A Study on Assembly Operation Model for Line Performance Estimation

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Abstract

In this paper the framework of an assembly operation model consisting of three models is developed; models of assembly products (e.g. products specifications), assembly methods (e.g. ways of parts supply) and workers' ability.

As an assembly operation determined by the operation model is composed of the assembly operation units, which includes the operation elements of checking operating instruction, searching assembly parts, grasping, moving, positioning and fixing the parts, some factors of the assembly products model, assembly methods model and workers' ability model are examined to clarify the influences of those factors on each assembly operation elements.

1. Introduction

In order to win the competition of the global business, an assembly shop is required to produce various products ordered from not only its own company but also from other companies. With a view of reducing production cost, a company sets up several assembly shops in various countries or areas, and employs temporary / part-time workers besides the regular workers according to the production quantities, and the labor cost depends on each worker's working skills.

In such situations, the company has to estimate the type and volume of each product, which will be produced during each production planning and sales period, and then has to select the assembly shop that can produce the products with the lowest cost.

Once an assembly shop is chosen, the planned production is executed. But as customers' needs become diversified and production lifecycle gets to be shorter, orders to an assembly shop change frequently; sometimes differs largely from the production plan. Therefore the situation such as the operating hours of each line differs from each other largely will be happened. In order to deal with such changes, it is necessary for the assembly shop to have the ability to change the assembly methods of its lines or workers' assignments to each line quickly and simply.

And for each assembly line, the flexibilities such as changing products' input sequence are required to deal with the daily change caused by such as workers' absence or urgent-due-date jobs and so forth.

2. Assembly Operation Model

An assembly line is composed of several assembly workstations and workers. In order to deal with the changes mentioned above, an assembly model is required to determine the assembly operation of each workstation within each line, and to assign workers to each workstation. The decision should be made considering the products' specifications, assemble methods and workers' ability.

An assembly operation can be considered as a set of assembly operation units, which includes the operation elements of checking operating instruction, searching assembly parts, grasping, moving, positioning and fixing the parts (Fig. 1). The operation can be determined by the operation model when the products' specifications, the workers' ability are known and the assemble method is chosen.

Some factors of products' specifications, assembly methods and workers' ability are shown in 2.1-2.3.

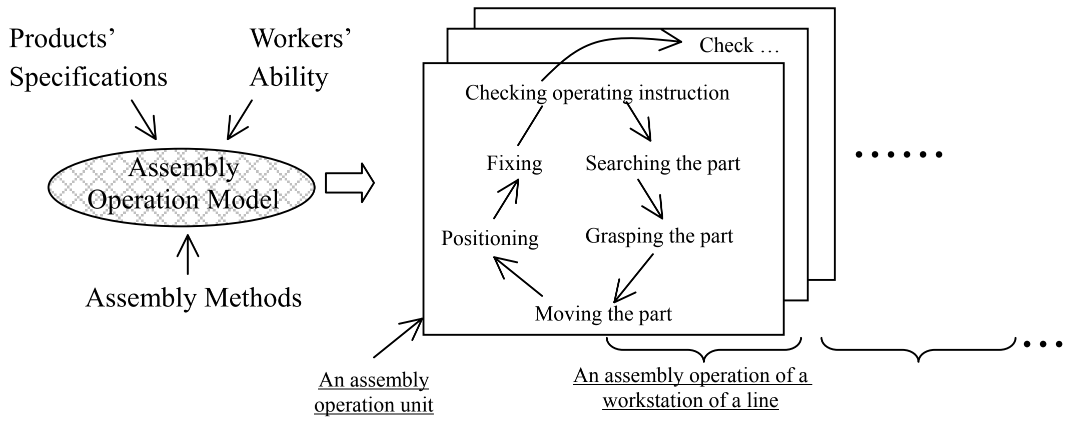

Fig. 1 The assembly operation model

2.1 Details of Products' Specification

(1) Physical Specifications of Products: e.g. parts composition of the product; size of the product and its parts; joining points; types of connection (e.g. screwing, pressing, clamping etc.)

