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Design of Time-Way for "H" Configuration of Eletroplating machine

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Abstract—**Design of Time-Way for electroplating machine is a complicated job especially in "H" configuration machine. Experienced engineer are the designers for these job. However, not only the result is not accurated, but also cause more setup time. This paper describes techniques to design Time-Way for cyclic hoist scheduling (CHS) of electroplating machine, which have an "H" configuration lay out. Tree search algorithm has been used to generate a machine sequence. An expert system based on engineer knowledge is used with tree search algorithm in order to generate a Time-Way. These techniques cannot guarantee the minimal cycle time for hoist scheduling problems. The results can be used very well in real industrial problems. These techniques give more accuracy; more efficiency and less setup time when compare to the design of Time-Way by engineers.**

Keyword:* *Cyclic hoist scheduling problem / Time-Way / Expert system

I. INTRODUCTION

A Plating machine is a machine that is designed for the metal surface plating industry. Generally the machine is designed to have chemical tanks and water rise tanks in line arrangement. There are hoists for lifting products from one tank to another. The hoist will travel on track. Hoists may have more than one set. Hoists that run on the same track cannot run opposite (Cross over) to each other and each hoist will have a working range that has been defined (Zoned). Which will subject to engineers who design a plating machine. This device is called an "I" configuration plating machine.

For the plating machine which require very long plating time, will be designed to have a lot of plating tank and if the tank placement is in vertical depth, it will require long area. So, there is a parallel arrangement for plating tank to reduce the overall length. And design the transfers mechanical to work between the parallel machines. This type of plating machine is called as an "H" configuration plating machine as illustration in Fig. 1 and the design of time-way for "H" configuration plating machine will have more specifications than the design requirements of plating machine with "I" configurations.

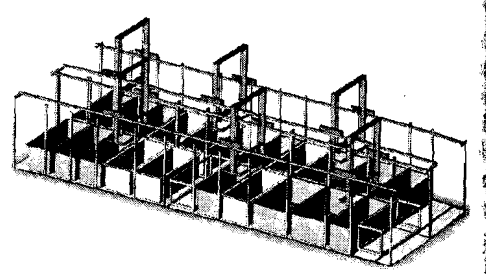

Figure 1. **"H" configuration electroplating machine.**

II. LITERTURE REVIEW

Study of Time-Way chart design for the plating ma[...] has began since 1976 by Phillips and Unger (1976) res[...] using Mixed-integer programming to find the optimal [...] time of a plating machine with one hoist and 13 Pl[...] process tanks. All of the research from Baptiste, Le[...] and. Varnier (1992) and research of Manier, et al. ([...] have studied in the case of multi hoists by using [...] constraint logic programming implemented with Prolog [...] solve the specification problems of the machine and pla[...] working combination of hoists to prevent collision. Pro[...] solving is similar to Branch and Bound algorithm, [...] assigning each branch decide troubleshooting in each [...] of work. And results from the search tree will be the [...] that hoists will work. All research explained the desi[...] Time-way of "I" Configuration plating machine, b[...] printed circuit boards manufacturing also use [...] configuration machine. This research is study incl[...] plating machine in "H" configuration.

III. SCOPE OF WORK

This research study Time-Way graph for printed ci[...] boards plating machine with scope of the following.

Plating machine could have multiple hoists running [...] same track with a multi position tank. The time required [...] each tank will be duration of time (Time-Windows) and [...] the "H" configuration arrangement. Scope of the resear[...] considered close to plating machine that is used in pri[...] circuit boards manufacturing.

