JOB SCHEDULING OF MULTI-OBJECTIVE MANUFACTURING WORKSHOP BASED ON DISCRETE DIFFERENTIAL EVOLUTION ALGORITHM

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ABSTRACT*: Job scheduling of manufacturing workshop is the core of production management of enterprises. Multiple procedures and multiple objectives of products, many machines that can be selected for processing in different procedures of each component, and the randomness of dynamic events of production equipment all bring about great obstacles for the job scheduling of manufacturing workshop. Based on the principle of discrete differential evolution algorithm, this study presents a job scheduling model of multi-objective manufacturing workshop with the objectives of completion time and total machine load. The results show that the goal of job scheduling is to achieve the satisfaction of both the manufacturer and the customer. In the face of the three optimal job scheduling goals of the shortest completion time, the minimum total machine load and the minimum maximum load of the machine, it is impossible to obtain the optimal solution for each goal, and only a set of non-dominating solutions can be obtained. The simulated test finds that the stability of the optimal dominating solution set obtained by the discrete differential evolution algorithm is higher than that of the objective evolution algorithm, the maximum completion time is the smallest, and the convergence is stronger. This study provides a theoretical basis for the application of discrete differential evolution algorithm, an intelligent optimization algorithm, in job scheduling of manufacturing workshop.*

KEYWORDS*: job scheduling, manufacturing workshop, discrete differential evolution algorithm, objective evolution algorithm, optimal dominating solution set.*

1 INTRODUCTION

With the rapid development of manufacturing industry in China, the market competition has become fiercer and fiercer. Enterprises must have fast, high-quality and low-cost production process to occupy advantages in the increasingly fierce competition (Vallejos-Cifuentes et al., 2019). Diversification of consumer demand has led to the diversification of products, which has also raised higher requirements for multi-objective and diversified production of products in manufacturing workshop (Wei, 2018; Zhu & Xu, 2019). Job scheduling of manufacturing workshop is the core of manufacturing of enterprises, and the efficient job scheduling optimization scheme is the core of improving the high-efficiency production of the whole production system. The existence of multi-objective manufacturing workshop makes it more difficult to schedule large-scale mixed flow manufacturing workshop (Huang, 2010). Currently, in the actual production process, multi-objective job scheduling of workshop dominates. An optimal job scheduling scheme is sought in the process of job scheduling of multi-objective manufacturing workshop, so that the production effect reaches the maximum value on the multiple objectives. Common multi-objective production job scheduling problems include completion time and cost or machine load (Zandieh et al., 2017).

Job scheduling of multi-objective manufacturing workshop, as a mode of advanced production planning and control, will directly affect the production cost and efficiency of the enterprise. It is necessary to realize the close connection of procedures by corresponding means, and to reduce no-load of the machine, production time and production cost (Frutos & Tohme, 2013; Zhang et al., 2013). Discrete differential evolution algorithm is a simple and efficient intelligent optimization algorithm developed in recent years, which has strong robustness and convergence ability. It has been widely used in fields of chemistry, mechanical engineering and electric power, but seldom used in job scheduling of manufacturing workshop (Rifai et al., 2016). In the differential evolution algorithm, there are three control parameters, namely, population size, zoom factor and cross factor. In the process of self-adaptation and allocation, the discrete differential evolution algorithm automatically adjusts the value of the zoom factor and the cross factor according to the diversity of the population, thus improving the effectiveness and robustness of the algorithm (Moslehi & Mahnam, 2011). Based on the principle of discrete differential evolution algorithm, this study presents a job scheduling model of multi-objective manufacturing workshop with completion time and total machine load as the optimization objectives. This study provides a theoretical basis for the application of discrete differential evolution algorithm in job scheduling of manufacturing workshop.

2 APPLICATION OF DISCRETE DIFFERENTIAL EVOLUTION ALGORITHM IN JOB SCHEDULING

The discrete differential evolution algorithm is a typical representative of heuristic optimization algorithms. Job scheduling of manufacturing workshop requires optimal allocation of start and stop processing time for each procedure of each component (Lakshmipathy et al., 2014). In the evaluation and preparation of job scheduling, the scheduling scheme needs to be checked whether it can meet the quantitative description of decision maker's satisfaction. Common evaluation indexes include minimum maximum completion time, minimum bottleneck machine load, minimum total machine load and minimum delay time (Kasemset & Kachitvichyanukul, 2012). Fig. 1 is a flow chart of a discrete differential evolution algorithm for solving job scheduling problems, where components to be produced form an initial population according to a certain method. Weights are randomly generated according to chromosome decoding specific to the component, and fitness is calculated. By means of evolution operation, such as selection, cross and mutation, chromosomes are preserved to a new population, so solution that satisfies the termination condition can be chosen.

