Improved heuristic algorithm for modern industrial production scheduling

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Abstract: Scheduling is one of the core links of modern industrial production. Scheduling needs to be designed according to the characteristics of the production line. In order to optimise the problem of workshop scheduling, the service-oriented programming idea and advanced technology to optimise the system development of mixed flow shop are adopted. The system is designed for applications in a distributed network environment. In this paper, an improved heuristic industrial production scheduling method is proposed to solve the scheduling system problem with multiple scheduling tasks, multiple processes, multiple stations, multiple constraints and rules. This method specifies the processing equipment, start time and completion time for each process of the production task. The application method shows that the proposed method can improve the automation and intelligence level of the scheduling process, improve the utilisation rate of equipment and other production resources, and give full play to the enterprise production capacity.

Keywords: production management; modern industrial; heuristic; scheduling.

Reference to this paper should be made as follows: Jiang, Y. and Pan, F. (2018) 'Improved heuristic algorithm for modern industrial production scheduling', *Int. J. Modelling, Identification and Control*, Vol. 30, No. 4, pp.284–292.

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This paper is a revised and expanded version of a paper entitled 'research on production scheduling optimization based on heuristic algorithm' presented at ICMIC2017, Kunming, 10–12 July 2017.

1 Introduction

The modern corporations are moving towards continuous, high-speed and automation with large devices. The focus is placed on high quality, low cost, just-in-time delivery and small lots with different varieties. In order to enhance their competitive power, many international corporations are developing computer integrated manufacturing systems (CIMS) which can improve productivity of large devices, reduce waiting-time between operations, save material and energy consumption, and cut down production costs. Production scheduling is a key component of CIMS. Its task is to determine the beginning time and the completion time of jobs on the machines so that the enterprise realises the high production.

In order to optimise the problem of such workshop scheduling, researchers need to adopt the service-oriented programming idea and advanced technology to optimise the system development of mixed flow shop. The importance of satisfying customer demands and achieving higher profits has increased the attention towards production scheduling in semiconductor assembly areas. Combination of productivity and flexibility provided by semiconductor assembly areas has attracted many research efforts for several years. In this paper, the research on the scheduling of modern industrial production is studied. The research on the scheduling problem of semiconductor packaging test is put forward, and a new research scheme and solution of packaging test scheduling based on job and resource dynamic optimisation are proposed. At the same time, the problem is solved by the establishment of the phased model and the algorithm, which reduces the complexity of the problem. The research of this project will fully combine the characteristics of packaging and testing production. At the same time, given the large gap between the existing production scheduling theory and the actual production and application, the project is a semiconductor packaging and testing enterprise for the actual research object, and assists packaging and testing enterprises to provide a feasible production scheduling, effective and practical system and method support.

2 Literature review

In the past several years, mathematical model and ant system meta-heuristic for production planning process of a mini plant are proposed (Vaidyanathan and Sampath, 2017; Eftekhari and Mahdi, 2016; Best and Bogdanski, 2017). Semiconductor manufacturers are increasingly assembling multiple chips into a single package to maximise the capacity of flash memories. Chung et al. (2014) propose a novel framework to find a good schedule for semiconductor packaging facilities by focusing on bottleneck stages while satisfying practical operational constraints. A genetic algorithm-based sequence optimiser is employed, and construction and performance evaluation of a schedule are separately addressed by a simulator. Lin and Chen (2015) presents a simulation optimisation approach for a hybrid flow shop scheduling problem in a real-world semiconductor back-end assembly facility. In recent years, there is study which demonstrates the value of the simulation optimisation approach for practical applications and provides directions for future research on the stochastic hybrid flow shop scheduling problem (Cho and Jeong, 2017; Li et al., 2015; Chamnanlor et al., 2015). Research on the scheduling problem of semiconductor wafer fabrication and propose a new dispatching rule based on the load balance. Then they (Zhang et al., 2016) present a new harmony search algorithm based receipt priority interval. Computational simulations based on the practical instances validate the proposed algorithm. For the problem complexity, those researchers omit some constraints, so those schedules need to be more designed according to the characteristics of the production line.

