Design and Control Problems of Manufacturing Cells
-제조 셀의 설계 및 운용 문제-

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요 지

본 연구에서는 물류의 개선 및 생산율 향상을 통하여 전 생산시스템의 생산성을 향상시키기 위한 효율적인 제조셀의 설계 및 운용시에 고려하여야 할 요소를 고찰하였다. 효율적인 제조셀을 형성하는데 발생하는 문제점(부품/기계군 형성, 설비배치, 스태핑, 셀 일정계획 및 운용)을 해결하기 위하여 필요한 요소별 지침을 제시하였다. 그러나, 셀생산의 장점을 충분히 얻기 위해서는 이들 요소들은 종합적으로 고려하여야 한다.

1. Introduction

Manufacturing cells are becoming a popular response to the problems of long lead times, high WIP inventories, poor utilization and schedule slippage. Traditionally, manufacturing facilities haven been organized into functional department. In this traditional organization, jobs may be moved between departments many times. Within a department, the job is the responsibility of the department supervisor or foreman. However, none of the functional departments has direct responsibility for seeing that the job is finished on time. Typical material flow is illustrated in Figure 1.

Manufacturing cells are defined by Hyde[21] as "… a technique for manufacturing small to midium lot size batches of parts of similiar process, of somewhat dissimiliar materials, geometry and size, which are produced in a committed small cell of machines which have been grouped together physically, specially tooled, and scheduled as a unit."

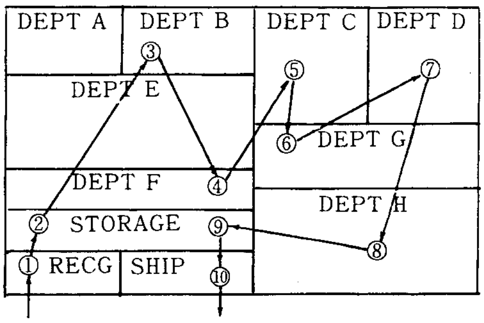

Figure 1. Typical Material Flow

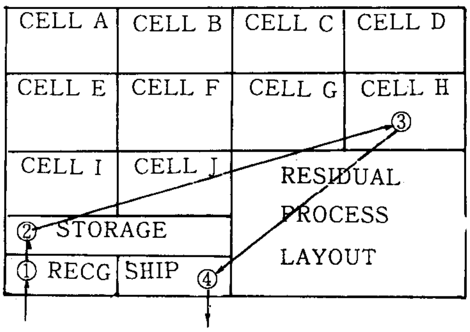

Figure 2. Material Flow in a Cellular Manufacturing System

It seems obvious that changing from traditional functional organization to manufacturing cells (Figure 2) can have a tremendous impact on the layout of the facility and the material handling systems.

The flexible cellular manufacturing is designed by the flexible production management (information flow) based on the given flexible production facilities (flexible type NC, machine center, or flexible manufacturing system). It is fundamentally important for the efficient and economical execution of production activi-

*Ph. D. Course in Dept. of Ind. Eng., Han Yang Univ.
접수 : 1992. 4. 14.
확정 : 1992. 4. 24.

ties to completely unify manufacturing processes(aspect of hardware) and production management(aspect of software). This unified and integrated approach to cellular manufacturing is significant concept to design flexible cellular manufacuring systems.

Analysis of the part being produced identified several part families that were good candidates for production in a cell. Based on these families, the formation of manufacturing cells utilizing existing equipment allowed the plant to simplify operations and gain control of production without huge investments in equipment.

The performance goals of a cell are illustrated in table 1.

Table 1. Goals of the Cellular Manufacturing.

ⓐ Reduced WIP on the production floor.
ⓑ Reduce material queues in front of production equipment.
ⓒ Increase inventory turns.
ⓓ Adaption of GT.
ⓔ Reduced material handling.
ⓕ Commonality of fixtures and jigs.
ⓖ Material movement reduction.
ⓗ Scheduling simplification.
ⓘ Floor space reduction.
ⓙ Incresed job satisfaction.