Fig. 2 shows the function of job scheduling of manufacturing workshop in the production system. The manufacturing workshop control room makes the main production plan according to the customer's order and sales plan, and then makes the material demand plan and the capacity demand plan. If all meet the requirements of the production plan, the job scheduling of manufacturing workshop is generated. The job scheduling of manufacturing workshop generally consists of two elements: manufacturing resources at the workshop level and the task elements of the production and processing. The two elements complete workshop work manufacturing with specified functional objectives at different time and space (Karthikeyan et al., 2014). A complete production operation is a comprehensive system with planning, control and coordination. The production plan and job scheduling are jointly completed through relevant coordination and cooperation of various departments within the enterprise (Lu et al., 2018).

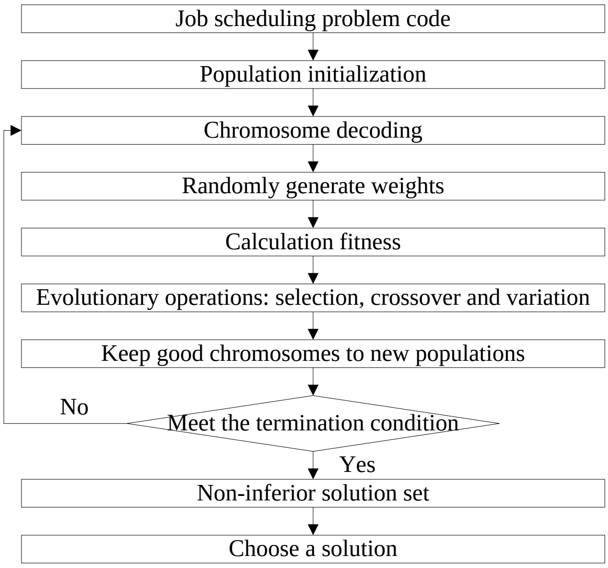

Fig 1. Flow chart of discrete differential evolution algorithm for job scheduling problem

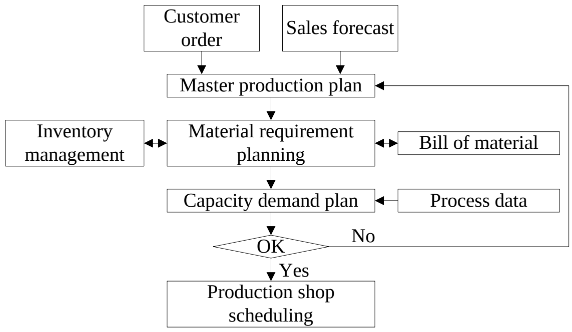

Fig 2 The function of job scheduling in production system

3 STUDY ON DYNAMIC JOB SCHEDULING OF MULTI-OBJECTIVE MANUFACTURING WORKSHOP

3.1 Study on dynamic job scheduling of manufacturing workshop with different scheduling cycles

Different job scheduling cycles have a great influence on job scheduling of manufacturing workshop. Generally, dynamic job scheduling is transformed into static job scheduling by using periodic rescheduling strategy according to different job scheduling cycles. However, different rescheduling cycles will also affect the optimal result of job scheduling. To facilitate the calculation, the probability method is adopted to simulate the arrival time of the components in the manufacturing workshop, and the arrival or completion time of each components in turn is included in the scheduling interval, and the multi-objective optimization calculation is carried out on each scheduling interval. In the periodic rescheduling model, the time of each rescheduling is regarded as the time when the scheduling starts next time, so that a scheduling interval is generated every time the rescheduling is performed, and the time duration is the sum of the time of each rescheduling. This study takes 5,000 components as an example, and each scheduling cycle is the cycle of 1,000 components. Fig. 3 shows total completion time and total tardiness obtained by dynamically scheduling 5,000 components under different rescheduling cycles. It can be clearly seen that as the rescheduling cycle increases, total completion time and total tardiness also increase. In addition, total completion time has a positive linear relationship with scheduling cycle, while total tardiness has a negative linear relationship with scheduling cycle. Fig. 4 shows total efficiency and total stability obtained by dynamically scheduling 5,000 components under different rescheduling cycles, clearly showing that total efficiency increases with the increase of rescheduling cycle while total stability decreases first and then increases with the increase of rescheduling cycle.

