

Characteristics and Problems of Cell Manufacturing System in Assembly Processes

— A Viewpoint as an Enabler of Improvement —

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Abstract

Reconsideration of conventional manufacturing systems employing belt conveyors in the assembly process is being accelerated along with the diversification of products and shortening of product life. As a result, the arrangement of workbenches in a U-shape, and manufacturing systems based on a one-man full assemblage scheme are in the limelight. It is claimed that this manufacturing system, referred to as the “cell manufacturing system,” is better than belt conveyor manufacturing systems, the reason being that it facilitates timely manufacturing of diversified products with zero loss caused by imperfect line balance. Also claimed is that it improves the productivity and morale of workers because it brings about self-completed assemblage that frees workers from the constraint of division of labor in the process. However, a second look at cell manufacturing systems reveals that there are several inherent problems in it itself and disputable points in its implementation. This paper discusses characteristics and problems of the cell manufacturing system from the viewpoint of industrial engineering and evaluate it as an enabler toward improvement.

1. Introduction

Recently there are a lot of magazines that carry articles with eye-catching captions about cell manufacturing systems. Such as, “This is the notable one-man manufacturing line! (July 1995 edition of the Factory Management),” “Introduction of one-man U-line enabled a cut of two thirds of labor (June 1997 edition of the Factory Management),” and “Removal of conveyors caused shock — One-man completion cell manufacturing (July 24, 1995 edition of the Nikkei Mechanical).” A manufacturing scheme called cell manufacturing has recently been attracting attention in Japan as an assembly process to facilitate small lot production of varied kinds with short delivery lead time.

As to the etymology and definition of cell manufacturing, there are several differing opinions. While there are a lot of papers that discuss the pros and cons of cell manufacturing in comparison with belt conveyors manufacturing (e.g. references [1] and [2]), only a few papers systematically argue inherent problems of cell manufacturing as a manufacturing system. In this paper first discusses the etymology and definition of cell manufacturing and then sheds light on inherent problems of cell manufacturing.

2. The etymology and definition of cell manufacturing

2.1 The etymology of cell manufacturing

It was in the early 1980s, when the concept of FMS (Flexible Manufacturing System) was extensively argued, that a word “cell” made its frequent appearance in discussions on manufacturing systems. In the FMS that is designed to cope with manufacturing of diversified products, product items and facilities are first split into groups. This matrix is then used as a base for adjustment of load between processes and between facilities for planning manufacturing sequencing. Product group and facility group in this system are referred to as a cell and a manufacturing system based on such group information was called Cellular Manufacturing.

On the other hand, there is a school of thought that says GT (Group Technology) already involved the concept of the cell before FMS. Another school of thought says that the cell concept originated from the manufacturing mode before

the mass production scheme introduced by Henry Ford.

Viewed this way, one can say that methods of making things practiced before the introduction of manufacturing systems employing belt conveyors invented by Ford are cell systems of a kind. By the same token one can claim that manufacturing systems after the 1980s are the true origins of cell manufacturing because no systems before them used such methods as assembly sequencing tables and GT. In either case, cell manufacturing is no brand-new concept.

However, the cell manufacturing frequently discussed in industry magazines published these days is defined more loosely (or vaguely in a sense). In essence it is, “a way of making things by a small number of workers without using conveyors.” It is said that this style of manufacturing was initiated by Compaq Computers in the 1990s. Instead of manufacturing driven by belt conveyors the company employed a manufacturing technique in which a team of four workers did everything at a workbench from assembly, installation of software, to the final inspection of a personal computer. Now the scheme is widely applied in Japan to manufacturing of a wide variety of products including TV monitors, audio-visual appliances, mobile telephones, printers and word processors.

Thus elements of “cell” are found in various instances in the history of manufacturing. They are self-completed fabrication by a craftsman in the pre-belt conveyors manufacturing era and an experiment at the Kalmar plant of Volvo in 1973. Group Technology which is invariably referred to in the discussion of cell systems is another instance as well as FMS in the 1980s.

