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Research on multi-objective static scheduling problem in machining workshop

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Abstract

After years of development, the overall level of the machine tool industry has been greatly improved, but compared with other industries, its degree of intelligence and digitalization is still not high, and most of them currently use traditional production modes based on manual operation and control. Especially in the workshop production scheduling, there are problems such as low degree of digitization, manual scheduling scheme, and low production efficiency; in actual production, dynamic events such as temporary equipment failures and additional orders from customers often affect the normal production plan. Therefore, in view of the above common problems, the paper takes the production scheduling problem of five types of parts in the machining workshop of a machine tool manufacturing enterprise as the research object, and uses the workshop scheduling theory and NSGA-II intelligent optimization algorithm to carry out multi-objective static scheduling problem research in the machining workshop.

Keywords

Machine shop; Multi-objective optimization; Production scheduling.

1. Introduction

Workshop scheduling is closely related to the interests of enterprises, and it is a problem that many scholars have been concerned about. As early as the last century, foreign scholar Johnson[1] carried out research on an assembly shop with two processing machines and took minimizing the completion time as the optimization objective. In 1975, domestic scholars Yue Minyi et al[2] discussed the problem of workshop scheduling, which laid the foundation for subsequent scholars to study this kind of problem.

The real economy is the source of wealth, and the manufacturing industry is the foundation of the country. The great rejuvenation of the Chinese nation depends on the construction of a manufacturing power, and green manufacturing is an important focus of the construction of a strong country, and it is an important part of China's green development[3]. A large number of data show that due to the unreasonable arrangement of processing tasks, the machine tools in the workshop are in idle standby state rather than processing state[4] most of the time, so the reasonable arrangement of workshop production methods is conducive to improving the production efficiency of the workshop and improving the efficiency of the enterprise.

2. Scheduling model establishment

2.1. Description of the scheduling problem

The scheduling problem of the machining workshop can be expressed as N different machine tool parts are processed on M machines, and the machine tool parts are processed in batches, and the batch number of each part is Q. Each component has at least n processes, and each process can be processed on one or more devices. Know the processing time of each operation of the part on the optional equipment and the operating power of the equipment. In order to

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shorten the processing time of the machine tool components and improve the utilization efficiency of the equipment, the processing sequence of the workpieces is reasonably arranged.

2.2. Symbol description and variable definition

In order to facilitate the description of the model establishment process, the following definitions of parameter variables are made, as shown in Table 1.

Table 1 Variable table

Variable	Variable description
M	Number of all machines, machine serial number k=1,2,3,...,n
N	Quantity of all workpieces, workpiece number i=1,2,3,...,m
M	Total number of workpiece processes, process number j=1,2,3,...,M
Oij	The jth operation of the i workpiece
Cmax	Completion time
ter	Machine k no-load time
tKstart	machine k boot time
tkc	Completion time of machine k

2.3. Optimize goals and constraints

(1)Minimum completion time

$$f_1 = \min(C_{\max}) \tag{1}$$

(2)Minimum equipment load

$$f_3 = \min\left(\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{M} C_{ijk} \times x_{ijk}\right) \tag{2}$$

The final optimization goal :

$$F = (f_1, f_2)^T \tag{3}$$

Restrictions:

$$\sum_{k=1}^{M_j} x_{ijk} = 1, i = 1,2,3\ldots,n;\ j = 1,2,3\ldots,m; k \in M_j \tag{4}$$

$$x_{ijk} \in \{0,1\}, \forall i, j, k \tag{5}$$

$$C_{ijk} \le S_{i(j+1)}, i = 1,2\ldots,n;\ j = 1,2\ldots,m; k \in M_j \tag{6}$$

$$C_{ijk} = TM_{jr} + S_{ijk}, i = 1,2\ldots,m; k \in M_j \tag{7}$$

In formula (4), it means that the processing of any workpiece in each process can only be assigned to one machine for processing.

In formula (5): xijk=1 if workpiece i is processed on machine tool k in j process, otherwise xijk=0.

In formula (6): It means that the machine cannot process the next process until the current workpiece is processed.