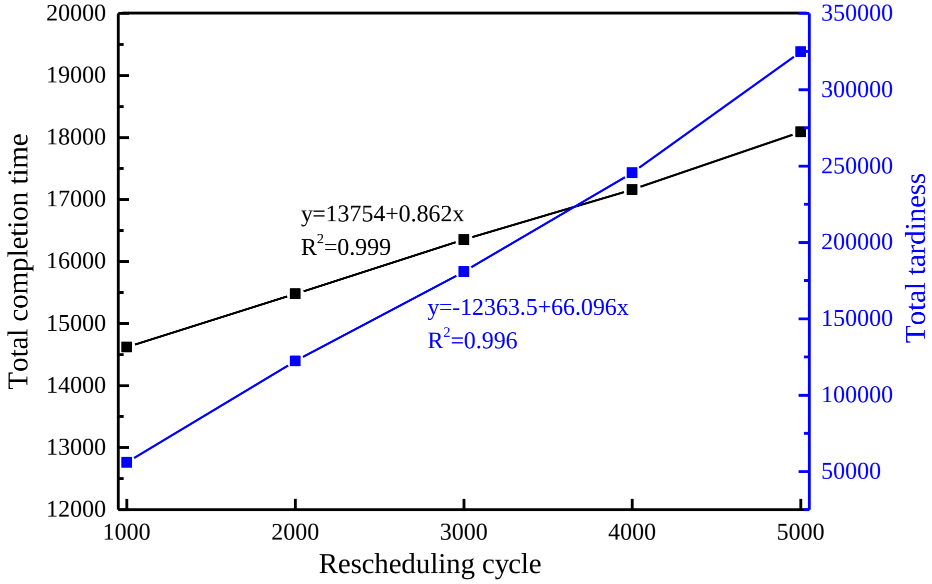

Fig. 3 Total completion time and total tardiness obtained by dynamic scheduling of 5,000 components under different rescheduling cycles

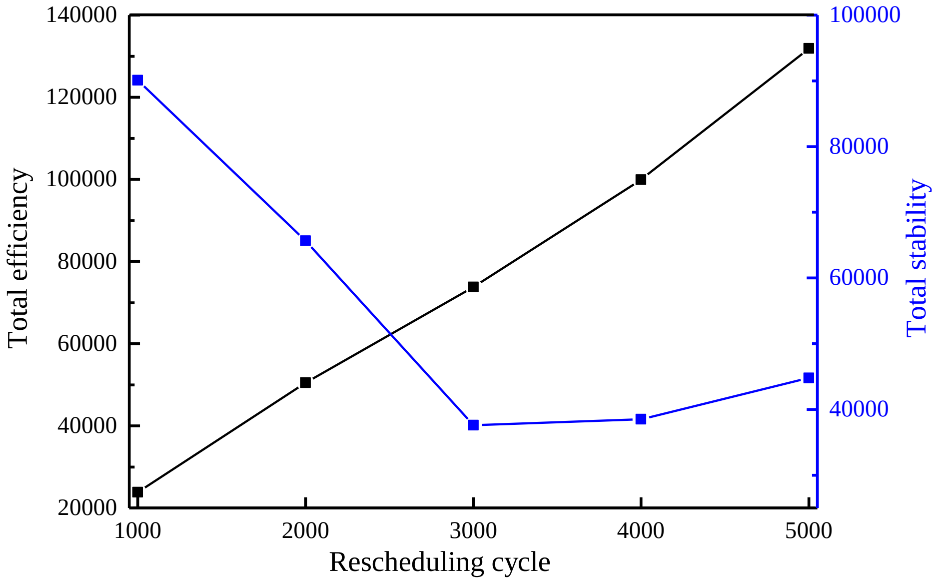

Fig. 4 Total efficiency and total stability of dynamic scheduling of 5,000 components under different rescheduling cycles

3.2 Dynamic job scheduling of manufacturing workshop with different dynamic events

Fig. 5 is a production job scheduling objective system. The objective of job scheduling is to achieve the satisfaction of both the manufacturer and the customer. The conditions for achieving the satisfaction of the manufacturer are capability index and cost index, and the conditions for achieving the satisfaction of the customer are delivery of goods by schedule, by quality and by quantity. Unexpected dynamic events are always encountered in the job scheduling of manufacturing workshop. Fig. 6 shows the common dynamic events in the discrete job scheduling system of manufacturing workshop, including component-related, equipment-related and time-related events. Wherein, component-related factors include change of component order, change of delivery date, uncertainty of processing time, and equipment-related dynamic events include unpredictable or predictable equipment failure. The unpredictable equipment failure includes machine blocking, load limitation, tool damage, etc. The job scheduling system can implement rescheduling by using the dynamic event as the trigger mechanism when the production system monitors the occurrence of the rescheduling driving factor by monitoring the state of the rescheduling driving factor without interruption.

