Research on Dynamic Scheduling Strategy of Workshop Intelligent Processing System

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Abstract: The bilateral assembly line balancing problem of intelligent processing systems is different from the traditional one-sided assembly line balancing problem, which mainly considers the priority of tasks, the operating orientation and the requirements of bilateral parallel operations. Firstly, the core algorithm of multi-objective optimization model based on constraints is established. Secondly, the model uses the heuristic balancing algorithm based on grouping strategy to perform task grouping scheduling and task group selection. The second type of equilibrium model of the bilateral assembly line common to the two processing steps; finally, the particle swarm optimization based on the dynamic step size to obtain the system efficiency of the two process processing.

1. Introduction

As shown in Figure 1, the workshop intelligent machining system consists of 8 computer numerical control machine tools, 1 track-type automatic guided vehicle, 1 RGV linear track, 1 feeding conveyor belt, 1 feeding conveyor belt and other auxiliary equipment. This system can control the material storage and transportation, equipment processing process to improve production efficiency. Among them, RGV is an unmanned, intelligent car that can run freely on a fixed track. It can automatically control the movement, complete loading and unloading and cleaning materials according to the instructions. The specific operation process can be briefly described as follows: Before moving the RGV to an idle CNC station, the raw material is grabbed from the loading conveyor by the mechanical arm, the clinker on the table is replaced with the raw material, and the clinker is cleaned on the RGV table. The material is discharged from the robot arm to the unloading conveyor. Analysis of production schedules for the following two specific cases:

(1) The material processing operation of one process, each CNC installs the same tool, and the material can be processed on any CNC;

(2) The material processing operation of the two processes, the first and second processes of each material are processed by two different CNCs in turn;

(3) In the production scheduling of the workshop, the working efficiency of the system during the two-process material processing operation.

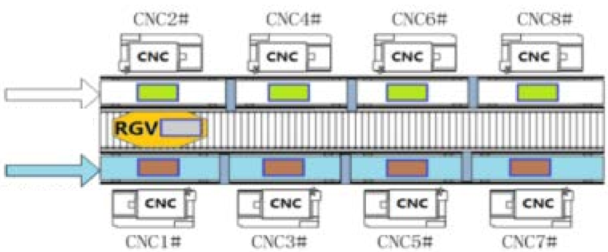

Figure 1 Schematic diagram of intelligent processing system

2. Problem analysis

RGV handling workpieces in different order of material processing operations will have a greater

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impact on the engineering efficiency of the system. Therefore, an efficient scheduling algorithm is needed to comprehensively schedule RGV and materials to optimize the job sequence and RGV execution order. The scheduling objectives for the processing system are: Determine the order of the workpieces on each CNC and the combined processing time of each process to minimize the completion time of the unit material processing operations. Therefore, a second type of equilibrium model of the bilateral assembly line is established, and multiple heuristic rules are used to derive the multi-objective optimization function, and the corresponding system efficiency is calculated. Assume that each material processing operation of RGV is defined as the following five steps:

(1) Move from the initial position of the RGV to the position of the CNC to be machined.

(2) Loading and unloading (combination of upper and lower materials).

(3) Processed materials (one or two processing steps combined).

(4) Finish cleaning of the material.

(5) Return to the initial position

3. Symbol Description

Table 1. Symbol Description

Symbol	Definition	Unit
GAMA	Repulsive force	N
H	Scope of rejection	m
k	Coefficient of body compressibility	kg/s2
chi	Coefficient of sliding friction	30000kg/s2
am	Width of simulation grid	m

4. The Model

4.1 Establishment of multi-objective optimization model based on constraints

The second type of balance problem of the bilateral assembly line is defined as [1]: given the number of stations m, a set of task sets are distributed as evenly as possible to each side of the assembly line under the relationship of the task order priority relationship and the operation direction requirements. In position, it has the shortest tact time. According to the actual problem, a multi-objective optimization model is established through a process and two processes. Define the variables of the following processing steps (j=1, 2 correspond to one or two processes):

S is a scheduling scheme; f (S) is the objective function value of the scheduling S.

