International Journal of Computational and Engineering

JUNE 2025 VOLUME10 NUMBER2

Publisher: ACADEMIC PUBLISHING HOUSE
Address: Quastisky Building, Road Town, Tortola, British Virgin Islands
UK Postal Code: VG1110

E-mail: editor03@acadpubl.com
http://www.acadpubl.com/ijce.aspx

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CONTENTS

A Review of the Fabrication Methods for Composite Materials Using Carbon Fiber Preforms

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Abstract: This article systematically reviews the main weaving methods of carbon fiber preforms and their research progress. Firstly, it introduces the process characteristics and optimization directions of traditional two-dimensional weaving technology, and focuses on analyzing the innovative breakthroughs and application status of three-dimensional braiding technology. It also discusses the development trends of interlayer reinforcement technologies such as sewing and needling. Meanwhile, it reviews the research progress of emerging weaving technologies such as additive manufacturing, and looks forward to the future development directions of carbon fiber preform weaving technology. The research shows that multi-scale structure design, digital intelligent manufacturing, and green sustainable development will become important development trends of carbon fiber preform weaving technology.
Keywords: Composite materials, Carbon fiber preforms, Weaving methods.

1. INTRODUCTION

Carbon fiber reinforced composite materials (CFRP), due to their excellent mechanical properties and designability, have become key materials in modern high-end equipment manufacturing [1]. As the reinforcing framework of CFRP, the weaving process of carbon fiber preforms directly affects the final performance of the composite materials [2]. In recent years, with the rapid development of aerospace, new energy vehicles and other fields, the performance requirements for carbon fiber preforms have been continuously increasing, driving the continuous innovation of weaving technologies. This paper aims to systematically review the main weaving methods of carbon fiber preforms, analyze the technical characteristics and research progress of each process, and provide references for research and application in related fields.

2. TRADITIONAL TWO-DIMENSIONAL WEAVING TECHNOLOGY

Two-dimensional weaving is the most fundamental process for preparing carbon fiber preforms, mainly including three basic weave structures: plain, twill, and satin. In the weaving process, the mechanical properties of the fibers are minimally damaged [3]. The plain weave, with its tight interlacing of warp and weft yarns in a 1:1 ratio, has the best dimensional stability and is widely used in secondary load-bearing structures of aircraft. The twill weave, by reducing the number of interlacing points, significantly improves the material's flexibility and is particularly suitable for components that need to withstand dynamic loads. The satin weave further reduces the interlacing density, allowing the fibers to maintain better linearity and performs well in areas requiring high stiffness.

In recent years, innovations in two-dimensional weaving technology have mainly focused on intelligent transformation and multi-functional composites. In terms of intelligence, Toyota's AI weaving system in Japan reduces weaving defect rates by 60% through real-time monitoring of yarn tension changes and machine learning algorithms to optimize weaving parameters. In terms of multi-functional composites, Toray's carbon fiber/copper wire hybrid preform maintains mechanical properties while achieving excellent electromagnetic shielding. Hexcel in the United States has developed gradient density two-dimensional fabrics, achieving a gradient distribution of strength in different parts of a single preform through regional differential weaving. However, two-dimensional weaving technology still faces challenges such as insufficient interlayer performance and difficulty in forming complex curved surfaces. Studies show that even with the latest developed nano-fiber interface reinforcement technology, the improvement in interlayer shear strength is only about 30%. These issues have prompted researchers to continuously explore more advanced weaving methods.

3. THREE-DIMENSIONAL INTEGRAL WEAVING TECHNOLOGY

Three-dimensional weaving technology achieves a true three-dimensional network structure through the spatial interlacing of multi-directional fibers, fundamentally solving the problem of insufficient interlayer performance. Due to its excellent mechanical properties, it has received extensive attention [4]. Modern three-dimensional weaving can be classified into four major categories: orthogonal weaving, angle interlock weaving, polar weaving, and full five-directional weaving. Orthogonal weaving, with its regular fiber arrangement and high fiber volume fraction (up to 65%), dominates in the main load-bearing structures of spacecraft.

The latest research data shows that the in-plane shear strength of carbon fiber composites using three-dimensional orthogonal weaving can reach 380 MPa, which is 1.8 times that of traditional laminated materials. Boeing innovatively used variable-thickness three-dimensional weaving technology in the manufacturing of the central wing box of the 787 passenger aircraft, reducing the structure's weight by 15% while doubling its fatigue life. In China, AVIC Composite Materials Co., Ltd. has successfully developed a large three-dimensional weaving machine capable of weaving rocket fuel tanks with a diameter of 2.5 meters and a length of 6 meters.

In terms of process control, the fourth-generation three-dimensional weaving machine developed by Rieter in Germany uses digital twin technology to achieve real-time simulation and optimization of the weaving process. The high-precision tension control system equipped on this machine can keep the fiber tension fluctuation within ±5%. The French Aerospace Agency has established a prediction model for process parameters and mechanical properties by introducing machine learning algorithms, reducing the development cycle of new products by 40%.

Despite the obvious advantages of three-dimensional weaving technology, its industrialization still faces three major bottlenecks: high equipment investment, low production efficiency, and difficult quality control. These factors jointly restrict the promotion and application of three-dimensional weaving technology.