2. Critical Issues

Every cell application is different, due to the local variations in part mix and production rates, equipment availiability, labor availiability and flexibility, and budget. However, several key issues should be addressed in any application to ensure success.

2.1 Batch Size

A key motivation for implementing a cell is to reduce lead time and the WIP inventory. When batch sizes are large, lead time is reduced by passing parts directly from one operation to the next without accumulating the entire batch. A cell designed to process large batchs must be designed and operated to support pipelining processing. When batches are small, pipelining is not an urgent requirement. As long as the cell does not build up a large amount of WIP, a batch may be permitted to accumulate between operations.

2.2 Part Mix

Parts assigned to a cell utilize some common processes, by definition. Processing rates, however, can vary from part to part for each process. Setup requirements also can vary significantly. Generally, as part commonality in the cell decreases, the need for potentially redundant capacity and labor flexibility will increase.

2.3 Cost of Capacity

When certain parts have long cycle times on a particular process, additional capacity will increase cell throughput. When the same process or machine is required for two different operations, with a setup to switch between them, additional capacity facilities processing completion in one pass through the cell. If process capaciy is relatively inexpensive, additional capacity should be considered to improve cell performance, even if some parts do not utilize the capacity.

2.4 Labor Flexibility

Attaining flexibility in the number of workers in a cell to adapt to demand changes is called Shojinka. To achieve the Shojinka, the proper layout is a U-turn layout. The most remarkable and important advantages of this layout is the flexibility to increase or decrease the necessary number of workers when adapting to the changes in production quantities.

Carefully-designed machine layouts helps develop this ability, but machine layout alone can not achieve Shojinka. In order to respond quickly, the worker must be multi-functioned : that is, he must be trained to a skilled worker for any type of job and at any process in a cell. Operator should be encouraged to help each other when problems arise. They must be trained on and expected to perform all the jobs in the cell on a routing basis[32].

2.5 Setup Times

Setup times reduction will increase both the flexibiliy and capacity of manufacturing cells. Setup reductions also facilitate reductions in batch sizes and lead times. Operators should be involved in and rewarded for setup reduction efforts. Six techniques[32] can be applied to reduce set up time.

Tech. 1 : Standardize the external setup actions.

Tech. 2 : Standardize only the necessary portions of the machine.

Tech. 3 : Use a quick fastener.

Tech. 4 : Use a supplementary tool.

Tech. 5 : Use parallel operations.

Tech. 6 : Use a mechanical setup system.

2.6 Process Planning

Process planning determines the process routes by considering alternative machine routing, and machine speeds for ordered products at each machine selected.

Process engineers must now optimize the use of the cell as a single machine rather than opimizing individual processes by getting more speed for each machine. Matching feeds and speeds to required production rates and utilizing labor for other operations during internal cycle times is a key to success with manufacturing cells.

3. Manufacturing Cell Design

Figure 3 illustrates one approach to designing a manufacturing cell and identifies five types of design decisions. Although we may discuss the five decisions individually, it should be clear that they cannot be made independently of each other. Detailing the cell design can be tedious if the facility contains more than a small number of parts, simply because of the amount of data. In many cases, the initial cell design can be based on a sample of parts from the family. A few high-volume parts typically will represent most of the cell load.

