

TITLE: CIM in the FTA Industrial Complex

INVESTIGATORS: S. Winchester - team leader; J. Cuculo, P. Grady, G. Hodge, G. Mock, M. Mohamed, A. Seyam, G. Smith.

CODE: S9211

GOALS: The overall goal of this multiple team research project is to create the computer based information integration technology required for an effective demand-activated, quick-response manufacturing environment in the fiber-textile-apparel complex. The vision for this systems development is to create the capability for a "textile information highway" on which resides dynamic, real-time, object-oriented information describing all aspects of a product's production history, properties, and quality. All the information describing the particular route any specific product takes through the multiplicity of possible value-adding steps would be openly available to the responsible organizations from fiber to final product at the retail point. This capability would provide knowledge-based decision making which integrates near-term point-of-sale information and longer-term fashion trends with the agile, responsive production system.

Current objectives are to design, test, and operate an integrated environment among machines, product/process data bases, and computers which enables the development of fundamental changes in design, manufacturing, and business/planning/decision making by:

- * Establishing architectures for a CIM network to provide a generic design for industry. These architectures will be demonstrated from the Textile Design Laboratory, the Management Systems Laboratory, and the Model Manufacturing Facility (MMF).
- * Defining philosophies and strategies for the FTA complex which will be supported by appropriate monitoring, control and analysis tools.
- * Creating the ability to integrate the FTA activities by defining and developing information transmission and retrieval systems for activities within and among textile companies.
- * Developing systematic decision making techniques for evaluating investments for controlling and managing operations in CIM technologies.

ABSTRACT: The CIM initiative at NCSU was initially organized in twelve project teams. Several of these projects were fully funded by NTC, while others were supported partially with "seed money" from NTC. The projects were reduced to nine in year 2 and then to five fully supported projects in year 3 beginning March 1994. To date, there have been ten theses completed, five publications, and ten presentations at conferences.

The first phase of integration research is nearing completion with distributed control systems prototypes and database management procedures defined and software implementation completed. The distributed control system serves as a teaching tool in the management systems lab. Phase two integration is under development and discussed in project S9412.

We have demonstrated that the major barrier to CIM growth is economic justification, but that justification is based primarily on simple payback and ROI procedures. We are also showing that a synergism exists when CIM and TQM are implemented in an integrated fashion.

Several projects are demonstrating technologies which improve product and process control for productivity and quality: wet-laid nonwovens processes, dyehouse process monitoring and control, knitted fabric monitoring and inspection, analysis of loom stops, adaptive loom control, and manmade fiber high speed spinning. These are important foundations for effective integrated information management systems that link value-added steps from fiber formation through dyeing and finishing.

WHAT WAS ACCOMPLISHED:

~~Technology transfer workshops were held with the following companies: Burlington Menswear, Fieldcrest Cannon, Frank Ix and Sons, Dan River, Elastic Fabrics, Glaxo Pharmaceuticals, Tultex, Liberty Fabrics, Unifi, Precision Fabrics Group, ATMI CIM Subcommittee, Bali Engineering, and Network Information Systems. A two-day short course on supervisory control and data acquisition (SCADA) systems was presented in Pontiac, Michigan by Dr. George Hodge and C. Hodges. Also, Dr. Hodge conducted in conjunction with IBM a one day short course for forty participants on ISO/9000.~~

Recently, a three day workshop was held in conjunction with IBM on Quality Functional Deployment (QFD) Methods using the software package Strategic Pointer/2000. Also, a conference on Quick Response in Textiles and Apparel was held in conjunction with American Production and Inventory Control Society - Textile and Apparel Specific Industry Group (APICS TASIG).

