Production Line Production Planning Model of Iron and Steel Enterprise

Guozhang Jiang, Enyuan He, Gongfa Li, Jianyi Kong, Liangxi Xie
College of Machinery and Automation
Wuhan University of Science and Technology
China
whjgz@wust.edu.cn

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ABSTRACT: *At present, iron and steel enterprise develops towards the direction with many procedure, many process, many variety and many specification, and reaches hundreds and thousands of product series and product mix, how to plan, organize and control steel production, production schedule of its product line are key issues. According to the main characteristics of production line of iron and steel enterprise, how to make aggregate production planning of iron and steel enterprise are analyzed. An aggregate production plan model of product line of iron and steel enterprise is proposed, which is calculated by using standard library function of the Matlab7.0 genetic algorithm toolbox to program. Penalty function was adopted in the course of getting solution. These parameters of scale of father population, crossover probability, mutation probability and penalty factor were combined and optimized. The result obtained is in accordance with the actual conditions of this enterprise basically that the optimization solution to production plans of real iron and steel enterprise by using the algorithm.*

Categories and Subject Descriptors
G.3: [PROBABILITY AND STATISTICS]; Probabilistic algorithms: **I.1.2 Algorithms**

General Terms:
Genetic Algorithms, Matlab

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1. Introduction

Aggregate production planning of enterprise which is the rational arrangement and use of existent equipment and personnel is the key problem that should be attached importance to according to the external environment, internal condition and development strategy. Therefore, many researchers devote themselves to the study, and have obtained achievements [1-3]. Reference [2] studies the problem of aggregate production planning with varieties of types by mathematical programming based on the HMMS model in aggregate production planning. Reference[2] solves the planning problems of multi-product production and manpower utilization with the optimal control theory. Nevertheless, the aggregate production planning method just takes into account the demand forecast by the solution of the minimum, without considering of the product pricing problem in sales, which affects the market conformance and effectiveness of aggregate production planning. Reference [4] discusses how to ascertain the optimal production quantity, the predetermined price and the feasible price of each stage product by the total cost of each stage with stochastic demand. These researches reflect the development of the study on aggregate production planning to some extent. In practice, different product line combinations, different production organization modes and different production planning managements also lead to different aggregate production planning of final product-line. Little literature studies the production planning and control from viewpoints of the production and management plan, particularly from the comprehensive perspective of product combination [5-6]. Production planning model [7] of steel enterprise and Production Planning Model [8] are studied. Therefore an aggregate production plan model of product line based on the product line of some steel company is established, and is feasibility is proved in practical application.

2. Aggregate Production Planning of Iron and Steel Production Line

The target of production planning is profit control that determines the profit of product line combination. According to the production flow of iron and steel enterprise, considering product objective profit, enterprise' production capacity, supply capability of raw material, restraint of energy and market change, in order to satisfy the order, the production planning should do the best to produce marketable products to maximize enterprise' profit, minimize lost cost of shortage and holding cost, reduce product cost, etc. Considering constraint conditions, some constraint conditions can be selected, such as product cost, restriction of productive capacity and supply capability of raw material, environment protection and energy consumption, etc. Table 1 shows the constrained data of production capacity which is the basic of production planning and regulated along with the change of production.

