Technical White Paper on Industrial Intelligent Coating Line Technology and Applications

Coating is a critical process in industrial manufacturing that determines product appearance, corrosion resistance, and service life. As the manufacturing industry upgrades toward automation, intelligence, and green development, traditional manual coating modes can no longer meet the comprehensive requirements of high efficiency, high quality, environmental compliance, and safe production.Industrial intelligent coating lines integrate modules such as spraying, drying, leveling, conveying, control, and exhaust gas treatment to form continuous, standardized, and intelligent closed-loop production systems, widely applied in machinery, automotive, steel structures, home appliances, hardware, building materials, rail transit, aerospace, and other fields.

This white paper provides comprehensive elaboration on the system composition, process principles, equipment configuration, planning and design, environmental supporting facilities, installation and commissioning, operation and maintenance, and typical industry applications of industrial intelligent coating lines.It offers clear, professional, and actionable technical references for enterprises in production line planning, equipment selection, process upgrading, and environmental transformation, helping enterprises achieve integrated goals of quality improvement, efficiency enhancement, cost reduction, emission reduction, and safety in coating production.

1. Core Value and Application Scenarios of Intelligent Coating Lines

Intelligent coating lines integrate spraying, leveling, drying, cooling, conveying and other processes into continuous production lines. Through standardized processes and automated control, they significantly reduce labor dependency and improve coating uniformity, adhesion, and appearance consistency, reducing rework and material waste. Overall production efficiency is far higher than traditional operating modes.

At the environmental level, intelligent coating lines equipped with enclosed spray rooms, exhaust gas purification systems, and waste heat recovery systems can achieve efficient paint mist treatment, VOC compliant emissions, and reasonable energy consumption control, meeting increasingly stringent environmental policy requirements. At the same time, the fully enclosed operation of the line effectively reduces solvent volatilization and dust dispersion, improves the working environment, and protects operators' occupational health.

Intelligent coating lines adapt to multi-variety, large-batch, or flexible production needs. From small hardware accessories and appliance shells to large construction machinery, steel structural parts, and automotive components, stable coating can be achieved through customized lines. Whether single-piece small-batch trial production or large-scale continuous production, they can provide stable and reliable solutions.

2. System Composition of Intelligent Coating Lines

Industrial intelligent coating lines are a highly integrated systematic equipment, mainly composed of pretreatment systems, coating systems, leveling and drying systems, conveying systems, electrical control systems, and environmental supporting systems.All modules operate collaboratively to achieve full-process automated operations.

The pretreatment system is responsible for oil removal, rust removal, dust removal, and passivation of workpiece surfaces to provide clean and uniform substrates for coating, which directly affects coating adhesion and corrosion resistance. Common configurations include spray pretreatment, grinding dust removal, blowing dust removal, etc., flexibly combined according to workpiece materials and process requirements.

The coating system is the core of the line, including manual coating stations, automatic coating machines, robot coating, and powder coating systems, which can achieve uniform film formation and controllable thickness. Equipped with high-precision spray guns, flow control, and air pressure adjustment, they ensure no missed spraying, no sagging, and no orange peel on complex workpiece surfaces, achieving dual excellence in appearance and performance.

The leveling and drying system provides a stable curing environment for coatings. The leveling section allows coatings to level naturally, improving surface finish; The drying section uses electric heating, gas, fuel and other heat sources, equipped with constant temperature control and hot air circulation to ensure rapid and uniform coating curing, improving production rhythm.

The conveying system handles continuous transfer of workpieces between processes. Common forms include overhead conveyor chains, roller lines, chain plate lines, and belt lines. The conveying system operates smoothly, accurately positions, and has adjustable speed, ensuring workpiece posture stability during coating, leveling, and drying processes without coating interference.

The electrical control system is the brain of the intelligent coating line. Using PLC and touch screen centralized control, it can achieve line linkage start-stop, automatic temperature adjustment, closed-loop conveying speed control, coating timing matching, fault alarm and recording, data monitoring, etc. It supports one-key startup, automatic operation, and fault self-diagnosis, greatly reducing operation difficulty and improving operational stability.

