3D Workstation Technical White Paper

In fields such as precision manufacturing, industrial coating, automated inspection, laser processing, scientific research experiments, and environmental protection equipment, precise workpiece positioning, multi-dimensional adjustment, and stable bearing are the core prerequisites for ensuring production quality and operational efficiency.

As the core equipment for achieving precision movement and positioning in three mutually perpendicular XYZ spatial directions, the 3D workstation, with its flexible adjustment capability, stable bearing performance, and precise positioning accuracy, enables multi-dimensional operations such as translation, lifting, and fine-tuning of workpieces within three-dimensional space, adapting to operational needs in different scenarios. It has become an indispensable key supporting component in modern industrial automation systems.

As industry upgrades toward high precision, automation, and intelligence, the market has set higher requirements for the 3D workstation's core performance including positioning accuracy, bearing capacity, operational stability, and adaptability. Traditional workstations have struggled to meet the demanding needs of high-end manufacturing and precision inspection scenarios. Modular, high-precision, intelligent, and customized 3D workstations are gradually becoming the industry mainstream, providing strong support for various industries to achieve efficient production and precise operations.

This white paper provides comprehensive exposition on the 3D workstation's core technology, structural composition, performance parameters, product classification, selection logic, installation and commissioning, operation and maintenance, and typical industry applications. It offers professional, clear, and actionable technical reference for enterprises in product selection, engineering support, and system optimization, helping enterprises improve operational accuracy, increase production efficiency, reduce operation and maintenance costs, and achieve high-quality development.

I. Core Value and Application Scenarios of 3D Workstations

The core value of a 3D workstation lies in achieving smooth movement and precise positioning of workpieces along XYZ coordinate axes through precise mechanical structure and control logic. It solves pain points in traditional operations such as large positioning deviations, cumbersome adjustments, and poor stability, while offering advantages of flexible adaptation, stable bearing, and easy integration, providing a reliable operating platform for various precision operations.

In the industrial coating field, as the core workpiece bearing and positioning component, the 3D workstation can precisely adjust workpiece height, horizontal position, and angle, cooperating with automated spraying equipment to achieve comprehensive, non-blind-spot spraying. It avoids coating defects such as missed spraying and sags caused by workpiece positioning deviations, greatly improving spraying quality and operational efficiency, adapting to diverse spraying needs from small precision workpieces to large structural components.

Especially in robotic spraying scenarios, the precise positioning capability of the 3D workstation enables coordinated linkage with robots, further improving the level of spraying automation.

In precision manufacturing and processing, 3D workstations can achieve precise positioning and fine-tuning of workpieces, providing stable support for cutting, drilling,grinding, and other processing procedures, ensuring processing accuracy meets design standards, reducing processing errors, and improving product pass rate. Whether it's small precision parts processing or large component precision assembly, 3D workstations can guarantee consistency and reliability of the processing process with their stable performance.

Additionally, 3D workstations are widely used in automated inspection and scientific research experiments, laser processing, biomedical, electronics processing, environmental protection equipment support, and other fields. With their flexible adjustment capability, stable bearing performance, and precise positioning accuracy, they adapt to personalized needs of different scenarios and have become important

equipment for promoting technological upgrades and efficiency improvements in various industries.

II. Core Structure and Working Principle of 3D Workstations

3D workstations adopt a modular, layered structural design. The core components include base, XYZ three-axis motion mechanism, drive system, guidance system, position feedback system, and control system. All components work together to achieve smooth movement and precise positioning of workpieces within three-dimensional space. The overall structure is compact, with strong rigidity and convenient operation, allowing flexible customization based on scenario requirements.

As the basic support component of the entire workstation, the base bears the core role of supporting the workpiece and stabilizing the overall structure, directly affecting the workstation's operational stability and positioning accuracy. Bases typically use high-strength cast iron, aluminum alloy, or natural granite materials, processed and aged with precision, possessing excellent rigidity, wear resistance, and deformation resistance, effectively reducing the impact of vibration on positioning accuracy. Natural granite bases also offer excellent thermal stability and vibration damping effects, ensuring mechanical accuracy is not affected by temperature changes during long-term operation, suitable for high-precision scenarios.

