

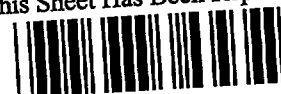
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**Operation Method of Equipment****Field of the Invention**

The present invention relates to an operation method of equipment, through which an appropriate composition of an assembling line is found by selecting machines for manufacturing a specific PCB (printed circuit board) so that a tact time (tact time: maximum work time necessary for a process) of the assembly line may not exceed the initial set tact time. The machines are selected from plural groups of mounting equipment which mount electronic parts onto a PCB (printed circuit board).

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**Background of the Invention**

In a mounting process of electronic parts, an assembly line has been composed by utilizing individual feature of each mounting machine, and thereby manufacturing a PCB. For example, in a mounting process of micro-chip parts, a high-speed surface mounting machine mounts the parts, and when mounting QFP (quad flat package) and others having so narrow spacing between pathways that a precise mounting is required, a robot type machine featuring precise mounting is employed after the process using the high-speed machine. Such an operation of combining different types of machines improves a quality and an efficiency of the entire assembly line. It is also a well-known operation method that a plurality of the same machines is placed in one assembly line in order to shorten a tact time of the assembly line. When determining compositions of these conventional assembly lines, a line manager has to do the following jobs manually.

1. Collect such data from the parts list for the specific PCB as numbers of parts, available machines for mounting the parts, individual tact time for

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mounting each part of each machine, maximum loadable numbers of parts into each machine.

2. Determine whether plural assembly lines are necessary for manufacturing this type of PCB, e.g. determine whether independent lines are necessary for insertion process, surface mounting process, and semiconductor mounting process. Then, assign each part to a line, and the following policy must be considered when a line composition is determined.

2-1. In general, assign a maximum loadable parts into a machine of the highest mounting speed among the group of machines. Surplus parts from the machine, or non-loadable parts into the machine are assigned to another machine of next higher mounting speed. The same procedure follows until all parts are assigned.

2-2. Reassign the parts within each line in order to smooth out the load to each machine so that a specific machine may not take an exceptionally longer tact time. For this purpose, an optimizing simulation using a computer are already available as a prior art.

2-3. After smoothing out, if the tact time of each line satisfies the desirable level, this line composition is finalized as an actual mounting line. If the tact time of each line could not satisfy the desirable level, a next possible machine is supplemented to the line composition so that the total tact time of the line may satisfy the desirable level. This procedure follows until the total tact time of the lines satisfies the desirable level.

The above procedure, however, leaves several problems to factory staff;

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(1) This kind of manual procedure requires a great deal of time and labor for finalizing a desirable line composition, in particular, when planning an annual business plan, a common line composition is to cover plural types of PCBs. In this case, try & error calculations are repeated until every tact  
5 time of lines for each type of PCBs becomes not more than a desirable time. When any PCBs encounter some changes in a trial production, or due to specification changes, the same kind of calculation must be repeated.

(2) When a factory is equipped with sizable equipment, it is not an optimal operation for the entire factory if there are disperses between each  
10 tact time of lines after finalizing the line compositions for plural types of PCBs. In this case, a line composition of each type of PCBs must be calculated considering factory's sizable equipment, and the calculations should be in too many numbers of combinations to deal with manually.

(3) Only specific line managers who know in detail about each tact time  
15 as well as mountable conditions of all parts can manage the above procedures and calculations, and ordinal workers cannot follow the procedure nor manage the calculations.

#### Summary of the Invention

The present invention provides an equipment operation method which  
20 determines a line composition by selecting appropriate machines from groups of equipment for processing designated products so that a tact time of an assembly line may not exceed a desirable tact time. The operation comprises the following three processes:

Process 1. Group the machines into plural groups based on a priority  
25 order of assigning parts to each machine considering the machines' features, and then store such data into an outside memory as the priority orders



within each group, a priority order between the groups, a mounting tact time of each loadable part to a machine, and tact time information proper to each machine.

Process 2. Calculate a tact time of each assembly line using the  
5 stored data after determining a line composition through selecting machines based on the priority order until all necessary parts for processing the product are loaded to the machines.

Process 3. Supplement machines to the line composition determined  
in Process 2 through machine selection based on the priority order until the  
10 tact time of the assembly line becomes not more than a desirable level, and calculate the tact time of the assembly line.

According to the present invention, a line composition of which tact  
time is not more than an initial set tact time can be automatically  
determined through selecting necessary machines from the equipment for  
15 processing a designated product.

### Brief Description of the Drawings

Fig. 1 shows schematic hardware used in the equipment operation  
method of the present invention.