(2) Production Specifications of Products: e.g. production volume of each product, lot size of the products

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2.2 Details of Assembly Methods

(1) Types of Assembly Lines: e.g. whether or not the assembly operations of a product is divided by several workers

(2) Ways of Parts Supply: e.g. supply all parts of each product at the first workstation of a line, or, only supply the necessary parts at each workstation

(3) Ways of Operating Instruction: e.g. information quantity included in an instruction manual; ways of indication (by paper or by CRT)

(4) Assembly Support Device: e.g. requirements for fixtures and tools

(5) Inspection Device

(6) Ways of Material Handling

⋮

2.3 Details of Workers' Ability

(1) Physical Ability: e.g. manual dexterity

(2) Intellectual Ability: e.g. experience in operation; knowledge of parts; know-how

(3) Mental Ability: e.g. concentration, responsibility

⋮

3. Examinations

In this chapter, some factors of products' specifications, assembly methods and workers' ability listed above are examined to clarify if they have any influences on the operation elements of the assembly operation unit.

[Experimental Conditions]

・ Products: small-sized toys
・ The parts of the product is arranged on the worktable
・ Workers are sitting at the worktable
・ Screwdriver is the only tool that can be used

[Elements of Assembly Operation Unit]

- Checking operating instruction
- Searching the part
- Grasping the part
- Moving the part
- Positioning
- Fixing

3.1 The Influence on Time required for Checking Operating Instruction

In this experiment, 2 kinds of instruction are made tentatively; one only contains the basic information on the parts and the operating procedure, and the other contains not only the basic information but also some additional information such as where the parts are placed, the joining position and the connection direction of parts.

Two products are used and their differences in the physical products' specifications are shown in table 1.

The workers have not undergone the training of this operation, which means it's the first time for them to assembly the products.

Table 1 The Difference in the Products' Physical Specification

Product	A	B
Number of joint	30	17
Number of parts	0～4	0～2
Number of similar parts	0～7	0～2
Number of mistakable joint directions	0～3	0～2
Types of connection	Screwing, Pressing, Insertion	Screwing, Pressing, Insertion

The total processing times of these 2 products are compared. Although the total time of the operation with the additional information is shorter than that of the operation only with basic information, concerning both of the products A and B, the time required for checking the instruction is increased in the former case as for the both products, especially for product A. One reason that can be considered is that product A contains more parts especially similar parts than product B, so that it requires more additional information to check.

Accordingly it is required to provide the additional information in a simply way.

3.2 The Influence on Time Required for Searching parts

It is described in literature [4] that there are two human action patterns for searching parts; searching parts by their easy-recognizable characters (pattern 1) and searching parts by comparing the parts one by one (pattern 2). In this experiment, one factor of the physical products' specifications, the parts' similarity is focused. We propose several parameters (e.g. the average side length of a part, the surface area of a part) to judge if the parts are similar, and analyze the relationship between the parts similarity and the searching action pattern.

Figure 2 shows that when the parts are similar, searching pattern 2 is used commonly, and the searching time of pattern 2 is more than that of pattern 1. Therefore when there are a lot of similar parts in a workstation, some methods to reduce searching time should be developed.

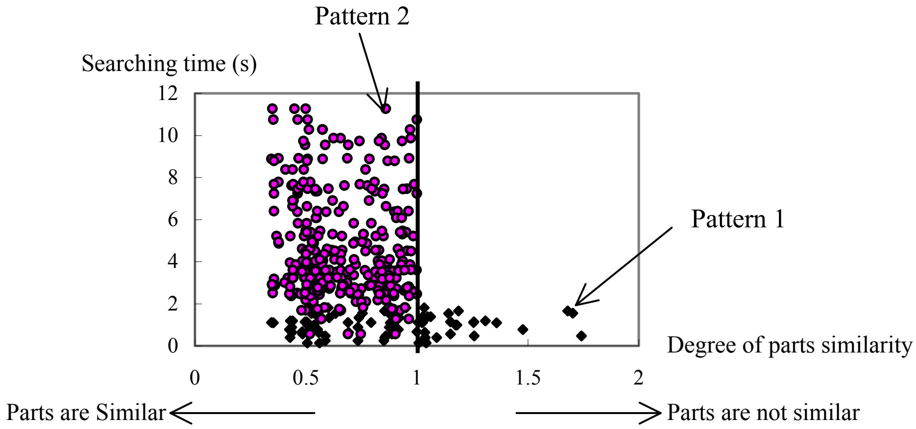

Fig. 2 Parts similarity and searching time

3.3 The Influence on Time Required for Grasping and Fixing Parts

In this experiment, we propose two parameters of workers' assembly ability and examine the influence of the difference in those abilities on processing time of grasping and fixing.

