Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені Ігоря Сікорського»
МЕХАНІКО-МАШИНОБУДІВНИЙ ІНСТИТУТ
Кафедра технології машинобудування

«На правах рукопису»

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Завідувач кафедри
______ Юрій ПЕТРАКОВ
(підпис) (ініціали, прізвище)
"___" ________ 2021 р.

Магістерська дисертація

на здобуття ступеня магістра
за освітньо-професійною програмою «Технології машинобудування»
зі спеціальності 131 «Прикладна механіка»

на тему: Оптимізація та підвищення ефективності планування цеху на основі генетичного алгоритму.

Виконав: студент 6 курсу, групи МТ-01мп
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Засвідчую, що у цій магістерській дисертації немає запозичень з праць інших авторів без відповідних посилань.

Студент __________
(підпис)

Київ – 2021 року

Національний технічний університет України

«Київський політехнічний інститут імені Ігоря Сікорського»

Механіко-машинобудівний інститут

Кафедра технології машинобудування

Рівень вищої освіти - другий (магістерський)

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Освітньо-професійна програма «Технології машинобудування»

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«__ »_________2021р.

.

ЗАВДАННЯ

на магістерську дисертацію студенту

ВЕЙ Сюйхун
(прізвище, ім'я, по батькові)

1.Тема дисертації Оптимізація та підвищення ефективності планування цеху на основі генетичного алгоритму_____

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затверджені наказом по університету від «__» ___2021 р. ___

2. Термін подання студентом дисертації«__» ____ 2021 р.

3. Об'єкт дослідження Виробнича лінія цеху робочого колеса відцентрового компресора

4. Вихідні дані ___План-схема виробничої лінії цеху відцентрових компресорів.

5. Перелік завдань, які потрібно розробити: Використовуйте генетичний алгоритм, щоб отримати найкращий план виробничої лінії цеху, створити імітаційну модель досліджуваної дільниці та виробничого комплексу, оцінити показники ефективності вихідної конфігурації досліджуваної дільниці та виробничого комплексу, розробити рекомендації щодо підвищення ефективності дільниці механічної обробки, перевірити доцільність впровадження запропонованих кроків, провести статистичні дослідження імітаційної моделі.

6. Орієнтовний перелік ілюстративного матеріалу рисунки, таблиці, формули.

7. Дата видачі завдання ____________________________

Календарний план

№ з/п	Назва етапів виконання магістерської дисертації	Термін виконання етапів магістерської дисертації	Примітка
1	Огляд літературних джерел	17.09.2021	
2	Ознайомлення з існуючими на ринку програмами	09.10.2021	
3	Генетичний алгоритм оптимізує компонування виробничої лінії цеху	10.11.2021	
4	Створити макетну модель виробництва цеху	10.11.2021	
5	Підготовка до публікації статі	25.11.2021	
6	Підготовка магістерської дисертації	27.11.2021	

Студент Вей Сюйхун

Науковий керівник дисертації Борис Воронцов

РЕФЕРАТ

Структура роботи.

Магістерська робота містить 4 розділи з висновками до кожного з них, загальні висновки, список використаних джерел, який викладено на 88 сторінці тексту, включає 32 рисунки, 29 таблиць та 28 використаних джерел.

Актуальність дослідження.

Зі стрімким розвитком світової обробної промисловості конкуренція між машинобудівними компаніями ставала все більш жорсткою, а проблема необгрунтованого розташування цехів механічної обробки ставала все більш серйозною. Виробництво підприємств потребує підвищення ефективності виробництва. Щоб підвищити корпоративну ефективність, зменшити виробничі й експлуатаційні витрати та підвищити ефективність цеху, оптимізація компонування цеху стала актуальною проблемою, яку необхідно вирішити в машинобудівній промисловості.

Мета й завдання дослідження .

Виробнича система цехів є важливою складовою виробничої системи підприємства, а системи в різних типах цехів становлять виробничу систему підприємства. У цеху, як основної одиниці виробничої системи, компонування обладнання має важливий вплив на ефективність, вартість і використання площі виробництва. Грамотно влаштована система виробництва цеху може не тільки підвищити ефективність логістики та заощадити витрати на обробку матеріалів, але й максимально використовувати виробничі потужності в цеху, при цьому раціонально використовувати простір, покращити робоче середовище працівників та підвищити ефективність роботи.

Завдання дослідження

– Провести детальний аналіз компонування цеху з обробки крильчатки відцентрового компресора та специфічної логістики виробництва.
– За допомогою методу SLP отримати імітаційну схему попереднього макета цеху.
– Оптимізувати компонування обладнання майстерні за допомогою генетичного алгоритму.

– Використовуйте програмне забезпечення моделювання заводу для створення моделі компонування обладнання цеху.
– Перевірити ефективність програми оптимізації моделювання.

Методи дослідження

Візуальне моделювання в середовищі Siemens Tecnomatix Plant Simulation 14.0, Попередній макет цеху отримано методом SLP, а оптимальний макет цеху – за допомогою генетичного алгоритму. Використовуйте програмне забезпечення Plant Simulation для перевірки моделювання.

Наукова новизна отриманих результатів.

Результати дослідження, проведені в рамках магістерської роботи, мають такі наукові новинки:

– Використання CATIA для віртуального моделювання обробки робочого колеса відцентрового компресора
– Використання методу SLP для моделювання макету майстерні
– Використовуйте генетичні алгоритми для оптимізації макета семінару.
– Використовуйте Plant Simulation для моделювання та оптимізації макета майстерні. Шляхом порівняльного аналізу отримано оптимальне розташування цеху обробки робочих колес відцентрового компресора.
– У поєднанні зі статистичною функцією Tecnomatix Plant Simulation

Публікації.

1. Сюхон Вей, Воронцов Б.С. Моделювання процесу автоматичної виробничої лінії на базі Tecnomatix / Wei Xuhong, Б.С. Воронцов // Молода наука - робота і нано-технології сучасного машинобудування: зб. наук. праць Міжнар. молодіжної наук.-техн. конф., 14-15 квітня 2021 р. – Краматорськ : ДДМА, 2021. – С.36-39.

2. Сюхон Вей, Воронцов Б.С. Дослідження нового типу відцентрового токарного кріплення / Wei Xuhong, Б.С. Воронцов // Комплексне забезпечення якості технологічних процесів та систем (КЗЯТПС – 2021): XI Міжнар. наук.-практ. конф., 26-27 травня 2021 р.: тези доп. – Чернігів : НУ «Чернігівська політехніка», 2021. –Т. 1. – С. 29-30.

ABSTRACT

Structure of work.

The Master's Thesis contains 4 sections with conclusions to each of them, general conclusions, a list of sources used, which outlined in 88 pages of text, includes 32 figures, 29 tables and 28 used sources.

Actuality of the research.

With the rapid development of the global manufacturing industry, competition among machinery manufacturing companies has become increasingly fierce, and the problem of unreasonable layout of mechanical processing workshops has become more and more serious. The production of enterprises needs to improve production efficiency. In order to improve corporate efficiency, reduce production and operation costs, and increase Workshop efficiency, so the optimization of workshop layout has become an urgent problem to be solved in the machinery manufacturing industry.

The purpose and objectives of the study .

Workshop production system is an important component of the enterprise's manufacturing system, and the systems in different types of workshops constitute the enterprise's manufacturing system. In the workshop, as the most basic unit of the production system, the layout of the equipment has an important influence on the efficiency, cost and space utilization of production. A well-arranged workshop manufacturing system can not only improve logistics efficiency and save material handling costs, but also maximize the use of production facilities in the workshop, while rationally using space, improving the working environment of workers, and improving work efficiency.

Research objectives:

Carry out a detailed analysis of the layout of the centrifugal compressor impeller machining workshop and the specific production logistics.

- Using the SLP method to obtain a simulation diagram of the preliminary layout of the workshop.
- Optimize the layout of workshop equipment through genetic algorithm.
- Use Plant Simulation software to build the equipment layout model of the workshop.
- Verify the effectiveness of the simulation optimization program.

Research methods.

Visual modeling in the environment of Siemens Tecnomatix Plant Simulation 14.0, The preliminary layout of the workshop is obtained through the SLP method, and the optimal layout of the workshop is obtained through the genetic algorithm. Use Plant Simulation software for simulation verification.

Scientific novelty of the obtained results.

The research results carried out as part of the master's degree thesis have the following scientific novelties:

- Using CATIA for virtual simulation of centrifugal compressor impeller processing.
- Using SLP method for workshop layout simulation.
- Use genetic algorithms to optimize the layout of the workshop.
- Use Plant Simulation to simulate and optimize the layout of the workshop. Through comparative analysis, the optimal layout of the centrifugal compressor impeller processing workshop is obtained.
- Combined with the statistical function of Tecnomatix Plant Simulation.

Publications.

1. Xuhong Wei, Vorontsov B.S. Process simulation of automatic workshop based on Tecnomatix / Wei Xuhong, Б.С. Воронцов // Молода наука - роботизація і нано-технології сучасного машинобудування: зб. наук. праць Міжнар. молодіжної наук.-техн. конф., 14-15 квітня 2021 р. – Краматорськ : ДДМА, 2021. – С.36-39.

2. Xuhong Wei, Vorontsov B.S. Research on a new type of centrifugal lathe fixture / Wei Xuhong, Б.С. Воронцов // Комплексне забезпечення якості технологічних процесів та систем (КЗЯТПС – 2021): XI Міжнар. наук.-практ. конф., 26-27 травня 2021 р.: тези доп. – Чернігів : НУ «Чернігівська політехніка», 2021. – Т. 1. – С. 29-30.

CONTENTS

ПЕРЕЛІК УМОВНИХ ПОЗНАЧЕНЬ, СИМВОЛІВ, СКОРОЧЕНЬ І ТЕРМІНІВ

SLP –Methods–Systematic layout planning

CATIA–Computer software–Computer Aided Three–dimensional Interactive Application

GA–Methods–Genetic algorithm

Preface

The design of the workshop layout is a science that combines many elements such as technology, economy, safety and environmental protection. A reasonable workshop layout plays a key role in improving the production efficiency of the company, reducing production costs, and increasing the competitiveness of the company.

Workshop layout refers to a reasonable and effective layout of the components, work sites, and production equipment in the workshop under the constraints of equipment and facilities and the internal area of the workshop in accordance with certain layout principles, so as to optimize the production process relationship between them. The cost of material transportation is the least. As the main undertaker of the production tasks of manufacturing enterprises, the production workshop is also the most fundamental component of the entire manufacturing system. Its work performance and organization are closely related to the manufacturing technology used, and will directly influence the manufacturing capabilities, The development cycle, product cost and product quality have a direct impact. The traditional workshop layout is being plagued by many worldwide problems. Every manufacturing enterprise needs to re-examine the original production layout in order to improve the ability to respond quickly to market demand, reduce production costs, so as to meet customer needs and changes in the market environment, and achieve maximum economic and social benefits.

On the one hand, companies can increase manufacturing equipment by building new workshops, and on the other hand, they can optimize the layout of existing workshops, improve efficiency and reduce production costs, quickly respond to market changes, meet customer needs, and create as many economic benefits as possible. .

In foreign countries, the company has a dedicated department to improve the layout design of the equipment in the workshop every four years. In the 1990s, the cycle of redesigning the equipment layout was shortened to one year, and the workshop layout design was done once the product was updated. , And sometimes even adjust the layout of their facilities in order to complete an order, and the layout of many companies' workshops are basically unchanged after completion, and it is difficult to adapt to the changing market situation. Therefore, strengthening the research on the layout of workshop equipment is of great significance to enhancing the competitiveness of the manufacturing industry.

SECTION 1

1.1 Development history of workshop layout

Workshop planning is a very early proposition. As early as in the handicraft era, people spontaneously began to use experience to adjust the positions of production tools and workbenches in the workshop to speed up production and work efficiency. Mathematician Gauss began to study the layout problem from a scientific point of view since the beginning of the year. It has a history of more than 180 years [1]. In 1911, engineer Taylor published "Principles of Scientific Management", and the production of the factory has entered the era of scientific management [2]. During the Second World War, engineers began to care about the facilities planning of manufacturing factories and workshops, and elevated the management of facilities and materials to a certain level, and explored the design of the factory through the study of working methods, and the layout of the workshop equipment. Study it as a technical issue. During this period, the methods of workshop layout were mainly empirical judgment methods such as flowcharts, and the objects with low efficiency and higher requirements for the operator’s experience were limited to processing equipment.

From the 1940s to the 1960s, the theory of facility planning developed rapidly, and the research on factory design expanded from initial work research to research on material handling methods and factory layout [3], and the scope of research objects for facility planning was expanded. , To become a discipline with independent subject direction and technical system. A series of mathematical planning methods are used to solve the optimization problems of the layout of the workshop, such as branch and bound, cutting plane method and so on. Therefore, there are still higher requirements for operator experience. In 1961, the systematic facility layout method (Systematic Layout PI~g, SLP) proposed by the American Muther (Muther) [4] enabled the workshop layout design to develop from qualitative to quantitative. The SLP method uses graphic models and chart analysis as a means to introduce quantitative concepts into the whole process of design analysis, making the layout design more scientific, systematic and rational. It is still widely used in general workshop layout design. a way. With the development of computer technology, from the 1950s to the 1960s, a group of facility planning and design scholars represented by Moore and others studied the application of computer technology for layout and optimization problems, and produced many applications. The layout program [4,5] written in high-level language, mainly including the CORELAP and ALDEP programs for new facilities and the programs COFAD and CRAFT for reconstruction and layout, which provide computer-aided facility layout support and help.

In 1967, Gonzalezl [6] and Sahniti proposed that the problem of facility layout is a complete problem. Since then, many heuristic methods have been used to obtain the approximate optimal solution of the problem [7,8], that is, approximate optimization methods. These methods can Roughly summarized into the following basic category construction method, graph theory method, simulated annealing method, hybrid method, genetic algorithm, etc.

1.2 Research status of workshop layout

In the 1960s, Richard Muther used his extensive factory design experience to invent the Systematic Layout Planning (SLP). This is the first comprehensive facility layout method combining qualitative and quantitative analysis of the relationship between logistics and non-logistics between operating units. This method makes the layout planning more scientific and reasonable [9]. Professor Holland of the University of Michigan in the United States was influenced by the natural selection view of biology in Darwin's theory of evolution, and based on the characteristics of genetic evolution, proposed the use of genetic algorithms to solve the layout planning problem [10]. Since then, this method has attracted the attention of a large number of other researchers, and has been widely used in workshop machine scheduling, workshop facility layout, logistics and transportation design and other issues, solving a large number of actual production problems in enterprises. In 2000, Seyedh Sabereh Hosseini took the production cycle and productivity into account when planning the facility layout, and believed that in the same workshop, the time benefit is greater than the logistics cost [11]. D Suhardini, W Septiani, S Fauziah (2003) not only considered the minimum logistics cost factor in the process of facility layout, but also considered the constraints of maximizing closeness among different operation units [12]. Sandan Kulturel Konak (2013) et al. used hybrid genetic algorithms and linear programming methods to solve the problem of the layout of continuous facilities in unequal areas [13]. Kharraja S (2014) et al. proposed a mixed integer linear programming formula suitable for the layout problem on the basis of the existing OT layout research, and optimized it with the help of related software [14]. S Shirzadi, R Tavakkoli-Moghaddam, RKia (2016) and others proposed a novel double-objective integer model, which takes the total cost minimization into consideration as operating time, operating sequence, intra-unit layout, alternative process routes, process route selection, The primary goal of machine capacity, parts demand, and part movement in batches is to use a multi-objective competitive algorithm to find the best solution [15]. Hosseni-Nasab H, Fereidouni S, Ghomi S (2018) and others have studied future trends based on layout evolution, seminar characteristics, problem formulation, solutions and other issues, and put forward a promising direction for facility layout issues [16].

In terms of workshop layout simulation, Peng Chew (1995) and others used artificial intelligence combined with simulation methods to simulate and analyze the production logistics system [17]. Anglani Aden (2002) and others combined UML and Arena simulation tools to invent the simulation modeling background of flexible manufacturing systems [18]. Pinto R (2016) combines the ReBORN Workbench simulation tool with genetic algorithm to improve the factory layout problem [19]. Kamila Kluska (2018) uses a hybrid modeling method to describe the elements of the logistics distribution system through Flexsim simulation software [20]. Furkan Yener (2019) and others proposed a mixed-integer quadratic model, using data mining technology to study warehouse design, and then adjust and improve the warehouse layout, reducing logistics costs [21]. Naha Prajapat, Tony Waller (2016) and others used the DES model to allow decision makers to evaluate various layouts and configurations to optimize production and optimize factory layout [22]. Ali Azaden, Sahar Jebreili, Elizabeth Chang (2017) and others proposed an integrated algorithm based on fuzzy simulation, fuzzy linear programming (FLP) and fuzzy data envelopment analysis (FDEA) to deal with unclear use environment and health indicators. Special circumstances of workshop facility layout design issues [23]. Legato Pasquale (2001) and others used simulation models to simulate the operation of the optimized system, visually observe the operating status, and analyze the feasibility of the optimized system [24]. Scott (2003) created relevant modules for the company's workflow in the Arena simulation model, discovered the problems in the company's production activities through the operation of the simulation module, classified the problem elements according to the degree of hindering the company's production and operation, and adjusted the current problems. , To minimize company losses [25]. Razavialavi, Seyedreza (2015) used simulation software to model the material handling system of the stockyard, and combined genetic algorithm with simulation to find the optimal layout that minimizes the material handling time [26] Prajapat Neha, Waller Tony (2016) Use Discrete Time Simulation (DMS) to optimize the plant layout, and set specific functions in the simulation model so that it can set a new layout in Excel [27]. Shaik Aqueeb Sohail and Rodrigues Lewlyn L.R. (2018) use system dynamics to model and simulate automobile manufacturing systems, analyze the changes brought about by the changes in facility layout, and improve the shop layout through a series of indicators. With the emergence of a series of simulation software and related mathematical models, many foreign researchers have explored a large number of algorithm models for facility layout planning, which has embarked on a new journey of layout planning.

