A Study on Integration of Process Planning and scheduling system for Holonic manufacturing – Modification of process plans with load balancing of machining equipment –

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A systematic method was proposed in the previous paper to obtain suitable process plans for individual products using a stepwise method of GA (Genetic Algorithm) and DP (Dynamic Programming), and to generate a suitable schedule using the methods of GA and DR (Dispatching Rule) for the entire products. In this research, the process plans of the individual product are modified with the help of the feedback information of the generated schedule. A systematic method based on the DP and the heuristic rule is proposed to modify the predetermined process plans, based on the load balancing of the machining equipment.

1. Introduction

To cope with the customers’ need, manufacturing has changed from mass production to batch productions. In case of small batch productions with dynamic changes in volumes and varieties of products, the conventional manufacturing systems are not adaptable, and thus new architectures of manufacturing system has been proposed which can cope with not only only dynamic changes in volumes and varieties of products, but also unscheduled disruptions. One of such manufacturing system is holonic manufacturing system.

In the previous papers[1][2], a systematic method was proposed to obtain suitable process plans for individual products using a stepwise method of genetic algorithm (GA) and dynamic programming method (DP), and to generate a suitable schedule using the methods of GA and dispatching rule (DR) for the entire products. In this research, the process plans of the individual product are modified with the help of the feedback information of the generated schedule. A systematic method based on the DP and the heuristic rule is proposed to modify the predetermined process plans, based on the load balancing of the machining equipment.

2. Objective Function

This research deals concurrently with both the process planning of the individual products, which are called, jobs, and the scheduling of all the jobs to be manufactured in the HMS. The following objective functions are considered for the scheduling task of the HMS.

(1) Make span: MS
(2) Total machining cost: TMC
(3) Weighted tardiness cost: WTC

3. Scheduling based on dispatching rules

A set of dispatching rules is adopted, in the research, for solving the scheduling problems. The dispatching rules give the priority to one job against all the candidate jobs that are waiting for the machining process of the manufacturing equipment.

Let the j-th process of the i-th waiting job be denoted by OP_{ij}(k), (i = 1, 2, …, m) and its processing time of the machining process be \( MAT_{ij}(k) \). Three different dispatching rules are applied to the waiting jobs.

(1) SPT (Shortest Processing Time)

This rule selects a job, which has the shortest processing time of the next machining process. If the processing time of the next process is \( MAT_{ij}(k) \), then the i-th job with the minimum value \( A_{i} \) in Eq.(1) is chosen as per SPT.

\[ A_{i} = MAT_{ij}(k) \] (1)

(2) SPT/TWKR (Shortest Processing Time / Total Work Remaining):

This rule selects a job, which has the lowest ratio of the processing time of the next machining process and the total remaining processing time of the remaining machining processes. If the processing time of the next process is \( MAT_{ij}(k) \), then the i-th job with the minimum value \( B_{i} \) in Eq. (2) is chosen as per SPT/TWKR.

\[ B_{i} = \frac{MAT_{ij}(k)}{\sum_{q=1}^{m} MAT_{iq}(k)} \] (2)

(3) Apparent Tardiness Cost (ATC):

The ATC rule is a composite dispatching rule that takes into account the due times, the weights and the processing times of the jobs. It gives a priority index called ATC for all the jobs. ATC index is given in Eq. (3).

\[ ATC_{i} = \frac{W_{i}}{MAT_{ij}(k)} \exp\left( - \frac{\max\{TD_{i} - C_{i} - t_{j}, 0\}}{\delta \times P} \right) \] (3)

where, 
ATC_{i}: ATC index for the i-th job.
\( W_{i} \): Waiting time of the i-th job.
\( MAT_{ij}(k) \): Processing time of the next machining process of the i-th job.
\( C_{i} \): Total remaining processing time of the i-th job.
\( TD_{i} \): Due time for the i-th job.
\( t_{j} \): Present time.
\( \delta \): Parameter that determines the impact of weights versus the slack, and \( \delta \) shall be 3.
p: Average of the total remaining processing time of all the waiting jobs.

4. Scheduler driven modification of Process Plans

4.1 Modification process

In the previous research[1][2], the integration between the process planning and scheduling was carried out such that the scheduling holon for multi-products used the process plan information obtained from the individual product holons to generate a suitable schedule, but the individual product holons did not use the feedback information from the scheduling holon.
4.2 Load balancing

The load balancing means here to reallocate all the machining features and their machining processes to the suitable machining equipment, in order that the load of all the machining equipment is well balanced, taking into consideration of the entire alternative machining equipment for the machining features.

The following steps are being taken during the load balancing.

STEP 1 Generation of load chart: The load chart of all the machining equipment is drawn based on the scheduling results.

STEP 2 Calculation of average balanced load: The average balanced load (ABL) is estimated from the load chart, based on the following equation.

\[
ABL = \frac{\sum \sum MAT_{ij}^{(k)}}{N}
\]

where,

i: ID of the job holon.

ej: ID of the machining features machined by the j-th position in the machining sequence.

k: ID of the process plans of the job holon i, which is selected in the scheduling process.

N: Total number of machining equipment.

STEP 3 Selection of machining equipment to be reallocated: The machining equipment with the maximum load is selected, which is reallocated first. The reallocation process is carried out step-by-step from the machining equipment with large load in the load chart.

STEP 4 Reallocation of machining features to selected machining equipment: The machining features are reallocated to the machining equipment selected in the STEP 3. There are many machining features to be reallocated, therefore, a heuristic rule is applied to the reallocation process. The LPT (Longest Processing Time) rule is used in the research to determine the machining features to be loaded to the selected machining equipment.

STEP5 Termination of reallocation process: The reallocation process is terminated, just before the load of the selected sets of feasible machining sequences of the machining features are generated applying GA, which can satisfy the constraints of the preference relations among the machining features. The DP method is then applied to minimize the objective function that is the normalized machining time and machining cost considering the future schedule of the machining equipment. GA and DP method is repeated again and again until the most suitable machining sequences and sequences of machining equipment are obtained.

4.3 Selection of suitable machining equipment

All the job holons are required to generate new sequences of the machining equipment under the constraints determined in the load balancing process.

The dynamic programming method is adopted to generate the new modified sequence of machining equipment.

5. Case study

The algorithm has been constructed and a prototype of the process planning and scheduling system has been implemented using C++ language.

Table 1 shows the case study result for different objective functions before and after balancing. For each objective functions, the most appropriate dispatching rules are being used.

5. Conclusion

Systematic methods for load balancing of the machining equipment and for modifying the process plans are proposed in order to obtain a modified processed plan based on the feedback information about the scheduling results. A prototype of the process planning and scheduling systems has been implemented. Some case studies show that the total make span can be improved by the modified process plans obtained after the feed back information of the scheduling.

Reference
