Research status and development trend of concrete spiral distributor

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Abstract. Concrete distributor is one of the key equipment for the industrial production of concrete product parts. Its performance directly affects the product quality and production efficiency of precast concrete components, which in turn affects the level of architecture industrialization of China. At present, the domestic concrete distributor has a low degree of automation and a simple mechanical structure. There is too much manual intervention in the production. It is impossible to achieve a real automatic distribution. Also, BIM data cannot be shared with the control system, resulting in low production efficiency. This paper summarized these problems which are in the context of big data, internet of things and intelligence, and proposed the upgrade ideas for precast concrete components production equipment. In order to break through the bottleneck that restricts the stability, refinement and intelligent development of precast concrete components distribution. The research and exploration in BIM data analysis mechanical structure optimization and control system upgrade were conducted. Then the overall development of mechanical equipment that meets construction standards of China will be promoted.

1. Introduction

With the proposal and implementation of Made-in-China 2025 [1], the concept of assembly building [2] has become a hot topic in the construction industry. The Guidelines on Developing Assembly Buildings are issued by the State Council, that pointed out that in the future. We will vigorously promote Assembly Buildings which is making up 30% of the new building area. As a modern building technology of energy saving, high efficiency and environmental protection.

Assembly building is gradually accepted by major countries all over the world which puts forward higher requirements for building industrial equipment [3-5].

Concrete distributor is the core equipment of precast concrete components production line in assembly building (see figure 1). Its performance will directly affect the precision and production efficiency of precast concrete components. The new generation of artificial intelligence is represented by big data and in-depth learning, will have a subversive impact on manufacturing industry which will be an inevitable trend for factories to realize information and intelligent production in the future.
The research of concrete distributor in developed countries is early. Users, manufacturers and designers are represented by the famous international enterprises such as German Ebawe Company, Avermann Company, Vollert Company and Soma Company. They are mainly studied the modern technology of scientific use, optimum design and intelligent control of concrete distributor. Ebawe's concrete distributor has a disposable width of 3000 mm. It can extract and transform the drawing information of concrete product parts, transmit it to the distribution system before production, also guide the distribution path planning and realize automatic and accurate distribution. The concrete distributor of Vollert Company has two ways: screw forced discharge and star-shaped axle-slip valve discharge. They can adapt to different concrete consistency and realize manual or automatic control functions. Soma has studied the seamless connection between the production information of precast concrete components and Building Information Modeling (BIM). It can optimize the data processing ability of the main control computer and developed the equipment interface for NC data exchange and feedback.

In China, the designers and the researchers of concrete distributor mainly study the mechanical structure, automatic control and operation efficiency of the distributor. At present, the distributor can be controlled manually according to the size of the components only through manual intervention.

Most domestic concrete distributors can be realized:
- automatic weighing and judging whether feeding is needed;
- the hopper of the distributor can be vertical lifting, adjusting the height of the material according to the thickness of the product. Also adjusting the distance between the material receiving and the feeding trolley to prevent concrete splashing.
- Manual and wireless control mode are adopted to operate the distributor. High degree of automation can also achieve interlocking control with feeding trolley, die table walking and vibration equipment etc, that can ensure that the production process of the distributing station is reasonable and reliable. However, there are many phenomena such as inaccurate blanking quantity of concrete distributor and excessive manual participation, which have not really realized automatic and accurate distribution.

It is obviously that there is still a big gap between domestic concrete distributors and developed countries’ automation and intellectualization. While foreign equipment can achieve refined distribution, but it cannot meet the domestic production status (such as the problem of steel bar). At present, the technologies of data exchange between the distributor system and BIM system which are path planning before concrete product parts manufacturing, precise control of distributor and intelligent production of concrete product parts, have become the key technologies that restrict the development of concrete distributor towards modernization, automation, precision and intellectualization.
2. Structure and operation principle of concrete distributor

2.1. Mechanical structure and operation principle of concrete distributor

The concrete distributor includes the distributing system and the walking system. The distributing system includes hopper, scatter device, spiral conveying appliance, gate assembly and bottom plate assembly.

The walking system includes steel structure bracket, trolley walking device and cart walking device. The walking device of the cart is a frame structure which can move forward and backward in the Y direction. It is driven by dual variable frequency motor. Also, its parallel track acts as the wheel tread of the walking device of the trolley.