1.3 The main content of the workshop layout design

1.3.1 Design of workshop layout

We can define the workshop layout problem as follows: Plant Layout Problem, also known as Facility Location Problem or Facility Layout Problem, FLP, refers to the layout of production equipment in a given space while requiring certain constraints (such as Area requirements, shape and size requirements, etc.) and optimize the objective function (usually including the cost of material transmission between equipment, etc.).

1.3.2 Elements of workshop layout

The several elements of the workshop layout are equipment, space, constraints and goals.

(1) Equipment: It is the basic unit and main research object of the workshop layout

(2) Space: refers to the area where the layout object is placed, which limits the scope of the layout object. Generally, it refers to a two-dimensional or three-dimensional space with a certain range, which results in a variety of constraints on the layout problem. In the workshop layout, it refers to a workshop site with a relatively standardized shape and a certain area.

(3) Constraints: It is the most basic judging rule for layout problems. Usually, the constraints on the layout of the workshop include area constraints, shape constraints, and boundary constraints generated by the layout site. Non-overlapping constraints are generated during the placement of equipment due to process settings and processing. The width of the channel, the spacing between equipment, and the fixed position constraints caused by immovable objects in the production workshop.

(4) Goal: The layout problem is an optimization problem, and target optimization is the key to the overall layout problem. It provides guidance throughout the layout process and evaluates the final layout plan.

1.4 The form of the workshop and layout

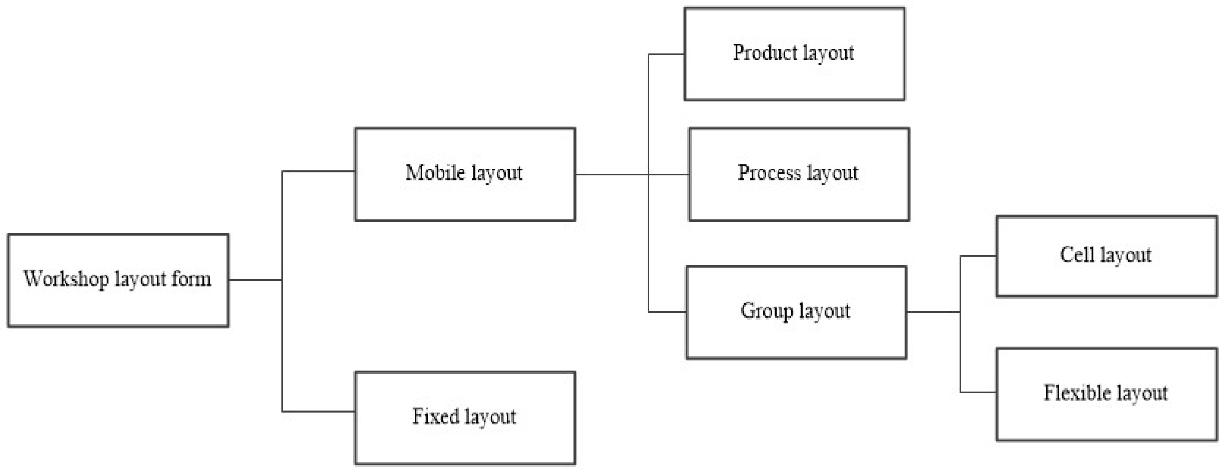


Figure 1.1 Workshop layout form

In modern manufacturing enterprises, according to various forms of production organization, the main types of layout generally adopted are: product layout, process layout, group principle layout, and positioning layout.

(1) product layout

In addition to the traditional linear layout, the common layout of workshops and workshops also includes semi-circular, U-shaped, S-shaped and other types, which are convenient for personnel operations and reduce material transportation.

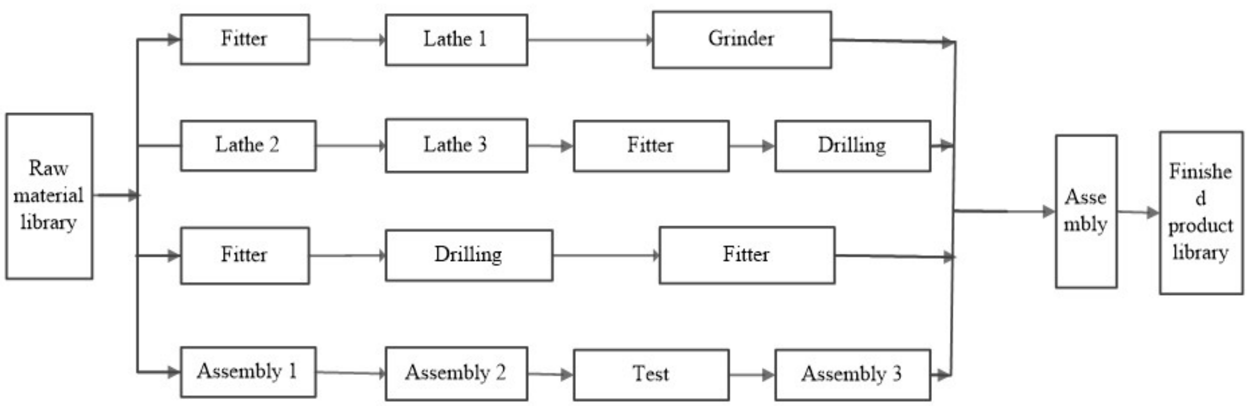


Figure 1.2 Workshop layout diagram

(2) Process layout

The process layout machine group layout is the most commonly used layout method in the manufacturing workshop, which is suitable for multi-variety and small-batch production methods. The process layout puts the equipment and processing links with the same function in the same area. When the production demand changes, the equipment and personnel in different areas can be quickly adjusted to meet the production requirements.

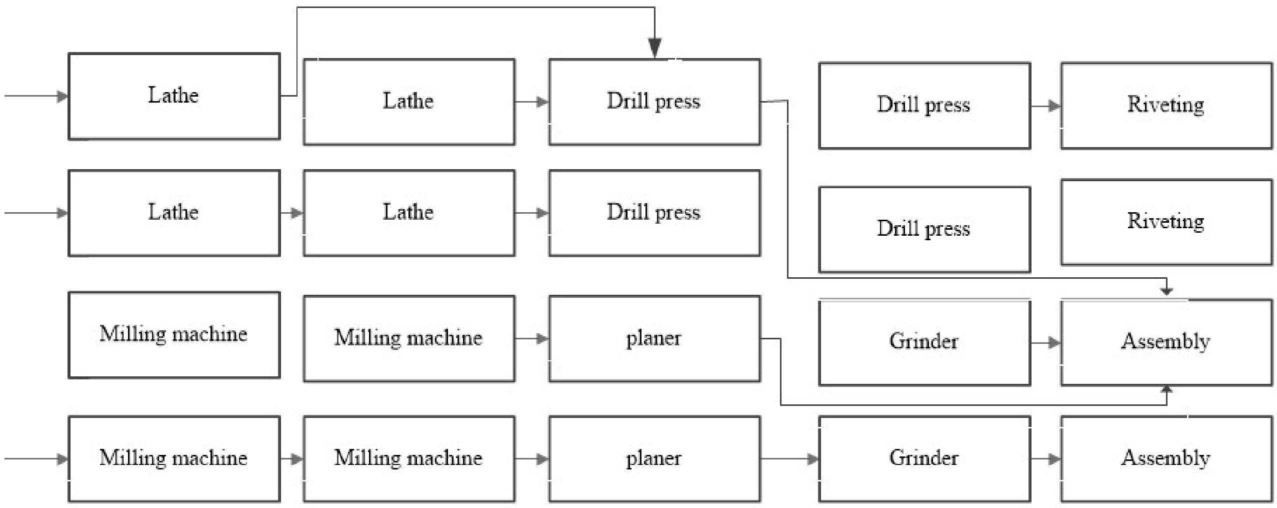


Figure 1.3 Process layout diagram

(3) Group layout

The grouping principle layout divides the equipment into groups according to the processing technology of the parts, forming a manufacturing unit independently, and each manufacturing unit corresponds to the processing and manufacturing of a group of parts with similar manufacturing technology.

(4) Positioning layout

Positioning layout is also called fixed layout. This layout method fixes the processing object in a certain position according to the characteristics of the processing object. People, materials, equipment, etc. are all around the product. The positioning arrangement is generally suitable for products with a larger volume or weight.

Table 1.1 Comparison of different facility layouts

Compare items	Workshop layout	Process layout	Group layout	Position the layout
mode of production	Mass continuous production	The finished product is produced in one piece	Medium and moderate production in batches	Production project-type production
Production process	Produced by product	Produced on order	Produced by processing unit	By item
Material handling charges	low	Very high	moderate	High
Production equipment	Dedicated equipment	Universal equipment	Universal equipment	Universal equipment
Device utilization	high	low	moderate	low
Arrangement adjustment costs	high	low	low	low
Set the focus	Line balance	Production flexibility	Efficiency and flexibility	project management

1.5 Design method of workshop layout

The workshop layout design method has been developed since the 1960s and has achieved rich results, among which there are mainly the following five types of methods.

(1) Placement method

This method is based on the actual area of the factory and the internal departments of the building, the scaled down samples are placed on the same floor plan to simulate the factory production system, and the position of the samples on the floor plan is adjusted by analyzing the relationship between the various departments. , Until the best layout plan is obtained. Due to the strong subjectivity of this method, it is more suitable for simpler factory facility layout.

(2) Mathematical model method

It refers to the establishment of corresponding mathematical models based on the reality of facility layout, using the principles of mathematics, operations research, and systems engineering, and solving facility layout problems through research models. Quantitative analysis of the model can effectively reduce the subjectivity of the design.

(3) Graphical method

This method refers to the combined application of the oscillating method and the mathematical model method, which mainly includes: spiral design method, simplified layout design method, mobile transportation formation drawing, etc. Due to the complexity of the operation and the difficulty of solving practical problems, it is not widely used in practice.

(4) System layout design

This method is the most representative of the methods of facility layout so far. It comprehensively considers and quantifies various factors related to the layout, and combines the layout conditions to restrict the combination and optimization in a discrete state. The program is evaluated and the best is selected. This method is the most widely used, and after being proposed, an improved layout method based on this method is proposed for different actual situations.

(5) Computer-aided layout technology

With the rapid development of computer technology, the corresponding computer-aided facility layout technology has become more and more mature. When faced with solving the facility layout of a complex production system, this technical method has some advantages over the above-mentioned methods. In the past ten years, this technical method has combined the mathematical model method to obtain the optimal layout plan by establishing a mathematical model that conforms to the reality and using the corresponding algorithm to solve it. At the same time, due to the rapid development of simulation software, simulation optimization and verification of existing layout schemes are carried out.

Conclusions

This Section first analyzes the history of the development of the workshop layout abroad, introduces the workshop layout, analyzes the factors of the workshop layout, and explains the workshop layout form and design method.

SECTION 2

2.1 Introduction to impellers

According to the structure of the impeller, it can be roughly divided into three categories: open impeller, semi-open impeller, and closed impeller. The fluid channel formed by the blades and the impeller body is a tunnel with two sides missing, and there is no front and rear cover. This type of impeller is an open impeller, and the blades are generally less than 2-5; the split channel composed of a half-open impeller has only one side For tunnels, if the fluid passages are tunnel-shaped, the impellers whose passages are not open are called closed impellers.

(a)Open impeller (b)Semi-open impeller (c) Closed impeller

Figure 2.1 Classification of impellers

According to the material characteristics of the impeller, it is divided into titanium alloy impeller, aluminum alloy impeller, and superalloy impeller; according to the direction of fluid movement, it can be divided into axial flow impeller, centrifugal impeller and mixed flow impeller.

The impeller processing workshop focuses on the processing of semi-open impellers. It is a small centrifugal impeller with long and short blades. The material used is aluminum alloy. The impeller size processed in this article has an exit diameter of 90mm, an inlet diameter of 20mm, and an impeller height of 23.5. mm. The shape of the blank is selected as the bar, and the diameter of the blank is selected as 100mm. In order to save material, the length is selected as 50mm, and the material is aluminum alloy bar (6061).

Table 2.1 Materialproperties of aluminum rods(6,061).

Al-6603									
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements	Al
0.20-0.6	≤0.35	≤0.1	≤0.1	≤0.49-0.9	≤0.1	≤0.1	≤0.1	≤0.05-0.15	Margin

2.2 Impeller process planning

2.2.1 Selection of processing centers

Figure 2.2 KMC600 Turning and Milling Machining Center

The KMC600 turning and milling machining center is specially designed for high-precision and high-speed machining in the manufacturing industry. It has a compact design and a high-rigidity frame made of innovative composite materials. All motion nodes along the X、 Y、 and Z axes are based on 2-sided support elements, which can perform maximum motion at a speed of up to 60 *m/min* regardless of the weight of the workpiece. The range of the table tilt function is ±130˚, which can well complete the impeller processing tasks.

2.2.2 Selection of machining tools

The choice of machining tools is also an important part of the impeller machining process design, which directly affects the accuracy of impeller machining at each stage. The commonly used processing tools for blank processing in impeller processing are divided into external turning tools, face turning tools, cutting tools, boring tools and forming tools, etc. The commonly used tools for milling are divided into spherical face, tapered face, flat bottom face milling cutter types, etc.

Table 2.2 Selection of tools

No	Material	Type	Diameter (mm).	Taper/tip angle	The number of edges	Use
T1	Cemented carbide	Turning tool	1.6	55°	2	Turning
T2	High-speed steel	Drill knife	7.0	118°	2	Drill
T3	High-speed steel	Reamer	7.38	0°	6	Reaming
T4	High-speed steel	Chamfering knife	12	45°	1	Hole chamfer
T5	High-speed steel	Ball end mill	2	3°	2	Milling rough machining
T6	High-speed steel	Ball end mill	2	3°	2	Milling finishing

2.2.3 Division of the machining stage and selection of cutting parameters

Impeller processing is divided into three stages: (1) Rough turning is to quickly remove large amounts of material, leaving a little margin for finishing, which ensures the accuracy of the blank; (2) Hole processing is divided into four stages, namely drilling Hole, reaming, reaming, hole chamfering. (3) Milling roughing is the preliminary processing of the shape of the impeller. Finishing is the slow and uniform processing of the margin left by the roughing. The spindle speed should be as large as possible and the processing speed should be as slow as possible to ensure the surface processing of the parts. Quality and processing dimensional accuracy.

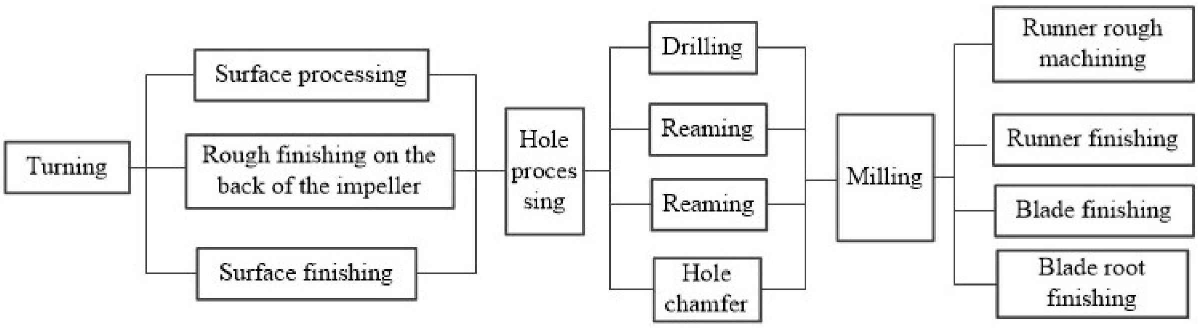


Figure 2.3 Impeller processing phase

(1) Selection of cutting parameters

The choice of cutting parameters affects the surface quality and processing efficiency of the impeller. When choosing cutting parameters, the following should be followed: high production efficiency is the goal for rough machining, and high product quality is the prerequisite for finishing. Combining processing cost and processing efficiency, comprehensive consideration includes cutting speed v, cutting depth, feed per revolution f, feed speed vf, feed per tooth af, etc., according to the selection order of -vf-af. The calculation of parameters can be based on the following formula:

$$v = \frac{\pi d_0 n}{60 \times 1000} \quad (2.1)$$

$$v_f = fn = a_f zn \quad (2.2)$$

$$v = \frac{d_0^q c_v}{t^m a_p^x a_f^y a_w^u z^p 60^{1-m}} \quad (2.3)$$

c_v of them is a constant, t is tool durability, m, x, y, u, p the value of depends on the type of tool、Materials and workpiece materials。d_0 is the outer diameter of the tool,

z is the number of tool teeth.Combined with the actual machine tools, tool materials and cutting dosage manuals, impeller machining parameters such as Table 2.3 are obtained

