, or no waste performance tracking taking place as mentioned earlier. The waste standards and creel loading time standards have not been recalculated or tightened in a number of years. It is quite unclear as to whether or not there is improvement or deterioration in both the amount of waste being accumulated and the amount of time being spent during set outs. Both of these performance related measures need to be tracked more closely and plotted for the management, as well as for the operators to be more aware of any trends or fluctuations.

### 5.2.2 Case Study B

Order Lengths

This plant is a filament yarn processing plant with order lengths ranging from 1,000 yards to 67,000 yards, thus making it a short to medium order provider. Table 13 below, includes the breakdown of their set order lengths.

Table 13

Case study B: set size order lengths, in yards

| | |
|---|---|
| Minimum | 1,000 |
| Median | 30,000 |
| Maximum | 67,000 |
| Most Common | 30,000 |

Plant Complexities

Plant B has a large complexity of warp styles running. They are running 150 different styles, with four styles making up 30% of the total production. About half of the total styles are small running programs, only occupying a small amount of looms for a short amount of time. The large complexity of this plant makes it crucial that there is good communication between the slashing and weaving departments in order to produce the fabric as efficiently as possible. This large complexity also suggests that there are many style changes, which can lead to excess waste accumulation.

Machine Configurations

The layout of the direct filament sizing machine is low to the ground allowing for a more direct path for the yarn, as well as lowering the machine's thread up length, reducing unnecessary yarn waste.

The equi-tensioned creel has small diameter guide rolls mounted to sides that permit the section beams to be individually drawn and joined together with the other beams. This also allows for all of the section beams to have an equal amount of tension applied.

The yarn from each of the section beams is pulled through the leasing section which separates each warp sheet and into the back hook reed, which keeps each adjacent end separated from the next. The ends are then guided into the size box where the size is applied to the yarns.

After exiting the size box, the yarn is introduced to the drying section, which includes a number of steam drying cans. The yarn sheet weaves its way over and under the steam cans until it reaches the leasing section, where the yarn is again separated into same number of sheets as there were in the creel area. After the yarn has been separated into the various warp sheets, the individual ends again must be separated from the adjacent ends. The front hook reed, or comb, makes sure that each individual end is wound correctly onto the loom beam. Figure 16 illustrates the layout of the direct filament sizing machine utilized in this plant.

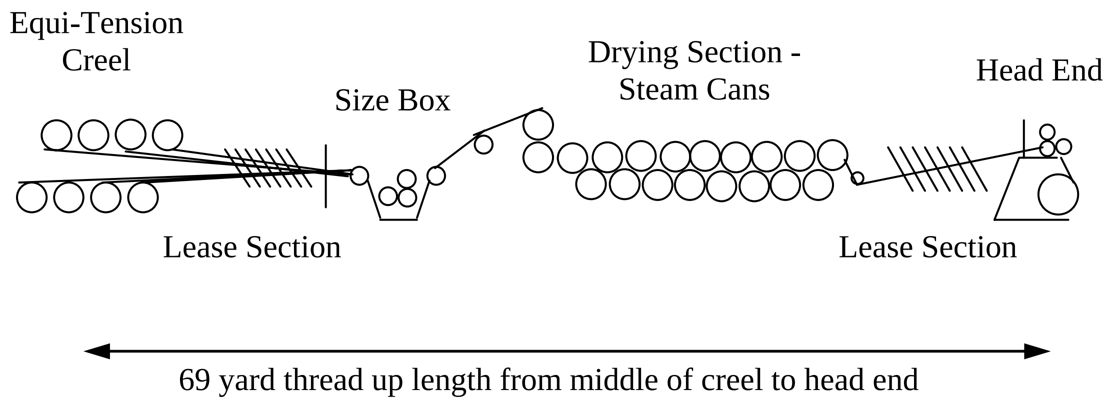


Figure 16. Direct filament sizing machine setup used in Plant B

Time Studies

One time study was conducted on the conventional filament sizer in this plant. The time study notes the time it took to creel in the set, the time to lay the ends in the comb, the actual run time, and the stop time, including time for doffing and time for machine stops.

There are again several important notes to mention here. The creeling time includes all set out duties other than laying-in the ends into the comb on the head end. The stop times do not take into account downtime for operator breaks or shift changes.

The set tracked is a style consisting of a 150 denier yarn, of a median order length for this plant, and includes approximately 700 yarn ends per section beam. The time study results are included in Table 14.

Table 14

Time study 5 on conventional filament sizing (150 denier, 30,000 yards, 700 ends/beam)

| | |
|---|---|
| Creeling | 152 minutes (2 people) |
| Laying In | 24 minutes (1 person) |
| Run Time | 432 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 13 minutes |
| **Total Time** | **661 minutes** |

Waste Analyses

Plant B virtually records no waste data generated in the sizing processes. Even though the waste at set out seems to be minimal and necessary to thread up, there are no standards or processes in place to keep the waste under control. Through the calculations of total waste pounds and total pounds produced the industrial engineering department estimates that there is 0.05% of the total throughput in warping is being wasted. It is also estimated that 0.80% of the total throughput in slashing is being wasted. This includes both slashing waste and beaming waste. It is also estimated that returned warps due to defects or runability problems account for another 0.01% of the total throughput in slashing is waste.

Waste Opportunities

There are a few areas in which this plant can work on improving waste generation. As mentioned above, there is no waste performance tracking. All of their waste standards are based on the budget revisions from the previous year. It appears as if a department, such as slashing, is losing money then it is assumed that they are generating more waste than usual. This gives the plant no idea how much they are really wasting and how much waste they should be generating.

This plant incorporates a leader cloth into the thread up procedure on one of their machines. This prevents good quality yarn from being wasted in the initial thread up of the machine. Based on the configuration of the style, 80 to 120 yards is saved on each thread up. This idea has been around for a long time, but this company has found a way to make it work on a consistent basis. Currently, it is only being used on one of their machines. If they could replicate this idea to the other machines, their waste numbers would decrease significantly.

### 5.2.3 Case Study C

Order Lengths

This plant is a filament yarn processing plant with a wide range of order lengths, from 2,500 yards to 100,000 yards. This plant has noticed a decrease in customer order length size over the last few years. Table 15 includes the breakdown of their set order lengths.

Table 15

Case study C: set size order lengths, in yards

| | |
|---|---|
| Minimum | 2,500 |
| Median | 52,000 |
| Maximum | 100,000 |
| Most Common | 52,000 |

Plant Complexities

Plant C has a large complexity of warp styles running. They are running 110 different styles, with an approximately equal percentage of each style accounting for the total production. A large complexity such as this increases the importance of skillful planning and execution of the entire supply chain to ensure that orders are correct and on time.

Machine Configurations

Plant C has several different types of warp preparation equipment. They utilize direct warpers, a sectional warper, a sample warper, a rebeamer, and conventional slashers.

The first machine discussed is the sectional warper. This machine is used primarily for striped pattern, short run styles. The creel is loaded with the appropriate number and color of yarn packages to complete the pattern. These ends are pulled through the lease reed and the guide reed and wound onto the pattern drum. The ends are under constant tension, which will allow for a constant and uniform build of the bands.

After the required number of bands has been built onto the pattern drum, they are unwound onto a loom beam. Figure 17 illustrates layout of the sectional warping machine.

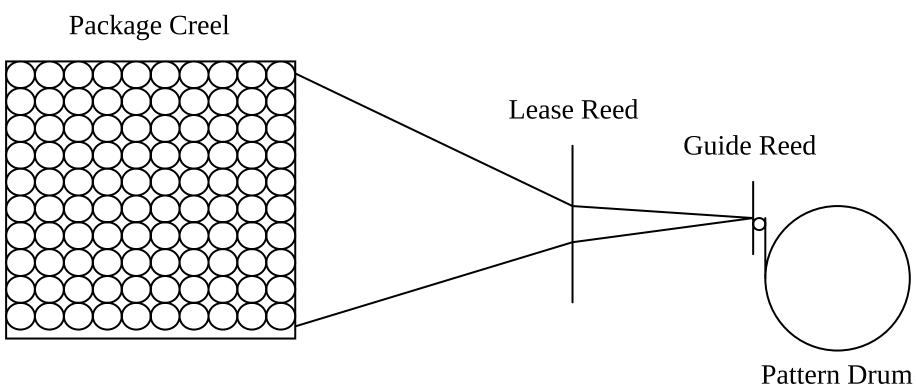


Figure 17. Sectional warper diagram

The next machine described is a conventional filament slasher. The equi-tensioned creel along with the lease rods, allows for a direct path of yarn from each section beam to the size box. The yarn from the section beams is separated by warp sheet is pulled into the back hook reed which keeps each adjacent end separated from the next. This prevents any ends from becoming crossed or twisted and also ensures the ends do not jump out of line for any reason. The ends are then guided into the size box where the size is applied to the yarns.

After exiting the size box, the yarn is again separated by the use of lease rods. These lease rods have cooled water circulating through them in order to cool the size around the yarn as it leaves the size box. After the chilled lease rods, the yarn passes through a wet split comb to keep the ends separated and to allow for complete drying of each individual yarn.

The yarn then passes through the predrying ovens and into the final drying section which includes four steam drying cans. The yarn contacts the dry cans, which are usually kept at a higher temperature than the predrying oven for final drying. Once exiting the drying section, the individual ends again must be separated from the adjacent ends. The front hook reed and comb make sure that each individual end is inline and not crossed or twisted. This will allow the warp to be wound correctly onto the loom beam. Figure 18 displays an arrangement of the machine.

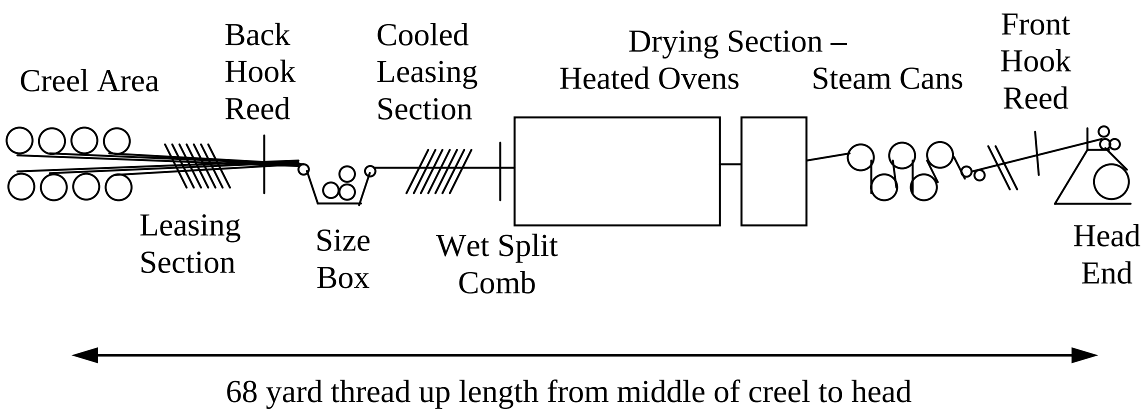


Figure 18. Direct filament slasher setup used in Plant C

Time Studies

Two time studies were conducted during this case study. One style is monitored in the warping process and another style in the slashing processes. The time studies note the time it takes to creel in the set, the time to lay the ends in the comb, the actual run time, and the stop time, including time for doffing and time for machine stops.

There are several important notes to mention here. The creeling time includes all set out duties other than laying-in the ends into the comb on the head end. The stop times do not take into account downtime for operator breaks or shift changes.

The first set tracked is a style consisting of a 2x150 Denier yarn, of maximum order length, and includes approximately 460 yarn ends per section beam. The time study results are included in Table 16.

Table 16

Time study 6 on warping (2x150 denier, 100,000 yards, 460 ends)

| | |
|---|---|
| Creeling | 125 minutes (4 people) |
| Laying In | 12 minutes (1 person) |
| Run Time | 186 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 52 minutes |
| **Total Time** | **415 minutes** |

The set which is tracked in the slashing department is a 200 denier style, of average order length, and consists of approximately 3800 ends. The results of this time study are included in Table 17.

Table 17

<u>Time study 7 on slashing (200 denier, 52,000 yards, 3800 ends)</u>

| | |
|---|---|
| Creeling | 129 minutes (2 people) |
| Laying In | 23 minutes (2 people) |
| Run Time | 867 minutes |
| Stop Time | |
| Doffing | 44 minutes |
| Stops | 26 minutes |
| **Total Time** | **1089 minutes** |

Waste Analyses

Plant C does a good job with controlling their waste. As a percent of total throughput pounds they generate 0.03% of waste in warping and 0.38% of waste in slashing. These waste numbers were generated from dividing the waste pounds accumulated over the past year in the respective department by the total throughput pounds. These figures do not indicate where the opportunities for waste reduction are in this plant, due to the fact that all types of waste are weighed together. More in-depth studies are needed to isolate the key waste drivers.

Waste Opportunities

One of the slashers has an upgrade in software which helps to control and monitor the settings of the slasher. It is recommended that the other machines also receive this software upgrade to improve the quality of their warps and to store and easily recall the settings of their large number of styles. Electronic monitoring and user-friendly touch screens allow operators to more accurately monitor the running conditions of the machine. These software upgrades enable the operator to know, in real time, any fluctuations or changes which may be occurring in the machine settings. This will aid in the reduction of raw material wastes due to improper machine conditions, as well as reduction of time wastes due to trouble shooting any problems with the machine. These software upgrades also allow for the individual settings of each style to be easily and quickly recalled on the machine, reducing the amount of time spent in the set out procedure.

### 5.2.4 Case Study D

Order Lengths

This plant is a filament yarn processing plant with order lengths ranging from 30,000 yards to 150,000 yards depending on style and customer requirement. The majority of their styles are 90,000 yards in length, representing large order sizes. The fact that this plant runs mostly high yardage sets means that their waste percentages should be fairly low and should not vary much. Any variation in waste accumulation should be due to special causes. Table 18 below, details the breakdown of their set order lengths.

Table 18

Case study D: set size order lengths, in yards

| | |
|---|---|
| Minimum | 30,000 |
| Median | 90,000 |
| Maximum | 150,000 |
| Most Common | 90,000 |

Plant Complexities

Plant D has a small complexity of warp styles running. They are only running 15 different styles, with six styles accounting for 95% of the total production. This small complexity allows for operators to know exactly how each style runs and what settings work best for each. This also allows for quicker set up times, as the operators are familiar with each of the styles and are usually running the same styles back to back.

Machine Configurations

This plant utilizes direct filament slashers which are equipped with equi-tensioned creels. The machine set up is comparable with that of plant B's sizing machines, although the machines are manufactured by different companies. The thread up length for this plant's direct filament slasher is 68 yards from the middle of the creel to the head end. The layout of the machine is pictured in Figure 19 below.

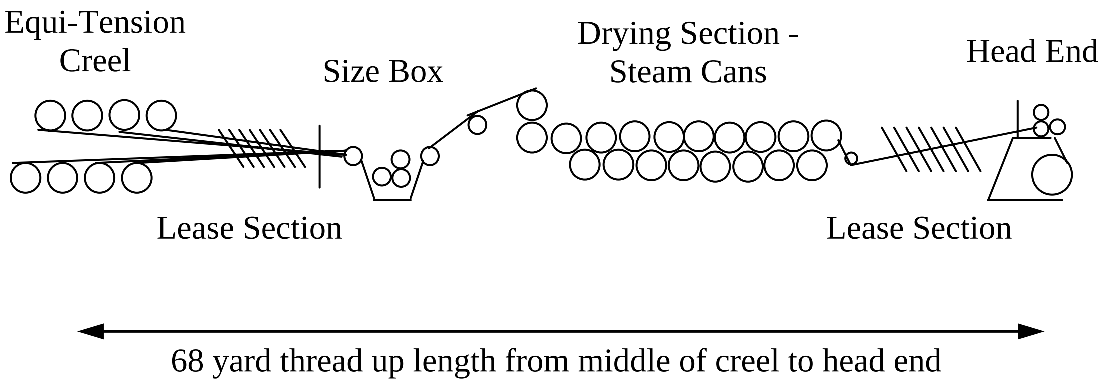


Figure 19. Direct filament slasher setup used in Plant D

Waste Analyses

Plant D has a contract with their yarn suppliers to return any yarn left on the section beams. This means that the only waste that the plant has is waste generated from set out and defects. The set out procedure is well defined in order to minimize waste from set outs. There is a minimal amount of waste generated in this sizing department.