Other researchers (Fordyce et al., 2015) present an improving system responsiveness which is best addressed by an advanced industrial engineering team that is typically the only group with the ability to see the forest and the trees. The corresponding basic system theoretical (Fliess et al., 2008) definitions and properties are presented within the framework of differential algebra, which permits to handle system variables and their derivatives of any order. Analysis a large number of studies (Hao et al., 2014) which have been conducted in the area of semiconductor final test scheduling problems. They propose a novel cooperative estimation of distribution algorithm to overcome these challenges. A suitable commutation logic (Shang and Wang, 2013) that prevents an uncontrollable growth of the uncertainties is introduced. The combined approach retains the stability and convergence features of the original adaptive strategy. The multiple model (Orjuela et al., 2008) approach is an elegant and a powerful tool for modelling real-world complex processes. In this modelling framework, a judicious combination of a set of submodels makes it possible to describe the behaviour of a non-linear system. Investigate the integrated delivery of automated material handling system and processing tools for a large-scale complex wafer fabrication facility (Manupati et al., 2016). With hierarchical rule-based scheduling approach, the combined sequential dispatching rules are formed to achieve better efficiency and effectiveness of the scheduling. Conduct a study on one-wafer cyclic scheduling for multi-cluster tools whose bottleneck cluster tool is process-bound (Zhu et al., 2013). The system is modelled by a Petri net. With this model, conditions under which a one-wafer cyclic schedule exists are developed. Describe evaluation results from the semiconductor domain and names restrictions and limits (Scholl et al., 2014). They also show that the backward-oriented simulation approach can be applied successfully for the scheduling of customer-specific orders. Propose a new model, using artificial immune system algorithm (Anuar et al., 2013). This algorithm is chosen due to its inherent self-learning capability and memory incubation features. The results from the experiments conducted show that the proposed algorithm is effective for the aforementioned problems.

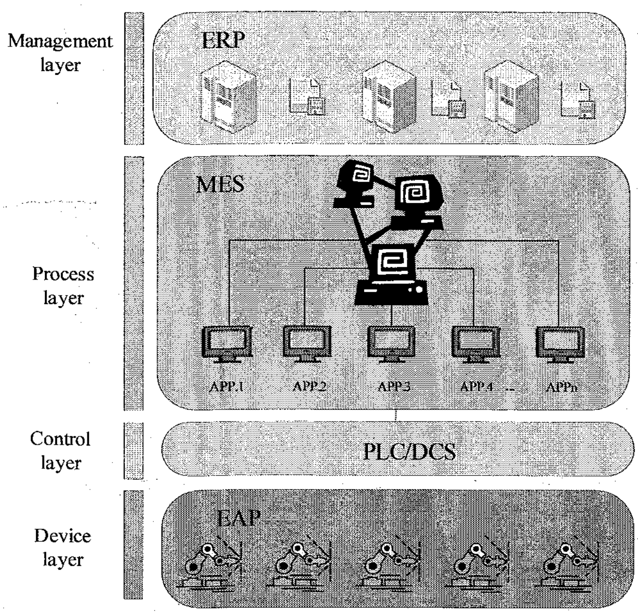
There is still a fault between the process and equipment levels that leads to a disconnect between the top plan management and the bottom shop production. Research on these production schedules does not fully provide effective methods and solutions. Combining with the characteristics of contemporary production, this paper analyses, concludes, summarises and extracts the performance indicators of production scheduling and gives a mathematical and quantitative formalisation method of corresponding indicators.

3 The description of scheduling process

The semiconductor industry faces one of the most challenging and rapidly evolving problems in each passing time. This project is mainly based on job and resource dynamic optimisation matching semiconductor packaging test production scheduling research. Semiconductor production mainly includes the following two stages: wafer production (front end), packaging test (also known as back end). Among them, the packaging and testing (assembly and test manufacturing, ATM) is the first transition to China's semiconductor industry, is also the most suitable for the development of China's industry, and is currently the focus of China's semiconductor industry.

Semiconductor production mainly includes the following two stages: wafer production (front end), packaging test (also known as back end). At present, China's semiconductor business organisation and management software support system is as shown in Figure 1. Most of the domestic packaging and testing enterprises have implemented management ERP system, process layer MES system and equipment layer EAP system, these systems can provide transparent management of production and improve production efficiency. The research on the production scheduling of semiconductor packaging and testing has become one of the common problems faced by packaging and testing enterprises.