Table 2.3 Selection of cutting parameters

Process number	Cemented carbide/High speed steel			Spindle speed of lathe n(r/mm)	Feed f (mm/r).	Lathe three-axis machining, five-axis machining Cutting amount	
	Process content	nife number	Tool type			Depth of cut ap(mm)	Cutting speed v_c(m/mm)
1	Turning the end face	T1	Turning tool	1200	0.3	4.9	377
2	Rough turning outer contour	T1	Turning tool	1200	0.3	4.9	377
3	Finish turning outer contour	T1	Turning tool	1500	0.1	0.1	340
4	Drill the center hole	T2	Drill	1200	0.125	52.5	0.3
5	Enlarging the center hole	T2	Drill	1200	0.125	52.5	0.3
6	Reaming center hole	T3	Drill	1200	0.042	52.5	0.3
7	Runner rough machining	T4	Chamfering knife	1200	0.25	4.41	0.3
8	Flow roughing	T5	Ball end mill	6000	0.1	10	2
9	Flow finishing	T6	Ball end mill	9000	0.05	0.5	1
10	Impeller blade finishing	T6	Ball end mill	9000	0.05	5	1
11	Impeller root finishing	T6	Ball end mill	9000	0.05	0.5	1

The name of the factory			Mechanical process card		Product number	JK50	Part diagram	1			
					The product name	Impeller	Part Name		Common items	Page 1	
Material	Aluminum alloy 6061		Types of blanks	Sticks	The shape of the blank	Φ100 x 55	Number of pieces per blank		1	Note	
							Number of pieces per unit		1.		
Process number	Process name		Process content			workshop	workshop sectio	equipment	Craft equipment	man-hour	
1	Impeller blank forming		Rough turning the outer contour and end face of the impeller					CNC lathe TOM-TCK32	Three-grab card tray ISQD turning tool （diamond 55）		
			Finish turning outer contour, impeller back end face								
			Rough turning outer contour								
			Finish turning outer contour								
2	Impeller blank drilling		Drill Φ7.38 hole					850 Three-axis processing centre	Design special fixtures R1B3D6 Drill knife Reamer Chamfering knife		
			Expand Φ7.38 hole								
			Reaming Φ7.38 hole								
			Φ7.38 Hole chamfer (back end of impeller)								
			Φ7.38 Hole chamfer								
3	Impeller forming		Roughing runner					Five-axis machining center KMC600	Design special fixtures R1E3D6 Ball head tapered knife Ball nose cone knife		
			Finishing runner								
			Finished impeller blades								
			Finishing the impeller root								
mark											
									design		

Figure 2. 4 Impeller process card

2.3 Based on CATIA virtual machining simulation

2.3.1 Processing of impeller blanks

According to the process card, the processing sequence from bar to blank is： Rough turning of the impeller outer contour and impeller back — Finish turning the outer contour of the impeller and the back of the impeller — Drilling — Expend holl — Reaming — Rough turning of outer impeller contour nose — Finish turning of outer impeller contour nose — Hole chamfer。

2.3.2 Impeller molding and tool trajectory generation

(1) Runner rough machining

Through simulation, we can check whether the tool has a collision problem with the machined part, and can also verify the rationality of the tool path generation.

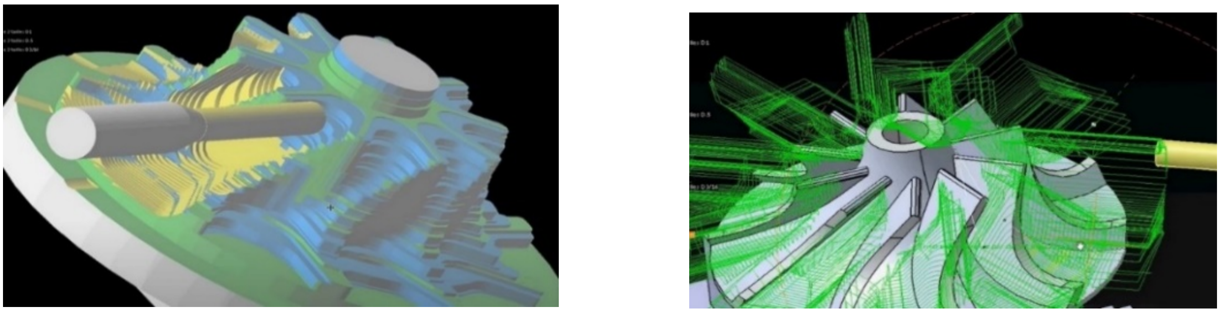


Figure 2.5 Runner rough machining

（2） Runner finishing

Runner finishing is a key step to ensure the machining accuracy of the impeller. In addition to ensuring the rough machining allowance, it is also necessary to ensure the correct tool path.

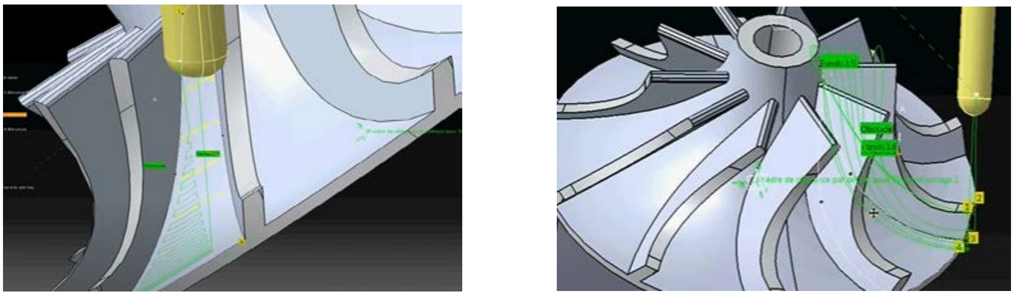


Figure 2.6 Runner finishing

(3) Finishing of impeller blades

The machining method selected for blade finishing is variable contour milling, the driving method is curved surface, and the tool shaft selects the side edge driving body method. This method helps to accurately machine the residual material at the corner of the blade, so as to achieve wide machining contact and small error. advantage.

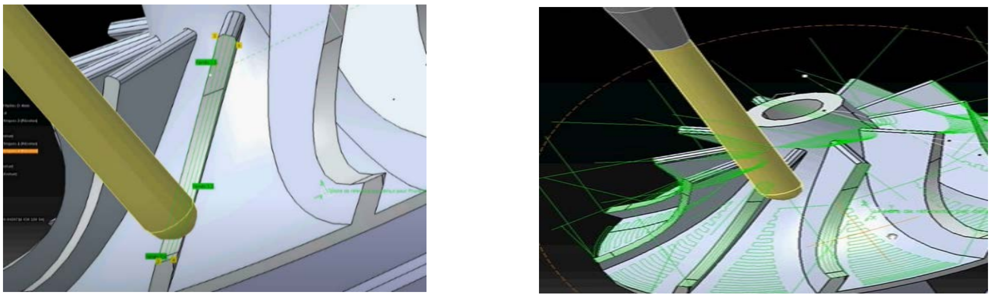


Figure 2.7 Impeller blade finishing

(4) Finish machining of the impeller root

Impeller root processing is based on the trajectory of the blade root fillet surface

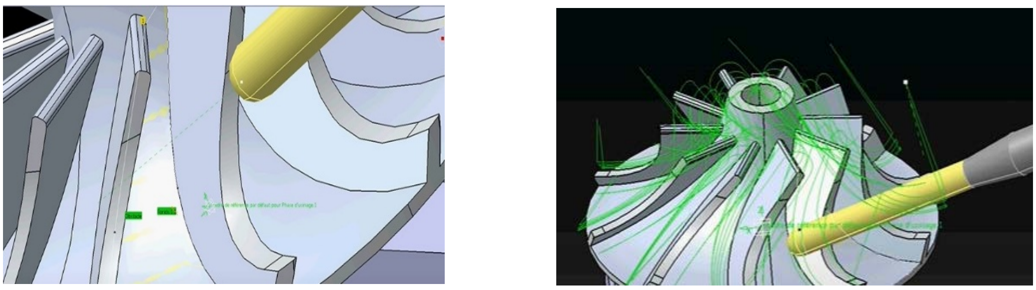


Figure 2.8 Finishing of the impeller root

2.4 Overall planning of impeller processing workshop

2.4.1 Production process analysis

According to the production nature of impeller processing, the workshop is divided into 8 operating unit areas, which are raw material area, processing area, rack area, inspection area, ground rail area, tool area, storage area, and rest area.

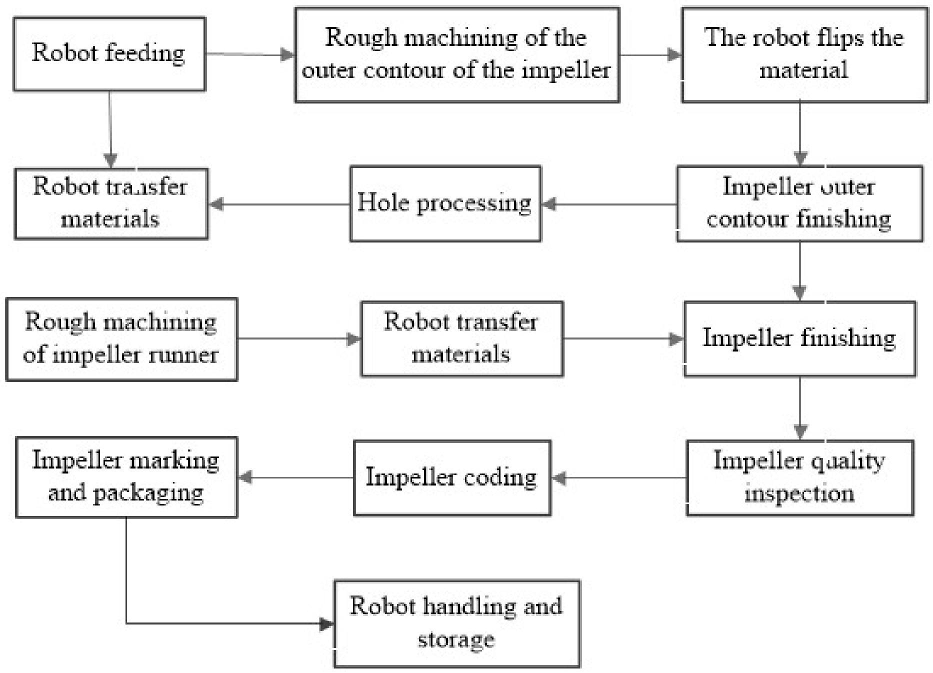


Figure 2.9 Production flowchart

2.4.2 Workshop equipment

The main equipment in the workshopincludes 1 raw material warehouse, 3 six-axis robots (1 inkjet robot and 2 material handling robots), 3 CNC machine tools (including CNC lathe (TOM-TCK32), three-axis machining center, five Axis machining center (KMC600)), 1 robot guide rail, 2 robot fixtures, 2 tooling fixtures, 5 material racks, 1 three-coordinate detection device, 2 tool boxes, 1 finished product warehouse.

Table 2.4 Equipment list

serial number	The device name	Number (each)
1	Raw material library	1
2	Six-axis robot	3
3	Robot rail	1
4	CNC machine tools	3
5	Robot fixture	2
6	Fixture	2
7	Rack	5
8	Three-coordinate detection device	1
9	Toolbox	2
10	Finished product library	1

Conclusions

This Section first gives a brief overview of the products processed by the workshopand introduces the working principle of the impeller, and then formulates the corresponding processing technology based on the actual processing requirements of the impeller, including the selection of blanks, the selection of tools, the division of processing stages, and the selection of cutting parameters. . The production process of the workshopwas analyzed and the production equipment was selected.

SECTION 3

This Section takes impeller processing line as the object, uses SLP method to statistics the relevant data, combines the logistics analysis to get the correlation diagram, and draws the location correlation diagram, and then uses Plant Simulation to lay out the preliminary layout map, using Plant Simulation The results of the genetic algorithm are verified and compared, and the results of optimization are obtained.

3.1 Process workshop layout based on SLP method

Combining the theoretical research of SLP method with practical application, a set of standardized, procedural and complete design processes is formed, which is divided into three stages: analysis, optimization, and selection, as shown in Figure 3.1

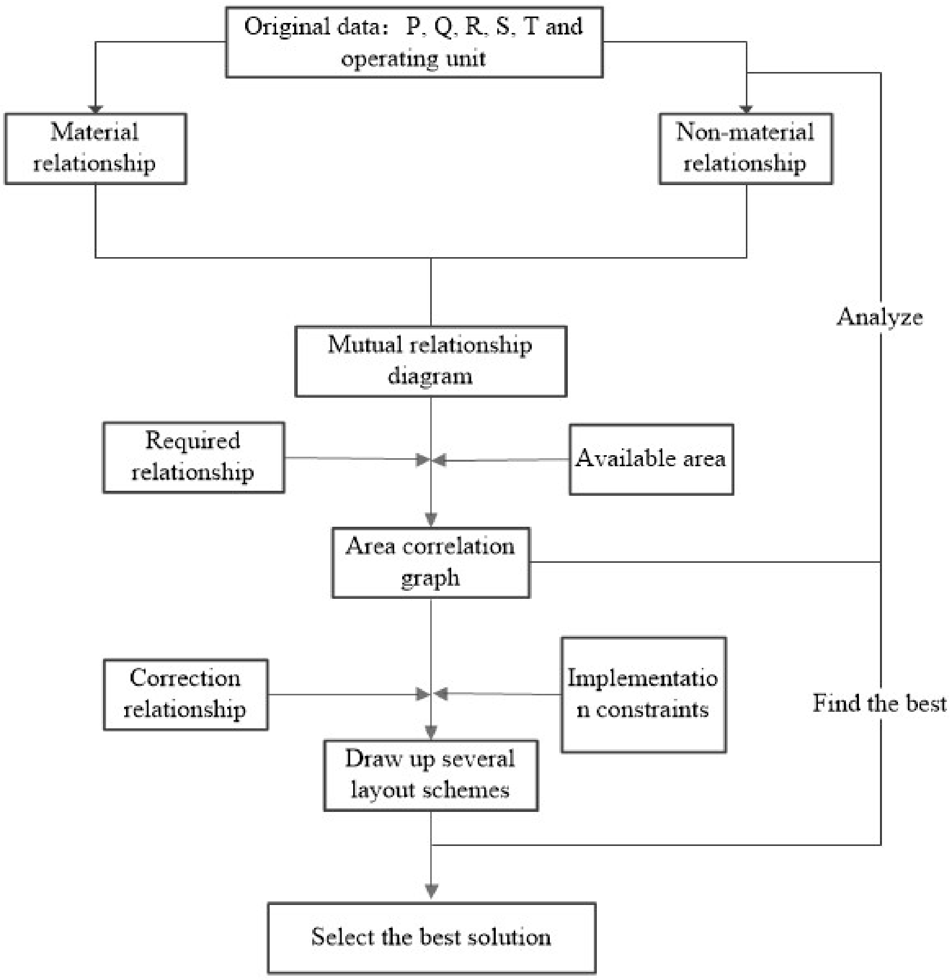


Figure 3.1 System layout design program diagram

3.2 Optimization and simulation of facility layout based on genetic algorithm

3.2.1 Brief introduction of impeller processing workshop

The research object selected in this paper is a small-scale centrifugal compressor impeller workshop. The workshopmainly uses a variety of machine tools for processing and production. The main products are mainly impeller parts.

The total planned area of the impeller processing workshopis about 112m2, and the annual output of impellers is 7,200. The annual output is 12 months and 10 hours a day. The monthly output should reach 600, considering the actual area of the workshopis small. , In order to minimize the facility layout area and logistics volume, the layout design of the processing workshop was carried out. The overall process planning of the impeller is divided into parts processing stage, quality inspection stage, parts coding inspection stage and product storage stage. And the workshopis divided into 8 areas.

Table 3. 1 Summary table of unit area

Serial number	Operating unit name	Purpose	Area(m^2).
1	Rest area	The workers rested	5
2	Processing area	Processing parts	26.4
3	Tool area	Storage tools	4.8
4	The detection area	Inspection part	3
5	The storage area	Products are stored	4.08
6	The track area	Move parts	14.4
7	Raw material area	Raw material library	6.12
8	Shelf area	Parts transfer	14.4
9	Total area of the venue		112

3.2.2 Material relationship analysis

In the impeller processing workshop, the material exchange between the equipment is regarded as logistics, combined with the production process flow of the workshop, the number of transports per unit time is statistically calculated, and the transport volume between each operation unit is obtained, as shown in Table 3.1, combined Handling volume table, you can get the logistics intensity and intensity grade as shown in Table 3.2

Table 3 .2 Handling scale

Name	Seating area	Processing area	Tool area	The detection area	Inbound area	Land orbit area	Raw material district	Shelf area	Total
Rest area	0	0	0	0	0	0	0	0	0
Processing area	0	0	298	54	0	387	0	302	987
Tool area	0	352	0	96	0	94	312	0	854
Detection area	0	0	106	0	0	0	0	0	160
Inbound area	0	30	0	0	0	314	0	156	500
Land orbit area	0	425	189	0	58	0	0	354	1026
Raw material area	0	0	0	0	0	0	0	0	0
Shelf area	0	158	47	0	0	285	0	0	490
Total	0	965	640	150	58	1080	312	812	8034

Table 3. 3 Material strength grade table

No	Operating unit pair	Logistics intensity	Logistics intensity level
1	6-2	425	A
2	2-6	387	A
3	6-8	354	E
4	3-2	352	E
5	5-6	314	E
6	3-7	312	E
7	2-8	302	I
8	2-3	298	I
9	8-6	285	I
10	6-3	189	I
11	8-2	158	I

12	5-8	156	0
13	4-3	106	0
14	3-4	96	0
15	3-6	94	0
16	6-5	58	0
17	2-4	54	0
18	8-3	47	0
19	5-2	30	0

3.2.3 Integrated relationship analysis of workshops

The determination of the comprehensive relationship of the operating unit is the key to the design of the system layout, and the way of determining it is to use the weighted method of the logistics relationship and the non-logistics relationship, the correlation of which can be determined by the following formula

$$TR_{ij} = mMR_{ij} + nR_{ij} \tag{2.1}$$

Among them, TR represents the quantitative value of the comprehensive relationship between *i* and *j*;

MR represents the quantitative value of *i* and *j* under the logistics relationship;

NR represents the quantified value of *i* and *j* in a non-logistics relationshi;

m:n represents the ratio of the relationship between logistics and non-logistics. Since the object of this article is the impeller processing workshop, the logistics relationship plays a major role, so *m:n=2:1* in this article.