Waste Opportunities

The only opportunity with waste includes better training of the operators to prevent defects, thus preventing excess waste. It is important to note that even though this company has a contract with its supplier to send back yarn waste, they are recovering raw material costs, but not value added costs sustained during the sizing process.

**5.2.5 Case Study E**

Order Lengths

This plant is another filament yarn processing plant with its order lengths ranging from 3,000 yard sample runs to 450,000 yards depending on the type of sizing technology. The 450,000 yard sets are run on the single end sizing machines, using full packages in the creel. The maximum order length they run on the conventional slashers is 120,000 yards. Table 19 notes Plant E's set order lengths.

Table 19

Case study E: set size order lengths, in yards

| | |
|---|---|
| Minimum | 3,000 |
| Median | 80,000 |
| Maximum | 450,000 |
| Most Common | 115,000 |

Plant Complexities

Plant E has a small complexity of warp styles running. They are running 18 different styles, with each of the styles accounting for approximately equal percentages of the total production. This small number of styles suggests that the operators are familiar with each style and are aware of the best running conditions for each. This aids in minimizing the amount of waste generated, as the operators know which styles are more susceptible to defects and runability problems.

Machine Configurations

This plant utilizes indirect, single end sizers and direct filament slashers. The single end sizers are equipped with inline or parallel creels. The yarn is pulled from the creel into the back hook reed which keeps each adjacent end separated from the next. The ends are then guided into the size box where the size is applied to the yarns.

After exiting the size box, the yarn enters into the drying section which includes three drying chambers. Once exiting each of the drying sections, the individual ends again must be kept separated from the adjacent ends. There should be adequate spacing between each of the yarn ends. The combs make certain that each individual end is inline and not crossed or twisted. The final comb on the head end ensures that the warp is wound straight onto the beam. These sized beams must then be combined together in the beaming process to produce a complete loom beam. Figure 20 illustrates the lay out of the single end sizing machine.

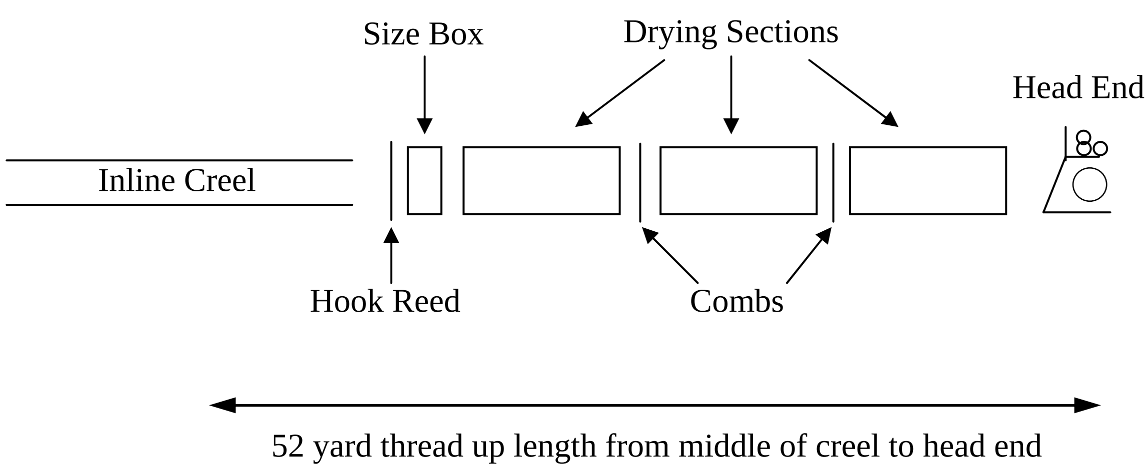


Figure 20. Indirect, single end sizing machine

Time Studies

One time study was conducted on the single end sizing process during this case study. The set tracked is a 50 denier style, of average order length, and consists of approximately 1000 ends. The time study described in the table below does not include the beaming process which combines each of the sized section beams together to make the final loom beam. It is also important to note that in single end sizing, yarn breaks will automatically stop the sizing process. The style running in the following time study is considered a good running style which does not typically have many yarn breaks. This is not always the case and it should be noted that stoppage times can vary considerably from style to style.

Table 20

Time study 8 on single end sizing (50 denier, 150,000 yards, 1000 ends)

| | |
|---|---|
| Creeling | 447 minutes (2 people) |
| Laying In | 38 minutes (1 person) |
| Run Time | 424 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 34 minutes |
| **Total Time** | **983 minutes** |

Waste Analyses

Plant E does a good job keeping the waste generated in slashing and sizing to a minimum. This plant runs mostly high yardage sets meaning that their waste percentages should be minimal and should not vary much. They report that 0.6% of their total throughput pounds in the slashing department are accumulated as waste.

Waste Opportunities

The only opportunity with waste includes better training of the operators to prevent defects, thus preventing excess waste. Most of these defects occur on the conventional filament slashers and not on the single end filament sizers. This is due to the fact that there is a greater separation between yarns and the yarn path is more direct in the single end sizing machine.

### 5.2.6 Case Study F

Order Lengths

This plant is a spun yarn processing plant, considered to run medium sized order lengths, ranging from 9,000 yards to 60,000 yards. Table 21 below, details the breakdown of their set order lengths.

Table 21

Case study F: set size order lengths, in yards

| | |
|---|---|
| Minimum | 9,000 |
| Median | 30,000 |
| Maximum | 60,000 |
| Most Common | 60,000 |

Plant Complexities

Plant F has a small complexity of warp styles running. They are running 20 different warp styles, with seven styles accounting for 75% of the total slashing production.

Machine Configurations

This plant utilizes conventional direct spun slashers which are equipped with cluster creels. The yarn is pulled from each of the section beams in the creel and guided into the size boxes where the size is applied to the yarns.

After exiting the size box, the yarn enters into the drying section which includes steam drying cans. Once exiting the drying section, the yarn sheets must be separated from one another. This takes place in the leasing section, where bust rods and lease rods separate the yarns into the same number of sheets as there are section beams. The comb on the head end ensures that each of the adjacent ends is separated and that the warp is wound straight onto the loom beam. Figure 21 illustrates the layout of the machine.

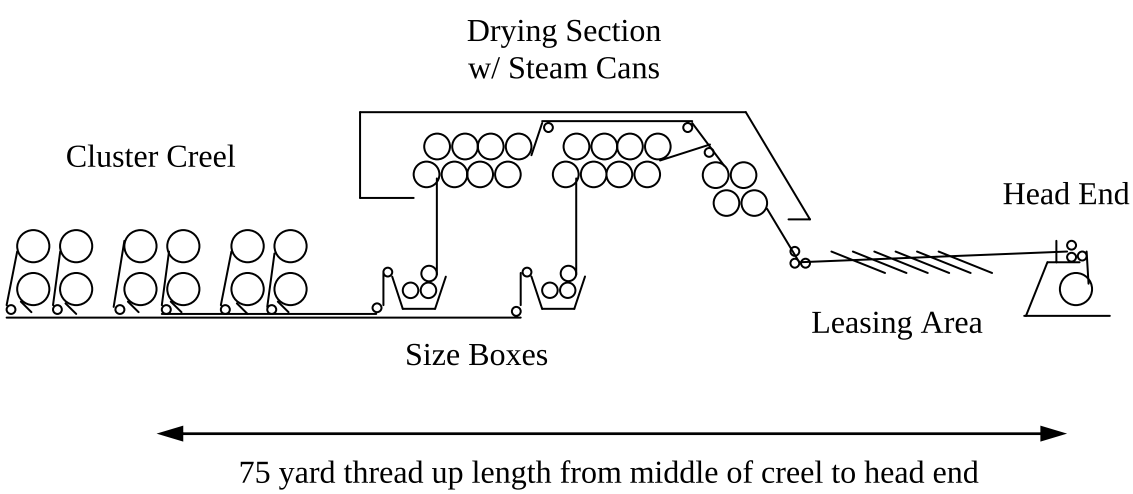


Figure 21. Conventional spun slasher setup used in Plant F

Time Studies

One time study was conducted in slashing during this case study. The set which is tracked is a 26/1 yarn count style, of maximum order length, and consisting of approximately 6500 ends. The time study for the slashing process in this case study is broken down in the table below.

Table 22

Time study 9 on spun slashing (26/1, 60,000 yards, 6500 ends)

| | |
|---|---|
| Creeling | 78 minutes (1 person) |
| Laying In | 47 minutes (1 person) |
| Run Time | 612 minutes |
| Stop Time | |
| Doffing | 48 minutes |
| Stops | 26 minutes |
| **Total Time** | **811 minutes** |

Waste Analyses

This plant generates most of its waste due to returned warps for runability problems in the loom or excessive defects. The normal procedure is to pull down 100 yards of the warp or until the defect is noticeably gone. The amount of waste generated in the slashing process itself is 0.76% of the total throughput. But, the waste generated from returned warps is 2.02% of the total throughput. This two percent of waste from returned warps could be eliminated with proper training and more attention and care for the warps as they are being slashed. Eliminating this returned warp waste would yield dramatic cost savings immediately.

Waste Opportunities

The opportunity with waste for this plant includes better training of the operators to prevent defects, thus preventing excess waste. The operators frequently have returned warps for the same defects. Crossed and twisted end and lost end defects seem to be the most common reasons for their returned warps. With more in depth training the operators would understand what is causing the defects and prevent them from occurring. There is also no standardized start up procedure used among all of the operators. This leads to numerous small remaining yardage beams coming back to the plant. These beams are usually completely wasted due to the fact that there is a small amount of yarn and it would take too much time to retie the beam into the loom.

There is also an opportunity with waste separation and accountability. Sometimes waste does not get properly accounted for due to operators not following correct procedures. Small amounts of yarn waste are occasionally found in the trash. Also, noticed in this plant is that operators do not work together as much as they could during the set out procedure. This would decrease the set out times as well as help prevent unnecessary downtime of the machine.

### 5.2.7 Case Study G

Order Lengths

This plant is a spun yarn processing plant with order lengths ranging from 6,000 yards to 60,000 yards depending on the style. This plant is considered to run small order lengths for spun slashing. Table 23 below, details their set order lengths.

Table 23

Case study G: set size order lengths, in yards

| | |
|---|---|
| Minimum | 6,000 |
| Median | 28,000 |
| Maximum | 60,000 |
| Most Common | 37,000 |

Plant Complexities

Plant G has a fairly average complexity of warp styles running. They are running 60 different styles, with one style accounting for 25% of the total production.

Machine Configurations

This plant utilizes conventional direct spun slashers which are equipped with cluster creels. These machines are unique due to the fact that they can process spun or filament yarn. It is crucial that these machines are cleaned between sets with extra care in order to prevent any contamination.  These machines are also equipped with three size boxes allowing for more yarn end separation throughout the thread up configuration.

Due to the different configurations of the size boxes and the drying cans this machine has a relatively long thread up length as compared to similar spun slashing machines.  This plays a role in the unavoidable waste that is accumulated at the end of each set out.  Below, Figure 22 illustrates the direct spun slasher with three size boxes.

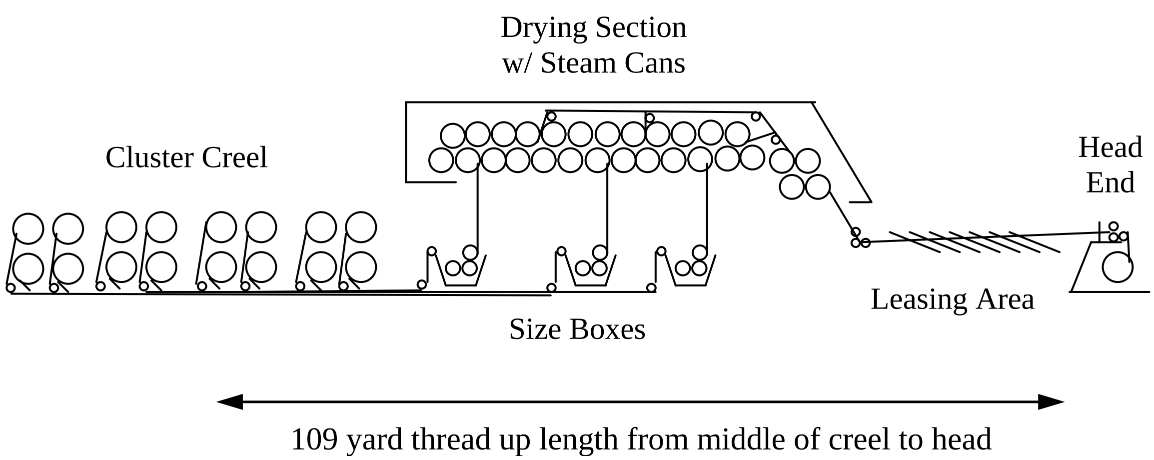


Figure 22. Direct spun slasher setup used in Plant G

Waste Analyses

This plant reports that 1.7% of the total throughput is waste from the warping department.  The slashing department reports 2.9% of the total throughout pounds are accumulated waste.

Waste Opportunities

As mentioned earlier, the thread up waste on this machine is higher than usual due to its greater number of size boxes and drying cans.   This presents an opportunity that needs to be addressed.  If it is possible to thread up the machine with something other than good quality yarn that is unavoidably going to be wasted then real money savings will immediately be realized.  Also, the set out times on this machine can reach up to eight hours, depending on the complexity of the style and the rethreading of the machine. Reducing this amount of downtime is another opportunity for this plant.  Teamwork, standard operating procedures, and diligence should allow these times to be reduced.

### 5.2.8 Case Study H

Order Lengths

This plant is a spun yarn processing plant with medium order size lengths, ranging from 9,000 yards to 60,000 yards.  Table 24 below, details their set order lengths.

Table 24

Case study H: set size order lengths, in yards

| | |
|---|---|
| Minimum | 9,000 |
| Median | 48,000 |
| Maximum | 60,000 |
| Most Common | 48,000 |

Plant Complexities

Plant H has a small complexity of warp styles running.  They are running 38 different styles, with one style accounting for 70% of the total production.  This one major style makes it easier for operators to quickly become experts on the optimum settings to make this style run as well as possible.

Machine Configurations

This plant utilizes conventional direct spun slashers which are equipped with cluster creels.  The yarn, after exiting the size box, enters into the drying section which includes steam drying cans.  The drying section is low to the ground, giving a more direct path for the yarn to travel.  This also enables the thread up length to be slightly lower since there is no unnecessary space wasted.  Once exiting the drying section, the bust rods and lease rods separate the yarns into several warp sheets.  The comb on the head end ensures that each of the adjacent ends is separated and that the warp is wound straight onto the loom beam.  The slasher is depicted in Figure 23 below.

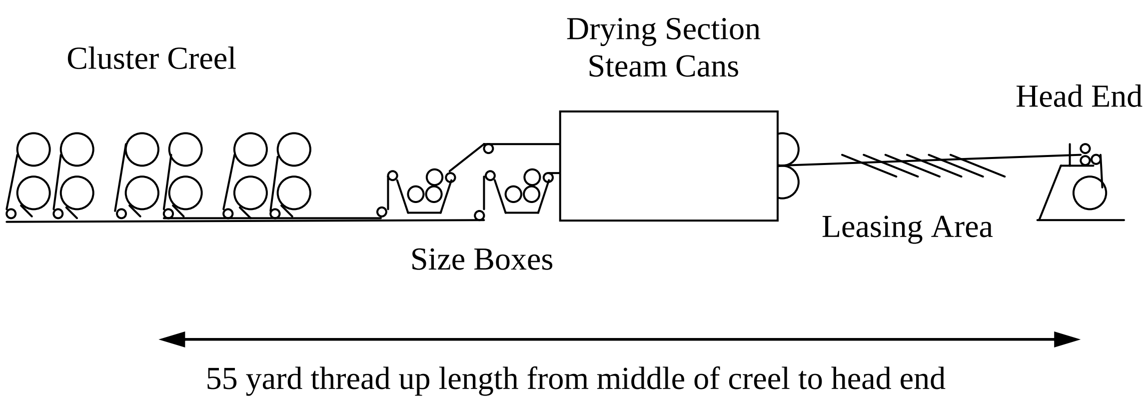


Figure 23. Direct spun slasher setup used in Plant H

Time Studies

There is one time study on the slashing process included in this case study.  The set which is tracked is a 15/1 yarn count style, of short to average order length, and consisting of approximately 1850 ends. The breakdown of the time study is included in the Table 25.

