IMPROVEMENT OF HEURISTIC METHOD FOR PRODUCTION PLANNING PROBLEM
IN AUTO PARTS SUPPLIER

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Abstract
We are interested in the print process on the manufacturing processes of auto parts supplier as an actual problem. The purpose of this research is to apply our scheduling technique developed in university to the actual print process in a private corporation. Rationalization of the print process is depending on the lot sizing. The manufacturing lead time of the print process is long, and in the present method, production is done depending on worker’s experience and intuition. The construction of an efficient production system is urgent problem. Therefore, in this paper, in order to shorten the entire manufacturing lead time and to reduce the stock, we reexamine the usual method of the lot sizing rule based on heuristic technique, and we propose the improvement method which can plan a more efficient schedule.

Keywords: Production Scheduling, Heuristic Method, Lot Sizing, Planning Substitution, Actual Print Process.

1. INTRODUCTION
The car industry which is advancing the reorganization is requiring the reform in all the business areas. Concretely, they are development of the global cooperated, the modulation of several auto parts for cost reduction and the cooperation of suppliers who enables system integration etc [1, 2]. Along with the reforms, it has been found that a lot of problems occur at the production stages. First of all, there is the development of production system for shortening the production lead time which can respond to customer’s diversified order immediately. Next, to answer such needs, it is necessary to review the mechanism of the production management such as manufacturing many varieties [3, 4]. Thus, for such improvement of the development efficiency, parts and platform share is newly caused. Accordingly, we should review the whole of production system [5, 6].

The flow of automakers from customer’s order to maker’s shipment is as follows. Automaker M-CO receives various parts delivery from the first supplier. Here, the depository means a warehouse which stores meter sets as the product of Y-CO. This is sharing by various suppliers, and can deal with the delivery at once.

Today, one of the most important thing in this business is how control the stock efficiently. Market’s and reduction’s complication of product life cycle cause the sudden change of demand, therefore stock control is very difficult. Nowadays, customers’ needs are diversified. To survive the competition, companies should deal with the customer’s demand who requests a free customizing as much as possible. The stock production which can supply quickly invents customer’s satisfaction. On the other hand, this causes the surplus stock, and has the risk generating a big loss. If it specializes in the production on orders, the supplier will never hold the surplus stock. However, the utilization rates of the factory worsen, and to manufacture the product from the beginning, the lead time becomes very long. For the stock parts supplier, delaying the delivery date and delivering the product to the automaker is never allowed. It is necessary to establish a new production method to shorten the delivery lead time.

The production planning problem is a problem of requesting an efficient production method according to the data like MRP, the print master and production capacity. In MRP, we confirm the production quantity of delivery dates on each parts numbers. In print masters, we confirm use inks and use plates of each parts numbers. Then, by considering these data and production capacity as the constraint, the production scheduling is made (see figure 1).
2. PRODUCTION MANAGEMENT PROBLEM IN ACTUAL PRIVATE CORPORATION

2.1 Outline of Target Problem

![Diagram of manufacturing process]

Figure 2 Manufacturing process of automotive parts producing company.

We have been working on the development of an efficient production system of the automotive parts producing company which produces the meter plates. Especially, in this paper, the production planning problem in the print process of the meter plates' design is studied. Figure 2 shows the manufacturing process in the actual producing company briefly. The print process is a work to manufacture the character plates of the meter set's tachometer, speed meter and fuelmata etc. The molding process is a work to manufacture plastic parts of the reception desk acrylic, the case to cover the meter set and etc. Mounting of substrate is a work to install electronic parts into the meter sets. Parts manufactured in three processes are united by the assembly process, and the meter sets are completed. A completed product is stored to in-house storage for manufactured goods.

In the print process of the character plates, two or more character plates in one big seat are printed at the same time without printing one by one. A typical face is printed 15 times by multilayer. The ink is dried after printing once. And when ink dries, the following print is done. Here, the use inks and the use plates are decided in each process.

2.2 Business Process Modeling

We constructed the business process modeling of the print process, and grasped the actual condition. By constructing the business process modeling of the print process, making the business visible becomes possible, and the recognition of realities can be advanced easily. From our recognition of business realities in print process, the following problems are clarified.

1. **Formation of large lot**: On the factory, the lot sizing is carried out in order to cut down the planning substitutions. Formation of the large lot can reduce the planning substitution. However, to print the design of the following delivery date, it causes a lot of stock.

