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Research on the Application of AGV Scheduling Strategy in Improving the Efficiency of Intelligent Manufacturing of Vehicle Parts

Xiao-Bo Dong[1,2], Xiang-Yun Yi[1*], Zhi Zhang[1]

[1] Department of mechanical engineering, Hebei Institute of Mechanical and Electrical Technology, Xingtai City 054000, Hebei Province, China

{xiaobo9832, xiangyun7987, zhang_zhi5278}@163.com

[2] Xingtai Metal Processing Equipment Intelligent Integration and Diagnosis Technology Innovation Center, Xingtai City 054000, Hebei Province, China

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Abstract. With the development of intelligent manufacturing and the upgrading of industrial structure, all industries are facing the transformation and upgrading towards refined and efficient production models. This article takes engine piston and connecting rod as the research object. Firstly, the production process of piston and connecting rod is analyzed, and then the corresponding processing equipment is listed. Then, the layout design of the piston and connecting rod workshop is completed according to the layout standards of the intelligent workshop; Secondly, the transportation problem of engine piston connecting rods between storage units and various processing units during the production process was further analyzed. The scheduling strategy under multiple AGV modes was studied, and an optimization model was established with the lowest comprehensive cost of time and distance. Finally, an improved genetic algorithm was used to solve the model parameters. The simulation experiment results show that the proposed method can improve production efficiency by 7.5%.

Keywords: AGV, intelligent manufacturing, scheduling strategy, genetic algorithm

1 Introduction

With the continuous development of intelligent manufacturing and the continuous improvement of manufacturing level, various industries have achieved significant growth in production scale and efficiency, which has also led to overcapacity in certain products. With the proposal of the “supply side” reform slogan, the domestic market is gradually segmented, the industrial structure is gradually improved and upgraded, and customers entrust customized product orders to enterprises for production. Therefore, the constantly developing demand for personalized customization is gradually changing the traditional manufacturing production mode. In this context, the country has proposed and vigorously promoted the implementation of the “Made in China 2025” strategy, and intelligent manufacturing has flourished in various industries [1]. For a large number of domestic mechanical manufacturing enterprises, adding intelligent manufacturing production lines on the basis of existing production processes to replace the discrete production mode dominated by single equipment has become an inevitable choice for digital transformation and upgrading of manufacturing enterprises [2].

Through the continuous accumulation of production technology and experience, current intelligent manufacturing enterprises generally have the following labels: intelligent manufacturing equipment, intelligent design process, excellent processing technology, informationized management, and agile and remote services. With the continuous growth of technological means, the deeper understanding of “intelligent manufacturing” has also deepened, that is, the deep integration of advanced manufacturing technology with new generation information technology, new generation artificial intelligence and other new technologies, forming new production methods and manufacturing technologies [3].

This article is based on the intelligent manufacturing process of the core component piston connecting rod of the engine, with the production and processing object being the engine crankshaft. Firstly, in terms of production equipment layout, innovative intelligent layout design is adopted to meet production needs. The complete design process mainly includes functional analysis, scheme design, simulation and debugging, etc. Then, advanced tech-

* Corresponding Author

nologies such as the Internet of Things, intelligent control, and industrial robots are integrated into the control and management system level [4].

In the traditional manufacturing industry, the transportation devices used in the production workshop are generally conveyor belts, forklifts, and even manual handling. These transportation devices and methods will occupy the space of the production workshop, as well as human resources in production. These space and labor costs will affect the enterprise's goal of achieving high efficiency and low cost. Therefore, intelligent manufacturing workshops without exception consider using AGVs for transportation. Therefore, this article focuses on the AGV scheduling strategy in the crankshaft production process, aiming to improve the flow efficiency between various processing modules, and minimize production costs, time, and power consumption under the premise of single and multiple AGVs.

Therefore, the work done in this article is as follows:

1) Firstly, the production process of engine piston connecting rods was analyzed, and then the production layout of the manufacturing workshop was designed based on the production process to minimize the cost of workpiece transportation and facilitate the operation of AGVs.

2) For the production scheduling problem, this article considers the premise of single and multiple AGVs running, with the goal of minimizing the comprehensive cost of total running distance and total running time, establishes an optimization model, and then performs optimization solution.

3) Finally, establish a simulation environment and use experimental simulation to validate the method proposed in this paper.

The chapter arrangement is as follows: Chapter 2 mainly lists the relevant research results, providing ideas and references for the development of this study; Chapter 3 discusses the layout design of intelligent manufacturing workshops; Chapter 4 analyzes the AGV scheduling strategy; In Chapter 5, a simulation environment was established for the workshop design scheme and scheduling strategy proposed in this article, and simulation experiments were conducted.

2 Related Research

In many application scenarios, relevant research has been conducted on AGV scheduling problems. This chapter compares and analyzes the research achievements of various scholars, and then determines the research direction of this article.

Jie Yang constructed an environmental model for the intelligent manufacturing and warehousing process, using two different conflict resolution models to plan collision free paths for multiple AGVs in the sorting warehouse area, thereby improving the production efficiency of the entire workshop [5].

Huiquan Yu aimed to optimize the idle time and vacancy rate of AGVs for completing tasks, and improved the Q-learning algorithm to generate multi AGV conflict free paths, ultimately achieving multi AGV path optimization [6].

Regarding the issue of energy conservation and emission reduction in intelligent manufacturing workshops, Yaming Guo aims to improve production efficiency by optimizing the energy-saving path planning strategy for a single AGV in the manufacturing workshop, with the goal of minimizing transportation distance and energy consumption [7].

Junlan Li takes transportation distance and energy consumption as optimization goals for AGV multi task transportation. Reasonably arranging the sequence and planning transportation paths for AGV multi task transportation can improve AGV energy efficiency [8].

Guoqiang Zhao proposed a matrix based intelligent production line layout in response to the personalized customization processing requirements of engine manufacturing enterprises. Then, combined with process simulation methods, the designed production line was optimized for site layout and virtual debugging. Based on the simulation results, the production line was built and successfully debugged [9].

The above scholars mainly focus on the construction process of optimization models. Hongyang Zhong focused on the characteristics of the joint scheduling optimization problem between machine tools and AGVs in the workshop, and based on this, established a mathematical model for the AGV machining equipment joint scheduling problem for precise algorithm solving. On this basis, he constructed a combination rule algorithm generation framework, embedded diverse heuristic rules, and designed multiple combination rule algorithms [10].

