Optimization Study on Enterprise Production Plan Based on Genetic Algorithm

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Abstract: This article aims at solving the common issues on enterprise production plan, based on combining JIT production idea and actual product characteristic, to establish an optimized production plan model, with advanced and delayed production as the least ambition and with the availability of the enterprise equipment and order quantity as constraint conditions. Meanwhile, GA is used to solving the optimization model, and is used in the practical cases, so that the production plan of the minimum cost is attained. The model has a great guiding significance on the decrease in the enterprise production cost, the development of the use ratio of equipment and the rapid production planning.

Keywords: Genetic algorithm, optimized model, production planning, simulation.

1. INTRODUCTION

The production plan is regarded as an important link in the production management of the enterprise. It determines and affects other function domains to a large extent, such as marketing, material supply, equipment maintenance, human resource, and planned activity of the financial cost department. Besides, it plays a vital role in the operation quality and development prospect of the enterprise [1, 2]. A good production plan is the premise for ensuring the timely delivery of products, improving the resource utilization rate, promoting the productivity effect of the enterprise, and reducing the production cost.

The core of Just-In-Time (JIT) is to pursue zero inventory or minimize the inventory as possible [3, 4]. In other words, under JIT production condition, the production cost of the enterprise is the lowest.

Genetic Algorithm (GA) refers to a search algorithm of an adaptive global optimization probability formed by simulating the inheritance and evolution process of the organisms in the natural environment [5, 6]. It is an optimization algorithm generating for simulating the evolutionary process of the natural organism based on Darwin's biological evolution. Firstly, generate a certain initial group, generally select the individuals through natural biological evolution, cross the genes, and then search for the optimal solution through the variation generated by the gene.

This paper establishes enterprise production plan optimization model based on JIT conception, and utilizes GA to carry out the simulation by combining with a production case, and then determines the optimal production plan.

2. PROBLEMS IN THE CURRENT PRODUCTION PLAN OF THE ENTERPRISE

Through the investigation on several manufacturing enterprises, it turns out that the following problems exist in the formulation of the production plan:

(1) Mainly depend on the personnel to formulate the production plan by hand. The accuracy of the data obtained through this method is low. Besides, it takes much time and increases the labor intensity of the formulators.

(2) Excessively depend on the market information when formulating the production plan, which causes that the enterprise cannot utilize its productivity regularly. Besides, some problems will occur. For instance, during a certain period, the production tasks are severely insufficient, and the productivity and equipment of the enterprise will be idle and wasted; however, during another period, the production tasks are so heavy, and even they cannot be completed in time after the workers work overtime, and thus the delivery of the order should be postponed.

(3) The production flexibility of the enterprise is not high. When a great change suddenly occurs in the market operation environment, the enterprise cannot make rapid adjustment and decision aiming at the change of the market environment in short term. For instance, the unexpected default of the enterprise production equipment, supply problem of the raw material, temporary change of the orders and other unexpected issues will give rise to the adjustment of the enterprise production plan, a waste of the productivity and equipment during the production or delayed delivery date.

3. ESTABLISHMENT OF MATHEMATIC MODEL

This paper establishes production plan optimization model based on JIT conception, i.e. rationally arrange and prioritize the production plan of the enterprise products ac-

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cording to the current order status of the enterprise, available capacity of the equipment, inventory cost, expense of contract breach, and other factors.

The production finished ahead of the schedule will increase the stock, occupy the circulating funds, and increase the stock cost [7, 8]; if the goods are not delivered on schedule, the enterprise should pay the fine. By taking the minimum advanced/delayed cost of the goods within the schedule as the objective function, this paper establishes the production plan optimization model. Besides, it defines each symbol and variable as follows:

Assume the enterprise plans to produce N kinds of products within T days.

d_i(t): The market demand of the product *i* on Day *t*;

x_i(t): The plan volume of production of the product *i* (i=1,2,…,N) on Day *t* (t=1,2,…,T);

α_i : The additional cost of the product *i* that are finished in advance;

β_i : The fine cost of the product *i* whose delivery date is delayed;

I_i(t): The stock of the product *i* by the end of *t*, and if I_i(t) is a minus, it represents its owed production output;

W_{ij}: The production hours of the product *i* required by the equipment *j* (j=1,2,…,K);

c_j(t): The available productivity of the equipment *j* on Day *t*;