Looking back over such history, we understand that the concept of cell manufacturing was not devised to treat only individual diversified products in the manufacturing process but to ease the design of processes and control of production by grouping process methods, facilities, and products with similar shapes and sizes. Therefore, it is dangerous to refer all of the manufacturing systems introduced in Japan in the context of manufacturing innovation for new manufacturing systems.

2.2 Definitions of cell manufacturing

A commonly used definition goes that the cell manufacturing system is a manufacturing system in which a worker or several workers in a group manually assemble a product without using belt conveyors (source: 1999 edition of Basic Knowledge of Contemporary Terminology). This definition is not necessarily appropriate because a substantial merit of the cell manufacturing system is derived not from the disuse of the belt conveyor, but to make up for the deficit of inflexibility that a worker is fixed to in a given process (or work) in the division of labor. Another problem of the definition is that there is no mentioning about workbench layout. It seems to go on the assumption that cell manufacturing is all based on U-shaped line manufacturing. Another confusing factor in the definition is that various manufacturers give their systems unique names (e.g. Clover line at Pioneer, Hanagasa line at Casio, Chaku-chaku line at Yamatake, and One-man completion stall at NEC).

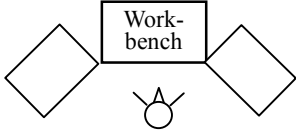
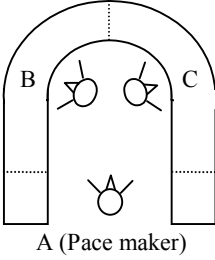
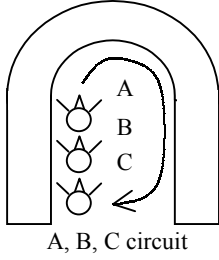
The term “cell manufacturing system” means not a single manufacturing system but several different systems. One of the classifications of cell manufacturing goes with the following three types. They are: One-man manufacturing system (Stall method), Division system, and Circuit system (Rabbit chasing method) (p. 37 of [2]). **Table 1** in the following page compares those three types to clarify the differences.

Among the three methods in **Table 1**, the most widely used in factories in actuality is the Division system, which employs a process arrangement to facilitate process division-based work by multi-skilled workers assigned to more than one process each. This system can be regarded as the same as conventional belt conveyor systems, with conveyor lines made U-shaped, except that the number of workers can be changed in accordance with the production volume, and that the process flow is regulated by the allocation of the same worker (pace controller) to the first and the last process.

The problem with the Circuit system, on the other hand, is that imbalance of working paces among workers will create time loss because a fast worker may pass slower workers or the fast worker may have to wait idly for the worker before him. Regarding the one-man manufacturing system, such considerations about the number of parts manageable by a worker, the worker’s skill level, and arrangement of parts placement to minimize parts handling time, are required in advance of implementation.

The above argument indicates that no one manufacturing system is decisively superior to the rest. Therefore, in building a manufacturing system, it is important to select (or rather develop) a method suitable to the needs of the company taking those factors into consideration; the level of manufacturing technology necessary for the products to be made, magnitude of fluctuations of the production volume, degree of diversity of product lines, and skill level of workers. The paper considers in the following chapters the points we should not overlook in implementing and improving the cell manufacturing system.

Table 1 Comparison of three types of cell manufacturing systems

	One-man manufacturing system	Division system	Circuit system
Image of systems			
Number of workers	1	More than 1	More than 1
Work division mode	No division (one-man completion)	Process division	No division
Layout	Workbench centered. Typically, parts are arranged U-shaped.	U-shape assumed for most cases	U-shape assumed for workers to return to the original point
Lot size	Basically one, but variation is possible	Basically one, but it is possible to put buffers between workers	Repetition of one
To cope with varying volume	Change the number of stalls	Change the number of workers (change process division)	Change the number of workers (too many will create passing problem)

3. The object and means in a manufacturing system

3.1 Distinction between the object and means

The output of a manufacturing system is “physical goods (product)” such as finished products and interim products. When we look at a manufacturing system by separating its elements into the object and means, the object here refers to a flow (a series of processes to apply changes) in which raw materials are transformed into a product [5]. Means here, on the other hand, refers to jigs and tools, facilities and workers employed in the manufacturing system which are used to apply forces, place things in predetermined positions and do other activities for the purpose of transforming prepared parts and materials into a product (Reference [5] and **Fig. 1** below). Workbenches in a U-shaped line and carts in a circuit system are all regarded as playing the role of means.

