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Scott Blake
Assembly Guidance

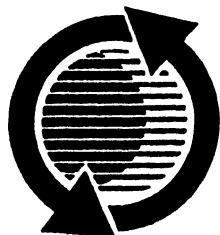
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ISSN 0148-7191

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Printed in USA

90-1203B/PG

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Abstract

The application of computers to manufacturing has been largely in the area of total automation. (CNC, robotics, etc.). This paper describes a computer based laser projection system which is currently in use in several specialized aerospace applications. The system delivers accurate dimensional information directly onto large (meters), complex work surfaces for manual manufacturing tasks. Most manual manufacturing processes can be dramatically improved by delivering electronic dimensional information (CAD data) accompanied by electronically based multi media work instructions directly to the person performing the work. The results of applying this system will be lower costs, higher quality and improved time to market for products which are manually prototyped or manufactured.

Introduction

"World Class Manufacturing" has become a popular topic in discussing the problems of the American Economy. In a recent NAE report on Removing Barriers to

World Class Manufacturing, Joseph Heim stated:

"The 'manufacturer of the future' confronts a daunting set of challenges: intense international competition in both domestic and foreign markets and incessant change in technology, product, process, customer requirements, and government regulation and constraint. The distinguishing characteristics of the globally competitive manufacturers will be the rapid, flexible, and innovative manner in which they respond to those dynamics, and the quality, competence and motivation of their work force."

In order to remain competitive, a development or manufacturing organization can no longer afford to operate as a group of independent elements. A "system view" must be adopted which takes advantage of technological and managerial innovations. The application of these innovations will improve the competitiveness of the complete organization.*

* Heim, Joseph A., "Removing Barriers To World Class Manufacturing," National Academy of Engineering, October 1992.

This paper describes technological innovations which address local as well as system-wide issues in development and manufacturing organizations. The technological innovations are combined into a system which uses many types of media, computers, and laser projection to improve product quality, organizational response time, and overall cost.

The organizations that are affected by the application of the system are engineering, development, production and quality. The types of activities that are improved through the application of the system include training, process evolution, dimensioning, assembly, recordkeeping, production planning and tracking.

The improvements described here are based on the following concepts:

1. Some tasks are performed better by people than by machines
2. Some tasks are performed better by machines than by people
3. A system where people perform the work they do best, using machines which carry out functions machines do best, will yield optimal output.

While there is evidence of concept 3 in some applications, in general, manual and automated manufacturing are two separate worlds. The power of microprocessors has been applied in a large way to totally automated manufacturing tasks, engineering, finance, word processing, and many other areas, but it has been absent

in direct use in the manual manufacturing world. This is due to a lack of effective methods of applying the power of microprocessors to manual manufacturing tasks.

Even with the widespread application of Computer Aided Design (CAD), the interface to manual manufacturing is still a physical drawing. Other instructions are still transmitted to workers in hardcopy (instruction books) which are generated on computers. Most of the tasks performed to carry out the instructions which have been generated on computers are performed with the same manual tooling techniques that were used before the advent of computers. Much of the documentation of the work is still carried out by people filling out forms where the data is manually entered into a computer.

These interfaces between computers and people are less than optimal. They require people to perform tasks in development and manufacturing which are likely to be of low quality, slow, and very expensive.

The reason that computer based machinery has not dominated development and manual manufacturing is that most of the tasks require visual, tactile and reasoning skills which are beyond the capability of machines. While the manufacturing tasks utilize the unique visual, tactile and reasoning skills of the workers, the workers are also required to perform many tasks which they perform poorly.

System Purpose

The laser and computer based system described here will:

- Enhance the visual, tactile and reasoning skills of the workers
- Relieve the workers of most tasks which they perform poorly
- Electronically integrate the manual manufacturing organization with other functional organizations.

The result of applying the laser and computer based system will be that throughout the organization it will be much easier for people to get what they need, where they need it, when they need it.

A person performing a manual manufacturing operation is involved in direct and overhead tasks. The direct tasks are those where material processing is occurring. Everything else is overhead. Overhead includes training, finding and reading instructions, finding and setting up tooling to carry out those instructions, checking the work, and documenting the work. In many cases these overhead activities are cumbersome, and, as a result, are done poorly or not at all. The quality of the performance of the overhead tasks has implications upstream and downstream of the direct manufacturing tasks.

Figure 1 lists manufacturing activities and compares the capabilities of an automated system with an unaided manual manufacturing system. It also rates the capabilities of manual manufacturing combined with the

laser and computer based system described here.

System Description

The combining of:

- Microcomputers that provide operator interface as well as sending and receiving data
- A vector scanning laser projector
- A registration system which can calibrate the relationship between the laser projector and the work surface yields a system which can enhance manual manufacturing in improving quality, speed and cost reduction. This system replaces many components and activities of a traditional manufacturing system. The components within a manual manufacturing system that are most significantly affected are:
 - Providing instruction and training to workers
 - Delivering production data to workers
 - Dimensioning of work
 - Recordkeeping
 - Process evolution

Providing Instruction and Training to Workers

The best place to train is the actual place where work will occur. The best time for training is as close as possible to the time when work will occur. It is difficult for traditional training methods to meet these requirements.

