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THE ON-LINE INSPECTION OF SEWN SEAMS

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RELEVANCE TO NTC GOALS:

Apparel manufacturing is traditionally very labor intensive due to the extensive style and fabric variation of the products. Most of the sewing machine manufacturers and some of the larger apparel companies have developed semi-automated sewing stations to perform operations which are constant across a large style range. These normally require an operator to load the machine, which then automatically sews and stacks the components. Although such stations improve production efficiency, they remove the almost unconscious operator inspection of the operation. The result is that only major seam faults are observed, for example, thread breaks. Other faults, mis-stitches or non-included seams for example, may not be detected until the garment is completed or perhaps not until after laundering. At this point, the manufacturer's cost is at a maximum. In order to reduce the number of defective garments it is necessary to develop complete seam monitoring systems that meet the apparel manufacturer's requirements of flexibility, cost, and reliability.

An interdisciplinary team of researchers from the College of Textiles at North Carolina State University and Georgia Institute of Technology are collectively investigating the constraints of the project. Presently, their approaches include: 1) industrial collaboration in order to compile a technology survey and determine design specifications, 2) the fundamental research of fabric and seams, and 3) the investigation of concepts which could potentially be used in a seam monitor.

GOALS:

SHORT TERM: Investigate new technology which could be used to monitor sewn seams. This will allow all aspects of seams to be automatically monitored including skipped stitches, incorrect tensions, seam allowances, and the number of plies sewn. Major stitch types are to be considered.

LONG TERM: Produce a "black box" to be attached to a sewing machine which would provide information that would allow for the real-time adjustment of the sewing machine settings in order to optimize performance.

TECHNICAL QUALITY AND ACCOMPLISHMENTS:

An interdisciplinary team of researchers from the College of Textiles at North Carolina State University and the School of Textile & Fiber Engineering at Georgia Institute of Technology have collectively addressed the following tasks: 1) industrial collaboration in order to compile a technology survey and determine design specifications, 2) the fundamental research of fabric and seams, and 3) the investigation of technological concepts which could potentially be used in a seam monitor. The technical quality of the research is reflected by progress made thus far in the first year of the project. A brief summary of the research effort for this reporting period is provided below.

A technology survey has been conducted by the team members at NCSU and Georgia Tech in order to develop the specifications for a seam monitoring device. This project has involved industrial collaboration with Russell Corp. R&D and the Levi Strauss Technology Center. Russell provided samples of seam faults in knitwear for classification and analysis, while Levi supplied twill denim and plain weave samples.

The following tables have been compiled as a result of the survey, indicating the stitch and seam types which were found to frequently require monitoring and the common defects observed. The types of fabric investigated included twill denim, plain weave, and knitgoods.

Table 1. Major Stitch Types Identified for Study

Stitch Type:	Seam Type:	Fabric Construction
401-2 needle chain stitch	felled inseam/riser	woven
	waist band	woven
Multiple-needle chain stitch		knit
301 lock stitch	leg hem	woven
		knit
516 safety stitch	side seam	woven
Overedge stitch		knit

Table 2. Common Seam Defects for Both Woven and Knit Fabrics

- raw edges
- needle cuts
- non-inclusion
- seam allowance/hem width variation
- puckering
- mis-matched seam
- pleat in hem or hem double folded
- improper thread tension
- incomplete operations (out of thread, thread or needle breakage)
- mis-stitches/skipped stitches

Several approaches have been pursued in this effort to inspect sewn seams. The first is the development of a method by which to indirectly measure thread usage to detect incorrectly sewn seams in a general sewing environment. This work will include three or more stitch types including the lock stitch, multiple needle chain stitch, and an overedge stitch. It will determine the applicability of thread motion ratio (TMR) technology to predict thread consumption and deduce seam quality or changes in quality. Since the multiple threads interact, a major area of investigation is to determine the minimum number of sensors required to reliably detect changes such as the sensitivity to breakage of a thread not being monitored directly with a sensor. During this period, tests are being made with a single position sensor. Cost is an important factor and it is also desirable to have a system which could be retrofit to existing machines. Preliminary results indicate that a single sensor can indeed detect changes in other threads and that one sensor may be adequate in monitoring the changes most important to the user. Multiple sensor heads may be needed for certain changes important in some applications. Therefore, in an upcoming research period a multiple position head will be procured for testing. Microprocessor speeds for low-cost units may be a factor and optimization of program code to enhance speed is an area of investigation.