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IV. DESIGN OF TIME-WAY

This research began to studied design of Time-Way for ic plating machine. Minimum cycle time and maximum le time which the machine could do has been calculated using physical requirements of hoist and timing of each k (Time-Windows) from the following equations.

$$\alpha = (N_s \times T_s) + T_f \quad (1)$$

$$\beta_0 = Max(L_i) + (2.5 \times T_s) \quad (2)$$

$$X_1 = Max(\alpha, \beta_0) \quad (3)$$

$$Y_1 = 3 \times X_1 \quad (4)$$

When i = 1,2,3,...n
n is normal tank

In a case there are multi position tank. The equations will as follows.

$$\beta_1 = \frac{(2.5 \times T_s) + Max(T_j)}{N_j} \quad (5)$$

$$\gamma_j = \left(\frac{U_j}{N_j - 1} \right) \quad (6)$$

$$X_2 = Max(\alpha, \beta_0, \beta_1) \quad (7)$$

$$Y_2 = Min(\gamma_j) \quad (8)$$

When j = 1,2,3,.... m
m is set of multi position tanks

ch parameter could be described as followings
is the minimum cycle time to consider the transfer steps of plating process.
is the minimum cycle time determined by time requirements of normal tank.
is the minimum cycle time determined by the time requirements of multi position tank.
is the maximum cycle time consider from the time requirements of multi position tank.
is maximum acceptable time of the normal tank.
is the number of transfer steps in the process.
is the number of multi position tank.
T_f is travel time for empty hoist to return to start tank.
T_j is the minimum immersion time of multi position tank.
T_s is 1 step transfer time requirement.
U_j is maximum immersion time of multi position tank.
X_1 is the minimum cycle time in case of a basic plating line.
Y_1 is the maximum cycle time in case of a basic plating line.
X_2 is the minimum cycle time in case of a plating line with multi position tanks.
Y_2 is the maximum cycle time in case of a plating line with multi position tanks.

A. Search Tree for the problem solving of basic plating machine.

Begin by defining the machine step to be a node and set the loading step to be node 1 and the starting node. After that, start search through each node without go back

While searching in each direction, nodes will be rearranged and check the possibility to sort the node in defined cycle time in same time.

Example 1. For the 4 steps of plating machine. The arrangement method and verification will be as followings.

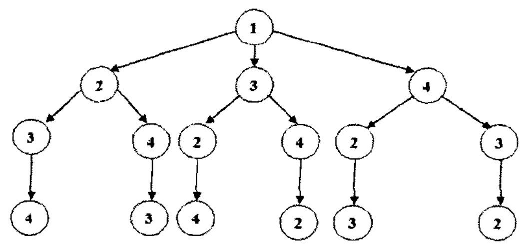

Figure 2. Tree chart for 4 nodes, starting from node 1.

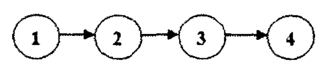

Figure 3. First path of search tree.

We will begin the search path at node 1 as in Fig. 3, each node represent 1 machine step. So we can use the start time of each step to put in the time axis (Time line) by setting the start time for the calculation to be center of required time for each tank. So start time is the midpoint (Mid) of the required time. Maximum required time for each tank is Max, and when minimum required time for each tank is Min as illustration in Fig. 4.

And the beginning cycle time will get from calculation of minimum cycle time. From example in Fig. 4, continuous node will be placed into time axis start from node 1 until node 4, node which an operation exceeds the cycle time will be provided into the next cycle time. As illustration in Fig. 5.

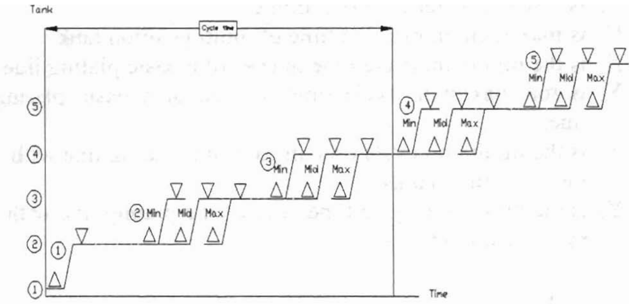

Figure 4. Sequence of 4 nodes in the time line.

