Research on Dynamic Scheduling Arrangement of RGV in Intelligent Machining System

Qinhong Zhang*
Tongji University, China

*Corresponding author e-mail: zhangqinhong0502@tongji.edu.cn

Abstract. The intelligent machining system scheduling arrangement is through the RGV that can receive intelligent control of the system, so as to install raw materials and unload clinker for each CNC and coordinate the production of CNC in the whole system. This paper analyzes the order in which work orders are issued to RGV, comprehensively uses C++ and Matlab software to explore the scheduling scheme of intelligent machining system, combines time series and genetic algorithm to research and optimize the scheme, and continuously improves after mutation, and finally gives the optimal RGV scheduling strategy.

1. The problem is raised

1.1. Background knowledge and problem generation
With the globalization of the economy, science and technology advance by leaps and bounds, modern manufacturing industry are facing a more competitive market environment. In order to meet the needs of the modern market, to meet the cruel competition and challenges from home and abroad, to adapt to the development of trend of the times, enterprises need to provide customers with the best service with the best quality in the shortest time. At the same time, the application of ultra-high-speed cutting, ultra-precision machining and other technologies, the rapid development of flexible manufacturing systems and the continuous maturity of computer integrated systems have put forward higher requirements for CNC machining technology.

CNC machine tools are important basic equipment for machine tool manufacturing, so its development has been receiving much attention. In recent years, China's machine tool manufacturing industry is facing both the good opportunity of manufacturing equipment development and the pressure of market competition. From a technical point of view, accelerating the advancement of CNC technology will be a key to solving the sustainable development of the machine tool manufacturing industry. Production scheduling has become a hot spot as production methods move toward a more agile direction.

1.2. Problems to be solved
First, general problems are studied. Taking an intelligent machining system as an example, the RGV dynamic scheduling model and the corresponding solving algorithm are given. Secondly, the practicality of the model and the effectiveness of the algorithm are respectively verified by using the three sets of data of the existing system operating parameters, the scheduling strategy of the RGV and the operating
efficiency of the system are given, it is also required to give the result of the machining operation data of one step using the given parameters for one shift of one process (i.e., 8 hours).

We have analysed the overall situation of the problem, and the specific process is shown in the following figure:

![Figure 1. Total analysis of the problem](image)

The above picture is a schematic diagram of the intelligent machining system involved in this problem, it consists of 8 computer numerical control machine tools (CNC), 1 rail-type automatic guided vehicle (RGV), 1 RGV linear track, 1 loading conveyor belt, 1 unloading conveyor belt and other auxiliary equipment. The RGV is a railcar that runs on a linear track and can automatically move and complete the loading and unloading operations according to the instructions. The RGV comes with a robot arm and two robotic grippers for placing and removing materials, and a cleaning groove for cleaning processed clinker.

CNC is used for processing materials. Since CNC can only install one type of blade at a time. When processing the materials of one process, the eight CNCs can complete the processing of the materials independently. When processing the materials of the two processes, 8 CNCs need to be divided into CNC processing the first process and the CNC replacement work of the second process can complete the material.

After a CNC completes the processing task of a material, it immediately sends a demand signal to the RGV. If the RGV fails to arrive at it immediately loading and unloading, the CNC will wait.

RGV is the core intelligent control link in the intelligent processing system, which can receive and send command signals, and then connect the whole system in series. RGV can only perform one of the
operations of moving, stopping waiting, loading and unloading and cleaning at the same time. The initial position of RGV is located between CNC1# and CNC2#. After RGV receives the demand signal of a certain CNC, it will determine the loading and unloading order of the CNC by itself and successively load and unload the CNC. According to the demand instruction, the RGV runs to a certain CNC where the operation is required, and at the same time, and the loading conveyor belt sends the raw material directly to the front of the CNC for the RGV feeding operation. The time required for the RGV to be an even numbered CNC to be loaded and unloaded at one time is greater than the time required for the odd-numbered CNC to load and unload at one time.

After the RGV completes the loading and unloading operation for a CNC, it will rotate the mechanical arm, and the clinker of one robot is moved to the top of the cleaning tank to clean the processed clinker. The time spent in the entire cleaning process is called the RGV cleaning operation time.

After completing a task, RGV immediately determines the execution of the next job instruction. At this time, if no other job command is received, the RGV waits in place until the next job command.

The loading conveyor belt moves with the RGV at any time to provide raw material for the RGV. The unloading conveyor belt transports the finished material after the final cleaning of the RGV.

2. Model assumptions and symbolic description

2.1. Model Hypothesis

(1) Assume that in the mode of processing materials in two processes, the cutter head cannot be replaced during the 8-hour single shift.