Figure 1 Diagram of the scheduling policy (see online version for colours)



The plan should be able to deal with large-scale complex scheduling problems. There are a variety of anomalies in the manufacturing process, including equipment failure, processing time uncertainty, rework, and emergency task insertion. Production scheduling should allow planning adjustments to accommodate the anomalies that occur in production. It is needed to use batch splitting scheduling policy to deal with mixed production mode's plans. Batch splitting scheduling policy is to divide the whole tasks into half-task batch and whole task batch. Then there will be a twice batch splitting to half-task batch and whole task batch according to the difference of sensor. The process is as follows:

H_f is the set of half-task plan, W_f is the set of whole-task plan.

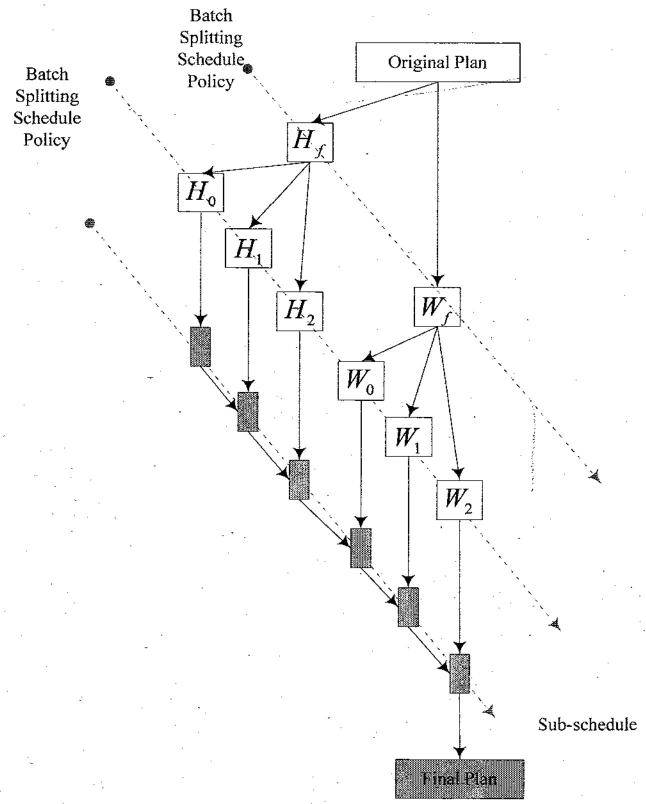
Step1 Set H_f, W_f according to the current time T_{now}.

Step2 According to the task, deadline sensor and no deadline sensor plan, proceed the twice batch splitting that divide the half task set H_f into set H_0, H_1 and H_2.

Step3 Whole task batch also splitting into H_0, H_1 and H_2.

Step4 There is limitation to start time of newly compiled plan to realise the cohesion of existing sensor and the former. There is limitation to start time of deadline plan. There is no limitation to no-deadline plan.

Figure 2 Diagram of the scheduling policy (see online version for colours)



4 Mathematical model

The research on scheduling problem is closely related to the production characteristics of the enterprise. Therefore, the research scheduling problem must start with the analysis of process and production organisation mode to find out its key problems, and then put forward effective research ideas and methods.

Table 1 Parameters table

Parameters	*Description*
$SI(i, j, k)$	The task after process j of task i processed on equipment k;
m_i	The total work station amount of task i;
Ω	The set of waiting tasks $i \in \Omega$, $\lvert\Omega\rvert$ is the total amount of tasks;
Ω_n	The set of tasks batch; $\Omega_1 \cap \ldots \cap \Omega_N = \Phi$, $\Omega_1 \cup \ldots \cup \Omega_N = \Omega$;
Ω^*	The set of no-producing tasks; $\lvert\Omega^*\rvert$ is the total amount of tasks;
R_α^*	The set of deadline tasks;
R_β^*	The set of no-deadline tasks;
Θ_i	The work station set of processing-task i;
pt_{ijk}	The work station j 's standard processing time of task i processed on equipment k;
ut_{jj+1}^i	The standard transportation time between work station j and work station j + 1 of task i;
st_{ijk}	The work station j 's processing start time of task i processed on equipment k;
et_{ijk}	The work station j's processing end time of task i processed on equipment k;
T_n	The deadline of deadline sensor task n;
$adjt_{cast}$	The standard interval time between tasks;
$C1_n$	The break-task penalty coefficient of sensor batch task n;
$C2_{ij}$	The redundancy time penalty coefficient of task i between work station j and work station j + 1;
$C3_n$	The no-schedule penalty coefficient of sensor batch task n;
X_{ijk}	The work station j 's optimising start time of task i processed on equipment k, the decision variable of model ;
y_{ijk}	If the work station j of task i processed on equipment k, = 1, $y_{ijk} = 1$, else $y_{ijk} = 0$;
$\delta_{(i,j,k)\to(i',j,k)}$	Task i and i''s time interval of The work station j and equipment k.