4. STITCHING AND NEEDLING REINFORCEMENT TECHNOLOGY

Stitching technology, as an economical and effective interlayer reinforcement method, has unique advantages in the manufacturing of large composite material components. Modern stitching processes have evolved from traditional lockstitch to various innovative forms such as double-needle stitching and ultrasonic-assisted stitching. Research by MIT shows that using carbon nanotube-reinforced stitching threads can increase interlayer fracture toughness by more than 50%. Airbus has adopted a robot automatic sewing system in the manufacturing of A350 wing panels. By optimizing the sewing path algorithm, the sewing efficiency has been increased by six times. Domestically, the Aerospace Materials and Process Research Institute has developed a curved surface adaptive sewing device, which has been successfully applied in the manufacturing of a certain type of satellite load-bearing cylinder, raising the product qualification rate to 98%.

Needle-punching technology, as another important three-dimensional reinforcement method, has made significant progress in process control in recent years. The latest intelligent needle-punching system launched by Dilo in Germany uses force feedback control technology to achieve precise adjustment of the needle-punching depth. Toray in Japan has developed a low-damage needle-punching process, which, by optimizing the shape of the punch needle and the punching angle, has increased the fiber strength retention rate to over 85%.

However, both of these technologies still have room for improvement. The main problem with sewing technology is that it causes stress concentration in the material. Even with micro-sewing technology, the stress concentration coefficient still reaches around 1.8. Needle-punching technology, on the other hand, faces the dual challenges of fiber damage and restricted resin flow.

5. RESEARCH PROGRESS IN EMERGING WEAVING TECHNOLOGIES

Additive manufacturing technology has opened up new avenues for the customized production of carbon fiber preforms. The most advanced continuous fiber 3D printing systems can now achieve multi-material co-deposition. In 2023, the National University of Singapore developed a new laser-assisted deposition technology, with the fiber volume fraction of the printed parts exceeding 50% and the tensile strength reaching 900 MPa.

In terms of intelligent manufacturing, the autonomous decision-making weaving system developed by the Fraunhofer Institute in Germany, combining industrial Internet of Things and digital twin technology, has achieved real-time optimization of process parameters. Domestically, the multi-robot collaborative weaving platform developed by Harbin Institute of Technology, using visual servo control, has successfully achieved the automatic placement of a 4-meter diameter wind turbine hub.

Nanotechnology has also brought new possibilities to carbon fiber preforms. Northwestern University in the United States has grown vertically aligned carbon nanotubes on the surface of fibers to create preforms with special interface structures, with the interlaminar fracture toughness of type I reaching three times that of traditional materials.

6. FUTURE DEVELOPMENT TRENDS AND CHALLENGES

Looking ahead, carbon fiber preform weaving technology will present three major development trends: first, multi-scale collaborative design, through the organic combination of macroscopic weaving structures and microscopic interface control, to achieve cross-scale optimization of material performance; second, the in-depth application of digital twin technology, in the future, intelligent weaving systems based on full life cycle digital twins will be commercialized; third, breakthroughs in sustainable development technologies, carbon fiber recycling technology is evolving from mechanical recycling to molecular-level recycling.

However, these developments also face severe challenges. At the fundamental research level, a deeper understanding of the strengthening and toughening mechanisms of multi-scale structures is needed; at the engineering technology level, the issue of manufacturing consistency for super-large-sized components must be addressed; and in terms of economics, further cost reduction through scale effects is still required.

7. CONCLUSION

Through a comprehensive analysis of carbon fiber preform weaving technology, it can be concluded that traditional two-dimensional weaving, through continuous innovation, still has competitiveness in the mid-range market; three-dimensional weaving, with its excellent overall performance, has become an inevitable choice for high-end applications; sewing and needle-punching technologies, as important supplementary processes, maintain an irreplaceable position in specific fields; while emerging additive manufacturing and intelligent weaving technologies represent the future development direction.

With the integrated application of new technologies, carbon fiber preforms are undergoing a profound transformation from "empirical design" to "digital optimization". It is expected that by 2030, the new generation of carbon fiber preforms will achieve breakthrough applications in areas such as composite material casings for aero engines and all-carbon fiber bodies for new energy vehicles.

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Research on Current Protection of Distribution Lines Connected to Distributed Power Sources

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Abstract: With the widespread application of distributed power sources in distribution networks, their integration has significantly impacted current protection on distribution lines. This paper explores the issue of current protection for distribution lines with distributed power sources, focusing on the research of protection setting. First, it analyzes the characteristics of short-circuit currents under different types of faults after distributed power sources are connected to the distribution network, establishing an accurate short-circuit current calculation model to provide foundational data support for subsequent protection settings. In terms of protection setting, it demonstrates the setting values and operating time limits of protection devices through practical examples, optimizing current protection performance to adapt to the new operating conditions brought about by the grid connection of distributed power sources.

Keywords: Photovoltaic Power Station; Short-Circuit Current; Setting Calculation

1. CALCULATION OF SHORT CIRCUIT CURRENT IN DISTRIBUTION NETWORK WITH PHOTOVOLTAIC POWER STATION

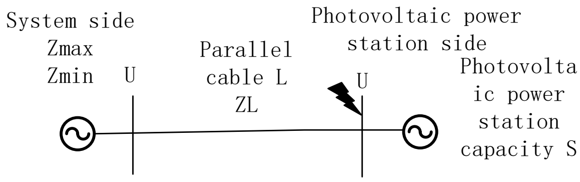

Figure 1 Impedance diagram of photovoltaic power station grid connected system

For the short circuit current calculation of the distribution network containing photovoltaic power stations, as shown in Figure 1, the calculation formula adopts nominal value calculation[1]:

In the first step, without considering the access of photovoltaic power station, Using existing short-circuit calculation methods, calculate the three-phase short-circuit current I_{k1} at the bus bar fault point under the main mode of the photovoltaic power station..