(2) It is assumed that in the mode of processing materials in two processes, the time consumed by removing the clinker from the second process CNC and not replacing the clinker from the first process CNC is fitted to a complete loading and unloading time.

(3) Since the initial position of the RGV only has a large influence on the first moving distance, it is assumed that the initial position of RGV has a negligible influence on the type and location arrangement of CNC in the two processes.

(4) Ignore the effect of random values after a fault on subsequent variability.

(5) Since the difference between the odd and even serial loading time is smaller than the moving time, the influence of the odd and even serial of CNC type and position arrangement in the two processes is ignored.

| Symbol          | Meaning                                                                 |
|-----------------|-------------------------------------------------------------------------|
| $E_{ij}$ (i=1, 2, j=1, 2...m×n) | RGV issued instructions criterion time function                        |
| $J_{in} / Ou_{in}$ (n=1, 2) | RGV loading and unloading time at the nth process CNC (odd/even)       |
| $C$              | Cleaning process time                                                   |
| $Move^{0}_{ij}$  | The initial position (i position) to the first process CNC loading and unloading position (j position) moving time |
| $Move^{1}_{ij}$  | The first process CNC loading and unloading position (i position) to the second process CNC loading and unloading position (j position) moving time |
| $Move^{2}_{ij}$  | Current position to the second process CNC loading and unloading position (i position) moving time |
| $Last_{in}$      | The remaining work time of the nth process CNC                           |
3. Model establishment and solution

3.1. Model establishment of two process flow without fault

The production of each material requires two passes of the CNC in the first process and the CNC in the second process to become clinker. Due to the cutter head cannot be replaced at any time in the process of machining, so the ratio of the time required for the 8 CNCs to complete the first process of the two process materials according to the CNC machining and the time required for the second process of the CNC machining to complete the two process materials is \( \frac{S_{21}}{S_{22}} \) to set the number distribution of CNCs for each of the two processes. The distribution scheme is as follows (the number of CNC in the first process is \( m \), the number of CNC in the second process is \( n \), and the selection of the distribution limit comes from the middle of the number ratio. value):

\[
\begin{align*}
\frac{S_{21}}{S_{22}} \leq 0.238 & \rightarrow m : n = 1 : 7 \\
0.238 < \frac{S_{21}}{S_{22}} \leq 0.467 & \rightarrow m : n = 2 : 6 \\
0.467 < \frac{S_{21}}{S_{22}} \leq 0.8 & \rightarrow m : n = 3 : 5 \\
0.8 < \frac{S_{21}}{S_{22}} \leq 1.33 & \rightarrow m : n = 4 : 4 \\
1.33 < \frac{S_{21}}{S_{22}} \leq 2.33 & \rightarrow m : n = 5 : 3 \\
2.33 < \frac{S_{21}}{S_{22}} \leq 5 & \rightarrow m : n = 6 : 2 \\
5 < \frac{S_{21}}{S_{22}} & \rightarrow m : n = 7 : 1 \\
\end{align*}
\]

Since the moving distance of RGV has an impact on the total production time, the placement location of the two CNCs will have an impact on the overall production efficiency. Considering that the eight CNCs are distributed symmetrically as a whole, on the basis of the principle of symmetry, all the placement modes of each ratio are enumerated for comparison, and each allocation scheme is placed as follows:
Table 2. Placement methods for each allocation plan

| 1:7 or 7:1 (2 possible)                  | 2:6 or 6:2 (4 possible)                  |
|-----------------------------------------|-----------------------------------------|
| ![Placement Diagram 1:7 or 7:1]          | ![Placement Diagram 2:6 or 6:2]          |
| ![Placement Diagram 3:5 or 5:3]          | ![Placement Diagram 4:4]                |
| ![Placement Diagram 3:5 or 5:3]          | ![Placement Diagram 4:4]                |

Two working procedure processing of initial stages and one procedure are the same, but when it
comes to the arrangement after the completion of the first process, since the working arrangement of
RGV at any time during the processing of the two processes involves two options, The first type, the
material processed by the first process CNC is transferred to the second process CNC that has completed
the processing, and the loading and unloading is replaced, and the clinker finished by the second process
is cleaned and sent away; Secondly, CNC is still in the processing state in the first process and there is
still some processing time before the completion of the process, at the same time, under the premise that the second process CNC is near completion, the clinker processed in the second process is replaced by the cleaning and then sent away. Construct two time functions as follows:

\[
E_{ij} = Ji / Ou_i + Ji / Ou_2 + C + \max\{Move_i^0 + Move_i^1, Last_2, \ Last_i + Move_i^1\}
\]

\[
E_{2j} = Ji / Ou_2 + C + \max\{M^2_{ij}, Last_2\}
\]

Assuming that the CNC allocation result is m first process CNC and n second process CNC, the first time function will generate a time function \(E_{ij}\) of \(m \times n\) matching results, and The second time function produces \(n\) kinds of time functions \(E_{2j}\), the \((m+1) \times n\) kinds of time function results are compared, selects the operation corresponding to the minimum time function, and schedules the RGV to obtain an initial solution.