Build the mathematical model of the mixed plan and scheduling of sensor is as follows.

$$\min Z = \sum_{n=1}^{N}\sum_{i=1}^{n} C1_n \begin{pmatrix} X_{SI(i,m_i,k),m_{SI(i,m_i,k)},k} \\ -X_{i,m_i,k} - pt_{i,m_i,k} \end{pmatrix} + \sum_{i\in\Omega}\sum_{j=1}^{m_i-1} C2_{ij} \begin{pmatrix} X_{i,j+1,k'} - X_{ijk} \\ -pt_{ijk} - ut_{j,j+1}^{i} \end{pmatrix} + \sum_{n=1}^{N}\sum_{i\in\Omega_n\cap\Omega_0} C3_n \left|X_{i,m_i,k} - J_n\right| \tag{1}$$

Subject to:

$$X_{SI(i,j),j',k} - X_{ijk} \ge pt_{ijk}, \quad i, SI(i, j, k) \in \Omega,\ j = 1, \ldots, m_i,\ j \in \Theta_{SI(i,j,k)} \tag{2}$$

$$X_{i,j+1,k'} - X_{ijk} \ge pt_{ijk} + ut_{j,j+1}^{i}, \quad j = 1, \ldots, m_i - 1,\ j+1 \in \Theta_i \tag{3}$$

$$X_{SI(i,m_i,k),m_{SI(i,m_i,k)}} - X_{i,m_i,k} \ge pt_{ijk} + adjt_{cast}, \quad i \in \Omega,\ SI(i, j, k) \in \Omega_0,\ m_{SI(i,m_i,k)} \in \Theta_{SI(i,m_i,k)} \tag{4}$$

$$X_{ijk} \ge 0 \quad i \in \Omega,\ j \in \Theta_i \tag{5}$$

$$st_{i,m_i,k} \ge T_n,\ i \in R_\beta^* \cap W_0 \tag{6}$$

The same equipment can only process the next task when the last one is over. Constraint (2) represents the constraint of processing time. Constraint (3) represents the constraints of the job order. The same task can only continue the next station when the last one is over. Constraint (4) represents that there is a setup time interval between adjacent tasks. Constraint (5) represents that the decision variables is nonnegative. Constraint (6) represents that the whole-task must be produced before the deadline when it has a deadline of sensor plan.

5 Solution methodology

5.1 The solution of whole-task mixed plan based on time and path

By considering the optimal equipment and work station, select the processing equipment and starting time. The select rule of the most optimal equipment is as follows.

The rule that selecting the process station that earliest entrance to sensor is:

$$R_1 = \min\left\{st_{i,m_i,k}\, y_{i,m_i,k}\right\} \tag{7}$$

Determine task i's options operation station set according to rule R_1. When there are several stations, select the feasible station to process that has least deliver time, just as follow:

$$R_2 = \min\left\{ut_{j,j+1}^{i}(k)\right\} \tag{8}$$

Regarding sensor plan which has a deadline should be produced ahead of time, that is to say:

$$S_1 = \left\{st_{i,m_i,k} \ge T_n\right\} \cap \left\{\min\left(st_{i,m_i,k}\right)\right\},\ i \in R_\beta^* \tag{9}$$

The choice rule of equipment to no deadline sensor plan is as follows:

$$T_1 = \left\{pt_{i'jk} \ge \sum\left(et_{ijk} - st_{SI(i,j,k),j,k}\right)\right\} \cap \left\{\min(st_{i'jk})\right\},\ i' \in R_\alpha^*,\ i \in \Omega \tag{10}$$

Make the choice of equipment T_1 from the beginning of converter. After the choice of T_1, determine the process starting time of task, and then select the next equipment. The rule is:

$$T_2 = \min\left\{ut_{j,j+1}^{i}(k)\right\},\ i \in R_\alpha^* \tag{11}$$

And then continue use T_1, do the equipment choice and determine task's process starting time in this station.