Through the division of logistics intensity and non-logistics intensity levels of operating units, each level is assigned its corresponding quantitative value, where *A=4*, *E=3*, *1=2, 0=1, U=0, X=-l* Then multiply the sum by m and n to get the comprehensive relationship level, and then formulate the comprehensive relationship table of the work unit, as shown in Table 3.4.

Table 3. 4 Comprehensive Interrelationship Table of Operating Units

Operation unit pair	Close relationship level				Comprehensive relationship	
	Weighted value of logistics relationship		Weighted value of non-logistics relationship			
	Grade	Fraction	Grade	Fraction	Fraction	Grade
1-2	U	0	I	2	2	0
1-3	U	0	0	1	1	0
1-4	U	0	U	0	0	U
2-3	I	2	0	1	5	E
2-4	0	1	0	1	3	I
2-6	A	4	X	-1	7	A
2-7	U	0	A	0	4	I
3-4	0	1	I	2	4	I
3-6	0	1	E	3	5	E
3-7	E	3	X	0	5	E
4-7	U	0	I	2	2	0
5-6	E	3	X	-1	5	E
5-8	0	1	0	1	3	I
6-7	U	0	E	*3*	3	I
6-8	E	3	U	0	6	E
7-8	U	0	0	1	1	0

3.2.4 The relative diagram of the location of the workshop operation unit

The location correlation diagram of the operating units is a concentrated expression of the closeness of the operating units. It is mainly to transform the comprehensive correlation table into a square matrix table. According to the quantitative value corresponding to the correlation level of the comprehensive correlation table, the comprehensiveness of each operation unit is calculated. The closeness values are summed and arranged in order, and the obtained values are shown in Table 3.5.

Table 3. 5 Ranking table of proximity to work units

Operating unit name	Rest area	Processing area	Tool area	Detection area	Inbound area	Land orbit area	Raw material area	Shelf area
Comprehensive proximity	2	12	11	5	5	15	10	6
Sequence	8	2	*3*	7	6	1	4	5

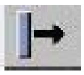
3.2.5 Simulation of workshop layout based on SLP method

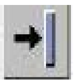
The layout of the impeller processing workshopbelongs to the multi-row continuous layout type. Since the material flow does not need to pass through the channels between the operating units during the impeller processing, the principles that should be followed in the layout process: (1)The distance between operating units, unit area, and maintenance space are all The binding is the total work unit area, ignoring the irregularities of the equipment shape. (2)The size of the total area of the equipment and the layout is known, and the horizontal and vertical distance between the equipment is known.(3)Plan the equipment according to the equipment arrangement order from top to bottom and from left to right. According to the floor area of each operation unit in the workshop and the logistics intensity between each operation unit, a data table is established, and the corresponding machine equipment is generated on the simulation panel by writing the SimTalk program, and the area data of each operation unit is read. Draw the area chart of the equipment. Read the equipment sequence generated in the table according to the location correlation diagram of the operating unit in turn, and adjust the sequence of the area diagram of each operating unit to obtain the preliminary plan of the SLP method.

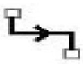
3.3 Simulation operation analysis of impeller processing workshop based on Plant Simulation

(1) Introduction to the simulation module

This article uses Plant Simulation simulation software to simulate the layout of the impeller processing workshop , mainly using the logistics module, resource module, information flow module, user interface module and tool module in the toolbox. The logistics module and the information module are used in the simulation process. The key model, its brief introduction is shown in the figure below

 Feeding entrance: provide materials for the processing and production process.

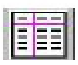
 Part storage: As a product storage function, it also controls product information。

 Connecting line: connecting the working process between the equipment and the equipment, reflecting the process flow。

 Simulation control: control the time and speed of simulation。

 Program method: use SimTalk language to edit the program to realize simulation function control

  It is transformed from the property setting of the program  method, which respectively represent the program reset method and the direct run method. Generally, it cannot be run directly.

 Table: used to count the relevant data of the product, the program can also directly read the data in the table to achieve simulation

(2) Define global variables

The use of global variables can eliminate repeated programming in the program, and play an important role in saving running time in programming. It has the characteristics of simple operation and high reading and writing efficiency. By setting global variables to define simulation properties, this can save program running time and make the defined data more reliable.

Table 3.6 Define global variables

Variable	Name	Function
Number_Of_Machme	Number of operating units	Generate job unit area chart
PartsNo	Number of parts	Record the number of transportation logistics
TableNeeds	Form access	From-to table for recording the model
X_pos_mit	X coordinate origin	For drawing reference points
XScale	Painting ratio	Record the proportion of the painting
Y_Max	Maximum row height	Record the accumulated value of the maximum row height

(3) Simulation ideas

By reading the machine code of the work unit in the machine sequence table, the corresponding work unit is generated at the work site, and then the length and width data of each work unit in the work unit table are read to calculate the area of each work unit, and the area data and location are combined The correlation diagram reads the serial number of each unit, exports the total site area and the area diagram of the work unit, and arranges them according to the corresponding positions.

(4) Program realization

Create a table by writing a program in Plant Simulation and fill in the logistics intensity of the operation unit, the area of the operation unit, etc.

Table 3.7 Area of Operation Unit

Operating unit name	Length（m）	Width（m）
Rest area	2.5	2.0
Processing area	11.0	2.4
Tool area	3.0	1.6
Detection area	3.0	1.0
Inbound area	3.4	1.2
Land orbit area	12.0	1.2
Raw material area	3.4	1.8
Shelf area	12.0	1.2
The total area	17.0	6.6

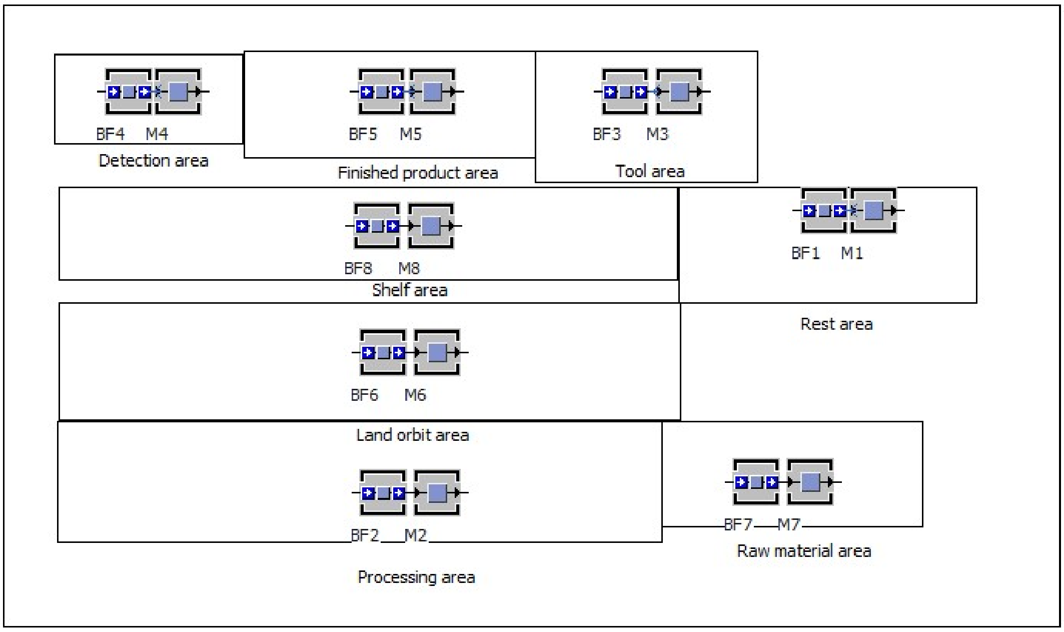


Figure 3.2 SLP method line layout

To sum up, SLP has the advantages of strong logic, wide application range, and close operation steps. However, through analysis of the preliminary layout of the workshop obtained by using the SLP method in Plant Simulation, it can be found that the operation unit includes the raw material area, the inspection area, and the inspection area. The placement of the rest area does not conform to the route of the processing technology, and the distance between the material rack area and the ground rail area of the operating unit is relatively large, which causes trouble in handling materials. The area is large, which affects the layout of other equipment, and the utilization rate of the site is small.

3.4 Balance analysis and optimization of impeller workshop

By controlling the actual situation of the impeller processing workshop , the impeller processing workshop belongs to a variety of small batch production methods. The SLP method combined with the genetic algorithm selection method is used to optimize the layout design of the workshop . The specific process is shown in Figure 3.3.

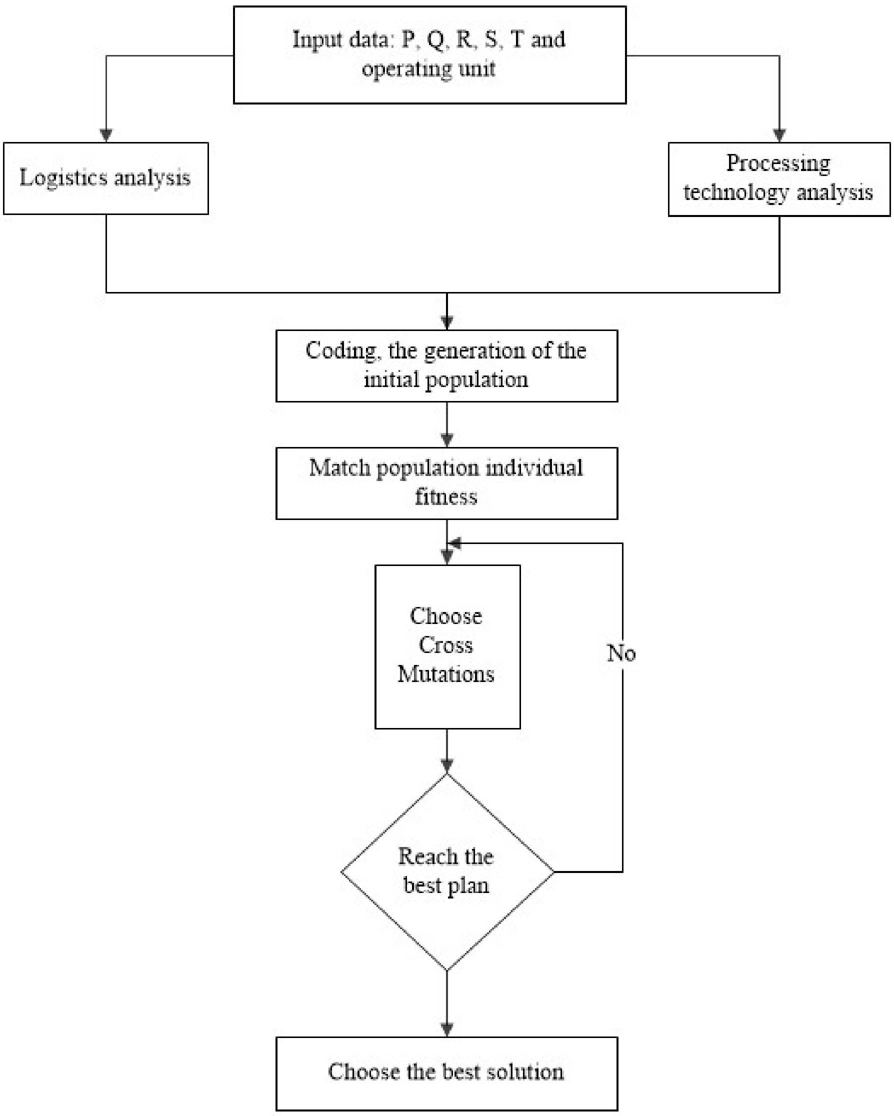


Figure 3.3 Flow chart for optimization of workshop layout

(2) Establish a workshop layout model

Combined with the specific conditions of the workshop, fully consider all factors affecting the layout in the workshop of the impeller workshop. The final goal of the layout model established in this article for the workshop of the impeller processing workshop is to obtain the minimum material flow and reduce its handling cost. The established workshop layout model is shown in Figure 3.4

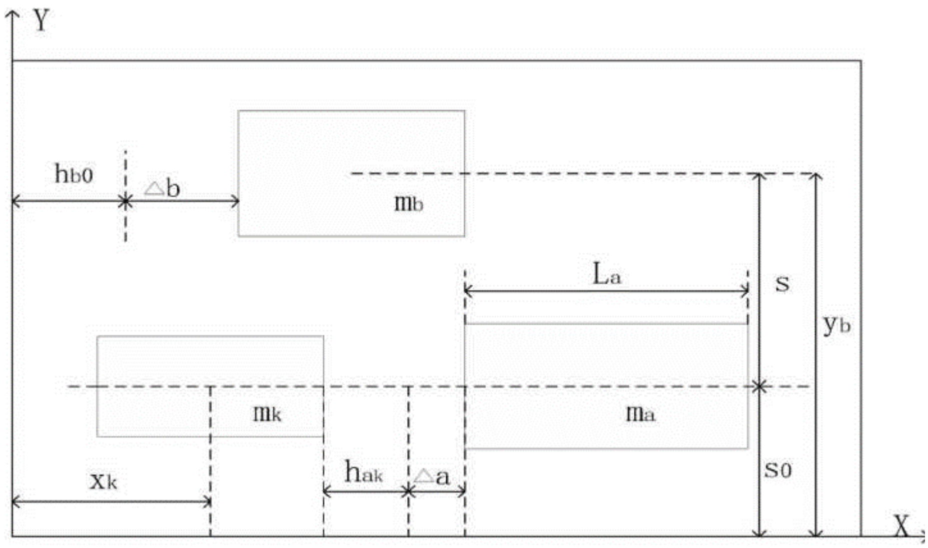


Figure 3.4 Workshop layout model

ma, mb, mk: represent three operating units;

La: represents the length of the operating unit a;

x_k: represents the abscissa distance from the work unit to the boundary;

yb: represents the ordinate distance from the operating unit 5 to the lower boundary;

hak: Said. The minimum distance between Shen and Shen;

$hb0$: indicates the minimum distance between the work unit b and the boundary

Δa; represents the net distance between operating units;

The impeller processing workshop studied in this paper is a multi-line continuous layout model, and the objective function value is determined by the transportation volume and the distance between the operating units. Therefore, the objective function of the volume I can be assumed to be

$$I = \sum_{a=1}^{n}\sum_{b=1}^{n} C_{ab}(I)\times D_{ab}(I) \tag{3.2}$$

$$C(I) = \begin{bmatrix} C_{11}(I) & C_{12}(I) & \dots & C_{1n}(I) \\ C_{21}(I) & C_{22}(I) & \dots & C_{2n}(I) \\ \dots & \dots & \dots & \dots \\ C_{n1}(I) & C_{n2}(I) & \dots & C_{mn}(I) \end{bmatrix} \tag{3.3}$$

$$D(I) = \begin{bmatrix} D_{11}(I) & D_{12}(I) & \dots & D_{1n}(I) \\ D_{21}(I) & D_{22}(I) & \dots & D_{2n}(I) \\ \dots & \dots & \dots & \dots \\ D_{n1}(I) & D_{n2}(I) & \dots & D_{nn}(I) \end{bmatrix} \tag{3.4}$$

The distance between devices is expressed as:

$$D_{ab} = |x_a - x_b| + |y_a - y_b| \tag{3.5}$$

$$x_a = x_k + (L_a + L_k)/2 + \Delta a = \Delta a + \Delta k + (L_a + 2L_k)/2 \tag{3.6}$$

$$y_a = (k-1)s + s_0 \quad k = 1,2,3\dots n \tag{3.7}$$

Among them, the total objective function I represents the total volume of goods; Cab represents the throughput matrix between each operation unit, Dab represents the distance matrix between the operation units; xa, xb represent the center coordinates of the operation unit a , K represents the number of rows of equipment layout.

The impeller processing and production layout process is also restricted by the area of the site, the length and width of the site, and the overlap of equipment, so there are the following constraints:

$$0 \le |x_a - x_b| + (L_a + L_b)/2 \le LX \tag{3.8}$$

$$0 \le |y_a - y_b| + (L_a + L_b)/2 \le LY \tag{3.9}$$

$$|x_a - x_b| \ge \left[(L_a + L_b)/2 + h_{ab}\right] z_{ar} z_{br} \quad a,b = 1,2,3\dots.n \tag{3.10}$$

Each device can only appear once,

$$Z_{ar}\begin{cases}1, & \text{Assignment unit } a \text{ to row } r\\0, & \text{Others}\end{cases} \quad (a,b=1,2,3\ldots n) \tag{3.11}$$

$$\sum_{r=1}^{n} z_{ar}=1 \quad a=1,2,3\ldots n \quad x_a, \quad x_b \geq 0 \quad \Delta a \geq 0 \tag{3.12}$$

Among them, *LX* and *LY* represent the length and width of the site, respectively, and *Zar* is the decision variable, which means that the operation unit *a* is on row *r*.

