Dynamic Scheduling Study of Flexible Job Shop Considering Machine Failure Rate

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Abstract. For the flexible job shop dynamic scheduling problem, set machine priorities based on machine failure rates, a scheduling model with the objective of minimizing the maximum completion time and machine load balance ratio is established, and an improved ABC algorithm is designed to solve it. An external solution set is introduced in the iterative optimization stage of the algorithm to realize the solution of the ABC algorithm for multiple objectives. The effectiveness of the optimal scheduling algorithm is verified by the classical flexible job shop scheduling problem.

Keywords: flexible job shop; production disturbance; rescheduling; MOABC

1 Introduction

In actual shop floor scheduling applications, the dynamic scheduling problem is more similar to the actual production environment. The flexible shop floor dynamic scheduling problem extends the scope of the traditional job shop scheduling problem and can cope with various unexpected shop floor disturbance situations in the actual production environment. It is a broader and more suitable scheduling problem for the actual production situation and has become one of the hot spots in the scheduling research field[1]. It is of great theoretical significance and engineering value how to better solve the dynamic scheduling problem of flexible job shop and realize the efficient and smooth operation of enterprise shop floor production.

Sun et al [2] constructed a rescheduling model with the objective of minimizing the fuzzy maximum completion time for the processing time uncertainty problem, and proposed an effective hybrid co-evolutionary algorithm (hCEA) for solving the scheduling scheme. Wang et al[3]constructed a scheduling model with the objective of minimizing total completion time, total machine workload and total energy consumption, and proposed a real-time digital twin scheduling method based on edge computing. Yu et al[4] constructed a scheduling model with completion time and total load as the objectives and solved it based on an improved artificial bee colony algorithm. Akkan et a[5] proposed a hybrid branch delimitation and local search rescheduling solution strategy for

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new order insertion events, considering the stability of the original scheduling scheme after order insertion.

Although scholars at home and abroad have made many achievements in the study of the Dynamic Flexible Job Shop Problem (DFJSP), they seldom take into account both energy consumption and scheduling stability objectives. In this paper, a multi-objective scheduling model with minimum equilibrium ratio of maximum completion time and machine load rate is established to address this problem, and an improved ABC algorithm is designed to solve the dynamic scheduling problem.

2 Dynamic Scheduling Optimization Model

The flexible job shop scheduling problem is described as follows: The workshop needs to complete the machining of n workpieces with a workpiece set of $I=\{1,2,\dots,i,\dots,n\}$;each workpiece contains N_i processes to be machined and the processes set is $O_i=\{O_{i,1},O_{i,2},\dots,O_{i,j},\dots,O_{i,N_i}\}$. The workshop has a total of m idle machines that can perform machining tasks, with a set of machines $M_k\left(k=1,2,3,\cdots,m\right)$. Dynamic scheduling is the selection of a new scheduling solution that meets the actual production according to the current production situation and demand in the workshop after a disturbance has occurred, and can be used in four types of strategies, including right shift rescheduling, local rescheduling, global rescheduling, and rescheduling ignoring the disturbance waiting cycle, respectively, as O^1 、 O^2 、 O^3 、 O^4 .The symbols and parameters required in the construction of the model are defined as shown in Table 1.

Table. 1. Definition of symbols and parameters

Symbols/parameters	Definition of symbols/parameters
P_{ijk}	machining time on machine k for the jth pass of workpiece i
L	An infinite positive number
C_i	Machining completion time for workpiece i
s_{ijk}	The moment when the jth process of workpiece i starts on the machine
f_{ijk}	Completion time of the jth process of workpiece i on the machine
t_{kl}	Machine k in production cycle l of operating hours
$\lambda_{kl}\left(t\right)$	Machine k in production cycle l of operating hours
x_{ijk}	$\begin{cases}1, \text{Process } O_{ij} \text{ on machine k}\\ 0, \text{ Others}\end{cases}$

y_{ijpqk}	$\begin{cases} 1, \text{Process } O_{ij} \text{ is processed on machine k before process } O_{pq} \\ 0, \text{ Others} \end{cases}$

The job shop is the core of the enterprise and its productivity determines the profitability of the enterprise. Therefore, in this paper, the scheduling model is constructed with the objective of maximum completion time minimisation and machine load balancing ratio. Also consider the machine failure rate constraint, the lower the failure rate the longer the working time, reducing the risk of machine failure disturbance.

$$\min C_{\max} = \min \max\left(C_i\right), 1 \le i \le n \tag{1}$$

$$\min S_M^2 = \sum_{k=1}^{m}\left(t_k - \bar{t}\right) \tag{2}$$

$$\bar{t} = \frac{\sum_{k=1}^{m} t_k}{m} \tag{3}$$

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$$C_{\max} \ge C_i, \forall i \tag{4}$$

$$s_{pqk} \ge f_{ijk} - \left(1 - y_{ijpqk}\right) \times L \tag{5}$$

$$\sum_{k \in M_{ij}} s_{i(j+1)k} \ge \sum_{k \in M_{ij}} f_{ijk} \tag{6}$$

$$\sum_{k \in M_{ij}} x_{ijk} = 1 \tag{7}$$

$$\left(t_a - t_b\right)\left(\lambda_b\left(t_b\right) - \lambda_a\left(t_a\right)\right) \ge 0, a \in k.b \in k \tag{8}$$

$$C_i \ge 0, \forall i \tag{9}$$

$$s_{ijk} \ge 0, f_{ijk} \ge 0, \forall i, j, k \tag{10}$$

3 Improving the Artificial Bee Colony Algorithm

The artificial bee colony algorithm is a meta-heuristic algorithm that mimics the honey bee honey harvesting behavior, which has a simple structure, easy implementation and convergence speed; to make it applicable to multi-objective solution problems, this paper introduces external solution sets to improve it.