The scheduling problem includes the following constraints: (1) At zero time, all processing equipments are available, and all workpieces in the material storage area can be processed; (2) At the same time, each equipment can only process one workpiece, and once (3) The processing time of each step of the workpiece is determined by the table, and no accidents occur; (4) The RGV trolley can only carry one workpiece at a time; (5) After the RGV completes the complete operation of the current dispatching operation Only start scheduling new scheduled jobs.

Establish a basic model of multi-objective optimization function for the above constraints:

$$\min f(S) = \sum_{i=1}^{N} \left[\sum_{x=1}^{n_i} \alpha_i \Delta t_{[i,x]h} + \sum_{x=1}^{n} \beta_i \Delta t_{[i,x]w} + \gamma_i \max(0, c_{[i,n_i]2} - t_{LF_I}) \right]$$

$$ST: \alpha_i \geq 0, \beta_i \geq 0, \gamma_i \geq 0;$$

$$t_{ES_i} \leq t_{[i,1]jky} = 1, 2; i = 1, 2, ..., N;$$

$$\sum_{y=1}^{m_{kj}} \sum_{k=1}^{m_j} X_{[i,x]jky} = 1, i = 1, 2, ..., N; x = 1, 2, ..., n_i; j = 1, 2$$

$$\sum_{y=1}^{N}\sum_{k=1}^{n_i} X_{[i,x]jky} = 1, j = 1,2,...,N; k = 1,2,...,m_j; y = 1,2,...,n_{kj}$$

$$t_{[i,x](j-1)} + p_{[i,x](j-1)} \le t_{[i,x]j}, i = 1,2,...,N; x = 1,2,...,n_i; j = 1,2$$

$$\sum_{x_2}^{n} X_{x_2jk(y+1)} t_{x_2j} - \sum_{x_1=1}^{n} X_{x_1jky}(t_{x_1jky} + p_{x_1j}) \ge 0, j = 1,2; k = 1,2,...,m_j; y = 1,2,...,n_{kj}-1$$

$$\sum_{k=1}^{m_i} n_{kj} = n, j = 1,2$$

$$r_{[i,x]j} \le t_{[i,x]j}, i = 1,2,...,N; x = 1,2,...,n_i; j = 1,2$$

$$f_{ij} = Y_i^k, \forall i, j, r, k$$

$$X_r^k = C_{ij} = \max\{X_s^k + T_{y_A^k, y_i^k}, C_i(j-1)\} + T_{Y_i^k, f_{ij}} + T_1 + T_{u1}$$

Equation (1) represents the target optimization function for the processing of the first and second processes, that is, the shortest time for solving the process in different cases; Equation (2) represents the value constraint for the given variable in the objective function; (3) It means that the start time of the first workpiece of RGV in the CNC process cannot be earlier than the earliest start time of the mold; Equation (4) means that each workpiece must be processed once in each process stage; Equation (5) means arbitrary A workpiece must be machined on a CNC in a certain process phase; Equation (6) means that the same workpiece must be processed in the previous process phase before processing in the next process phase; Equation (7) means that the same CNC can only be used. Another workpiece can be machined after machining one workpiece; Equation (8) indicates that the sum of the number of workpieces processed on all machines in each process phase is the total number of workpieces; Equation (9) indicates that each workpiece only reaches the first After one process, it can be arranged for processing; (10, 11) indicates the completion time of the current handling task of RGV and the completion time of O(i, j) when the target CNC equipment is not faulty.

4.2 Implementation of balancing algorithm

● Task grouping

According to the characteristics of the bilateral assembly line, the lower limit of the production tact in the second type of balance problem of the bilateral assembly line is

$$C_{min} = Max\{|T_{SUM}/m|, |T_{SUML}/(m/2)|, |T_{SUMR}/(m/2)|, t_{max}\}$$

For the process processing situation, the given task combination, its operating orientation is determined as follows:

a. If any of the tasks in the processed material group are L-type (or R-type), arrange the task group on the left (or right) station of the assembly line.

b. If the tasks included in the processed material group are all E-type, determine the orientation of the assembly by the following rules:

1) Arrange this task group to the side where work begins early;

2) If there is a conflict, calculate the sum of the working time of the type that has not yet been assigned and the type of R task, and select the shorter side of the total material operation time to arrange;

3) If there is still a conflict, choose one side at will.

