Technical White Paper on Industrial Dust Control Robot Automated Grinding System

As national environmental protection policies continue to tighten, regulations such as the Air Pollution Prevention and Control Law and Dust Explosion Safety Procedures have been fully implemented.Metal dust and particulate matter generated from industrial grinding, polishing, and deburring processes have become core pain points in environmental governance and safe production.Traditional manual grinding modes suffer from severe dust pollution, occupational health hazards, quality instability, low efficiency, and rising labor costs.They struggle to meet the comprehensive needs of modern manufacturing for upgrading, green development, and compliant operations.

The Industrial Dust Control Robot Automated Grinding System integrates industrial robot technology, intelligent force control technology, AI visual recognition technology, and efficient dust control technology.With 'source dust removal, precision grinding, zero dust diffusion, and high-efficiency intelligence' as core advantages, it achieves automated grinding processes, closed-loop dust control, andsolves traditional grinding's dust pollution, efficiency bottlenecks, and quality defects, becoming the preferred solution for surface treatment upgrades in environmental protection equipment, machinery, automotive parts, construction machinery, and other industries.

This white paper systematically discusses the technical principles, core structure, environmental advantages, performance indicators, selection logic, application scenarios, maintenance specifications, and industry trends of the Industrial Dust Control Robot Automated Grinding System. Drawing on GB16297-1996 Comprehensive Air Pollutant Emission Standards, GB/T3470 Environmental Protection Technology Engineering Specifications, and T/ZZB3917-2024 Robot Flexible Grinding System, it provides enterprises with professional technical references for system selection, engineering support, dust compliance, and cost optimization, helping enterprises achieve efficient grinding, dust compliance, cost reduction, efficiency improvement, and green development. technical references,

helping enterprises achieve the comprehensive goals of efficient grinding, dust compliance, cost reduction, efficiency improvement, and green development.

I. Technical Principles and Core Environmental Value

1. Working Principles

The Industrial Dust Control Robot Automated Grinding System uses a multi-axis industrial robot as the core execution unit, combined with an intelligent force control system, AI visual recognition system, and efficient dust collection and treatment device.Through preset programs or real-time visual scanning, it achieves automated, precision grinding of workpiece surfaces and closed-loop dust control. Its core workflow includes:AI visual scanning and modeling → intelligent path planning → constant force precision grinding → source dust capture → compliant emissions, with no manual intervention required, achieving synchronous closed-loop operation of grinding operations and dust control.

The system monitors grinding contact force in real-time through a 6-axis force sensor, dynamically adjusts robot posture and grinding pressure,achieving adaptive compliant grinding, avoiding insufficient or excessive grinding; meanwhile, the grinding end integrates a negative pressure dust port, capturing dust the moment it is generated.Combined with pulse filter cartridge dust removal, high-efficiency filtration, dust concentration monitoring, and other technologies,The efficiency improves to over 98%, thoroughly preventing dust diffusion and achieving fundamental dust pollution control from the source.

2. Core Environmental Value

Compared with traditional manual grinding, the core advantages of the Industrial Dust Control Robot Automated Grinding System focus on four dimensions: dust control, occupational health, energy efficiency, and quality stability. perfectly matching the green production and compliant operation needs of the environmental protection equipment industry.

In terms of dust control, the system achieves a dust collection rate of ≥98%, filtration accuracy of 0.3μm, and dust emission concentration of <1mg/m³, far below the GB16297-1996 Comprehensive Air Pollutant Emission Standards limits,

thoroughly solving the pain point of traditional grinding 'dust everywhere and severe pollution'; meanwhile, the system is equipped with real-time dust concentration monitoring and automatic alarm functions, ensuring continuous compliance of dust emissions and avoiding environmental penalty risks.

In terms of occupational health, the system achieves unmanned grinding operations, thoroughly isolating workers from high-concentration dust and high-noise environments, eliminating occupational disease risks such as pneumoconiosis and respiratory diseases, significantly reducing corporate labor disputes and safety hazards; the system operating noise is ≤75dB, complying with industrial enterprise noise emission standards, avoiding noise pollution to the surrounding environment.