A Comparison of Automated, Manual and Computer/Laser Assisted Manual Manufacturing Activities

	<u>Total Automation</u>	<u>Manual Only</u>	<u>Manual Manufacturing w/ Proposed Laser and Computer Based System</u>
<u>Obtaining Proper Production Data</u>	Excellent	Slow & Error Prone	Excellent
<u>Dimensioning</u>	Complex	Slow & Error Prone	Simple & Accurate
<u>Handling Diverse Material</u>	Difficult	Excellent	Excellent
<u>Recordkeeping</u>	Excellent	Fair	Excellent
<u>Learning Curve for New Process</u>	Slow & Expensive	Fair	Optimal
<u>Process Evolution</u>	Always requires People	Good	Optimal
<u>Inspection</u>	Difficult	Difficult	Good

Figure 1

When training is performed in a location and time removed from a manufacturing activity, the interruption of attention reduces the effectiveness of that training. The interactive multi-media functions on the proposed system allow the assembler to request moving color pictures with sound at any time during production. This media can be adjusted to provide the maximum value in providing the information required for any manufacturing process. This media can take any appropriate form: laser dimensions, video, audio, CAD, still photos, etc.

Delivering Production Data to Workers

Many manufacturing problems are associated with the production, maintenance and storage of hardcopy of production data. The time required to implement changes in instruction manuals or blueprints which are used on the shop floor is significant and often not done correctly. Electronic data is much easier to control and update. A single responsible system manager can deliver clear data to many people for many applications in a fraction of the time required to handle hardcopy.

Dimensioning of Work

One area of manufacturing which consumes large amounts of time and tooling involves dimensioning. Dimensions for manufacturing are generated on a Computer Aided Design (CAD) system. These dimensions are stored electronically and plotted out for assemblers to use. When an assembler uses one of these plots (a blueprint) they must go through many complicated steps. The actual sequence of accomplishing the overhead task of dimensioning from a blueprint requires:

1. Deciphering the blueprint to determine which step is performed next
2. Obtaining a tool which can be used to create the dimension shown on the blueprint
3. Memorizing the dimension and its references from the blueprint
4. Reorienting from the blueprint's scaled down dimensions to the full size work area
5. Using the tool to reproduce the memorized dimension deciphered from the blueprint
6. Verifying that all of the previous steps have been done correctly
7. Performing the action which references the place where the actual manufacturing will occur (mark, align, scribe, etc)

The laser projection system eliminates these steps by projecting dimensions at the touch of a button. The elimination of these steps

(which present many opportunities for error) speeds the process by having the assembler perform only the tasks that the assembler performs best.

Recordkeeping

The gathering, storing and sorting of data is easily accomplished with computers. The system described here utilizes simple button pushes accompanying each step in a manufacturing process. The pushing of these buttons triggers the storage of sequenced, timed events which are stored for future use in Industrial Engineering Studies, production verification and process analysis.

Process Evolution

By reviewing detailed data on each step in a manufacturing process it is possible to isolate techniques that contribute to high or low quality. By identifying and correcting or communicating specific activities, the best manufacturing process will evolve in a clear and positive way. This ability to measure and easily implement process changes is a fundamental component of a Total Quality Management (TQM) program.*

* Blake, Scott, "Laser/Computer-Based Tooling for Composites: Impact on TQM Objectives," SME #EM90-180, 1990.

Economic Justification

An Example of Cost Savings Resulting From the Elimination of Ply Placement Templates in Hand Laid Composites Manufacture in Aerospace

In the Aerospace Industry, the production of many parts made of advanced composites is performed using a process known as hand layup. The assembler places pre-cut plies of material (prepregs of carbon, kevlar, glass and honeycomb) onto a mandril to build up a laminate. Accurate positioning of these plies is required to assure that intended part performance characteristics are achieved.

A comparison is made between traditional template tooling and a system using vector scanned laser light. Two examples are used to provide projected costs, where cost models are available. The assumptions for the examples are:

- Part #1: a medium sized, complex curved tool which is 4' by 6' with 40 pieces in the layup kit (plies and honeycomb)
- Part #2: a large sized, complex curved tool which is 5' by 12' with 80 pieces in the layup kit (plies and honeycomb)
- Each ply has 6 scribe marks (eyebrows in each template) per ply
- Both tools require 2 physical templates, one for plies before honeycomb, and one for plies laid up over honeycomb

- Templates are stored on end in a special rack on wheels, which is located with easy access to the tool

- A total labor rate of \$52.65/hr. based on the following assumptions:

- labor rate: \$15/hr.*
- benefits: 30%
- correction factor: accounting for fatigue, delays, and personal time: .35 **

- Overhead Rate: 2.00

- Template Handling Time:
 $H=0.000107A^{0.7701}$

Where: H=Hours per template,
A=Area in inches ***

Part #1 Template Handling Cost:
\$291/part

Part #1 Laser System Operation:
\$42/part

Savings: 85%

Part #2 Template Handling Cost:
\$1,242/part

Part #2 Laser System Operation:
\$86/part

Savings: 93%

* Employment Hours and Earnings, United States, 1909-1984. Volume II, Bulletin 1312-12, U.S. Department of Labor, Bureau of Labor Statistics, March 1985, p324.