● Task group selection

Use the following sequence and rules to select the most appropriate task group: 1) Select the task group that can start the work time at the earliest; 2) When a conflict occurs, select a group with a shorter wait time; 3) When a conflict occurs, the choice has the most A group of long working hours; 4) When a conflict occurs, select a group with more subsequent tasks; 5) When a conflict occurs, select one.

Suppose U represents the set of processed materials without pre-ordered tasks, Gk represents the processed material group obtained by the grouping method. Let C be the current beat time, J and J' be an adjacent work at a certain position. Bit, Sj(Sj') is the time at which the job can be started at the jth (j') station, Dk is the sum of the waiting times of some tasks in the task group Gk, and Tk is the operation time of all the task jobs in the task group Gk. And, Dmax is the non-productive time available under the current allocation plan. The balancing process is as follows:

1) Given the number m of stations, calculate the lower limit of the beat Cmin according to equation (12) and let C=Cmin.

2）Calculate the Dmax value, Dmax=m*c−Tsum.

3) Let J=1, J'=J+1, Sj=Cj'=0.

4) By step 123, obtain FG=G1, G2,..., Gk. If FG=FG+Gk, go to step 9.

5) According to the previous allocation rules, find a suitable task group Gr.

6) According to the orientation of Gr, assign it to station J or J', update SJ=SJ+Dr+Tr, U=U−Gr, Dmax=Dmax−Tr.

7) If Dmax<0, then let C=C+1, go to step 2 or go to step 4.

8) Dmax=Dmax−2C−j(j′). If Dmax<0, let C=C+1, go to step 2.

9) If U≠0, let j=J', J'=j+1, Sj=S'=0, go to step 3; otherwise, output C and the specific task assignment of each station.

4.3 Establishment of the second type equilibrium model of bilateral assembly line based on constraints

In the production of beats and machining tasks, the first type of assembly line balance problem is obtained for the minimum number of stations; in the case of the number of work stations and processing tasks, the second type of assembly line balance problem with minimum beats is used. The unilateral assembly line balance is the problem background. The multi-constraint and multi-objective optimization model is constructed. The dynamic step size method based on step-by-step reduction of the beat search range and the improved particle swarm optimization algorithm based on the automaton backtracking algorithm are used to improve the computational efficiency of the algorithm global search. Balance the assembly line and get a more realistic assignment of tasks. Based on the above constraints, a second type of model for bilateral assembly is established. The task scheduling strategy is as follows:

$$\left\{ \begin{array}{l} I = \{ k|T_k(d) = L, k = 1,2,\ldots,n \} \\ J = \{ l|l \quad is \quad even \quad and \quad 0 < l \le m \} \end{array} \right. \quad or \left\{ \begin{array}{l} i = \{ k|T_k(d) = R, k = 1,2,\ldots,n \} \\ \{ l|l \quad is \quad odd \quad and \quad 0 < l \le m \} \end{array} \right\}$$

The above formula indicates that tasks that need to be completed on the left side in the task grouping process cannot be arranged to the right of the assembly line, and tasks that need to be completed on the right side are not arranged to the left of the assembly line;

$$\sum_{k=1}^{m} X_{ik} \le \sum_{k=1}^{m} X_{jk}, \forall T_i \to T_j, T_j \in T$$

$$\lambda \ \ge \sum_{i=1}^{n} X_{ij}(t_i + D_{ij}), \forall W_j \in W$$

$$T = T_i|i = 1,2,3...n; T_i = t_i, d$$

$$X_{ij} \in \{0,1\}, i = 1,2,\ldots,n, j = 1,2,\ldots,m$$

Where: λ is the tact time, T is the task set, T=Ti|i=1, 2,..., n, Ti=ti,d, that is, each task contains two attributes of operation time attribute ti and direction attribute d The value of d can be R (indicating that this task needs to be arranged on the right side of the assembly line), L (indicating that this task needs to be arranged on the left side of the assembly line) or E (in both sides); Ti→Tj is the priority relationship, that is, the task Ti is Dj is completed before Tj; when Dij is assigned to the Wj station, the pre-order task of Ti exists in the adjacent station, and the operation completion time is later than the Ti start operation time. For the assignment of tasks in the first and second processes, the basic relationship constructed as above is required. Wherein, the formula (14) indicates that the arrangement of the tasks needs to satisfy the order priority relationship; the sum of the operation time and the waiting time of all the tasks arranged in the table (15) is not to exceed the tact time; the formula (16) indicates that the tasks in the task set are The smallest unit can be assigned units, which can no longer be split or arranged to different stations.

