Towards Demand Activated Manufacturing: Optimization and Synthesis of Short-Run Fabric Production

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Project Statement

To develop methods for specification and design of efficient production systems for quick response, small lot woven fabric production. These systems can be characterized as having short lead times for delivery as well as lot sizes as small as 1,000 yards.

Project Goals

In order to fully implement the mission of the NTC, two goals are being addressed. The first is to develop partnerships with industry in order to gain insight into the particular areas where small lot system deployment is needed. By studying actual production situations, design methodology can be developed which when utilized by industry will enable them to run their production processes more efficiently. The second goal is to create a methodology for the specification of a small lot production system for a given set of production requirements. This tool will help companies make intelligent capital investment decisions in designing short run production systems. The methodology will be developed using information gained through interaction with the industry. Thus, the two project goals are closely integrated. The following addresses the work being done to realize each goal. The contacts made with industry will be discussed first, followed by the work on system design methodology.
Goal I - Industry Interaction

An industry partnership has been developed with CMI Industries’ Clinton fabric division. Clinton Industries produces fabrics for a wide range of end uses, from automotive applications to home furnishings. A project team has been created comprised of NTC researchers and Clinton engineering and management personnel. The objective is to utilize simulation models to assist Clinton in evaluating the performance of their manufacturing systems in light of an increasing percentage of small lot orders. Models have been developed that are specific to Clinton’s manufacturing situation, and are currently being validated to ensure they accurately imitate system performance. When this step is completed, the models will be utilized in three areas:

1) System performance can be predicted for different product mixes containing small lot orders before having to react at manufacturing facilities.

2) Production standards for time and cost to complete an order can also be evaluated when small lot sizes are present in the order mix. The system simulation will show any discrepancies between standards based on typical production lengths compared to time and costs when short length orders are introduced.

3) Strategies for scheduling a wide range of small lot orders will be evaluated. When only a limited number of styles are being produced with long lead times for production, scheduling is not a challenge. When a larger mix of smaller orders is introduced, scheduling becomes problematic.
The modeling of these production systems has allowed a deeper insight into the process interactions that are important in small lot system design. For example, it has been seen that yarn formation can be modeled as a continuous flow process, and is not greatly sensitive to small lot manufacturing. Weaving preparation however, is a discrete process and is sensitive to both lot size and labor availability. The effective capacity of a particular warping and slashing system will depend on the order mix and the human assets available. Weaving is not as sensitive to lot size due to the great length of time required to run out a beam. However, this process is extremely sensitive to labor availability, as untended loom stops can adversely affect system performance.

These insights gained through partnership with industry show that any methodology for small lot system design cannot be based only on capacity in terms of the number of machines or on processing rates. Labor utilization, job mix, and queuing effects must also be considered to correctly determine an appropriate system.

In addition to the work done in partnership with Clinton Industries, plant visits have been made to other manufacturers in order to evaluate small lot production strategies that have been implemented within industry. Equipment manufacturers have also been surveyed to determine the range of existing products available for fabric manufacture as well as their performance capabilities and cost. Taken altogether, this information is being used as input for the second project goal.
Goal II - Design Methodology

Completed Work

A framework for the design of small lot manufacturing systems has been developed. Although the work has been centered around the design of weaving preparation systems, it can be extended to include other textile systems of interest. Figure 1 shows a schematic representation of the design framework.

![Framework for Small Lot Manufacturing Design]

Figure 1: Framework for Small Lot Manufacturing Design

The framework shown in Figure 1 allows inputs to be defined in the Input Requirements Module by job style, length, order frequency, and lead time limitations. Inputs can be specified from expected distributions to meet a known demand. This would be applicable if
modifications to an existing system were being considered. The inputs can also be entered as a proposed specification to determine if a viable system is possible from the given design parameters. The Design Parameters Module allows the specification of available technological and resource options. Value ranges for each of these can be specified for a particular design scenario. The parameters in this module can be tightly specified so as to design a system based on known, available resources. They can also be left intentionally loose, resulting in the design output of a list of required specifications for new equipment.

The Decision Module formulates a system design that will meet the input and parameter specifications with a minimum capital expenditure. Key to the operation of the Decision Module are the Design and Analysis Engines. The Design Engine identifies a candidate system from the list of technological options. This system then moves to the Analysis Engine which will utilize the simulation methodologies developed earlier in the project to determine if it meets the input requirements. As seen in Figure 1, this is an iterative process that continues until an appropriate design has been achieved. At this point, the successful proposal is output to the Selected System Module, where all information needed to correctly implement the design is recorded.

**Current Work**

The design framework has been created to provide a blueprint for the development of small lot, quick response manufacturing systems. The framework is being embodied as a tool in order to realize the goal of a working design methodology. A number of the module elements in the framework are currently under construction. Details of the work are described below.
Design Parameters

The specification of resources such as equipment, plant, and personnel is being done by type, performance, and cost. Scheduling methodologies are also being evaluated for their effectiveness for different systems. The current focus has been on the different yarn creeling alternatives in terms of their setup time requirements for small lots. Four different creel types are being specified. These are, single end, truck, indexing, and magazine creels.

In addition, the performance characteristics of warping alternatives in conjunction with these creel types is being determined. These and other parameters, once specified, will provide the building blocks for system design by the Decision Module.

Design Engine

The Design Engine has not yet been specified but is expected to be a computer tool which can compare conditions from the Input Requirements Module with available resources from the Design Parameters Module and create a candidate system. There are a number of different alternatives for creeling, warping, and slashing in weaving preparation. Which components constitute the appropriate system may not be obvious, nor applicable for every situation. In Figure 2 a flowchart is shown for weaving preparation.
A job can be modeled moving through the system from node to node (numbered 0 through 10) with the arcs between nodes representing possible paths. As an example, a job being processed by a direct warper utilizing a magazine creel and requiring package winding before warping can be modeled by the path (0-1-6-7-9-10). The choice of a particular system...
can greatly affect the time required to complete a job. In Table I below the job time in minutes is shown for a 5,000 and a 25,000 yard job based on three routings.

<table>
<thead>
<tr>
<th>Path</th>
<th>Job Length (yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>(0-3-7-9-1 0)</td>
<td>388</td>
</tr>
<tr>
<td>(0-5-7-9-1 0)</td>
<td>292</td>
</tr>
<tr>
<td>(0-5-8-9-1 0)</td>
<td>241</td>
</tr>
</tbody>
</table>

Table I: Three Possible Job Routings

Path 1 represents the use of a single end creel / direct warper combination. By replacing the single end creel with an indexing creel (Path 2) 96 minutes are saved at both job lengths. Path 3 represents the use of an indexing creel / sectional warper combination. It is seen that at 5,000 yard job lengths, this system requires less time to process a job than the direct warper (Path 2). At 25,000 yard lengths however, the direct warping system outperforms the sectional warper.

The results shown in Table I illustrate that the choice of system is dependent on the length of the job inputs. The Design Engine will require the ability to choose the correct system components for the specified job mix. Additional requirements will consist of the ability to optimally assign personnel assets to the system, and minimize capital expenditures.

Analysis Engine

The candidate system produced by the Design Engine will be based on a first order approximation of performance based on fixed setup times, processing rates, and the number of