$$I_{k1}^{(3)} = \frac{U}{\sqrt{3}*(Z_{max}+Z_L)} \quad (1)$$

In the second step, only consider the full power generation of photovoltaic power station short-circuit current calculation according to the Technical Regulations for Photovoltaic Power Station Access to the Grid: When a short circuit occurs on the grid side, the short-circuit current output by the photovoltaic power station to the grid should not be greater than 150% of the rated current, and I_{k2} is calculated.

$$I_{k2}^{(3)} = 1.5*\frac{S}{\sqrt{3}*U} \quad (2)$$

In the third step, I_{k1} and I_{k2} are superimposed in phase, and the total short-circuit current I_k of the short-circuit fault point is calculated, that is, $I_k=I_{k1}+I_{k2}$. This short-circuit current is the maximum short-circuit current of the distribution network containing the photovoltaic power station.

$$I_k^{(3)} = I_{k1}^{(3)} + I_{k2}^{(3)} = \frac{U}{\sqrt{3}*(Z_{max}+Z_L)} + 1.5*\frac{S}{\sqrt{3}*U} \quad (3)$$

When selecting the operation mode, the fault form of the large mode is three-phase short circuit and the short circuit current provided by the photovoltaic power station is considered, The type of minor fault is a two-phase short circuit on the bus bar, which does not consider the short-circuit current provided by the photovoltaic power station and is used for sensitivity verification.

$$I_k^{(2)} = \frac{U}{2*(Z_{min}+Z_L)} \quad (4)$$

2. PROTECTION REQUIREMENTS FOR DISTRIBUTION LINES

(1)The distributed power supply side must have the ability of self-protection during the process of grid fault and recovery;

(2) For the distributed power supply with large capacity or the distributed power supply with rotating motor type connected to the distribution network, the protection sensitivity of the connected distribution network line should be calculated. If it does not meet the requirements, longitudinal differential protection or distance protection and other protection functions should be configured;

(3) If the distributed power supply has the ability to send short circuit current to the fault point and may lead to protection malfunction, the direction discrimination element should be added[2];

(4) When a short circuit occurs in a photovoltaic power station, the short-circuit current provided by the photovoltaic power generation system does not exceed 1.5 times its rated current, and the short-circuit current is small, so the overcurrent protection on the photovoltaic power station side can be stopped[3].

3. REQUIREMENTS FOR RECLOSING OF DISTRIBUTION LINES

(1)When the distributed power supply is connected to the 10kV distribution network by a dedicated line, the dedicated line may not be equipped or the reclosing may be stopped;

(2)When the distribution line needs to be put into service with reclosing, the coordination between the reclosing time and the on-grid and off-grid control time of the distributed power supply should be verified (the reclosing time setting should be greater than 2.0s)[4]. For the public grid lines connected with synchronous motor type distributed power supply, the undervoltage detection function of reclosing should be added when conditions permit.

4. CURRENT PROTECTION SETTING SCHEME FOR PHOTOVOLTAIC POWER SUPPLY CONNECTED TO DISTRIBUTION NETWORK

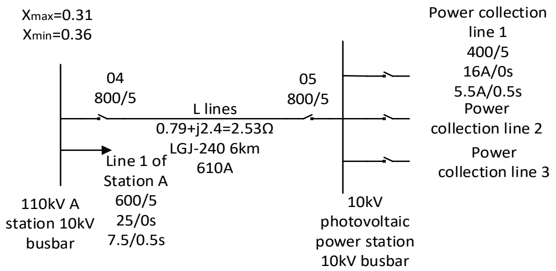

Figure 2 Schematic diagram of setting values for parallel cables of distributed power sources

As shown in Figure 1, the 10kV photovoltaic power station is connected to the grid through the 10kV bus of Substation A at 110kV. Optical fiber differential protection is configured on both sides of the 10kV grid-connected line L as the main protection, and three-segment current protection as the backup protection. Two-segment current protection is configured on the 10kV collector line. The settings are shown in Figure 1. The photovoltaic power station has a generation capacity of 20MW, with an equivalent impedance of j1.3Ω. Without considering the effect of branch coefficients, the settings for differential protection and current protection on both sides of the 10kV grid-connected line L are calculated (using nominal values).

4.1 DIFFERENTIAL CURRENT START VALUE

On the side of L line Jia station, the sensitivity is set at more than 4 times the minimum fault current when two phases are short-circuited at the end of the line (system side)

$$I_{dz} \le \frac{10500}{2*(2.53+0.36)*(4*(800/5))} = 2.84A \quad (5)$$

On the side of L line photovoltaic power station, the sensitivity is set at more than 4 times of the minimum fault current when two phases short circuit at the end of the line (on the side of photovoltaic power station)

$$I_{dz} \le \frac{10500}{2*(2.53+1.3)*(4*(800/5))} = 2.14A \quad (6)$$

The values on both sides are the same, take 2A.

4.2 CURRENT PROTECTION ON THE SIDE OF L LINE STATION A

(1) Current instantaneous protection: set according to the maximum three-phase short circuit current at the end of L line:

$$I_{dz} \ge \frac{1.3*10500}{1.732*(2.53+0.36)*800/5} = 17.34A \quad (7)$$

Take 20A,0s, line protection with direction, the direction points to the line.

(2) Time-limited instantaneous current protection: 1.1 times that of the instantaneous protection of the lower photovoltaic power station collector line: 16A/0s,400/5.

$$I_{dz} \ge \frac{1.1*16*400/5}{800/5} = 8.8A \quad (8)$$

Take 9A,0.5s, the direction of the line protection band, and the direction points to the line.