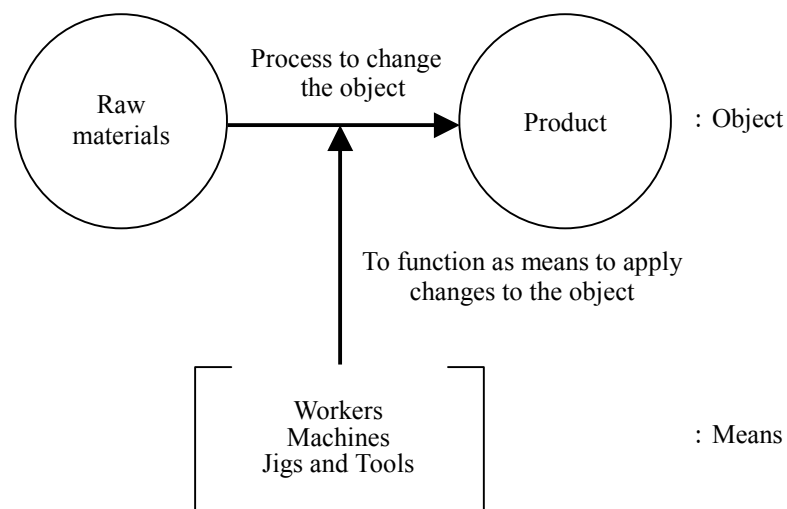


Fig.1 Object and means in a manufacturing system

(Source: Zentaro Nakamura: “Mono-Koto Analysis,” JMA Management Center, 1991)

When this concept of splitting the manufacturing system into the object and means is applied to cell manufacturing systems, we find that considerations get long on the means side, such as layout of workbenches and workers' behavior patterns, but short on the object side. For example, in an assembly line designed for assembly of a miniature precision part in cycle time of 30 seconds, a piece of work at each process of a series of 5 - 6 processes assigned to a single worker is completed in far shorter time (e.g. 15 seconds) than the designed cycle time. A case like this is omnipresent in any assembly processes of cell manufacturing.

Generally speaking, in a cell manufacturing system, the cycle time is set fairly longer than the time actually necessary to complete assembly in order to keep the cycle time undisturbed while keeping worker's rate of operation high. "Waiting time" accompanying interim products at each facility is justified by the rationale that a shorter cycle time to cut down on the waiting time will only yield greater volume than necessary on the selling side and only end up in the warehouse as inventory.

In this mode of operation, a piece of assembly work that only takes 90 seconds net (15 seconds x 6 processes), for instance, is allocated 180 seconds (30 seconds x 6 processes) to keep pace with the cycle time of workers. Even the former 90 seconds includes various overhead time such as time for setting the object to a machine at an assembly point and time for conveying the object from an assembly point to the outlet area. The time really spent on assembly itself is, therefore, much shorter than this (in most cases it is less than half the 90 seconds).

Then, a question like "is it possible to develop a facility that can be operated with net assembly time?" will come up. If such a system is developed with bare minimum features and mechanism, it will be instrumental in miniaturizing the facility, reducing the cost and in transforming it to an in-line system. Engineering efforts for the development of such a cell system will get manufacturing technologies concentrated in generating ideas to facilitate elimination of idle movement of the object and integration of assembly points to help prevent minor stoppages and defective products in the end. This in turn will prompt improvement in product design, such as making parts common to different products because shapes and other characteristics of parts will be recognized in the efforts as important design factors. Those efforts are crucial in that they will further induce technical innovations and reinforce the company's technical competency in the long run.