4.4 Design based on dynamic step size and improved particle swarm optimization

Although the particle swarm optimization algorithm can generate different distribution schemes, these schemes have great limitations. That is, the processing tasks only flow to the workstations in one direction, and the mutual circulation of processing tasks cannot be realized between the various workstations. Therefore, the automaton backtracking algorithm is used to backtrack the various schemes so that the load of each station is the same. A dynamic step size method that gradually reduces the beat search range is used to improve the overall algorithm efficiency:

1) Delimitation: Determine the beat variation range. The variable C on the left side of the equation takes the set tempo with absolute redundancy.

$$C_{T,max} = max\left\{ \frac{\sum_{i=1}^{n} t}{m}, max(t(i)) \right\}$$

2) Parameter initialization: The important parameters in the dynamic step size method are α, β, γ, which represent the preliminary long control accuracy factor and the current step size, respectively.

3) Calculation topic:

$$\left\{ \begin{array}{c} C_{T,1} = C_{T,min} \\ C_{T,2} = C_{T,1} + dt \\ \cdots \\ C_{T,t} = C_{T,t-1} + dt \\ \cdots \\ C_{T,\left[\frac{C_{T,max}-C_{T,min}}{dt}+1\right]} = C_{T,\left[\frac{C_{T,max}-C_{T,min}}{dt}+dt\right]} \end{array} \right\}$$

$$\left\{ \begin{array}{c} C_{T,1} = \triangle\, t, S_{eq}, 1 \\ C_{T,2} = \triangle\, t, S_{eq}, 2 \\ \cdots \\ C_{T,t} = \triangle\, t, S_{eq}, t \\ \cdots \\ C_{T,\left[\frac{C_{T,max}-C_{T,min}}{dt}+1\right]} = C_{\left[\frac{C_{T,max}-C_{T,min}}{dt}+1\right]}, S_{eq\left[\frac{C_{T,max}-C_{T,min}}{dt}+1\right]} \end{array} \right\}$$

In the above formula, the process of solving the model proposed by the beat C of the assembly line Δt and Seq, l is solved by the improved P SO algorithm, and the optimal processing task assignment matrix Seq, l is the beat CT of the assembly line, respectively. Excellent objective function value and optimal processing task allocation matrix, CT always searches for CT, l, the processing task assignment matrix generated for the first time in the search, thus completing the improved dynamic dynamic step algorithm of the population to obtain the most The good processing task assigns the matrix Seq, l and the corresponding fitness function value Δt, and finally, narrows the optimized beat range and ends the search.

$$\left\{ \begin{array}{l} C_{T,max} = C_{T,j} + dt \\ C_{T,min} = C_{T,j} - dt \end{array} \right.$$

4) shorten the step size: let dt=α/3, get the best values of the second group of particles: CT, l, Δt, Seq, l and more precise CT, opt=CT, j range [CT ,min, CT,max]. 5 cycles: cycle to step dt=α/β, get the set of CT, l, Δt, Seq, l, output minimum beat CT, opt=CT, j. 6 correction: dynamic The step value is a non-integer change, so the opt will be larger than the actual value by the obtained CT. To correct the correction, the CT can be corrected by the obtained task assignment matrix Seq, opt.