(3) Overcurrent protection: in accordance with the cooperation of 1.1 times overcurrent protection of the lower photovoltaic power station collector line: 5.5A/0.5s,400/5.

$$I_{dz} \ge \frac{1.1*5.5*400/5}{800/5} = 3.03A \quad (9)$$

Take 5A,2s, line protection with direction, and the direction points to the line.

(4) Reclosing: 3s is taken according to the coordination with the islanding protection of the inverter (the reclosing time should be greater than 2.0s).

4.3 CURRENT PROTECTION ON THE SIDE OF L LINE PHOTOVOLTAIC POWER STATION

(1) Current instantaneous protection: set according to the maximum three-phase short-circuit current at the end of L line:

$$I_{dz} \ge \frac{1.3*10500}{1.732*(2.53+1.3)*800/5} = 12.86A \quad (10)$$

Take 20A,0s, line protection band direction, the direction points to the line.

(2) Time-limited instantaneous current protection: cooperate with the first line instantaneous protection of lower station A at 1.1 times: 25A/0s,600/5.

$$I_{dz} \ge \frac{1.1*25*600/5}{800/5} = 20.65A \quad (11)$$

Take 22A,0.5s, the direction of the line protection band, and the direction points to the line.

(3) Overcurrent protection: cooperate with the first line overcurrent protection of lower station A at 1.1 times: 7.5A/0.5s,600/5.

$$I_{dz} \geq \frac{1.1*7.5*600/5}{800/5} = 6.19A \quad (12)$$

Take 6.5A,2s, line protection with direction, the direction points to the line.

(4) The reclosing is out of service.

5. CONCLUSIONS

This paper studies the calculation model of short-circuit current in distribution networks when faults occur after photovoltaic power sources are connected. Applying the computational results to actual projects can effectively guide the selection of electrical equipment, reasonably reduce overall project costs, and provide foundational data support for subsequent protection setting. In terms of protection setting, it addresses the issues of sensitivity, selectivity, and speed of traditional current protection caused by the grid connection of distributed power sources. By demonstrating the setting values and action times of protection devices through practical examples, the performance of current protection is optimized.

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Research on OBE-based Teaching Reform of Database Principles and Applications in Vocational Education

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Abstract: In the context of the deepening of the reform of vocational education, the traditional database teaching is out of touch with the needs of vocational positions, and the cultivation of practical ability is insufficient and other problems. This paper is based on the concept of Outcome-Based Education (OBE), combined with the characteristics of electrical automation technology in vocational colleges and universities, reconstructs the teaching objective system with vocational ability as the core, optimises the teaching content of 'project-driven + practical integration', innovates the 'online and offline hybrid' teaching mode and constructs the 'multi-dimensional' assessment and evaluation mechanism. The study shows that the introduction of the OBE concept effectively improves students' database application ability and vocational literacy, and provides a model that can be used for vocational education curriculum reform.

Keywords: OBE; Database Principles and Applications; Vocational Education; Teaching Reform

1. INTRODUCTION

Database technology as the core support for data storage, processing and interaction in electrical automation system, its application ability has become one of the necessary vocational skills for electrical automation technology students. However, the following problems are common in the teaching of database principles and application courses in vocational colleges and universities: the teaching objectives focus on the teaching of theoretical knowledge, which is out of touch with the actual needs of vocational positions; the teaching content is mainly based on traditional relational databases, and there is a lack of cutting-edge technologies, such as industrial Internet of Things databases, real-time databases, and other cutting-edge technologies; Teaching methods are based on teachers' lectures and students' passive acceptance; practical sessions are mostly verification experiments and lack of real projects; assessment and evaluation favour theoretical knowledge testing, which is difficult to comprehensively reflect students' practical ability and professionalism[1].

OBE focuses on students'learning outcomes, emphasises the educational concept of "reverse design and forward implementation", and focuses on cultivating students' ability to solve complex problems and lifelong learning, which is highly in line with the talent cultivation goal of vocational education, which is 'employment-oriented and competence-based'[2]. Introducing the OBE concept into the teaching of database principles and applications courses, through reconstructing teaching objectives, optimising teaching contents, innovating teaching methods and improving assessment and evaluation, helps to solve the problems existing in traditional teaching and enhance students' database application ability and career competitiveness.

2. THE OBE CONCEPT

The OBE concept emphasises that educational activities should be oriented towards the learning outcomes that students ultimately achieve, and that the setting of teaching objectives, the selection of teaching content, the design of teaching methods and the implementation of teaching evaluation all revolve around what students 'can learn' and 'what they can do'[3]. Its core ideas include student-centredness, outcome-orientation and continuous improvement.

The essence of vocational education is to cultivate high-quality technical and skilled talents to meet the needs of social and economic development, and its core is the cultivation of vocational ability, and the OBE concept emphasises the 'output of ability', which is highly consistent with the goal of cultivating talents in vocational education. Applying the OBE concept in vocational education can accurately meet the needs of vocational positions, strengthen the cultivation of practical ability and promote the reform of the evaluation system[4].

3. OBE-BASED DESIGN FOR TEACHING REFORM IN DATABASE COURSES

3.1 Reconstruction of Teaching Objectives Based On Vocational Competence

According to the demand for occupational positions in the electrical automation technology major, combined with the outcome-oriented principle of the OBE concept, the teaching objective of the course is set as to cultivate students' ability to use database technology to solve practical problems in the field of electrical automation. The teaching objectives are decomposed into specific milestone achievement objectives, as shown in Table 1.