2. **Extension of the manufacturing lead time**: In print process, to raise the productive efficiency, production process is bringing together the plates which use the same edition and the process which uses the same color ink. This is done although their delivery date are later. Because these production proceeds than the delivery date, the unnecessary things in now are made together. As a result, the manufacturing lead time becomes long.

3. **Uncertainty of know-how for lot sizing**: In current print process, the lot sizing has been done by relying on the worker's intuition and experience. Shortening at the lead time from the order to the delivery is the most essential subject. It is necessary to clarify the know-how for doing the lot sizing.

2.3 Analysis of Current State

By the data analysis of the print process, the following know-how is clarified.

1. The print process adopts the method of paying in installments. The size of lot is enlarged as much as possible. To keep the delivery date, the manufacturer has to produce a required product each time.

2. In the factory, producers give priority to the reduction in the planning substitution frequency, and the lot sizing is done. Its purpose is to raise utilization rates. However it has the critical fault; products which should be delivered later are also contained to the same lot sizing together.

3. As a result of the lot sizing, printed seats are divided into three if the total is about 1000. Similarly, they are divided into two if the total is about hundreds. If the total is 100 or less, they are not divided. This reason is that when the products without the division of the lot are turned to the line, other things cannot be produced, and they may break their delivery date.

4. The line product seats over the production instruction amount from 50 to 70. The reason is to cope with the change of the demand. It is not possible to reproduce if there is lack in the product.
Table 1 Example of problem and solution in lot sizing problem.

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Table: Example of problem and solution in lot sizing problem.

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(5) The production line decreases the planning substitution frequency by doing the lot sizing according to the same inks or the same editions.

2.4 Scheduling Technique

In this section, the production planning problem to minimize the frequency of planning substitution is examined. There are two methods of lot sizing in this case. One method is to bring together the parts which both the kind of inks and editions are the same, the other method is to bring together the parts which only the kind of inks is the same. Now, most important thing in the lot sizing is which kind of inks to select when an ink changes, an edition often changes too. Therefore, we manage the lot sizing as much as possible according to the kind of inks. And, we shorten the time required to planning substitution.

Table 1 shows a concrete example. The left table (1-a) is a state before planning, and the center table (1-b) is a state after planning. Kinds of parts are expressed from A to E, and the process is expressed from 1 to 6. In each process of parts, alphabets are shown as the inks. The solution in table 1 is obtained by the usual method.

Procedures of the usual method are expressed as follows. First of all, the usual method consider occurrence counts (1-c) of inks and select an ink with the highest frequency. In the case of table 1, from the result of calculating occurrence count of each ink, the ink with the most occurrence counts is cleared "a". Therefore, ink "a" is brought together as much as possible. And, the ink brought together is never divided; this processing is repeated according to the occurrence count. This method pay attention to only the occurrence count, processes excluding this are done at random. It is necessary to set a clear rule to obtain an effective solution of the lot sizing.

3. IMPROVEMENT OF HURISTIC METHOD

3.1 Formulation

The component and the formulation of the lot sizing in the print process are shown as follows. The lot sizing problem can be formulated for a single stage with infinite production capacity and a single machine to be planned.

Input data

\[ I_p^j \] : The \( j \)th print process in the parts \( P \)
\[ x_p^j \] : Printing time of \( I_p^j \)
\[ s_p^j \] : The time for print to begin of \( I_p^j \)

\[ C_p^j \] : The cost exchanging ink at \( s_p^j \), \( j = 1, 2, \ldots, J, \ p = 0, 1, 2, \ldots, P \)

Set

\[ W = \{ 1, 2, \ldots, P \} \] : The set of parts
\[ P = \{ I_1^p, I_2^p, \ldots, I_M^p \} \] : The set of print process for which one parts is necessary

\[ \text{Minimize} \quad \sum_{j=1}^{J} \sum_{p=1}^{P} C_p^j, \quad (1) \]

Subject to

\[ s_{p+1}^j > s_p^j + x_p^j, \quad (2) \]
\[ s_p^j + x_p^j - s_{p-1}^j = 0; \forall I_p^j, \forall I_p^j \in W. \quad (3) \]

Where equation (2) expresses the relation of the early order, equation (3) express that the machine does not have idle time. \( s_p^j \) indicates the beginning time of job \( I_p^j \) which processed immediately before job \( I_q^j \) which begins processing at time \( s_p^j \). \( C_p^j \) is \( C_p^j = 0 \) when \( I_p^j = I_q^j \), and when \( I_p^j \neq I_q^j, C_p^j \) is \( C_p^j > 0 \). Here, in the problem handling in this research, it is defined that the print time of all processes \( s_p^j \) and the cost exchanging ink \( C_p^j \) is the same.