Theses topics, publications, and presentations from this work are:

Theses:

- * T. Shail, *CIM and the Dyehouse*, Thesis, NC State, 1994.
- * J. Campos, *Weft Knit Facility Data Model for CIM*, Thesis, NC State, 1994.
- * B. Pardo-Figueroa, *Economic Justification of Computer Integrated Manufacturing Systems (CIM) in Textiles*, Thesis, NC State, 1994.
- * B. Schuler, *Analysis of Loom Stoppages*, Thesis, NC State, 1994.
- * M. Carruthers, *Large Scale Database Design and MRPII Software Implementation for a Vertically Integrated Textile Model Manufacturing Facility*, Thesis, NC State, 1994.
- * M. Williams, *A Design of a Production Control System for Ring Spinning*, Thesis, NC State, 1993.
- * W. Wang, *Computer Integrated Manufacturing in Wet Nonwoven Process*, Thesis, NC State, 1993.
- * L. F. Fryer, *Computer Integration of Short-Staple Spinning Enterprise*, Thesis, NC State, 1992.
- * W. R. Masri, *Analysis of Multi-Attribute Decision Analysis (MADA) Software Products*, Thesis, NC State, 1992.
- * L. Hosford, *CIM in Textile Design for Jacquard Looms*, (draft) Thesis, NC State.

Publications:

- * P. Grady, L. Fryer, G. Hodge, and J. Rust, *Computer Integrated Yarn Manufacturing*, IEEE Transactions on Industry Applications, May/June 1994, pp. 517-527.
- * J. Raghaven and J. Cuculo, *Effect of Process Parameters in Melt-Spinning on As-Spun Fiber Properties*, The Proceeding of the Graduate Polymer Conference, (April 1994).
- * L. Fryer, J. Rust, and P. Lord, *Influence of Cotton Variables on Subsequent Process Performance*, Beltwide Cotton Conferences, San Diego, CA, (January 1994).
- * P. Grady, L. Fryer, J. Rust, and G. Hodge, *CIM Systems for Yarn Manufacturing*, The Proceedings of The Instrument Society of America National Conference, Chicago, IL, (September 1993).
- * P. Grady, L. Fryer, G. Hodge, and J. Rust, *Computer Integrated Management of Yarn Manufacturing*, The Proceedings of Institute of Electrical and Electronics Engineers 1993 Annual Textile, Fiber and Film Industry Technical Conference, Atlanta GA, (May 1993).
- * J. Denton, J. Cuculo, and P. Tucker, *A Computer Simulation of High-Speed Spinning of PET*, Journal of Applied Polymer Science, In Press..

Presentations:

- * G. Hodge, *Application Development Using PlantWorks for the Textile Industry*, Presented at the CIM in Higher Education Conference, Salt Lake City, UT, (March 1994).

- * G. Hodge, *Applying PlantWorks to ISO 9000*, Presented at the ISO 9000 Workshop, University of South Carolina, Columbia, SC, (December 1993).
- * W. Wang, A. Seyam and G. Hodge, *CIM in Wet-Lay Nonwoven Process*, Presented at Nonwovens Fundamental Research Conference, Clemson, SC, (June 1993).
- * G. Hodge and C. Hodges, *Selection of SCADA Systems*, Presented at CIM in Higher Education Conference, Grand Rapids, MI, (June 1993).
- * G. Hodge, *ISO/9000 and PlantWorks*, Presented at CIM in Higher Education Conference, Grand Rapids, MI, (June 1993).
- * G. Hodge, *Talking to Machines with PlantWorks*, Presented at Computer Integrated Textile Design Association (CITDA) Conference, Greensboro, NC, (May 1993).
- * A. Donaldson, *Toward the Year 2014, and All That*, Presented at CITDA Conference, Greensboro, NC, (May 1993).
- * G. Hodge, *CIM Education and Training and CIM Economic Evaluation*, Presented at the Sara Lee Manufacturing Automation Technology Shoot-out, Raleigh, NC, (December 1992).

Manuscripts:

- * D. Sigmon, *CIM and Quality Control in the Textile Industry*, Manuscript.
- * J. Campos, B. Pardo-Figueroa, T. Shail, and D. Sigmon, *Barriers to the Implementation of CIM*, Manuscript.
- * D. Sigmon, *Implementing a CIM Program in a Spinning Plant*, Manuscript.

The project teams developed generic distributed control systems prototypes for key textile operations: slashing, weaving, dyeing, knitting, apparel, and spinning. In addition, investment decision and systems integration models were developed. The results for each project are described below:

1. Information Integration Technology:

Overall Design of CIM System

J. Cuculo, P. Grady, G. Hodge, G. Mock, M. Mohamed, A. Seyam, G. Smith, S. Winchester; M. Carruthers and C. Hodges - graduate students.