The walking device of the trolley can move along the X direction on the walking device of the cart. It is generally driven by a single variable-frequency motor. The hydraulic cylinder is vertically mounted lifting. It can realize Z direction movement of the hopper. A weighing sensor is installed on the frame of the hopper and trolley walking so that it can device to monitor the concrete weight in the hopper.

The hopper is a component which is used to undertake concrete and complete the distribution. The dispersing device mixes the concrete in the hopper forcibly. In this way it can ensure the good fluidity of the concrete.

The spiral conveying appliance uses screw to discharge material forcibly. It arranges multiple screw rods in the width of material distribution. Each screw is driven by a separate variable frequency motor. It can be driven and controlled speed independently so that meet the requirements of fine distribution. The structure of the concrete distributor shows in figure 2.

The working process are as follows: concrete is dumped into hopper of distributor through torpedo tank; starting of scatter device; opening of gate corresponding to distributor area according to component shape; starting of screw drive motor to distribute material.

Through the movement of the walking device of the cart and trolley, the concrete is evenly laid on the die table. The switch of the gate and the start and stop of the screw motor completed during the traveling process. After the distributing finished. In order to prevent the residual concrete from solidifying inside the hopper, the bottom plate assembly is opened. Also, the hopper is quickly washed.

![Figure 2. Structure of concrete distributor.](image)

2.2. Control system and operation principle of concrete distributor

The computer is connected with the basic automation controller. The instructions are downloaded to the controller through PLC programming. The controller sends instructions to the variable frequency motors that can drive the cart and the trolley to the starting point of the material distribution.
Then the controller generates instructions to start the scatter motor and sends instructions to open the gate of the corresponding material distribution area. Finally it drives the variable frequency motor of the corresponding spiral conveying appliance and also distribute concrete material. A weighing sensor is installed at the joint of hopper and trolley that can detect the concrete weight in hopper. The weighing sensor transmits data with the PLC controller. When the concrete content in the distribution equipment is insufficient, the PLC controller will send out alarm instructions to remind the operator.

Distribution control system belongs to primary control (see figure 3). In the production, it is impossible to realize the operation of automatic control equipment. It needs to be controlled by human through external wireless remote control for the distribution. According to the size information of the component, the operator can determine the distribution path and the numbers of openings by himself.

![Figure 3. Distribution control system.](image)

3. Research direction and development trend of spiral distributor

As a big construction country, China is moving towards strongly. The extensive construction mode needs to be upgraded and transformed [5]. It needs to be supported by industrialization and informatization as the core. The full life cycle of the product, the digitization of the entire manufacturing process and the modular integration of ICTs will result in a production model of highly flexible, personalized products and services. Under this new production mode, the assembly-type construction equipment will be promoted for information fusion and intelligent production. The spiral distributor is the core equipment in the production line of precast components. The importance of product optimization and upgrading is self-evident.
3.1. Optimization and upgrade of the mechanical structure of the spiral distributor
The wheel-rail structure is adopted in the walking device of the distributor traditionally. The walking wheel driven by the variable frequency motor that travels along the track in the direction of X and Y. Slipping and creeping will inevitably occur. The precise positioning cannot be achieved, resulting in inaccurate blanking point and uneven blanking volume. Adding a rack and pinion mechanism to the cart and the trolley. Using the servo motor to drive. Changing the gear to the active part. Driving the walking wheel to walk on the track. Walking wheels play only support and guide roles, gear and rack drive which can effectively avoid skidding, creeping and other problems. The rotor speed of the servo motor is controlled by the input signal which can respond quickly and has high positional accuracy. It can also ensure the smooth running of the low speed and heavy load for the cart and trolley.

The spiral conveying appliance is driven by a variable frequency motor. The discharge amount is adjusted by frequency conversion speed regulation. But there is a gap between the actual speed and the theoretical speed of the screw, resulting in inaccurate discharge. Especially in the later stage of screw wear. The difference between the theoretical discharge amount and the actual discharge amount is larger, it cannot achieve fine distribution. The relationship between screw blade diameter, screw shaft diameter, pitch, screw speed, power consumption and wear are vague. It needs further study and optimization. Wear-resistant material is needed for the helical blade in the design. It can effectively increase the service life of the screw. The encoder is added to each screw variable-frequency motor so that the motor can achieve closed-loop control in speed regulation. It can keep the actual speed consistent with the theoretical speed. The screw is optimized by discrete element method, computational fluid dynamics, lightweight structure design and experimental method. The power consumption and wear are minimal when the materials output is satisfied then. In the later stage of screw wear, the screw speed is compensated by predicted life model that ensure the blanking amount stable.