The XYZ three-axis motion mechanism is the core for achieving 3D adjustment, adopting a layered stacked design, typically consisting of three independent motion units: X-axis (horizontal transverse), Y-axis (horizontal longitudinal), and Z-axis (vertical lifting). Each axis can move independently or work in coordination, achieving arbitrary position adjustment of workpieces within three-dimensional space. The structural design of the motion mechanism directly determines the workstation's stroke, bearing capacity, and positioning accuracy. Mainstream structures include ball screw transmission, synchronous belt transmission, linear motor transmission, and other forms, adapting to different precision and load requirements.

The drive system provides power support for workstation movement, divided into two categories: manual drive and electric drive. Manual drive uses handwheel

adjustment with simple structure and low cost, suitable for scenarios with low precision requirements and adjustment frequency. Electric drive uses stepper motors or servo motors as driving sources, cooperating with drive controllers to achieve precise speed and position control, with high positioning accuracy and smooth operation, suitable for automated and high-precision operation scenarios. Some high-end models can also be equipped with braking functions to improve the stability of vertical movement.

The guidance system is responsible for guiding each axis movement direction, ensuring smooth movement without deviation. Core components include linear guides and cross-roller guides.

Linear guides have advantages of strong bearing capacity, good wear resistance, and small movement resistance, suitable for heavy-load scenarios. Cross-roller guides offer higher guiding precision and rigidity with smooth movement without clearance, suitable for high-precision, short-stroke scenarios, effectively ensuring the workstation's straightness and parallelism.

The position feedback system is the key to achieving precise positioning. Through components such as grating scales, magnetic scales, and rotary encoders, it real-time collects position information of each axis movement and feeds it back to the control system, forming closed-loop control to ensure positioning accuracy meets requirements. Grating scale feedback has the highest accuracy, achieving micron-level or even nanometer-level positioning, suitable for high-precision scenarios. Magnetic scales have strong anti-interference ability and adapt to harsh environments, suitable for complex industrial site scenarios.

As the workstation's 'brain', the control system coordinates all components to work together, divided into local control and remote control. Local control uses PLC controllers and touchscreen HMI interfaces, allowing intuitive setting of motion parameters and positioning coordinates with simple and easy operation. Remote control can achieve remote operation and parameter adjustment through upper computer software and IoT modules, adapting to intelligent production line integration needs and enabling linkage control with spraying equipment, inspection instruments, etc.

The working principle of 3D workstations is based on closed-loop control logic. The control system sends motion commands, the drive system drives the XYZ three-axis motion mechanism to move along set trajectories, the guidance system ensures precise movement direction, the position feedback system real-time collects motion position information and feeds it back to the control system, and the control system adjusts motion parameters based on feedback information to achieve precise positioning and smooth adjustment of workpieces. The entire process has high automation, high positioning accuracy, and stable operation.

III. Product Classification and Core Performance Parameters of 3D Workstations

According to drive method, structural form, precision grade, and application scenario, 3D workstations can be divided into multiple types. Each product type has its own focus on performance and adaptation scenarios, and enterprises can flexibly select based on their own needs.

Classified by drive method, they can be divided into manual 3D workstations and electric 3D workstations. Manual 3D workstations use handwheel adjustment with simple structure, low cost, and convenient maintenance, requiring no external power supply, suitable for scenarios with low precision requirements, low adjustment frequency, and small workpieces. Electric 3D workstations use motor drive with closed-loop control, offering high positioning accuracy, smooth operation, and high automation, suitable for high-precision, automated, high-volume operation scenarios. They are currently the mainstream type in the industrial field. Electric 3D workstations can further be divided into stepper motor drive and servo motor drive. Servo motor drive has higher positioning accuracy and response speed, suitable for demanding precision scenarios.

Classified by structure, they can be divided into desktop type, gantry type, cantilever type, lifting type, and other types. Desktop 3D workstations have compact structure and small floor space, suitable for precise positioning and adjustment of small workpieces. Gantry 3D workstations have strong rigidity and large bearing capacity, suitable for positioning and processing of large workpieces and heavy components, with good stability.

Cantilever 3D workstations offer flexible operating space, suitable for multi-angle adjustment and operation of complex workpieces. Lifting 3D workstations focus on Z-axis lifting adjustment, allowing flexible height adjustment of workpieces, adapting to different operational height requirements. Some high-end models also use four-axis linkage mechanism drive to ensure the workstation maintains a horizontal posture while achieving precise position adjustment within 3D space.