The objectives of this team are to integrate the individual process area applications and to provide a common design for accounting, order entry, production routing, data-acquisition and control of the CIM facility.

We developed distributed control systems prototypes in the areas of: slashing, weaving, dyeing, knitting, apparel, spinning, and systems integration. Two industrial partners contributed information and expertise in developing these systems.

In addition, we developed an integrated distributed control system prototype for weaving which includes the processes of order entry, greige good ticketing, fabric inspection, roll packaging, and shipping. We are also continuing the development of the distributed control systems prototype to include from spinning through apparel.

A technical framework for the first phase of a CIM implementation in a vertically integrated textiles/apparel manufacturing facility is completed. Integration considered in this study spans from spinning to finished product. A technique for implementing large databases is introduced. A software implementation procedure is presented that allows a team selected from the client firm to systematically capture workcenter data for a variety of need perspectives. The context for implementing an MRP II system is described, and a forms-based procedure for implementation is introduced. The cornerstone of CIM implementation, the interface between the design/engineering database and the MRP II system, is presented.

A Total Quality-Computer Integrated Management System S. Winchester, P. Grady, and D. Sigmon - graduate student.

The purpose of this research is to identify how the combination of TQM and CIM manufacturing and management strategies and practices can facilitate the implementation and continuous impact on the environment of the company to meet their mission and objectives in the most consistent way, and from this information, build a model of a program combining the two strategies.

First, we have studied the impact, purpose, scope, and practices of both TQM and CIM philosophies and their possible impact on each other. Then, we developed and validated a questionnaire which represents a model of the implementation process and use of both TQM and CIM programs. The questionnaires were used to analyze six companies who have successful programs in the textile industry with one benchmark company outside the industry. The questionnaires were used in interviews conducted at these companies consisting of three to six interviews per company with individuals in each company familiar with either one of the two programs or both of them. From the answers to these questionnaires, ratings were given to each company in leadership, planning, implementation, communication, and information management with each of these representing major elements of TQM and CIM. Finally, a rating related to success was given based on the interviewees' views of the success of each program. From these ratings, statistical analysis was done and conclusions are being drawn. The next step is to finish the combined model and write the conclusions.

2. Analysis and Decision Technology:

Multi-Attribute Decision Analysis

G. Hodge and B. Pardo-Figueroa - graduate student.

A survey of textile executives was conducted to characterize how investment decisions were made in computer integrated manufacturing technology. A total of eighteen useable responses were obtained.

Respondents were asked to rank a list of potential barriers to CIM. The overall rank ordering of the barriers starting with the most significant was 1. economic, 2. conceptualization, 3. organizational, 4. human, and 5. technological. For the possible economic barriers to CIM the rank ordering starting with the most significant was 1. high capital cost, 2. effect on the ROI rate, 3. long term investment payback, 4. insufficient investment incentive, 5. high risks associated with these systems, 6. existence of cheaper alternatives available, and 7. expensive endeavor for large corporations.

ROI and payback period continue to be the most frequently cited techniques for analyzing investments in CIM. However, respondents indicated the need to include additional factors with may not be readily calculated in dollars.

3. Computer-Aided Process Technology:

CIM in Wet-Laid Nonwovens

G. Hodge, A. Seyam, and W. Wang - graduate student.

This project is completed with the submission of the thesis. We have modified the design of automation for the wet-lay process and have completed development of the PlantWorks application which will monitor and control this process.

The objective of this research is to develop a system to enhance the performance of the existing wet-lay nonwovens process. The existing laboratory scale wet-lay web forming systems are used for short runs to develop new products. Despite numerous control points,

the laboratory model and many industrial wet-lay machines are designed to run manually. The disadvantages of the manual control wet-lay system are possibility of overflow, and waste of time and material. These drawbacks adversely influence environment and labor safety. CIM approach can enhance the performance of the existing manual system and advance it to be used in practical industry for relatively long runs. The PLC is selected to execute most activities in the low level of the system structure. The computer node is physically connected to the PLC so that IBM's PlantWorks application can be written to perform the supervisory control and data acquisition on the computer for the wet-lay process. IBM's Distributed Automation Edition (DAE) provides a tool for communication among applications. The work focused on applying CIM to a one-ply wet-lay experimental machine made by Neue Bruderhaus which is available in the Nonwovens Cooperative Research Center Laboratory.