The process of process decoupling and algorithm optimization provides a new approach. Shichao Guo from Wuhan University of Science and Technology studied the operation strategy of AGV cars in the new energy battery pack room. Based on the characteristics of battery production, he designed AGV response rules based on material whole package distribution. Then, using actual production data from the intelligent workshop, he built a simulation model, and finally combined statistical methods to optimize the number and carrying capacity of AGVs using analysis of variance and sensitivity analysis [11].

3 Intelligent Manufacturing Layout Design for Piston Connecting Rods

In the first chapter, the content of intelligent manufacturing was analyzed. In order to improve production efficiency and build a remote and visual management platform, it is necessary to design the layout of the production process and the entire production workshop. The design of the production layout is based on the piston connecting rod production process, considering the operation problems of AGV in material extraction processing and production transportation. Therefore, this chapter first analyzes the process flow of the engine crankshaft and the required production equipment, and then establishes an intelligent manufacturing design scheme at the physical and data levels.

3.1 Analysis of Piston Connecting Rod Production Process

The processing object of the target production line is a 2.0T inline four cylinder engine piston connecting rod from a certain automobile company, as shown in Fig. 1. The connecting rod is a slender and non circular rod with a variable cross-section, and the cross-section of the rod body gradually decreases from the large end to the small end. It is composed of three parts: the large end of the connecting rod, the rod body, and the small end of the connecting rod. The large end of the connecting rod is separated, half is integrated with the rod body, and half is the connecting rod cover, The connecting rod cap is assembled together with the crankshaft main journal using bolts and nuts [12]. Now describe the processing techniques and equipment used in production.

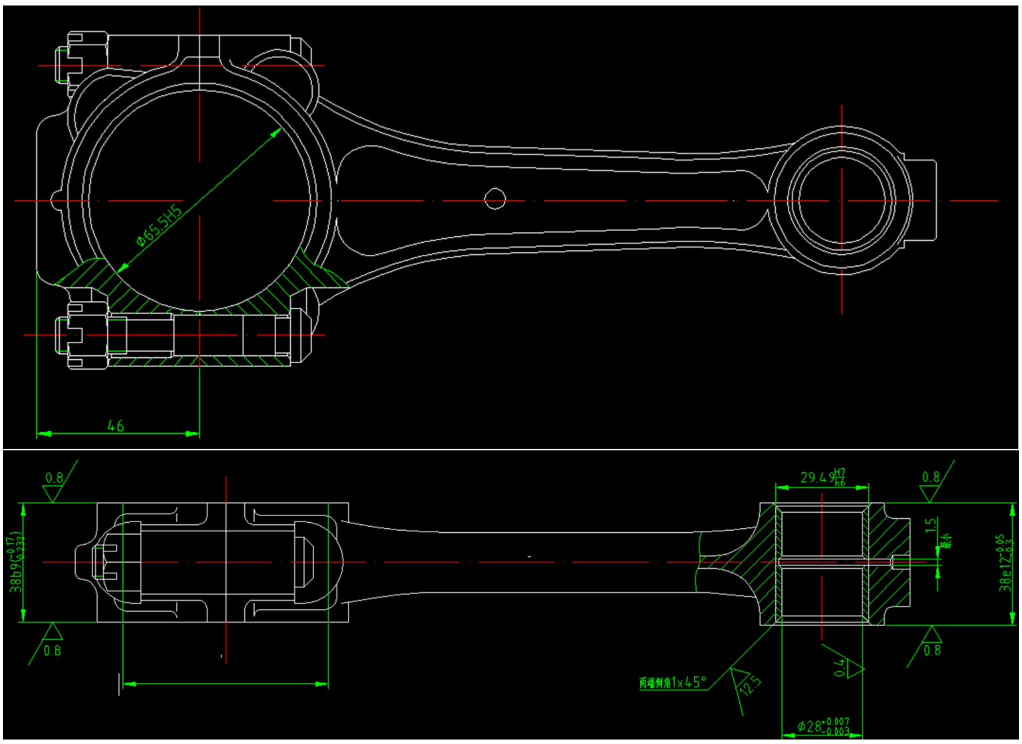

Fig. 1. 2D drawing of piston connecting rod

The structure of the piston connecting rod is complex, and its production process involves more than ten processing steps from rough parts to processing and forming. The material of the crankshaft connecting rod in this article is steel, with a selection of 45 steel and the use of forging forming technology [13]. The intelligent production line is mainly responsible for completing the mechanical processing and manufacturing of forged blanks. From raw material loading to final inspection and qualification, a total of 10 processes including milling two end faces and precision grinding are required, involving multiple processing machines. The process flow and processing equipment are shown in Table 1.

Table 1. Processing process flow and processing equipment

Operation sequence	Process name	Device name	Number
1	Milling the end face of the connecting rod	End face milling machine	2
2	Rough grinding of connecting rod end face	CNC grinding machine	1
3	Drill	Machining Center	2
4	Milling the side of the hole	CNC milling machine 1	1
5	Rough milling joint surface	CNC milling machine 2	1
6	Milling groove	CNC milling machine 3	1
7	Fine ground joint surface	Axle journal grinder	3
8	Processing threaded holes	CNC machining center	1
9	Milling chamfers	CNC milling machine 4	1
10	Accuracy testing	Three coordinate precision measuring instrument	1

The production line is the main functional line of the processing process, and the overall layout of the target production line is arranged in a straight line, covering an area of 1824 square meters. The specific equipment connection method and overall line layout are shown in Fig. 2. The production line can be divided into 5 automated production units according to the configuration of AGV. The production line is equipped with 14 processing equipment, including machining centers, CNC milling machines, grinders, etc. In addition, due to the existence of mismatched rhythms, regular product quality inspections, and temporary material replenishment during the machining process of piston connecting rods, material buffer zones are configured between each manufacturing unit for serial connection. AGVs are paired with specific industrial robots to handle workpieces and loading and unloading operations, and are accompanied by auxiliary facilities such as inspection tools to complete the production of piston connecting rods.