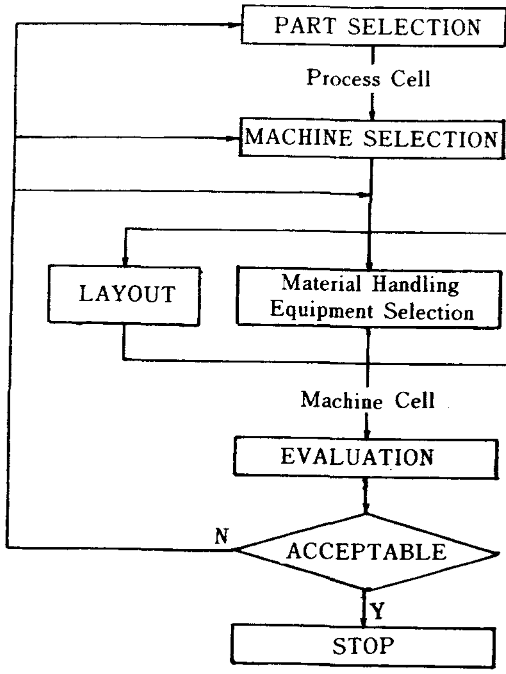

Figure 3 Cell Design Methodology

3.1 Part Family/Machine Grouping

The part family/machine group fomation problem could be defined as one of identifying and grouping parts and then assigning families to cells. A number of different analytic techniques have been developed for identifying part families and grouping machines. These analytic techniques generally require access to a relatively complete data base containing such information as process routes, part attributes, fixturing and tooling requirements.

3.1.1 Part Family Grouping

Two exiting techniques for part family grouping are : (a) classification and coding([22], [43]) (b) cluster analysis([10], [38]).

Group technology classification codes assign an alpha-numeric code to each part based on the part attributes, which may include factors such as the handling requirements, lot size and demand rate, in addition to fixturing and tooling. Using GT codes, parts which have the same code, or similar codes are assumed to be in the same family.

A number of commercial(for e. g., BRISH, CODE) as well as non-proprietary(for e. g., OPITZ, KC−1) coding schemes are currently available. These coding systems are not appropriate for finding part families for cell design. This is due to the fact that they group parts which are similar in design features but are processed on the same set of machines [8]. MICLASS system, however, can be used to form part family and machine grouping by considering both design and part routing.

Cluster analysis([10], [4, 5, 6, 7, 8, 9]) is a mathematical technique that attempts to replace the ad hoc manipulation of the production flow matrix with a more formal method. Application of cluster analysis requires specifying a mathematical expression for the distance between two part types in terms of similarity.

3.1.2 machine grouping

Machine grouping determines exactly which production machines will be in the cell, and the number of machines of each type needed to meet the processing requirements.

A truly useful analytic method for selecting the machine types for a cell does not exist. Process engineers should define processing requirements and prepare a set of functional specifications. The decision maker should compare the functional specifications with the capabilities of available equipment. Other factors, such as acquisition costs, also should be considered. The grouping of parts and machines can be done sequentially or simultaneously. In the sequential approach, the mahines are grouped first, for instance, and then the parts are allocated to the machine groups.

Machine grouping problem can be classified by two sub-classes namely : (a) non-algorithmic procedures, and (b) algorithmic procedures.

De Beer, et al. [15] use non-algorithmic techniques based on visual examination of matrices constructed from routing sheet information. De Beer and de Witte[16] extends their earlier approach by considering the divisibility of operations.

Algorithmic procedures can be classified as (a) cluster analysis([30], [17], [41]), AND (b) graph theoretical method[37].

3.1.3 machine-part family grouping

The simultaneous approach, known as machine-part grouping tries to achieve the grouping in one step. Machine-part family grouping techinques can be classified as three sub-classes as (a) production flow analysis (b) algorithmic techniques (c) combinatorial techniques.

Production flow analysis is a technique for forming part families that uses existing process plans. For each part, a list of machine codes is determined from the process routing. Production flow analysis is, however, quite subjective for cell formation.

Algorithmic techniques manupulates the rows and columns of the machine-part matrix to form the groups. Some typical examples are the rank order clustering method(ROC) of King[23, 24], cluster identification and cost analysis algorithms of Kusiak and Chow[27], the clustering and data reorganization algorithm of Slagle, et al[39], matching algorithm of Bhat and Haupt[3], and rank energy algorithm of Kusiak[28]. The network-based methods, on the other hand, represent the machine-part family matrix in the form of a bipartite graph and use netwrok decomposition techniques to form the groups. Examples are the methods of Chandrasekaran and Rajagopalan[12], and Kumar, et al.[26]. Askin and Subramaniam[1] developed a heuristic procedure to fom machine groups which considers the costs of WIP and cycle inventory, intracell movements and setup, variable processing and fixed machine costs.

Co and Araar[14] presented a three-stage procedure for configuring machines into manufacturing cells, and assigning cells to process specific set of parts. Choobineh[13] proposed a two-stage procedure in which the part families are formed using clustering techniques and the assignment of part families to machine cells is done using an integer programming model.