Process Monitoring and Control in the Dyehouse

G. Hodge, G. Mock, and T. Shail - graduate student.

The purpose of this research is to develop a generic model of a batch dyeing and finishing plant. During this past year, we developed a CIM model using IDEF technology developed by the United States Air Force. There are several modeling techniques available for performing this type of analysis. The most common are Data Flow diagrams, Process Flowcharts, Process Simulation, and IDEF. The IDEF technology was chosen to show the information flows, product flows, and human interactions that occur in this type of plant.

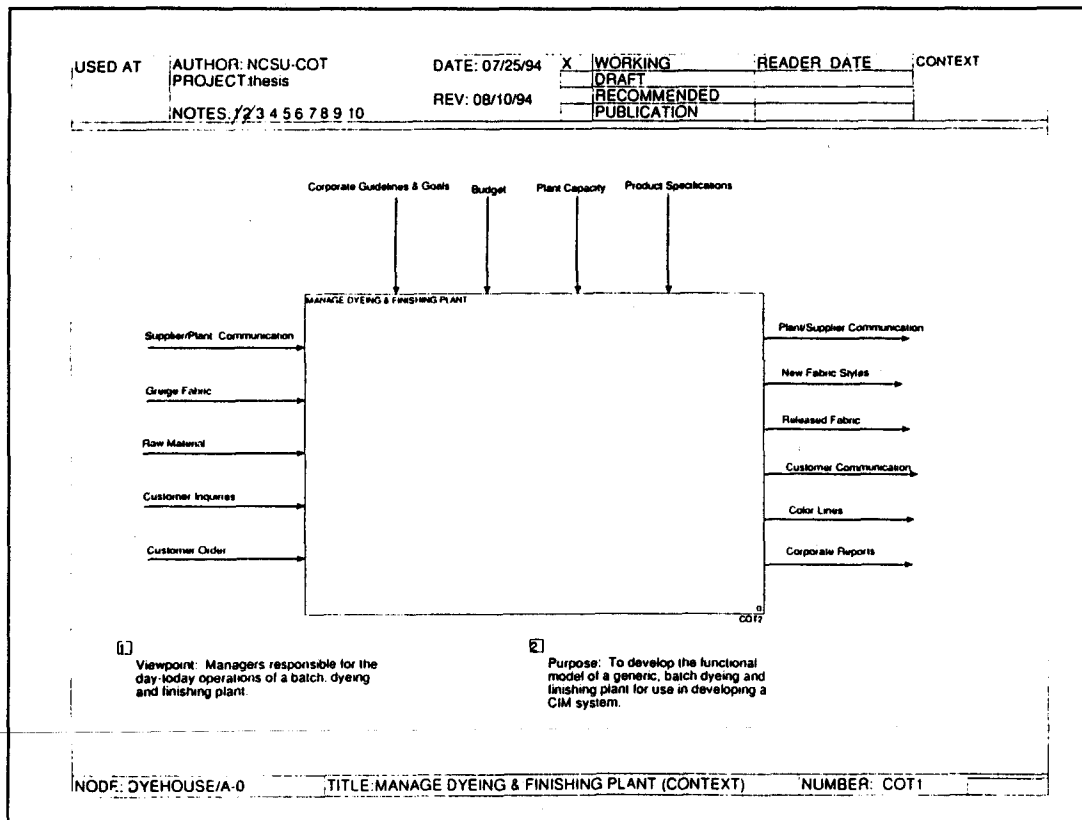


Figure 1: Dyehouse Model/A-0

The graduate student assigned to this project worked as a summer intern at a dyeing and finishing plant gathering data by interviewing personnel from machine

operators all the way up through the plant production manager. From this information, a generic dyehouse model was developed.