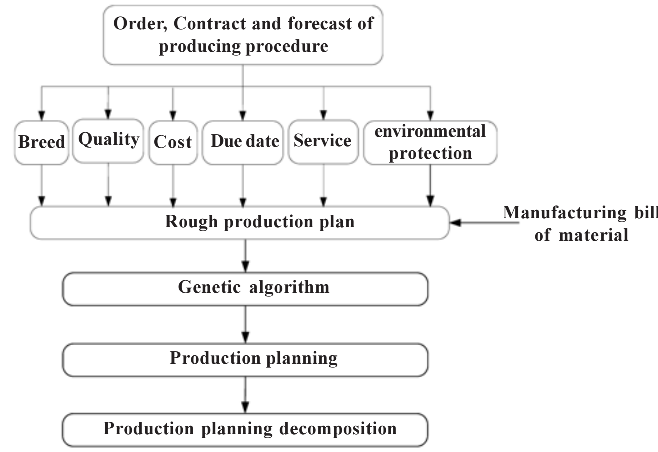

Figure 1. The research method of production plan

Production capacity	Year			
	2003	2004	2005	2006
Hot metal(productivity)(kt)	0	0	13250	18250
Molten steel(productivity) (kt)	3000	3000	11000	16250
Cold rolled plate(kt)	2420	2200	2200	2700
Galvanized sheet and colour coated steel plate (kt)	590	800	1000	1000
Thick Plates (kt)	1110	1200	1300	1300
Heavy section steel(kt)	680	800	900	900
Wire rod(kt)	840	800	800	800
Medium plate(kt)			900	900
Seamless pipe(kt)			400	500
Medium and small section steel(kt)			250	250
Hot rolled sheet(kt)			7200	9200
Steel for cold-rolling(kt)			2800	3700
Hot rolled sheet(kt)t			4400	5500
Cold rolled non-oriented silicon steel(kt)			600	1000

Table 1. Constrained data of production capacity of an iron and steel enterprise

3. Aggregate Production Planning Model of Iron and Steel Production Line

Firstly, the materials are described in product manufacturing plan in the iron and steel enterprise. In production process, the materials undergo physical and chemical changes, from the solid (iron ore material, etc.) to fluid state (hot metal, molten steel), then to solid state (semi-finished product, plate, convolve), to attain the standard of consumer request, which causes it is different from assembling manufacturing industry. It not only adopts the contract model or the market forecast model, but also uses the optimal method combining the contract and the market forecast. Figure 1 shows the research method of production plan.

The task of aggregate production planning is to distribute production capacity of plan period rationally, make sale plans of the varieties and the destinations, and generate the production and scheduling planning of each process, in accordance with market and management strategy of enterprise, whose core is the producing model of production line.

3.1 Description of the model

Supposed that the products with m varieties and n specifications are produced, the plan period is divided into T phases in iron and steel enterprise. In virtue of the internal and external sales and production with process, establishing the model, all the variables and parameters are described as follows: R is the set of raw materials, E is the set of final products, F is the set of process units, T is the set of plan periods, L is the set of orders, V is the set of steel grades, S is the set of specifications, v is a steel grade, s is a specification (thickness × width/outer diameter), f is a process unit, l is a indent number, t is a plan period, I is a raw material, j is a final material, in order to the convenience of discussion.

1) Description of the combined production planning model

X_{vst} -- the product quantity with the v^{th} kind of steel grade and the s^{th} kind of specification that sale to enterprise external in the t^{th} period;

Y_{it} -- the quantity of the i^{th} material that buy from enterprise external in the t^{th} period;

Z_{ift} -- the quantity of the i^{th} material produced in the f^{th} process unit in the t^{th} period in enterprise;

St_{it} the volume of stock of the i^{th} material in the t^{th} period;

W_{ft} -- the quantity of the standard productive man-hour in the f^{th} process unit in the t^{th} period during normal production;

V_{ft} -- the quantity of the standard productive man-hour in the f^{th} process unit in the t^{th} period during overtime production;

T_{rt} -- the actual delivery time in the t^{th} period;

T_{at} -- the advanced delivery time in the t^{th} period;

T_{dt} -- the delay delivery time in the t^{th} period;

S_{ft} -- the normal productive capacity in the f^{th} process unit in the t^{th} period;

q_{fij} -- the quantity of the i^{th} material that can produce the j^{th} material in the f^{th} process unit;

θ_{tij} -- the conversion of the i^{th} material that can produce the j^{th} material in the t^{th} period;

δ-- the average coefficient of waste products;

ρ_t -- the environmental cost of unit product in the t^{th} period;

δ_{ft} -- the proportion coefficient for overtime production in the f^{th} process unit in the t^{th} period;