(1) Movement-Control Ability: According to GATB (General Aptitude Test Battery), which is used to inspect one's suitable occupation, one who has the abilities shown below is considered to be suitable for assembly work.

- Manual dexterity
- Ability to make his (her) eyes, hands, or fingers work together to execute works quickly and correctly

We use the method of GATB to evaluate these abilities, and define their average scores as worker's "movement-control ability".

Product C and D are used in this experiment and Table 2 shows their physical specifications.

Table 2 Physical Specifications of Products C and D

Product	C	D
Number of Parts	31	23
Number of Parts' Types	16	16
Types of connection (numbers)	Screwing (8), Pressing (8), Insertion (10), Winding (2)	Screwing (4), Pressing (8), Insertion (6), Winding (2)

Table 3 shows that there is a strong interrelationship between the movement-control ability and the processing time of grasping parts and fixing parts. Moreover, we also analyze the interrelationship between the movement-control ability and the processing time of each connection type for fixing parts, the result of which is shown in Table 4. From it, we can find that the screwing, pressing and insertion time are especially influenced by the movement-control ability of workers.

Table 3 The Correlation between Movement-Control Ability and Each Element's Processing Time

Operation Element	Grasping	Fixing
Correlation Coefficient	-0.78	-0.91

Table 4 The Correlation between Movement-Control Ability and Each Connection Type's Processing Time

Connection Type	Screwing	Pressing	Insertion	Winding
Correlation Coefficient	-0.89	-0.8	-0.81	-0.68

(2) Experiences of workers: Here, the number of experiences concerning each connection type is focused.

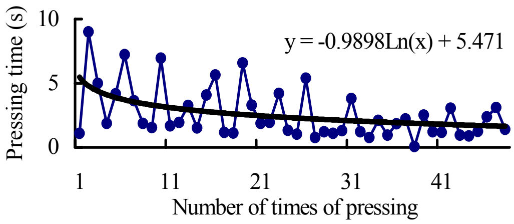

Fig. 3 Learning curve of pressing

The learning curve of each connection type is calculated. Figure 3 shows the learning curve regarding one of those types, "pressing", as an example.

Moreover, the parameters of processing in each connection type, such as the depth of pressing and so forth, are considered. It is confirmed from the observation that learning curve of each connection type differs with its parameters.

Thus the processing time of fixing parts is influenced not only by the workers' ability but also by the products' specifications.

4. Conclusion

In this paper, some examinations are conducted to prove that the operation time is influenced by the products' specifications, assembly methods and workers' ability. However, further studies on this subject are needed, where more substantial experiments with well-sorted-out models should be performed.

References

[1] GATB (General Aptitude Test Battery), The Ministry of Labor (Japan) , 1983

[2] Hironobu Nishida; A Study on Determination of an Operation-Difficulty-Index in Manual Assembly Operation (part2)-Correlation between Recognition of Production Orders and Age or Experience-, Research Bulletin of Hiroshima Institute of Technology, 1988

[3] Hironobu Nishida; A Study on Determination of an Operation-Difficulty-Index in Manual Assembly Operation (part3)-Method of Production Orders: CRT Display and Broadcast6-, Research Bulletin of Hiroshima Institute of Technology, 1990

[4] Katsuhiko Yokozawa; Basic Process of Vision Information Processing, Production Research, Vol.44, No.12, 1992

[5] Mitsuyuki Kawakami, Toshio Ueno; On the Reasonable Assembly Work Amount to the Kinds and Number of Parts, Journal of Japan Industrial Management Association, Vol.40, No.6, 1990

[6] Shimon Y. Nof; Industrial Assembly, Chapman & Hall, 1997