In formula (7): represents any workpiece, and its completion time depends on the processing time and start time on a certain machine.

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3. Solve the algorithm design

3.1. Introduction to NSGA-Ⅱ Algorithm

The NSGA-II algorithm was proposed by Srinivas and Deb on the basis of NSGA in 2000. It is more superior than the NSGA algorithm: it uses a fast non-dominated sorting algorithm, and the computational complexity is greatly reduced than that of NSGA; it uses crowding and crowding. The degree comparison operator replaces the shared radius shareQ that needs to be specified, and is used as the winning criterion in the comparison of the same level after quick sorting, so that the individuals in the quasi-Pareto domain can be extended to the entire Pareto domain, and evenly distributed, maintaining the population Diversity; an elite strategy is introduced, which expands the sampling space, prevents the loss of the best individual, and improves the computational speed and robustness of the algorithm.

3.2. Algorithms are currently flawed

NSGA-II selects individuals of the same non-dominant level by calculating the crowding degree distance of individuals. It is believed that the larger the crowding degree distance, the better. This method is especially suitable for solving dual-objective optimization problems, but when solving optimization problems with more than three objectives, the crowding degree The individuals selected by distance sorting are unevenly distributed on the non-dominated layer, which is easy to fall into local optimum, which affects the convergence and diversity of the algorithm.

3.3. Improved solution algorithm design

3.3.1. Improve algorithm flow

Step 1: Set the algorithm parameters (the number of iterations Gen, the population size N, the mutation probability Pv, the crossover probability Pc).

Step 2: Use the multi-rule population generation method to generate an initial population P with a number of N. And set the iteration number of the population to 0.

Step 3: Determine whether the current number of evolution Gen is the initial generation 1, if it is the initial generation, sort the population non-dominantly, and calculate the crowding degree of the individual; otherwise, go to step 4.

Step 4: According to the sorting level of the individuals and the optimal crowding degree, select the better individuals from the population for genetic operation, and obtain a new generation of population P1.

Step 5: Merge the parent population and the child population to generate a new generation population P2.

Step 6: Perform the operation of step 4 on the new generation population, select the optimal individual as the next generation population, and add one to the evolution times.

Step 7: Go back to Step 3, if Gen is 0, continue with the operations from Step 4 to Step 6.

Step 8: Determine whether the algorithm reaches the maximum number of iterations, if so, skip the iteration and output the current solution; otherwise, continue the algorithm iteration.

Step 9: Use the AHP decision method to decide the optimal solution from a set of output solutions.

Step 10: According to the optimal solution, draw a scheduling Gantt chart.

3.3.2. Chromosome encoding and decoding

In this paper, a hybrid double-layer coding based on substituting workpiece processes and processing equipment that is widely used in most researches is used. The same sequence

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number is used for the process of the same part to be processed, and different workpieces are judged according to the order in which they appear in the chromosome.

3.3.3. Chromosome initialization method

In view of this situation, this paper adopts a multi-rule generation method for initializing the population. The following two rules are mainly adopted: (1) The energy consumption corresponding to the equipment selected for each workpiece process is small. If there are more than one optional processing machines with the smallest energy consumption, choose one[5]; (2) The processing selected by the workpiece process The equipment is generated by random methods, and the corresponding energy consumption is not necessarily the smallest.

3.3.4. Chromosome crossover method

The machining shop scheduling problem is a typical flexible shop scheduling problem. It is easy to generate illegal solutions by using a single crossover method. Therefore, this paper adopts a hybrid crossover method based on process and machine, and divides the crossover operation into two parts: process crossover and machine crossover[4]. conduct. For process coding, any ordering of processes is a feasible solution. However, the number of processes for each workpiece is fixed, so the number of occurrences of each gene representing the workpiece serial number is also fixed. If random crossover or single-point crossover is used, a large number of infeasible solutions may be generated.