Table 1 Specific Milestone Achievement Objectives

Phase Name	Phase Outcome Objectives
Basic Database Knowledge	Ability to accurately understand the basic concepts, architecture and data model of databases, and proficiency in installing and configuring mainstream relational database management systems.
SQL language application	Skilled in using SQL statements to complete tasks such as database creation, table manipulation, data query and update, able to write complex SQL query statements
Database Design	Ability to perform requirement analysis, conceptual, logical and physical design of database based on actual needs in the field of electrical automation, ability to draw E-R diagrams and relational models, and ability to meet the paradigm requirements of database design
Database development and management	Be able to use database development tools (e.g. Java, C#, etc.) to implement the connection between the database and the application, and be able to develop simple database application systems; be able to perform backup, recovery, performance optimisation and security management on the database.
Awareness of new database technology	Be able to understand the basic principles and application scenarios of new database technologies such as industrial IoT database and real-time database, and be able to use at least one new database to complete simple data storage and query tasks.
Integrated Project Practice	Be able to work in a team to complete a database project in the field of electrical automation, including the whole process of requirement analysis, design, development, testing and maintenance, and be able to write and present project reports.

3.2 Optimization of the Teaching Content of ‘Project-Driven + Practical-Physical Integration’

Closely aligned with the needs of professional positions in electrical automation technology, the course breaks the traditional theoretical knowledge-centred system and builds a teaching content system with project as the carrier and vocational ability cultivation as the core. The teaching content follows the principle of ‘from simple to complex, from single to comprehensive’, covering database foundation, SQL language, database design, database development and management, new database technology and other knowledge. And into the intelligent manufacturing workshop data management, industrial equipment operation status monitoring data storage and analysis of industrial automation field actual cases, enhance the relevance and practicality. At the same time, the project-driven teaching method is used to break down the teaching content into specific project tasks, such as ‘industrial equipment management database design’, ‘electrical automation data query system development’ and so on. Through the completion of the project to achieve the teaching objectives, to help students master the database technology knowledge and skills.

In addition, the implementation of integrated teaching mode, breaking the boundaries of theoretical and practical teaching, teachers first theoretical explanations, and then guide students to practical operation to verify the application of knowledge, such as explaining the syntax rules of the SQL statement, so that students in the database management system to write and execute the SQL statement, to achieve the do-it-yourself learning and learning to do to comprehensively improve the quality of teaching and students' practical ability.

3.3 Innovation of ‘Online-Offline Hybrid’ Teaching Model

The course adopts the online and offline integrated teaching mode, with the construction of online teaching platform as the core, building an online teaching resource library containing micro-video, graphic and textual electronic courseware and teaching cases, problem banks and online tests and other resources, providing students with a fragmented independent learning platform, and providing real-time feedback on the learning situation through the testing function. At the same time, offline classroom teaching is project task-oriented, implementing group cooperative learning, where students analyse problems, formulate solutions and practice under the guidance of teachers (as guides and organisers), focusing on cultivating teamwork, communication and problem-solving skills[5]. The online and offline teaching is closely integrated, students use online resources to study before class to clarify the objectives and key points; teachers combine the online data with the online pre-study, targeted lectures and Q&A to improve efficiency; students complete homework and tests through the online platform after class, and teachers provide timely feedback to consolidate knowledge. In addition, the online platform supports discussions and exchanges, creates a good learning atmosphere, and realizes the complementarity and linkage of the whole teaching process.

3.4 Construction of a ‘Multi-Dimensional’ Assessment and Evaluation Mechanism

In the assessment and evaluation system of database courses, the model of diversified assessment and evaluation subjects, comprehensive content and diversified methods is fully implemented. Break the traditional single teacher evaluation body, the introduction of student self-assessment and group mutual evaluation, the construction of a multi-subject system, in which the student self-assessment to help its reflection to improve, the group will be evaluated to promote the exchange of experience and collaborative ability to cultivate. The assessment and evaluation content not only covers the theoretical knowledge of the database, but also extends to the practical ability, teamwork ability, innovation ability, learning attitude and other dimensions, theoretical knowledge through online tests and other tests, practical ability based on the project tasks and other evaluations, teamwork ability with the help of the group mutual evaluation and teacher observation to determine the innovation ability from the project results to measure the demonstration of the attitude of learning through the attendance, homework and other measurements. The assessment and evaluation method adopts a combination of process and summative assessment, with process assessment accounting for 60% of the total grade through classroom performance, assignments, experiments, project milestones, etc., and summative assessment accounting for 40% of the total grade through comprehensive project defence and final examination evaluation to comprehensively and objectively evaluate students' learning outcomes.

4. CONCLUSIONS

Introducing the OBE concept into the teaching of database principles and application courses in vocational colleges and universities, through reconstructing teaching objectives, optimising teaching contents, innovating teaching modes and perfecting assessment and evaluation, it effectively solves the problems existing in traditional teaching, improves students' learning interest and practical ability, and enhances the quality of teaching and the level of talent cultivation. From the effect of recent teaching reform, the efficiency of teachers and the initiative of students in learning have been more obviously improved.

In the future, it is necessary to further deepen the teaching reform, strengthen the cooperation with enterprises, introduce more practical industrial projects and new technologies, and constantly update the teaching content and teaching methods; strengthen the guidance for students' personalised learning to meet the needs of different students' career development; and set up a more perfect teaching quality monitoring and continuous improvement mechanism to ensure the sustained and in-depth promotion of the teaching reform.