The optimization process of the two processes is similar to the optimization process of one process. The initial solution of the RGV work sequence is also selected as the original chromosome gene. Each time node that issues a work order to the RGV is a position node that can be abruptly transformed. When solving the initial solution, the CNC or CNC combination with the smallest value in \((m+1) \times n\) time functions is selected each time to enable RGV to complete the next operation, thereby achieving local optimum.

To find a global optimal, the second and third small CNCs in each comparison are selected as the mutation mode, because the later work schedule in the RGV arrangement will change with the earlier work schedule of the time series. In the genetic principle, the pre-sequence DNA arrangement will affect the subsequent DNA arrangement. Therefore, the whole chromosome is divided into several parts from front to back, and each part is subjected to independent random mutation operation in the order from the arrival to the next. The best mutation in the segment that increases the total number of processed materials is retained. Better optimization can be achieved by increasing the number of segmentation segments and increasing the number of mutations.

3.2 Model establishment of one or two process flow processes in case of failure probability

For this problem, it needs to be considered on the basis of the former situation. So this situation involves one or two processes, when the machine CNC is in the process of processing materials, the fault may occur, and the rest of the situation is similar to the normal case without failure.

Therefore, for this case, involves the probability parameter settings key points of the three places. The first is the probability of failure in the material processing process, can be set to 1%. For the method of generating this probability, before the material is processed, the design programming produced a random integer of 1-100. If the random integer is equal to 50, then it is determined that the material will be faulty during the process. Secondly, if it is determined in the judgment of the previous step that faults will occur in the process of this machining, considering the selection of the time point of the failure, it can be seen from the time \(t\) required for machining on different CNCs.

\[
t = \begin{cases} 
S_{11} \\
S_{21} \\
S_{22}
\end{cases}
\]

Where:

\(S_{11}\) is the time required to process a one process material;

\(S_{21}\) is the time required to process the first process of a two process material;

\(S_{22}\) is the time required to process the second process of a two process material.
A random number of 0-t can be generated at the time point of failure during material processing, and the random number can be determined as the time point of failure. Finally, for the time required for troubleshooting, a random number can be generated in the time domain that may be required for troubleshooting. The random number can be determined as the troubleshooting time, and the troubleshooting time can then be added to the remaining CNC work events.

4. Evaluation of the model

4.1. Model Benefits

(1) The timer matrix is introduced to calculate the remaining working time of each CNC. On the one hand, it is easy to distinguish the working state of the CNC, and on the other hand, it has a basis for judging the disposal method of the next material.

(2) For the two groups of process scheduling problems, first consider the number of possible different types of CNC and location arrangement, and then optimize the arrangement of processing scheduling. The previous step greatly simplifies the operation and difficulty of the latter step.

(3) When failure occurs, the probability of failure, the point in time at which the fault occurred, and the time required for troubleshooting are considered, and three random numbers are introduced to represent the above parameters.

4.2. Insufficient model

(1) The objective function established by the model is the amount of clinker produced, and it is based on the limitation that the total time is fixed to eight hours, the genetic algorithm is used for optimization. In the optimization process, it is inevitable that there will be repeated processes, which increases the running time of the program. If the problem can be transformed into an optimal scheduling model under certain conditions of the number of processed materials, and then mutated and optimized for a certain length of material scheduling matrix, which will be more consistent with the rules of genetic algorithm and easier to implement.

(2) The mutation process when using the genetic algorithm only mutates the entire scheduling segment. The mutation method is too simple, and the screening efficiency for the better solution is not high enough.

(3) For the processing of different CNC number and location arrangement in the two processes, it is simply determined by calculating the ratio of time required for different types of CNC processing. The determination method is too simple, and there may be a better arrangement and algorithm to deal with it.

When step 2 need to consider the time point at which the fault occurred and the time required to troubleshoot the fault, the random number is selected to serve as the basis for determining the above parameters. In fact, the default of this method is that the time of failure and the time required for troubleshooting are subject to the uniform distribution of a certain parameter. However, in the actual situation, the distribution of the above parameters is not necessarily so, which leads to the deviation between the model and the reality.

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