3.4.1 Workshop layout model solution and program realization

(1) Workshop layout model solution process

1）Chromosome coding

In practical applications, there are three main ways of chromosome encoding, including floating-point encoding, binary encoding, and symbol encoding. Because the layout problem of the impeller processing workshop only involves the adjustment of the regional position, and has nothing to do with the value, so this article uses symbol coding. Use the serial number of the work unit and the clear distance between them to encode. Its general form is

$$[\{m_1, \quad m_2, \quad m_2,\ldots, \quad m_n\},\{\Delta_1, \quad \Delta_2, \quad \Delta_3,\ldots, \quad \Delta_n\}] \tag{3.13}$$

Where m represents the number of the operating unit; Δi represents the net distance between the operating unit i-l and i; and when the total length of each row of operating units exceeds the total length of the layout site, the last operating unit is automatically arranged to the next row.

2）Initial population

The selection of the initial population is random, and it will directly affect the optimal results of the genetic algorithm. When selecting, it cannot be too large or too small. Too large will easily lead to the algorithm area being too large and failing to converge within the specified range; Too small will easily lead to the optimization result is too one-sided or premature convergence. Because this article uses the SLP method to plan the initial result operation unit sequence as the first chromosome sequence, that is, the operation unit sequence (4,5,3,8,1,6,2,7), and then add some random sequences as Is the initial population.

3）Fitness function

The size of the fitness function value is the basis for judging the pros and cons of individual populations, and the functional relationship between them is proportional. In combination with the optimization situation in this article, we want to get the minimum material flow, so we choose the direct conversion method, that is, the fitness function after conversion is *fit_F(x) = I(x)*. Since the automatic line wrapping strategy is adopted in the layout process, it is necessary to ensure that the length of each column does not exceed the total width, which is an unreasonable penalty item. Therefore, the fitness function in this article is composed of an objective function and a penalty function. Since it is a minimum problem, it can be expressed as：

$$Pr\begin{cases} 0, (k-1)s + S_0 \le LY \\ G\ , \text{Other} \end{cases} \tag{3.14}$$

$$fit\_F(r) = \frac{1}{(Ir + Pr)} \tag{3.15}$$

Among them, *Pr* is the penalty item, *k* is the number of rows arranged by the work unit, *Ir* is the objective function, *G* is the penalty value of a positive number, and *LY* is the width of the field.

(4）Choose

Selection is the first step in the operation of genetic algorithm. According to the principle of genetic law, a certain proportion of chromosomes are selected for inheritance, so that the probability of an individual being selected is proportional to the fitness function. Roulette selection has simple operations, stable randomness, and convergence. Strong and other advantages, so this article adopts this method.

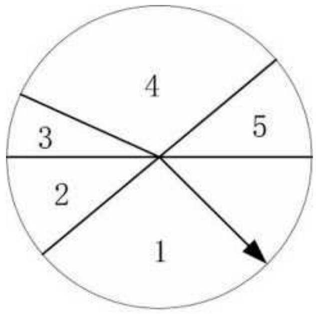


Figure 3.5 Roulette Selection

Suppose there are *n* individuals in the group, and the fitness of each individual is *Fa*, so the probability of individual *a* being selected can be expressed as

$$Pa = \frac{Fa}{\sum_{b-1}^{n} Fb} \tag{3.16}$$

The roulette wheel selection method obtains a new population, and the selection probability of individuals is more uniform, and the higher the fitness, the greater the probability of being selected.

5）Cross

There are various crossover methods in genetic algorithms, including single-point crossover, multi-point crossover, arithmetic crossover, cyclic crossover, and partial matching crossover. According to the specific characteristics of the impeller processing line, this article chooses partial matching crossover to be used for the genetic operation of the order of the operating units, and arithmetic crossover is selected for the genetic operation of the net distance between the operating units. The probability of crossover is generally 0.5-0.9. Probability is 0.8

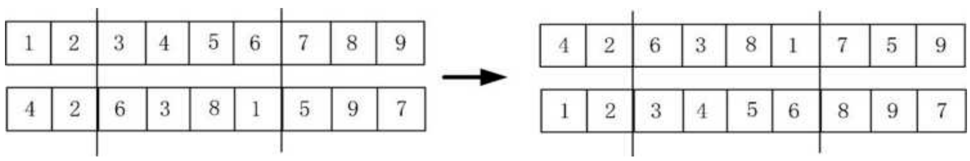


Figure 3.6 Partially matched cross

Arithmetic crossover refers to the two new chromosomes obtained by the cross calculation of two parent chromosomes, assuming that the two parent individuals are X_A^{i+1}, X_A^{i+1} the new individual formed after arithmetic crossover is

$$X_A^{t+1} = aX_B^i + (1-a)X_A^i \tag{3.17}$$

$$X_B^{i+1} = aX_A^i + (1-a)X_B^i \tag{3.18}$$

Among them, *a* is a random number between [0,1]

6）Mutations

The mutation operation is to prevent the population from being too single in the iterative process, and to cultivate better next-generation chromosomes. The mutation operation is mainly used to determine the net distance between each operation unit of the workshop. According to the probability of mutation, r net distances are randomly generated in the net distance range *[Umin, Umax]* to replace their net distance codes, and then selected from the new chromosome population The best one will replace any one of the original eight chromosomes. In this paper, the mutation probability is 0.1, where *r=8*, *[Umin, Umax]*= [0,1.5].

7）Genetic termination

According to the population size of the impeller processing line, the population size is limited to 300.

(2) Program realization

The total area of the impeller processing workshop is 112 m^2, of which the length of the site is 17 *m* and the width is 6.6 *m*.

The genetic algorithm involves parameters: the initial population is 50, and the initial results generated according to the SLP layout design are used as the individuals of the initial population, and the remaining individuals are randomly obtained; the penalty value T is *500*, and the minimum distance between operating units is *0.6m*; operating units The minimum distance from the boundary is *0.5m*; the range of the net distance of the work unit is *[Umin, Umax]= [0,1.5]*. Then, according to different iteration parameters (as shown in Table 3.8, different layout schemes are solved respectively。

Table 3.8 Parameter group control table

Paramter group	Population size	(maxGen)	Crossover probability	Mutation probability
1	50	50	0.8	0.1
2	100	50	0.8	0.1
3	200	50	0.8	0.1
4	300	50	0.8	0.1

3.5 Simulation verification and result analysis of impeller processing workshop

Workshop layout optimization simulation

In order to verify the accuracy of the optimization results of the established impeller processing workshop layout model, the plant simulation software was used to establish a digital model of the impeller processing workshop. The genetic algorithm tool GAWizard was used to encode the serial number of the operating unit, and then to decode it by writing a program. Operation, combined with the model established in the SLP layout, through the settings of the genetic algorithm tool as shown in Figure 3.7, where the selected genetic algebra is 20

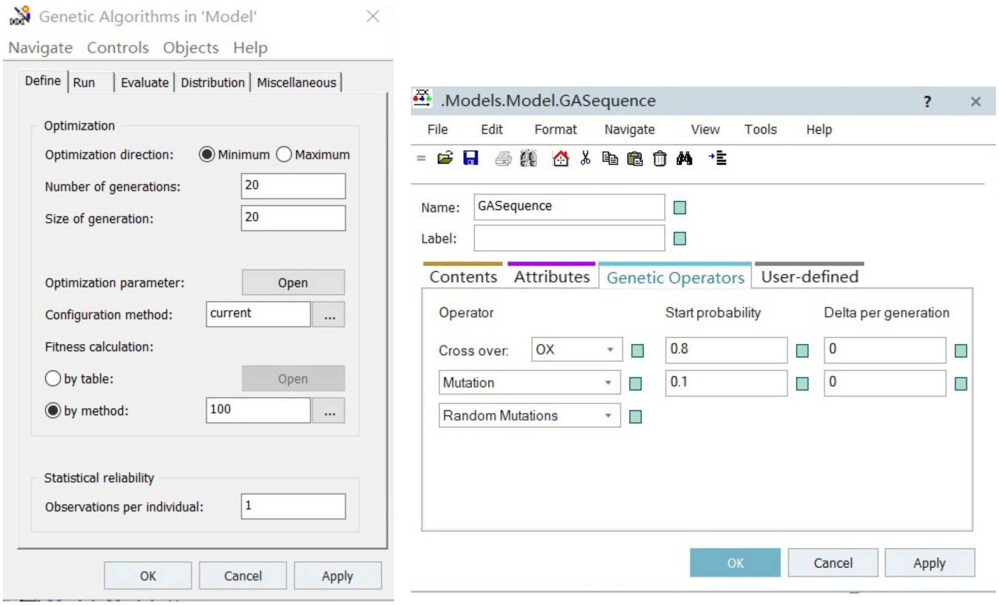
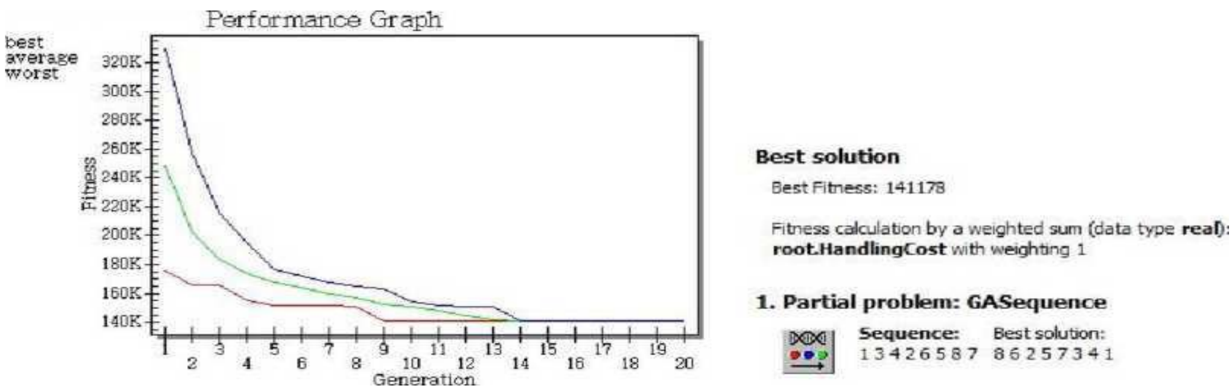


Figure 3.7 Genetic algorithm settings



（a）Convergence curve （b）Optimal sequence

Figure 3.8 Optimization result

By analyzing the simulation results of Plant Simulation to optimize the layout of the impeller processing workshop, it can be found that the genetic factor converges at about 14 generations, and the optimal layout sequence is [86257341], and the optimal objective function value is [1411783.6]

By comparing the layout of the SLP method, it can be seen that the layout optimized by the genetic algorithm is more in line with the processing route. The distance between the raw material area and the detection area and the processing area is more compact, and the distance between the rack area and the ground rail area is more suitable, which reduces material handling. And the total area of facility layout is reduced compared to before optimization. The value of logistics volume is reduced from 190726 before optimization to 141178, which is a decrease of 49548. The optimized results are compared as follows.

Table 3.9 Comparison results

Name	Layout sequence	Total logistics
SLP	45381627	190726
Plant simulation	86257341	141178

Material flow $V=\sum Wij \times Dij$ HandlingCost= 190726

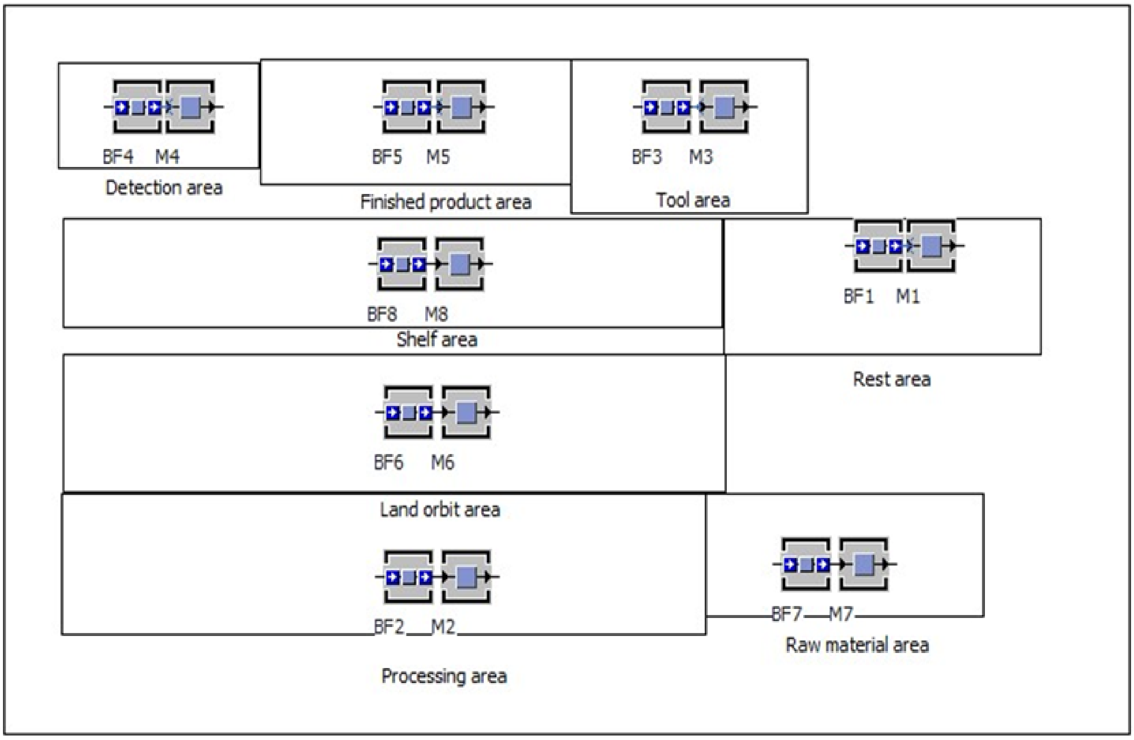


Figure 3.9 Before the optimization of workshop layout

Material flow $V=\sum Wij \times Dij$ HandlingCost= 141178

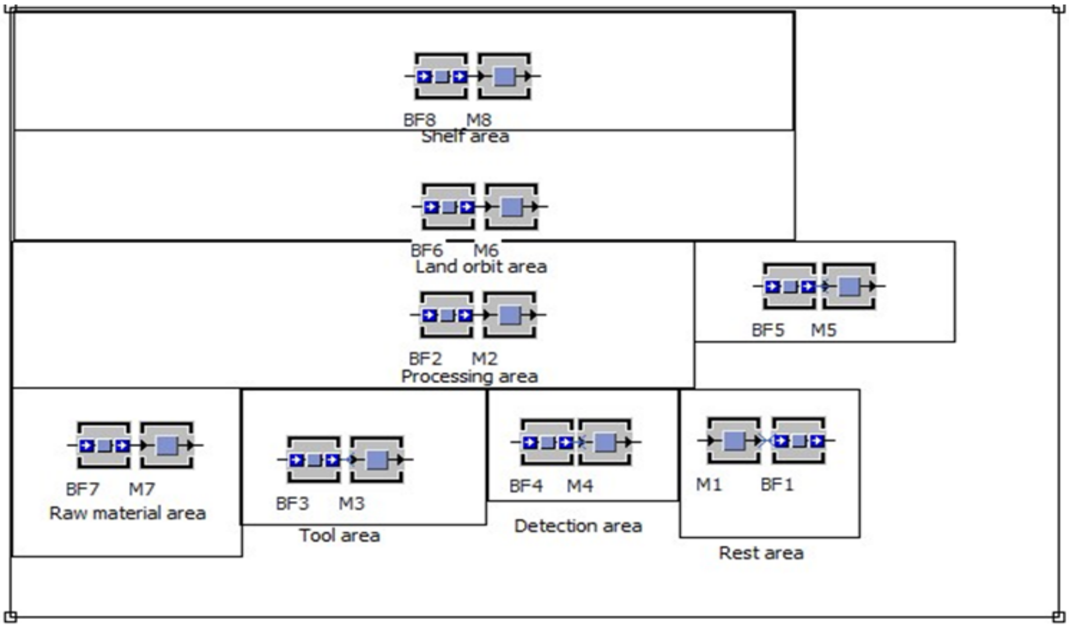


Figure 3.10 After the optimization of the workshop layout

According to the optimization results, the optimized layout of the impeller processing workshop facilities is obtained, and the two-dimensional layout diagram of the impeller processing workshop is drawn according to the area ratio based on the coordinate data of the operation unit obtained from the optimization results.

