Study of an Automatic Logistics System for the Engine Production Line

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***Abstract* - Logistics system is an important element for the engine production line, and the automation degree affects the efficiency of the production line. This paper presents an automatic logistics system for the engine cylinder block production line, based on a type identification and tracking subsystem, and an automatic transmission and storage subsystem. The logistics system achieves the mixed manufacturing of 3 type engines dynamic through the integration of a visual identification module with the cylinder block features, a QR code marking module and a scanner. The cylinder block transfers among several stations automatically, realized by the PLC control of the delivery car, storage shelf and the transfer vehicle. The system design fully considers the security and stability. Combined with a friendly interactive system, the operational convenience is improved. In the applications, the system can increase the efficiency of the engine production line and reduce manpower effectively.**

Index Terms - Automatic Logistics, Visual Identity, QR code, PLC control.

I. INTRODUCTION

With the development of the large-scale automated production lines, the automation of production has become increasingly important [1, 2]. The advantage of the automation consists of small footprint, saving manpower, high reliability and stability. Automatic logistics system has been an integral part of the production line, replacing the traditional manual logistics gradually [3]. For the engine manufacturing industry, the automatic logistics not only reduces personnel costs and increase efficiency, but also ensures the safety of the product.

The key of an automatic logistics system is to introduce the information flow of all parts for the engine production line. Especially, a variety of type engines are produced at the same production line [4, 5]. It meets the needs of modern production mode of the zero inventory product supply. The QR code, which is composed by black and white graphics in a fixed size square region, can store sufficient amount of information, to unify identity of the different type parts [6, 7]. The QR code satisfies the logistics required of automatic recognition of different types of parts, automatic storage of parts, automatic transfer lines and other technical aspects. Based on the QR code, an automatic logistics system needs lots of different technical solutions. Identification of parts creates QR codes, control component builds the information flow, and transport equipment composes the logistics platform.

In this paper, we describe a novel automatic logistics system for the cylinder block transport of the engine production line. The pipeline system consists of an engine cylinder block type identification module and QR code printing equipment to provide logistics information. With the QR code, the production information is tracked by the QR scanner for each station and PLC control system. The transport system is composed by the conveyor line, delivery car, storage shelf and transfer vehicle. With the fully research of the identify success rate, security and stability of the logistics transportation links, the system uses the industrial grade hardware, and has a friendly human machine interactive features.

The rest of this study is organized as follows. In Section II, the framework design of the logistics system is described. Section III presents the main technology details and related algorithms. Section IV presents the software and the application performance of the system. Finally, in Section V, we discuss our conclusions.

II. SYSTEM DESIGN

For the design of the automatic logistics system, the first work is to determine the product categories, manufacturing processes and other technical parameters. The engine production line has 3 type cylinder blocks, and 2 assembly lines to produce 6 type engines at the same time. In order to ensure the production continuity, the cylinder block storage area should have a certain margin, and transfer and storage must be automatic. The whole logistics system structure is shown in Fig. 1, in which a vision identification system and a mark system are located at the entrance of the conveyor line, providing the type parameters for the latter process; the cylinder block is transported by a delivery car from the conveyor line to the storage area; the cylinder block is transferred to different assembly line by a transfer vehicle. During the whole transfer process, the cylinder block is circulated by the gravity among the storage shelf, the transfer vehicle and the assembly line. The movement of the cylinder block on the transfer line is on the galvanizing hollow cylinder, and the horizontal movement is drove by a speed chain transmission.

Specifically, the complete workflow of the cylinder block from the conveyor line to the assembly line is as follows: a) 3 type engine cylinder blocks enter the conveying line, and distinguish through a visual identification system; b) Based on

the identified type, the marker system print a QR code, which consist of the offline same, the shift, and the type of the cylinder block, on the special marking area. QR code is used in the subsequent step of the information confirmation; c) When the cylinder block turns into the delivery car, firstly the QR code is got by a scanner. Then the block is delivered to a storage shelf entry based the block type; d) the cylinder blocks are into the storage shelf from the entrance to the exit slip position in turn; e) After the transfer vehicle docking with the storage shelf, the cylinder blocks slip into the transfer vehicles by gravity, and transport to an assembly storage line; f) the cylinder block type is confirmed by a QR code scanner before entering the assembly line, to complete the whole assembly.