In terms of energy efficiency, one robot can replace 3-5 skilled workers, achieving 24-hour continuous operation, grinding efficiency improved 3-5 times, and working hours reduced by 60-70%; intelligent force control and path optimization technology reduce abrasive consumption, improving abrasive utilization by over 40%; meanwhile, the dust control system uses energy-saving fans and automatic frequency regulation, making dust control equipment energy-saving by over 30%, significantly reducing enterprise operating costs during long-term operation.

In terms of quality stability, the system, through constant force control and precision trajectory planning, keeps grinding precision error stably within ±0.05mm, and surface roughness (Ra value) stably below 0.8μm. The good product rate improves from 85% for manual work to over 99%, thoroughly solving the problems of poor consistency and high rework rate in manual grinding.

II. Core Structure and Key Component Analysis

1. Overall Structure

The Industrial Dust Control Robot Automated Grinding System consists of six core parts: intelligent robot unit, intelligent force-controlled grinding unit, AI visual recognition unit, dust collection and treatment unit, workpiece positioning and conveying unit, and intelligent control unit. All units work collaboratively to achieve automated, intelligent, and environmentally-friendly grinding processes. The system design is scientific and reasonable, and can be flexibly designed and installed

according to enterprise production sites, workpiece specifications, and dust types. It meets the dust control and grinding needs of different working conditions.

2. Key Component Analysis

The intelligent robot unit is the core execution component of the system, using 6-axis/7-axis industrial robots with advantages of high flexibility, precise positioning, stable operation, and dust interference resistance. Repeated positioning accuracy ≤±0.05mm, capable of all-round, no-dead-angle grinding of complex curved surfaces and irregular structural workpieces. Robots use dust-proof sealed design with protection class IP66, suitable for harsh working conditions with high dust and high humidity; some high-end models use 7-DOF redundant robots, working radius up to 1.2-2.5m, covering large workpiece processing ranges.

The intelligent force-controlled grinding unit is the core for achieving precision grinding, consisting of a 6-axis force sensor, floating grinding head, and quick-change tool system. The 6-axis force sensor monitors grinding contact force in real-time with force control accuracy of ±0.5N. Through force/position hybrid control technology, it dynamically adjusts grinding pressure and posture, achieving adaptive compliant grinding. The floating grinding head uses pneumatic /electric drive, adaptable to various abrasives such as sand belts, grinding wheels, polishing wheels, and wire brushes, supporting dynamic force adjustment to avoid overload damage to workpieces. The quick-change tool system achieves tool changes in 30 minutes, significantly improving production flexibility.

The AI visual recognition unit is the system's 'intelligent eye', consisting of 3D laser scanning camera, visual processor, and AI algorithm module. The 3D laser scanning camera can real-time scan workpiece contours, generate high-precision 3D models, and automatically identify surface burrs, flash, and defects with recognition accuracy exceeding 98%. identifying workpiece surface flash, burrs, and defects with recognition accuracy exceeding 98%. The AI algorithm module is based on deep learning technology, The AI algorithm module supports automatic planning of optimal grinding paths, supporting no-dead-angle grinding of complex curved surfaces and irregular workpieces; simultaneously, it integrates workpiece positioning and

dimension detection functions, with collision detection coverage improving to over 96%, eliminating

The dust collection and treatment unit is the core guarantee of the system's environmental performance, consisting of source dust suction device, sealed dust removal room, pulse filter cartridge dust remover, dust concentration monitor, and automatic ash cleaning system. The source dust suction device is integrated at the grinding end. Using high-pressure negative pressure design, dust is captured the moment it is generated, with dust collection rate ≥98%. The sealed dust removal room adopts fully enclosed structure to prevent dust overflow; the pulse filter cartridge dust remover uses PTFE-coated filter cartridges with filtration accuracy of 0.3μm and dust removal rate ≥99%. The dust concentration monitor real-time monitors workshop dust concentration and issues alarms when limits are exceeded. The system uses pulse reverse-blowing technology to automatically clean filter cartridges, extending filter element life, and reducing maintenance costs by over 30%.