$D_{vst}^{\min}$ -- the minimum demand of the v^{th} kind of steel grade and the s^{th} kind of specification in the t^{th} period (ascertain the order demand);

Pr_{vst} -- the forecasting demands of the v^{th} kind of steel grade and the s th kind of specification in the t^{th} period;

$O_{it}^{\min}$ -- the maximum output of the i^{th} material in the t^{th} period;

P_{vst} -- the selling price of the i^{th} material in the t^{th} period;

C_{it} -- the unit purchasing cost of the i^{th} material in the t^{th} period;

Sp_{it} -- the unit stock cost of the i^{th} material in the t^{th} period;

Cw_{ft} -- the cost of the standard productive man-hour in the f^{th} process unit in the t^{th} period during normal production;

Cv_{ft} -- the cost of the standard productive man-hour in the f^{th} process unit in the t^{th} period during overtime production;

Sv_{ft} -- the cost of the standard productive man-hour in the f^{th} process unit in the t^{th} period during normal production;

α_t -- the compensation expense per unit product for advanced delivery in the t^{th} period;

β_t --the compensation expense per unit product for delay delivery in the t^{th} period;

Q_t -- the fixed costs including the fixed wages, the depreciation charges of machines and the whole sales expense in the t^{th} period;

3.2 Establishment of the model

1) The objective function

$$\max \sum_t \left\{ \begin{array}{l} \sum_{v\in V}\sum_{s\in S} P_{vst}X_{vst} - \sum_{i\in R}[Cw_{ft}W_{ft} + (Cv_{ft}+Sv_{ft})\,V_{ft}] \\ -\sum_{i\in R} Sp_{it}St_{it} - Q_t - \alpha_t(T_{rt}-T_{at}) - \beta_t(T_{dt}-T_{rt}) - \rho_t Z_{it} \end{array} \right\} \quad (1)$$

In the function, $\sum_{v\in V}\sum_{s\in S} P_{vst}X_{vst}$ denotes the sales income in the t^{th} period, $\sum_{i\in R} C_{it}Y_{it}$ is the purchasing cost, $\sum_{f\in F} Cw_{ft}W_{ft}$ is the normal processing cost, $\sum_{f\in F}(Cv_{ft}+Sv_{ft})V_{ft}$ is the overtime processing cost, $\sum_{i\in R} Sp_{it}\,St_{it}$ is the stock cost, Q_t is the fixed cost, $\alpha_t(T_{rt}-T_{at}) - \beta_t(T_{dt}-T_{rt})$ is the penalty cost for advanced or delay delivery.

2) The constraint conditions

$$Y_{it} + St_{it} - St_{i,t+1} - \sum_{f\in F}\sum_{j\in E}(1+\delta)\,q_{fij} = 0\ (\forall i\in R, t\in T) \quad (2)$$

$$\sum_{f\in F} Z_{jft} + St_{it} - St_{i,t+1} - X_{vst} = 0\ (\forall j\in E, t\in T) \quad (3)$$

$$Z_{j,t+1} = \theta_{tij} Z_{it} (\forall i\in R,\ j\in E, t\in T) \quad (4)$$

$$Y_{it} \le Su_{it} (\forall i\in R, t\in T) \quad (5)$$

$$D_{vst}^{\min} \le X_{vst} \le D_{vst}^{\min} + \Pr_{vst} (\forall i\in R, t\in T) \quad (6)$$

$$W_{ft} \le S_{ft} (\forall f\in F, t\in T) \quad (7)$$

$$V_{ft} = \delta_{ft}\, S_{ft} (\forall f\in F, t\in T) \quad (8)$$

$$Sf_{it} \le St_{it} \le O_{it}^{\max} (\forall i\in R, t\in T) \quad (9)$$

In the conditions, (2) is the equilibrium constraint of raw material, (3) is that of production and marketing of product, (4) is that of production flow, (5) is the purchasing constraint, (6) is the product demands constraint, (7) is the standard production capacity constraint, (8) is the overtime production capacity constraint and (9) is the storage capacity constraint.