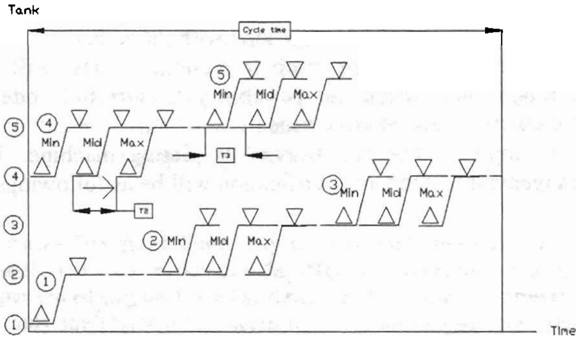

Figure 5 Arranging of node within cycle time.

At Mid position is the start of working point which be defined for calculation in the beginning. When all of nodes have arranged in one cycle time. We will see that there is overlapping run simultaneously from Fig. 4, they are node 4 and node 1, which 1 hoist cannot do 2 works at the same time. So, there have to be move of some node away. The example is to move node 4. When moving node 4 can move away without making the time of plating tanks are outside the scope of the relevant period, the time will be.

$$\Delta T_{sf} = \Delta T_{sb} = Min(T_2, T_3) \qquad (9)$$

Each parameter can be explained as follows.

ΔT_{sf} is the possible time to move a node, in case of moving forward.

ΔT_{sb} is the possible time to move a node, in the case of moving backward.

T_2 is the possible time to move a node without any effect to plating time to be out of defined time for that tank.

T_3 is the possible time to move a node without any effect to plating time to be out of defined time for next tank.

To verify that the node can be moved successfully or not, will compare with the time that hoist will move to work at that node after the end of the previous node. The time the hoist needs is T1.

$$T_1 = (|D_T - C_T| - 1) \times F_s + S_s \qquad (10)$$

Parameters could be described as follows.

T_1 is the time that hoist need to move to work in next node.

D_T is tank which hoist will move to work in next node.

C_T is current tank which hoist parking.

F_s is the time to traveling 1 tank at a maximum speed of the hoist. Unit is seconds per tank.

S_s is the time to traveling 1 tank at the minimum speed of the hoists. Unit is seconds per tank.

From equation (10) time T_1 was used to verify the success moving of node. Every time that moving the node will calculate the value T_1, if $T_1 < \Delta T_{sf}$ or if $T_1 < \Delta T_{sb}$ the node movement is successful, if $T_1 > \Delta T_{sf}$ or if $T_1 > \Delta T_{sb}$ is considered a movement of node is failed. Will out from the result searching of this root node and search in the next root node. If all nodes has been searched and cannot find the result, will increase the cycle time further 1 second and start the process of searching result again. If still cannot find the result, will increase the cycle time. More and more until reach maximum cycle time to stop the search. Search result will be achieved when all nodes to be put in the cycle time and hoists can then run to work every node. After finish putting nodes in the cycle time, will calculate the actual time in each tank. And present in the time chart.

B. Verifying of Hoist collision.

The algorithm is, check the location of each hoist in each step in time axis, then subtract the position of nearest hoist and compare the result to the distance of the hoists that not collide (Hoist gap).

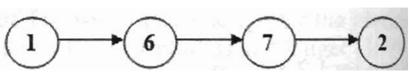

Figure 6. Node arrangement of hoist A.

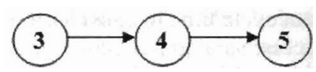

Figure 7. Node arrangement of hoist B.

Example 2. The plating machine has 2 hoists and 7 machine steps after get the node arrangement from tree search as illustration in Fig. 6 for hoist A and Fig. 7 for hoist B. Will have the collision check as followings.

- Set the position in time axis at each hoist park to be L1,L2, L3, ..., L14 as shown in Fig. 8.