20 Fig. 2 depicts a structuring method of control information used in an embodiment of the present invention.

Fig. 3 depicts data composition of the control information used in an  
embodiment of the present invention.

25 Fig. 4 depicts an information flow chart of determining a line composition used in an embodiment of the present invention.

Fig. 5 depicts another information flow chart for determining a line



composition used in an embodiment of the present invention.

Fig. 6 depicts further information flow chart for determining a line composition used in an embodiment of the present invention.

Fig. 7 depicts still further information flow chart for determining a  
5 line composition used in an embodiment of the present invention.

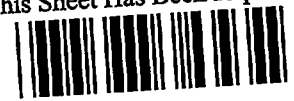
### Exemplary Embodiments of the Invention

The invention disclosed in Claim 1 provides an equipment operation method which determines a line composition by selecting appropriate  
10 machines from groups of equipment for processing designated products so that a tact time of an assembly line may not exceed a desirable tact time. The operation comprises the following three processes:

Process 1. Group machines into plural groups based on a priority order of assigning parts to each machine considering the machines' features,  
15 and then store such data into an outside memory as the priority orders within each group, a priority order between the groups, a mounting tact time of each loadable part to a machine, and tact time information proper to each machine.

Process 2. Calculate a tact time of each assembly line using the  
20 stored data after determining a line composition through selecting machines based on the priority order until all necessary parts for processing the product are loaded to the machines.

Process 3. Supplement machines to the line composition determined in Process 2 through machine selection based on the priority order until the  
25 tact time of the assembly line becomes not more than a desirable level, and calculate the tact time of the assembly line.



When manufacturing a specific product by using plural groups of equipment, the invention disclosed in Claim 1, thus, can automatically determine a line composition of which tact time is not more than an initial set time by selecting necessary machines from the groups of equipment.

5       The invention disclosed in Claim 2 provides an equipment operation method which determines a line composition by selecting appropriate mounting machines from groups of mounting equipment for mounting electronic parts to designated PCBs so that a tact time of an assembly line may not exceed a desirable tact time. The operation comprises the  
10 following three processes:

Process 1. Group the machines of the mounting equipment into plural groups based on a priority order of assigning electronic parts to each machine considering the machines' features, and then store such data into an outside memory as the priority orders within each group, a priority order  
15 between the groups, a mounting tact time of each loadable electronic part to a mounting machine, and tact time information proper to each mounting machine.

Process 2. Calculate a tact time of each assembly line using the stored data after determining a line composition through selecting machines  
20 based on the priority order until all necessary electronic parts to be mounted on to the designated PCBs are loaded to the mounting machines.

Process 3. Supplement mounting machines to the line composition determined in Process 2 through machine selection based on the priority order until the tact time of the assembly line becomes not more than a  
25 desirable level, and calculate the tact time of the assembly line.

When manufacturing a specific PCB by using plural groups of



mounting equipment, the invention disclosed in Claim 2, thus, can automatically determine a line composition of which tact time is not more than an initial set time by selecting necessary mounting machines from the groups of mounting equipment.

5

An exemplary embodiment of the present invention is described here by referring to the drawings. The equipment operation method cited in this embodiment is applicable to the mounting process of electronic parts.

Fig. 1 shows schematic hardware used in the equipment operation  
10 method of the present invention, where a CPU 3 contacts with a control information 2 stored in an outside memory 1 through input/output. The outside memory 1 may be a relevant data base system or a file which is known as a public domain.

Process 1, i.e. a structuring method of control information, is  
15 explained based on Fig. 2. Electronic parts 4 are mounted on a PCB 5 by various types of mounting machines 8. Available machines are depend on shapes and characteristics of parts, and there is a priority order which parts must be mounted first. Considering these factors, parts are assigned to machines (Part Assignment 12.) An assignment table 6 contains  
20 information about parts to be mounted on a PCB. A partial-assignment-table 7 contains partial assignment information integrated from the assignment table 6. The plural groups of equipment are grouped based on equipment's features and a line composition is determined in Process 2 and onward. Mounting equipment 9 is grouped into an equipment GROUP 10,  
25 an equipment TYPE 11 (each machine is included in the equipment group 10), and a mounting machine 8 (each mounting machine is included in the



equipment type 11.)

When there are different mounting methods, the equipment GROUP is used and a line is composed based on a same mounting method. There may be several equipment GROUPS such as a surface mounting group, insertion machine group, and semi-conductor mounting group. The priority order of part assignment is applied between the groups.

The equipment TYPE is used when there are different features within a same equipment GROUP. There may be several types such as high-speed mounting machine, and multifunctional mounting machine. The priority order of part assignment is applied between the types and also between each machine.