Classified by precision grade, they can be divided into standard precision, precision, and ultra-precision types. Standard precision 3D workstations have positioning accuracy between 0.1-1mm, suitable for general positioning and adjustment scenarios. Precision 3D workstations have positioning accuracy between 0.01-0.1mm, suitable for industrial coating and general precision processing scenarios. Ultra-precision 3D workstations have positioning accuracy between 0.001-0.01mm, using grating scale closed-loop control and high-precision guiding components, suitable for precision inspection, high-end manufacturing, scientific research experiments, and other demanding precision scenarios. Some models can achieve positioning accuracy below 1μm after compensation.

Core performance parameters are the key to measuring 3D workstation performance and are also the core basis for enterprise selection. They mainly include positioning accuracy, repeat positioning accuracy, bearing capacity, motion stroke, motion speed, rigidity, and other indicators. Positioning accuracy refers to the precision with which the workstation moves to a set position, which is the core performance indicator directly determining operation accuracy. Repeat positioning accuracy refers to the deviation when the workstation moves to the same position multiple times, reflecting the workstation's operational stability. High-quality models can achieve repeat positioning accuracy within ±3μm.

Bearing capacity refers to the maximum weight the workstation can stably bear. Depending on structural design and materials, bearing capacity ranges from a few kilograms to dozens of tons. Small precision workstations typically have bearing capacity within 100kg, while large gantry workstations can have bearing capacity above 50 tons. Motion stroke refers to the maximum distance each axis can move. X and Y axis strokes are typically between 50-5000mm, and Z axis stroke is between 50-

1000mm, customizable based on scenario requirements. Motion speed refers to the maximum movement speed of each axis. Electric workstations typically have motion speed between 0.1-50mm/s, adjustable based on operation requirements.

Additionally, indicators such as rigidity, wear resistance, anti-interference ability, and noise also affect the workstation's service life and operational stability. Higher rigidity means less deformation during bearing and movement, resulting in higher positioning accuracy. Better wear resistance means longer service life and lower operation and maintenance costs. Good anti-interference ability ensures stable operation in complex industrial environments.

IV. Material Selection, Process, and Production Standards

The performance stability and service life of 3D workstations fundamentally depend on material selection and production process. High-quality raw materials and refined production processes are key to ensuring the workstation's positioning accuracy, rigidity, and wear resistance.

In raw material selection, bases use different materials according to application scenarios. High-strength cast iron is used for general scenarios, possessing excellent rigidity and deformation resistance. Natural granite or high-strength aluminum alloy is used for precision scenarios. Natural granite offers excellent thermal stability and vibration damping effects, while aluminum alloy offers advantages of lightweight and corrosion resistance. Core motion components such as guides and lead screws use high-quality alloy steel, processed through quenching, tempering, and other heat treatment processes to improve hardness and wear resistance. Drive motors use well-known brand stepper motors or servo motors to ensure stable power output and rapid response. Position feedback components use high-precision grating scales or magnetic scales to ensure positioning accuracy meets standards.

In production process, advanced precision machining, aging treatment, and assembly debugging processes are used to ensure each component's accuracy and fit. Bases undergo rough machining, precision machining, and aging treatment to eliminate internal stress and avoid deformation during use. Guides and lead screws undergo precision grinding to ensure surface smoothness and dimensional accuracy,

reducing movement resistance. During component assembly, precise positioning and debugging are used to ensure smooth movement of each axis without jamming or clearance, with positioning accuracy meeting requirements.

In quality testing, each batch of products undergoes strict performance testing including positioning accuracy, repeat positioning accuracy, bearing capacity, motion stability, noise, and other indicators. Testing uses professional testing instruments to ensure accurate test data. A product traceability system is also established to trace the production and testing records of each batch, ensuring stable and reliable product quality. All products comply with national industry standards such as GB/T17421.1-1998 'General Rules for Machine Tool Inspection'.

V. Selection Logic and Adaptation Principles

Selection of 3D workstations requires comprehensive consideration of multiple factors including application scenario, operation requirements, precision requirements, bearing capacity, and installation space, ensuring precise selection and strong adaptability while considering economy and maintenance convenience, avoiding problems such as insufficient positioning accuracy, insufficient bearing capacity, or over-configuration, reducing production and operation costs.