The workpiece positioning and conveying unit is responsible for automatic workpiece conveying and precise positioning, using belt conveyor lines, turntable conveyor tables, or heavy-duty ground rails. Positioning accuracy ≤±0.1mm, enabling continuous, automated grinding operations of workpieces. The conveying unit links with robots and control systems to achieve the entire process of workpiece loading, positioning, grinding, and unloading without manual handling, reducing errors and dust pollution caused by manual intervention.

The intelligent control unit is the system's 'brain', consisting of industrial PLC, touch screen, remote monitoring module, and data

acquisition system. The PLC supports multi-device linkage control and can preset various grinding programs to meet the

grinding needs of workpieces with different specifications; the touch screen supports parameter settings, program editing, operation monitoring, and fault alarm functions.

The module supports cloud data transmission and can achieve remote debugging, remote maintenance, real-time dust concentration monitoring, and filter element life reminders.

The data acquisition system records grinding parameters, dust concentration, equipment operating status, and supports production data analysis and optimization.

III. Core Performance Indicators

The performance indicators of the Industrial Dust Control Robot Automated Grinding System directly determine its dust control effect, grinding quality,

and operational efficiency. All indicators comply with national and industry-related standards,

and meet the dust control and grinding needs of the environmental protection equipment industry.

1. Dust Control Indicators

Dust Collection Rate: ≥98%

Dust Filtration Accuracy: 0.3μm

Dust Emission Concentration: <1mg/m³ (Compliant with GB16297-1996)

Dust Concentration Monitoring Range: 0-100mg/m³

Dust Concentration Alarm Threshold: 10mg/m³

2. Grinding Performance Indicators

Robot Repeated Positioning Accuracy: ≤±0.05mm

Grinding Force Control Accuracy: ±0.5N

Grinding Precision Error: ≤±0.05mm

Surface Roughness (Ra Value): ≤0.8μm

Good Product Rate: ≥99%

Grinding Efficiency: One robot can grind 30-150 workpieces per hour (adjusted according to workpiece size)

3. Operation and Safety Indicators

System Operating Noise: ≤75dB

Robot Working Radius: 1.2-2.5m

Abrasive Adaptation: Sand Belt, Grinding Wheel, Polishing Wheel, Wire Brush, etc.

Protection Class: IP66

Safety Protection: Explosion-proof, Leakage Protection, Overload, Emergency Stop, Dust Explosion Protection

System Service Life: ≥8000 Hours

Core Component Service Life: ≥15000 Hours

Failure Rate: ≤1%

IV. Product Classification and Applicable Scenarios

The Industrial Dust Control Robot Automated Grinding System can be divided into three major categories according to grinding methods, robot models, dust types, and application scenarios. All categories are suitable for dust control and grinding needs of the environmental protection equipment industry and can be flexibly selected according to specific enterprise working conditions.

1. Constant Force Precision Grinding Robot System

Core uses 6-axis force control technology and AI visual recognition, suitable for precision workpieces, complex curved surfaces, and high-precision grinding of irregular structural workpieces. Applicable to precision components of environmental protection equipment, fan blades, irregular pipes, precision instruments, automotive parts, aerospace parts, etc., capable of surface polishing, deburring, trimming, grinding, and other processes. High precision, excellent dust control effect, dust collection rate ≥98%, grinding precision error ≤±0.05mm, stable quality, good product rate ≥99%.

2. Heavy Workpiece Dust Control Grinding System

Uses heavy-duty industrial robots and large-flow dust collection devices, suitable for rough grinding, deburring, rust removal, and polishing processes of large and heavy workpieces. Applicable to environmental protection equipment shells, boxes, large castings, construction machinery, ship parts, heavy machinery, etc. This

system has large robot load and wide working radius, covering large workpiece processing ranges; strong dust collection capability, equipped with large-flow pulse filter cartridge dust remover, dust emission concentration <1mg/m³, thoroughly solving dust pollution problems in heavy workpiece grinding.

3. Integrated Dust Control Grinding Production Line

Consists of multiple robots, automatic conveyor lines, sealed dust removal room, dust treatment system, and drying system. Applicable to large-scale, standardized workpiece batch grinding production, such as environmental protection filters, purification equipment shells, castings, die-castings, hardware parts, etc.