Adopt the method of Section 5.2 to solve the problem after the choice of equipment.

5.2 The solve method of half-task mixed plan based on locked path

Establish the priority constraints of mixed charging plan of sensor:

- Rule (1) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in \Omega$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then task i has the high-priority over task .
- Rule (2) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in \Omega$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then task i' has the high-priority over task i.
- Rule (3) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in \Omega$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then there is no priority constraint that satisfying scheduling.
- Rule (4) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in \Omega$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then they have the same priority.
- Rule (5) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in R_\alpha^*,$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then task i has the high-priority over task .
- Rule (6) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in R_\alpha^*,$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then task has the high-priority over task i.
- Rule (7) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in R_\alpha^*,$ and $\delta_{(i',j,k)\to(i,j,k)} < 0,$ then there is no priority constraint that satisfying scheduling.
- Rule (8) If $\delta_{(i,j,k)\to(i',j,k)} \geq 0, i \in R_\alpha^*,$ and $\delta_{(i',j,k)\to(i,j,k)} \geq 0,$ then they have the same priority.

When they have the same priority, the choice to this couple of tasks is based on the flexible influence on scheduling sequence. The evaluation method of flexible of scheduling sequence is as follow:

$$\phi\big((i,j,k)(i',j,k)\big) = \sqrt{\begin{matrix}\min\left(\delta_{(i,j,k)\to(i',j,k)}, \delta_{(i',j,k)\to(i,j,k)}\right) \\ \times \max\left(\delta_{(i,j,k)\to(i',j,k)}, \delta_{(i',j,k)\to(i,j,k)}\right)\end{matrix}} \quad (12)$$

The solve method step is as follows.

Step 1 Get the sensor muster of half-task H_1, muster of deadline sensor plan H_0 and muster of no-deadline sensor plan H_2. Then get the descending sort plans according to the start time of furnace.

Step 2 Select the last task from W_1, according to the delivery time between equipment. In order to maintain the stability of production, get the next stage's start time according to the time of this stage's et_{ijk} and the time to former same task production equipment $ut^i_{j,j+1}(k,k')$.

Step 3 Calculate $\delta_{(i,j,k)\to(i',j,k)}$ and $\delta_{(i',j,k)\to(i,j,k)}$.

Step 4 If one of the sequencing decisions meet rule (1) to (4), get the sensor muster of half-task H_1. Select the earliest task in terms of starting time from H_1, get next stage's starting time. Calculate $\delta_{(i,j,k)\to(i',j,k)}$ and $\delta_{(i',j,k)\to(i,j,k)}$. If one of the sequencing decisions meets the rule (1) or (4), conform the task's processing starting time in this stage according to constraint. Then jump to step (5); if one meets the rule(1), then look back upon; if none sequencing decision meets the rule(1),(2) or (3), then jump to step (7).

Step 5 Add a new task, and then jump to step (4).

Step 6 Every unsorted couple of border upon tasks calculates $\varphi((i,j,k)(i',j,k))$. Select the smallest task and to arrange it's time. If $\delta_{(i,j,k)\to(i',j,k)} \geq \delta_{(i',j,k)\to(i,j,k)}$, then task i will be processed prior to task i' on equipment k working station j, otherwise behind i'; jump to step (5).

Step 7 If none sequencing decision meets the rule (4), then seek a solution to get the half-task plan of the tasks, stop. Otherwise jump to step (6); If one meets the rule (5) or (6), conform the task's processing starting time in this stage according to constraint, and then jump to (8); if one meets the rule (7), then look back upon; if none sequencing decision meets the rule (1) to (8), then jump to step (10).

Step 8 Add a new task, and then jump to step (1).

Step 9 Every unsorted couple of border upon tasks calculates the $\varphi((i,j,k)(i',j,k))$. Select the smallest task and to arrange it's time and equipment.

If $\delta_{(i,j,k)\to(i',j,k)} \geq \delta_{(i',j,k)\to(i,j,k)}$, then task i will be processed prior to task i' on equipment k working station j, otherwise behind i'; jump to step (8).