First, determine the precision grade based on precision requirements. If only used for general positioning and adjustment without excessive precision needs, standard precision 3D workstations can be selected with high cost-effectiveness. If used for industrial coating and general precision processing scenarios, precision workstations should be selected with positioning accuracy controlled between 0.01-0.1mm. If used for precision inspection, high-end manufacturing, and scientific research experiment scenarios, ultra-precision workstations should be selected with positioning accuracy reaching below 0.01mm, prioritizing models equipped with grating scale closed-loop control.

Second, select bearing capacity and structural form based on bearing requirements. For small workpieces (weight < 100kg), desktop 3D workstations can be selected with compact structure and small floor space. For medium workpieces (weight 100-1000kg), standard gantry or lifting workstations can be selected. For large

heavy workpieces (weight > 1000kg), large gantry workstations must be selected to ensure rigidity and bearing capacity meet standards. Also, select appropriate motion stroke based on operation space size to ensure the workstation can meet workpiece adjustment needs, avoiding insufficient stroke affecting operations.

Third, select drive method based on automation requirements. For manual adjustment scenarios, manual 3D workstations can be selected with low cost and convenient maintenance. For automated, high-volume operation scenarios, electric 3D workstations should be selected, prioritizing servo motor drive with high positioning accuracy and fast response speed, enabling linkage with other automation equipment. For high-precision scenarios, closed-loop control models equipped with grating scales or magnetic scales are recommended to ensure stable positioning accuracy.

Finally, select product type based on installation space and maintenance needs. For space-constrained scenarios, compact desktop workstations can be selected. For scenarios requiring multi-angle operations, cantilever workstations can be selected. For large workshops and heavy operation scenarios, gantry workstations can be selected. Also, prioritize products with simple structure, convenient maintenance, and easily procurable accessories to reduce later operation and maintenance costs. For special needs, customized products can be selected to ensure precise adaptation between the workstation and operation scenario.

VI. Installation, Commissioning, and Operation & Maintenance Key Points

Correct installation, standardized commissioning, and scientific maintenance are key to ensuring 3D workstations perform at their best, extending service life, and reducing operating costs. Whether manual or electric 3D workstations, their installation and maintenance must follow corresponding standards to avoid problems such as decreased positioning accuracy or equipment damage caused by improper operation.

In installation, a flat and solid installation site must be selected to ensure the base fits tightly with the ground without tilting or wobbling, avoiding vibration's impact on positioning accuracy. Before installation, clean dust and debris from the installation site,

and check whether all workstation components are intact without damage or deformation. During installation, ensure smooth movement of each axis without jamming or clearance, keep guide and lead screw surfaces clean without debris attachment. For electric workstations, properly connect power and control cables, ensuring standardized wiring to avoid short circuits or poor contact. After installation, adjust the workstation's level to ensure precise movement direction of each axis.

During commissioning, manual workstations require adjusting each axis handwheel, checking movement smoothness and positioning accuracy, and adjusting clearance to a reasonable range. Electric workstations require no-load operation, load operation, and positioning accuracy testing, gradually optimizing motion parameters to ensure positioning accuracy and repeat positioning accuracy meet set requirements with stable linkage operation. During commissioning, check the accuracy of the position feedback system and calibrate components such as grating scales and encoders in a timely manner to ensure accurate feedback data.

In daily maintenance, regularly clean workstation components, especially core components such as guides, lead screws, and grating scales, to avoid dust and debris attachment affecting movement smoothness and positioning accuracy. Regularly add lubricating oil to guides and lead screws to reduce movement resistance, improve wear resistance, and extend service life. Regularly check drive motors, controllers, and wiring to ensure normal operation and promptly troubleshoot any faults.

For electric 3D workstations, regularly calibrate positioning accuracy to avoid accuracy deviation caused by long-term operation. Regularly check the operating status of motors and reducers to avoid overload operation. Regularly back up control system parameters to prevent parameter loss. Also, establish operation and maintenance records documenting operating status, maintenance content, and fault situations for timely understanding of workstation operating conditions, early detection of hidden dangers, and reduction of fault incidence.

VII. Typical Industry Application Solutions

With their flexible adjustment capability, precise positioning accuracy, and stable bearing performance, 3D workstations are widely used in various industrial and

scientific research scenarios. Combined with the needs characteristics of different industries, customized adaptation solutions can be provided to ensure precise matching between workstations and operation needs, maximizing performance.