3.2 Layout, Equipment, Staffing

The physical characteristics of the workpieces are important considerations in cell design. The size and shape of the material affect the material handling equipment as well as the between-part setup times in the cell. The number of components has a large impact on the configuration and material handling associated with an assembly cell. Parts feeding and material interface requirements must be carefully defined and designed to be flexible in order to accommodate future changes in product design, materials and components.

Cell capacity may be determained by processes, manning or handling equipment. In a well designed cell, material handling should not be the limiting factor. The key machine determines ultimate cell capacity, and is the one with the longest cycle time in which the machine and/oroperator is occupied.

The approaches taken to designing the layout, material handling equipment and staffing will differ significantly, depending on whether a physical cell or a logical cell is implemented. With physical cells, the objective is to hand off parts between processes, thereby avoiding batch accumulation whitin the cell. Logical cells typically accumulate the batches for movement between work stations.

Staffing-For both physical and logical cells, the ideal is to have multifunction operators. For physical cells, the operator assignment may change with each different part type, and an operator may tend two or more processes simultaneously. For logical cells, the staffing of a work station may change to balance operator workloads, but it is less likely that an operator will tend two different machines simultaneously.

Layout-Cell layouts should reflect material handling flexibility and consideration of workplace ergonomics. Processing routings must be reviewed carefully to ensure that the material handling system can accomodate all the potential paths through the cell.

In laying out a physical cell, two key performance considerations are the oppertunities for assigning operators to more than one machine and for satisfing all the required part routes.

The layout problem for logical cells is different, in that different layouts affect primarily the material handling system. In laying out a logical cell, two considerations are minimizing the material handling resources required and minimizing the responce time of the material handling system to requests for material movement.

Tool and equipment maintenance- Continuous operation within a cell means that each sequential operation needs to be ready to receive the workpiece. Preventive maintenance (PM) is the operative term. Reliability and consistant performance is needed to manufacture high conformance workpieces. Downtime in the cell can have severe impact on its performance. Also, if a phase of piece of equipment fails in the cell, compensating factors may take over. Alternative workcenters, outside vendors, or even part completion in tool room could be the approved solution.

3. 3 Evaluation

The completed design of the cell must be evaluated with respect to the planned production rates for the family of parts to be processed in the cell. The nature of the evaluation is different for Physical and logical cells.

For a physical cell with simple material handling equipment and direct part handoff between machines, evaluation can be relatively simple.

Logical cells are much more difficult to evaluate. Since they have several different types of parts in process at the same time, they may have queues of parts at each work station, and the failure of one work station does not require other work stations to cease operations.

Two types of evaluation tools are available. Queueing network analysis will indicate average throughput, average work station utilization and average material handling system utilization, but will not be able to determine maximum queue size, maximum WIP levels or maximum part flow times. Simulation can be used to estimate literally any performance measure of interest, but the cost and time it takes to develop the simulation model usually are significant factors.

4. Manufacturing Cell Scheduling and Control

Manufacturing cells should appear as single entities to the scheduler or scheduling system. The capacities within the cell must be matched to the required production rates so that the cell does not accumulate significant internal WIP. The production requirement for a part family hould be described in terms pieces per unit time. Then a uniform plant loading concept can be applied to load the cell so that capacity for the plant is balanced in the same manner as the capacity within the individual cells.

Balanced work flow is so important that redundant capacity should be considered to achieve it. Where older equipment is available, redundant apacity may not be expensive to obtain. Bottleneck processes are candidates for redundancy, because adding capaciy to these processes may alleviate the need for a second cell or an additional shift.

For loading of a physical cell, changeover requirements should influence part processing order. The scheduler should have a priority scheme, determined by process engineers, which lists the preferred order of processing.

5. Conclusion

Manufacturing cells offers both cost and quality-control advantages over the traditional manufacturing systems. Several Problems involved in designing and controlling the manufacturing cells are surveyed and discussed in this paper. In this paper, some guidelines for designing and controlling the manufacturing cells are addressed.

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