The generic dyehouse model is a good representation of a typical dyehouse because it is based on the operations of an actual dyeing and finishing plant. The model is valuable as a systems analysis tool and could be used to construct an IDEF0 model of an actual plant by providing a model from which a systems analyst could build a specific site model. This model is also useful as a benchmarking tool because it allows the personnel of a dyeing and finishing plant to see how a typical plant operates and make comparisons. The 'As-Is' model represents the functions performed by a dyeing and finishing plant and provides an understanding of dyeing and finishing from which the 'To-Be' model could be developed. Figures 1 and 2 show the two highest levels of the generic model. Figure 1 is the A-0, or context level of the diagram, and Figure 2 is the A0 level of the diagram.

As a result of this research, CIM was defined and the barriers to implementing CIM were identified. Possible solutions to these barriers were identified and discussed. IDEF0 is a solution to overcoming many of the barriers to CIM. The ease of use and low cost of IDEF0 models allow them to overcome many of the system design and implementation barriers facing dyeing and finishing plants.

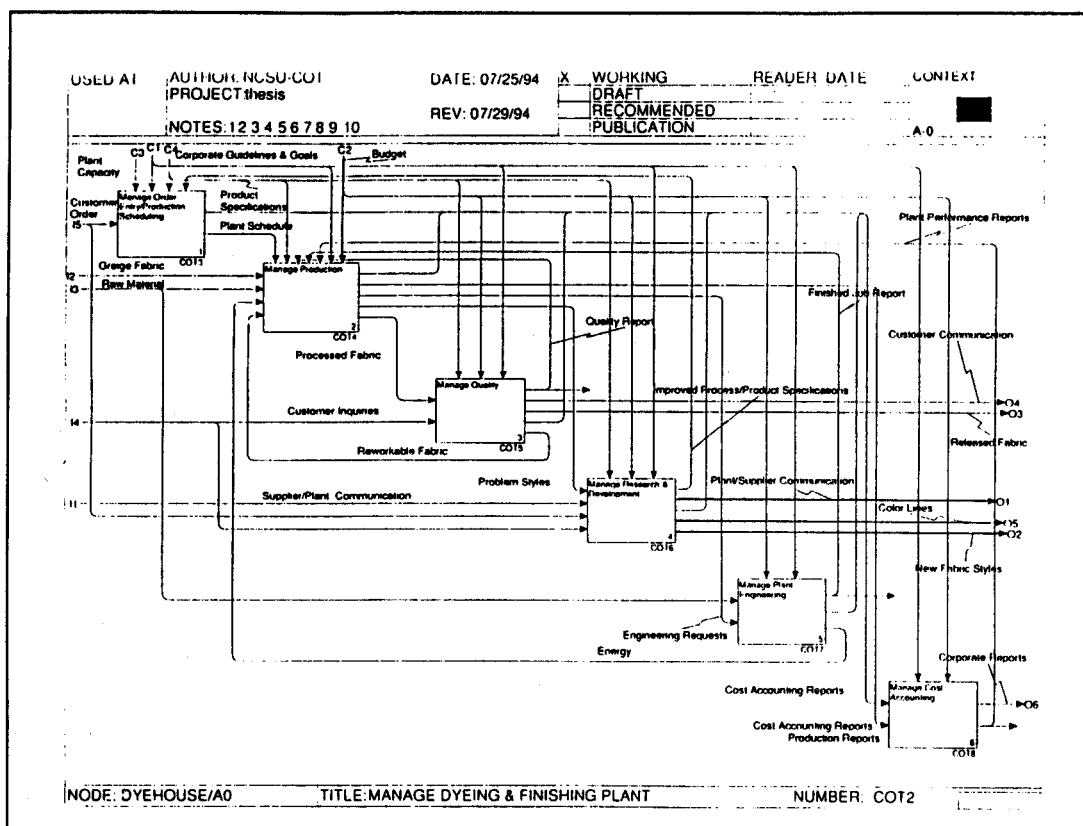


Figure 2: Dyehouse Model/A0

Knitted Fabric Inspection and Monitoring

G. Hodge, G. Smith, and J. Campos - graduate student.

Using data flow diagramming techniques, a model of a weft knitting plant was developed. Figure 3 shows the Level 0 model which divides the plant into ten functions. These functions are further subdivided with the Manage Production tasks being investigated in the most detail. A data glossary of all terms was also developed. This

functional model could be used to design and specify components of a CIM system for a weft knitting facility. It also identifies where other research on CEO enterprise models for scheduling fit in the overall operation of a manufacturing facility. For an example, see Figure 4, Task 1: Process Orders.