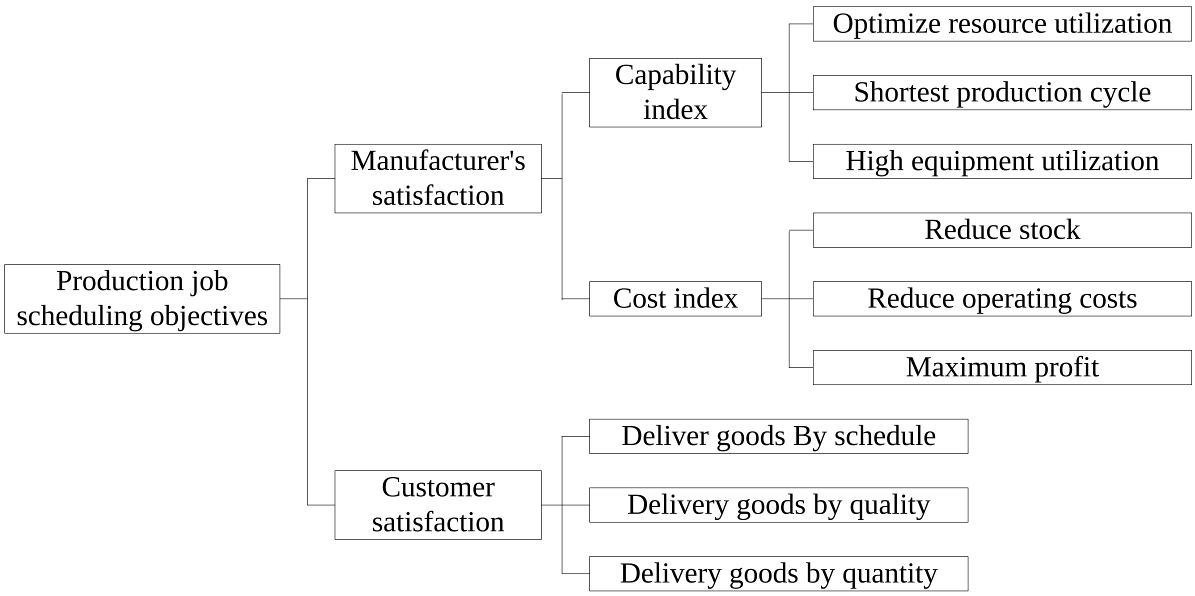

Fig 5. Target system of production scheduling

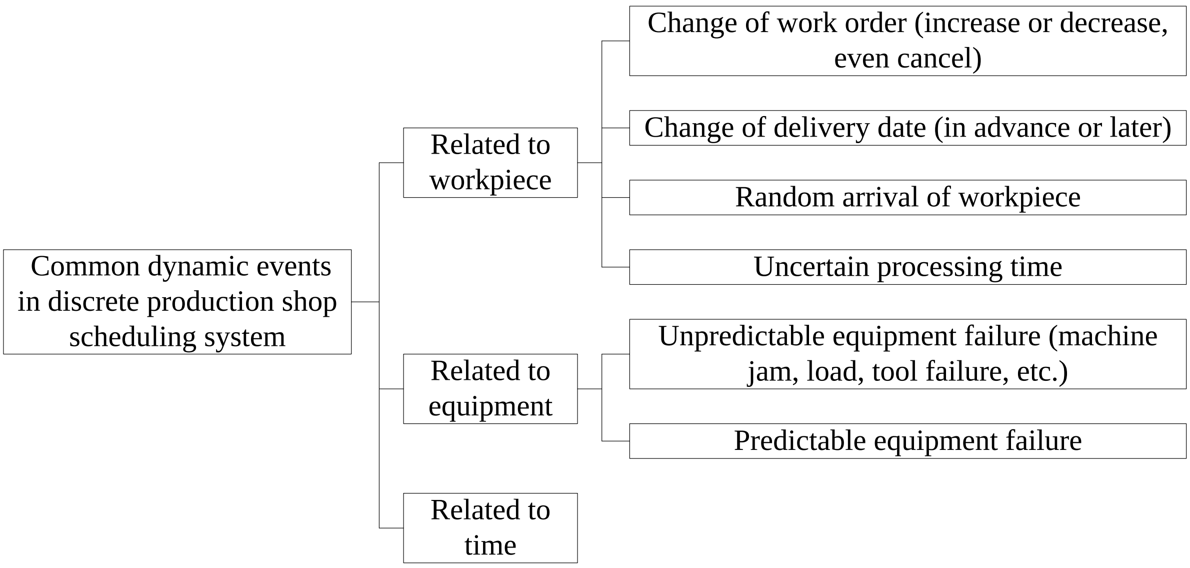

Fig. 6 Common dynamic events in discrete production shop scheduling system

4 JOB SCHEDULING OF MULTI-OBJECTIVE MANUFACTURING WORKSHOP BASED ON DISCRETE DIFFERENTIAL EVOLUTION ALGORITHM

4.1 Discrete differential evolution algorithm for job scheduling of multi-objective manufacturing workshop

In actual production, many machines can be selected for different procedures of each component, and different procedures spend different time on different machines, which also brings great difficulties to the job scheduling of manufacturing workshop. Assuming that there is an n-dimensional decision vector X=(x1, x2,…, xn), there are m and preferential objectives, and these m objectives conflict with each other, we take the minimization of job scheduling objective as an example, then the multi-objective production job scheduling problem can be expressed as:

$$\min f(X)=[f(X_1), f(X_2),\dots, f(X_m)] \quad (1)$$

Where, $f(X_i)$ is the objective vector, and the optimization objective of job scheduling multi-objective of manufacturing workshop is to seek an optimal decision vector X^*, so as to ensure that the result of each optimization objective is optimal.

Optimization objectives include:

(1) Shortest completion time:

$$f_1=C_m=\min\{\max\{C_i\}\} \quad (2)$$

(2) Total machine load:

$$f_2=W_i=\min\{\sum_{k=1}^{m} W_k\} \quad (3)$$

(3) Maximum machine load:

$$f_3=W_m=\min\{\max W_k\} \quad (4)$$

The actual job scheduling of manufacturing workshop often needs to consider the simultaneous optimization of multiple production objectives, which further increases the difficulty of job scheduling. Three optimization job scheduling objectives make it impossible to obtain the optimal solution for each objective, but only a set of non-dominating solutions can be obtained. At