Technique and outfit of large-scale intelligent PC external wall panel mixing production line

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Abstract. The production of concrete products is the key problem of our infrastructure construction, and the automation degree of this production equipment shows the level of science and technology in our construction industry. To promote the development of concrete production technology and increase the degree of its equipment, the production technology and main parts of PC external wall panel mixing production line are analysed and annotated in this paper. This production line consists of a moving device and carriers, cleaning spraying and marking system, placing concrete and vibrating system, surface treatment system and curing System, and so on. This production line is observed, checked and controlled by a cluster control system consisted of center control sub-system, cycle control sub-system of concrete tray, and curing sub-system of concrete product. The study of the large-scale intelligent PC external wall panel mixing production line helps promote our production technology of the concrete products and drive the development of our construction industry.

1. Foreword

The complete set of equipment technology for PC component production is one of the key technologies of construction industrialization in the world at present. It takes prefabricated component production, prefabricated construction as the mode of production, integrated design, production and construction as the whole industrial chain. As compared with traditional architecture, it improves the quality of building products, and achieves the maximum value of building energy efficiency, environmental protection and life cycle. It is an internationally recognized technology industry of sustainable development [1, 2].

In China, Vanke is one of the earliest real estate companies which took housing industrialization as an important strategic goal and put industrial technology into commercial development. In 2008, Shenyang Vanke cooperated with Shenyang Modern Construction Industry Co., Ltd of Yatai Group. A three-story industrial test building was built in Vanke Charming City. After the successful cooperation, Yatai Group introduced a set of automatic production lines for PC components, the main equipment of which was provided by Hebei New Earth Machinery and Electrical Manufacturing Co., Ltd. [5]. China construction companies, Shenyang Wanrong Modern Construction Enterprise Co., Ltd., Northern Heavy Industry Group Co., Ltd., and some large domestic enterprises and real estate companies also build and use the concrete factory production line. After nearly ten years of development, both component users, component production units and component production equipment suppliers have accumulated rich experience in the field of housing industrialization. However, as compared with the developed countries such as Japan, there is still a big gap [6-10] in our
country. As far as China is concerned, there are still some problems, such as low prefabrication rate, poor production quality, simple production equipment and low degree of intelligence, etc. High intelligence complete set technology and equipment of the production line still rely on import [11-14]. Therefore, we are still facing problems of digestion and absorption, and then independently develop the large-scale intelligent PC component production line that is suitable for China's national conditions.

Figure 1. Flow chart of PC external wall panel mixing production line.
On the basis of participating in the production of large-scale intelligent PC external wall panel mixing production line, this paper analyses and interprets the complete process, key components system and working principle of the production line, which is used in the production of large-scale intelligent PC external wall panel mixing production line by the Northern heavy Industry Group Co., Ltd. The research in this paper not only provides the basis for the domestic design and manufacture of large-scale intelligent PC external wall panel production line, but also provides practical guidance for the further study of the key parts of the production line.

2. Technology of PC external wall panel mixing production line
The main products of domestic assembled integral shear wall structure system are external wallboard, internal wallboard, composite floor slab, balcony board, air conditioning board, staircase, and so on. External wallboard, internal wallboard, composite floor slab can be mass produced on the mixed automation production line. The process technology of PC external wall panel mixing production line mainly includes: product line design, layout of process equipment configuration and drawing of process flow chart; determine the composition of production equipment, main parameters, workshop layout and water, electricity, gas supply requirements; according to the layout of equipment in the workshop, plant design requirements, civil construction requirements, etc. Figure 1 is the flow chart of PC external wall panel mixing production line.

The PC external wall panel mixing production line is a comprehensive multifunctional production line, which can produce different sizes and different types of board components. The main production parts of PC external wall panel mixing production line include: moving device and carriers, cleaning spraying and marking system, placing concrete and vibrating system, surface treatment system and curing system, as shown in figure 2.

2.1. Moving device and carriers
PC external wall panel mixing production line is a continuous annular production line, which is a set of complete logistics system, in which the moving device of the production line includes moving wheels, driving wheels and transversing devices, and the carriers of the production line is the mould platform.

The moving wheels and the driving wheels are fixed in the production line. The moving wheels are mainly used to support the mould table. In general, there are more than five pairs of moving wheels under each die stand at the same time (depending on the size of the drive wheel, the load of the mould table). The driving wheel is used to drive the mould table, so in the production line, one drive wheel is placed every few moving wheels. Ensure that at least one pair of driving wheels are driven under the mould table. The moving wheel and the driving wheel can only cause the mould table to move in one direction, that is, the longitudinal direction. In order to make the mould table move horizontally, a ferry vehicle must be used. The transversing device is the equipment that carries the platform transverse and realizes the switching line track. The transversing device is used in pairs, and it is shown in figure 3.
The mould table is the carrier of the PC external wall panel. The whole process of placing, vibrating, shaping and curing the concrete members of the slab type is carried out in the mould table. A production line needs dozens or even hundreds of mould tables according to its production capacity. The mould table has a tool type. Universal, fluidity features, can produce different sizes of wallboards and floors, and can produce a variety of building component products.