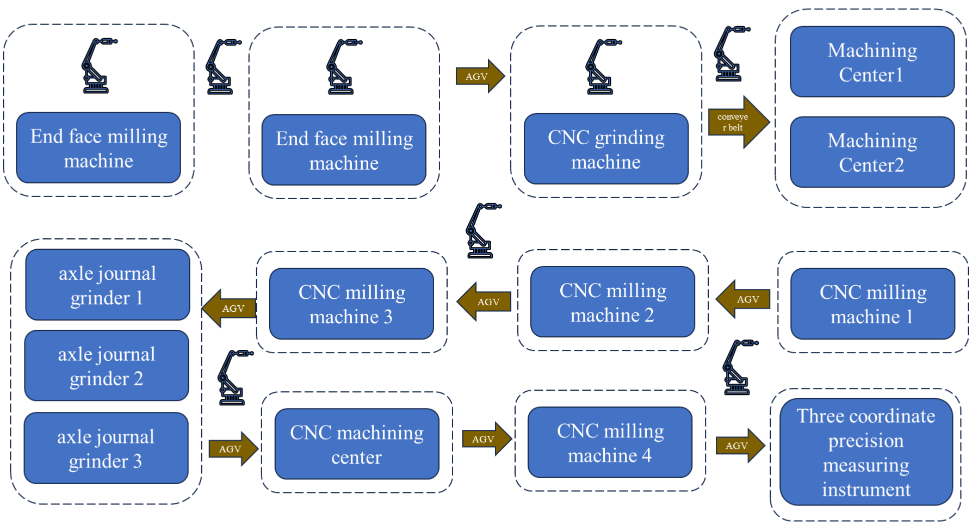

Fig. 2. Production line layout plan

3.2 Design of Intelligent Manufacturing Workshop System for Piston and Connecting Rod

The intelligent workshop needs to process all data during the processing process, so the system adopts a B/S architecture, so that workshop production employees can conveniently perform remote operations and interactive operations. In the B/S architecture, the communication between the browser and server adopts the HTTP protocol. The browser sends a request to the server, which processes the request and returns a response to the browser [14].

According to actual production needs, the framework of intelligent manufacturing systems can be seen as a bottom-up construction method, which includes hardware layer, data layer, resource layer, business layer, and display layer in sequence. The overall system framework structure is shown in Fig. 3.

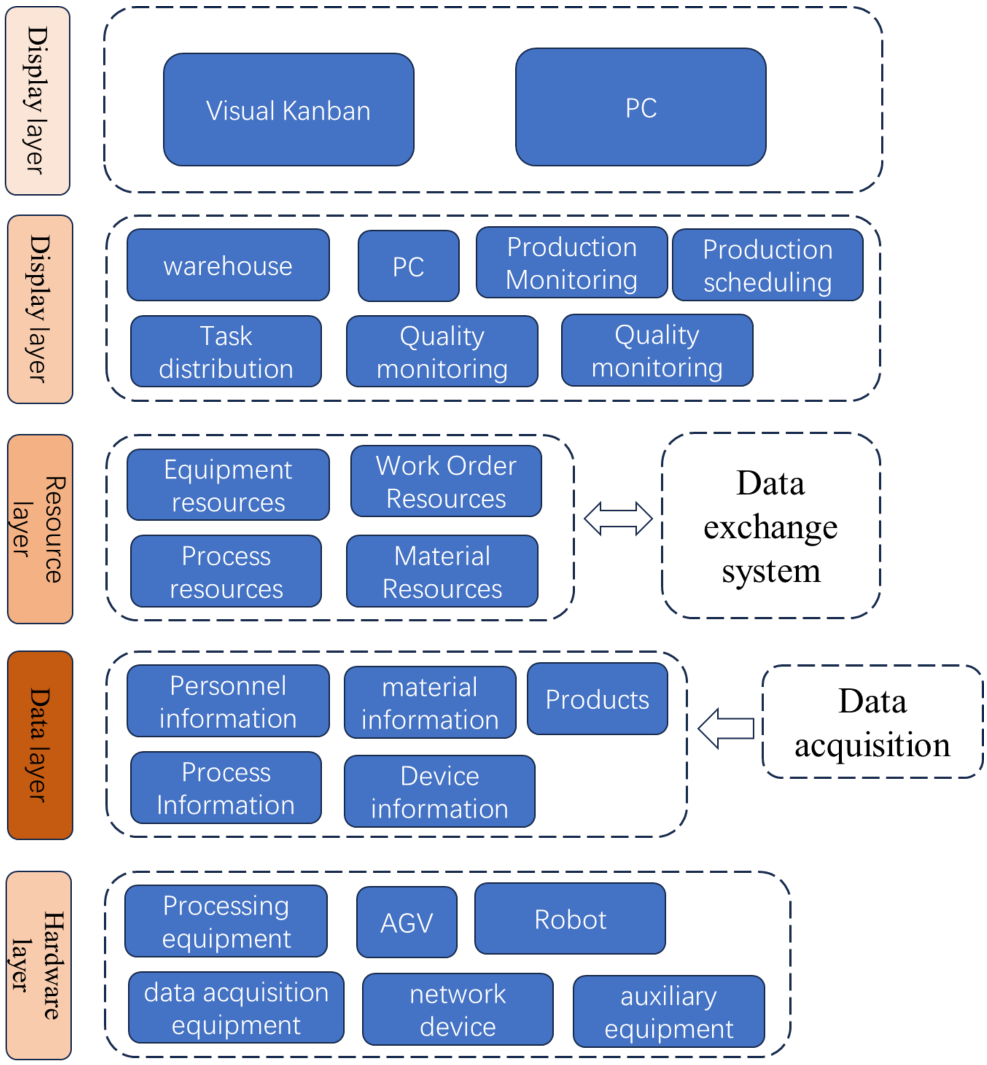

Fig. 3. Overall system framework

1) Hardware layer: including various processing equipment, AGVs, industrial robots, auxiliary equipment, data acquisition equipment, network equipment, etc. involved in the production process.

2) Data layer: This layer mainly determines the data collection method of the intelligent manufacturing system for piston and connecting rod, and the data sources are generally divided into two aspects: ERP import and data collection. The content of ERP import includes personnel, materials, and basic resource information of the piston and railing production workshop. The data collection methods include RFID, PDA, scanning gun, etc.

3) Resource layer: This layer aims to allocate production resources in the piston and connecting rod processing workshop, including production equipment, personnel, processes, materials, as well as information related to production documents, products, and orders.

4) Business layer: This layer is the core layer of the piston and connecting rod intelligent manufacturing system, which is based on the support layer, data layer, and resource layer to achieve system material management and production monitoring, providing strong support and guarantee for workshop production.

5) Display layer: This layer is the level where the piston and connecting rod intelligent manufacturing system interacts directly with users, mainly including production visualization dashboards, PC terminals, and mobile clients [15].