present, multi-objective evolution algorithm is used in job scheduling of multi-objective manufacturing workshop, but its convergence and accuracy of rescheduling are not high. This study introduces a new discrete differential evolution algorithm into multi-objective problem solving to obtain the global optimal solution of job scheduling of multi-objective manufacturing workshop.

4.2 Experiment simulation and result analysis

This study adopts the framework of discrete differential evolution algorithm to establish the population and mutation operator of multi-objective manufacturing workshop. The increase of population size and evolution iterations will increase the running time of the algorithm. In comparison with multi-objective evolution algorithm, computer simulation technique is used to calculate the influence of different initial population and evolution iterations of manufacturing workshop on the non-dominating solution set in a certain scheduling area. Fig. 7 is an optimal dominating solution set of the two algorithms under different initial populations, and it can be clearly seen that the stability of the optimal dominating solution of job scheduling of multi-objective manufacturing workshop decreases with the increase of the number of initial populations. However, the stability of the optimal dominating solution set obtained by the discrete differential evolution algorithm is higher that of the multi-objective evolution algorithm on the whole. Fig. 9 is a comparison of the convergence of the two algorithms under different initial populations, and it can be clearly seen that the maximum completion time calculated by the discrete differential evolution algorithm is the smallest, and the convergence is stronger than that of the multi-objective evolution algorithm.

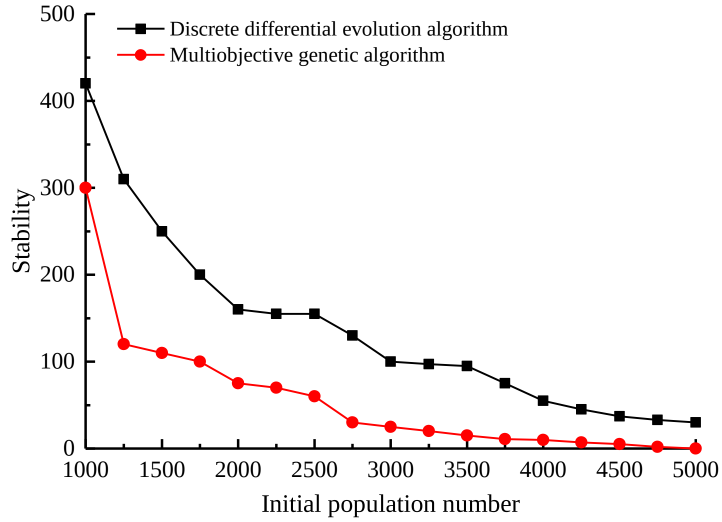

Fig. 7 The optimal dominating solution set of two algorithms under different initial populations