Therefore, the objective function and constraint condition of the production plan optimization model is as follows:

$$\min F(p)=\sum_{i=1}^{N}\sum_{t=1}^{T}\Big[\alpha_i \max\big(0\ \ (x_i(t)-d_i(t)+I_i(t))\big)+\beta_i \max\big(0\ \ (d_i(t)-x_i(t)-I_i(t))\big)\Big] \quad (1)$$

$$\text{s.t.} \sum_{i=1}^{N} w_{ij}x_i(t)\le c_j(t)\quad t=1,2,...,T,\ j=1,2,...,K \quad (2)$$

$$\sum_{i=1}^{N} x_i(t)=d_i(t)\quad t=1,2,...,T \quad (3)$$

$$x_i(t)\ge 0\quad i=1,2,...,N,\ t=1,2,...,T \quad (4)$$

Among them, Constraints (2), (3) and (4) refer to the production capacity constraint, order quantity capacity, and non-negativity constraint of the production respectively.

4. APPLY GA TO SOLVE

The flow chart of GA is showed in Fig. (**1**) [9]. In essence, its solution procedure is a constant iterative computation process. This algorithm sets the coding of the decision variable into a character string with limited length as the chromosome. As each individual is equivalent to a feasible solution of the problem, and a group of individuals forms a population of a generation; the objective function is equivalent to the environment where the population is located, and its value can be transformed into the fitness of the individual towards the environment. starting from the initial population, simulate the evolutionary process, and leave the individual with high fitness and also reconstitutes new population through the survival of the fittest; apply the crossing, variation and other means to generate new population, and keep the superior population enter into the next generation.

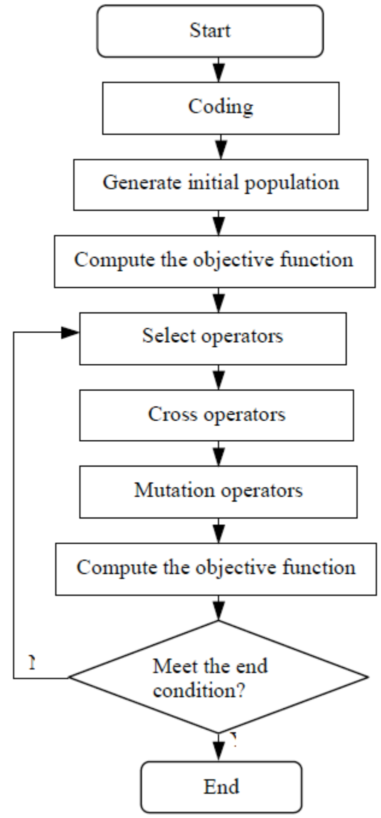

Fig. (1). Flow chart of genetic algorithm.

4.1. Coding

Except the form of determining the chromosome arrangement of the individual, the coding method also determines the individual to transform into the expression form of solution space from the gene form of searching space [10]. Therefore, the coding method determines how to conduct the genetic evolution algorithm of the population and the efficiency of the algorithm to a great extent. The coding methods of GA are mainly as follows: binary system coding method, floating number coding method, and symbol coding method. This paper adopts the most common binary system coding method, and uses the binary system symbol string with certain strength to present the individuals of the population. Its allele is composed of two-value symbol set $\{0,1\}$.

4.2. Initial Population

This paper adopts M randomly generated individuals conforming to the constraint condition to constitute the initial population. The size of M is generally 20~100. C language program generating the initial population is:

```
vector<vector<product_de>>gen_ZQ_de(int ZQ_num, int Day_num){
    vector< vector<product_de> > gen_ZQ_temp;
    vector<product_de> vec_pro_de;
```

```
        gen_ZQ_temp.clear();
        for(int i=0; i<ZQ_num; i++){
         vec_pro_de = gen_RST_de(Day_num);
         gen_ZQ_temp.push_back( vec_pro_de );
        }
        return gen_ZQ_temp;
    }
```

4.3. Fitness Function

The fitness function value is an important part of GA. In general, the fitness function is transformed from the objective function. The fitness value of the individual from the population determines its viability. During the survival of the fittest, it is necessary to sort the fitness of the chromosome. Therefore, the fitness function value is required to be non-negative. With regard to solving the maximum problem, the fitness is equal to the objective function. This paper is about the optimal problem of solving the minimum of the objective function. The following formula is adopted for the fitness function:

$$F(X)=\begin{cases} R_{\max}-f(X) & f(X)<R_{\max} \\ 0 & f(X)\geq R_{\max} \end{cases},$$

$f(X)$ refers to the objective function; R_{max} refers to a relative big number input in advance, or the maximal objective function value when evolving into the current generation, or the maximal objective function value of the current generation or population of the recent generations.