Table 25

Time study 10 on spun slashing (15/1, 30,000 yards, 1850 ends)

| | |
|---|---|
| Creeling | 44 minutes (2 people) |
| Laying In | 22 minutes (2 people) |
| Run Time | 564 minutes |
| Stop Time | |
| Doffing | 20 minutes |
| Stops | 13 minutes |
| **Total Time** | **663 minutes** |

Waste Analyses

Plant H does an excellent job on minimizing the waste generated in slashing. Their teamwork and standard operating procedures during set out ensure that the downtime of the machine is minimal, and the waste accumulated is minimal, as well. The set out procedure is well organized and well executed.

This plant accumulates 1.9% waste of the total throughput in the warping department. The slashing department only generates 0.06% waste of the total slashing throughput. There is also 0.54% waste of total slashing throughput, which is returned due to defects and runability problems in weaving. This is an excellent job by the slashing department.

Waste Opportunities

The only opportunity in regards to waste in this plant is training of new operators. The operators which are currently working in this department have been there for over twenty and thirty years and will be retiring soon. It is important for these operators to well train new associates. The good work that this department does on reducing waste should not be lost with the retiring of the present operators.

### 5.2.9 Case Study I

Order Lengths

This plant is a spun yarn processing plant with average sized order lengths, ranging from 28,000 yards to 60,000 yards. Table 26 below, details their set order lengths.

Table 26

Case study I: set size order lengths, in yards

| | |
|---|---|
| Minimum | 28,000 |
| Median | 45,000 |
| Maximum | 60,000 |
| Most Common | 60,000 |

Plant Complexities

Plant I has a small complexity of warp styles running. They are running 15 different styles, with two styles accounting for 70% of the total production. This means that the operators are familiar with exactly how each style runs. A small plant complexity should indicate a low amount of waste generation, keeping all other factors constant.

Machine Configurations

This plant utilizes conventional spun slashers which are equipped with cluster creels. After exiting the size box, the yarn enters into the drying section which includes steam drying cans. The two yarn sheets meet for the final four dry cans and then are separated from one another in the leasing section with the bust and lease rods. The machine configuration is shown in Figure 24 below.

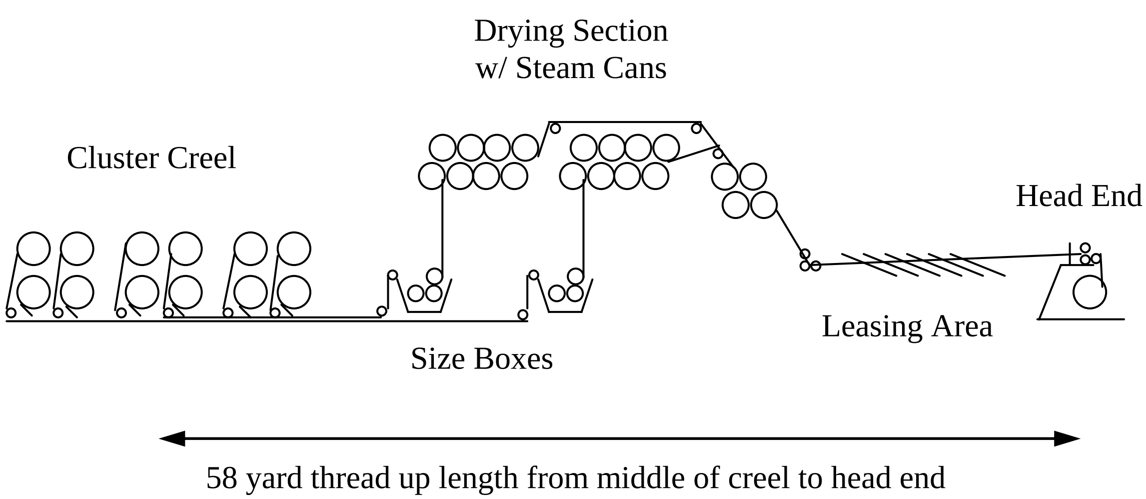


Figure 24. Direct spun slasher setup used in Plant I

Time Studies

There is one time study included in this case study. The set which is tracked is a 26/1 style, of maximum order length, consisting of approximately 6500 ends. The breakdown of the time study is included in Table 27.

Table 27

Time study 11 on spun slashing (26/1, 60,000 yards, 6500 ends)

| | |
|---|---|
| Creeling | 121 minutes (1 person) |
| Laying In | 42 minutes (1 person) |
| Run Time | 600 minutes |
| Stop Time | |
| Doffing | 50 minutes |
| Stops | 53 minutes |
| **Total Time** | **866 minutes** |

Waste Analyses

Plant I does a good job on minimizing the waste generated in slashing. This plant accumulates 0.95% waste of the total throughput in the warping department. The slashing department only generates 1.07% waste of the total slashing throughput. There is also 0.9% waste of total slashing throughput, which is returned due to defects and runability problems in weaving. This means that the total amount of waste accumulated due to the slashing process is close to two percent.

Waste Opportunities

This plant can improve on their set out times and waste numbers if they would work together better. The set out procedure is completed by only one person, which equates to excess downtime of the machine. There needs to be more teamwork between the operators during this procedure in order to decrease the set out time.

There is also too much waste being left on the section beams in the creel. The operators are told to run the beams down until they see a 50 yard chalk mark which has been added by the warping operator at warping. This mark indicates that there is 50 yards of yarn left on the beam. The problem is that since the yarn count is fairly small, the chalk line can be seen through a few layers still on top on the line. The operators are stopping the slasher when they see this mark. The beams should be run down until one of the beams runs out. The chalk line should be an indication for the operator to watch the beams carefully and stop them at the appropriate time. This early stoppage of the beams equates to approximately 14 or 15 extra pounds of waste per set. This may not seem like much, but annualized this number is significant. What is more alarming is that there could potentially be 40-50 yards more fabric made from this yarn. This is where the larger money savings could be realized.

### 5.2.10 Case Study J

Order Lengths

This plant is a spun yarn processing plant with short order lengths, ranging from 11,500 yards to 41,000 yards depending on style and customer requirement. Due to the short yardages that this plant runs, set outs are more frequent. Waste also becomes a larger factor when there are more frequent and smaller runs, as it will be a greater percentage of actual throughput yards. Table 28 details the set order lengths of this plant.

Table 28

Case study J: set size order lengths, in yards

| | |
|---|---|
| Minimum | 11,500 |
| Median | 24,000 |
| Maximum | 41,000 |
| Most Common | 41,000 |

Plant Complexities

Plant J has an average complexity of warp styles running. They are running 49 different styles, with five styles accounting for 38% of the total production.

Machine Configurations

This plant utilizes conventional direct spun slashers which are equipped with equi- tension creels. The drying cans are located lower to the ground for overhead clearance reasons. The two yarn sheets meet for the final six dry cans and then are separated from one another in the leasing section, where bust rods and lease rods separate the yarns into the same number of sheets as there are section beams. The comb on the head end ensures that each of the adjacent ends is separated and that the warp is wound straight onto the loom beam. This machine has a 70 yard yarn thread up length from the middle of the creel to the head end.

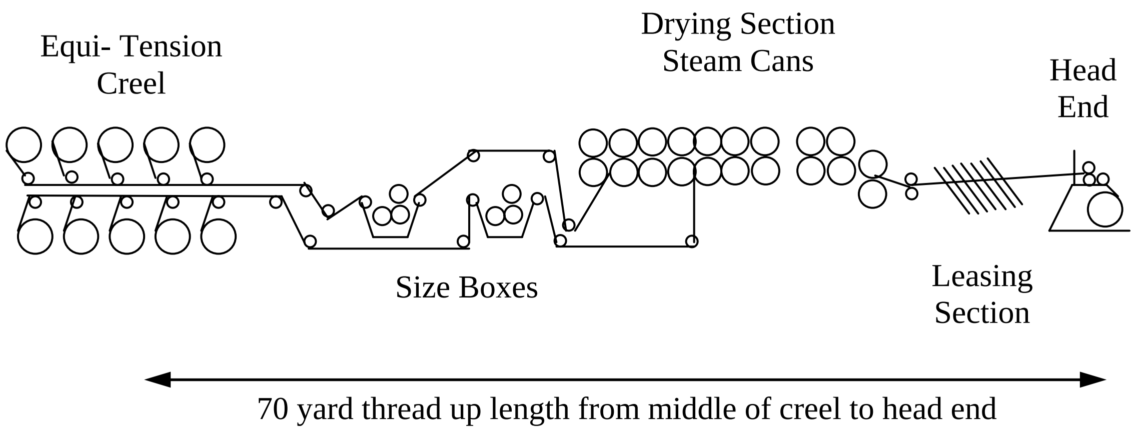


Figure 25. Direct spun slasher setup used in Plant J

Time Studies

One style was tracked in slashing during this case study, a 16/1 yarn, of median order length for this plant, containing approximately 4100 ends. The breakdown of the time study is included in table 29 below.

Table 29

Time study 12 on spun slashing (16/1, 26,000 yards, 4100 ends)

| | |
|---|---|
| Creeling | 115 minutes (1 person) |
| Laying In | 40 minutes (1 person) |
| Run Time | 315 minutes |
| Stop Time | |
| Doffing | 40 minutes |
| Stops | 23 minutes |
| **Total Time** | **533 minutes** |

Waste Analyses

Plant J does a good job on minimizing the waste generated in slashing. They accumulate 1.62% slashing waste of the total throughout pounds in slashing. There is some room for improvement in this area though.

Waste Opportunities

There are standard start-up procedures, but it does not appear that the operators are following these procedures. This is concerning because many of their warps are returned with small yardages remaining on the beam, indicating start up problems. There is also excessive creel waste left in the creel after the set is run. This is usually due to the fact that some of the beams are purchased directly from an outside yarn supplier and the beams are not of the same exact lengths. This causes one or two section beams to run out early while there is still yarn left on the remaining beams. The yarn supplier needs to be contacted in this case and asked to properly meter the section beams to a consistent length.

The waste for each set is all weighed and recorder together. This presents a problem because there is no indication of whether the set out waste, the creel waste, or incidental waste is causing more waste than it should. Each type of waste should be recorded separately so that it may be tracked and improved upon. The waste standards for this plant should also be revised, as it has been a number of years since they were reviewed. This will allow for a more accurate calculation of how much waste should be generated from each style.

### 5.3 Case Study Comparisons

This section compares the case studies in this research in order to identify commonalities within the industry in regards to order lengths, plant complexities, machine configurations, and waste analyses. To generate more meaningful results, the filament yarn processing plants are grouped together and the spun yarn processing plants are grouped together.

Order Lengths

During this research each plant was questioned about the minimum, median, maximum, and most common order length sizes for their slashing and sizing process. Table 30 includes the order length information for the filament yarn processing plants involved in this research. They are arranged in ascending order from the smallest most common order length size to the largest most common order length size.

Table 30

Filament yarn order lengths, in yards

| **Case Study** | **Minimum** | **Median** | **Maximum** | **Most Common** |
|---|---|---|---|---|
| B | 1,000 | 30,000 | 67,000 | 30,000 |
| C | 2,500 | 52,000 | 100,000 | 52,000 |
| A | 5,000 | 78,000 | 150,000 | 75,000 |
| D | 30,000 | 90,000 | 150,000 | 90,000 |
| E | 3,000 | 80,000 | 450,000 | 115,000 |

Excluding case study D, the average minimum order length size for the filament yarn processing plants is 2,875 yards. The average median order length for these five case studies is 66,000 yards. Excluding case study E, which utilizes single end sizing supplied from creel packages, the average maximum order length size is 116,750 yards. The average most common order length for these five filament case studies is 72,400 yards.

Table 31 below, includes the order length information for the spun yarn processing plants involved in this research. They are again arranged in ascending order from the smallest most common order length size to the largest most common order length size.

Table 31

Spun yarn order lengths, in yards

| Case Study | Minimum | Median | Maximum | Most Common |
|---|---|---|---|---|
| G | 6,000 | 28,000 | 60,000 | 37,000 |
| J | 11,500 | 24,000 | 41,000 | 41,000 |
| H | 9,000 | 48,000 | 60,000 | 48,000 |
| F | 9,000 | 30,000 | 60,000 | 60,000 |
| I | 28,000 | 45,000 | 60,000 | 60,000 |

The average minimum order length size for these spun yarn processing plants is 12,700 yards. The average median order length for these five case studies is 35,000 yards. The average maximum order length size is 56,200 yards. The average most common order length for these five filament case studies is 49,200 yards.

Plant Complexities

This section describes the degree of plant complexity for the case studies involved in this research. The issue of plant complexity refers to the number of different styles being run and the frequency of style changes. For example, a plant may run 50 different styles, but the majority of their production may consist of just one or two styles. Even though they manufacture a large number of styles, they would still be considered to have a small plant complexity, due to the majority of the production consisting of one or two styles. Table 32 and Table 33 detail the complexities of the filament yarn and spun yarn processing plants involved in this research. The last column in each of the tables describes how much of the total production the major styles represent. The case studies are arranged in ascending order from the smallest plant complexity to the largest.

Table 32

Filament yarn plant complexities

| **Case Study** | **# of Styles Running** | **# of Major Styles - % of Total Production** |
|---|---|---|
| D | 15 | 6 = 95% |
| E | 18 | Approximately Even Distribution |
| A | 75 | 2 = 25% |
| C | 110 | Approximately Even Distribution |
| B | 150 | 4 = 30% |

Table 33

Spun yarn plant complexities

| **Case Study** | **# of Styles Running** | **# of Major Styles - % of Total Production** |
|---|---|---|
| I | 15 | 2 = 70% |
| H | 38 | 1 = 70% |
| F | 20 | 7 = 75% |
| J | 49 | 5 = 38% |
| G | 60 | 1 = 25% |

As mentioned earlier, just because a plant runs fewer styles than another does not necessarily mean that its plant complexity is lower. This is the case with spun yarn plants H and F, as described in Table 33. Plant H runs 18 more styles than plant F, although plant H has a smaller plant complexity. This is due to the fact that 70 percent of plant H's total production comes from one style. This indicates a lower style frequency than that of plant F, in which seven styles make up seventy-five percent of the total production.

The average number of styles running in the filament yarn plants included in this research is 74 styles. The average number of styles running in the spun yarn plants included in this research is 36 styles.

### Machine Configurations

Different sizing technologies have various machine configurations, resulting in a range of machine thread up lengths. The thread up length mostly differs depending on the creel type, the number of size boxes used, the layout of the drying section, and the overall length of the machine. The thread up length directly affects the amount of waste generated in the set out process unless the yarn can be substituted for something else during the thread up of the machine. It is also important to note that the set out procedure followed by the operator will affect the amount of waste generated.

The following tables denote the machine configuration and thread up length of each of the case studies included in this research. The machine configuration column in the table describes the type of technology and any distinguishing attributes of the machine. The thread up length indicates only the length of yarn required to reach from the middle of the creel to the head end of the machine. A set out procedure may call for more yards to be utilized in order to start up the new set. Table 34 includes the filament yarn plant machine configurations arranged in ascending order by thread up length.