In pursuit of improvement with focus put on cycle time, on the other hand, most of the substantive improvement such as described above cannot be expected because what is paid primary attention to is not the movement of the object but behavior of workers. Cycle-time oriented pursuance of improvement of worker's efficiency will not unveil fundamental technical requirements for the realization of desirable changes of the object.

3.2 Conveyance as means

Similar problems are oftentimes observed in conveyance systems. In most U-shaped cell manufacturing systems, conveyance of parts and materials is left to the workers by design. Some systems are designed in such a way that a worker temporarily assembles parts with the right hand while he is conveying things with the left hand. In other cases soldering is administered half way through conveyance. As far as changes to the object are concerned, conveyance is an event without any added value.

Accordingly it is appropriate to devise the reduction of man-hour on conveyance as much as possible. For example, a gravity applied automatic conveyance system connecting one process to the next will reduce man-hour on conveyance. This scheme can also avoid possible product defect caused by static electricity applied through hand touching or by damaging force applied by hand. If we closely observe the way a worker conveys things we will notice that things are differently oriented or shifted vertically. Those movements are valueless for the object to be turned into a product. The above discussion indicates that there still is room for engineering to pursue improvement from a standpoint of the object in most of U-shaped cell manufacturing systems.

3.3 Risks involved in development of means-oriented facilities

It is generally said that cell manufacturing is suitable for manufacturing of diversified products because it eliminates arrangement work inherently necessary for the belt conveyor scheme. On the other hand, however, it pushes up facility cost and eats up larger space because each item or group of items needs the installment of a cell dedicated to it. Development, by focusing on the movement of the object, of streamlined processing facilities and conveyance systems to reduce time wasted will not only contribute to the enhancement of manufacturing technologies but also to the reduction of production cost.

4. Worker's morale and work-worthiness

4.1 Meaning of work-worthiness

It has been reported in many papers introducing cell manufacturing that workers come to have stronger sense of responsibility and their morale boosted because a single worker (or a small group of workers) can work on a product from the beginning to the end all by himself. A close look at their work content will reveal, however, that it is made up of many simple tasks such as picking, putting, turning and holding that add no value. In some cases spaces between adjacent processes are made so small to reduce the number of footsteps to walk that there in the cell are only processing machines and workbenches installed almost without tools.

From the viewpoint of pursuing work which none other than man should perform, it is not acceptable that simple tasks not adding any value are loaded on multi-skilled workers, who are placed there as a presupposition of cell manufacturing. Truly, skills of workers are stunning in soldering, minute wiring and others on a flat workbench. But persevering at attempts to devise tools to ease their work should generate ideas of plain automation of those tasks. Good tools cannot be devised if only we watch and analyze the movement of workers. We need to closely observe and examine the movement of the object instead.

Viewed this way, problematic is a conception called automatic popping-out or "Chaku-chaku line (One-after-another line)." Here a part is automatically popped out upon completion for the worker to pick up and set at the next processing machine. In this method the worker is used as a conveying tool. Speaking of automatic popping-out mechanisms, some machines are designed to pop out parts off aligned orientation. Production system engineers should pay more attention to the movement of the object.

4.2 Work-worthiness with one-man completion arrangement and risks

One more thing to point out about work-worthiness is work-worthiness with the one-man completion arrangement. If the simple logic goes that work-worthiness is derived from many tasks loaded on a single person, the one-man completion manufacturing system will be the most satisfying manufacturing system. However, in actuality, there naturally is a limit to the number of parts that can be handled by a single person and there are not so many skilled workers available who can assemble many different kinds of items from the beginning to the end all by himself. Nevertheless, arguments praising one-man completion arrangement die hard.

The one-man completion manufacturing system is acceptable if it is designed in such a way that the worker himself is allowed to increase the number of parts to handle and change the layout of the cell at his own discretion. However, if it is an arrangement in which the worker's capability is stretched through education and training so he can challenge human limits set by planning staff, then one must be reminded that such a system will not last long if morale of the worker appeared to be boosted up at a glance.