A second approach is the development of a skipped stitch detector using optical sensing. This work determines the specifications for reliable detection by optical means of detecting skipped stitches on several types of stitches including lock stitch and chain stitch. In many applications a single skipped stitch is unacceptable and significant losses occur in value of the product. A single skipped stitch is important to all applications in that it is an indicator that some machine adjustment is needed and the problem will likely get worse with time. Currently, some success has been had with the lock stitch machine. A simple R-S flip-flop circuit is fed to a computer-simulated instrument to count missed stitches. Sensitivity to thread color and to machine speed will be determined during the next reporting period.

A number of other means by which seam quality could be monitored have also been investigated. Radiography studies indicate that the edges of the fabric within a seam may be distinguished. This may be accomplished visually from the analysis of x-ray exposed film as well as through computer-aided analysis of the image which can be projected onto a luminescent screen. Such images may be particularly useful in the characterization of sample seams.

Since a seam monitoring device could potentially contain a light source and optical sensor, optical characterization of various fabric samples has been initiated. This study might eventually indicate the wavelength which might appropriate the widest range of fabrics and dye types. Other sensor technologies which are currently available, such as capacitive and through-transmission ultrasonic sensors, appear to be limited in their usefulness in monitoring seams due to their inability to distinguish numerous layers of fabric and their low resolution. Other techniques involving mechanical rollers, strain gauges, or edge marking have also been considered.

A needle penetration experiment designed and built at NCSU under Project S92-3 for the on-line identification of fabrics may also prove useful for the determination of seam quality. This system utilizes a force transducer on the needle bar to monitor the force required to penetrate the fabric beneath the presser foot. Since the force varies with the number of layers of fabric it penetrates, this technique may be of interest in the development of an on-line seam monitor.

The use of beta-particle source and detector as a method of inspecting seams has also been investigated. Although a device utilizing such a technology may appear to be

~~impractical at the current time, information gathered from such fundamental research may~~ prove valuable in the future as automation progresses.

Preliminary work involving denim fabric indicated that charged beta particles are less penetrating as compared to uncharged gamma rays and x-rays which are readily transmitted through the fabric. A 1 mm diameter collimator coupled to a conventional geiger counting device was designed to test various isotopes, including ^{85}Kr and $^{90}Y^{90}Sr$. The $^{90}Y^{90}Sr$ source was determined to be the most suitable source for the density of the denim fabric, based on the energy of the beta particles emitted which determines the absorption coefficient, μ (cm^2/g), of the source. Using the beta gauge described above with the $^{90}Y^{90}Sr$ source, the intensity of the beta ray transmitted through various numbers of layers was determined. For the sake of observing possible edge effects, the edges of the fabric panels were displaced such that an additional layer was added to the stack every 12 mm, and the stack was translated between the source and detector. The difference in beta ray intensity through 0, 1, 2, 3, and 4 layers can be clearly distinguished as seen in Figure 1. These results indicate a beta-particle gauge could potentially be used in such a "black box" to monitor the number of layers of fabric included in a sewn seam.