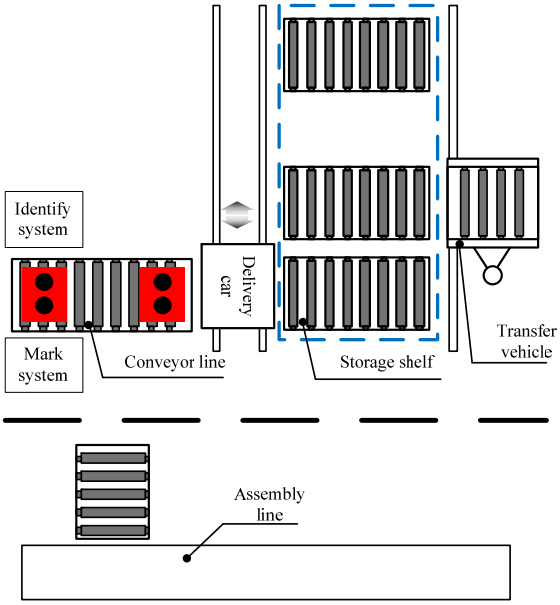

Fig 1. Schematic of the logistics system framework

Above logistics system has a set of PLC-based automatic control system to achieve all functions. Friendly human machine interface, manual control panel and other auxiliary modules ensure the stable and reliable operation of the system.

III. Main Technology And Algorithms

The control module of the logistics system is constituted by Siemens S7 series PLC and the supporting peripherals constitute. The Master station uses a CPU315-2PN/DP, mainly to control the identify camera, transmission lines and switch amount. At the same time, marking IPC, human-computer interaction touch screen, visual systems, QR code scanner and other hardware devices are connected to this PLC [2]. The slave station uses a CPU224, mainly to control the delivery car of the start-stop and position. The hardware connection scheme of the system is shown in Fig. 2.

The whole system is connected by MPI and Ethernet fieldbus network, the master station CPU315-2PN/DP and the slave station CPU224 is connected by MPI, others are connected by Ethernet. The CPU224 is installed on the delivery car, and the MPI communication cable uses the sliding touch line for extending the cylinder block storage area.

The following will describe the type identification, automatic storage and transfer in detail, especially the control strategies.

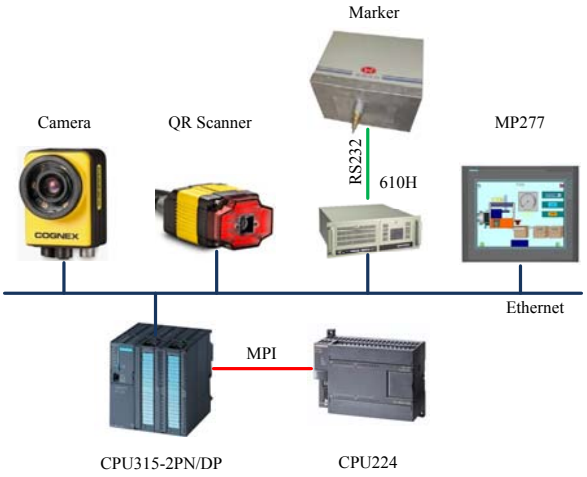

Fig 2. Hardware connection of the control module

A. *Image recognition of the cylinder bore*

The type identification is based on the characteristic differences between the cylinder bore. 3 type cylinder blocks, producing at the same line, are based the same rough, and the difference is the diameter of the cylinder bore(102 mm, 107 mm and 109 mm). The vision measurement program is shown in Fig. 3. A vision system is installed directly above the cylinder bore. When the cylinder block is transported under the visual system, it is lifted by a pneumatic mechanism and precise positioned by a positioning pin to ensure the measure precision of the vision [8, 9].