2.2. Cleaning spraying and marking system

Cleaning spraying and marking system is the production preparation system, which prepares for the production of PC components, including: cleaning machine, spray machine and marking machine.

Cleaning machine is fixed in the cleaning station, used for cleaning surface of the mould table. The front end of the cleaning machine is equipped with scraper. The function of the scraper is to remove the large concrete attachment. The height and angle of the scraper can be adjusted to avoid the damage caused by the scraper to the surface of the mould table during the cleaning process. A rolling brush is arranged at the back of the mould table sweeper for cleaning local attachments. The rolling brush is driven by the motor and rotates around. The concrete residue is removed by the tangential force formed by rotation. The height of the rolling brush is adjustable. According to the use of rolling brush, it needs to be replaced regularly. A mobile crap box is arranged at the bottom of the mould cleaning machine for waste collection and disposal. The crap box can move along the track below it to facilitate the rapid cleaning of waste. The cleaning room is equipped with negative pressure suction and dust removal device to control the discharge of fly dust and ensure no dust in the work station.

After the marking machine is arranged on the mould table cleaning machine, most of the marking machines used in the current production line of prefabricated components are numerical control marking machines, which can quickly and accurately draw the position of the edge die embedded parts on the bottom die and improve the placement of the edge die. It is a matter of accuracy and speed of embedded parts. NC marking machine directly inputs information from U disk or production data line, automatically draws points and lines on mould table as required, draws the external outline and characteristics of components to mould table according to drawing requirements. Ink jet printing is used in the marking mode, and the side die mounting position will install the mould strip according to the drawing line datum to prepare the concrete around construction. The marking machine moving system is controlled by servo controller, the line is controlled by a servo controller.

The spraying machine is arranged after the marking machine, spraying the mould release agent on the mould table, so as to facilitate the smooth release of the maintained components. When the mould table moves to the spraying machine station, the spraying machine starts, and the nozzle and brush roller of the spraying machine are adjusted to an appropriate height through a lifting device. According to the instruction, the nozzle corresponding to the area where the prefabricated components are placed is opened, the brush roller starts to rotate, the nozzle is sprayed, the brush is driven by the motor, and the spray area of the mould table is forced to be coated evenly. According to the movement of the spray gun, the Spraying machine is mainly of two types: Rotary spraying and reciprocating spraying.
Rotary spraying is mostly used for special-shaped components or small area spraying, while reciprocating spraying is mainly for prefabricated buildings. Board, prefabricated wall panels and other large area spray. The spraying machine is shown in figure 4.

![Figure 4. Structure of spraying machine.](image)

1-Spray device; 2-Brush roller device; 3-Waste liquid recovery unit; 4-Lifting device

2.3. Placing concrete and vibrating system
Placing concrete and vibrating system are the key links of the production line. The main equipment includes concrete placing machine and vibrating machine. Whether the concrete placing machine is uniform or not, whether the vibration is dense or not, it determines the quality of the components. In the production line, the concrete placing machine station coincides with the dense vibrating station, and the efficiency of the production line is improved by using the method of vibrating while placing.

![Figure 5. Concrete placing machine and simulated placing concrete.](image)

The concrete placing machine is used to place concrete evenly and quantitatively into the mould of concrete members. In the production line, the concrete placing machine is required to have plane two coordinate motion control and vertical hopper lifting function. Due to the need of the production line,
it is required to have a high degree of automation of the feeder. According to the drawing size and the design thickness, the uniform concrete placing machine can be controlled by the program, and the control system has a computer interface. The control system has a computer interface, which is easy to realize the function of reading drawings and data directly from the central control room computer system. The concrete placing machine requires fast concrete placing machine speed and easy operation, and its moving speed can be adjusted without electrode. The concrete placing machine can be manually controlled and automatically controlled. The concrete placing machine and simulated placing are shown in figure 5.