** Ostwald, Philip, Cost Estimating, Prentice Hall, Inc., New Jersey, 1984, p47.

*** Northrop Corporation, "Advanced Composite Cost Estimating Manual," AFFDL-TR-76-87

Cost Comparison for Templates vs Laser System for Dimensioning Hand Laid Composites*

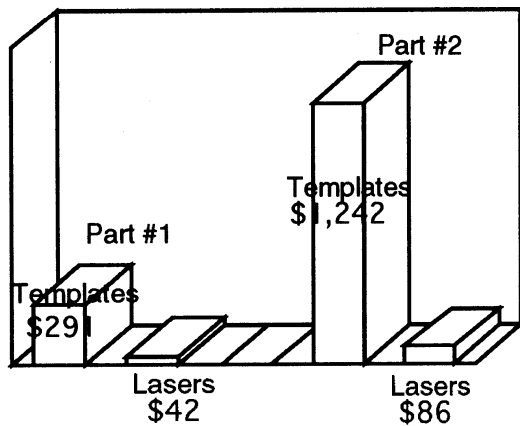


Figure 2

Fabrication represents 72% of the cost in finished composite parts.** The savings of 70% to 90% at key production stages will significantly reduce the finished part cost.

Other Benefits

The basis of all improvements related to this system is the value of rapidly available, appropriate information. Each form this information takes in a more rapidly available, appropriate context is a benefit.

* Blake, Scott, "Replacing Composite Hand Layup Templates with a Simple Projection System," SAMPE Symposium and Exposition Series, May 1989.

** "Fabrication 70 percent of cost for advanced composites," Advanced Composites, pg 12, July/August 1988.

The forms for this improved information flow include:

- work order scheduling
- work order tracking
- process information (training)
- dimensioning for production
- dimensioning for inspection
- Engineering Change Orders (ECOs)

The result of this improved information flow is a system-wide increase in speed, an improvement in quality, and a reduction in overall cost. These improvements are generic goals for any manufacturing organization.

Risk reduction is achieved in prototype or early stage production because hardware tooling is expensive to produce or modify. The laser tooling, handling dimensions and patterns electronically rather than physically, is created quickly and is easily modified.*

Current Applications

Since 1989 a system which combines computers with a laser projection system has been in use in the Aerospace Industry. This product is called LASERGUIDE and it is an electronic dimensioning system. It is used to replace templates which are required to define the boundaries of plies of composite material and honeycomb core which are being built up by hand to create a laminate.

* Hyatt, Donald G., "Design Producibility at MDHC," Composites in Manufacturing 8, Conference Reading, SME, January 9, 1989.

LASERGUIDE is in use building composite internal primary aircraft structures, airfoils, and skins.

The experience in these applications has included a significant reduction in production time, compatibility with CAD systems, success with "paperless" documentation, a rapid application of engineering changes, a highly favorable reception by assemblers and an improvement in quality of parts produced.

A pilot program integrating graphic work instructions with LASERGUIDE was initiated in the Spring of 1993. This system employed all of the functions described in this paper. The total system is expected to enter widespread application in early 1994 in the construction of hand laid composite aircraft parts.

Other Applications

The initial applications for the type of system described here are in the aerospace industry. The applications involving advanced composites require frequent engineering changes on expensive parts produced in small quantities. The system can be applied in any application which requires information delivery and tracking in manual manufacturing. The laser can project onto large complex curved surfaces. Other audio and visual media can easily be transmitted.

Examples of other applications include welding, any process requiring lofting techniques, rapid prototyping with wood, metal, cloth

or plastic, wiring, plumbing, painting and general assembly.

Conclusion

A system combining laser projected dimensioning with multi-media graphic work instructions can improve many indirect and direct manufacturing processes. The system is based on currently available technologies which can easily be cost justified for many applications. These technologies allow production workers to get the information they need, where they need it, when they need it so they can produce parts of the highest quality in the shortest time at the lowest cost. Combining computers and other machines for tasks that perform better than people, with people performing processes that are not easily performed by machines, will yield optimal results. Examples of this type of system are in use producing parts with the improvements listed here. Secondary benefits are gained in management and other manufacturing overhead activities in areas of work order scheduling and tracking. Process data for evaluation is easily compiled and process improvements are easily implemented.

Achievement of the goals listed here (quality improvement, shorter time to market and lower unit cost) will be necessary to compete in the global manufacturing marketplace. The system described here will provide a major step forward for leaders in this arena.