Multi-workpiece simultaneous grinding with high efficiency, compliant dust control, and stable quality can significantly reduce labor costs and improve production standardization levels, meeting the large-scale production needs of large environmental protection equipment enterprises.

V. Industry Application Scenarios

The system can be widely applied in environmental protection equipment, machinery manufacturing, casting processing, automotive parts, construction machinery, aerospace, shipbuilding, hardware processing, medical devices, and other industries, especially suitable for scenarios with severe dust pollution, strict environmental requirements, complex workpieces, and high precision requirements.

1. Selection Logic and Adaptation Principles

The selection of the Industrial Dust Control Robot Automated Grinding System requires comprehensive consideration of enterprise dust control requirements, workpiece specifications, grinding precision, production scale, dust types, and other factors, following the principles of 'dust compliance, precise adaptation, economic rationality, and high energy efficiency' to avoid dust non-compliance, cost waste, and quality instability issues caused by selection errors.

2. Selection Based on Dust Control Requirements

For regions or industries with strict dust emission control, priority should be given to models equipped with triple dust control systems: source dust suction + sealed dust

removal room + pulse filter cartridge dust removal, ensuring dust collection rate ≥98% and emission concentration <1mg/m³ to meet local environmental standards; for conditions with high dust concentration and large particle size, select large-flow dust treatment devices; for flammable and explosive dust (such as aluminum powder and magnesium powder), select explosion-proof dust control systems with dust concentration monitoring and explosion protection devices. equipped with dust concentration monitoring and explosion protection devices.

3. Selection Based on Workpiece Specifications and Grinding Precision

For regular-shaped, large-area workpieces (such as environmental protection equipment shells and boxes), select heavy workpiece dust control grinding systems with high efficiency and excellent dust control; for complex curved surfaces and irregular workpieces (such as fan blades and irregular pipes), select constant force precision grinding robot systems equipped with AI visual recognition and force control systems to ensure no-dead-angle grinding; for precision workpieces with high precision requirements (such as environmental protection instrument components), select constant force precision grinding robot systems with grinding precision error ≤±0.05mm and stable surface roughness; for small-batch, multi-specification workpieces, select flexible systems supporting quick product changes and program switching; for large-batch, standardized workpieces, select integrated dust control grinding production lines to achieve fully automated and large-scale production.

4. Selection Based on Production Scale

For small enterprises and small-batch production, select single-robot grinding systems with lower cost and flexibility;for medium-sized enterprises and medium-batch production, select 2-3 robot linkage systems balancing efficiency and cost; for large enterprises and large-scale production, select integrated dust control grinding production lines to achieve large-scale and standardized production, reducing long-term operating costs.

5. Selection Based on Dust Types

Metal dust (iron, steel, aluminum, copper, etc.): select pulse filter cartridge dust removal system with filtration accuracy of 0.3μm and dust removal rate ≥99%; non-

metal dust (plastic, rubber, wood, ceramic, etc.): select high-efficiency filtration + activated carbon adsorption system to ensure simultaneous treatment of dust and odors; flammable and explosive dust (aluminum powder, magnesium powder, etc.): select explosion-proof dust control system equipped with dust concentration monitoring, explosion-proof fans, and anti-static devices. explosion-proof dust control systems equipped with dust concentration monitoring, explosion-proof fans, and anti-static devices.

VI. Other Selection Key Points

During selection, system compatibility, maintenance convenience, after-sales service, and intelligence level should also be considered. Priority should be given to systems that can adapt to various abrasives, support remote debugging and maintenance, and are equipped with AI visual and force control technologies to reduce later maintenance costs; simultaneously, select suppliers with professional after-sales service teams to ensure rapid repair when equipment malfunctions,

1. Installation, Debugging, and Maintenance Specifications

Correct installation, standardized debugging, and scientific maintenance are key to ensuring efficient, stable, and environmentally-friendly operation of the Industrial Dust Control Robot Automated Grinding System. Relevant specifications must be strictly followed to avoid equipment damage, dust non-compliance, and safety accidents caused by improper operation.