In actual production, the production line only needs to be equipped with one operator, compared to traditional production which requires 17 operators (14 people for each processing link, 1 material mover, 1 inspector, and 1 marking person). This not only saves 16 operators, but also ensures that automated operations such as loading and unloading, material handling, etc. increase processing efficiency by more than twice. In addition, the entire production line can ensure a processing qualification rate of over 99.8%.

The system operation and data processing architecture are shown in Fig. 4.

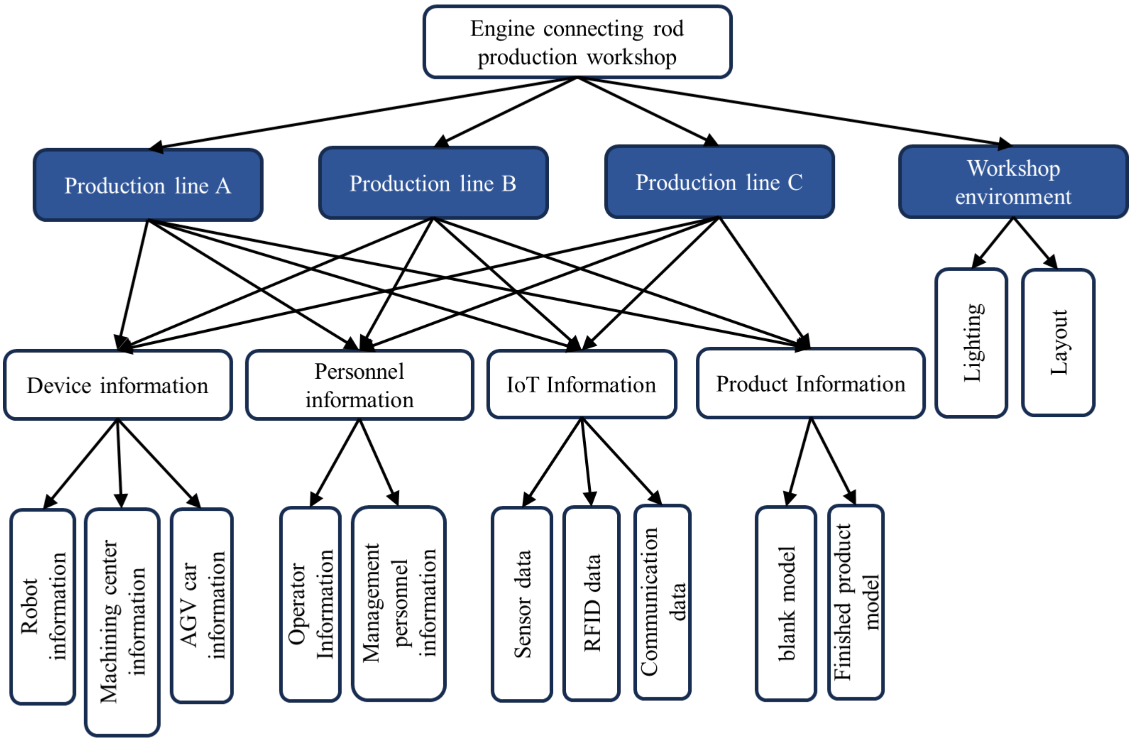

Fig. 4. System operation and data processing architecture diagram

Firstly, the system imports basic information such as production tasks, personnel, equipment, and processes. Then, the warehouse material management module prepares and inspects materials, and distributes them to the current day's inventory, which is then distributed to the line side inventory for use by the production line. The system generates a production plan based on existing resources and sends dispatch information to the production workers' workstations and generates paper dispatch orders. Production workers collect the required materials from the front warehouse based on dispatch information and upload data in a timely manner during the production process. After statistical analysis of these production data, the system is used for workshop visualization and real-time adjustment of production plan parameters to achieve closed-loop production. Finally, the finished products that have undergone quality inspection will be delivered on time, and corresponding production records will be established based on the collected production data and product inspection results [16].

The various functional modules of the production process clock play different roles, and data transmission and communication are completed between them through data links. The main research object of this article is the AGV vehicle scheduling strategy, so the functions of AGV cars will be described:

1) Processing process: The system sends processing instructions to the AGV car to send the raw material tray of the connecting rod to the processing unit. The RFID reader on the conveyor reads the information of the material tray, and the operator loads the material to the machining center for rough machining of the connecting rod. The AGV docking mechanism delivers the pallets to the AGV trolley. Realize functions such as automatic connection of AGV car material trays, automatic loading and unloading of robots, CNC machine processing, ultrasonic cleaning, RFID, etc.

2) Intelligent warehousing process: The intelligent three-dimensional raw material warehouse is used to store the raw materials of connecting rod components, consisting of a roadway warehousing frame, roadway stacker crane, AGV docking mechanism, warehousing management platform, PLC control unit, monitoring system, platform, and other accessories. The process of raw material outbound is as follows: the system issues a material retrieval instruction, the stacker accurately positions and takes out the corresponding material tray, places it in the AGV docking mechanism, reads the RFID electronic tag information, and the AGV cart transports the raw material tray.

3) Rear processing stage: Based on the storage capacity of finished products, including three-dimensional warehouses, six axis robots, coordinate measuring machines, AGV carts, assembly machines, marking machines, RFID and other components, to achieve automatic detection, assembly, marking, logistics, and information tracing functions for piston connecting rods.

This section mainly describes the data flow in the entire production workshop and the design of various functional modules, clarifying the role of AGV cars in each link.

4 AGV Scheduling Strategy

As can be seen from the content of the third section, The flow of workpieces between different processing techniques requires the cooperation of material transportation vehicles, which transport materials in various processing stages. Based on the actual work situation, this article equips multiple AGVs, so it is necessary to study the multi vehicle scheduling problem of AGV cars.

4.1 Decision Planning for Multi AGV Scheduling System

Generally speaking, the scheduling problem of AGVs is mainly divided into static scheduling, dynamic scheduling, and joint scheduling. The research methods for AGV scheduling problems are mainly divided into four categories: traditional methods, modeling and simulation methods, intelligent optimization methods, and hybrid optimization methods, which are respectively applicable to solving different static or dynamic scheduling problems. In the actual scheduling process, it is not possible to pursue a single optimization direction, and the optimization results need to be comprehensively considered. Therefore, for the scheduling problem of multiple AGVs in the connecting rod machining workshop, some basic scheduling rules can be set to reduce the computational workload of the entire system, which requires prioritizing the AGVs in each job. Generally speaking, the priority formulation strategies mainly include task prioritization strategy, first in, first out strategy, job type strategy, fixed vehicle strategy, remaining power strategy, etc [17]. They determine the priority of different job AGVs based on different goals. The advantage of the above method is that it can respond to dynamic changes and has low time complexity. For the multi AGV scheduling in this article, the priority scheduling strategy is shown in Fig. 5.