The main function of the vibrating machine is to remove the air and excess moisture from the concrete and to make the edges or edges of the concrete to be formed accurately, and then to obtain a high quality prefabricated component product, as shown in figure 6. There are two forms of vibration table commonly used in precast component production line: horizontal vibration, including horizontal ring and X, Y directional vibration, combined vibration, including horizontal ring and X, Y horizontal vibration, and Z direction vertical vibration. The exciting force in the process of vibration is mainly obtained by the moment of inertia produced by the vibrating motor or the eccentric body driven by the motor, in which the frequency and amplitude of the vibrating motor and the magnitude of the moment of inertia can be set according to the requirements of PC component products.

![Vibrating machine](image)

**Figure 6.** Vibrating machine.
1-Vibrating frame; 2-Double fixed bearing; 3-Synchro belt system;
4-Moving wheel; 5-Hydraulic system

2.4. **Surface treatment system**

Surface treatment equipment includes a vibration smoothing machine, polishing machine and napping machine.

The effect of the vibration smoothing machine is to smooth the concrete surface in the template, and its structure is shown in figure 7. The vibration smoothing machine can flatten the plate components before and after, at the same time, the trolley moving device is mounted on the cloth machine or its own cross beam to move longitudinally. By moving in the horizontal direction and the longitudinal direction, the complete covering of the components on the mould table can be realized. In order to reduce the harm of vibration to the equipment, the leveling device should be used to reduce the damage to the equipment. Generally, the two-stage damping method, such as the joint damping of rubber shock absorber and rubber pad, effectively solves the vibration problem between the vibrating rod and the vibration frame.
The napping machine is mainly used in the production of superimposed floor. After the vibrating process, when the preform of the superimposed floor is not solidified, an isometric shallow ditch is drawn, which makes the surface of the superimposed floor rough and increases the roughness of the surface. When the laminated floor plate is loaded by the laminated floor through the drawing machine, the unsolidified preform is contacted at the bottom of the isometric drawing plate of the drawing plate group, and the preform moves forward with the mould table, and the resistance to the drawing group and the gravity of the drawing group itself make the drawing sheet form a certain swing angle. The bottom side of the right angle on the surface of the prefabricated parts with equal spacing groove. The napping machine is simple in structure and easy to maintain. It can save energy by using gravity and mould table.

The polishing machine is placed in front of curing kiln, and its function is to achieve the highest degree of smoothness of visual facet of precast concrete components. It consists of a leveling disc for rough leveling and an electric mud knife for fine leveling. The mud knife directly touches the surface of the prefabricated member, and the head of the mud knife is connected to the adjustable guide rail
side plate through a threaded rod to form a moving track up and down. The clay knife head is fixed on the wing arm and polished according to the surface quality of concrete. The head of the mud knife can be adjusted up and down, and the angle of the floating blade can be adjusted mechanically. At the same time, the speed of the rotary machine of the mud knife can also be adjusted. The polishing machine is shown in figure 8.

2.5. Curing System

The curing System is another key link in production line, which is mainly composed of curing kiln and stacker.

The curing kiln is a vertical three-dimensional silo structure, each containing a temperature control device and a humidity control device, which can automatically control temperature and humidity, as shown in figure 9. The temperature curve of heating-constant temperature-cooling is used to avoid cracks or other defects affecting the strength of the members. The curing kiln is designed for stacking, the lowest layer height is realized, the kiln body is small, the building elevation is greatly reduced, the building construction cost is saved, the maintenance volume is reduced, and the maintenance energy consumption is saved. Kiln body insulation board and door plate high temperature resistance, fire resistance, flame retardant, good insulation effect. Kiln with steam heating pipe, humidification pipe, and ventilation piping.

![Figure 9. Curing kiln.](image1)

![Figure 10. Stacker.](image2)

Stacker is a lifting transportation equipment which can store the cast concrete components in the corresponding hole of steam curing kiln. Stacker is shown in figure 10. The stacker is a highly automatic equipment. The position of kiln door is automatically located, the time of entering and leaving the kiln is recorded automatically, and the kiln door is opened efficiently and smoothly, and the position of mould table is automatically fixed and locked before entering and leaving the kiln. In safety protection, there are marching, lifting, opening and closing, in and out of the kiln must have a safe interlocking function, the operation of sound and light alarm device. The winch mechanism is equipped with anti-skipping detection to ensure the safety and reliability of the mechanism. The quality of PC components and the production capacity of the whole production line are directly affected by the performance of the stacker and the level of technical level. The structure of the stacker can be divided into the upper track hanging type and the bottom track moving type, which can travel along the track direction. The hoisting device can make the platform body and the roller trolley move along the vertical direction, so that the stacker can push the components of the different openings of the stacker.