3.2 Approximate Solution

3.2.1 The usual method

A heuristic rule is considered by solving multi case problems repeatedly. The procedure for the lot sizing is shown as follows. To begin with, we define the sets \( P_e \in P \) and \( P_o \in P \). At each iteration time, executable job set \( P_e \) is decided, then sets of jobs evaluated by our heuristic rule are \( P_o \).

Set

\[ P_e : \text{The set of executable print process} \ I_p^j \]
\[ P_o : \text{The set of evaluated print process} \ I_p^j \]

Procedures 1

1. BEGIN
2. IF \( P_e \neq \emptyset \)
3. \( |P_o| = 0 \); \( \emptyset \)
4. BEGIN
5. IF \( |P_e| \neq |P_o| \)
6. Evaluation of \( \forall I_p^j \in P_e \)
   based on Rule A, Rule B or Rule C;
7. Update of \( P_0 \);
8. ELSE
9. END OF RETURN ;
10. RETURN
11. Arrangement of \( \forall f_j^0 \in P_0 ; \)
12. Update of \( P_0 ; \)
13. ELSE
14. END OF RETURN ;
15. RETURN

We explain the priority level of Rule A as follows. Here the priority indicates that it is higher if the numerical value is small. The function \( f_c(I_j^0, \forall I_j^0) \) gives that if \( I_j^0 = \forall I_j^0 \), its output value is 1, in the cases of other, the output value is 0.

The priority is set as 1 if the same ink is used continuously in the parts. By selecting the inks which are already settled, the necessary inks in the processing after this become to be settled with the inks in other parts easily.

The priority is set as 2 if the process using the same ink in the parts does not exist at the later. The possibility doing the lot sizing of the case which the same ink does not exist in the later process is lower than that the case which the same ink exist. Therefore, selecting it on the early step, the using ink is made easy to bring with the inks of other parts.

The priority is set as 3 if the process using the same ink in the parts exists several times. Where the sum of the function \( f_c \) is larger, the priority is lower. This is set for the reason why the possibility doing the lot sizing of such ink is very high. That is, the existing frequency is higher, the order is lower.

The priority is set as 4 when the same ink exists until two steps later from this process in other parts. The value of steps as two is selected according to experience by experimenting on the problem repeatedly.

Priority level of Rule A
(1) \( I_j^0 = I_j - 1 \); \( j \neq 1, \forall I_j^0 \in P_0 \)
(2) \( I_j^0 \neq I_j - 1 \); \( i = j + 1, j + 2, \ldots, M_p, \forall p \in P \)
(3) \( \sum_{i=j+1}^{M_p} f_c(I_j^0, \forall I_j^0) ; \forall p \in P \)
(4) \( I_j^0 = \forall I_j^0 + 2 \); \( p \neq q, \forall I_j^0 \in P_0 \)

In addition to the usual method, the improved selection rule as the priority level of Rule B is added. We explain the priority level of Rule B as follows. As we examine the problem of many cases, to examine until the three steps later can obtain a better result than until the two steps later is understood.

We prepared two improvement methods as follows. Where \( P_{e+n} \) is the set of jobs which are \( n \) steps later from the jobs in set \( P_0 \). The priority 1 at Rule B and Rule C denotes that the occurrence count of the job which uses the same ink as \( I_j^0 \) is one time in \( W \). The priority 3 ~ 5 expresses that there is the job \( I_j^0 \) which use the same ink as \( I_j^0 \) at \( n \) steps later in other parts.

Priority level of Rule B (improvement 1)
(1) \( I_j^0 \neq I_j^0 \); \( \forall I_j^0 \in P_0, \forall I_j^0 \in W \)
(2) \( 1 \sim 3 \) at Rule A

Priority level of Rule C (improvement 2)
(1) \( I_j^0 \neq I_j^0 \); \( \forall I_j^0 \in P_0, \forall I_j^0 \in W \)
(2) \( 1 \sim 3 \) at Rule A
(3) \( I_j^0 = I_j^0 \); \( p \neq q, \forall I_j^0 \in P_0 \)
(4) \( I_j^0 = \forall I_j^0 \); \( p \neq q, \forall I_j^0 \in P_0 \)
(5) \( I_j^0 = \forall I_j^0 \); \( p \neq q, \forall I_j^0 \in P_0 \)

Here, as a result of the calculation, the ink is selected arbitrarily if all the order of priority becomes the same.