4.4. Design of the Genetic Manipulation

1. Selection (reproduction)

The selection manipulation is established on the basis of evaluating the fitness of the individual. It is mainly aimed at avoiding the gene deletion, and improving the global convergence and computational efficiency. The common methods for selection operator are as follows: proportional selection method, optimal retention policy, deterministic sampling selection, random selection, ranking selection, random tournament selection, etc [10]. This paper adopts the deterministic sampling selection method. The specific step is: firstly, compute the survival expectation amount $N_i = M\cdot F_i / \sum_{i=1}^{M} F_i$ (M is the size of the initial opulation; F_i is the fitness function) of each individual in the population of the next generation, and apply the integral part of N_i to confirm the survival amount A of each corresponding individual in the population of the next generation; carry out descending sort on the individual according to the decimal part of N_i, select (M-A) individual in order and put it into the population of the next generation. In this selection manipulation, there is no doubt that the individual with relatively high fitness will be retained in the population of the next generation.

2. Crossover (recombination)

This paper adopts single-point crossover operation. Namely, adopt pairwise coupling towards the individuals in the population, and randomly set the position after certain loca in the individual of each pairwise coupling as the cross point. However, with regard to the individuals which are not coupled, interchange some chromosomes of both individuals in the cross point based on the crossover probability, and then generate two new individuals. After the crossover, check the new generated genes whether they conform to the constraint condition or not.

3. Mutation

This paper adopts binary coding. The mutation operation is to invert the genic value of the individual on the change point with certain mutation probability. Namely, if the original genic value is 0, the mutation operation changes this value into 1; if the original genic value is 1, the operation will change it into 0; from Reference [10], the value range of the mutation probability P_m is 0.0001~ 0.1.

5. SolutIon Case

A battery manufacturing enterprise should produce two different types of battery within 10 days – Type I and II. The additional cost generated after producing a battery in advance is RMB0.01 and RMB0.011 respectively, while the penalty cost resulting from the late delivery is RMB0.012 and RMB0.015 respectively. The enterprise can produce 60,000 batteries of Type I or 20,000 batteries of Type II. During the initial phase of the plan, the inventory of both products was zero, and the order quantity demand is shown in Table **1**:

Table 1. Total Order Quantity of Two Types within 1 to 10 Days Order unit: a thousand batteries.

Type	Time(day)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
I	0	0	60	0	50	0	0	85	0	30
II	0	45	0	0	20	0	35	0	0	25

Establish the production plan mathematic model through the above data:

Objective function:

$$\min \mathrm{F}(p)=\sum_{t=1}^{T}\Big[0.01\max\big(0,\left(x_1(t)-d_1(t)\right)\big)+0.012\max\big(0\ \left(d_1(t)-x_1(t)\right)\big)\Big]$$
$$+\sum_{t=1}^{T}\Big[0.011\max\big(0,\left(x_2(t)-d_2(t)\right)\big)+0.015\max\big(0,\left(d_2(t)-x_2(t)\right)\big)\Big]$$

Constraint condition:

$$\begin{cases} 0\leq x_1(t)+3x_2(t)\leq 60000 \\ \sum_{t=1}^{T} x_1(t)=225000 \\ \sum_{t=1}^{T} x_2(t)=125000 \\ x_1(t)\geq 0 \\ x_2(t)\geq 0 \\ T\in[1,10] \end{cases}$$

In the solving process through GA, the selected values of each parameter are respectively as follows: population size M=20, crossover probability p_c=0.8, mutation probability p_m=0.05, max iteration G=1,000. Compile the program and conduct solution, and then obtain the optimal production plan of the enterprise, which is shown in Table **2**. Besides, it figures out the cost of the early and delayed production is RMB2, 390.

Table 2. Optimal Production Plan of the Enterprise Order unit: a thousand batteries.

Type	Time(day)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
I	0	0	36	24	42	12	3	48	33	27
II	20	20	8	12	6	16	19	4	9	11

CONCLUSION

The superior production plan can give full play to the current production capacity of the enterprise, improve the production efficiency, realize the optimal configuration of the enterprise resource, and improve the competitiveness effect. This paper establishes the enterprise production plan optimization model and applies it into the specific cases, and adopts GA to solve the objective function. It turns out that adopting the optimization model to optimize the production plan not only can meet the production capacity and market demand, but also can minimize the additional production cost of the enterprise, which provides feasible guiding significance for formulating the production plan.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: April 10, 2015 Revised: May 20, 2015 Accepted: June 15, 2015