Table 34

Filament yarn plant machine configurations

| **Case Study** | **Machine Configuration** | **Thread Up Length** |
|---|---|---|
| A | Two Platform Conventional Filament Sizer with Heated Ovens and Drying Cans | 42 Yards |
| E | Single End Sizer with an Inline or Parallel Creel | 52 Yards |
| C | Conventional Filament Sizer with Heated Ovens and Drying Cans | 68 Yards |
| D | Conventional Filament Sizer with Drying Cans | 68 Yards |
| B | Conventional Filament Sizer with Drying Cans | 69 Yards |

Table 35 describes the spun yarn plant machine configurations arranged in ascending order by thread up length. Unless otherwise noted, conventional spun slashers contain two size boxes and overhead steam heated drying cans.

Table 35

Spun yarn plant machine configurations

| **Case Study** | **Machine Configuration** | **Thread Up Length** |
|---|---|---|
| H | Conventional Spun Slasher<br>Cans Low to Ground | 55 Yards |
| I | Conventional Spun Slasher | 58 Yards |
| J | Conventional Spun Slasher | 70 Yards |
| F | Conventional Spun Slasher | 75 Yards |
| G | Conventional Spun Slasher<br>with Three Size Boxes | 109 Yards |

Waste Analyses

This section compares the amount of waste generated in the sizing process for the case studies included in this research. The amount of waste for each case is reported as the amount of waste generated during the sizing process as a percent of the sizing department's total throughput pounds. The case studies are again separated by filament and spun yarn processing to provide more accurate and clear representation. Table 36 describes the amount of waste generated in the filament yarn sizing process, arranged in ascending order from the least amount of waste generated to the most.

Table 36

Filament yarn plant waste analyses

| **Case Study** | **Waste Generated During Sizing** |
|---|---|
| D | Not Available |
| C | 0.38% |
| E | 0.6% |
| B | 0.8% |
| A | 1.0% |

Plant D has a contract with their yarn supplier in which they return all waste generated in the sizing process. Therefore, this plant does not record or report any generated waste; although in reality, there is accumulated waste.

Table 37 describes the amount of waste generated in the spun yarn slashing process, arranged in ascending order from the least amount of waste to the most.

Table 37

Spun yarn plant waste analyses

| Case Study | Waste Generated During Sizing |
|---|---|
| H | 0.06% |
| F | 0.76% |
| I | 1.1% |
| J | 1.6% |
| G | 2.9% |

Plant H, as mentioned before, has experienced operators, standard set out procedures, which maximize the utilization of good quality yarn, and a shorter thread up length. All of these factors contribute to the small amount of waste generated in the slashing process. Plant F and plant I produce similar yarn styles at similar order lengths, although plant I generates 0.34% more waste than plant F. Some of this surplus waste is due to the fact that plant I does not run as much yarn off of the section beams in the creel as they could. They usually stop the slasher off when there is fifty to sixty yards left on the section beams. This excess waste left on the section beams in the creel could potentially be processed into good quality fabric. Assuming that there are conservatively, twenty-five sets run per week, on a six day work week, fifty weeks out of the year, a total of 62,500 yards of potential fabric are wasted. This potential finished fabric costs approximately $1.25 per yard, including raw material, sizing material, and labor. This wasted yarn left on this creel could potentially equal over $78,000 per year.

Plant G, due to its large plant complexity, machine configuration, and set out procedures, accumulates a large amount of waste during the slashing process. Substituting the good quality yarn used in this set out procedure would greatly reduce the amount of waste generated in their slashing department.

The section describing waste sources, in the review of literature, noted that waste is also generated in succeeding processes due to the previous processes. This waste should also be included in the waste analyses of the slashing and sizing processes. As previously mentioned, not all plants keep accurate records of this waste as they should. Unfortunately, only two of the filament plants included in this research keep up with and report this waste. The numbers are relatively small and do not reflect significant deviations from the previously reported waste figures. This however, is not the case with the spun yarn plants. Three of the five plants in this research track and record this waste information and it does have a noteworthy effect on their total waste accumulated due to the slashing process.

Table 38 depicts the waste generated during the slashing process, as well as, waste accumulated due to returned warps for runability problems in the weaving loom. These runability problems are most often caused by an excessive number of defects in the warp which trigger multiple loom stoppages. These returned warps are usually pulled down until the defect is no longer visible, cut off, and is then sent back to the weave room to be retied. This leads to a large amount of unnecessary time and labor loss. The beam may also be completely cut off as waste if the defect runs the entire length of the beam or if the beam contains only a small amount of remaining yardage. Typically, warps are not retied if they are less than 500 yards, unless the yarn is expensive and it proves to be worth the time and labor to retie the warp into the loom. Table 38 depicts the changes in total waste due to returned warps in ascending order from the least amount of total waste to the greatest amount of total waste.

Table 38

Total waste accumulated due to the spun slashing process

| Case Study | Waste Generated During Slashing | Waste Generated due to Returned Warps | Total Waste Accumulated due to Slashing |
|---|---|---|---|
| H | 0.06% | 0.54% | 0.6% |
| J | 1.6% | N/A | N/A |
| I | 1.1% | 0.9% | 2.0% |
| F | 0.76% | 2.02% | 2.78% |
| G | 2.9% | N/A | N/A |

Plant F in this case, seems to be doing a good job of minimizing waste generated during slashing. Although after adding in the waste from returned warps, plant F now has the second highest percentage of waste accumulated due to the slashing process. This suggests that plant F must concentrate on reducing defects and returned warps in order to minimize the amount of accumulated waste in slashing. This plant is also wasting more time correcting the mistakes they have made, and is causing decreases in loom efficiency in the weaving department.

## 5.4 Best Practices

This section highlights some of the best practices being utilized out in the industry today. These and other practices can be applied in manufacturing facilities as long as companies are willing to allow their employees to brainstorm, come up with new ideas, and implement and embrace change. This section combines those practices seen in the filament yarn and spun yarn processing plants because the concepts are interchangeable with only minor adjustments made to fit the change in technology.

### Teamwork

Teamwork, as old as an idea as it may seem, is still one of the easiest ways to decrease downtime, increase productivity, and reduce the possibility of defects. Teamwork is utilized mostly in the set out procedure to decrease the amount of downtime of the machine. With each operator assigned a specific duty, the process is completed in a timely and organized fashion. Duties can be executed simultaneously, dramatically reducing downtime. It is also important for operators to help train one another and further develop skills in areas where they might be deficient. Teamwork offers several advantages. It promotes accountability and responsibility among operators as they do not want to disappoint their teammates. Teamwork increases moral, as operators do not feel added pressures all on themselves. It also builds working relationships which can prosper and proliferate throughout the department. Teamwork and cross training also enhance the self worth of operators, as they feel that they are a part of the team, and that their actions directly affect the results of the team.

Standard Operating Procedures

Standardized operating procedures are essential in manufacturing quality, consistent products. These standard operating procedures must be followed by all operators at all times. Standard procedures keep operators from improperly fulfilling their assigned duties. This however, does not indicate that these procedures should not be improved. Standard operating procedures must be reinvestigated in order to enhance their purposes. Benchmarking other departments or companies is an advantageous technique to measure and evaluate similar operating procedures. Many practical and productive ideas are shared or adopted from other companies or industries. Several of these ideas are discussed in the next few sections.

Warp Width Retainer

Typically, during the set out procedure the new set of yarn is tied to the old set of yarn in order to thread up the machine without losing the proper thread up configuration. Usually these sets of yarn are separated into four to eight bundles and tied to one another. The more knots or ties used to attach the two sets together the fewer yards that will be wasted before the new set becomes straight enough to lay-in the ends in the front comb. This is due to the smaller angle created at the knot, indicating that the ends are closer to parallel.

A warp width retainer device is used in some plants to clamp the ends in the exact sequence just behind where the knots are tied. The observed warp width retainer was made of a metal rod welded to a spring with a removable hooked wire, although it is not essential that it be made of metal. Figure 26 illustrates this width retainer device.

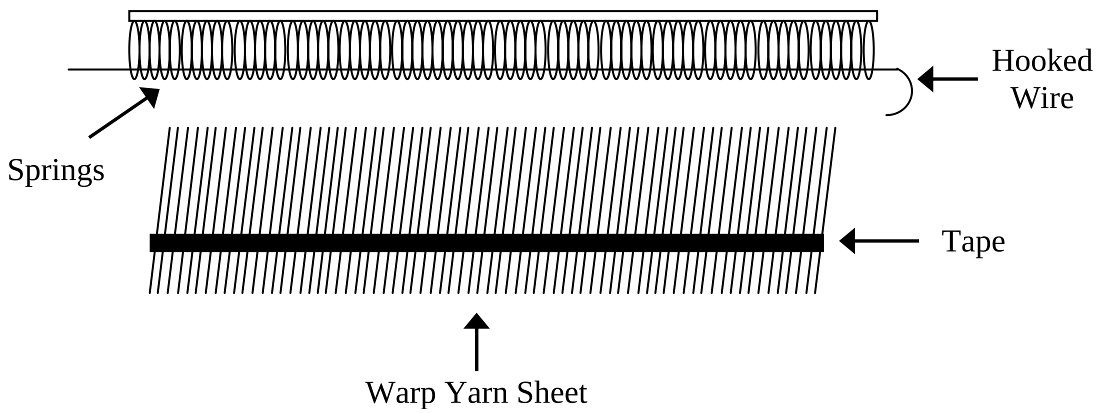


Figure 26. Warp width retainer

After taping the warp sheet to ensure the ends are straight and not crossed, the springs are lowered onto the yarn sheet, in front of the tape, allowing each end to be threaded between each of the wire springs.  The hooked wire is then inserted to lock the yarn ends in place, not allowing them to become crossed or twisted with one another. The ends of the yarn which are protruding from the warp width retainer can be used to connect this new set of yarn to the previous set of yarn without losing the proper arrangement of yarn ends.

This width retainer then travels through the slasher with the yarn keeping each end straight and in the correct order.  Once the width retainer reaches the front comb at the head end of the machine, the ends are simply pulled over and laid into the comb in exact sequence.  It is important to quickly check to make sure that the proper number of ends is in each dent before starting up the new set.  This width retainer greatly reduces the amount of time used to count in each individual yarn end into the comb.  It also reduces the amount of yarn wasted from the beginning of the new set, as the yarn is kept straight and inline.

Set Out Time Reduction

In order to reduce the amount of time spent during the set out procedure, operators must work on joint tasks together and separate tasks simultaneously. It is also important that required tools be quickly and easily obtainable. There are many improvements which can be made in the set out procedure to reduce the amount of downtime of the machine. Several plants visited in Europe had set out times comparable to less than half that of some plants visited in the US.

These plants utilize set out teams which are responsible for certain tasks in the set out procedure. They work quickly and efficiently to ensure that the machine is back up and running as soon as possible.

Section beams in the staging creel are ready to be moved behind the sizing machine as soon as the previous set is finished. The yarn from these staged beams is already pulled to the front of the creel with each beam taped to maintain the integrity of the yarn ends.

The cleaning of the size box rollers is enhanced by the use of a spray bar already mounted over the size box. This spray bar negates the need for a hose which the operator must retrieve, turn on, and return. This hose is not only a tripping hazard while in use, but also leads to housekeeping issues when it is not returned properly. The spray bar is equipped with an on - off valve which is operator friendly and easily accessible. Shadow boards are also conveniently located around the slasher, displaying required set out tools, preventing the operator from having to waste time searching for needed items.

The following paragraph describes the set out duties of one of the plants visited. The entire set out procedure was completed in twenty minutes. Not only did the procedure used by this plant reduce the amount of time spent during the set out, but it also reduced the amount of waste between the sets to a minimum. Only fifteen to twenty five yards of yarn were wasted during the set out.

The new set to be run was a 550 yard order, with an end count of 9,500 ends. All of these ends are wound onto a beam during sample warping. After the set is complete at the sample warping machine, a detachable warp width retainer device is inserted into the warp sheet, clamping the ends in place. Once the set running in the slasher has reached its end the size box is emptied and the new set is tied to the old set. After tying the sets together, the size box rollers are ready to be cleaned. The slasher is started back up and the cleaning takes place while the knots are passing through the size box.

The lease strings from the sample warper should still be in place in the new warp sheet. The slasher is advanced until the lease strings have passed through the size box. At this time the size box is filled with size. The slasher continues to advance in slow speed until the knots near the leasing section. The lease rods are then removed to allow the knots to pass to the head end. Once the knots reach the comb, the comb is lowered and the yarn from the old set is taped across the width and has now been completely utilized, with the exception of the yarn used to tie the sets together.

At this time the warp width retainer is pulled over the comb and the ends are laid into the comb in their respective dents. The lease strings of the new set should now have entered the leasing area and the lease rods are reinserted to separate the sheds. As soon as the last lease rod is inserted the new, sized yarn should begin to appear in the leasing area. Once this yarn reaches the comb, the slasher is stopped. The yarn sheet is cut after the comb and the beam is doffed out of the machine. A new beam is inserted, the ends are tied around the beam and the slasher is started and back in production.

The little waste which is accumulated on top of the previous beam is pulled off by hand and cut away from the good yarn of the previous set. The ends of the previous set are tied in knots to keep the ends together. The set out waste is weighed, recorded, and thrown into the appropriate waste buggy. The procedure is well organized and well executed with the help of cooperative teamwork.

### Leader Cloth

One of the more practical concepts widely used in the dyeing and finishing industry to join fabric sets is the leader cloth. This leader cloth is usually a piece of off quality fabric which will be used as connector between fabrics of two different color shades in dyeing. It is sewed to the end of one set and to the beginning of the next. The leader cloth will then be used during the transition of one color to the next, so that neither one of the sets will be wasted during the transition phase. This leader cloth is then cut out and the two sets are left with maximum quality fabric dyed the correct color shade.

This same idea can be used in the sizing and slashing process to connect sets. Usually, the warp sheet of one set is divided into sections and those sections are tied to sections of the new set. This ensures that all of the yarn ends are threaded properly through the machine. The yarn at the end of the last set is usually wasted because it is left in the machine to bring the new set through. The yarn at the beginning of the new set is wasted as well, as the set is prepared and the ends are laid into the comb. The use of a leader cloth between the sets maximizes the utilization of the yarn from both sets. There are no significant set out time differences between choosing whether to use the leader cloth. Table 39 below, describes how the leader cloth is utilized to reduce the amount of yarn waste.

Table 39

Leader cloth used to connect slashing sets

| Step | Action |
|---|---|
| 1 | One of the beams in the creel begins to run out signifying the end of the set |
| 2 | The machine is stopped and the size box is turned off and emptied |
| 3 | Separate top and bottom sheds of warp sheet from creel and group each shed into two sections |
| 4 | Cut and tie off each section, making four sections |
| 5 | Four strips of leader cloth, precut / ripped to length of machine, are tied one to each of the sections |
| 6 | The yarn in the machine is advanced until the cloth reaches the end of the drying section and the machine is stopped |
| 7 | The loom beam is doffed with maximum yarn wound onto the beam. A new beam is inserted into the head end to pull up the new set |
| 8 | Cleaning duties are performed in the size box area |
| 9 | The next set is moved into the creel area and the yarn ends of each beam are pulled to the front of the creel |
| 10 | The top and bottom sheds from the creel are split into two sections each and tied to the four ends of the leader cloth |

Table 39 (Continued)

Leader cloth used to connect slashing sets

| | |
|---|---|
| 11 | Each beam is taped twice in order to keep the ends coming off the beams straight.  The second taping job is sandwich taping, with one piece on top of the shed and the second on the bottom of the shed strictly under the first |
| 12 | The yarn is advanced and the lease strings are inserted into the warp sheds |
| 13 | The yarn is then advanced until the lease strings reach the leasing area |
| 14 | The lease rods are inserted and the ends are counted into the comb |
| 15 | The size box is turned on and filled with the new size bath |
| 16 | The yarn is advanced until the sized yarn reaches the head end |
| 17 | The machine is stopped and the yarn and cloth is cut off from the beam |
| 18 | The waste is removed from the floor, separating the yarn from the cloth |
| 19 | The sized yarn is pulled down around the beam and the new set is started up |
| 20 | The yarn waste is weighted, reported, and thrown into the appropriate buggy |
| 21 | The leader cloth is either saved to be reused or is thrown into a buggy |
| 22 | Minimal yarn waste is accumulated due to the use of the leader cloth |

Performance Tracking

Record keeping and performance tracking is another best practice used in the industry which needs to be adopted in all areas of manufacturing.  Performance which cannot be measured, cannot be controlled or improved.  This is true also of set out times and waste measurements. Set out times should be documented and tracked for each operator, accompanied by established goals for reduction.