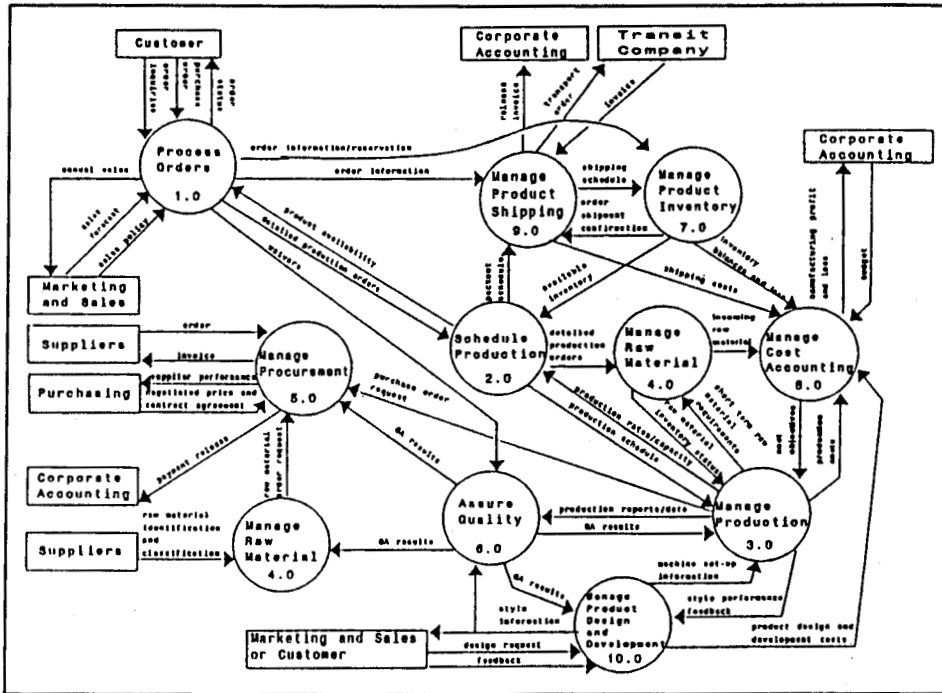


Figure 3: Level 0 Facility Model

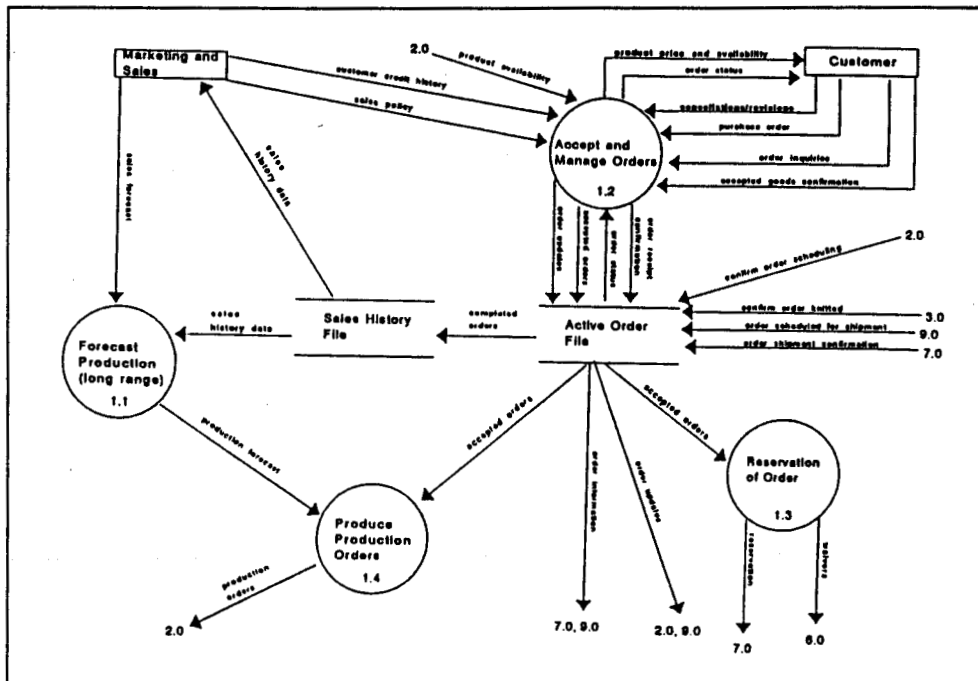


Figure 4: Task 1.0 Process Orders

Analysis of Loom Stops

G. Hodge, A. Seyam, and B. Schuler - graduate student.

This project is completed with the submission of the thesis. The benefits include the ability to predict the efficiency of, and therefore accurately cost new styles. Also, planning can be more effective and inventory levels can be reduced when the efficiency of new styles can be predicted. This research used loom monitoring systems which captured weaving information on productivity and stop causes.

Data was obtained from two separate sources: Case I involved 27 different styles, all with a spun yarn warp, woven on air jet looms at varying speeds. In Case II, styles with similar warp characteristics were woven at constant loom speed. Data was analyzed for Case I using statistics software to determine how efficiency is effected by 1) the degree of tightness and 2) the number and type of loom stops. From this, several conclusions were drawn, most significant that the speed (ppm) has a strong negative linear correlation with the fabric degree of tightness (R value of 0.87). Also, if the loom speed is kept constant, as the fabric degree of tightness increases, the weaving efficiency decreases. The statistical analysis of case II data indicated that the fabric degree of tightness on loom speed is similar to that of fabric degree of tightness on weaving efficiency.