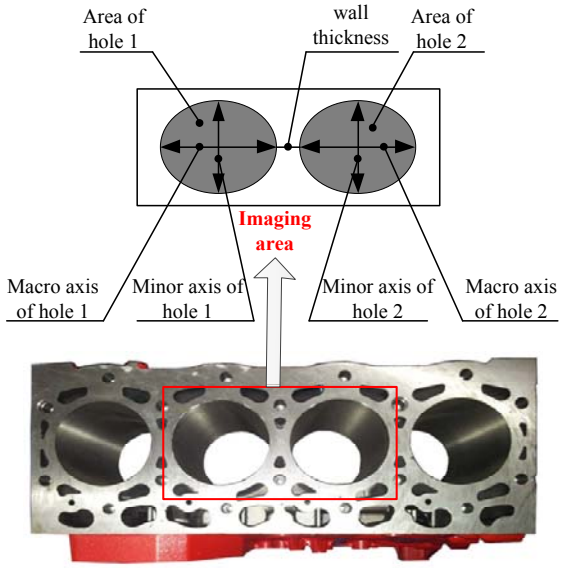

Fig 3. Cylinder bore image recognition solution

The installing of the visual system can ensure two cylinder bores stable in the image. To realize reliability, robustness and 100% accuracy of identification process, the solution uses means of features to discriminate the type of the cylinder block. The detailed flow of above algorithm can be expressed in Fig. 4. Firstly, the image edge is extracted by

Canny edge operator, and its regional connective areas are searched, then the smaller regional connectivity areas are abandoned [10]. An ellipse is fitted with the remaining connectivity areas of the edge pixels, and then two best-fit ellipses are selected by the principle of minimum residual and proximity, using this method to overcome the noise and light interference largely. Secondly, the areas of the two ellipses are calculated. Along with the line connecting the center of two ellipses, the wall thickness of the cylinder bores is characterized between the two pixel pitch [11]. In the commissioning phase, the cylinder block type is determined artificial, and the macro and minor axes, area and wall thickness is calculated by above method. The cluster center of the two cylinders, which is saved into the system database, is determined by the clustering techniques. In the operational phase, each cylinder bore characteristics are extracted and judged by calculating Euclidean space from its cluster centers with the two types.

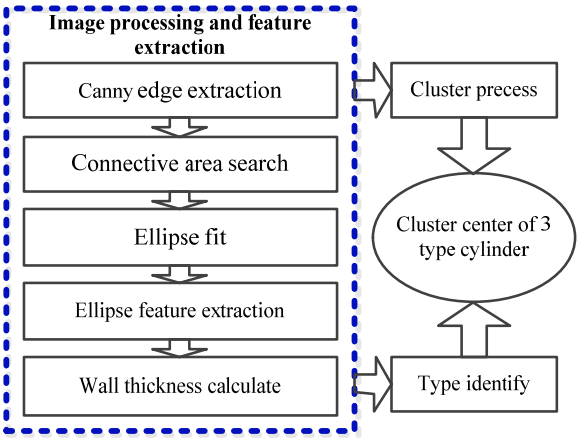

Fig 4. Image recognition flowchart

After the cylinder block type identification, PLC controls marking machine to print the QR and plain code, which contains the production information of the cylinder block, on the upper right corner. The marking machine is BJ-GAZX series of Jinan Yi Heng. The movement of the marking head is achieved through a pneumatic mechanism. The actual layout of the system is shown in Fig. 5.

B. Cylinder block automatic storage

Due to the storage area is shared for 3 type cylinder blocks, the storage capacity of each type is adjusted based on the production plan dynamically. The delivery car needs determine the type and surplus of each line. The storage type of each line is set on the man-machine interface.

The process of cylinder automatic storage is in the Fig. 6. When the cylinder block moves to the end of the conveyor line, it waits the delivery car in place. The cylinder block movement is stopped by a lift pneumatic cylinder to prevent accidents. Then the cylinder block moves onto the top of the delivery car smoothly by the position sensors. The first work is to scan the QR code for getting the type information of the cylinder block after position. Then the slave PLC control the delivery car moves to the object storage shelf and docks accurately. With the master PLC, the cylinder blocks are stored continuous in the storage area.