As mentioned in several of the case studies' waste opportunities sections, better record keeping would help in reducing waste. Companies who are not sure of the sources of their waste, cannot easily attack and eliminate this excess waste. Superfluous time and money is spent fighting the symptoms instead of the root causes of the waste. Waste records hold operators accountable for their work and the quality of the product. Any returned warps for runability problems should be the responsibility of the operator who ran the warp. This responsibility makes them accountable for their own mistakes and enables them to see the mistakes they have made.

Waste performance should be tracked by set, operator, style, and machine. This allows analyses to be performed to determine if the root causes of the waste are man, method, or machine related. Defect cause analyses should also be performed to determine the root causes of the defect.

During this research, an extensive defect cause analysis was performed on one of the case studies. Through this analysis the root causes of several reoccurring defects were identified. Returned warps for runability problems were investigated over a twenty week period. More than thirty-five distinct data analyses were performed including the following, often broken into subsets: distribution paretos on return cause, yardage remaining, beam number, slasher number, return plant, yarn supplier, style, and operator; mosaic plots on return cause by operator and return cause by slasher number; and analysis of variance on the yardage remaining on the returned beam by operator.

The distribution paretos on return causes allow the operators to understand what defects are most prevalent.  Projects should then be focused on finding the sources of this defect and implementing countermeasures to prevent it from occurring.

The distribution paretos on yardage remaining, locate where the defects are occurring in the warp.  In the case of this plant, forty-eight percent of the returned warps contained less than five hundred yards, as illustrated in Figure 27.

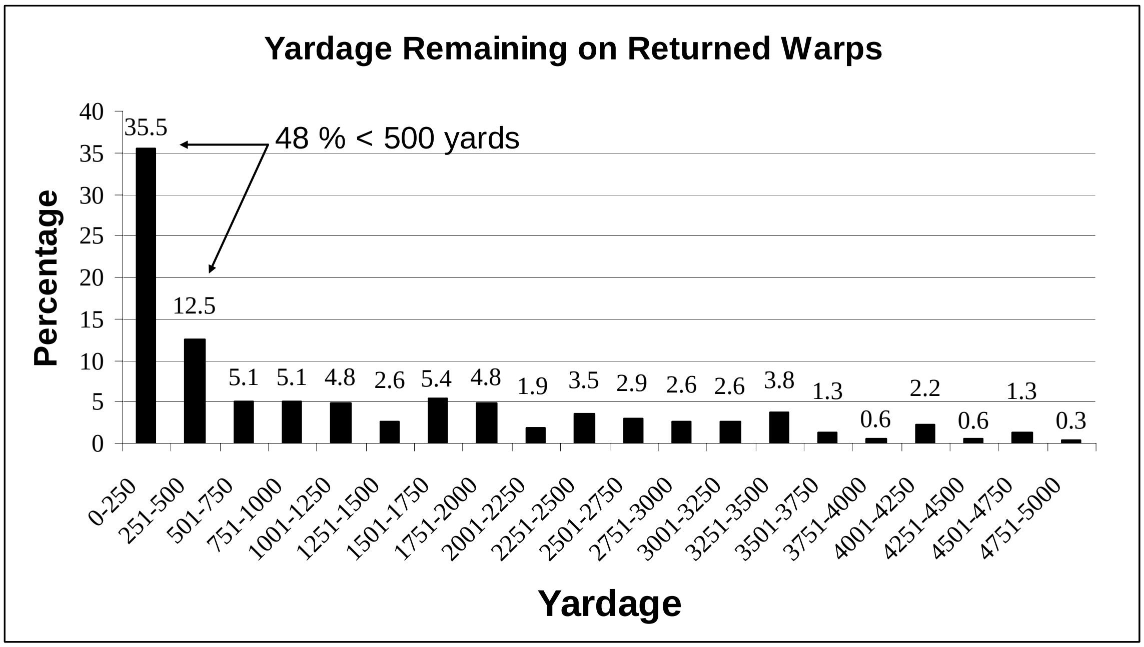


Figure 27. Distribution pareto of yardage remaining on returned warps

The results of this graph indicate that there is a problem with the start up of the warp in the sizing process.  This is apparent because the end of a warp in the weaving process represents the beginning of the warp in the sizing process.

As previously mentioned, most warps are pulled down one hundred yards to ensure the defect has been removed, and there is the assumption that warps containing less than five hundred yards are completely wasted. This waste yardage should be equal to the yardage remaining on the warp beam. If these assumptions are correct and the data collected is fairly reflective of the true norm, then the forty-eight percent of the returned warps account for sixty-six percent, or two-thirds, of the total waste yardage. Assuming that the styles are evenly distributed throughout the yardage groupings, these returned warps account for two-thirds of the waste pounds generated from returned warps. It is highly recommended that the operators in this plant work together to develop a standardized start up procedure which will produce good quality warps.

After generating the mosaic plot on return cause, broken down by operator and grouped by slasher, it is apparent that all operators on slasher number one have a disproportionate percentage of hard size returned warps relative to other operators. The mosaic plot showing this information is included in Figure 28.

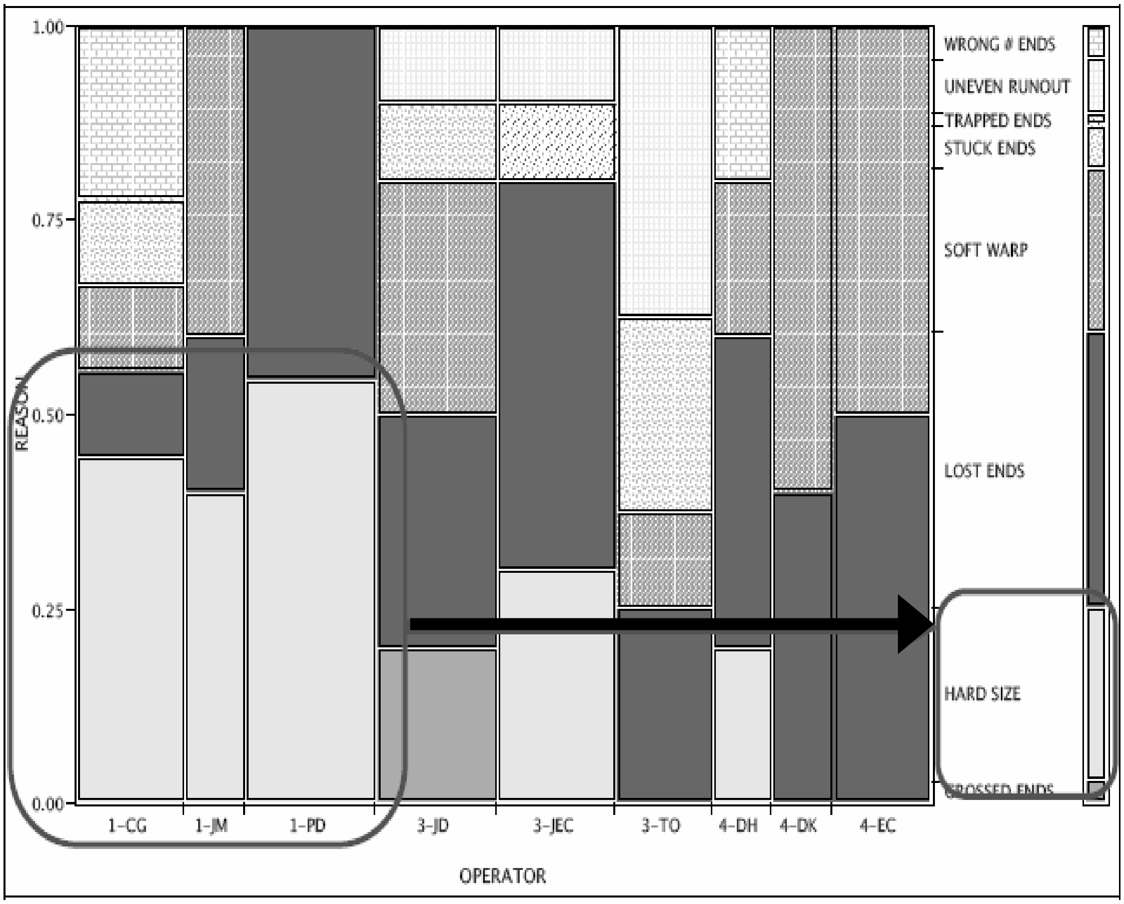


Figure 28. Mosaic plot on return cause by operator

The results of this analysis help conclude that there is a machine related problem with these returned warps. After investigating this irregularity further, it is determined that size is splashing out of the size box onto the yarn causing hard size defects. Countermeasures were then put into place and the percentage of hard size defects on this machine was reduced by half.

This analysis and others could not have been performed if precise records were not kept on the returned warps. The hard size defect may have continued to occur without anyone knowing the root cause of the defect. Accurate record keeping and performance tracking can enable sources of waste to be identified, attacked, and eliminated.

### 5.5 In-Depth Case Study Waste Analysis

This section describes how performance tracking and accurate record keeping can identify and isolate root causes of waste. During a different case study, access to multiple waste records was obtained to help detect hidden sources of waste which were not readily visible.

There were 166 different slasher sets represented as data collection points for this analysis. These sets were chosen based on the most commonly run styles. Eleven different styles were selected and for each the following information was collected: style, date slashed, slasher number, set identification number, yards per set, standard set out pounds per set, actual set out waste pounds, actual creel waste pounds, other waste pounds, yarn denier, fiber type, and end count.

From the collected information it is possible to also calculate the additional needed information: set out waste yards, pounds per set, and total waste pounds. This information, along with the gathered records can provide clues identifying root sources of the waste generated in the slashing process.

Through observation and calculations the slashers in this case study have an unavoidable waste amount of eighty yards during each set out. The unavoidable waste is calculated by adding the machine thread up length to the amount of yards the warp sheet is advanced in order to ensure no ends are out of lease and that there are no crossed ends before the starting up of the machine. This means that any set out containing less than eighty yards of set out waste is inaccurately weighed or recorded. Due to the unavoidable waste calculation, all sets that have less than eighty yards of set out waste have been excluded from these analyses because of their inaccuracy. This resulted in twenty-four data points being excluded during the analysis. There are also occurrences when data is missing. This is sometimes due to the fact that there is no data for that specific chart. For example, the charts on other waste may contain sets which did not have any other waste occurrences.

To reduce waste in manufacturing there are several key steps which must be followed. It is important to first understand the present situation. Doing this also requires knowing information about and understanding past history. This is why accurate record keeping and performance measures are vital. It is useful to know how, how often, and where waste is collected, weighed, and reported.

After understanding the situation, the next step is to analyze the phenomena, in this case, the accumulation of waste in the slashing process. It is then valuable to pareto the various causes which may be contributing to this waste. Investigation into each of these causes is imperative if the true sources of the waste are to be identified. This inquisition into the causes can be accomplished through observation, trial and error, as well as, performing multiple cause analyses.

To understand the waste accumulated in this case study, there are many factors to consider. This waste analysis focuses on the amount of accumulated set out waste, but also mentions the impact of creel waste and other waste to determine the root causes of this excess waste.

The amount of set out waste is analyzed by first identifying from where the waste is being generated. Figure 29 illustrates the actual number of yards of waste accumulated during the set out procedure for the two fiber types that this plant processes, as well as the individual averages and standard deviations, or variances, of the data.

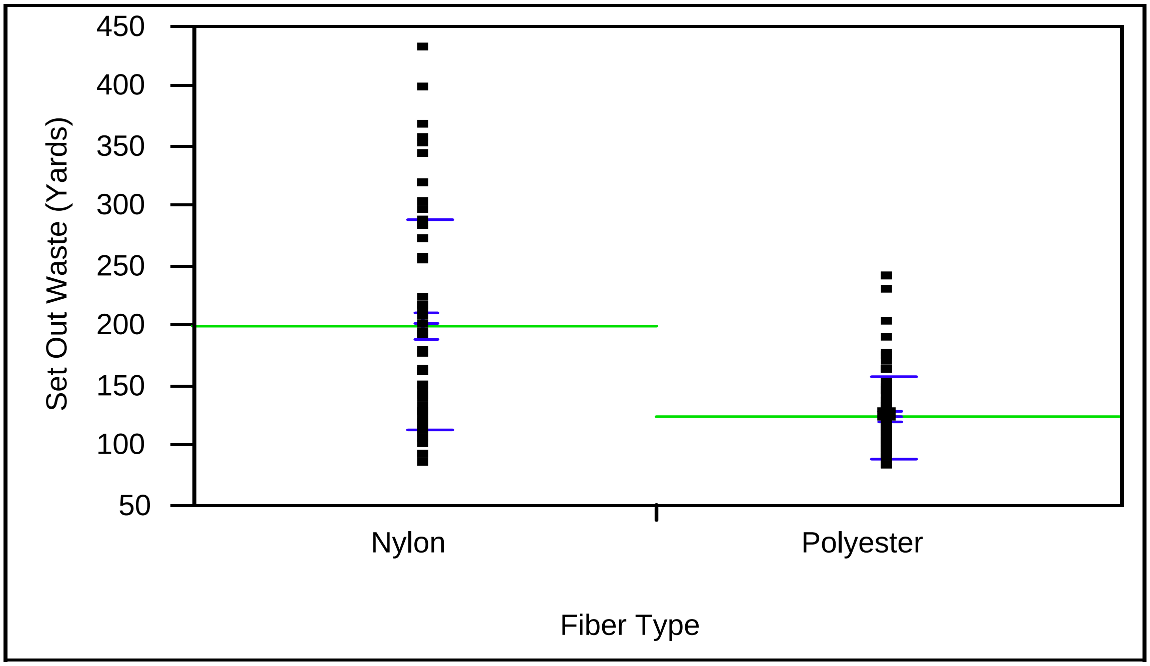


Figure 29. One way analysis of set out waste by fiber type.

From Figure 29, some would generalize that there is an opportunity with the set out waste of the nylon styles, but in reality, the set out waste of both fiber types should be improved. The nylon fiber styles average 201 yards of set out waste, while the polyester styles average 124 yards of set out waste. There should not be any significant differences in the amount of set out yards wasted due to fiber type. The yarn is threaded through the machine in the same manner with no deviation to the set out procedures. Unless difficulties arise in the set out procedure, all set out waste yards should average around ninety yards, as the unavoidable thread up length is eighty yards long. One reason that one fiber type may have more set out waste is if it creates more problems in the thread up of the machine and causes difficulties during set out, resulting in excess yarn being wasted. It is also possible that if that fiber type was only run on one machine or by one or two operators that these variables could affect the amounts of waste generated. However, in this case study multiple operators and several different machines run both types of fibers. This requires the investigation to probe further into the root causes. The following figures depict the amount of set out waste accumulated according to the yarn linear density, or denier, of the nylon sets and polyester sets, respectively.