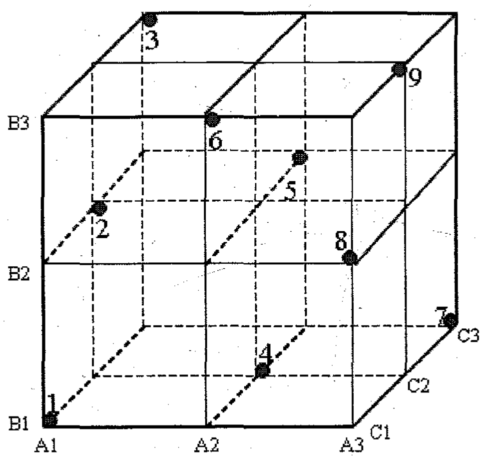
Step 10 If none sequencing decision meets the rule (8), then seek a solution to get the half-task plan of the sensor, stop. Otherwise jump to step (9).

6 Numerical results

In the real world, the impact of the test results of more than one factor, different factors on the test results also have different effects, when the number of factors and the level of increase, if a comprehensive test, the number of trials will be a sharp increase in a test It is very difficult to arrange all the tests. How to design the test scientifically to obtain high reliability test data is the main problem that researchers and engineers need to solve in experiment design.

Orthogonal table is the use of mathematical principles to produce a good standardised table. Orthogonal design is to use orthogonal table design test, this design method is called orthogonal optimisation. In mathematics, the sum of the inner product of the two vectors is zero, that is $a_1b_1 + a_2b_2...a_nb_n = 0$, then the two vectors are said to be orthogonal. For the 4-factor and 3-level tests, only 9 trials are required, and these nine tests are usually some orthogonal points of the linear space as shown in Figure 3. Because the orthogonal table constructs the advantage of equalisation (evenly dispersed), it can be used to select a few experiments with strong representations to obtain the optimal or better value.

Figure 3 Schematic diagram of orthogonal experiment (see online version for colours)



6.1 The characteristics of orthogonal design

Orthogonal design has the characteristics of 'balanced dispersion, neatly comparable and representative'.

1 Equilibrium dispersion

Orthogonal table in any column, the level of the number of equal (different figures represent different levels). For example, in the L9 (34) orthogonal table (in Table 1) 1, 2, 3, each appear three times, which shows that in the arrangement of the test, the selected level of the combination is evenly distributed (the level of each factor Appear the same number of times).

All possible combinations of the various levels between the two columns appear and equal to the number of occurrences.

In the orthogonal table of L9 (34), (1, 1), (1, 2), (1, 3), (2, 1), (2, 2), (2, 3), (3, 1), (3, 2), (3, 3) appear once. That is, one level of each factor is equal to the number of possible combinations of the other levels of the other, indicating that the match between any two columns is uniform. The so-called equilibrium dispersion, refers to the use of orthogonal table selected by the combination of the level of the combination of all levels of the distribution is uniform. As can be seen from Figure 3.1, in the cube, any plane contains three '(•)', any line contains a '(•)'.

2 Neatly comparable.

Neatly comparable means that each level of each factor is comparable. Because at any level of each factor in the orthogonal table, all levels of the other factors are balanced, as in the three factors of A, B, and C, the three levels of A, A1, A2, and A3 There are three different levels of B, C, see Figure 3.1. In these nine levels of combination, the A factor level includes the B and C factors of the three levels, although with different ways, but B, C are in the same position. So the A factor between the three levels of comprehensive comparability. Similarly, B, C factors between the three levels also have comprehensive comparability.

3 Representative

The level of any column in the orthogonal table appears so that all tests include all the levels of all factors; all horizontal combinations of any two columns appear, allowing the combination of any two factors to be a comprehensive test. Due to the equilibrium dispersion of the orthogonal table, it can be seen that the orthogonal design points are uniformly distributed in the comprehensive test point, which is very representative. Therefore, the optimal conditions for some trials should be consistent with the optimal conditions for comprehensive trials.

Table 2 Orthogonal table L9(34)

L9(34)	*Column number*			
	1	*2*	*3*	*4*
1	1	1	3	2
2	2	1	1	1
3	3	1	2	3
4	1	2	2	1
5	2	2	3	3
6	3	2	1	2
7	1	3	1	3
8	2	3	2	2
9	3	3	3	1

6.2 Common terms

6.2.1 Experimental index

In order to measure the quality of the test results or the level of treatment effect, in the test of specific traits or observation of the project known as the test indicators. For example, the test index in the dispatch model is the least costly penalty for pouring and molten steel waiting.