Fig 5. Cylinder block type identify and QR code marking

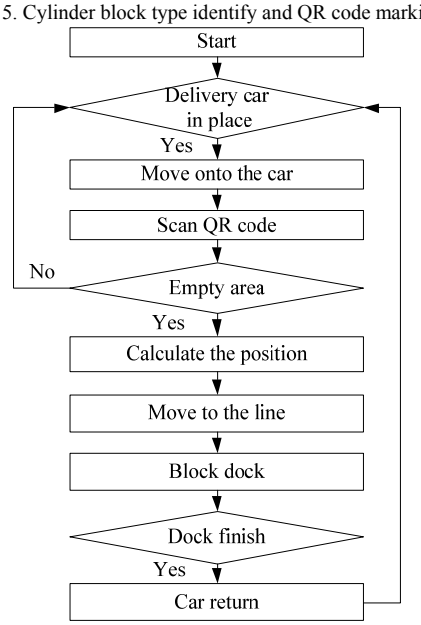

Fig 6. Cylinder block automatic storage flowchart

C. Cylinder block transfer

For an efficient automatic logistics system, only simple storage control is not enough, the transfer of the cylinder block from the shelf to the assembly line is needed. In particular a transfer vehicle is used to transfer the cylinder blocks between the two storage lines. In order to ensure a

sufficient storage capacity, the capacity of each storage shelf is much greater than the transfer vehicle. In order to realize the automatic transfer, the cylinder blocks are storage in segmented. The specific programs are as shown in Fig. 7. To prevent the collision between the cylinder blocks, which is on a tray, each storage line has 3 segments, and a scissor lift mechanism stops the movement of the cylinder block. The cylinder blocks slide onto the transfer vehicle at the end of the shelf. Cylinder blocks transfer to the assembly line using the same method.

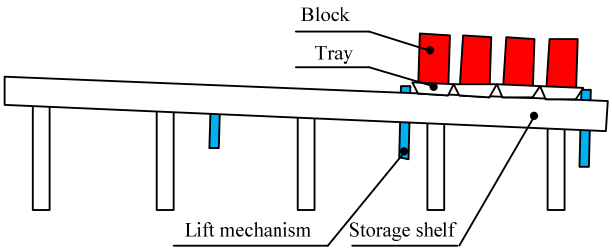

Fig 7. Cylinder block segmented storage scheme

The scissor lift mechanism is drove by a cylinder, and the detailed design is shown in Fig. 8. The red dotted line is the initial position, and the cylinder can slide backwards along the roller. The lift mechanism will rise when the specific segmented line is full, as shown in the black solid line.

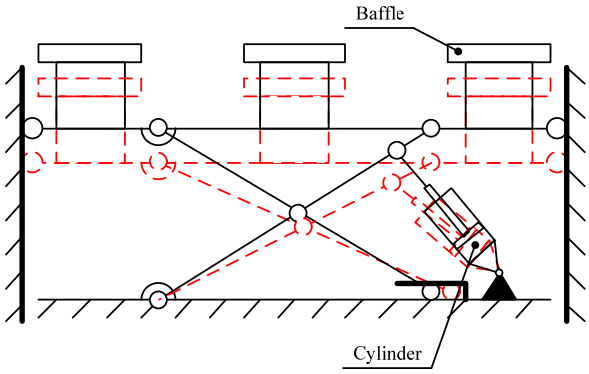

Fig 8. Scissor lift mechanism structure

In the case of the gas or electricity off, the lift will lower, and the cylinder block will slip on the ground and cause an accident, cylinder with brake locking device is selected, and one-way valve is used in the gas loop.

IV. Software And System Applications

The software structure is shown in Fig. 9. System software is divided into 4 parts: Marking server program, touch screen program, master station PLC and slave PLC program. Marking server program contains type identify by camera and marking control; touch screen achieves a friendly interactive features; the slave PLC is responsible for the delivery car control; the master PLC achieves the overall process control.