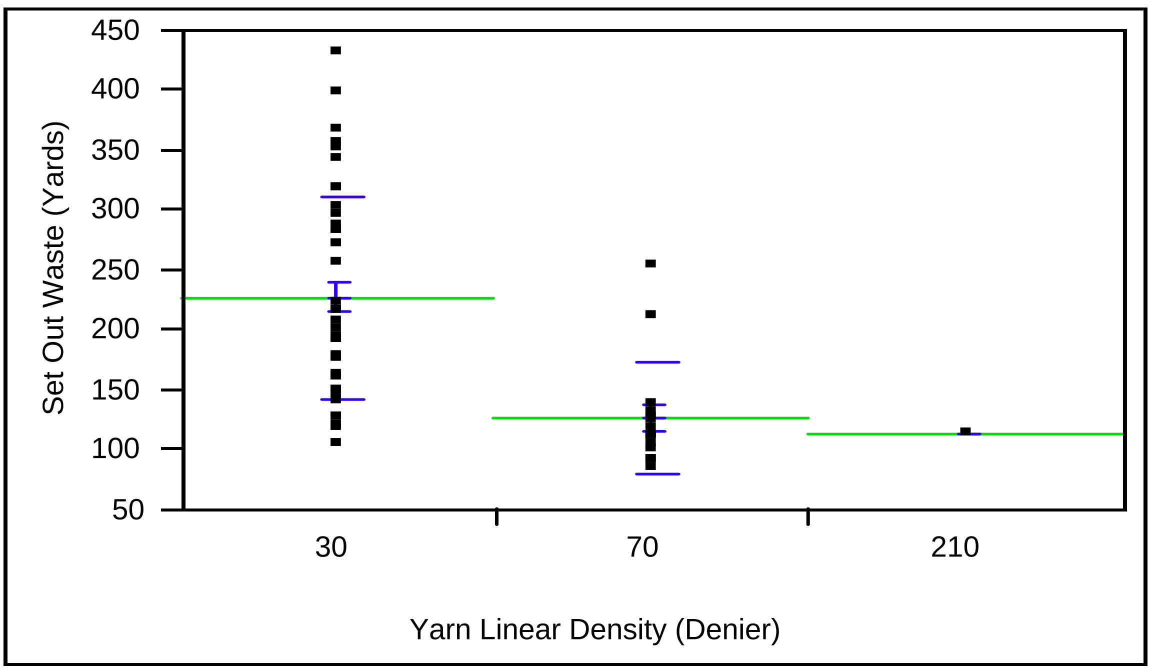


Figure 30. One way analysis of set out waste of the nylon sets by yarn linear density

The immediate indication to the high set out waste yardage for the 30 denier nylon yarn is that it is more delicate and more difficult to handle; consequently, it has the tendency to cause more problems in the set out procedure, resulting in more yarn waste. Finer denier yarns are more likely to break due to their frailty. As the chart above indicates, seventeen of the eighteen sets which have more than 250 yards of set out waste are 30 denier yarn sets.

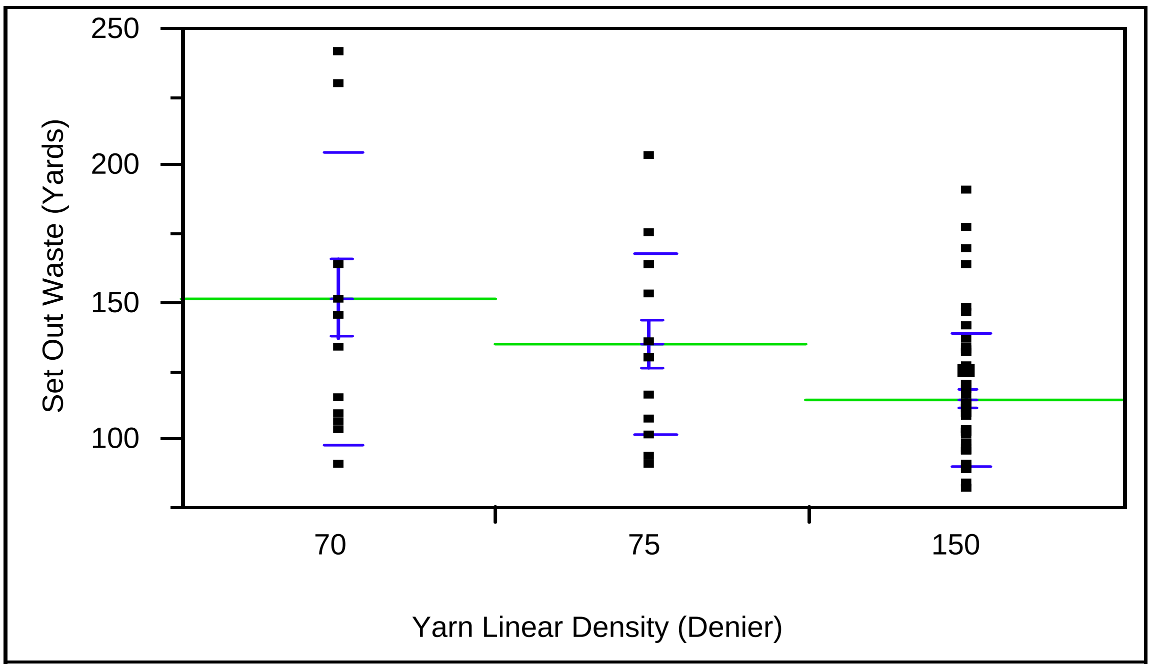


Figure 31. One way analysis of set out waste of the polyester sets by yarn linear density

Again, this chart illustrates that the finer denier yarns tend to have a higher average yardage of set out waste. All three polyester yarn denier styles have a large set out waste variance, which is discouraging. The outliers in this chart are much lower than the outliers in the previous nylon chart, suggesting that there is more opportunity for improvement in reducing the set out waste of the nylon fiber styles.

Exploring the set out waste issue further the different styles of each fiber type are analyzed according to their set out waste.  The following chart illustrates the set out waste generated for the nylon fiber sets by style number.

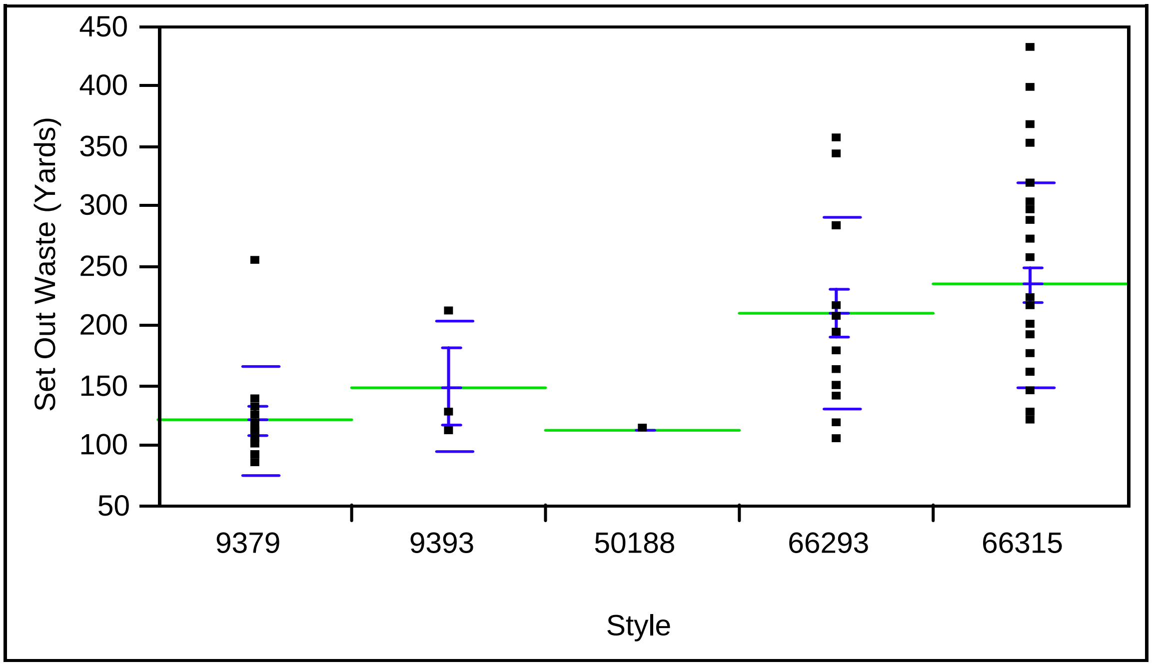


Figure 32. One way analysis of nylon style set out waste by style number

Nylon styles 66293 and 66315, both 30 denier styles, have a higher average of set out waste, as well as, a larger variance of set out waste.  Further investigation into these styles is needed to determine the causes of this increased set out waste.  Figure 33 depicts the set out waste of the polyester sets by style number.

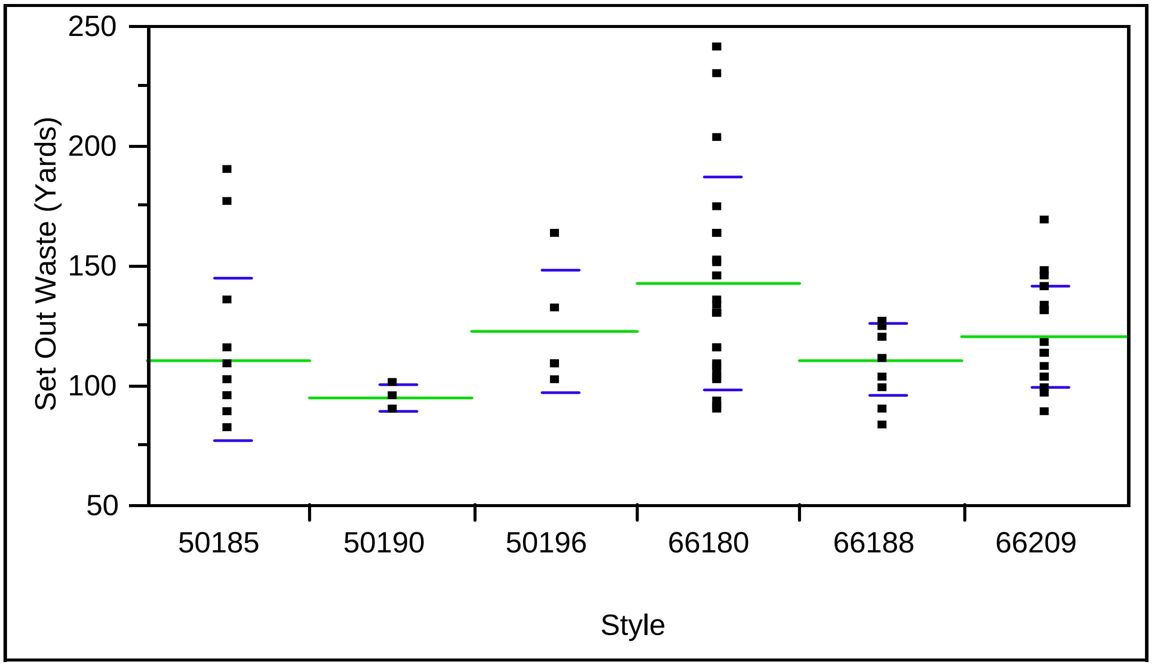


Figure 33. One way analysis of polyester style set out waste by style number

According to Figure 33 above, polyester style 66180, a 70 denier style, has the highest average, and largest variance, in set out waste of the styles included in this analysis. The cause for this excess and variable loss in set out waste must be isolated and counteracted.

In order to identify the root causes of this excess set out waste it is important to analyze the waste by individual slasher to indicate whether a machine or operator related issue is causing the spike in waste. Figure 34 illustrates the actual set out yards reported for the included sets detailed by slasher number.

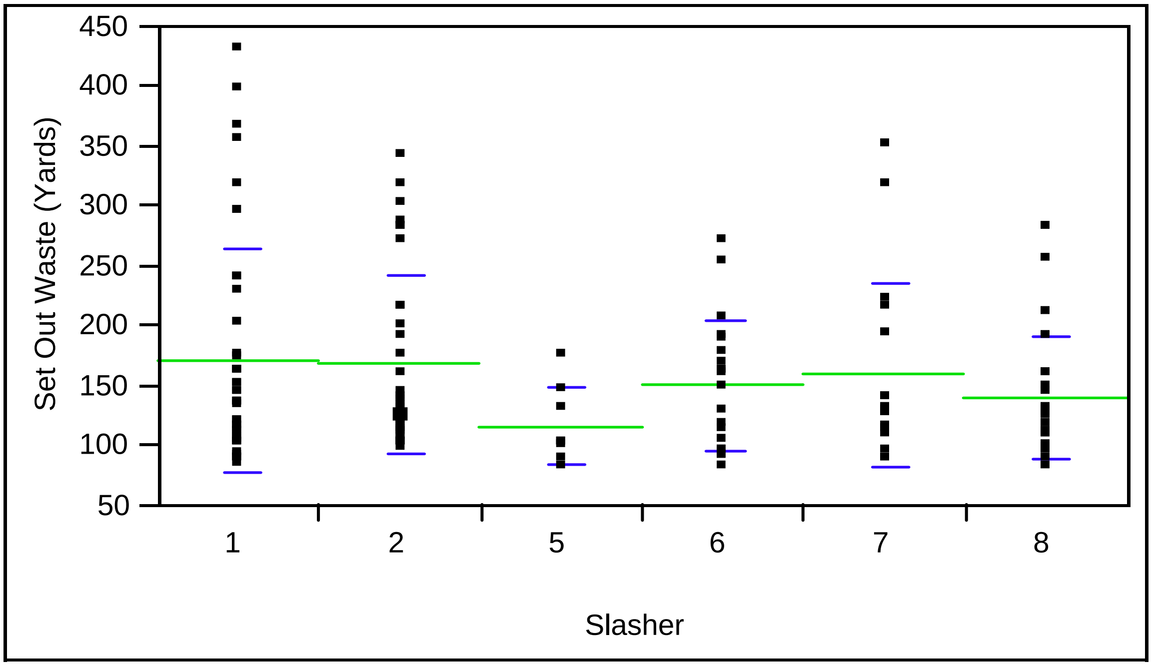

Figure 34. One way analysis of set out yards by slasher number

The one way analysis of set out yards by slasher, above, shows the amount of set out yards recorded for each slasher, along with their respective mean and standard deviation. This chart indicates that slasher number one has a larger variance in set out yards when compared to the other slashers. After further exploration of this waste analysis, a root cause of the increased set out waste on slasher number one should be realized. Slashers two, six, seven and eight also have high variances in set out waste. There could be a number of different reasons for this variance. A large variance in set out yards on any particular slasher may indicate that there is an operator related opportunity, such as poor training or use of improper procedures, or a machine related issue causing the higher amount of set out yards. It is also possible that if one style is predominantly run on one slasher that it could cause the variances to increase. No matter what the cause, multiple analyses must be performed to find the root causes of the high amounts of set out waste being accumulated.

All three of the before mentioned styles which had the highest average and largest variance of set out waste have run on slasher number one, as indicated in Figures 35 through 37.

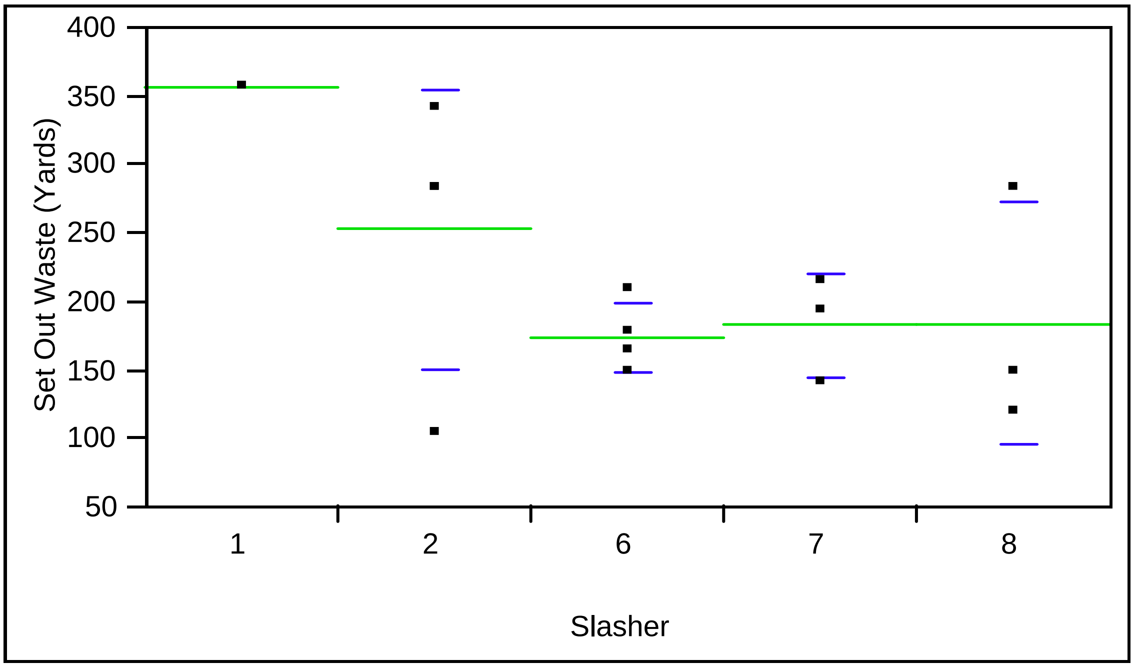


Figure 35. One way analysis on set out yards of style 66293 by slasher number

This chart indicates that style 66293, a 30 denier nylon yarn, has large amounts of set out waste when it is run any of the slashers. This suggests that the style is difficult to run, regardless of the machine or operator running it. However, there are higher set out yards wasted when the style is run on slasher numbers one and two. This indicates that operators or machine settings could be to blame for the excess set out yardage wasted.