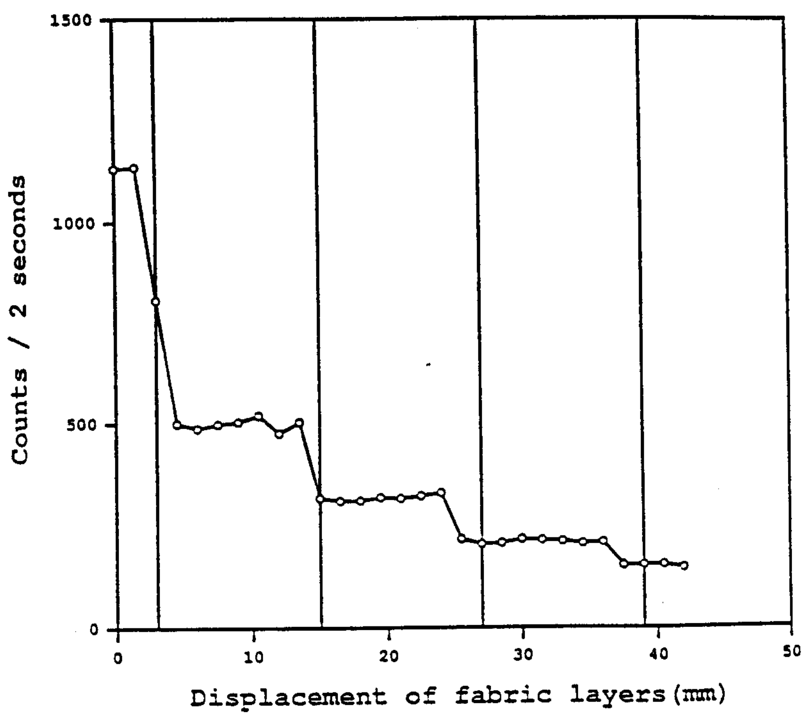

Figure 1. The intensity of beta-particles transmitted through 0, 1, 2, 3, and 4 layers of fabric.

From collaborative discussions with industrial contacts it has been determined that such a "black box" could be located either between the folder and the presser foot or within a few inches behind the presser foot. Attention must be given to size restrictions for the sensor and control unit, which vary on each sewing operation. A sensor could possibly be coupled to the feeder in order to predict the quality of the seam and provide feedback to correct the fault before it was sewn. Both good and "bad" seams will be characterized and modeled to aid in the development of these concepts.

RESOURCE MANAGEMENT

The management structure of the project is based on the establishment and pursuit of common goals and objectives by a team of interdisciplinary researchers while maintaining a sense of individual ownership and responsibility to meet those goals. The management team is led by Dr. T. Clapp, who coordinates reporting, communications, and resource allocation for the project. Meetings are held as necessary to discuss ideas and disseminate results of specific tasks.

The work is primarily conducted by the PIs, a post-doctorate research associate, and a graduate student. A list of contributors to the project in addition to the PIs reflects the diversity of backgrounds and interests.

Other Faculty: Dr. Robin Gardner (Nuclear Engineering),
Dr. Kuruvilla Verghese (Nuclear Engineering)
Post-Doctorate Research Associate: Dr. Kimberly Gossett (Physics)
Graduate Students: George Barrett (Textile and Electrical Engineering),
Zhaofeng Zhu (Nuclear Engineering)

COLLABORATION

As the project has developed, our team has sought to develop additional research partners and transfer technology to industry. A list of these organizations is given below:

	Organization	Type
1.	The Department of Nuclear Engineering at NCSU	Research Organization
2.	The Levi Strauss & Co.	Apparel Manufacturer
3.	Russell Corp. R&D in Alexander City, AL	Apparel Manufacturer
4.	$(TC)^2$ in Raleigh, NC	Research Organization
5.	Pacific Northwest Laboratories	Research Organization
6.	Turck Inc. in Plymouth, MN	Equipment Supplier
7.	Lion Precision in St. Paul, MN	Equipment Supplier
8.	Engineering Research Lab at NCSU	Research Organization
9.	Visolux Sensor Tech in Matthews, NC	Equipment Supplier
10.	The Southern Tech Apparel Demonstration Site, Atlanta, GA	Research Organization

Visits

1. M. Gunner, presentation made to Levi Strauss & Co. at their Technology Center in Richardson, TX on April 21, 1994.
2. K. Gossett, visit made to the Levi Strauss & Co. Technology Center, Richardson, TX, and to one of their manufacturing plants in Wichita Falls, TX, June 6-9, 1994.