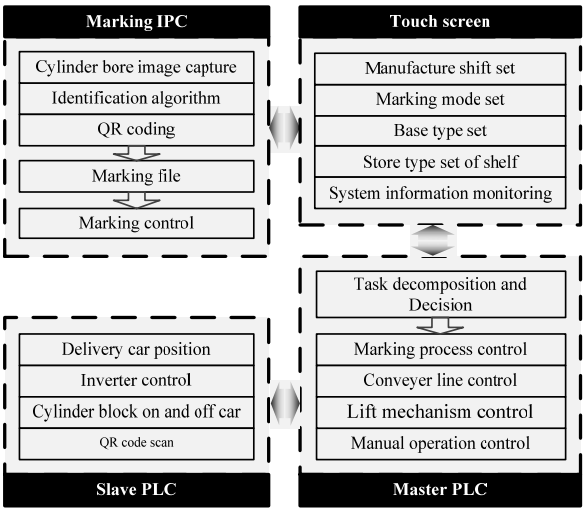

Fig 9. Software structure

The software interfaces of the automatic logistics system are shown in Fig. 10 and 11. The main function of the software include the following aspects: a) After the cylinder block positioning completed, the image processing program starts automatically, and the QR marking file is generates based on the shift set, printing time and other information; b) According to the QR marking file, the marking head is drove to the marking position and works; c) Workers set the shift, the cylinder block type of each shelf, record the storage cylinder block number, and check the alarm information on the touch screen; d) the cylinder block is controlled to transfer between conveyor, delivery car, and storage shelf automatically; e) the delivery car trolleys with the storage shelf based on address; f) By controlling the lift mechanism, the cylinder block is stored in 3 segments.

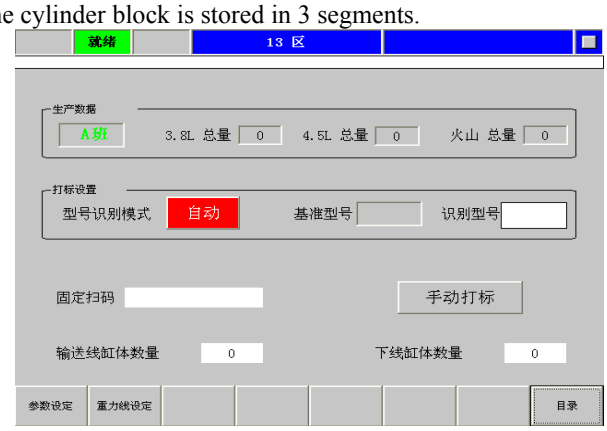

Fig. 10 Touch screen interface

In practical application, the logistics system can identify with a success rate of 100%, and automatic storage and transfer 3 type cylinder blocks shown in Figure 12. Compared the precious logistics system, the automatic one has increase productivity of more than 30%, and save manpower more than 50%.

Fig. 11 Type identify and mark system interface

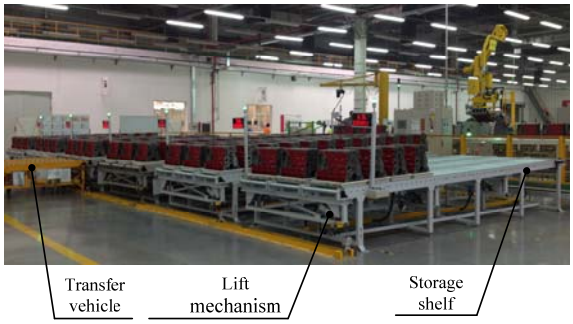

Fig. 12 Automatic logistics system application

V. CONCLUSION

In this paper, a novel automatic logistics system has been designed and developed for the engine production line. Through the integration of the visual setup, QR code marking system, delivery car, storage shelf and transfer vehicle, the system achieved type identification and tracking of the cylinder block throughout the whole process, and the cylinder block was stored and transferred automatically between different process stations. Thus the efficiency of the production line was greatly improved. For the stability and security requirements of application, the high-performance industrial camera, fieldbus, and industrial marking system were used. The image processing algorithm based on the different feature of the cylinder block to improve the success rate of the identification. The automatic logistics system had a legible man-machine interface, convenient manual operation, stable PLC programs. The system has been used in a production line for the engine cylinder block, improving work efficiency, saving manpower, getting good reviews.

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