The flexible job shop scheduling problem involves the selection of processes to machines and the processing sequence together, and this paper uses a two-layer coding policy for coding. An example is shown in Figure 1.

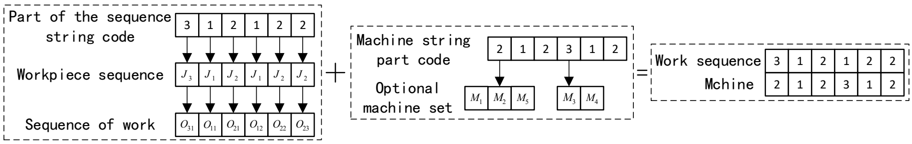

Fig. 1. Example of double-layer coding

The initial solution of standard artificial bee colony algorithm has a large gap between the advantages and disadvantages of the initial solution, is more stochastic, difficult to get quality assurance, and easy to fall into local optimu [6]. In this paper, we adopt the combination strategy of RS, GS and LS to improve the initialization strategy. The employing bee stage uses IPOX operator with multipoint crossover operation for crossover variation, while introducing external solution sets to solve the problem of non-dominated solutions existing in multiple objectives. In order to be applicable to multi-objective problem solving, the probabilistic selection formula based on population individuals is selected for individual fitness value calculation in the following bee stage, and roulette wheel is used for selection by dominance relationship and crowding degree distance for superiority selection. The calculation formula is as follows.

$$f_i = F(i)\left(\sum_{i}^{N/2} F(i)\right)^{-1} \tag{11}$$

$$F(i) = \left(R^i \exp\left(2m^i / N\right)\right)^{-1} \tag{12}$$

A hired bee will abandon a solution set and turn into a scout bee to search for a new feasible solution set again when the number of iterations of a solution set exceeds the maximum number of searches and still no improvement. In this paper, new solutions are generated by random generation with underlying replacement.

Based on the above discussion, the improved artificial bee colony algorithm is presented.1) Double coding of processes and machines based on the rescheduling model; 2) Set initial parameters and initialize subpopulations according to initialization rules; 3) Create the external solution set and move all non-dominated solutions to the external solution set to complete the initialisation of the external solution set;4) The hired bee performs a search to get new food sources and updates the external solution set;5) Follow the bee to search for solutions, get new food sources and update the external solution set;6) Determine if there is a food source that needs to be abandoned; if so, the food source is abandoned and the scout bee looks for a new food source to replace it; otherwise, go directly to step 7;7) Determine whether the search for a solution has reached the maximum number of iterations, and if so, output the external solution set and the calculation is complete; otherwise, go to step 3 for a loop.

4 Algorithm Validation

Using the classical 8X8 flexible job shop scheduling problem to verify the arithmetic example, simulate the failure of machine 3 at t=55 and need 20mins to eliminate and insert a new order at t=75, the new order task information is shown in Table. 2, and solve the resulting scheduling scheme is shown in Figure 2.

Table. 2. Order information

		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8
J_9	O_{91}	4		4	5	10		7	5
	O_{92}	10	3	5		4	3		
	O_{93}		10		5	6	2	4	5
	O_{94}	10		7	4	9	8	6	

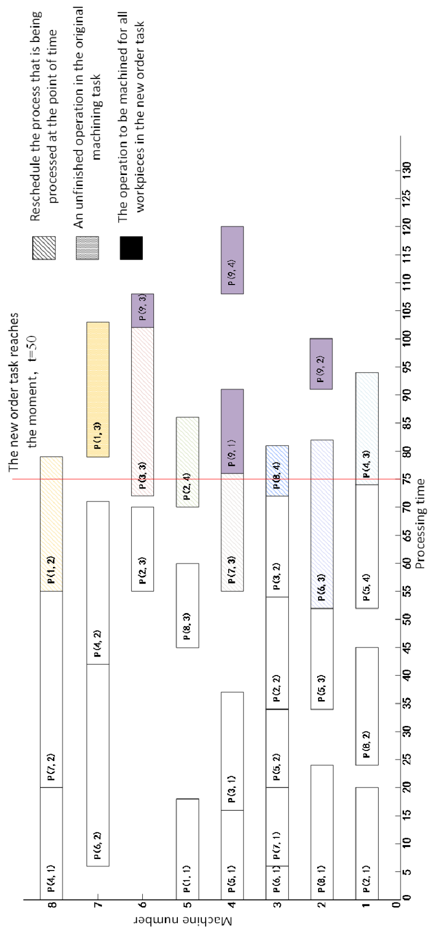

Fig. 2. New order insertion disturbance resolution rescheduling solution

The analysis of the calculation example shows that the proposed dynamic scheduling optimization method for flexible job shop is effective.

5 Summary

In this paper, a multi-objective dynamic scheduling model with the objective of minimising the maximum completion time and machine load balancing ratio is established for the uncertain disturbance problem of flexible job shops in actual production, and an improved ABC algorithm is designed to solve the model. An external solution set is introduced in the iterative optimisation phase of the algorithm to realise the solution of the ABC algorithm for multiple objectives; only in the initialisation phase is there a combined strategy of RS, LS and GL to improve the quality of the initial solution and solve the problem that the ABC algorithm tends to fall into local optimum. The effectiveness of the optimal scheduling algorithm method is verified through the classical flexible job shop scheduling problem.

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