Another thing that makes realization of the one-man completion arrangement difficult is that the number of tools will become too great to be managed by one person if torque to tighten screws and size of screws are all different without getting standardized. Problems in enabling the one-man completion arrangement should be regarded as signals to prompt clarification of primary requisites to be addressed in product design and process design.

Some companies make it a practice to give awards of overseas travels to workers qualified as being capable of one-man manufacturing. Some companies post the names of such people in process charts. In most cases near the cell manufacturing areas there are people working along conventional conveyor lines for labor division manufacturing due to continued production of legacy products. What about the morale of those people? It should be noted that excessive pursuance of the one-man full assemblage scheme involves various risks, including one of losing employees solidarity for propelling improvement activities.

5. A viewpoint of self completion

5.1 Self completion and improvement in related functions

Some argue that improvement of spiritual aspects such as strengthened sense of responsibility and heightened joy of making things is not the only merit of the manufacturing scheme in which one worker (or a group of small number of workers) manages the whole process from the beginning to the end. They claim that there also is another merit, which is improvement of efficiency of indirect functions attributable to self-sufficient production management, reasons being that functions such as production planning, progress control, and material ordering and purchasing are distributed to each responsible line department from a centralized organization. Also central quality assurance function can be downsized due to increased quality awareness in line departments.

However, streamlining of operations of raw material purchasing, product announcement and shipment, production

planning and quality assurance and others, should originally be pursued independent of whether or not the manufacturing system is cell based or belt conveyor based. It does not automatically follow that cell lines can take over those functions just because their size is small.

5.2 A view of a total process

Improvement of the manufacturing processes should be carried out from a wider viewpoint of the product cycle starting from order reception, raw materials procurement, product shipment, and up to product distribution. A fact that the cell manufacturing system is inherently oriented towards one-product-at-a-time production flow will not help prevent material inventory from getting stockpiled if material purchasing is done based on batch order placement.

It is clear that if it is only the manufacturing department that constructed a production system capable of yielding small volume products with short delivery lead-time, the company's overall competitive power remains not reinforced. A proof of a successful organization lies in timely communications to the manufacturing department on true marketing status. A manufacturing system designed to facilitate adjustment of manufacturing speed to selling speed will end up in operations with an unrealizable objective "flattening of finished product inventory" unless the system is built as part of company's total streamlined process.

5.3 Prerequisites for improvement of total process

The notion is hastily formed that the introduction of a cell manufacturing system will shorten the lead-time between order reception and product delivery owing to heightened self completeness in manufacturing. Also it is an illogical jump to say that a cell system will make indirect departments lean, owing to their functions distributed to direct departments. Functional improvement of material procurement and product distribution should be embodied as a prerequisite for improvement of the manufacturing system regardless of what type of manufacturing scheme is adopted.

Therefore, we firstly must remove causes of disturbance to the manufacturing processes by activating improvement activities such as 5S, QC and PM, and then remove or simplify overhead functions falling into disuse, concurrently with transferring of them to manufacturing lines as much as possible. All of these activities are a down-to-earth approach towards self-completion manufacturing in the long run.

6. Speed of improvement activities

6.1 A warning to hasty introduction of cell manufacturing

One other thing to point out about the cell manufacturing system is the hastiness with which it is introduced. In today's management climate of competition in speed, a hastily introduced cell manufacturing system involves various hidden risks.

Oftentimes a decision to introduce a cell manufacturing system is made in a counseling session involving a consultant who says, "Get rid of the belt conveyors immediately." Such a manner of introduction will create not only a problem of making it means-oriented as opposed to object-centered but also potential problems brought about by sudden changes to the manufacturing system.

Essentially, improvement activities should be performed spontaneously by people of the company sharing ideas with each other in the process of identifying and solving problems the company is faced with. It is permissible to solicit advice and clues from outside parties including consultants when at a loss, but it should not be forgotten that it is the employees of the company in the end that have accountability for carrying out improvement activities. It is in the process of steadily carrying out such improvement activities that employees' awareness is heightened and problem solving competency is developed, which in turn strengthen a company's constitutional capabilities.