3.2.2 Proposal method
Some matters for the search of solution on improved method are reported. A critical matter is to gather the planning substitution locally. We thought that local search technique from forward of early order causes it. In this paper, we propose the search method which optimizes the schedule obtained improvement 2 to solve the difficulty.

The procedure is shown as follows. Proposal method searches just reversing the order of preceding each part. From schedule \( S \) obtained improvement 2, the set of executable job \( P_e \) obeying the reversing order is taken out. The schedule to which \( P_e \) is taken out is assumed to be \( S_f \). Then \( P_e \) is planned by improvement 2, as a result, the obtained schedule is assumed to be \( S_f \). Here, \( S_f \) is a function which outputs the frequency of planning substitution from schedule.

Finally, \( S_f \) is combined with \( S_f \). The pattern is enumerated as long as the restriction of the early order in each part is kept, the schedule with minimum substitution is chosen. When two or more schedules with the same planning substitution appear, they are maintained up to the setting capacity, and carried over to the next step.

Procedures 2
1. \( LS(S) \);
2. BEGIN
3. IF \( P_e \neq \emptyset \)
4. Decision of \( S_f(S_f \in S, \hat{P}_k \notin S_f) \);
5. Evaluation and Arrangement \( \forall I_j^0 \in \hat{P}_k \)
Based on Procedures 1;
6. Update of \( \hat{S}_f \);
7. IF \( LS(S_f+S_f) \leq LS(S) \)
8. \( S=S_f+S_f \);
9. \( LS(S) \);
10. Update of \( \hat{P}_k \);
11. ELSE
12. END OF RETURN ;
13. RETURN
4. SIMULATION RESULTS
4.1 Simulation Conditions
Our model is simulated by using actual obtained data in the print process. In the problem used for the simulation,
its data is pulled out from the manufacturing history trace according to parts and made. There are two kinds of methods of pulling out data, one is a method of the attention in a specific day, another is a method of providing a constant period and planning production. Especially, the latter case is done in the business on an actual print process by this form, therefore it can be said that it is a more realistic case. In this paper, we simulate the latter case. Table 2 expresses an example. The period of simulation is set a week similar to the actual work. In table 2, the alphabets written in each process of parts are corresponding to the color of ink used by the actual factory.

4.2 Result for Actual Print Process

Table 3 shows the schedule of the planning print process as the simulation result. Here, at each time, it is possible to confirm what kind of ink is actually used. All steps are 237, steps are shown by dividing into three by 1 ~ 79, 80 ~ 158 and 159 ~ 237. In each step, the every particular items from the left are the part number, the processing order, the use ink, and the frequency of planning substitution. The number of planning substitution is the item which should be paid attention, therefore to make easily to consider, the part whose substitution is done reverses the color. Where, (1) expresses a solution by using the method based on Rule A, (2) is expresses a solution by using the method based on Rule B and (3) is expresses a solution by using proposed method.

From the result of simulation, we can confirm that the frequency of planning substitution is 68 times at the improvement 1, 65 times at the improvement 2 and 51 times at the proposal method. Especially in the proposal method, There is not a series of over three substitutions. This means that the proposal method can solve the difficulty of improvement 1 and 2 on which substitution concentrates locally. Thus, it has been understood that we can obtain an effective solution by using proposed method. Considering the necessary time for a planning substitution is about 20 minutes or less, shortening of about 25% from improvement 2 is very worthy.

5. CONCLUSION

In this study, we grasped the actual business in the print process which a part supplier has. And we proposed a heuristic solution method for the production planning problem. To begin with, by the business realities grasping on an actual factory, we proposed a new know-how. So far, the workers depended on his experience and intuition when they worked in the print process. To this, we proposed a clear rule as the selection rule of the lot sizing. Moreover we applied the proposal method to the concrete problem, its effectiveness is confirmed. In simulation, we used the data that the print process had actually done. From comparison with the results of obtaining by the simulation and the actual production, we were able to show the effectiveness of our logic.

References

Table 3 Simulation result

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