3.2. Optimal upgrade of control system of spiral distributor
Usually the control strategy of the distributor control system is simple. There is even no control strategy. It is impossible to achieve intelligent and accurate distribution. Component BIM information cannot be transmitted to the control system through the interface, which requires manual conversion and low efficiency. Lacking of positioning sensors, the distributor cannot locate quickly and accurately. The control system has no prediction model of the materials output and cannot accurately control the materials output; in the later stage of screw wear. There is no rotational speed compensation control model to ensure uniform materials output. Heavy sensors become detection components which do not play a role in the control system. Lacking of production process monitoring and prediction result in the distributor cannot operate reliably and accurately.

On the basis of the lower computer programming controller, the upper computer industrial control system is added to the distribution control system. The programming controller mainly realizes the multi-direction motion control of the distributor, the control of the spiral conveying motor and the control of the gate cylinder. The function of the upper computer reads the graphical data of the components parsed by BIM, divide, process the distributor area in the upper computer software and transmit the distributor area data to the PLC controller. The controller controls the work of the executing mechanism [6-8]. The encoder added to the screw motor and the weighing sensor provided by the distributor are used to collect the signals in the process of distribution. The collected data are fed back to the control system to form a closed-loop PID regulation. The programmable controller is implemented in the form of main program calling subroutine, which is convenient for system debugging and upgrading. A control algorithm is added to the program to ensure the stability of the motor starting and stopping stages.

BIM is an important technology to promote the development of new industrialization and construction industry informatization [9]. Based on BIM technology, the BIM-compatible information parsing interface is designed by using data compatibility extraction, symbol recognition of building components and topological relationship tree building method. The component is identified by vector graph symbols so that the component has its own "ID number". The component data parameters are
transmitted to the distribution control system through the corresponding interface. The optimization theory is adopted in the system in order to the generation and calculation of the distribution path. It can realize the automatic distribution path planning and guide the automatic distribution of the distributor. The visual control interface of the distributor is shown in figure 4.

For the automated intelligent distribution system, the detection module is indispensable. The component thickness information and positioning information of the distributor need to be extracted and fed back through the detection technology. In the process of distributing material, the pre-calibrated position of the distributor can be measured by laser displacement sensor. The thickness information of the component can be measured by ranging method. The information can be fed back to the control system. Through the feedback information, the position compensation and quality compensation can be carried out by the control system. It ensures the distributor can deliver material accurately.

![Visual control interface of the distributor](image)

Figure 4. Visual control interface of the distributor.

Before the distribution production, the concrete distribution machine is driven by the distribution cart and the distribution trolley. It locates the pre-production starting such as the end point of the edge touching. According to the BIM analysis of the concrete component information to calculate the required concrete quality, distribution path, spiral speed and other production process information for distribution production. The distribution trolley is equipped with the distribution machine. According to the calculated distribution path, it moves in the corresponding position in the side touch on the distribution crane beam. At the same time, the screw of each distribution port rotates at a certain speed. It pushes out the concrete in the hopper. Finally pour it into the distribution area surrounded by the side formwork of the bottom formwork tray. When the distribution trolley moves to the side mold of the door and window hole, the corresponding screw stops rotating. The prediction quality of concrete materials transported by screw. The quality is detected by the weighing sensor of the distributor. The quality of materials is analyzed by BIM information are applied to the distribution control system that achieve closed-loop accurate discharge.

4. Conclusion
With the rapid development of computer technology and artificial intelligence technology, driven by the national manufacturing 2025 policy. The era of intelligent production is on the way. Digital, automated, refined and intelligent distribution technology can liberate the labor force to the greatest extent, realize automatic, accurate and stable operation of the distribution machine. Also, it improves production efficiency comprehensively.
Based on the optimization and upgrading of the mechanical structure of the distributor. To meet the requirements of the automation control system, improve the accuracy and stability of the distribution and upgrade the distribution control system. The control system can plan the distribution path according to the BIM analytical data and carry out automated production. The application of detection and positioning technology can guide the automation production by real-time feedback signals. It also ensures the accuracy of the distribution.

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