Adaptive Loom Control for Slashing Defects

M. Mohamed, P. Grady and S. Benmakhlof - graduate student.

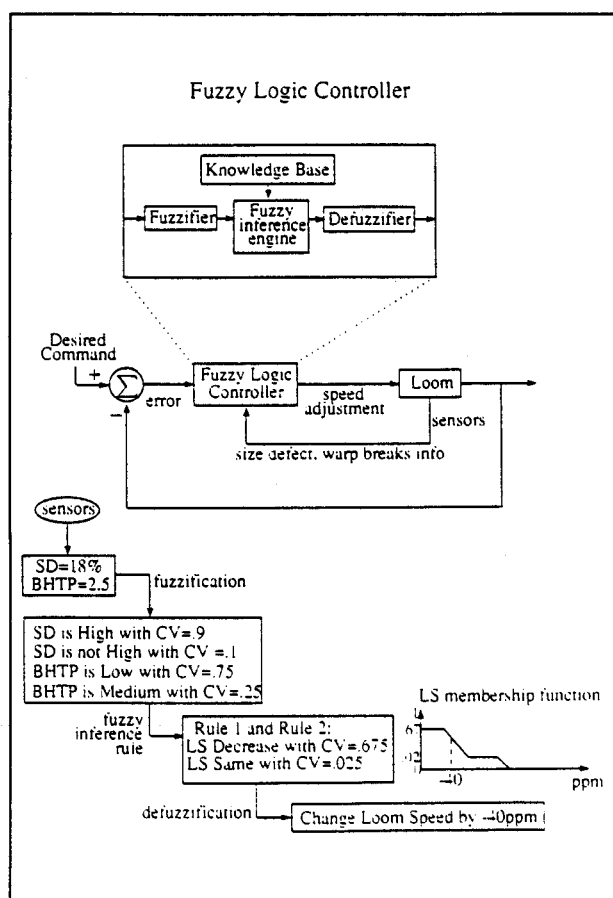


Figure 5: Fuzzy Logic Controller

Since high loom speeds make stops more costly, it is not always advantageous to operate at the highest possible loom speed. The cost is reflected by the high cost of the machine and the increased potential for producing poor quality fabric. One of the sources of loom stops is yarn defects caused by slashing. If the defect is detected during weaving, prior to the occurrence of the warp break, and the speed is adjusted accordingly to avoid a stop, the loom will become more efficient. The objective of this research project is to have the information coming from the slasher make the loom self adjusting for warp defects. This research strategy is:

1. To determine the relationship which correlates the warp characteristics, the loom speed, and end breakages. This expertise will be very valuable in order to optimize the speed of the loom.
2. To install a variable speed motor and a controller on the loom so the microprocessor automatically adjusts the loom speed to minimize the number of breaks based on a signal received from a sensor or according to a statistical model.