The environmental supporting system includes paint mist purification, exhaust gas treatment, exhaust and supply air, waste heat recovery, and other units, ensuring no odor, no dust, and no exceeding-standard emissions during production, meeting environmental inspection and safe production requirements.

3. Coating System Technology and Process Characteristics

According to processes, coating systems can be divided into two main directions: liquid coating and powder coating. Liquid coating lines are mostly used for workpieces with high appearance requirements and strong corrosion resistance needs. Powder coating lines have advantages of environmental protection, wear resistance, strong adhesion, and low cost, and are increasingly widely applied in industrial manufacturing.

Automatic coating uses reciprocating machines or robots for execution, with stable motion trajectories, uniform coating speed, and high film thickness consistency. Robot

coating features multiple degrees of freedom, strong flexibility, and offline programming capability, suitable for special-shaped parts, complex structural parts, and high-precision requirement workpieces.

Spray rooms adopt enclosed design, equipped with water curtain, water swirl, pump-free water curtain, or dry filtration devices to efficiently capture and treat paint mist, avoiding paint mist dispersion and polluting the workshop environment. The supply air system is filtered and purified to ensure a clean coating environment and reduce the impact of particles and impurities on coating appearance.

Intelligent coating systems support parameter storage, formula switching, and multi-variety flexible production, enabling rapid line change and reducing debugging time,

and improving production line utilization. Through precise control of spray gun flow rate, fan pattern, and atomization pressure, paint waste is reduced, coating utilization is improved, and comprehensive production costs are lowered.

4. Drying, Curing, and Heat Circulation Systems

Drying and curing is a key link to ensure coating performance. Intelligent lines use hot air circulation drying ovens with uniform internal air duct design, stable temperature field, and small temperature difference. They ensure synchronized curing of coatings on all parts of workpieces. Oven bodies use thermal insulation materials to reduce heat loss, improve thermal efficiency, and lower energy consumption.

Heat sources can be flexibly selected according to enterprise site conditions, including electric heating, gas heating, fuel heating, steam heat exchange, etc. Systems are equipped with high-precision temperature control modules that can perform segmented temperature control according to process curves, achieving automatic control of heating, insulation, and cooling to ensure coatings do not yellow, crack, or become brittle.

Some lines are equipped with waste heat recovery devices to recover and utilize heat from drying exhaust gas, further reducing energy consumption and achieving green and energy-saving production. Air curtains are installed at drying oven entrances and exits to reduce heat leakage and improve overall operational economy.

5. Conveying Line Types and Matching Scenarios

The conveying system determines line layout and production efficiency, requiring customized design based on workpiece dimensions, weight, shape, and output.

Overhead conveyor lines are the most commonly used form in the coating industry, suitable for hanging-type workpieces. They have small footprint, smooth operation, and can be arranged in multiple layers, suitable for large-batch continuous production. Roller-type and chain-plate-type conveyor lines are suitable for box bodies, plates, and large workpieces with strong carrying capacity and stable operation. Belt-type and mesh-belt-type lines are suitable for small precision workpieces with gentle operation and accurate positioning.

Intelligent conveying systems are equipped with variable frequency speed regulation, positioning stops, and accumulation functions, which can automatically adjust speed according to coating, drying, and cooling rhythms to achieve process rhythm matching. The entire line uses safety interlock; abnormal situations automatically stop to ensure equipment and personnel safety.

6. Line Planning, Design, and Selection Principles

Intelligent coating line planning requires comprehensive design based on workpiece characteristics, output requirements, site conditions, and process requirements. Workpiece size, weight, and material determine coating methods, oven dimensions, and conveying forms; daily output and annual capacity determine line length, station quantity, drying time, and conveying speed.

Process route design follows the logical sequence of pretreatment, coating, leveling, drying, and cooling to reduce detours and cross-contamination. Workshop layout needs to consider loading and unloading spaces, logistics passages, maintenance and repair spaces, and environmental equipment placement positions to ensure smooth logistics, convenient operation, and easy maintenance.

Environmental protection and safety must be incorporated into the preliminary design, including paint mist collection efficiency, exhaust gas treatment methods, explosion-proof electrical configuration, ventilation, firefighting, and emergency measures to ensure the line meets safety regulations and emission requirements.