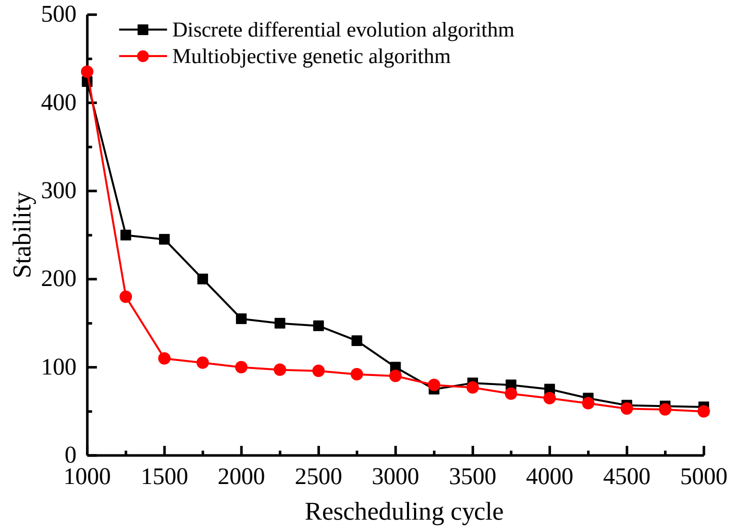

Fig. 8 The optimal dominating solution set of two algorithms under different evolution Algebras

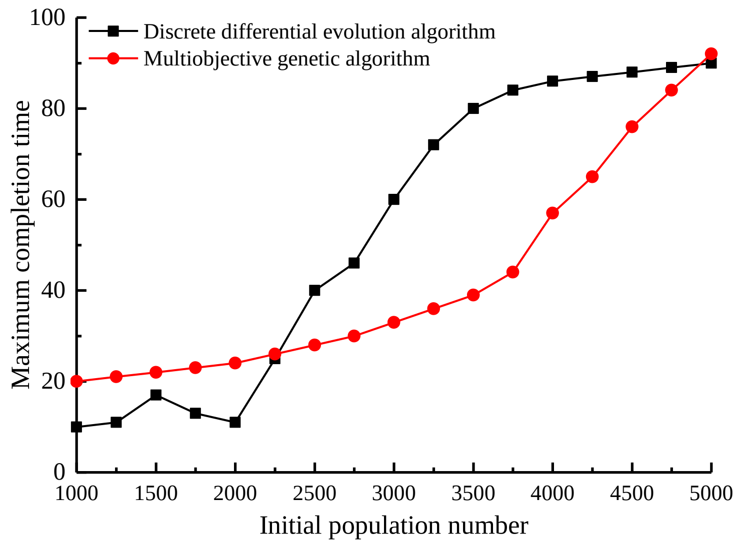

Fig. 9 Convergence comparison of two algorithms under different initial populations

5 CONCLUSIONS

Based on the principle of discrete differential evolution algorithm, this study presents a job scheduling model of multi-objective manufacturing workshop with completion time and total machine load as the optimization objectives. The specific conclusions are as follows:

(1) With the increase of rescheduling cycle, total completion time and total tardiness increase. Total completion time has a positive linear relationship with scheduling cycle while total tardiness has a negative linear relationship with scheduling cycle. Total efficiency increases with the increase of rescheduling cycle while total stability decreases first and then increases with the increase of rescheduling cycle.

(2) Common dynamic common dynamic events in the discrete job scheduling system of manufacturing workshop include component-related, equipment-related and time-related events. When the production system monitors the occurrence of the rescheduling driving factor, rescheduling may be implemented with a dynamic event as the trigger mechanism.

(3) The objective of job scheduling is to achieve the satisfaction of both the manufacturer and the customer. Compared with the multi-objective evolution algorithm, the stability of the optimal dominating solution set obtained by the discrete differential evolution algorithm is higher, the calculated maximum completion time is the smallest, and the convergence is stronger.

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