4. Designing of the Genetic Algorithm

4.1 Chromosome Encoding Design

These variables in the model are all real number, so dimension of the model is high. For some high dimension continuous function optimizing problems requiring high precision, binary encoding can be used except some disadvantages, and float encoding can also be used.

4.2 Initial population

Based on the genetic algorithm toolbox of Matlab 7.0, function gaoptimset $(\text{'}PopulationSize\text{'}, L)$ is used to create initial population with L chromosomes at random.

4.3 Treatment of fitness function

In the course of settlement about model constraints, adopting penalty function to reduce the fitness ability of individuals that don't not satisfy constraints, then their reproducing can be controlled. How to build a fitness penalty function is the key problem. Penalty function form is as follows:

$$Penalty\, f(x) = \sum_{j=1}^{m} R_{ij} f_j^2(x) \qquad (10)$$

'i' different constraint-against level to the j^{th} constraint at first is built, different penalty coefficient R_{ij} is determined focusing on every level. The higher the constraint-against level is, the greater the value of R_{ij} is. The penalty function used in program can be described in (11).

$$Penalty\, f(x) = \begin{cases} rho * sum(abs\,(ceq)) \\ \quad Dissatisfy\ the\ equation\ constraint \\ mu * sum(c\,(c < 0))\ \hat{}\ 2 \\ \quad Dissatisfy\ the\ inequation\ constraint \end{cases} \qquad (11)$$

In (11), rho is equation penalty coefficient, while mu is inequation penalty coefficient.

This algorithm adopt choice function——Stochastic uniform (stochastic symmetrical distribution function) in Matlab 7.0 gads genetic algorithm toolbox (@selectionstochunif), and the fitness function is goal function.

4.4 Crossover operator and mutation operator

Crossover operator and mutation operator adopt standard functions of Matlab 7.0 gads genetic algorithm toolbox. Crossover operator used standard crossover function——Scattered (@crossoverscatter), and mutation operator adopt standard aberrance function——Gaussian (mutationgaussian).

4.5 Convergence problem

Convergence used dynamic weight to change penalty coefficient. The convergent condition is $|f_i - f_{i+1}| \leq pTol$, here $pTol$ is an enacted positive value which is little enough ($i = 1, 2, ..., n$). When the convergent condition is not met, dynamic weight function is used:

$$\text{rho} = \min\{\text{rho} * \text{pStep, le30}\};$$

$$\text{mu} = \min\{\text{mu} * \text{pStep, le30}\};$$

In these two functions, le30 is a greater positive number. When rho and mu use weight values, the algorithm will be convergent.

5. Solution for the Aggregate Production Planning Model of Iron and Steel Production Line

The products of an iron and steel enterprise consist of wire rod, bar, medium plate and high speed wire rod. In this paper, considering the products of 5 specifications including wire rod (ϕ 8, ϕ10), bar (ϕ25, ϕ16) and medium plate (6-32mm), the model is solved based on the practical data. The solution of linear programming adopts the general software, such as optimization toolbox and genetic algorithm toolbox of MATLAB, to program. Related parameters are shown in Table 2.

Material / Paramete / Parameter	Iron ore	Limestone	Coal	Wire rod (Φ8)	Wire rod (Φ10)	Bar (Φ25)	Bar (Φ16)	Medium plate (6-32mm)
Price(yuan/t)	950	170	930	3620	3630	3410	3400	4500
Stock cost(yuan/t)	14.7	5.1	19	/	/	/	/	/
Safety stock(kt)	2000	800	3000	/	/	/	/	/
Producing cost(yuan)	/	/	/	2300	2300	2000	2000	2500

Table 2. Related parameters and values of the model

According to the practical requirement, when the plan period T is one year, the annual program demand is 600000 t, making up 30 percent of the total production quantity that is 2000000t, and the production cost of unit man-hour is 900000yuan under the normal production condition. On the basis of experience, the conversion from iron ore to molten iron is 50% and the average coefficient of waste products is 20%.