6.2.2 Experimental factor

The factors influencing the test index studied in the experiment are called test factors. Such as the scheduling model in the continuous casting and pouring molten steel waiting for the penalty factor is called the factor. When the test of the factors only one, known as the single factor test; if two or more factors at the same time on the impact of test indicators, known as the two factors or multi-factor test. Test factors commonly used capital letters A, B, C, ... and so on.

6.2.3 Level of factor

The specific factor or quantity level of the test factor is called the level of the factor, referred to as the level. As in the scheduling model, the penalty factor takes different values, representing different levels. The factor level is represented by the letters 1, 2, ... that represent the factor. Such as A1, A2, ..., B1, B2, ..., and so on.

6.2.3.1 Test the main steps

The main steps of the orthogonal design are as follows:

Step 1 Determine the level according to the target and the needs of the test.

Step 2 Choose the appropriate orthogonal table and determine the test program.

Step 3 Organise the implementation of the test.

Step 4 Test results analysis.

6.2.3.2 Select factors to determine the level

The choice of factor level is mainly based on the objectives of the study to determine, so first of all to analyse what factors will affect the target, and according to the experimental cost and orthogonal table to determine the final factor. The selection of the horizontal value is based on the empirical value of the experiment to determine or randomly given.

6.2.3.3 Orthographic table selection

Orthogonal design is the key to select the appropriate orthogonal table, orthogonal table selection directly affect the experimental results and analysis of the experimental results. Usually select the orthogonal table to go through three steps: First, according to the research content to determine the research factors and levels; Second, according to the test conditions, determine the number of trials; Third, the above situation to select the orthogonal table L.

Explanation of the symbols of the orthogonal table.

The general form of the orthogonal table is Lt(nq), and the symbols are as follows:

L represents the orthogonal table

T the number of rows of the orthogonal table is also the number of trials

N the number of factors

Q the number of columns of the orthogonal table to accommodate the maximum number of factors

T n^q, q = number of factors = basic number of columns.

1 organise the implementation of the test

Will be determined in advance of the experimental factors, the level of the number of columns according to the orthogonal table to arrange the number of factors and the level of value, so that the implementation of the table, according to the experimental number of experiments in order to experiment n times.

2 as a trend graph

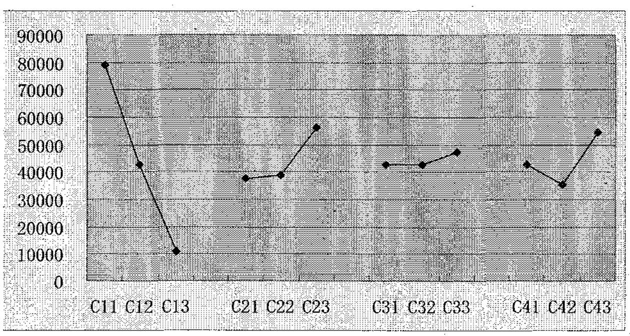
In this paper, we choose the smallest orthogonal table L4 (23) to illustrate how to use the orthogonal test results as a trend graph. First, the same factor with the same level of the corresponding experimental results were added to get the corresponding sum of the values of I and II, and then the average of its I / k_j and II / k_j. Finally, with the factor and the horizontal value of the horizontal axis, with its corresponding average value for the vertical axis can draw the corresponding trend.

Table 3 L_4 (2^3) orthogonal test result table

No		C_1	C_2	C_3	*Test index*
Test no	1	1	1	1	y1
	2	1	2	2	y2
	3	2	1	2	y3
	4	2	2	1	y4
Ij		I1 = y1 + y2	I2 = y1 + y3	I3 = y1 + y4	
IIj		II1 = y3 + y4	II2 = y2 + y4	II3 = y2 + y3	
kj		k1 = 2	k2 = 2	k3 = 2	
I/kj		I1/k1	I2/k2	I3/k3	
II/kj		II1/k1	II2/k2	II3/k3	

The factors and horizontal values are the horizontal axis and the corresponding average value is the vertical axis.