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Design and Manufacturing of CNC Grinding Machine for Large Ceramic Slag Removal Device

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Abstract: The ceramic slag remover is the key component in paper making equipment and also the vulnerable component. After the ceramic cone bucket and the stainless steel protective cover are bonded, the extra ceramic outer edge needs to be repaired and grinded. At present, the noise dust pollution is serious, the efficiency is low, the labor intensity is high, and the product precision is low. A special grinding machine is designed and manufactured through repeated experiments. Two sets of gear boxes are installed on the balance disc to connect cup type grinding wheel. The grinding wheel rotates around the axis while rotating. The radius of revolution is adjusted according to the radius of the workpiece. By controlling the speed of rotation and the feed of the grinding wheel through PLC, the end face grinding of the ceramic cone cylinder whose diameter is more than one meter is realized. The surface roughness is greatly improved and the production efficiency is increased by more than 30 times.

Keywords: Ceramic Grinding; End Face Grinder; Automatic Control; Rotation and Revolution

1. INTRODUCTION

The slag remover in papermaking equipment is used to remove impurities from fiber pulp. It is a key and vulnerable component in papermaking equipment, with high product quality requirements, difficult processing, and high market demand. Ceramic vertebral bodies with stainless steel protective covers are widely used as corrosion-resistant and high-strength slag removers.

There are different models of ceramic cones, with a minimum diameter of 50mm, a maximum diameter exceeding 1000mm, a length of up to 3 meters, and a wall thickness of 10-20mm. When matched with a stainless steel outer protective sleeve, the protruding ceramic end face due to deformation usually needs to be ground flat. At present, production enterprises use manual handheld angle grinders for grinding, and pneumatic angle grinders with water-cooled lubrication do not meet the required power. Electric angle grinders cannot be ground with water due to electrical safety reasons. Due to manual operation, dust pollution is severe and is the main source of dust and noise in the workshop. High labor intensity, harsh environment, low efficiency, severe consumption of grinding wheel in waterless grinding, uneven grinding surface, and low precision. However, the processing range of general mechanical equipment is smaller than the end face size of large ceramic cones, which cannot meet the requirements.

Due to the length of large ceramic cones reaching up to 3 meters, when the cones are vertically clamped, the height of general equipment is limited, so the cones must be placed horizontally. At present, there are no grinding equipment for large end faces exceeding 200 millimeters on the market, mainly due to the limitation of tool length, insufficient rigidity of the tool holder after elongation, and vibration [1]. At present, there is no ready-made method or equipment that can meet the processing requirements, and there is an urgent need for specialized machine tools to improve the process.

2. DESIGN PROPOSAL

The entire equipment is shown in Figure 1, including the base and bed [2], and the connection relationship of the gearbox is shown in Figure 4. The bed body 5 is equipped with a power mechanism and a rotary grinding mechanism, and the bottom is installed on the top of the base 8 through a linear feed mechanism. The opposite side of the rotary grinding mechanism is equipped with a workpiece clamping mechanism fixedly installed on the base 8; The rotary grinding mechanism includes a revolving mechanism and a self rotating grinding mechanism. The revolving mechanism is a balance disk 10 installed in the middle on the output end of the power mechanism, and the self rotating grinding mechanism is installed on top of it; The power mechanism is installed on the upper part of bed 5, and the output end is connected to the revolving and self rotating grinding mechanisms through a transmission mechanism.

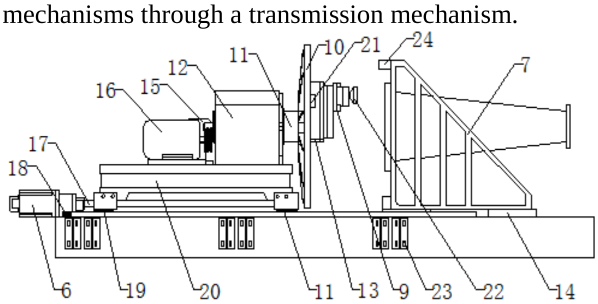

Figure 1. Schematic diagram of internal structure

(1) Install guide rail 18 on bed 5, and the worktable's forward and backward movement is controlled by a servo motor.
(2) The grinding wheel head needs to self rotate and revolve on the support disk. Due to the weight of the gearbox being over 20 kilograms, using a metal disk can effectively solve the dynamic balance problem of the grinding head and facilitate the addition of a balance block. Use a 1-meter diameter cast aluminum disc 10; Add 3 circular reinforcing ribs and 6 diagonal reinforcing ribs with a wall thickness of 10mm.
(3) Design 2 concentric shafts, supported by 4 bearings, with independent rotation of the inner and outer shafts. Install a disc on the outer shaft and a main shaft pulley on the inner shaft.
(4) Design a guide rail on the disc to move the grinding head; The curvature radius of the guide rail is on the same trajectory as the center of the disc. Connect the guide rail to the disc with bolts.
(5) The grinding head installed on the disc is composed of two gearboxes 25 and 28, and the spindle drives the grinding wheel to rotate through the gearboxes.
(6) When adjusting the grinding radius, loosen the fastening bolts at the bottom of the grinding head and move the grinding head along the guide rail so that the outer edge of the grinding wheel does not touch the inner edge of the stainless steel flange of the cone barrel. After adjusting in place, tighten the grinding head bolt.
(7) During grinding, the grinding wheel rotates at high speed, and the disc drives the grinding head to rotate along a certain radius. Drive the bed to move through the feed mechanism to achieve grinding wheel feed.
(8) Workpiece 1 is fixed horizontally on the base fixture support, with the conical end face perpendicular to the horizontal plane. The grinding wheel rotates on its own axis while revolving around the spindle in a vertical plane. The revolution diameter can be adjusted according to the size of the workpiece diameter, ranging from 10 to 1000mm.