So the model can be calculated simply in MATLAB7.0 environment, of which the population scale is 100, the crossover probability is 0.95 and the mutation probability is 0.2. The variation curves of target value and target mean is shown in Figure 2. Results of the model optimization are shown in Table 3, which is coincident well with practical case.

Variety	Wire rod (Φ8)	Wire rod (Φ10)	Wire rod (Φ25)	Wire rod (Φ16)	Medium plate (6 - 32 mm)
Output (kt)	305.3	420.6	145.1	225.7	4585

Table 3. Results of the model optimization

5. Conclusion

An aggregate production planning model of production line of an iron and steel enterprise is build. The optimal combined outputs of several products (wire rod, bar and medium plate) is calculated by using standard library function of the Matlab7.0 genetic algorithm toolbox to program. The optimization solution to production planning of the iron and steel enterprise accords with the actual production outputs basically that by using the algorithm. The model has well guidance to production planning of enterprise.

Iron industry of our country can have sustainable development, could march towards the steel powerful country.

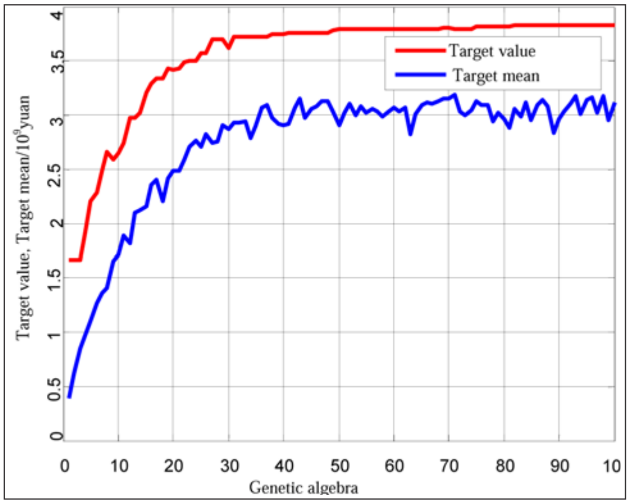

Figure 2. Changes of target value and target mean value

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Author Biographies

Guozhang Jiang was born in Hubei province, P. R. China, in 1965. He received the B.S. degree in Changan University, China, in 1986, and M.S. degree in Wuhan University of Technology, China, in 1992. He received the Ph.D. degree in mechanical design and theory from Wuhan University of Science and Technology, China, in 2007. He is a Professor of Industrial Engineering, and the Assistant Dean of the college of machinery and automation, Wuhan University of Science and Technology. Currently, his research interests are computer aided engineering, mechanical CAD/CAE and industrial engineering and management system.

Dr.Gongfa Li received the Ph.D. degree in mechanical design and theory from Wuhan University of Science and Technology in China. Currently, he is an associate professor at Wuhan University of Science and Technology, China. His major research interests include modeling and optimal control of complex industrial process. He is invited as a reviewer by the editors of some international journals, such as Environmental Engineering and Management Journal, International Journal of Engineering and Technology, International Journal of Physical Sciences, International Journal of Water Resources and Environmental Engineering, etc. He has published nearly ten papers in related journals.

Jianyi Kong received the Ph.D. degree in mechanical design from Universität der Bundeswehr Hamburg, Germany, in 1995. He was awarded as a professor of Wuhan University of Science and Technology in 1998. Currently, he is the president of Wuhan University of Science and Technology, China. He services on the editorial boards of the Chinese journal of equipment manufacturing technology. He is a director of the Chinese society for metals, etc. His research interests focus on intelligent machine and controlled mechanism, dynamic design and fault diagnosis in electromechanical systems, mechanical CAD/CAE, intelligent design and control, etc.

Liangxi Xie is an associate professor in Wuhan University of Science and Technology, China. He major in mechanical design and theory and focus on the research of rotorary vane steering gear (RVSG) and vane seals. He has published more than ten papers in related journals.