3.3.5. Chromosomal mutation method

As an aid to genetic manipulation, mutation generates new individuals by altering genetic segments of chromosomes. This operation can improve the local search ability of the optimization algorithm and increase the diversity of the population. Like the crossover operation, the chromosomal mutation operation is divided into process mutation and machine mutation. SWAP[6] operation was used for process mutation, and adjacent gene exchange was used for machine mutation.

4. Case studies and validation

In order to verify the superiority of the improved algorithm designed in this paper to solve the multi-objective scheduling model compared to the NSGA-II algorithm, this paper uses the international benchmark example (8×8) proposed in Kacem [7] to test and analyze.The three benchmark examples proposed by Kacem are all traditionalmulti-objective FJSP problems, which are consistent with the machine shop scheduling problem of machine tool manufacturing enterprises studied in this paper.

Table2 8×8 Comparison of results of calculation examples

Target	NSGA-Ⅱ	AL+CGA	SPT	HGA	This paper
Completion time (min)	18	18	19	14	14
Total equipment loa (min)	82	79	91	77	73

It can be seen from the data comparison that for the two benchmark problems, the optimization objectives solved in this paper are better than the NSGA-II algorithm, and are equal to or better than their solution results compared with other algorithms. Therefore, the improved algorithm in this paper is effective and feasible, and a good solution can be obtained when solving the multi-objective FJSP problem.

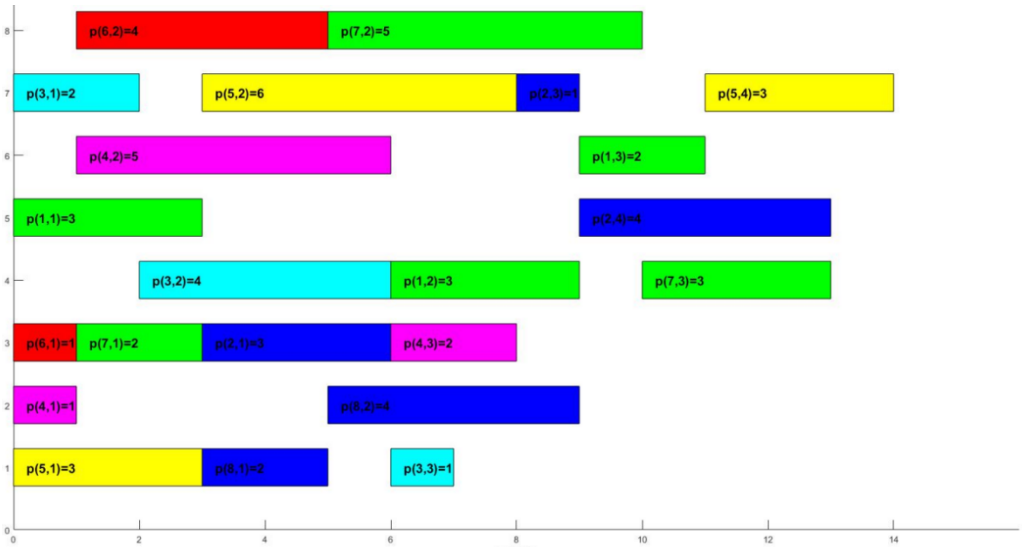

Fig. 1 An Optimal Solution of 8×8 Scheduling Problem

In Fig. 1, the ordinate represents the processing machine number, and the abscissa represents the processing time, and the unit is min.

5. Conclusion

For the problems of low efficiency, high equipment energy consumption and frequent disturbance events in the production process of machine tool manufacturing workshops, this paper focuses on the scheduling problem of machine tool manufacturing workshops with the characteristics of multi-variety and flexible production process. As the research object, in order to improve the workshop production efficiency and reduce the energy consumption of the workshop equipment, after analyzing the characteristics and characteristics of the production process of the machine tool workshop of a machine tool manufacturing enterprise, the establishment of a method to minimize the maximum completion time and reduce the equipment energy consumption is established. The multi-objective optimization scheduling mathematical model of the machine shop with the optimization objectives of minimizing equipment load and minimizing equipment load is designed, and a solution algorithm suitable for the mathematical model is designed, which improves the production efficiency and energy utilization rate of the workshop.

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