Intelligence level can be configured according to enterprise needs, from semi-automatic lines to fully automatic robot coating lines, from centralized control to IoT remote monitoring, all can achieve customized construction, balancing practicality and investment rationality.

7. Key Points in Environmental and Safety Design

Coating production involves organic solvents, paint mist, and VOC exhaust gases. Environmental protection and safety are core contents of line design. Spray room enclosed design, equipped with efficient paint mist filtration devices, ensures no odor and no paint mist dispersion in the workshop. Exhaust gas treatment systems are configured according to concentration and airflow, using activated carbon adsorption, catalytic combustion, zeolite rotors, RTO, and other technologies to achieve stable compliant emissions.

The line electrical system is designed according to explosion-proof grades. Motors, control cabinets, lighting, and switches all use explosion-proof configurations to eliminate electrical spark risks. Emergency stop buttons, safety door interlocks, and alarm devices are installed throughout the line to ensure rapid response to abnormal situations.

Ventilation systems ensure air circulation in the workshop and reduce solvent concentrations. Firefighting, leak collection, emergency exhaust, and other configurations are complete, comprehensively improving production safety levels.

8. Installation, Commissioning, and Operation Maintenance

Line installation must be strictly executed according to standard processes of foundation construction, equipment positioning, structural assembly, pipeline connection, electrical wiring, and thermal insulation sealing. During commissioning, empty load operation, conveying linkage, temperature debugging, coating debugging, and exhaust gas treatment linkage are completed in sequence to gradually optimize parameters and bring the entire line to optimal condition.

Daily maintenance focuses on key components such as spray guns, nozzles, filters, conveyor chains, temperature control sensors, fans, and burners. Regular cleaning, lubrication, and calibration ensure equipment accuracy and operational

stability. Environmental equipment should be regularly inspected for ash removal and filter material replacement to ensure purification effectiveness does not degrade.

Establish equipment operation records to document temperature, speed, energy consumption, faults, and maintenance content for data analysis and predictive maintenance, extending equipment service life and reducing downtime risks.

9. Typical Industry Application Solutions

In the construction machinery and steel structure industries, large overhead coating lines can achieve continuous coating and drying of workpieces with strong coating corrosion resistance and uniform appearance, meeting outdoor long-term corrosion resistance requirements.

The automotive and parts industry uses robot coating + accumulation conveyor lines to achieve high-precision, high-appearance, high-efficiency production with strong consistency and low rework rate.

The hardware and home appliance industries use small automated coating lines with small footprint, fast rhythm, and flexible line change, suitable for multi-variety small-batch production.

Powder coating lines are widely used in furniture, building materials, and chassis cabinet industries with advantages of solvent-free environmental protection, wear-resistant and corrosion-resistant coatings, and lower comprehensive costs, becoming increasingly favored by enterprises.

10. Development Trends of Intelligent Coating Technology

In the future, industrial coating lines will develop toward higher levels of intelligence, flexibility, green development, and energy saving. Robot coating, visual positioning, online film thickness detection, and AI parameter optimization will gradually become widespread, achieving unmanned, high-precision production.

Line modularization and standardization levels will improve with faster delivery, simpler installation, and stronger scalability. Energy consumption will continue to be optimized, and technologies such as waste heat recovery, hot air circulation, and intelligent variable frequency will further reduce operating costs.

Environmental technology will continue to upgrade. Low-VOC processes, efficient exhaust gas purification, waste heat recovery, and zero-emission solutions will become mainstream directions, promoting comprehensive green transformation of the coating industry.

11. Conclusion

Industrial intelligent coating lines are core equipment for modern manufacturing to achieve high-quality, high-efficiency, and environmentally compliant production.Through systematic design, modular configuration, intelligent control, and standardized maintenance, enterprises can significantly improve coating quality, increase production efficiency, reduce comprehensive costs, and meet safety and environmental requirements.

This white paper provides comprehensive technical references and solution guidance for enterprises. Enterprises can customize the most suitable intelligent coating line solutions based on their product characteristics, production needs, site conditions, and policy standards. to achieve coordinated development of intelligent manufacturing and green manufacturing.