The structure of control information 2 including the grouping mentioned above is detailed by referring to Fig. 3. The control information 2 is grouped depending on relevant information, and each table of the control information 2 is controlled independently. Each table can refer to others by using a relevant item as a key.

There are eight tables, i.e. an assignment table 21, part attribute 22, equipment master 23, equipment operation 24, user's equipment 25, equipment TYPE 26, equipment GROUP 27, and line composition 28.

The attributes of a specific PCB are controlled with the assignment numbers (cad-id) of the assignment table 21. The part assignment number(sub-id) on the part assignment table specifies the parts thereon, a part number(part-id) thereof specifies an electronic part thereon, a number of an electronic part(part-num) is a quantity of the part to be mounted onto the PCB. A machine number(mc-id) specifies a machine to which the parts are assigned. A part mounting tact(tact) is a tact time for mounting a part



onto the PCB by the machine. The machine number and the part mounting tact time are set as computing results of the CPU. When a specific part must be assigned to a specific machine beforehand, a machine number can be assigned before a computing process.

5       The part attribute 22 is linked with the electronic part through the part number(part-id) to set the attribute thereof. In this embodiment, a part shape number(shape-id) is used for specifying a part shape. Other data such as a measurement of a part, or species of parts including QFP (quad flat package) and SOP (small outline package) can be used for the part  
10   number.

The equipment operation 24 sets the part tact time of the part corresponding to the part shape number(master-id), which part is mounted onto the PCB by the equipment specified with the species number.

The equipment master 23 controls every aspect of the equipment.  
15   The species number(master-id) specifies a species of equipment, a type number groups features of equipment, a part loadable number(max parts) is a maximum loadable quantity of parts to a machine, and a loading tact time is a travel time for transferring a PCB. A tool change tact(change-tact) sets a time to be spent for changing chucks or nozzles transferring parts before  
20   mounting. This tool change tact time is used in general type machines such as a robot type. Other tact times proper to the machine can be supplemented to this table.

User's equipment 25 controls the equipment which a user keeps in his factory. A machine number (mc-id) specifies a machine, and a species  
25   number(master-id) is linked to the species of equipment controlled by the equipment master 23. The priority order of part assignment (priority) is



applied to when assigning the same type of machines within a same line.

The equipment TYPE 26 controls the priority order of type numbers (master-type) on the equipment master 23. The type numbers of equipment are linked with the type numbers listed on the equipment master 23. An  
5 assignment priority order is a priority order of the equipment types. The equipment group number (group-id) is used when one type of PCB needs different lines.

A computation result is written into the line composition 28. A line number(line-id) specifies the computation result, and a machine number is  
10 proper to machines composing a line. The machine number is linked with the machine number on the user's equipment table. A machine tact (mc-tact) is a tact time of each machine comprising the line. A composition order (order) is an order of machines comprising the line.

A procedure for determining the line composition is now explained by  
15 referring to Fig. 4 through Fig. 7. In the Figs, Process 2 is processed in S1-S5, and Process 3 is processed in S6.

In Fig. 4, the control information made in Process 1 is written in (S1), and select a part assignment table No. corresponding to a PCB in order to specify the PCB (S2). Then assign the parts to each equipment group (S3).

20 The process in S3 is now detailed: take out any single electronic part = p from the part assignment table AR (S31), and assign the electronic part to the equipment group having the higher priority. The smaller "n" becomes, the higher priority has the equipment group. When a loadable machine is available among the machines belong to the equipment group (S32), assign  
25 the electronic part to the part assignment table AR(n) corresponding to the equipment group (S33). When the electronic part cannot be loaded into any



machine, execute an error process (S34) and then end the process.

In Fig. 5, take out any single part from the part assignment table AR(n), and assign the part to loadable machines of equipment TYPE (m) which belongs to a proper equipment GROUP (n), then supplement the  
5 machines assigned with the part to a partial line L (m) proper to the equipment TYPE (S4).

Now the process in S4 is detailed: take out any single electronic part from the part assignment table AR(n) (S41), and judge whether the part can be loaded to any machine of the equipment TYPE T(m) which belongs to the  
10 equipment GROUP G(n) (S42). In this case, let us assume that the part can be loaded to a machine belonging to only one specific equipment TYPE. The smaller "m" becomes, the higher priority order has the equipment TYPE. Select the machines satisfying the above condition based on the priority order, and assign the parts satisfying (S42) to the selected machines (S43).  
15 When a present loadable part quantity of the machine is greater than zero (S45),  $NUM(M(s)) > 0$ , supplement the machine to a partial line L(m) corresponding to the equipment TYPE T(m) (S46).