Different task priorities determine the execution timing of different tasks, and more importantly, the task urgency determined by task level settings can serve as the main strategy for conflict coordination among multiple AGVs, thereby achieving conflict avoidance among multiple AGVs. Furthermore, the urgent insertion of important tasks will not affect the stability of the system, making the scheduling system more robust.

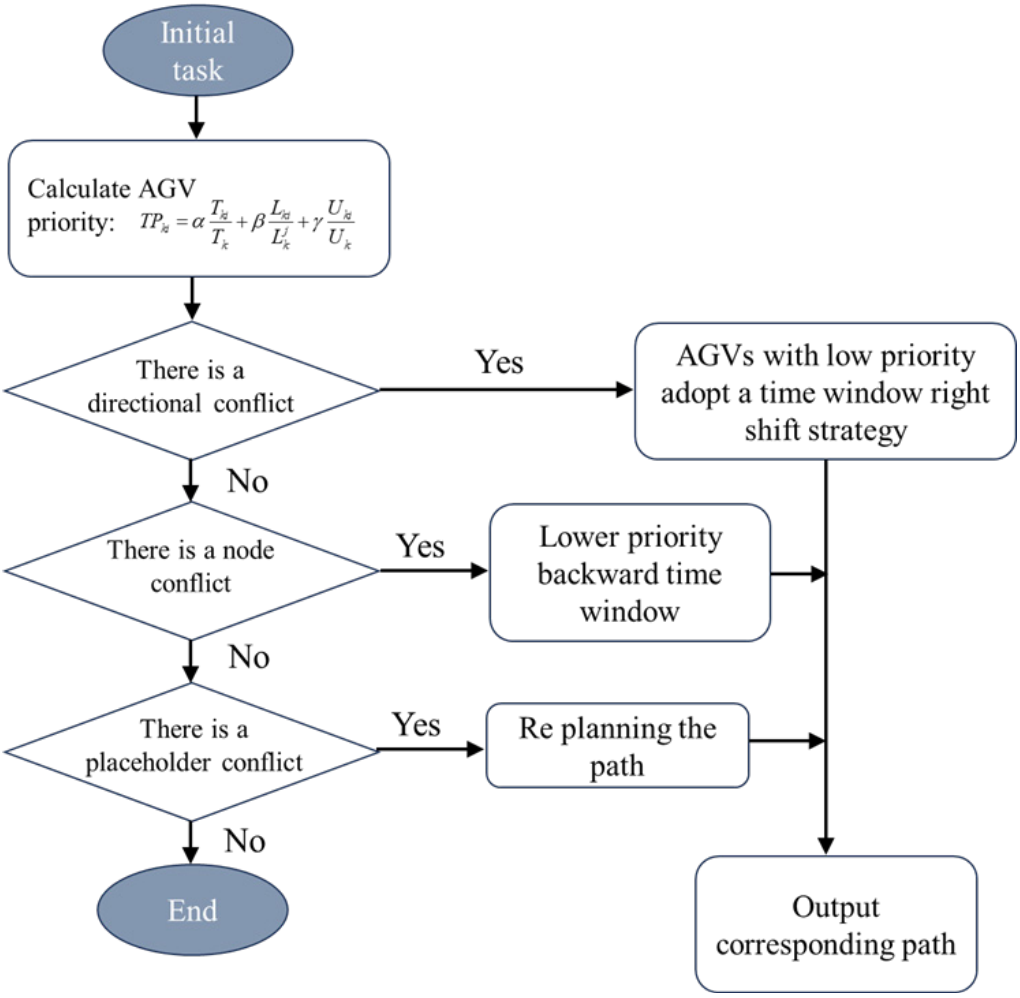

Fig. 5. AGV priority strategy diagram

4.2 Establishment of AGV Scheduling Model

AGV scheduling methods can be summarized into two types. The first type is to assign a waiting task to one AGV transport vehicle at a time. After one AGV completes its execution, the next waiting task is assigned according to the rules. Another type is multi task collaboration, which aggregates all AGV information and centrally processes it to find the optimal method that meets the conditions, and formulates the most reasonable allocation plan [18].

This article establishes an online scheduling system based on the processing speed of information and the richness of existing information, which updates and processes system information in real-time. That is, whenever new dynamics occur in the processing process, the scheduling system will immediately update the new dynamic tasks to the system and assign them to AGVs. Due to the real-time nature of task processing, the above strategy does not have the problem of task accumulation, which means that the least number of tasks are allocated to the computer per unit of time, reducing the hardware requirements for the computer. However, more reasonable and efficient planning methods need to be configured, so the rationality of the planning strategy is required to be higher.

In actual production, it is necessary to assign multiple tasks to multiple AGVs. In order to facilitate the construction of an accurate mathematical model, it is first necessary to simplify the problems in the AGV scheduling process. The simplified content is as follows:

(1) The time statistics of AGV vehicles, from the start of the vehicle to the end of the vehicle's task execution

stop, do not include the time for loading materials from the starting point;

(2) When the AGV car is in motion, it is considered that the driving speed is constant;

(3) When AGV transport vehicles perform the same set of tasks, they only perform a single task once without repeating it, and there is no situation of running around a certain workstation repeatedly.

Based on the above simplified processing, it is assumed that there are currently K tasks and M AGV cars. This article adopts a centralized scheduling method to combine multiple tasks, and the combined tasks are executed by the m AGV. The objective function is to combine the total distance cost of completing all tasks, the total time cost of completing task groups, and the lowest energy consumption. The optimization objective is to minimize the numerical result of the function [19]. Therefore, the expression of the objective function is:

$$\min A = \sum_{i=1}^{K}\sum_{j=1}^{K}\sum_{m=1}^{M} S_{i,j,k} \times n_{i,j,k} + \min\left(t_m\right) + E_{\min}. \quad \textbf{(1)}$$

In the formula, $S_{i,j,m}$ represents the distance traveled by a single transport vehicle from task starting point i to task ending point j. $n_{i,j,m}$ represents the total number of consecutive executions of a task by the transport vehicle, and t_m represents the minimum total time cost for AGV transport vehicle m to complete the entire task group.

$$t_m = \sum_{i=1}^{K}\sum_{j=1}^{K} S_{i,j,m} \times t_{i,j,m}. \quad \textbf{(2)}$$

In the formula, $t_{i,j,m}$ represents the time cost of AGV transport vehicle m from task start point i to task end point j.