Innovation point:

One is that the cup-shaped grinding wheel rotates and revolves, and the grinding head moves within the guide rail of the disc, achieving the processing of ceramic cones with different radii.

The second is that the motor power is transmitted to the grinding wheel through two gearboxes, solving the problem of cable winding when the grinding wheel rotates along the trajectory when it is directly connected to the power motor, and achieving grinding with a large turntable and grinding head.

3. STRUCTURAL DESIGN

3.1 Orbital Grinding Mechanism

A 1KW variable frequency motor with a 1:50 reducer, connected to a balance disk through a spindle box. The revolving main shaft 32 and the self rotating main shaft 31 are two concentric shafts supported by four bearings, and they rotate independently. The outer axis is the revolving main shaft 32, with a balance disk 10 installed. The inner axis is the self rotating main shaft 31, with a main shaft pulley installed.

3.2 Self Rotating Grinding Mechanism

The 3KW frequency modulation motor is transmitted to gearboxes 1 and 2 through the spindle box, driving the grinding wheel to rotate at high speed. The first gearbox has a circular track, and the second gearbox can rotate as a whole along the track. The position of the second gearbox can be adjusted according to the radius of the processed parts. The diameter range of the processed ceramic cone is 0-1000mm or larger.

Each set of gearboxes consists of three gears, with the center of the plane on a straight line. The first gearbox 28 is fixed on the balance disk 10, and the second gearbox 25 is installed on the output end of the first gearbox 28 through a disk adjustment guide mechanism, which can rotate and adjust around the passive wheel axis of the first gearbox. A grinding wheel 22 is installed on the output end of the second gearbox 25. The driven wheel gear shaft of the first gearbox 28 is connected to the driving wheel gear shaft of the second gearbox 25 using an elastic coupling.

The disc adjustment guide mechanism includes a disc guide 26, which is equipped with multiple sets of adjustment holes corresponding to the outer edges of the disc guide 26 and the second gearbox 25, and is connected as a whole through multiple adjustment holes and multiple sets of bolts. The disc guide 26 is also equipped with an annular protrusion for circumferential rotation adjustment of the second gearbox 25.

There are multiple counterweight adjustment holes on the end face of the balance disk 10, and a counterweight adjustment block 21 is installed through the multiple counterweight adjustment holes.

The spindle motor 16 drives the spindle gear, which is transmitted through three stages and finally transmitted to the grinding head gear, driving the grinding wheel 22 to rotate. The speed is adjusted by the self rotating spindle frequency modulation motor.

The selection of gear size involves the transmission of the main shaft to the grinding wheel, and the distance between the main and secondary shafts is relatively long. If only one pair of gears is used for transmission, the size of the gears will inevitably be very large. This not only increases the structural size and weight of the machine, but also wastes materials and makes manufacturing and installation inconvenient. By using a gear train consisting of three gears for transmission, the size of the gears can be much smaller, and manufacturing and installation are also more convenient.

Bearing selection, considering the weight of the two gearboxes, the thickness of the grinding head support bearing should be minimized as much as possible. The thickness of the roller bearing is larger than that of the ball bearing, and the selection of the ball bearing is determined through experiments. [4]

Due to the fact that the end face of the stainless steel flange of some models of slag removers is higher than that of the ceramic cone, the outer edge of the grinding wheel can only be inside the stainless steel flange during grinding, and cannot touch the outer edge of the stainless steel, otherwise it will damage the grinding wheel. In this state, when grinding with a part of the outer edge of the grinding wheel, the force on the grinding wheel is unbalanced [3], and the inner and outer rings of the bearing are subjected to torque force through the steel ball, making the bearing a vulnerable part that needs to be replaced frequently [4].

Resin diamond cup-shaped grinding wheel is selected for the grinding wheel [5].

3.3 Transmission Feed Mechanism

The transmission mechanism includes a revolving main shaft 32 and a self rotating main shaft 31 that rotate independently. The revolving main shaft 32 and the self rotating main shaft 31 are two concentric shaft sleeves arranged inside and outside, with the revolving main shaft 32 on the outer side and the self rotating main shaft 31 on the inner side. The revolving main shaft 32 and the self rotating main shaft 31 are supported by two pairs of centripetal bearings, with one end connected to the power mechanism and the other end connected to the balance disk 10 and the self rotating grinding mechanism, respectively.

The feed mechanism is driven by a servo motor through a screw guide to drive the bed, which in turn drives the disc and grinding wheel to move forward and backward to achieve feed [6].

3.4 Workpiece Clamping Mechanism

Including fixture limit block 2, clamping positioning bracket 7, and adjusting base plate 14, one side of the workpiece clamping mechanism is equipped with a cutting fluid spraying mechanism.

The positioning bracket consists of two right angled triangular brackets, each with a positioning hole in the middle. The center height of the hole is equal to the center height of the grinding head's revolution. The bolt holes evenly distributed on the stainless steel sheath flange of the ceramic cone tube serve as positioning holes, and the workpiece is fastened to the bracket, with the center of the workpiece aligned with the center of the grinding head's revolution. The end face of the vertical bracket serves as the positioning surface, and the end face of the workpiece flange serves as the clamping surface. After clamping with bolts, the end face of the workpiece remains parallel to the end face formed by the revolution of the grinding head. If there is a slight error in parallelism, the height can be fine tuned by adjusting the base plate to keep the rotating end face of the grinding head parallel to the end face of the workpiece. When processing conical cylinders of different sizes, as long as the distance between the two clamping brackets is adjusted to be equal to the diameter of the stainless steel conical cylinder flange, the positioning accuracy of the workpiece can be ensured.