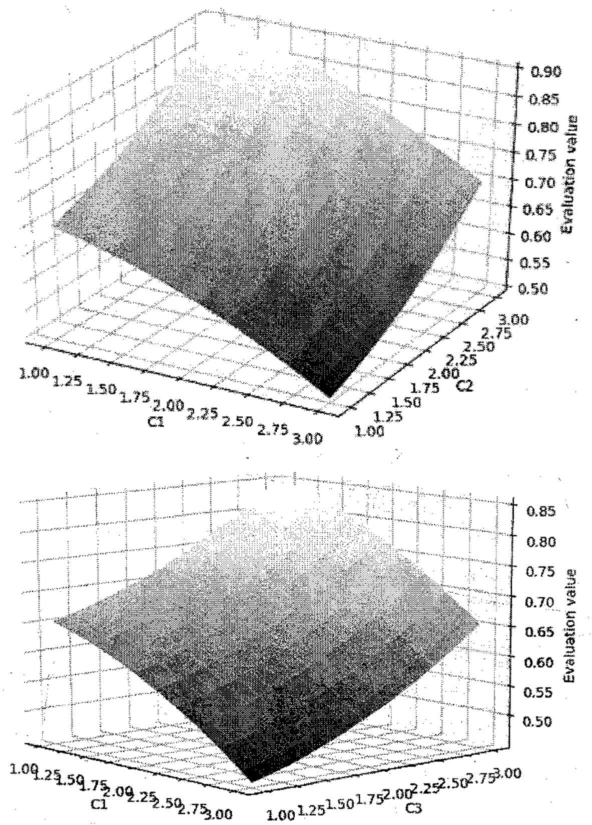
Figure 4 Trend graph (see online version for colours)



In order to further study the effect of the heuristic method, the influence of the change of the parameters is analysed. As shown in Figure 2, as the size of the scheduling C_1

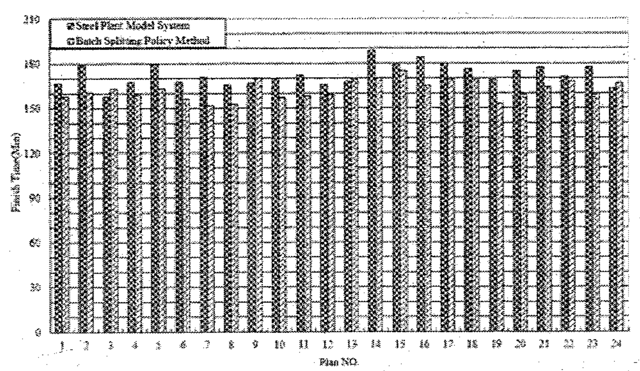
increases, the performance of the algorithm decreases continuously. At the same time, the performance of the algorithm increases continuously if there are more devices C_2 with better performance and if there are more devices C_3.

Figure 5 Evaluation value influence with parameters (see online version for colours)



A comparison is made between the improved scheduling algorithm and model system. There are 36 plans that the finish time of each plan is shown in Figure 6. Using the improved algorithm, average task finish time reduces 13.5 minutes. The improved algorithm has a better performance.

Figure 6 The finish time comparison (see online version for colours)



After be applied operation in a plant, the performance index is as follows: The average planning time is 8.4 seconds; the dynamic adjusting time is about 4.5 seconds.

7 Conclusions

This article is based on the operation and resource dynamic matching optimisation and multi-objective production scheduling method combining hierarchical step by step solution ideas into the field of production scheduling. In the scheduling before the optimal allocation of jobs and resources to optimise the constraints based on the production operation and equipment manufacturing capabilities to match the relationship between the model change in the past only in the production scheduling process to assign resources strategy to reduce the production system in the method. The complexity of scheduling problems reflects the organic combination of innovative ideas and methodological feasibility.

Match the job and the resource best before scheduling. The complexity of the production scheduling problem of the senor package test is reduced, which reflects the innovation of the idea and the feasibility of the method. In this paper, an analysis of the sensor schedule is made under the background of factory in a large enterprise. The main content of this paper is as following:

1 according to the flow of actual product process, describe the scheduling process

2 on the basis of analysing the processes' complexity, build the mathematical model, and propose the scheduling algorithm of sensor to solve the difficult problem

3 test the algorithm by using the actual data, it is verified that the improved scheduling algorithm is efficient.

Acknowledgements

This work was supported in part by the Liaoning Province Science and Technology Project (2015106015).

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