During the AGV scheduling process, some conditional constraints need to be applied, and the constraint function is represented as follows:

1) Each task will only be executed by one AGV.

$$x_{i,j,m} = 1. \quad \textbf{(3)}$$

2) Each task must be completed within the specified deadline.

$$\sum_{i=1}^{K} x_{i,j,m}\left(t_{i,m} + t_{i,j,m} - t_{j,m}\right) - t_{line} \leq 0. \quad \textbf{(4)}$$

3) Energy consumption, in order to reduce the difficulty of analyzing AGV energy consumption, this article mainly approaches from the perspective of AGV motion. The total energy consumption during the transportation process is decomposed into standby energy consumption, uniform linear motion energy consumption E_{line}, and uniform turning motion energy consumption E_{turn}. The minimum energy consumption of AGV throughout the entire process is expressed as:

$$E_{\min} = \min \sum_{1}^{K} \left(P_d * t_{ij}^{v} * \frac{\sum_{1}^{s-s_1} F_q * D^{s-s_1}}{\eta} + \frac{\sum_{1}^{kT}\left[\frac{F_q}{4} * \sum_{i=1}^{n} R_i * \theta\right]}{\eta} \right). \quad \textbf{(5)}$$

In the formula, $E_{\min}$ represents the minimum power and P_d represents the standby power of the AGV. When the AGV performs a uniform linear motion, the acceleration is zero. When turning at a uniform speed, the static friction between the vehicle and the ground provides complete centripetal force. There are a total of s stages in AGV speed movement, where there are s_t nodes that pass through a constant speed turn, and $s - s_t$ nodes in the constant speed part. The driving force for uniform motion is expressed as:

$$F_q = f \cdot m_{AGV} \cdot g. \quad \textbf{(6)}$$

In the formula, F_q represents the driving force, m_{AGV} represents the total mass of AGV and cargo during uniform motion, in units of Kg, f is the rolling friction coefficient, and the total energy consumption during AGV turning is:

$$E_{turn} = \frac{\sum_{1}^{kT}\left[\frac{F_q}{4} * \sum_{i=1}^{n} R_i * \theta\right]}{\eta}. \tag{7}$$

In the formula, η represents the power factor of the walking drive motor, θ represents the turning angle of the car, and $\sum_{i=1}^{n} R_i * \theta$ represents the turning radius of the car wheels. The actual number of wheels can be determined based on the existing situation. Further calculation reveals the total energy consumption during uniform straight-line driving:

$$E_{line} = \frac{\sum_{1}^{s-s_1} F_q * D^{s-s_1}}{\eta}. \tag{8}$$

In summary, the final mathematical optimization model is obtained:

$$\min A = \sum_{i=1}^{K}\sum_{j=1}^{K}\sum_{m=1}^{M} S_{i,j,k} \times n_{i,j,k} + \min\left(t_m\right) + \min \sum_{1}^{K}\left(P_d * t_{ij}^{v} * \frac{\sum_{1}^{s-s_1} F_q * D^{s-s_1}}{\eta} + \frac{\sum_{1}^{kT}\left[\frac{F_q}{4} * \sum_{i=1}^{n} R_i * \theta\right]}{\eta}\right). \tag{9}$$

After the above operations, the establishment of the optimization objective function has been completed. The objective function takes into account practical processing problems. Further work requires the use of artificial intelligence algorithms to optimize the objective function and find the optimal solution. This article uses an improved genetic algorithm to solve the objective function.

4.3 Improve Algorithm Design

1) Chromosome expression and coding

Each chromosome represents a task allocation plan composed of different AGV delivery tasks. The first half of the chromosome represents the AGV number, and the second half of the chromosome fragments represent the speed at which the AGV executes tasks. Each AGV can only perform one task at a time, therefore, the gene encoding on the chromosome can represent the AGV's sequence number, and the gene sequence is the task set. It is necessary to find the optimal allocation scheme that can complete the task to balance the three optimization objectives [20]. The chromosome coding is shown in Fig. 6.

4	2	5	···	1	1.0	1.4	0.6	···	1.7
1	2	3	···	10	11	12	14	···	20

Fig. 6. Chromosome coding

2) Population initialization

The first 10 digits in the figure represent the corresponding AGV car number, the 11th digit represents the running speed of the corresponding car number, and the second row represents the gene encoding number.

Step 1: Organically combine global selection, local selection, and random selection to encode and decode multiple processes, machines, and processing times.

Step 2: Calculate the crowding distance and use Pareto optimization method to construct a memory library.

Step 3: Based on the dynamic crossover probability, select the best individuals from the population through a roulette wheel strategy.

Step 4: Perform POX crossover on the process codes of the selected individuals, and evenly cross the machine codes to generate new individuals. Step 5: For individuals in the new population, perform neighborhood search mutation on the process code based on the mutation probability, and select the machine mutation with the shortest processing time for the machine code.

Step 6: Mutation and crossover until the number of new individuals reaches the population size.

Step 7: Merge the memory bank with the new population and update the memory bank.

Step 8: If the maximum number of iterations is reached, output a high-quality solution; otherwise, proceed to step 3.

3) Algorithm improvement design

The crossover probability P_j and mutation probability P_b of genetic algorithms are the key factors determining the performance of genetic algorithms. Therefore, by introducing adaptive strategies, P_j and P_b can automatically change with fitness values, ensuring both population diversity and algorithm convergence. The expression methods for crossover probability P_j and mutation probability P_b are as follows:

$$P_j = \begin{cases} \dfrac{\lambda_1\left(h_{\max} - h^{'}\right)}{h_{\max} - h_a}, h^{'} \ge h_a \\ \lambda_2, h^{'} < h_a \end{cases}. \tag{10}$$

$$P_b = \begin{cases} \dfrac{\lambda_3\left(h_{\max} - h\right)}{h_{\max} - h_a}, h^{'} \ge h_a \\ \lambda_4, h^{'} < h_a \end{cases}. \tag{11}$$