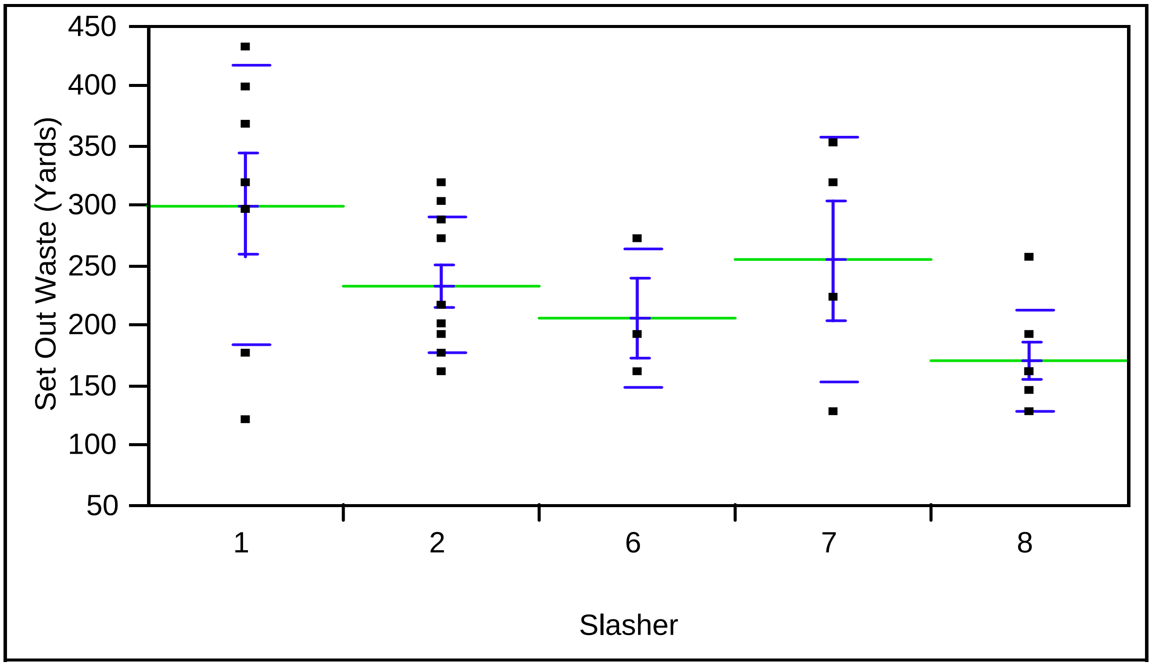


Figure 36. One way analysis on set out yards of style 66315 by slasher number

This chart shows that style 66315, a 30 denier nylon yarn, also has occurrences of large amounts of set out waste when it is run on the other machines, again indicating that it is a difficult style to run. Yet once more, when it is run on slasher number one, the set out waste average yardage is higher than the other slashers. Figure 37 illustrates the last of the three problematic styles for excess set out waste. It is the 70 denier polyester yarn style 66180.

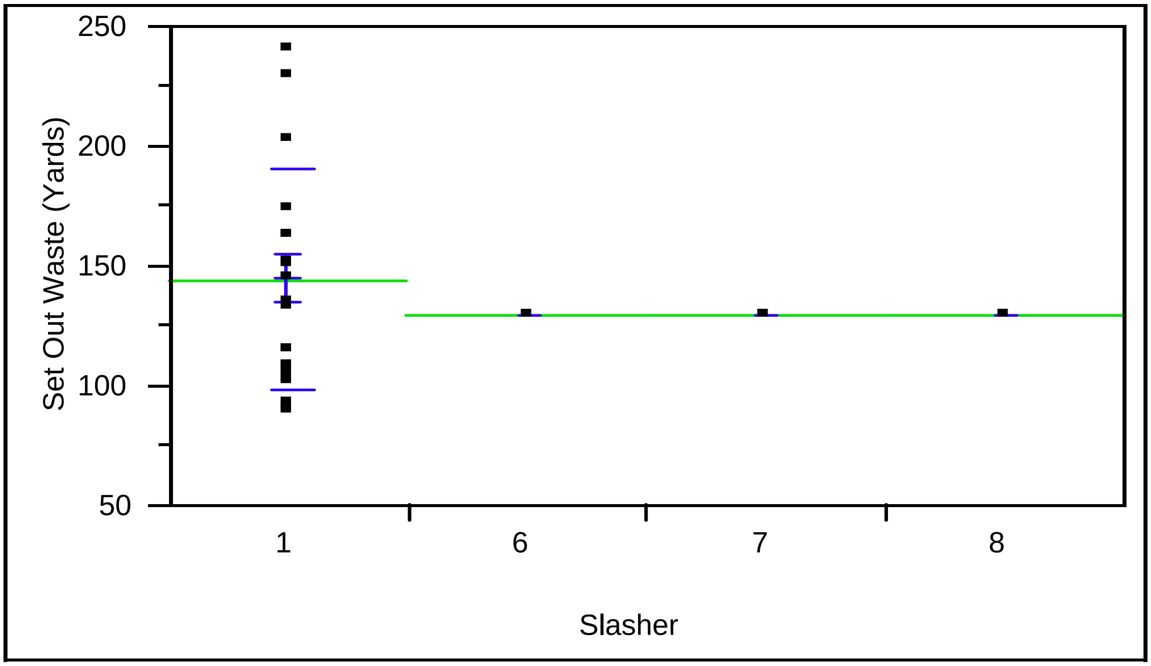

Figure 37. One way analysis on set out yards of style 66180 by slasher number

This chart for style 66180, a 70 denier polyester yarn, just as the others shows different sets of the same style run on multiple slashers with the largest yardage of set out waste occurring on slasher number one.  The chart shows that twenty-four out of the twenty-seven sets are run on slasher number one, with an average of 144 yards set out waste.  The other three sets for this style were run on three different slashers and averaged 129 yards of set out waste on each.  This chart, along with the others mentioned previously, suggests that there is an operator or machine related issue with slasher number one.  Why is the set out waste always greater on slasher number one?

Due to the fact that there are multiple sets run on slasher number one, which have a fairly normal yardage of set out waste, 80 to 120 yards, the data suggests that an operator is to blame for the excess set out waste generated on slasher number one.  This could be due to inexperience, lack of training, use of improper procedures, or simple carelessness.  The large variance of set out waste also suggests that the root cause is operator related because if it was a machine related issue then the data points would all be skewed towards the high end of the set out waste instead of scattered about.

The last two charts for the 30 denier nylon styles, Figures 35 and 36, also indicate that allowing an inefficient or improperly trained operator for slasher number one to run an already difficult to handle yarn, results in substantial losses of raw material and time wastes. This operator related issue wastes almost 100 more yards of yarn per set out than the other operators on this same style.

Without the use of these waste analyses this company might never have known that they have an opportunity to reduce substantial amounts of waste just by examining and correcting operator practices. This company should take the time to retrain all of their operators in standardized set out procedures, ensuring that raw material and valuable time are not continuously wasted during the set out procedure.

Creel waste is another facet of this in-depth waste analysis that is sometimes overlooked and forgotten about in the manufacturing process. The amount of creel waste left on the section beams in the creel area should be as minimal as possible. The section beams should be run until one of the section beams is completely out of yarn. Hopefully all the section beams contain the exact same yardages and the tension on each of the beams is the equal. When this is true, all of the section beams should run out at approximately the same time. There are several reasons for excessive amounts of creel waste left on the section beams. Runability problems with the section beams or breakouts in the section beam will cause creel waste to be high. Also when one or more of the section beams runs out of yarn well before the others, the remaining yarn on the other section beams must be wasted. Breakdowns of the machine towards the end of the set will also cause creel waste to be higher than usual.

When there are runability problems with the section beams towards the end of the set it suggests an opportunity with the start up of these beams in the warping process. It is recommended to first investigate the reason for the left over yarn on the section beams. If the section beams are not being fully depleted due to unwinding problems improper warping practices or troubles at the start up of the warping process could be to blame. If some of the beams are reaching their full order length with no unwinding problems, while others run out, then there could be excessive stretch in the slasher or the yardage on the section beams are not equal. If order lengths in slashing are being reached and there is still yarn left on the section beams the stretch taking place on the yarn in the slasher could be too high which will cause end breaks on the weaving loom. It is also possible that the set lengths are set too high in the winding and warping processes and should be lowered to conserve raw material.

Other waste, considered to be incidental waste that is not included in set out or in creel waste, is also an important waste measurement to track. This waste may be caused due to breakouts in the slasher causing rethreading of the slasher, bad start ups which must be wasted and completely started over, breakdowns of the machine for any reason which cause the yarn in the slasher to be wasted, as well as, the yarn on the loom beam if it is too small to be resent to the loom by itself. Sometimes operators record set out waste in the “other” category if the set out creates a large amount of waste. As mentioned before, the finer denier yarn styles are more susceptible to breaking if the filaments begin to separate from the bunch. This could lead to higher amounts of other waste caused by breakouts.

Recording and tracking set out waste, creel waste, and other waste separate from one another will allow for a much easier and more accurate waste analysis to be completed. Without separating these wastes, all of the waste opportunities are hidden beneath one another and are difficult to isolate, attack, and minimize. Once again, waste can be caused by man, method, or machine related issues or can be a combination of these issues, but without waste tracking and careful analysis they will continue to plague the warp preparation processes and exhaust overall profitability.

## 5.6 Defect Prevention

Special care and attention must be taken in the warp preparation processes in order to prevent defects from occurring. Defects can occur at any moment, anywhere in the process. Even the best and most experienced operator can cause or miss defects. This is why it is imperative to train operators extensively on defect prevention. Most of the knowledge of properly running a slasher comes from on the job instruction, although defect prevention literature should be required as a learning tool.

This section focuses on controls in each area of the slashing or sizing process, which should not be ignored or disregarded. Emphasized are the creel area, the sizing area, the drying section, the leasing section, and the wind up area on the head end. Each section discusses elements of the machine and how, if properly controlled, they can help prevent defects from occurring.

Creel Area

There are numerous items to be checked in the creel area before and during the running of the machine.  Alignment is a very important aspect of the creel.  The yarn must be able to travel through the machine as straight as possible.  This means that the creel, including the section beams and the guide rollers must be perfectly aligned with the size box, the drying section, the lease rods, and the front comb.

The brakes on the creel need to be in good working order to prevent any uneven running out of the section beams.  If one beam has more tension on it than the others then it will overstretch the yarn and either cause breaks or too much yarn to be left on the beam at the end of the set.  Brakes should be checked and replaced periodically in order to maintain proper and equal tension on the section beams.

The bearings and rollers throughout the creel, as well as the rest of the machine, need to free of burrs and scratches as these will cut and weaken the yarn as it passes over. These bearings and rollers should also turn freely to prevent any unnecessary sliding of the yarn across these surfaces.  The rollers should be cleaned each day to ensure there is no buildup of waste which may cause end breaks or weakening of the yarn.

Even though the amount of tension needed on a yarn varies, it is important to keep the tension as low as possible in the creel section.  Just enough tension to keep the ends from going slack is recommended.  Most industry experts suggest approximately twenty grams of tension in this area.  Frequent tension checks should be conducted to guarantee there is not too much tension being applied.

It is of the utmost importance that operators check the quality of the section beams before the set is started.  Operators should check for burred or damaged beam heads and any visible defects in the yarn on the section beams. It is also very important to check to make certain that the correct style, yarn count / denier, number of ends, and yardage length all match up. If any of these items mentioned do not coincide the set should not be run and immediate action should be taken to correct the issue.

Good housekeeping, however mundane it sounds, is crucial to running good warps. The creel needs to be free of lint which may be carried over into the size box. This lint will accumulate size and either attach to the yarn exiting the box and cause a hard size defect or will stay in the size box and cause maintenance issues.

Sizing Area

The sizing area contains several critical elements which affect the quality of the size applied to the yarn. There are several factors in this area which affect the size pick up, the size encapsulation and the size penetration. The size bath must be free of contamination to ensure no hard size is transferred to the yarn. In the case of spun slashing, the size box needs to be boiled out, drained, and thoroughly washed out between each set. For filament slashing, the box should still be drained and washed out after each set.

It is important to confirm that the size jets, which emit the size into the box, are in good working condition and are properly agitating the size bath. It is also important to make sure that the jets are washed off after each set, due to the fact that as the size cools it may clog the jet. If the jet is clogged it will not emit the proper amount of size into the bath, throwing off the percent solids. It will also cause part of the bath to stagnate, which will cause hard size to form. Before starting up the new set the size bath's temperature, level, and percent solids should all be verified to be within specifications.

The squeeze roller in the size box should be checked for any scratches, cuts, or grooves, which may cause yarn breaks or inconsistent size encapsulation around the yarn. The shore hardness of the rolls should also be checked periodically to ensure that the proper amount of pressure is applied to the yarns as they pass through the size box. The shore hardness of the rolls determines how much size is squeezed out of the yarn.

The tension should be checked in the size box area on each set to guarantee that the yarn is not being overstretched or that it is too slack, which can cause ends to cross and entangle. It is important to remember that the yarn will stretch more in the size box area because it is wet and it is easier for the individual fibers to slip past one another.

The slasher speed also affects the size box area, as excessive creeping or stoppage of the machine will allow the size to congeal and harden on the walls of the size box, creating the possibility of hard size defects to occur.

### Drying Section

After the yarn exits the size box it usually passes directly into the drying section. There is typically a predrying area and a final drying area. The predrying area is set at a slightly lower temperature to ensure good encapsulation of the size around the yarn before it dries. Correct temperatures will dry the size uniformly around the yarn and provide adequate moisture content. If the temperature is too high, the size will flash dry the yarn. Flash drying means that the size migrates away from the heat to the unexposed side of the yarn. This will create weak areas on the yarn and will lead to increased hairiness and end breaks in the weaving process. If the temperature is too low, the size will not fully dry around the yarn and it will cause the ends to stick to one another, creating stuck end defects. Stuck end defects occur when two or more yarn ends either from the same shed or from neighboring sheds stick together and enter into the same dent in the comb. These ends will break in the weaving process, as they will not be able to fit through the opening in the dropwire. Proper leasing, moisture control, and maintaining proper settings are essential in preventing stuck end defects.

If cylinder cans are used in the drying section, it is recommended that the cans be Teflon® coated to prevent lint and size build up. The can edges should be kept clean in order to avoid hard size, stuck ends, and rolled ends from occurring. If drying chambers are used, they too must be kept clean of lint which may attach to the wet yarn.

The speed of the machine also influences the drying of the size on the yarn. Speeds that are too high will not allow the size to be adequately dried around the yarn. Conversely, excessive creep or slow speeds will over dry the yarn, making it brittle and weak. Not only will this cause the yarn to lose breaking strength, but also elongation.