2. Installation Process

Select a site that is flat, firm, well-ventilated, and far from flammable and explosive materials to ensure equipment is placed stably without tilting or shaking. Before installation, check whether all components are intact, connections are firm, electrical circuits are standardized, and dust treatment device pipe connections are sealed to avoid dust leakage. The installation positions of robots, conveyor lines, and dust removal equipment need to be reasonably arranged to ensure unobstructed grinding paths and no dead angles for dust collection. After installation is complete, perform leak testing and system sealing performance checks to ensure no dust overflow or leakage.

3. Debugging Phase

First, perform no-load trial operation to check robot operation trajectories, grinding parameters, and dust treatment device operation status, ensuring all components operate normally without abnormal noise or leakage. After no-load trial operation is normal, perform trial grinding using workpieces and abrasives consistent with actual production to adjust grinding pressure, rotation speed, path, and other parameters. Test surface roughness and good product rate to ensure compliance with standards. Simultaneously, test dust control effects and measure dust concentration to ensure compliance before entering the formal operation phase. During debugging, simultaneously optimize grinding paths and dust collection plans to reduce dust leakage and improve grinding quality. collection plans, reducing dust leakage and improving grinding quality.

VII. Daily Maintenance Specifications

A comprehensive maintenance log needs to be established to record equipment operating status, maintenance content, fault situations, and dust concentration data. Before daily operations, check robot joints, grinding heads, abrasives, and dust collection devices, ensuring no blockage, leakage, or looseness; check dust concentration monitors, automatic ash cleaning systems, and safety protection devices, ensuring normal operation. After operations, clean residual dust and debris from grinding heads, abrasives, and dust collection ports; clean dust collection

1. Regular Maintenance Specifications

Weekly: lubricate robot joints, check conveyor line operation status and adjust tension; check filter cartridges and filter elements of dust treatment devices and clean surface dust. Monthly: check wear of grinding heads and abrasives and replace them timely; calibrate grinding parameters, positioning accuracy, and dust concentration monitors. Every 3-6 months: replace dust treatment device filter elements and check operation status of robots, control systems, and dust treatment devices. Annually: perform comprehensive system inspections, evaluate core component performance, replace aging components, and calibrate parameters to ensure long-term stable system operation. core component performance, replace aging components, and calibrate parameters to ensure long-term stable system operation.

2. Fault Handling Specifications

When encountering problems such as equipment failing to start, abnormal grinding, dust emission exceeding limits, dust concentration alarms, or abnormal equipment noise, immediately stop for inspection and troubleshooting, contact professional personnel for repair, and strictly prohibit unauthorized disassembly of equipment. After fault handling, perform trial operation and dust testing to ensure the system returns to normal and dust compliance before resuming production.

VIII. Typical Industry Application Solutions

1. Environmental Protection Equipment Shell Dust Control Grinding Solution

For shell grinding needs of exhaust gas treatment equipment, wastewater treatment equipment, environmental protection fans, purification equipment, and other products, heavy workpiece dust control grinding systems equipped with large-flow dust collection devices and pulse filter cartridge dust removers are adopted. This solution can achieve all-round uniform grinding, deburring, rust removal, and polishing of shells; dust collection rate ≥98%, thoroughly solving dust pollution problems; one robot can grind shells at 30-50 pieces per hour with efficiency improved over 3 times; grinding precision is stable, surface roughness is uniform, and good product rate ≥99%, meeting environmental protection equipment mass production needs.

2. Environmental Protection Equipment Precision Component Dust Control Grinding Solution

For grinding needs of environmental protection instrument components, fan blades, irregular pipes, precision environmental protection equipment components, and other complex workpieces, constant force precision grinding robot systems equipped with AI visual recognition and force control systems are adopted. This solution can automatically identify workpiece contours, generate optimal grinding paths, and achieve no-dead-angle grinding of complex curved surfaces; grinding precision error is ≤±0.05mm, surface roughness is stable, and good product rate ≥99%; dust collection rate ≥98% and emissions <1mg/m³, ensuring dust compliance; simultaneously reducing abrasive consumption and improving production efficiency to meet high-precision grinding needs of precision components.