In the formula, $h_{\max}$ is the maximum fitness value of the population, h_a is the average fitness value of the population, $h^{'}$ is the larger fitness value among the two individuals to cross, h is the fitness value of the individual to mutate, λ_1, λ_2, λ_3, λ_4 is a constant, and the value range is between $0 - 1$. In the early stages of iteration, the improved algorithm may cause the genetic population's excellent model to be unable to effectively disperse due to the small probability value of the optimal solution. The optimal solution remains almost unchanged and eventually stops. Therefore, this article improves the cross mutation probability to enable continuous adaptive adjustment based on the population's evolution. Set the adaptive crossover probability as follows:

$$P_j = \begin{cases} P_{j\min} + \dfrac{\left(P_{j\mathrm{mi}d} - P_{j\min}\right)\left(h_{\max} - h^{'}\right)}{h_{\max} - h_a} \\ P_{j\max} - \dfrac{\left(P_{j\max} - P_{j\mathrm{m}id}\right)\left(h^{'} - h_{\min}\right)}{h_a - h_{\min}} \end{cases}. \tag{12}$$

$$P_b = \begin{cases} P_{b\min} + \dfrac{\left(P_{b\mathrm{mi}d} - P_{b\min}\right)\left(h_{\max} - h^{'}\right)}{h_{\max} - h_a} \\ P_{b\max} - \dfrac{\left(P_{b\max} - P_{b\mathrm{m}id}\right)\left(h^{'} - h_{\min}\right)}{h_a - h_{\min}} \end{cases}. \tag{13}$$

In the formula, $P_{j\,\min}$ and $P_{j\,\max}$ are the minimum and maximum values of the crossover probability, respectively. The crossover probability is generally within the range of [0.65 − 0.85], $P_{b\,\min}$ and $P_{b\,\max}$ are the minimum and maximum values of the crossover probability, respectively. The crossover probability is generally within the range of [0.01 − 0.1], and $P_{j\,(b)\,mid}$ is the median of both values.

The process of solving the optimization strategy for multi AGV car scheduling using improved algorithms is shown in Fig. 7.

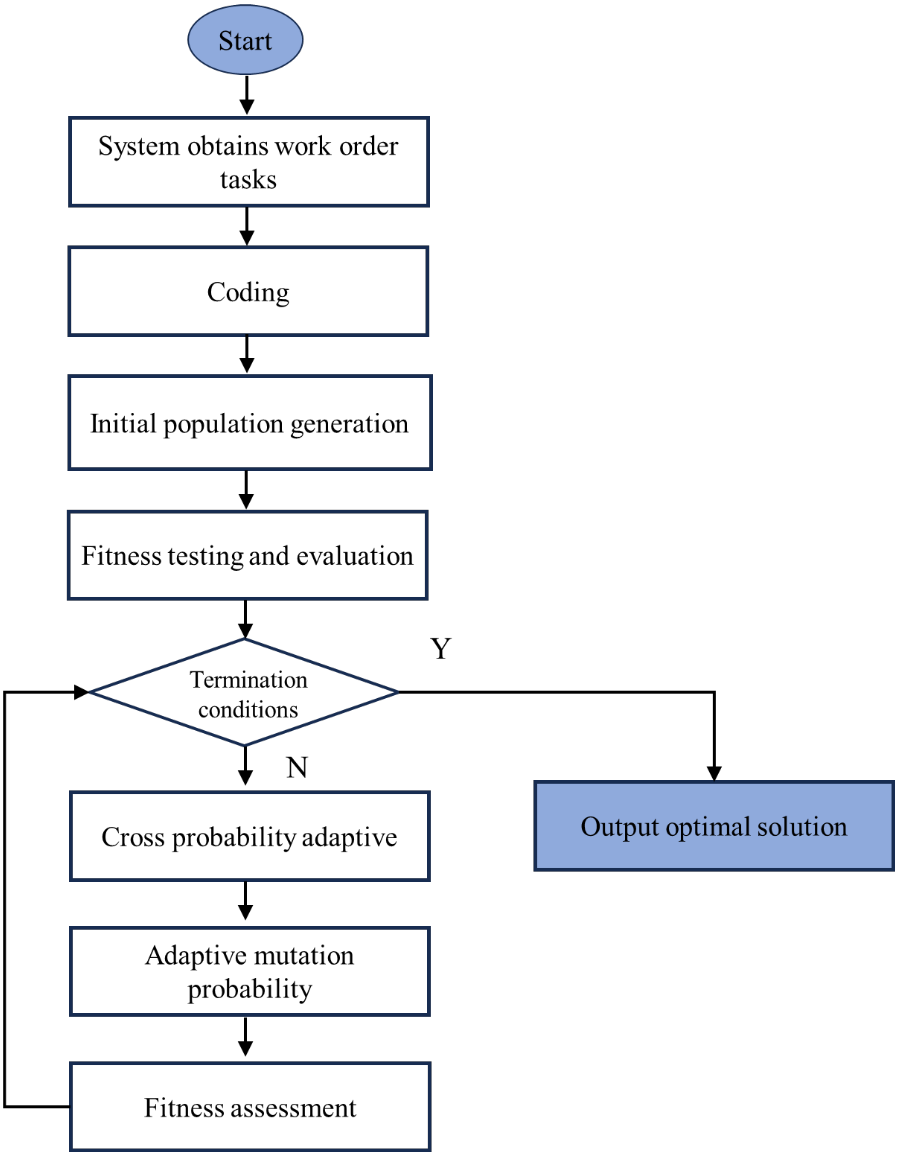

Fig. 7. Schematic diagram for finding the optimal solution

5 AGV Scheduling Strategy

In order to verify the scientificity of the intelligent machining production layout for engine piston connecting rods designed in this article, as well as whether the efficiency improvement of AGV scheduling strategy in machining is significant, MATLAB simulation experiments were designed in this article, and then an improved genetic algorithm was used to solve the objective function in Chapter 4.

The total number of tasks set by the task system is 20, and all transportation tasks are carried out by 5 AGV transport vehicles. The goal of the algorithm is to use the optimal strategy to allocate 20 tasks to 5 AGV vehicles based on task requirements, so as to minimize the total distance traveled and time consumed by the 5 AGV transport vehicles.

This simulation experiment arranges a unified position as the starting stop point for AGV transport vehicles. All AGV transport vehicles depart from this stop point, complete all tasks, and return to the stop point. Then, an improved genetic algorithm is used to solve the problem separately. The simulation parameters are set as follows: the map size is 10 * 10, and the population size is 80. The simulation results are shown in Fig. 8.