Leasing Section

The leasing section is influential in the prevention of crossed and twisted end defects in the warp. A properly leased warp should have no crossed or twisted ends. Each end should be accounted for in its correct shed and appropriately separated from adjacent sheds, reducing the chances of stuck ends.

The frequency that a set should be leased varies by style, with smaller diameter yarn styles requiring more regular leasing procedures. The reasoning behind this is because smaller diameter yarns have less space to clear in order to cross over one another. It is imperative that leasing should be done at the beginning of each new set to ensure that all ends are straight and no ends are crossed causing excess tension during the unwinding process. After any breakout or multi-end lap it is recommended to lease again in order to guarantee no ends have become crossed or twisted. Flat sticks are useful tools when checking for crossed and twisted ends or ends that are out of lease near the comb. It is also important to keep the bust rods and lease rods free from burrs, scratches, or any buildup which may break the yarn as it travels to the head end of the machine.

Tension in the leasing section is also important to the quality of the warp. The tension in this area should be sufficient to split the sheds about four to five inches behind the busting rod. This will provide a good split of the yarn, which is not too harsh and does not run the risk of trapping ends under the rod. If the tension is too low, the ends will break upon splitting at such a harsh angle. If the tension is too high in this area then there will be excess stretch on the yarn, which can lead to end breaks in windup or in the weaving process.

Wind Up Section

The wind up section at the head end of the machine is the final area affecting the quality of the warp before it is transferred to the beam. The comb needs to be free of lint and trash build up which may cause an end break or even a breakout of multiple ends. The dents in the comb should be straight and evenly spaced to provide a uniform warp sheet and prevent any ends from rolling. The tension and press roller should be set correctly in order to pack the yarn tightly onto the loom beam, ensuring maximum yardage capacity. Many weavers agree that hard beams give better weaving performance than soft beams. In fact some beams are returned to slashing departments as defective due to soft warps. Alignment of the loom beam is crucial to producing a quality warp. The beam needs to be perfectly aligned to prevent high and low selvages which will result in rolled and trapped ends which can not be properly drawn into the loom. The beam journals also need to be in good working condition to keep a uniform build on the loom beam. The final procedure of the slashing process is one of great importance. This is the taping of the warp during doffing. An incorrect or bad tape job can result in rolled and twisted ends which will be drawn into the loom incorrectly and will cause excessive tension, which may lead to end breaks. In order to ensure that the ends of the warp sheet stay together the tape must extend across the entire width of the loom beam. It is also important to note that care should be exercised when folding the tape around the ends of the warp sheet to prevent rolling of warp ends.

## Summary

There are many factors influencing the quality of the warp throughout the entire slashing process. Operators need to be thoroughly and properly trained to guarantee that no area of the slasher is overlooked or ignored. Proper training enables operators to do the job correctly the first time, lowering the chances for defects to occur. Operators must know what problems and defects can occur in all areas of the machine. Additionally, the operators must cycle their machines, looking, listening, and smelling for abnormalities. From the beginning of the slashing process to the winding up of the loom beam, attention and awareness are instrumental in producing a quality warp.

### 5.7 Technology Comparisons

The purpose of this section is to provide a time study comparison of available technologies in use in the industry today. The technologies discussed include: sample warpers, sectional warpers, automatic warpers, and single end sizing machines.

The following information, in Table 40, describes the amount of elapsed time and the amount of man hours it takes to prepare and run a 150 denier, 170 yard (154 meter) order with six colors and 2359 yarn ends. The running speed of the sectional warper is 800 meters per minute.

Table 40

Time Study for a 170 yard sample order run on a sectional warper (Source: Karl Mayer)

| Action | Elapsed Time | Man Hours |
|---|---|---|
| Pulling & Staging Yarn | 0.75 | 0.75 |
| Reconing Yarn | 1.0 | 1.0 |
| Creeling & Tying-in Ends | 1.5 | 3.0 |
| Drawing-in Section Reed | 0.25 | 0.5 |
| Warping w/ Manual Leasing, Cutting, & Tying of Sections | 0.5 | 0.5 |
| Beaming | 0.5 | 1.0 |
| **Total** | **4.5** | **6.75** |

In order to produce this sample order on the sectional warper it would take an elapsed time of four and a half hours including six hours and forty-five minutes of labor time.

The next time study compares the Karl Mayer GOM with a single end sizing machine for the same sample order. Table 41 details the times required to run this 170 yard sample order with six colors and 2359 yarn ends. The run speed is again 800 meters per minute.

Table 41

GOM vs. single end sizing machine (Source: Karl Mayer)

| | GOM | | Single End Sizer | |
|---|---|---|---|---|
| **Action** | **Elapsed Time** | **Man Hours** | **Elapsed Time** | **Man Hours** |
| Creeling | 0.25 | 0.25 | 0.15 | 0.15 |
| Run Warp | 1.15 | 0.25 | 8.40 | 2.0 |
| Cutting | 0.25 | 0.25 | 0.25 | 0.25 |
| Prebeaming | 0.1 | 0.1 | 0.2 | 0.2 |
| Beaming | 0.25 | 0.25 | 0.25 | 0.25 |
| **Total** | **2.0** | **1.1** | **9.25** | **2.85** |

The time taken for each of the machines to run the sample is compared in Table 42. It is important to note that the GOM sample warper and the sectional warper times do not include the sizing process. This is not a fair comparison of processing times if only one of the technologies includes time for the subsequent process. For a more reasonable comparison, the amount of time needed to size these warp yarns must be added to the time spent warping the yarn for the GOM and the sectional warper.

Table 42

GOM vs. single end vs. sectional warper (Source: Karl Mayer)

| Technology | Job Time (Hrs) | Labor (Hrs) |
|---|---|---|
| GOM Sample Warper | 2.0 | 1.1 |
| Single End Warp Sizer | 9.25 | 2.85 |
| Sectional Warper | 4.5 | 6.75 |

The following study, included in Table 43, compares the time taken to produce a 1000 meter order with 4800 yarn ends on an automatic warper versus a conventional sectional warper. The automatic warper carries out most of the job actions unassisted. After manually warping the first section, the rest of the job is completed with no manual labor unless a yarn end breaks. Conversely, with the sectional warper, there is manual leasing, cutting, and tying preparation of each section. The auto-warper can warp up to 600 meters per minute and is capable of warping orders up to 6144 meters in length, depending upon yarn count and density. Table 43 compares the Suzuki K7A Auto-warper with a conventional sectional warper running at the same speed. The table indicates the time spent creeling in the required number of wound packages, warping the first section using each of the technologies, the processing time for the remainder of the needed sections, and the unloading and beaming times.

Table 43

Suzuki K7A Auto-warper vs. sectional warper (Source: Suzuki Warper Ltd.)

4800 ends; 1000 meter order

| | **Sectional Warper** | **Auto-warper** | | | |
|---|---|---|---|---|---|
| **# of Creels** | 400 | 400 | 160 | 80 | 40 |
| **# of Sections** | 12 | 12 | 30 | 60 | 120 |
| **Action** | **Man Hours** | | | | |
| Creeling | 2.0 | 2.0 | 0.8 | 0.42 | 0.25 |
| Warping 1st Section | 0.55 | 0.55 | 0.3 | 0.17 | 0.83 |
| Conventional Warping | 1.47 | | | | |
| Auto-warping | | 0.97 | 2.42 | 4.83 | 9.67 |
| Unloading/Beaming | 0.5 | 0.75 | 0.75 | 0.75 | 0.75 |
| **Total** | **4.52** | **4.27** | **4.27** | **6.17** | **11.5** |
| **Manual Work** | **4.52** | **3.3** | **1.85** | **1.33** | **1.08** |

As seen by the results in the table, the automatic warper dramatically reduces the amount of manual time required to run this order size. Even though the total amount of processing time increases as the number of required sections increases, the auto-warper is still advantageous. If there is not a lot of time pressure to get the warp made, the operator can be tending to another machine or performing another task. The amount of inventory required per set can be decreased if processing time is not too demanding.

### 5.8 Emerging Technologies

New technology is continuously being developed to aid the textile manufacturer in becoming more cost competitive, whether it is increasing flexibility or optimizing the utilization of machines and raw materials. There are several emerging technologies on the horizon to better service the warp preparation processes.

One of these concepts is a smart beam being developed by Karl Mayer which will include a computer software data chip that will accompany a warp beam from the warping process through the sizing process. This data chip will store all of the essential information about the warp, tracking the length of the yarn down to the last yard. This system will let the operators know exactly how much yardage is left on each section beam in the creel, allowing the warp yarn to be fully utilized, lessening the amount of creel waste left on the section beams.

Another emerging technology is the increased length capacity of sample warping. Sample warping is becoming more and more essential to meeting the increased customer demands for smaller, quicker turn around type products. Increasing the warp length capacity of these machines makes them more versatile and more economically appealing. Karl Mayer will showcase an increased length capacity to their GOM sampling warper at ITMA 2007. The enhanced GOM will feature additional creel capacity allowing for the warp length to be increased from 770 yards to over 1000 yards. The new machine will have a creel capacity of up to twenty-four wound packages. The increased warp length will allow for more short order production runs to be processed on the warp sampling machine, which in the past would have had to be run on sectional warpers. The time and raw material savings of this sample warper have already been discussed in previous sections.

A concept which has gained popularity in Europe and Asia is commission warping and sizing. Companies are specializing in one specific area of the warp preparation process and are contracting their services out to other textile companies who either do not have the capital for, or do not want to invest in, higher technological equipment for shorter order sizes. These commissioned warpers and sizers receive raw material and instructions for processing and, of course, charge a processing fee for their services. Due to the higher inventory of raw material, these commissioners are able to combine order lengths of different sizes, reducing the amount of downtime for set out and change over. The capacity utilization of their machines is increased and their overhead costs are thus, decreased. Whether or not this concept will be adopted into the US textile industry is uncertain.

Fully automated, vertically integrated manufacturing facilities are not readily available and do not come without a high price tag, although the benefits allow for direct competition with any foreign goods. One plant visited in Italy was fully automated, with automatic doffing devices, AGV's to transport raw material from process to process, robotic arms to automatically creel packages, and other automated equipment to decrease the amount of manual labor needed to manufacture fabric from start to finish. The initial investment in this type of automation is substantial, although a company with the desire to stay competitive with lower wage foreign goods will benefit and prosper in the end. The return on investment is accelerated by lowered labor costs and increased productivity. During this visit a time study was conducted on the warping process. The entire set out process took one hour and fifteen minutes for a 500 end count style. The only manual labor involved in the set out process included blowing off the creel with an air hose, gathering the ends from the packages in the creel, bringing them to the front, and laying them into the comb. The manual labor involved in the set out process took less than forty minutes. This same style would have taken two and a half to three hours to complete in a non-automated setting.

Even though most companies do not have the financial backing to invest in a fully automated plant, automation will continue to play a major role in reducing the costs of manufacturing in countries which have higher labor wages. This automation will increase the cost competition of US and European companies against lower wage foreign goods. Automation of processes and emerging technology are the wave of the future in textile, and all other, manufacturing processes.

# 6. CONCLUSIONS

Throughout this research it is apparent that there are different approaches and practices which work best for certain technologies and companies, but nevertheless, there is room for improvement in each case. Improvements need to ensue in operator training, performance measuring, and advancing technology upgrades. Operators, management, and manufacturers all need to be asking themselves the hard questions on why things are like they are. How and why is waste generated? Why is there variation in waste between similar styles, order lengths, and technologies? How can waste be reduced and eventually eliminated?

This research has begun to answer some of these questions; however, it is crucial to the survival of this textile industry in the US to continue to seek out the answers for these questions and others on a daily basis at all manufacturing levels. Cost analyses on alternative technologies and equipment must be completed and evaluated. Waste analyses should be conducted to identify the source and root causes of the generated waste. These analyses, along with the desire to flourish, will help to reduce time, labor, and raw material wastes and in turn increase the cost competitiveness of the manufacturer.

As order length sizes continue to decrease and plant complexities increase, manufacturers must be willing to change their approaches, practices, and procedures. Process engineering, innovative controls, and new technology will help manufacturers understand the causes of waste, eventually reducing and eliminating it completely.

“New manufacturing strategies for competitive advantage require: focus on customer satisfaction based on strategic management of quality, and a focus on manufacturing excellence based on the principles of continuous improvement and elimination of waste [29, p.101].” These Japanese manufacturing philosophies from the 1980’s have transformed manufacturing all over the world. The desire of today’s manufacturer is to shift towards lower cost, superior quality, greater flexibility, and highly innovative process technologies. This is not an easy, straightforward task, but is one which must be accomplished in order to endure the increased demands of the marketplace.

There are several ways in which the US textile manufacture can begin to reduce and eliminate waste generated in the warp preparation processes which have been discussed throughout this research. The US textile industry, vendors and manufacturers, should work together focusing their efforts on establishing best practices, which decrease time, labor, and raw material wastes, and developing new and improved technologies that are superior in producing faster, higher quality goods at a lower cost. Future research into these areas will give the US textile industry a strong competitive advantage in innovative technologies.

US textile companies that plan to survive and remain profitable must continue to improve and innovate. Remaining stagnant in an ever changing marketplace is disastrous. Success will only come to those who measure, control, and improve their processes and procedures, reducing and eliminating waste where ever it exists, continually striving for excellence and nothing less.

# 7. RECOMMENDATIONS FOR FUTURE RESEARCH

The results of this research indicate that waste in the warp preparation processes can be reduced by various methods. Because this research was limited by time and industry data, the following are related areas for possible future research studies:

1. Further analysis of time and raw material waste between different warp preparation technologies using the same warp sheet characteristics, including same number of ends, fiber type, yarn linear density or count, order length, percent size add-on, etc. This research will help to identify exactly which technologies are best suited for reducing generated waste in the warp preparation processes.
2. Further in-depth analysis of labor costs and machinery costs of new or used warp preparation equipment and return on investments. This research will provide financial data to support the shifting from one technology to another.
3. Research on technology and equipment production capacity analysis. This research will help to identify what technologies are best suited for which order length sizes.
4. Investigation into the integration of warping and sizing processes. Plants in Turkey and China are already placing sizing equipment in between the package creel and the head end of the warping machine, although processing speeds are minimal, ten to twenty-five yards per minute.

5. Analysis on the effect on percent size add-on and waste accumulation when running the size machine in creep or slow speed. This research will investigate the repercussions in weaving of processing yarn at slow speeds.
6. Research and trials using polymeric sheet or other leader type fabric to connect succeeding sets in slashing. This is already being practiced for heavy, wool yarns. This research will identify ways to eliminate the need for good yarn to be wasted during the threading up of the machine during set outs, potentially saving up to a hundred yards of yarn per set.
7. Research and trials using a tying-in machine or thermal bonding machine to fuse ends together for succeeding slasher sets. This is done in denim production with continuous dyeing and sizing machines using accumulators. This research will ensure that the yarn ends will stay straight and inline throughout the entire thread up of the machine. This will also negate the need for counting each individual yarn into the front comb, saving valuable time and labor costs.
8. Research and trials using reusable, detachable, flexible combs which could be transferred from the warping process to the slashing process to eliminate having to count in each individual end into the comb. Again, this research will reduce time and labor wastes in the counting or laying in process and will prevent the yarn ends from crossing causing future end breaks.
9. Analysis of advances showcased at ITMA 2007. ITMA 2007 will include a section on waste reduction. This analysis may lead to emerging technologies or solutions to reduce accumulated waste in the warp preparation processes.

10. Research and trials on technology which eliminates the need for the sizing process. Scientists at the Southern Regional Research Center, in New Orleans, Louisiana, have developed a research approach to try and eliminate the requisite for warp sizing. The approach involves improving yarn quality and structure, developing a simple method of cleaning and twist-setting the yarn, modifying critical loom components to minimize yarn abrasion during weaving, and fundamental understanding of certain yarn failures. Successfully eliminating the sizing process would revolutionize the warp preparation process, potentially lowering the cost of production.

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