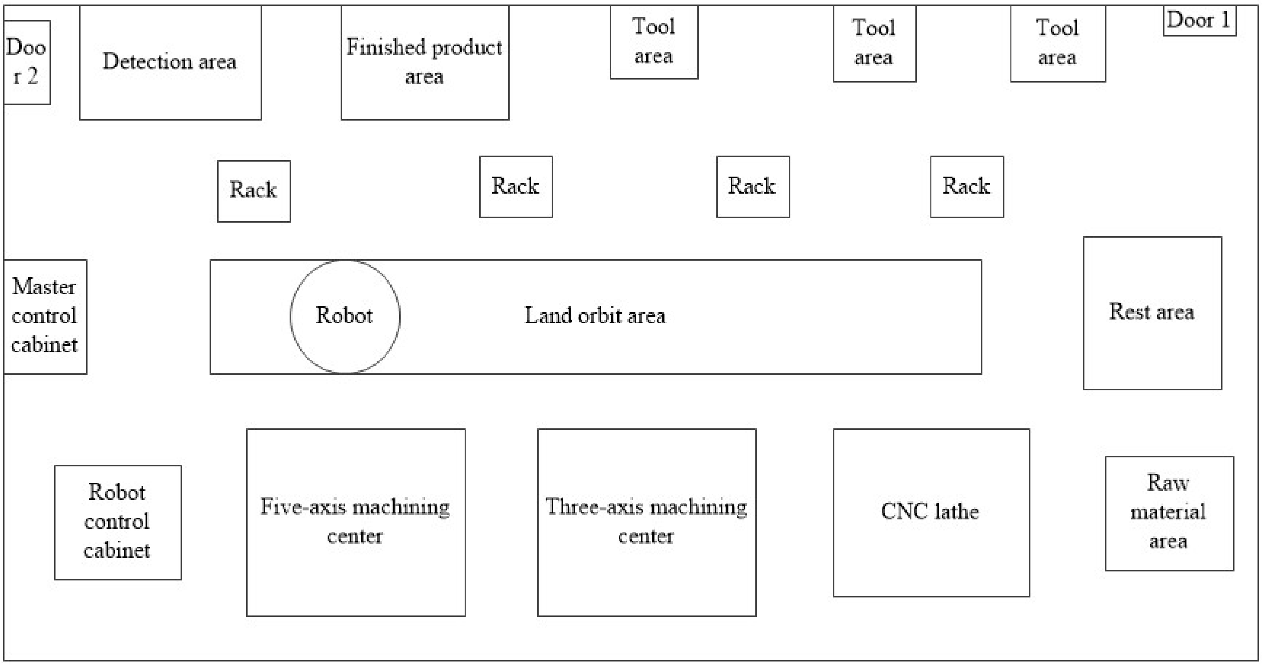


Figure 3.11 Two-dimensional layout diagram of impeller processing workshop before optimization

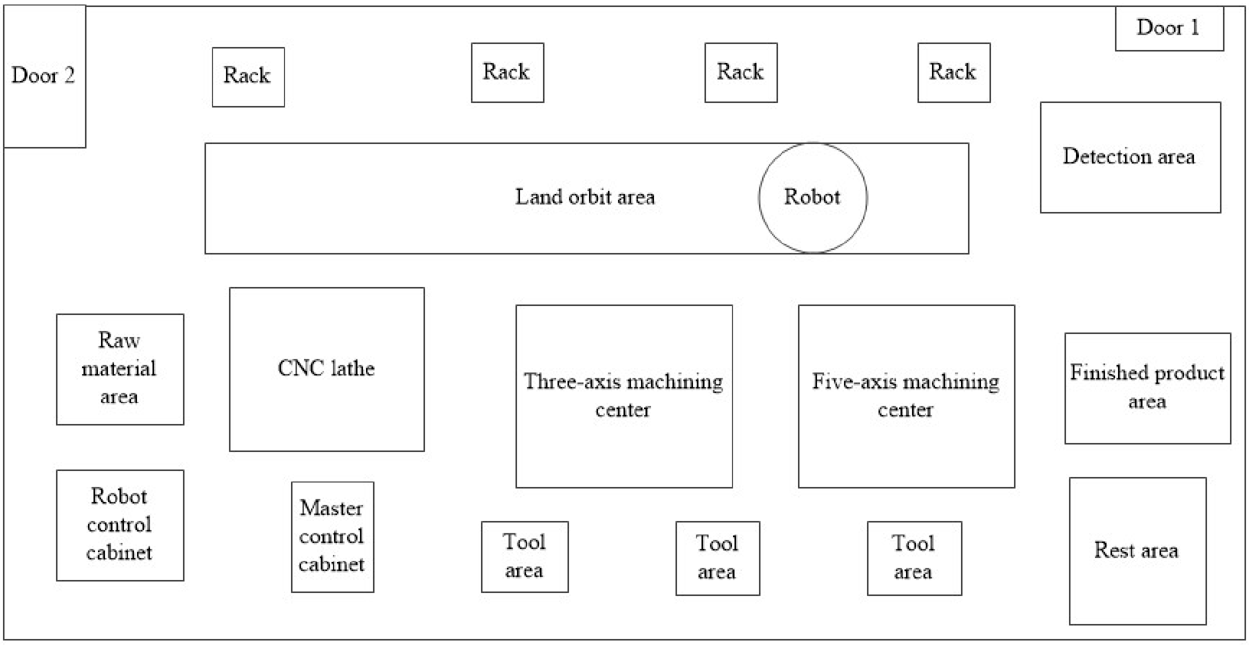


Figure 3.12 Two-dimensional layout diagram after optimization of impeller processing workshop

3.6 Simulation operation analysis of impeller processing workshop based on plant simulation

3.6.1 Simulation model of impeller processing workshop

Table 3.10 Processing time of each step

Process	Work step	Processing content	Process equipment	Auxiliary time	Time	Handling time	Processing time
Turning	1	Rough turning impeller back	Turning tool	T1+T2+T3	0.75	0.2	6.93
	2	Precision turning of the impeller back	Turning tool	T3	0.05	0	4.25
	3	Rough turning the leading edge of the impeller	Turning tool	T1+T2+T3	0.75	0	5.99
	4	Finish turning the leading edge of the impeller	Turning tool	T3	0.05	0.2	4.62
Three axis Milling	5	drilling	Drill	T1+T3+T6	0.75	0.2	0.36
	6	Expend	Drill	T4	0.02	0	0.74
	7	Reaming	Reamer	T4	0.02	0	0.36
	8	Chamfer on the back of the hole	Chamfering knife	T4	0.02	0	0.25
	9	Hole end face chamfer	Chamfering knife	T1+T2+T3	0.75	0.2	0.25
Five axis Milling	10	Roughing runner	Ball end mill	T1+T3+T5	0.75	0.2	24.38
	11	Finishing runner	Ball end mill	T3	0.05	0	21.93
	12	Finished blade	Ball end mill	T3	0.05	0	1.39
	13	Finishing the impeller root	Ball end mill	T3	0.05	0.2	4.65
		Totally			4.06	1.2	79.5

Among them, *T1* is the auxiliary time of workpiece clamping (about 0.2min); *T2* is the auxiliary time of the first lathe tool setting (0.5min); *T3* is the fast forward time (0.05min); *T4* is the tool change time (0.02min); *T5* It is the auxiliary time of the first milling machine tool setting (0.5min);

Combine the data in the table to establish models of equipment, workers, and action paths required by each process in the impeller processing workshop; the processing workshop is divided into lathe processing, three-axis processing, five-axis processing, inspection center, coding, and marking. Packing six workstations, and adding an information panel to set the parameters of each regional equipment and count the output of the workshop in a production cycle;

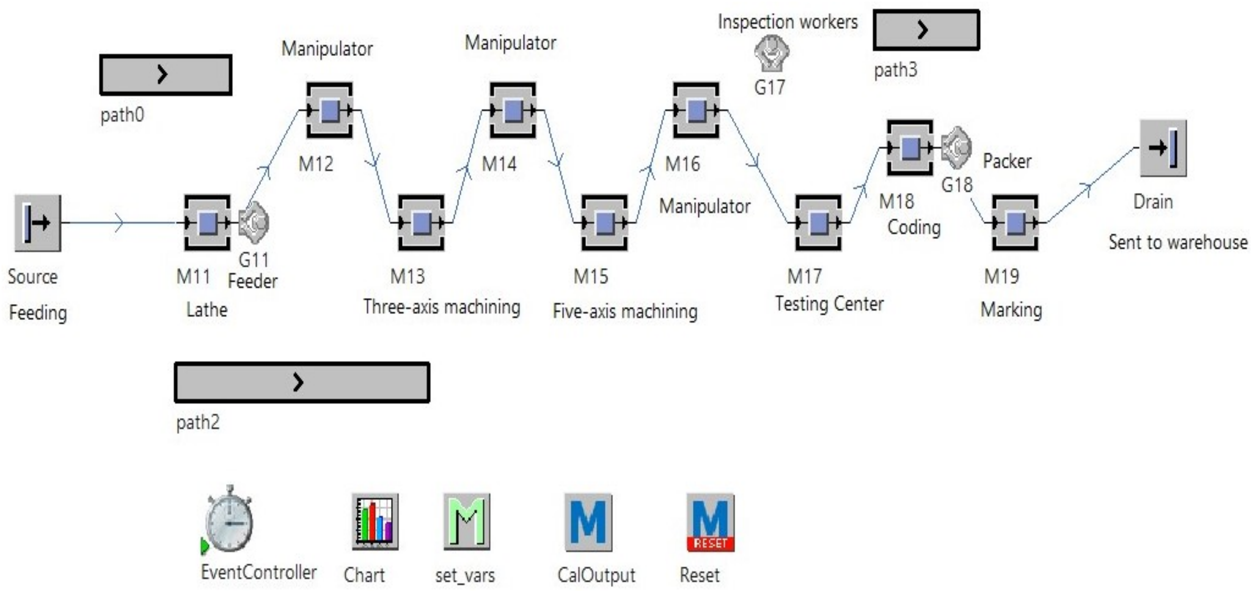


Figure 3.13 Simulation model

The equipment failure rate is set to 2%, and the running simulation starts. The previous simulation controller set time is 13 days (set a month and 31 days as the production cycle,work 10 hours a day, the total time is 13 days), for a production cycle Perform analysis.

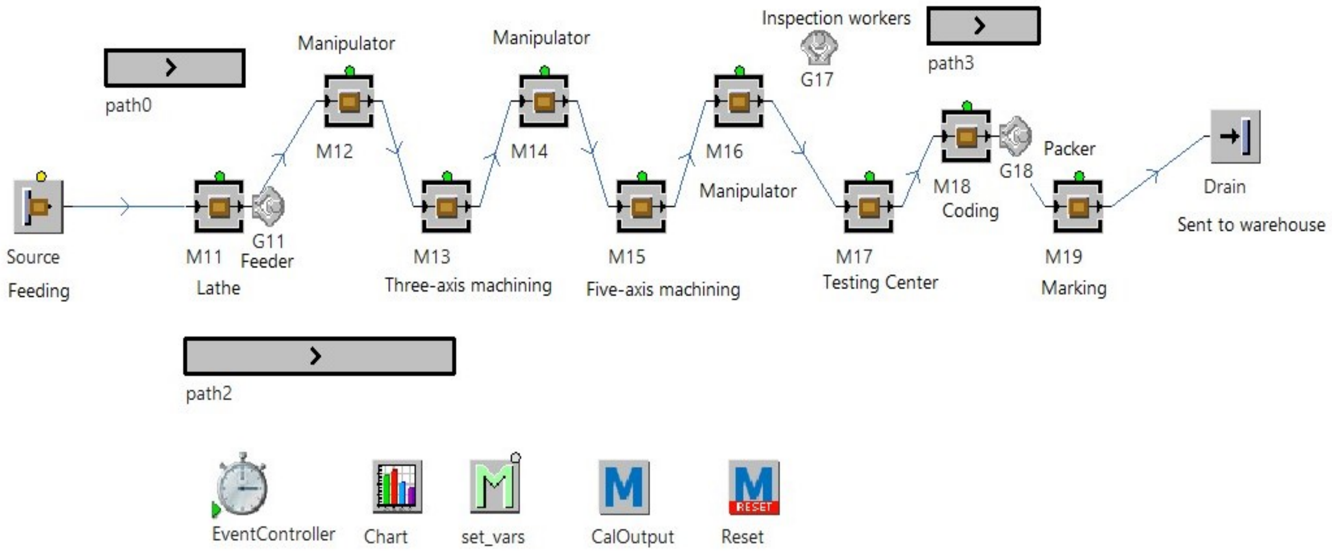


Figure 3.14 Simulation running

M11	23.67%	0.00%	74.60%	1.73%	0.00%	0.00%	0.00%	0.00%	0.0000
M13	4.38%	0.27%	93.24%	2.12%	0.00%	0.00%	0.00%	0.27%	0.0000
M15	97.60%	0.12%	0.01%	2.28%	0.00%	0.00%	0.00%	0.12%	0.0000
M17	18.59%	79.46%	0.03%	1.92%	0.00%	0.00%	0.00%	79.46%	0.0000
M18	3.10%	94.93%	0.00%	1.97%	0.00%	0.00%	0.00%	94.93%	0.0000
M19	3.10%	96.90%	0.00%	0.00%	0.00%	0.00%	0.00%	96.90%	0.0000

Figure 3.15 Statistics of each process information

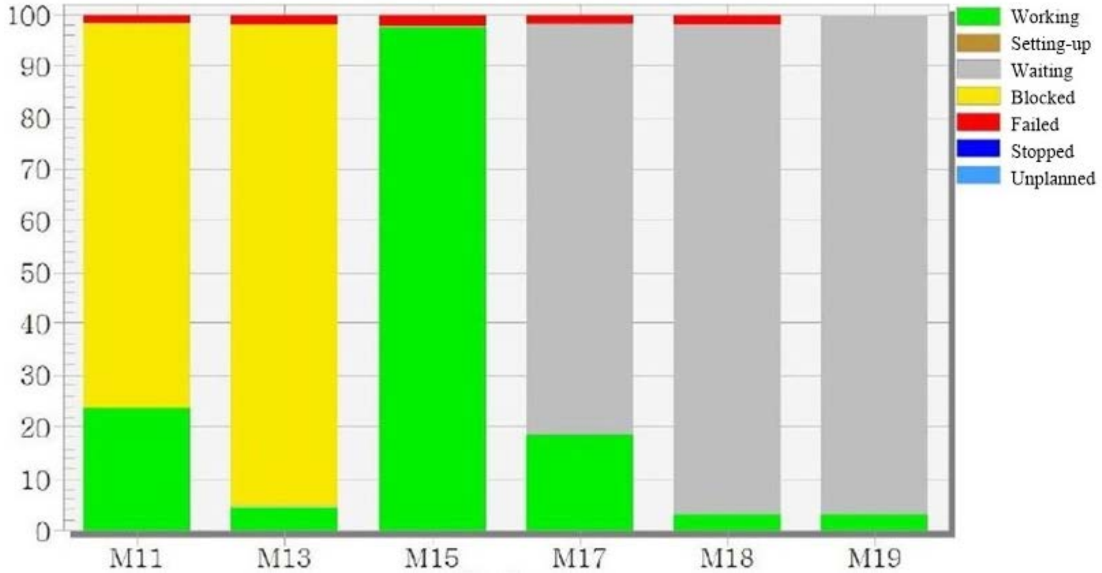


Figure 3.16 Data Statistics

According to the information statistics table and the station analysis diagram, the processing time of M15 (five-axis processing) in the entire production cycle reached 97.86%, positioning M15 as the bottleneck process, which seriously affected the balance of the workshop processing process, resulting in product processing During the process, lathe processing (Mil) and three-axis processing (M13) were seriously blocked, and the detection area (M17), coding (M18), marking and packaging (M19) were severely waiting, and the working hours of six workstations could be found Serious imbalances have appeared, reducing product processing efficiency and export output.

3.6.2 Balance analysis of workshop in impeller processing workshop

In the process of dividing the production process, the division of time for each process cannot be completely equal. If the process time difference is too large, it will lead to product accumulation and congestion in the production and processing, thereby affecting the balance of the workshop. Workshop balance refers to the analysis of the time load of the processing process. By locating the bottleneck process, the time load between each process is adjusted to achieve the balance of production capacity, so that the process time of each workstation is as equal as possible, so as to reduce the waste of time and the blocking of the workpiece. In order to improve the overall efficiency of the workshop, in order to calculate the balance rate of the impeller processing workshop to judge the balance of the workshop, the following concepts need to be introduced:

(1) Production beat

Production cycle refers to the interval time between continuous production of two identical products under normal production conditions. Its calculation formula is:

$$CT = \frac{Tw}{Q} \quad (3.19)$$

Where *Tw* refers to the effective processing time in the production cycle, and *Q* refers to the planned output。

(2) Bottleneck process

The bottleneck process refers to the process with the longest processing time in the product processing. The bottleneck process is the most direct factor that affects the production efficiency of the workshop. It not only affects the output speed and accumulation of materials, but also affects the production capacity of other processes, which is a balance optimization The most critical place in the world.

(3)Total process time

The total process time refers to the total time of product processing from the first process to the end of the last process. The calculation formula is:

$$T = \sum_{i=1}^{n} Ti \tag{3.20}$$

Where *Ti* represents the time consumed in step *i*.

The balance rate of the workshop is determined by the total process time, the number of workstations, and the bottleneck process time. The formula is：

$$B = \frac{\sum_{i=1}^{n} Ti}{N \times max(Ti)} \times 100\% \tag{3.21}$$

Among them, *Ti* represents the time consumed by process i in the workshop, *N* represents the total number of workstations, and *B* represents the balance rate.

By substituting the number of known data workstations=6, bottleneck process time=*51.3 5min*, total task time=*79.5min*, finally get the balance rate *B=31.8%*.

According to the above data, it can be seen that the balance rate of the workshop is too low, which directly affects the production efficiency and product output of the workshop. Based on the above analysis combined with the actual operation of the workshop, the problems existing in the workshop are summarized:

(1) The lack of a temporary storage area in the workshop leads to a long waiting time for processing of some products, which causes the accumulation of products and causes blockage;

(2) The processing procedures of the workshop are improperly divided, and the designated processing equipment of individual procedures does not match, resulting in excessive processing tempo and reduced cycle output;

(3) The excessive number of workstations on the workshop leads to large differences in processing time during the production process, which affects the balance of the workshop;

3.6.2 Workshop optimization goal of impeller processing workshop

Combining with the problems of the above workshop, it is necessary to reallocate the limited process to each workstation, and under the premise of meeting the production process sequence, make the number of workstations occupied at least, and meet the time of each workstation as balanced as possible, and at the same time make the production quantity meet The expected value in the cycle is 600, and the time consumed by the bottleneck process and production cycle is reduced.