Change an equipment TYPE based on the priority order until all the parts satisfy the condition of (S42), and execute the same process (S47). If  
20 some part cannot meet any equipment TYPE, then return the part to the part assignment table (S48).

Process the remained parts on AR (n) (S5). The details of S5 is explained by referring to Fig. 6.

Take out any single part from AR(n) (S51), and judge whether the part  
25 can be loaded to a machine of the equipment TYPE T(m) belonging to the equipment GROUP G(n) (S52). When a machine M satisfies the above



condition and also belongs to the existing partial line  $L(m)$  (S53), and an assignment results in  $NUM(M) > 0$ , i.e. the present loadable part quantity is greater than zero (S54), assign the part to the machine.

When the part does not satisfy the above (S52) condition, degrade the  
5 priority order one by one, and execute the same process. If some unassignable parts remain (S55), supplement a new machine to the partial line  $L(m)$  (S56).

After such a process, i.e. take out any single part from a part assignment table and assign it to a machine, is successively executed until  
10 all parts are assigned (S57), move on to Process 3.

Process 3 is detailed by referring to Fig. 7. Integrate the partial lines set up type-wise in Process 2 into one of a line of the equipment GROUP  $G(n)$  (S6). Then, smooth out the line (S7) so that differences between tact times may be minimized. The total tact time of each machine is a sum of a  
15 loading tact, tool change tact listed on the equipment master 23, and part mounting tact  $\times$  quantity listed on the equipment operation 24. The tact time of a line is the longest tact time of the machines.

When a line tact time does not satisfy the initial line tact time (S8), supplement a machine based on the priority order of equipment GROUP,  
20 equipment TYPE, and machine, in this order.

Smooth out the supplemented line, and when a reduced rate of the line tact time is greater than the set value, S8 judgment is given, and when the reduced rate is less than the set value, remove the supplemented machine from the line.

25 Execute the end process (S11) to each line, and write computation results into the control information (S12) to end the entire process.

### Industrial Applicability

According to the present information, when producing a specific PCB by plural mounting equipment, a line composition of which tact time is less than the initial set tact time can be automatically determined. Thus the present invention can save a lot of time and labor which a conventional method by manual work requires.

In planning an annual business plan, a common line composition is needed for plural types of PCBs. For this case, the present invention can repeat calculations automatically for every type of PCBs until the tact times of all types of PCBs are satisfied.

The present invention enable any staff in the factory to find a line composition through inputting control information. Therefore, it is not any more necessary to rely on a skilled person about the mounting conditions of equipment for determining the line composition.

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What is claimed is:

1. An equipment operation method which determines a line composition by selecting appropriate machines from groups of equipment for processing designated products so that a tact time of an assembly line may not exceed a desirable time, said operation comprising the steps of:

Step 1. Grouping machines into plural groups based on a priority order of assigning parts to each machine considering the machines' features, and then storing such data into an outside memory as the priority orders within each group, a priority order between the groups, a mounting tact time of each loadable part to a machine, and tact time information proper to each machine.

Step 2. Calculating a tact time of each assembly line using the stored data after determining a line composition through selecting machines based on the priority order until all necessary parts for processing the product are loaded to the machines.

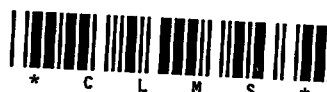
Step 3. Supplementing machines to the line composition determined in Step 2 through machine selection based on the priority order until the tact time of the assembly line becomes not more than a desirable time, and calculating the tact time of the assembly line.

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2. An equipment operation method which determines a line composition by selecting appropriate mounting machines from groups of mounting equipment for mounting electronic parts to a designated printed circuit board (PCB) so that a tact time of an assembly line may not exceed a desirable time, said operation method comprising the following the steps of:

25

Step 1. Grouping the machines of the mounting equipment



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into plural groups based on a priority order of assigning electronic parts to each machine considering the machines' features, and then storing such data into an outside memory as the priority orders within each group, a priority order between the groups, a mounting tact time of each loadable electronic  
5 part to a mounting machine, and tact time information proper to each mounting machine.

Step 2. Calculating a tact time of each assembly line using the stored data after determining a line composition through selecting machines based on the priority order until all necessary electronic parts to be mounted  
10 on to the designated PCB are loaded to the mounting machines.

Step 3. Supplementing mounting machines to the line composition determined in Step 2 through machine selection based on the priority order until the tact time of the assembly line becomes not more than a desirable time, and calculating the tact time of the assembly line.

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