3. To conduct a cost analysis to determine the feasibility of this system.

During the past year, we were able to purchase a computer system and software for the research project. Square D also donated an AC inverter that will control the speed of the loom by using a personal computer to vary the frequency of the motor. We are in the process of installing and making the closed loop system that involves the computer, the inverter, and the loom. We have also developed a theoretical fuzzy control model that will act as the intelligence engine for our system. See Figure 5 for an example of how this model will work.

CIM and Fiber Formation

J. Cuculo, P. Grady, S. Winchester, and J. Raghavan - graduate student.

This year, we have focused on improving our simulation developed last year. The main purpose of the improvement was to incorporate spinline crystallization. Also, improvements were made in the program structure to render it easier to understand and to modify if desired.

At present, our computer program can simulate the crystallization observed at high spinning speeds only at a rudimentary level. We have spent considerable time and are still in the process of studying the crystallization kinetics under stress and non-isothermal conditions. We use the Nakamura model to describe crystallization kinetics in which crystallization kinetics can be written as:

$$X_c / X_\infty = 1 - \exp \left\{ - \left(\int_0^t f(T(\tau), \Delta n(\tau)) d\tau \right)^{na} \right\}$$

where X_c and X_∞ are the crystallinities corresponding to time t and at the end of the crystallization process. The functional form of the crystallization rate constant orientation, k_{A0} , used was, following the empirical expression by Katayama and Yoon

$$k_{A0} / k_A = \exp \{ C_1 / T^{(k)} \Delta T (1 - 1/(1+C_2(T^{(k)} / (\Delta T) (\Delta n)^2)) \}$$

$$k_A = \exp \{ A - (B / T - D \max) - (C / (T^{(k)} \Delta T)) \}$$

where: C_1, C_2	:	Constants
A, B, C	:	Constants
D_{max}	:	Half width at T_{max}
$T^{(k)}$:	T in Kelvin

where k_A is the crystallization rate constant for unoriented polymer, Δn is the birefringence of the fiber and T the fiber temperature.

The above kinetic expressions were combined with melt spinning equations to obtain a complete profile of velocity, diameter, temperature, stress, birefringence and crystallinity of the fiber.

We are in the process of making changes in our program to allow the user to select the different empirical coefficients available for several physical parameters and other expressions used in the melt-spinning equations.

RESOURCE MANAGEMENT: The existing facilities and staff at NCSU are uniquely suited to this research. The Model Manufacturing Facility contains up-to-date equipment representing the key textile operations. The Management Systems Lab has up-to-date computing equipment including the IBM in Higher Education facility. Integration of these systems can be achieved with minimum investment and effort.

Leveraging this capability with equipment, software, and technical support from industry is important. For instance, key to the dyehouse research project was the contribution by IBM of an AS/400 computer and PlantWorks software. Technical support was provided from IBM, Morton Machine Works, and Datatex.

The Faculty bring expertise covering every aspect of textile products and processes from fiber production to dyeing and finishing and including fabric design. By collaborating on this complex system, the best technical knowledge and research experience is brought to bear. We have established forums for interaction of faculty and graduate students to discuss CIM research results and interact on new strategies and approaches.

Because of the NTC sponsored CIM effort, we were able to get a \$57,000 grant from Duke Power to sponsor a future search workshop on "CIM in the FTA Complex". This workshop brought 40 thought leaders from an international array of companies representing all phases of textile operations, machinery, sensors and controllers, computers and software industries. University and industry research groups were also represented along with NCSU graduate students and extension personnel, bringing the total participants to 60. The purpose of this effort was to undertake a "whole-system" reshaping of the capability for CIM to change the competitive capability of the domestic industry. The MMF, MSL, faculty and students along with the outstanding meeting and support facilities were key to the success of the meeting. Progress of these teams will largely depend on the continued support of the NTC universities.