3.7 Simulation verification and result analysis of the workshop of the impeller processing workshop

3.7.1 Simulation ideas

The effective working time of the impeller processing workshop is 10 hours per day. The number of impeller processing is expected to reach 600 or more per month. According to the actual requirements of the workshop and combined with the optimization goals of the workshop, the following simulation ideas are formulated:

(1) According to the processing route, plan the immediately preceding process of each process to redistribute the process of each workstation; the specific data is shown in Table 3.11.

(2) Generate the initial coding sequence through the form of chromosome coding, and then judge the rationality by calling the code;

(3) Use genetic algorithms to generate offspring through operations such as crossover and mutation, and assign processes to corresponding workstations. The allocation rule is to first assign tasks with more follow-up work;

(4) Properly allocate workstations and evaluate the suitability of the workshop, and store the best code in a preferred way.

Table 3.11 Statistics of each process

Task	Time(s)	Illustrate	Process
1	90	Robot feeding	/
2	625	Rough machining of the outer contour of the impeller	1
3	150	The robot flips the material	2
4	376	Finishing of the outer contour of the	2,3
5	134	Hole processing	2,4
6	120	Robot transfer materials	5
7	1520	Rough machining of impeller runner	2,4,6
8	90	Robot transfer materials	7
9	1699	Impeller finishing	8
10	600	Quality Inspection	7,9
11	200	Impeller coding	/
12	172	Impeller marking and packaging	9
13	173	Robot handling and storage	7,9,11,12

3.7.2 Simulation modeling steps

(1) Set up genetic algorithm optimization tools “GAOptimization”

The advantage of this tool is that it can implement custom algorithm nesting. Set it, where the genetic algebra is 100 and the number of generations is 10, then select the genetic algorithm control script "evaluate" to evaluate the sequence of the process, and "termination" controls its end.

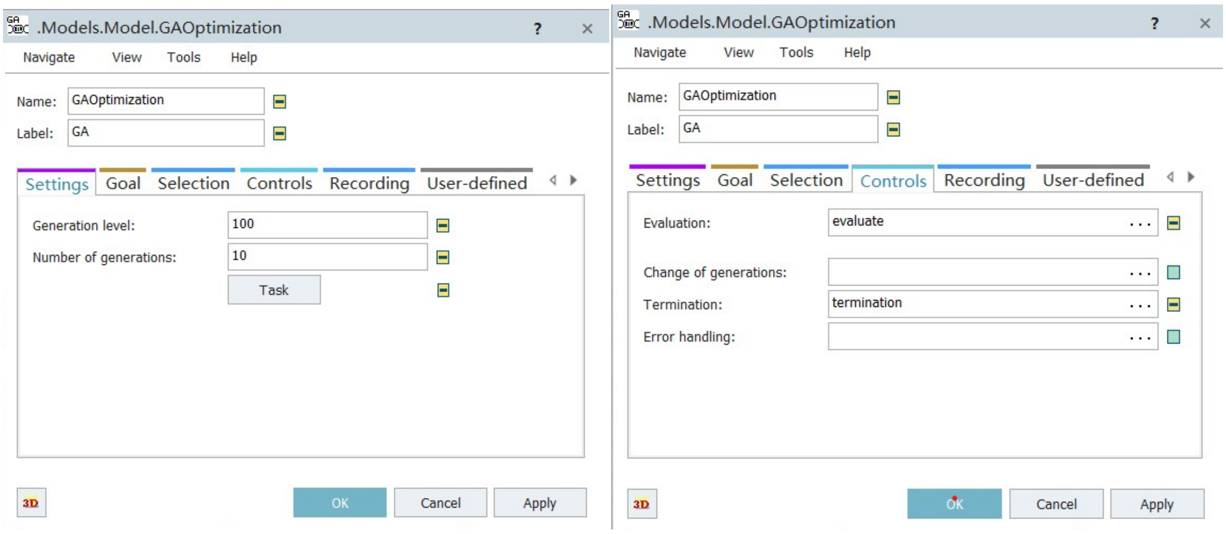


Figure 3.17 Genetic algorithm settings

（1）Processing procedure code

Count the processing time of each process in the form of a table, the unit is second, there are a total of 13 processes, and each serial number corresponds to each process. Then the statistics of the immediately preceding process of each process are listed in Table (a) after the process.

	integer 1	integer 2	table 3	integer 4	integer 5	integer 6
string	Job	Time	Precede	Ori	Opt	Station
1	1	90	A	1		
2	2	625	A	2		
3	3	150	A	3		
4	4	376	A	4		
5	5	134	A	5		
6	6	120	A	6		
7	7	1520	A	7		
8	8	90	A	8		
9	9	1699	A	9		
10	11	600	A	11		
11	12	200	A	12		
12	10	172	A	10		
13	13	173	A	13		

(a) Process initial coding

	integer 1
1	2
2	3
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

(b）Immediate process

Figure 3.18 Process code

（2）Code implementation process

By writing the code, the correctness detection and evaluation of the initial coding of the processing procedure is realized first, and then the immediately preceding and immediately following procedures are judged and the tasks arranged in advance in the coding are exchanged and adjusted. The offspring produced by the crossover and mutation of the genetic algorithm are checked for rationality, and then the best code is selected and stored in the table through the station allocation and fitness evaluation.

3.7.3 Result verification and analysis

Click to start optimization. After genetic algorithm allocation, it is finally optimized into 4 workstations. The processes allocated by each workstation are recorded in the "ProStation", and the optimal process allocation obtained is recorded in the "BestSolution" table. According to the genetic operation, the final optimization result is that 1-6 procedures are allocated to workstation 1; 7-9 procedures are allocated to workstation 2; 10 procedures are allocated to workstation 3, and 11-13 procedures are allocated to workstation 4.

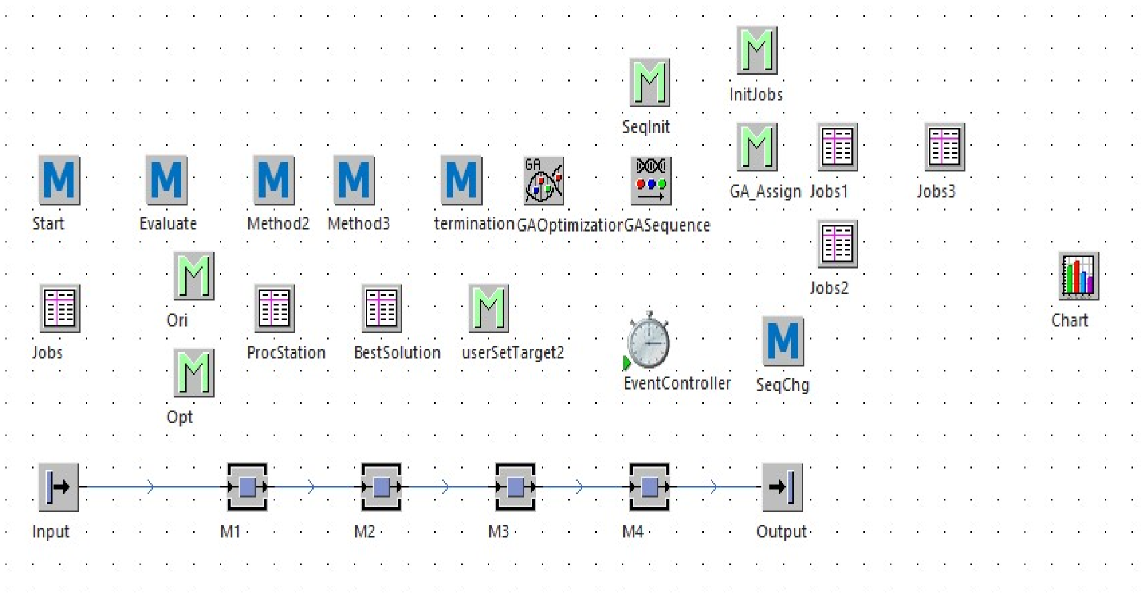


Figure 3.19 Optimal workstation allocation

	integer 1	integer 2	table 3	integer 4	integer 5	integer 6
string	Job	Time	Precede	Ori	Opt	Station
1	1	90	A	1	1	1
2	2	625	A	2	2	1
3	3	150	A	3	3	1
4	4	376	A	4	4	1
5	5	134	A	5	5	1
6	6	120	A	6	6	1
7	7	1520	A	7	7	2
8	8	90	A	8	8	2
9	9	1699	A	9	9	3
10	11	600	A	11	10	4
11	12	200	A	12	11	4
12	10	172	A	10	12	4
13	13	173	A	13	13	4

	integer 1	integer 2
string	Machine	Time
1	1	1495
2	2	1610
3	3	1699
4	4	1145

Figure 3.20 Process code

Based on the above optimization results, it can be found that after the optimization, the original process has been rearranged and the original processing process has been adjusted as follows: 1. The lathe processing and the hole processing of the three-axis machining center are combined on the lathe; , Split the rough and fine machining of the five-axis machining, perform the rough machining of the runner on the three-axis machining center, and perform the subsequent finishing of the impeller on the five-axis machining center; 3. Add before the five-axis machining center and the three-axis machining center Two temporary storage areas are combined with inspection, coding, marking and packaging workstations; after optimization, 4 workstations are obtained, and the time allocation of each workstation is obtained, and based on the above data, it is substituted into the workshop for operation.

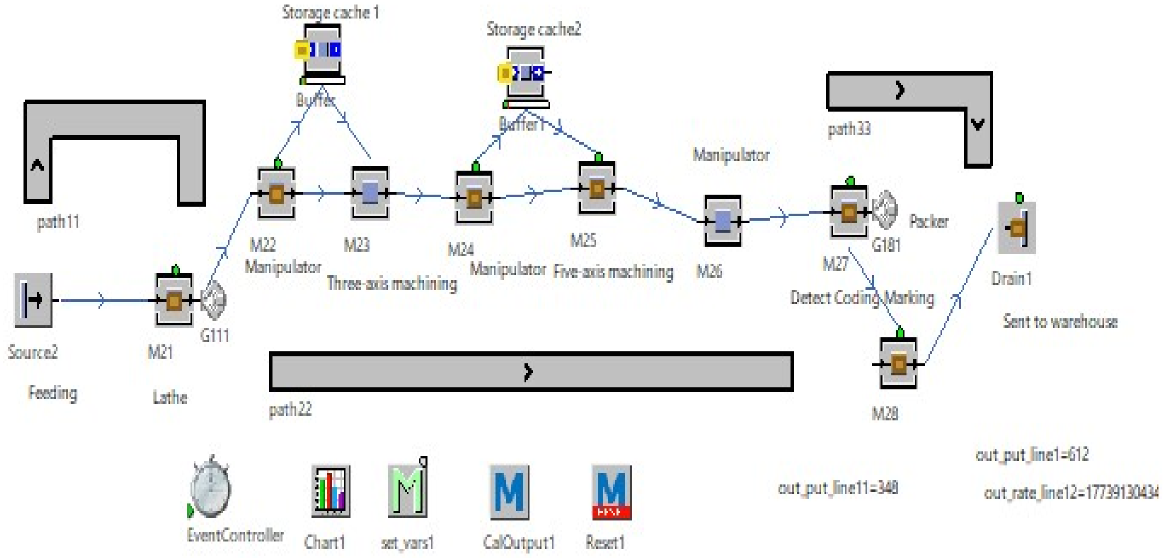


Figure 3.21 Balance optimization results

3.8 Comparative analysis before and after optimization

Through the simulation results obtained, the relevant data before and after optimization can be compared, and it can be clearly found that not only the output has reached the expected target after optimization, but the blockage in the working process has been greatly improved. The number of contrast workstations has been optimized from the original 6 to 4, and the working time balance has been greatly improved during the production process. Through calculation, the production cycle was reduced from the original 51.35min to 30.59min. Comparing the blockage of each workstation, it can be found that the blockage of the two workstations 1 and 2 has been significantly improved after the optimization, which can be found by comparing the balance rate of the workshop. The balance rate has been increased from 31.8% to 65.0%, and the goal of optimization has been achieved overall, thereby improving production efficiency.

M11	23.67%	0.00%	74.60%	1.73%	0.00%	0.00%	0.00%	0.00%	0.0000	
M13	4.38%	0.27%	93.24%	2.12%	0.00%	0.00%	0.00%	0.27%	0.0000	
M15	97.60%	0.12%	0.01%	2.28%	0.00%	0.00%	0.00%	0.12%	0.0000	
M17	18.59%	79.46%	0.03%	1.92%	0.00%	0.00%	0.00%	79.46%	0.0000	
M18	3.10%	94.93%	0.00%	1.97%	0.00%	0.00%	0.00%	94.93%	0.0000	
M19	3.10%	96.90%	0.00%	0.00%	0.00%	0.00%	0.00%	96.90%	0.0000	

Figure 3.22 Workstation production situation after optimization

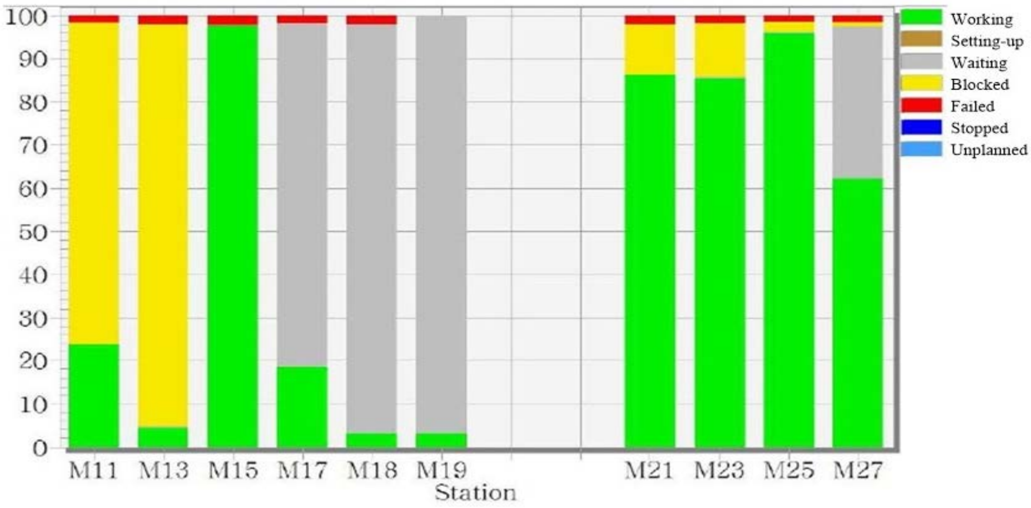


Figure 3.23 Comparison before and after optimization

Table 3.12 Balance before and after optimization

Name	Before optimization	Optimized
Beat	51.35mm	30.59mm
Number of workstations	6	4
Balance rate	31.8%	65.0%

In summary, by analyzing the problems existing in the impeller processing workshop, the optimization goal was formulated, and finally through modeling and simulation and verification, the results showed that the optimized cycle time was saved by 20.76 minutes compared with the cycle time before optimization, and the number of workstations was reduced from that before optimization. The 6 of them have been changed to 4, and the balance rate has been increased from 31.8% before optimization to 65.0%. The results prove that all indicators of the optimized workshop have been significantly improved, and the optimization goal has been achieved.

Conclusions

This section uses Plant Simulation software to analyze the layout of the workshop, finds problems through operating data analysis, finds specific problems in the workshop, and formulates corresponding optimization goals and optimization plans based on related problems in the workshop, and combines the optimization plan to simulate the layout through modeling and simulation. Optimize and verify, and finally meet the goal of workshop layout optimization.

SECTION 4

4.1 Description of the project idea

The genetic algorithms can better solve the problems in the layout of the workshop. The review of the workshop layout optimization field in the first part of the master's thesis shows that in production and application, reasonable planning of the workshop layout can improve the production efficiency of the enterprise and enhance the competitiveness of the enterprise. Description of the idea of startup - project is given in Table 4.1

Table 4. 1 - Description of the idea of a startup project

Content of the idea	Areas of application	User Benefits
Optimize workshop layout through genetic algorithm – systems	1.Production sector	Increase in production,reducing design and production time, reducing the cost of production, scaling workshops,improving environmental friendliness, etc.
	2. Services	Expansion of the scope of activity,management of development strategies, improving the quality of service, introduction of new technologies, etc.

Considering the existing market for optimized workshop layout, we can conclude that there is currently no competitive proposal for introducing genetic algorithms into the production process. At the same time, if there are further developments and new competitive proposals, it is still necessary to highlight the shortcomings and advantages of the proposed proposals in order to choose the right strategy for working in the chosen field. Let us define the list - technical economic properties and characteristics, based on the model “Porter's 5 Forces”:

– the amount of investments - the cost of introducing “GA-system” into the production process, in general, is high, due to the significant need for material and intangible resources;

- fixed costs - in general, are also quite significant, because licensed versions of multifunctional products have a high cost, but at the same time are able to cover a significant number of industries;
- variable costs - are quite insignificant and include modifications of digital equipment or additional equipment of the software product with applications to expand technological capabilities;
- reliability - is high and is provided by direct communication with the software provider and quick solution of errors in the system. Digital equipment is also marked by a significant period of uptime;
- manufacturability - for the software product is high and increases with the development of technology, thanks to direct communication with the manufacturer, which provides customers with the supply of updates to the existing system. For digital equipment used in the process of digitization of production processes, manufacturability is a critical factor, because the relentless process of development of the computer means that the newly purchased equipment becomes obsolete in a short time. The impact of this factor is somewhat smoothed out by the long term support for existing equipment by software suppliers;
- ergonomics is also a critical factor in the provision of Genetic Algorithms, because it requires a large-scale campaign to train staff, because it often requires complex algorithms to properly collect and archive data;
- profitability - is high, because it does not require significant material resources. At the same time, significant human resources and long-term training are needed for the right choice, application and further work with the the implemented genetic algorithm to optimize the layout of the workshop;

4.2 Technological audit of the project idea

If we distinguish from the concept of "implementation of GA - system", the task of creating a "digital twin" or conducting simulation of processes related to production, you can reduce the process of technological audit of the project idea and distinguish the means of implementing the project idea. Technological audit of the project idea is given in Table 4.2.