- Find the first step of each hoist locate in which location of time axis. As illustration in Fig. 8 first step of hoist A is at L1 tank 1, hoist B is at L3 tank 5. Difference of tank is 5 - 1 = 4 which 4 > 2, so this position will have no collision.
- Consider to next steps of the hoists which are in position before the time axis. A sample from the hoist A, which the position is before the time axis and next step of hoist A is L2 tank 4 compared with hoist B which locate at L3 tank 5. The difference of tank is 5 to 4 = 1, which 1 < 2 show that this position has collision of hoists. Can be concluded that the arrangement of node illustration in Fig. 6 and Fig. 7 cannot do the hoist scheduling.
- There is another case of difference of hoist position less than the "Hoist gap". Which should be concluded that the hoists will crash in that time period. But in reality, could add more sequence to let hoist run away from each other. For example at the time that hoist B locate at L12 tank 3, hoist A is at L13 tank 4 , a difference of 4 to 3 = 1, 1 < 2, but can add machine step to hoist B after node 5 to move to tank 7 and waiting at time T2 and hoist A waiting at time T1 at tank 1 before do the next step. work of hoist A and hoist B added that this will not be specify in beginning of defining plating process, so that when hoist A at tank 4 hoist B at tank 7. The difference of tank is 7 to 4 = 3, 3 > 2 makes no collision at this time.

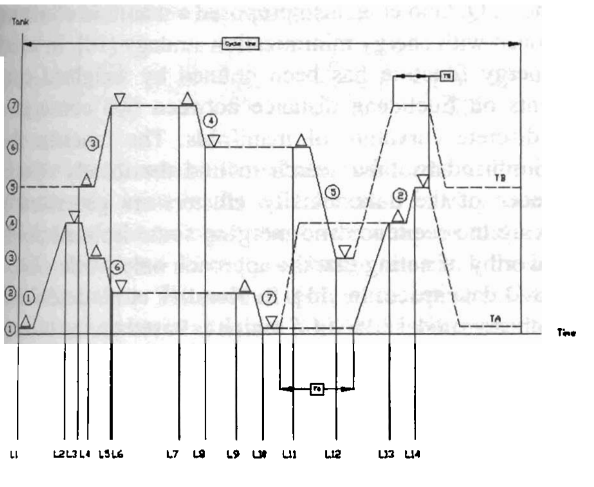

Figure 8. The collision check.

C. *The solution of problems for plating machine with "H" configuration*

A study of past problems in a case that "I" Configuration machine in this section will consider the problem of "H" Configuration machine, which having tanks to transfer products between two "I" Configuration machines. The hoist scheduling will use algorithm as "I" Configuration machine but only choose the result of tree search that hoists are not run cross over the transfer tanks, while its active work. The same approach is used to check the collision of the hoist and transfers. The transfer assumed to be a hoist and consider the active step in the time axis for collision check.

V. TEST RESULT

TABLE I. TEST RESULTS

Design by	Search time	Cycle time		Imm. time		Test time	Rework time
		Graph	Actual	Graph	Actual		
Software	4:00:00	0:04:08	0:04:08	In range	In range	3:00:00	-
Engineer	4:30:00	0:04:30	0:04:08	In range	Out of range	3:00:00	3:00:00

Time unit in table is hour: minute: seconds

From experiments with a Pattern plating process, which has 5 hoists. The results will be compared with the design Time-Way by engineers at the in Table I compares the data consists of "Search time" comparison of the design performance, "Cycle time" and "Imm. time" comparison the accuracy of Time-Way and "Test time" and "Rework time" the result will be comparison down time of the machine during test run new Time-Way.

VI. CONCLUSION

Designing of Time-Way by these algorithm spent less time to find the result comparision with designing by engineers. The accuracy of Time-Way is better. These algorithm is also designed using less cycle time of plating machine which enhancing the productivity of the machine. Time-Way design by this algorithm also increases the value of a plating machine. The Time-Way design could be done for many processes and saved in the computer and downloaded to plating machine when required.

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