3. Control system of mixed production line for PC exterior wall panel

According to the site layout and functional area classification of the PC outer wall panel hybrid production line, the control system of PC outer wall board hybrid production line is divided into three
basic subsystems: central control subsystem, mould table circulation subsystem, component maintenance subsystem, and so on. The production line with high degree of automation uses a manipulator to carry on the side touch cleaning and the setting, the reinforcement net placement and the lattice beam placement. Therefore, the control system also includes the edge die cleaning and placing subsystem, Steel mesh placement subsystem and lattice beam placement subsystem [15].

The central control subsystem mainly used for the management and control of the production process of precast concrete components. The specific functions are as follows: effective arrangement and control of the motion process of the mould table, optimization of all operation data and transportation process. At the same time, the automatic detection and transmission of fault information can be realized. The initial data is transmitted to the monitoring system for preprocessing, and the processed data is transmitted to each independent device in a precise time. The equipment is produced on the basis of received data. Throughout the process, production-related data are stored and analyzed for use in other production plans and ERP System control.

Mould table circulation subsystem is mainly used to control the movement of each equipment on the production line. The control subsystem consists of one master station, one input and output module slave station. Several frequency conversion drive slave stations (corresponding to each equipment frequency conversion debugging requirement) and one pneumatic valve slave station. The system controller runs three PLC units, which are respectively used to control transporting and fixing mould table, moving transvers device, dumping component, vibrating concrete, smoothing component, opening and closing curing kiln door, and placing concrete, and so on.

The central controller of maintenance subsystem adopts industrial computer. Its operating interface is very friendly, which is convenient for man-machine interaction and suitable for field use. The operating system has a perfect function and can set the parameters of temperature and humidity. It can record the temperature curve or report in real time. It has the function of printing the data report and the playback of the record temperature. The control cabinet is composed of PLC system, industrial temperature controller, temperature sensor, humidity sensor, etc. Multi-channel digital and analog signal input module. After receiving the process parameters of the upper computer, it can form a closed-loop control system, according to the arrangement in the maintenance kiln multi-point. According to the temperature sensors arranged in the kiln, the temperature signals of different positions are collected and the steam valves are automatically adjusted to form a temperature environment in which the temperature gradient is required in the curing kiln. At the same time, the spray valve can be sprayed or ventilated automatically according to the sensor signal.

The edge mould cleaning and placement subsystem, the steel mesh placing subsystem, the lattice beam placing subsystem. Each of the three subsystem controllers runs one PLC. The edge die cleaning and placing subsystem PLC unit mainly completes the cleaning of the edge die and the bottom die of the die. The placement of edge molds, And put the cleaned edge die into the edge die library and take out. The steel mesh placement subsystem PLC unit completes the finished production and stores the steel mesh into the mould table. The lattice beam placement subsystem mainly completes cutting the finished lattice beam according to the requirements. And put into the mould table.

4. Comparison and discussion
At present, China's domestic PC component production equipment is generally not automated, with excessive manual participation and serious concrete waste. Foreign imported equipment has a high degree of automation and less manual intervention. However, due to the different design concepts of PC board components at home and abroad, most of the foreign PC components are of standardized design, and the steel bars do not leak out. This makes automation easier. The domestic PC components are mostly personalized design, and the leakage of steel bars leads to the inability of mold design to be standardized. The molds can only be placed by hand. At the same time, the mold life cycle is short and waste is serious; due to leakage of component steel bars and embedded parts, surface treatment equipment cannot work normally, and manual intervention is often required, or manual treatment is not required by surface treatment equipment. The concrete placing machine does not reach the actual
automatic fabric, the placing concrete accuracy is not high, often requires secondary placing concrete, resulting in decreased placing concrete efficiency. Therefore, to make the PC board production line process and complete sets of equipment automation intelligent, and in line with China's national conditions, but also need to invest considerable energy.

5. Conclusion
(1) The PC external wall panel mixing production line can be systematized, intelligent and automated. The work links of each component part have very strong coupling in mould table carrier moving, mould table cleaning, marking, placing and vibrating concrete, smoothing, polishing, napping and the whole process of the curing and storage. Under the action of cluster control system, all key parts have good coordination, and the high quality large concrete prefabricated parts can be produced efficiently.

(2) As compared with the traditional concrete processing technology, large-scale intelligent PC external wall panel mixing production line has the following characteristics: high level of process equipment, complete semi-automatic or automatic control, less operation workers, small error caused by human factors, high processing efficiency. Furthermore, its subsequent scalability is strong, and can be changed and expanded according to requirements.

(3) The research and development of large-scale intelligent PC external wall panel mixing production line break the dependence of our country on foreign concrete production technology and equipment and inject continuous power into the domestic concrete factory production. It is of great significance to improve the production efficiency and resource utilization ratio.

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