Table 4.2 - Technological audit of project ideas

No	Project idea	Technologies of its implementation	Availability of technology	Availability of technologies
1	Production process simulation study	Application of GA-system,namely systems Genetic Algorithms - for research and optimization of production processes	There are a large number of systems for modeling and researching the production-processes of different industries ofproduction and-non-production of other spheres	Nearly allprog-bound appshave costlessstudent licenses,which have-somewhat truncated functionality
2	Implement their-programs for-themselves-mement about-thisprojection andproduction thanks to GA-system	Select and customize favorites GA - system for unique you customer's help	There is a wide range of GA systems that can be integrableto-existing Plant Simulation systems	In general, they are not suitable for non-professional users because they have reached their full potential. Only in a wide range of systems integrated with other software products

4.3 Analysis of market opportunities

To create a successful product, the availability of service requirements must be determined in advance, and these services will be executed as part of the creative implementation of the startup project. At the same time, it must be understood that lack of competition does not mean 100% success of the created project, but complete failure because the created idea is irrelevant. In order to consider risks, threats and evaluate the market environment, it is necessary to conduct a demand analysis (Table 4.3).

Table 4.3 Startup Demand Analysis - Project

№	Market condition indicator	Characteristic
1	Market dynamics	Stagnant
2	Existence of restrictions for an entrance	General stagnation of economy and production sphere, lack of experience in simulation modeling and implementation of Genetic algorithm for various industries, general conservativeism and distrust of modern means of modeling and research
3	Specific certification requirements	The use of genetic algorithms can improve production efficiency more efficiently on the basis of the original workshop layout. The certification needs to be certified according to the national standards before the activities of these products can be carried out in the country. It is best to obtain the official representative of the company-Software Obtain the certificate from the manufacturer

Having considered the results of the demand analysis, we can conclude that the implementation of the project on the basis of existing software products is quite complex and expensive. To get a positive result from the implementation of the startup project, it is necessary to develop a unique technology for the use of existing GA systems, taking into account the realities of the existing market. The next step is to identify potential customer groups and indicative requirements for the provision of services (Table 4.4).

Table 4.4 - Identify potential customer groups

No	The need that shapes the market	Target audience	Differences in the behavior of different potential target customer groups	Consumer requirements for the product
1	The need for optimism about existing production-pros andthe oppression of property showsinthe company Detailed management and tracking of design, production and logistics are required.	Outdated products that require modernization and new subprisingsat the designstage Companies using modern technology Genetic algorithm can better integrate the use of plant simulation software, and better improve production efficiency	Research on simulated scale problems, that is, all processes in the enterprise or various departments and businesses that determine the final cost of the service provided by this research The behavior of potential target groups is affected by the material factors of the service provided, which depends on the quality and quantity of available material and intangible resources, the implementation scale of GA system optimization, and the cost of licensed services.	Completeness of conducting research, ie taking into account all important factors. At the same time, the expediency of detailing the model is substantiated, which requires additional costs. Adequacy and clarity of the received The key requirements are the reliability and correctness of the software, the availability of support, and the speed of response to system errors

After determining the potential customer base, it is necessary to evaluate the market environment to facilitate the implementation of the project idea. To this end, we determine possible threat factors (Table 4.4) project implementation and opportunity factors (Table 4.5).

Table 4.5- Risk factors that impede the project implementation

No	Factor	Content of the threat	Possible reaction of the company
1	The decline ofthe production industry	In the absence of interest in the development of the production sector, the sense of implementation of GA-systems	Curtailment of activities to reduce losses or complete re-profiling of work areas
2	High costper touch of technologic	The full-scale implementation of GA-the system in the processes that occur in enterprises is very costly measure, with investments notone-time, because license support is a paid service	Consider the feasibility of full implementation and find the best solution for each customer. Demonstration of research details under simulated conditions
3	A skeptical attitude towards research using digital technologies	Lack of data,GA implementation experience-Competing companies' systems and general distrust of the use of simulation methods, especially in the layout of outdated companies	Deployment of a marketing company, which will include information on the experience of implementing GA -systems and methodology for simulation modeling at foreign and domestic enterprises.
4	Insufficient experience in modeling various production configurations or implementing GA-systems	Due to the limited implementation of GA technology in the domestic market, each new project requires a unique approach, which will lead to an increase in service delivery time.	Using the experience of foreign companies,search for analogues and similar factors that will allow to apply the experience of other projects

5	Marketing and management mistakes	As the project is a pioneer in the domestic market, there is a high risk of making wrong decisions in organizational and financial matters product promotion and development strategy	In the initial stages of implementing the idea of a startup project, it is necessary to involve experts on work organization, work with clients, work with staff, etc. Due to this it is possible to develop an algorithm for further work that can be implemented without the involvement of advisers from various fields

The opportunity factor to start the project must be more important or equal than the threat factor.

Table 4.6 -Opportunity Factors

No	Factor	Content of the feature	Possible reaction of the company
1	Need to modernize outdated production facilities	The domestic modern manufacturing industry is a backward enterprise, a modern production complex constructed in accordance with foreign models. Optimization is crucial to the competitiveness of domestic products in the world market	To simulate the production process of various scales and develop the service proposal to optimize the steps to achieve the required indicators
2	The necessity of product life cycle management	Almost all global companies in production and non-production fields use various GA systems to organize processes. Therefore, in order to be able to work together on projects, domestic companies must implement the principles of data and product lifecycle management.	Prepare for the implementation of the GA system and integration into the Plant Simulation software already in use
3	The necessity of implementing international quality standards in existing production processes	Product quality standards require that each product has a traceable system product life cycle stage, from the design stage to the end of the design stage. This method can only be implemented by introducing the GA system	It is emphasized that all companies with international ISO quality certificates must implement the QMS concept as one of the functions of the GA system.

Due to the lack of such suggestions in the domestic market, it is impossible to conduct various competitive analyses to determine competitiveness factors. Taking into account the international market, we concluded that the supply market is saturated, and each offer depends on 88 software manufacturers for implementation and research. In other words, competition is between companies and software product manufacturers, not between representatives of these products.

The final stage of market analysis of project implementation opportunities is a study by SWOT – analysis[28], which is the creation of a matrix of strengths and weaknesses, as well as threats and opportunities (Table 4.7).

Table 4.7 - SWOT - startup analysis - project

Strengths: Implementation of modern technologies in the global trend of technology "Industry 4.0"	Weaknesses: Lack of experience in implementing technologies in multifactorial production processes and taking into account the characteristics of domestic enterprisesdomestic enterprises
Opportunities: In a stable economic situation there is a wide market of potential customers, due to the general obsolescence of the domestic manufacturing industry	Threats: Skepticism about the introduction and research by means of modern technologies of domestic enterprises, as well as the general stagnation of the manufacturing sector

Based on SWOT analysis, an alternative to market behavior strategy for successfully launching projects in the market was determined. In order to determine the approximate time for market implementation of alternative strategies, it is necessary to rely on the available recommendations of potential competitors that can be brought to the market. The alternative way to implement the idea of starting the project in the considered case is to use other types of software that differ in functionality, licensing services, available resource requirements, terms of service, etc.

4.4 Development of the project market strategy

The initial stage of developing a market strategy for the project is a description of the target groups of potential consumers (Table 4.8).

Table 4.8 - Description of target consumer groups

No.	Description of the target group of potential customers	Readiness of consumers to accept the product	Targeted demand within the target group	Intensity of competition in the segment	The level of complexity and entry into the segment
1	Enterprises that need to optimize existing production capacity	Low, due to lack of experience in implementing similar enterprises	Low	Low	High
2	Production complexes that are at the design stage and need to forecast resource needs and performance indicators	Medium or high, because new enterprises are built with regard to energy efficiency and feasibility of investment, which can be predicted through a simulation model.	Medium	Low	High
3	Businesses that need to manage the life cycle of a product that is produced as part of the production process	Medium or low, due to the lack of resources required to use the GA system, a large amount of capital investment is required	Low	Low	High

So, after describing the target groups of consumers, we choose a strategy of differentiated marketing, which means working with several groups of potential consumers, developing a strategy for each of the groups. The next step is to define a basic development strategy for each consumer group. Using the guidelines [28] set:

- specialization strategy as a basic development strategy, which means
- concentrating and meeting the needs of only a selected market segment, without intending to cover the entire market. This usually means low
- competitiveness of the company, however in our case of the unique offer in the market, this problem at present is not critical.
- Along with the development strategy, it is necessary to choose a strategy of competitive behavior for the future conditions of a competitive market. Using the guidelines [28], set:
- the strategy of occupying a competitive niche as a strategy of competitive behavior of the company, which means choosing and working in a narrow niche market and is derived from the strategy of specialization as a basic development strategy.

Having determined the basic strategy of development and competitive behavior, we determine the positioning strategy (Table 4.9) according to the guidelines [29].

Table 4.9 - Feature positioning strategy

Micro	Positioning level
Product type positioning	The object relative to which the positioning is taking place
Strategy	Relation to brands -competitors
Brand Expert	Placement in the product category
New independent brand	Placement relative to existing brands on the market

According to the tangible attributes of branded goods	The type of product properties on which the positioning is based
Multi-dimensional positioning	Number of selected positions
Independent positioning	Staged positioning
Independent positioning	Relation to the existing market position

The analysis allows to distinguish eight main classes of market positioning strategies. The used classification, taken from the methodical guidelines [29], allows the company to form a system of market positioning strategies aimed at increasing the competitive advantages of the company. A systematic vision of the concept of the company's behavior during the individualization of its brand and brand creation allows achieving the greatest efficiency and positive result of launching a startup project, having developed a system of solutions for market behavior.Development of a marketing program for a startup project

The initial stage is the formation of a marketing concept of the product, which will be presented to the consumer (Table 4.10).

Table 4.10- Identify the key benefits of the concept of a potential product

No	Need	The benefits offered by the product	Key advantages over competitors
1	Optimization of existing production capacity	Increased productivity of existing resourcessat down	The uniqueness ofthe offer of anew service to the-imitation process

2	Predicting the behavior of the future production process	Development of algorithms for future production, forecasting resource needs and efficiency indicators	Use of software that is the market leader in discrete event simulation tools
3	The need for step-by-step control of the product life cycle	Providing process management technologies within the enterprise, from the design process to the disposal process	Flexible technology for implementing GA systems-a product that can take into account the level of detail required and the coverage of the entire enterprise processthe enterprise

The next stage is the development of a three-level marketing model of the product, which takes into account the idea of the service, its physical components and features of the service. To do this, take into account the results of a preliminary analysis of the competitiveness of the product (Table 4.11)

Table 4.11 - Description of three levels of the service model

Product Levels	Entity and Components
I. Service as planned	Basic consumer needs: Optimization of existing production processes, forecasting of future production capacities, product life cycle management. The main functional benefit: increasing the profitability of production profitability
II.Service in real performance	1. The results of simulation research 2. Visualization 3. Develop steps to increase efficiency 4. Forecasts of resource needs and performance indicators 5. Ready-made product life cycle management system based on GA-system
III. Reinforced service	An advertising campaign that includes information about the experience of using solutions offered by other companies of various scales Scale
Due to which the potential product will be protected from copying:	Design of know-how

It is impossible to determine the limits of the set prices, because there are no competitive offers in the market of services, and the final price of services includes many factors, such as scale, level of detail, availability of additional services and so on. This is followed by the definition of the optimal sales system, which determines the following components of the system:

- sales options - sales on their own or with the involvement of intermediaries;
- selection of the optimal depth of the sales channel;
- choice of type of mediation.

The formation of the sales system is shown in Table 4.12.

Table 4.12 - Definition of sales system

No.	The specificsof the 100-year-old'seye-watering business	Sales features that the supplier ofgoodsshould perform	Sales Channel Depth	Optimal sales system
1	It iscarried out on the frontorder for the provision of services, after which the customer develops theproject's technical equipment, discussesthe masses-and detailsof the provision of services	The supplier should properly assess thetying and feasibility of carrying out certain works and provide the ordered final costof providing services	Zero-level channel	Sell your own Forces

The last component of the marketing program is the creation of the concept of marketing communications, which is associated with a predetermined positioning strategy, as well as the specifics of customer behavior (Table 4.12). The result of the point of development of the marketing program of the startup project is to become a management program that includes the concept of service, sales methods, advertising campaign tools and forecasting of pricing opportunities based on the requirements and needs of potential customers, competitive advantages, market condition and dynamics services within which the project.

Table 4.13 - Marketing communications system

No	The specifics of the behavior of target customers	Communication channels used by target customers	Key positions selected for positioning	The task of the advertising message	The concept of advertising appeal
1	General distrust and skepticism about the effectiveness of the introduction of GA - systems and simulation in the realities of the domestic manufacturing industry industry	Advertising on industry resources and activities recommendedby the players market,party nerity, corporate channels	Uniqueness and efficiency of the offered services, individual approach, long-term support	Reporting information on the effectiveness of technology implementation, which is confirmed by the experience of other companies	Promoting the characteristics of the offered services, such as exclusivity within the market environment, individual approach and high efficiency

Marketing communications combine all elements of business process implementation when launching a startup project - from an advertising campaign to packaging. Promote the receipt of mutually agreed and convincing marketing appeals to the target audience, which should most effectively contribute to the achievement of the goals of service providers in a market environment.

Conclusions

During the implementation of the fourth section of the master's dissertation, which is a stage of development of a startup project, the following studies of the future project were performed:

- description of the project idea, with the disclosure of the content of the idea, possible areas of service, highlighting the strengths and weaknesses of the idea of a startup project, both for the supplier, in our case the service, and for consumers;
- technological audit of the project idea, with the selection of key proposals within the startup - project, determining the availability and availability of technological means to provide services to the founders of the project;
- analysis of market opportunities, which includes analysis of demand for a startup project, identification of potential consumer groups, identification of threat factors for product entry into the market and factors of project implementation opportunities, as well as SWOT - analysis of future services;
- development of the market strategy of the project, which includes the definition of the basic strategy of the company's development, competitive behavior and product positioning within the market environment;
- development of the marketing component of the project, which contains the definition of key benefits of the future product, a description of the service model, the choice of sales system and the establishment of a marketing communications system. Considering the data obtained during the research, we can conclude that

That a startup project has the prospects of market commercialization, due to the presence of market demand caused by the realities of the domestic manufacturing industry. At the same time, the market in which the startup project is planned to be implemented is in a state of stagnation due to general economic problems, but the proposed product has the potential for high profitability in the market. Looking at groups of potential customers, we determine that the demand for services within the startup project is medium or low, due to general skepticism about the use of modern digital technologies in the domestic market. The barrier to market entry is high, due to possible insufficient demand, limited trading practices, irreversible costs, but these factors are somewhat offset by the lack of similar offers in the market, and therefore low competition in the market and high competitiveness of the proposed product. Alternative options for project development are entry into other sectors of the production sector, such as agriculture and the oil and fuel industry, which are in better economic condition, and therefore can provide a stable demand for the services offered. Further implementation of the project is appropriate if we consider the use of simulation and implementation of GA - systems not only in mechanical engineering, but also in other industries.

GENERAL CONCLUSIONS

As an important part of the mechanical manufacturing field, the layout of the workshop has always been the focus and research content of many scholars, and it is also an important method for many enterprises to apply and promote. Research shows that a reasonable layout of workshop workshops can help companies effectively reduce production costs and improve production efficiency. This paper applies the relevant theories and methods of facility layout to the optimization of the company's workshop layout. Through the analysis of the production process and layout of the centrifugal compressor impeller workshop, it finds out the current facility layout problems. Plant Simulation is the main simulation platform. By simulating and optimizing the facility layout, material handling, processing and production processes in the impeller processing workshop, the production efficiency of the impeller processing workshop is effectively improved and the purpose of reducing research and development costs is achieved. The main work content is as follows:

(1) Briefly introduced the research background of the workshop layout and the current development research status of the workshop layout, summarized the significance of the research on optimizing the layout of the workshop workshop, and summarized the research content and the development of the research system framework.

(2) Introduced the main form of workshop layout and the key technology and research route of workshop workshop layout. A brief introduction to the function and application of simulation related software is also given. Using CATIA for virtual processing simulation, the impeller processing process plan was formulated in combination with the impeller processing requirements and actual production conditions, and the processing flow and production requirements of the impeller workshop processing workshop were analyzed, and the workshop hardware equipment plan and overall structure were determined.

(3) Combining the construction requirements of the impeller workshop processing workshop and the actual situation, the layout plan of the workshop was formulated, and the preliminary layout drawing of the workshop was obtained by using the SLP method

according to the relevant data. The genetic algorithm is used to optimize the layout of the workshop facilities, and PlantSimulation is used to optimize the layout of the workshop. Through comparative analysis, the optimal layout of the impeller processing workshop is obtained.

(4) Use PlantSimulation to simulate the impeller processing process. Through the workshop capacity analysis, balance analysis, bottleneck identification and other operations, the workshop is balanced and optimized based on genetic algorithm and combined with lean production, and optimization goals are set, and finally verified by simulation. The optimized plan was obtained, the optimized result was obtained and the balance rate of the workshop was improved, and the production target was achieved.

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