In the industrial coating industry, 3D workstations serve as core supporting components adapting to various spraying scenarios. For small precision workpiece spraying, desktop electric 3D workstations can be selected with high positioning accuracy and flexible adjustment, cooperating with automatic sprayers to achieve precise spraying, avoiding defects such as missed spraying and sags. For large steel structural components and construction machinery parts spraying, gantry 3D workstations can be selected with strong bearing capacity and large stroke, enabling comprehensive adjustment of workpieces and cooperating with robotic spraying to achieve automated operations, improving spraying efficiency and quality. In welding coating scenarios, 3D workstations can also serve as welding platforms adapting to welding positioning needs of automotive frames and building metal components.

In the precision manufacturing and processing industry, 3D workstations are used for precise workpiece positioning and processing assistance. For small precision parts processing, ultra-precision desktop workstations can be selected with positioning accuracy reaching micron level, ensuring processing errors are within allowable ranges. For large component assembly, gantry workstations can be selected with strong rigidity and large bearing capacity, achieving precise positioning and assembly of components and improving assembly accuracy and efficiency. For laser processing scenarios, high-speed electric 3D workstations can be selected with fast response speed and precise positioning, cooperating with laser equipment to achieve precise cutting, engraving, and other operations.

In environmental protection equipment support scenarios, 3D workstations are used for positioning and adjustment of environmental testing equipment and exhaust gas treatment equipment components, achieving precise positioning of testing probes and treatment components, ensuring stable operation of environmental protection equipment and accurate testing data. For example, in VOCs testing equipment, 3D workstations can adjust the position of testing probes to achieve multi-point, precise testing, improving testing efficiency and accuracy.

VIII. Technical Development Trends

With the continuous development of industrial automation, intelligence, and high-precision processing, the technical development of 3D workstations will advance toward high precision, intelligence, modularization, customization, and environmental protection, gradually meeting the high-end needs of various industries and providing stronger support for modern industrial development.

In high precision, through material modification, precision machining process upgrades, and positioning feedback technology optimization, the workstation's positioning accuracy and repeat positioning accuracy will be further improved, gradually breaking through to nanometer-level precision, adapting to more demanding scenario requirements for high-end manufacturing and precision inspection. Also, through structural optimization to reduce movement clearance, rigidity and stability will be improved, ensuring accuracy stability during long-term operation.

In intelligence, through integration of IoT, artificial intelligence, and big data technologies, intelligent monitoring, remote control, fault early warning, and predictive maintenance of workstations will be achieved. Through sensors, real-time collection of operating parameters uploaded to cloud platforms for remote monitoring and parameter adjustment. Through AI algorithms analyzing operating data, fault hidden dangers will be detected in advance, achieving predictive maintenance and reducing downtime risk. Deep integration with intelligent production lines will enable coordinated linkage with robots, testing instruments, and other equipment, improving automated production levels.

In modularization and customization, further improvement of modular design will be made to achieve rapid combination and replacement of all components, shortening delivery cycles and improving adaptability. According to personalized needs of different industries and scenarios, customized products and solutions will be provided, including customization of structural form, stroke, bearing capacity, precision grade, and other aspects, meeting diverse operation needs. Also, the application of standardized components will further improve product universality and maintainability.

In environmental protection and energy saving, drive systems and structural design will be optimized to reduce energy consumption and improve energy utilization. Environmentally friendly, wear-resistant, and recyclable raw materials will be adopted to reduce environmental pollution. Lubrication systems will be optimized using long-acting lubricating oils to reduce lubricating oil consumption and environmental pollution, achieving green production and green use.

IX. Conclusion

As core equipment for achieving precision positioning and multi-dimensional adjustment, 3D workstations play an irreplaceable role in precision manufacturing, industrial coating, automated inspection, scientific research experiments, and other fields, directly affecting operation accuracy, production efficiency, and product quality. With the continuous upgrading of industrial technology, the application scenarios of 3D workstations will continue to expand, and performance requirements will continue to increase.

This white paper comprehensively expounds on the core technology, product characteristics, selection logic, maintenance points, and industry applications of 3D workstations, providing enterprises with professional, systematic, and actionable technical reference.