3. Environmental Protection Equipment Large-Scale Dust Control Grinding Production Line Solution

For batch production needs of large environmental protection equipment enterprises, integrated dust control grinding production lines are adopted, consisting of multiple robots, automatic conveyor lines, sealed dust removal rooms, and dust treatment systems. This solution can achieve fully automated processes of workpiece loading, positioning, grinding, dust removal, and unloading; it can process 100+ workpieces per hour with efficiency significantly improved; dust is centrally collected and treated with dust emission concentration <1mg/m³, grinding parameters are unified, quality is standardized, and good product rate ≥99%; labor costs are significantly reduced. It achieves large-scale and green production.

IX. Technology Development Trends

As environmental policies continue to tighten, industrial intelligence continuously upgrades, and manufacturing green transformation accelerates, the Industrial Dust Control Robot Automated Grinding System will develop towards being more environmentally friendly, intelligent, efficient, flexible, and energy-saving, further meeting the green production and intelligent upgrade needs of the environmental protection equipment industry.

1. Continuous Upgrading of Environmental Performance

In the future, systems will adopt more efficient dust control technologies, integrating advanced processes such as electrostatic dust removal, bag dust removal, low-temperature plasma, and dust recycling and reuse to achieve near-zero dust emissions; simultaneously, low-dust and high-wear-resistant abrasives will be promoted to further reduce dust generation; dust recycling technology will be continuously optimized to achieve dust recycling and reuse, reducing resource consumption and achieving resource recycling.

2. Continuous Improvement of Intelligence Level

AI visual recognition, big data analysis, Internet of Things, digital twin, and AI algorithm optimization technologies will be widely applied in systems. Achieving automatic workpiece identification, autonomous optimization of grinding paths, real-

time dust concentration monitoring, intelligent fault warning, remote maintenance, and data-based management; robots will have more flexible movement capabilities, stronger anti-interference performance, and higher grinding precision; offline programming and digital twin technologies will further spread, enabling simulation of grinding processes before actual production, reducing debugging time and improving operational efficiency.

3. Obvious Trend of High Energy Efficiency

Systems will adopt more efficient motors, servo systems, and dust treatment devices to reduce energy consumption; robot motion trajectory optimization technology will continuously improve, shortening grinding paths and enhancing grinding efficiency; simultaneously, through intelligent regulation of grinding parameters and dust treatment parameters, energy consumption, abrasive consumption, and dust emissions are reduced, achieving higher cost-effectiveness and helping enterprises achieve 'dual carbon' goals.

4. Growth of Flexible Adaptation and Customization Needs

For different types, specifications, and dust types of environmental protection equipment, personalized and customized dust control grinding system solutions will be provided, achieving 'one machine, one working condition' precise adaptation; integrated grinding production lines will be further upgraded to achieve full-process integration of grinding, dust removal, inspection, drying, and packaging. Simultaneously, systems will link with enterprise ERP and MES systems to achieve real-time monitoring of production data, analysis, and production optimization, integrating into intelligent manufacturing systems.

X. Conclusion

The Industrial Dust Control Robot Automated Grinding System is core equipment for the industrial surface treatment field to practice green development concepts, achieve dust control compliance, and promote intelligent manufacturing upgrades. It is also key support for the environmental protection equipment industry to reduce costs, increase efficiency, transform to green practices, and enhance competitiveness. By integrating industrial robot technology, intelligent force control technology, AI visual

recognition technology, and efficient dust control technology, it thoroughly solves the pain points of traditional manual grinding such as dust pollution, efficiency bottlenecks, quality defects, and occupational health risks, achieving automated, intelligent, and environmentally-friendly grinding processes that meet enterprise needs for efficient production and stable quality while ensuring dust compliance, environmental compliance, and safe and reliable

This white paper systematically discusses the technical principles, core structure, performance indicators, selection logic, maintenance specifications, industry applications, and development trends of the Industrial Dust Control Robot Automated Grinding System. Drawing on the latest national standards and industry trends, it provides enterprises with comprehensive technical references.