Dynamic scheduling strategy: (1) Correction of machine availability time When the dynamic scheduling starts, there are three states in the machine: First, the machine is in an idle state, and the machine is already in the process of re-scheduling. In the idle state, it is now possible to start processing another process, and the machine starts processing time is the rescheduling time. Second, the machine is in the processing state. In order to ensure the continuity and stability of the process, it is not possible to interrupt the machining. The machine rescheduling time is the time when the machine completes the current process. The third is that the machine is in a fault state, and the machine is scheduled to start processing time is the time when the machine is repaired. (2) Correction of the machining workpiece task matrix In the dynamic scheduling time, the workpiece has two states: First, the workpiece has completed the processing of all the operations, and the workpiece is moved into the completion window. Second, the process has not completed all the processing of the process. For the completed machining process, it is removed from the machine sequence matrix and the time matrix, but the process that has not been processed remains, and the time at which the workpiece can be processed is Scheduling time; for the process being processed, the process is completed, and then the process is removed from the machine order matrix and the time matrix, and the time at which the workpiece can start machining is the time at which the process is completed. Eventually, the process that the workpiece has not started and the newly added workpiece form a new to-be-scheduled collection.

position	Case1		
	assigned task	revised assigned task	sum of waiting time
1	2,4,12	2,5,12	591
2	1,10,24,5,21	1,10,24,4,21	657
3	3,15,17,18	3,15,17,22	650
4	7,23,14,9,22	7,16,14,9,18	618
5	6,11,8,27,20,19	6,11,8,9,20,19	638
6	10,16,22,6,25,9	13,7,20,5,10	612
7	15,22	22,3,28	631
8	14,17,30,24,11	27,16,30,26,25,29	648
1	2,4,12	2,5,12	634
2	1,10,24,5,21	1,10,24,4,21	633
3	3,15,17,18	3,15,17,22	657
4	7,23,14,9,22	7,16,14,9,18	636
5	6,11,8,27,20,19	6,11,8,23,20,19	663
6	13,16,28,26,25,29	13,12,30,28,11	645
7	5,9,30,21,27	27,18,30,13,30,25	664
8	23,18	31,3,8	626
	640		
1	2,4,12	2,5,12	654
2	13,16,28,26,25,29	13,32,30,28,14	644
3	3,15,17,18	3,15,17,22	645
4	7,23,14,9,22	7,17,14,9,18	676
5	6,11,8,27,20,19	6,11,8,10,20,19	656
6	13,16,28,26,25,29	13,32,30,28,14	654
7	1,10,24,5,21	1,10,24,4,21	623
8	29,15	9,4,18	673

4.5 Determination of the operational efficiency of the system

In the particle swarm optimization algorithm based on dynamic step size, the parameters are set as follows: population size Ssum=100, maximum iteration number Msum=200, inertia weight w=1, learning factor c1=1.3, c2=1.5, initial step size α=1 , β = 60, the upper limit of the number of times of convenience is N = 100. The more theoretical the number of groups in the algorithm, the better the optimal beat is obtained. The obtained results show that there are multiple optimal load smoothing coefficients, which reflects that the same solution is searched in multiple groups. The processing task automaton backtracking algorithm and the particle iterative optimization path are used, and the final load of each station is roughly the same. The assembly line balance rate makes the processing time as close as possible under the optimal conditions, which can intuitively reflect the operating efficiency of the system. Therefore, we calculate the assembly line balance rate to reflect the actual system work efficiency. The following formula is used to improve the corrected optimal beat and assembly line balance rate and the assembly line balance rate in the particle swarm:

$$Z_1 = C_{T,opt} = min\{C_{T,opt}, max\{S_T(J)\}\}$$

$$B = \frac{\sum_{k=1}^{m} S_T(k)}{mC_T}$$

5. Conclusion

Because the static scheduling of the workshop is difficult to adapt to the uncertainty of the actual production and the characteristics of dynamics, such as the actual production, the production plan changes and other such emergencies have a greater impact on the production system. In order to solve the defects of poor flexibility and weak adaptability of the inherent intelligent algorithm, the two-stage assembly line balance model with multiple processes is combined with the particle swarm optimization based on dynamic step size in the actual production process, so that the dynamic scheduling strategy is proposed. Based on algorithms and model improvements to improve the efficiency of the system. The complex scheduling process in the dynamic environment is very feasible and effective according to the ease of operation and high flexibility of the model system constructed in this paper. The above processing task allocation scheme meets the actual production needs of the enterprise. Assembly line production planning has a good guidance and reference.

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