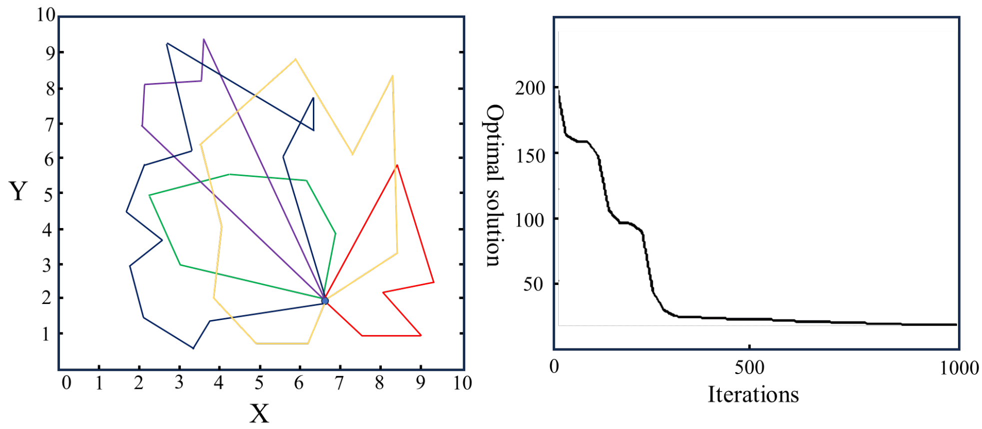

Fig. 8. Simulation experiment results

From the graph, it can be seen that the starting and ending points of the experimental AGV are the same. The AGV starts from the same point to schedule tasks, and finally completes the tasks and returns to the starting point. The total path of the task is 83.2791, with 929 iterations

In order to demonstrate the effectiveness of the proposed AGV strategy in improving work efficiency, the 20 tasks in this paper were randomly assigned to 5 small cars without providing an allocation strategy, i.e. conventional scheduling. The improved algorithm Gantt chart is shown in Fig. 9.

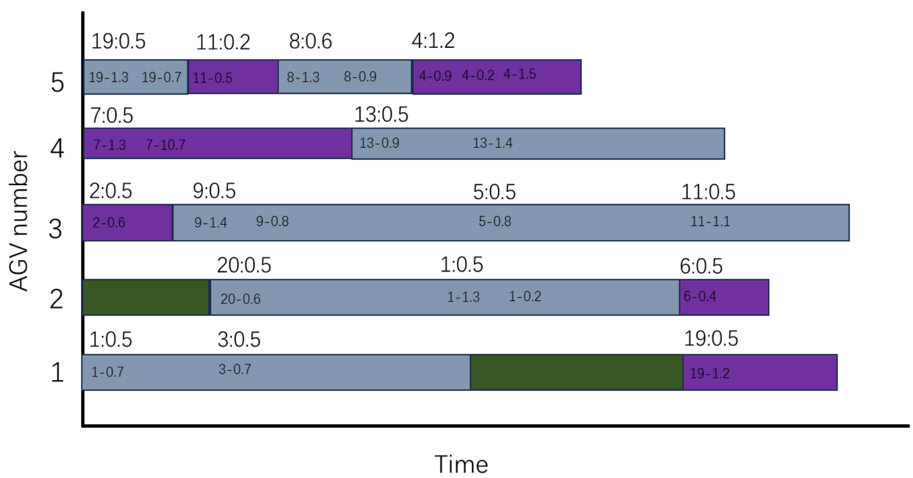

Fig. 9. AGV scheduling Gantt chart

The different colors in the figure represent different processes, with green representing the AGV charging process. When the remaining AGV charge is less than the charging threshold, it needs to be charged and returned to the charging area for charging. The blue and purple colors represent the process of AGV executing tasks, which respectively represent the time required for AGV to retrieve materials from the charging area to the material storage area and the time required for AGV to move from its current position to the target workstation. The horizontal axis in the figure represents the completion time of the task, and the vertical axis represents the AGV number of the completed task. The numerical meanings represent the task number, AGV speed, and AGV energy consumption, respectively. For example, Task 19 was executed by Vehicle 1 at a speed of 0.7m/s, with an energy consumption of approximately 0.5.

The comparison results are shown in Fig. 10.

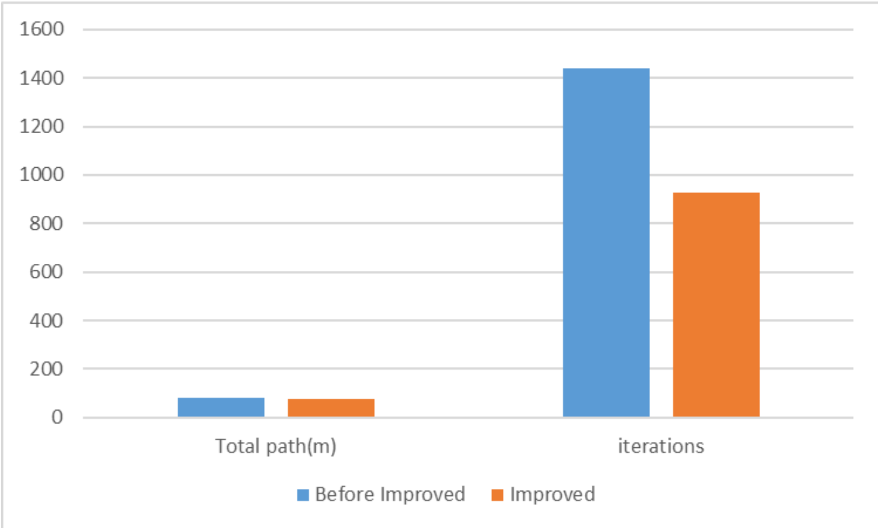

Fig. 10. Comparison results

From the above figure, it can be seen that the total distance of the solution result is 7.5% shorter than the solution result of the pre optimization algorithm, and the solution result is better.

6 Conclusion

This article takes engine piston and connecting rod as the research object. Firstly, the production process of piston and connecting rod is analyzed, and then the workshop layout design with intelligent manufacturing as the core is completed; Then, further analysis was conducted on the transportation problem between storage units and various processing units in the production process of engine piston connecting rods, as well as the scheduling strategy of AGVs. An optimization model was established with the lowest comprehensive cost of time and distance. Finally, an improved genetic algorithm was used to solve the model parameters and obtain ideal results.

However, there are some shortcomings in the work process of this article, which are also future research directions:

1) Partial simplification was made in the scheduling process of AGV, but there are situations in actual production that cannot be simplified. Therefore, a model that is closer to the actual situation should be established.

2) When scheduling AGVs, there are situations where multiple tasks are dispatched simultaneously.

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