The first concern about actual cases of introduction of cell manufacturing viewed from this angle is that in most cases it is started out with instructions by consultants that order the removal of conveyors. The company has the ownership of and responsibility for improvement activities and the company is the beneficiary of the result, but we may wonder if this statement is true or not in those cases. Naturally, such consultant-led approaches might neither allow people to spend sufficient time on the study of the object of the manufacturing system, nor draw their attention to the necessity of having the manufacturing system synchronized with the improvement of processes before and after the system.

As has been claimed in many papers, it is true that the introduction of a cell manufacturing system will increase labor productivity because of reduction of imbalance-caused loss time and reduction of workers movement. However, long-term improvement of constitutional capabilities of the company will not be achieved only with them. Furthermore, we should not forget that in most cases cell manufacturing is quickly introduced in part of the factory floor designated as the subject of improvement so that new cells and conventional belt conveyors coexist side by side. In such situations it is highly doubtful that all workers are equally motivated to cooperate with improvement activities of the manufacturing department.

6.2 A viewpoint of long term continual improvement activities

It may sound paradoxical in the era of speed competition if we say that improvement activities can only bear fruits if steadily continued for a long period of time. “A long period” means at least 3 years and most cases 5 to 10 years. Activities advanced step by step over long period of time will cultivate true capabilities of problem-solving because a solution to one step will disclose another problem to be solved in subsequent steps.

By the same token, the effects of the cell manufacturing system will be secured if it goes with improvement steadily accumulated in materials purchasing and distribution departments that sandwich the manufacturing department. It also needs prerequisite rationalization in indirect departments serving the manufacturing department as well as technical advancement in facilities, tools and conveyance methods. The effects thus obtained will in turn be reflected in building up a cell manufacturing system suitable to the company. It cannot be overemphasized that hastily introduced cell manufacturing will mask vital problems and carries risks of drawing management attention only to short term effects at the cost of forgotten long value of term improvement activities.

7. Conclusion

The cell manufacturing system, as a manufacturing system to supply diversified products in short delivery lead-time, is instrumental in reducing in-process inventory with its flexibility, which is not available with the conventional belt conveyor lines. Quite a few companies that introduced cell manufacturing systems were reportedly successful in improving their business performances by increased sales resulting from inventory reduction and drastic shortening of manufacturing lead-time. Behind those success stories, however, there are varied inherent problems. They include problems caused by means-oriented approach based on adherence to cycle time of workers and abolishment of belt conveyors, problems associated with work-worthiness of workers, total system problems attributable to improvement disparity in pre- and post-manufacturing processes, and problems resulting from hasty introduction of the cell manufacturing system. Also, definition of the cell manufacturing system remains fuzzy.

Therefore, at this juncture it is more practical to composedly regard the cell manufacturing system as something that has manifested problems in the area of production engineering and control, hidden behind the conventional division of labor. Things to be addressed in solving the problems are standardization of product design, reduction of the number of parts, downsizing of facilities, achievement of self-sufficiency in the facility construction, realization of smooth information flow from the sales front to manufacturing lines, improvement of processes involving shipment, distribution and sale, streamlining of indirect departments, and others.

One big merit of the cell manufacturing system is again that it sheds light on problems that do not easily surface in organizations based on process division or functional division manufacturing, analysis for solutions of which should be tackled in a cross functional manner.

Thus, a crucial advantage of the cell manufacturing system is that it works as an enabler for propelling improvement activities as well as for problem identification. It should be remembered that an attitude to impulsively follow the fashion of cell manufacturing and hastily implement it runs a great risk of losing professional credibility, both in businessfield and academic aspect.

Reference (All in Japanese)

- [1] “Special feature — This is the notable one-man manufacturing line!” Vol.41, No.8, Factory Management, Nikkan Kogyo Shinbum, July 1995
- [2] “Removal of conveyors caused shock — One-man completion cell manufacturing, ” No. 459, Nikkei Mechanical, July 24, 1995
- [3] “Special feature — Introduction of one-man U-line enabled a cut of two thirds labor,” Factory Management, Nikkan Kogyo Shinbum, June 1997
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