4. CONTROL SYSTEM

Including PLC controller SIEMENS-S7-200, 12 inch touch display screen, I/O terminal board module, etc. to control the spindle motor and servo motor to drive the grinding wheel feed. It has functions such as coordinate system management, safety protection, process parameter setting, and external communication [7].

The touch screen enables human-machine dialogue and allows manual input of workpiece parameters. Realize the switching between automatic and manual operation modes [8].

5. PROCESSING OPERATION STEPS

5.1 Clamping Workpieces

According to the diameter of the workpiece, adjust the distance between the two supports of the clamping device. The distance between the positioning holes is equal to the distance between the two opposite holes on the workpiece flange, and clamp the workpiece.

5.2 Adjustment of Grinding Wheel Revolution Radius

The ceramic cone end face and the concave step surface of the stainless steel flange are in the same plane. Adjust the rotation radius of the grinding head according to the radius of the workpiece, loosen the fastening bolt on the disc guide 26, and rotate the second gearbox 25 to make the outer edge of the grinding wheel 22 equal to the processing radius of the workpiece 1. Slowly rotate the large blade and fine tune it

After adjusting the position of the second gearbox 25, the large plate stops rotating and locks the bolt of the second gearbox 25 disc.

5.3 Startup

After workpiece 1 is clamped and positioned, start the machine and adjust the spindle speed according to the diameter of grinding wheel 22. The servo motor drives the grinding wheel 22 to feed. The grinding wheel 22 rotates at high speed, and the balance disk 10 drives the grinding head to rotate along a certain radius. Balance disk 10 moves forward and backward to achieve feed. At the same time, the balance disk 10 rotates at low speed, and the grinding head of the grinding wheel 22 grinds within the adjusted radius range. Simultaneously, feed is achieved by servo motors.

5.4 Adjustment of Cutting Parameters

Choose a cup-shaped resin grinding wheel, and based on the grinding force of silicon nitride ceramics and experimental data on wheel blockage, different linear velocities and feed rates have varying curves on blockage [9]. Taking a 200mm diameter cup-shaped diamond resin grinding wheel as an example, the optimal speed is 750r/min and the feed rate is 0.03mm/r, which means that the grinding wheel rotates once and the feed rate is 0.03mm [10].

Adjust the spindle motor speed according to the diameter of the grinding wheel. The grinding effect is better when the linear speed of the grinding wheel is between 400-500m/min. Adjust the revolution speed according to the grinding feed rate. Generally, 15-20 revolutions per minute yields better results.

6. EXPERIMENTAL EFFECT

Taking a 500mm diameter slag remover as an example, a 3kw main motor was inspected at the production site, with a noise level of 30 decibels, no dust pollution, circulating cooling and lubricating fluid, a surface roughness of 0.8, and a beautiful appearance. During manual grinding, one workpiece can be ground in 8 hours per working day, and the equipment can grind every ten minutes, increasing efficiency by 30 times.

7. SUMMARY

The device rotates the grinding wheel while revolving along a certain radius for grinding. The movement radius of the rotating grinding wheel is adjusted according to the size of the workpiece end face, and the rotation diameter can reach 1 meter or more.

Overcoming the problems of low efficiency, high strength, and high pollution in the end face processing of large ceramic cones, avoiding the problems of high cost and limited travel caused by the use of large equipment for processing large end faces.

High machining accuracy, the machining end surface formed when the grinding head rotates around the axis of the cutting disc can be parallel to the workpiece end surface, without being affected by the deformation of the cutting disc, fully ensuring the machining accuracy of the workpiece.

Low equipment cost. Compared with general grinding machines for processing large-sized workpieces, the equipment cost is less than one tenth.

Long lifespan, simple operation, large power transmission through gearbox, and not easily damaged.

Safe and efficient, well protected equipment, eliminating safety hazards caused by manual operation.

The processing method of the ceramic end face of this equipment is also suitable for the end face processing of other materials, as long as different cutting tools are replaced according to the workpiece material.

After three years of practical production application and continuous optimization of the design, small-scale production has begun.

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Research and Practice on Cultivating On-Site Engineers for Advanced Manufacturing Based on Industry-Education-Research Integration Consortium

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Abstract: With the rapid evolution of next-generation information technologies, cross-domain integration and intelligentization have emerged as dominant trends in the smart manufacturing industry. The increasing demand for knowledge- and technology-intensive roles necessitates a finer alignment between talent supply and industry needs. Current theoretical studies on on-site engineer cultivation remain predominantly broad and fragmented, with limited systematic exploration into competency requirements, developmental trajectories, and training mechanisms for such professionals. The absence of influential theoretical frameworks in this domain restricts both the depth of existing research and its practical applicability. This study leverages platforms such as electrical automation technology discipline clusters and adopts Chinese-style apprenticeship models to empirically explore the cultivation of on-site engineers. By investigating discipline-specific talent development patterns, it aims to establish standardized training criteria and offer replicable models for collaborative enterprise-school strategies in nurturing advanced manufacturing practitioners.

Keywords: Industry Education Integration; Advanced Manufacturing; On-site Engineers

1. INTRODUCTION

Amid the global transformation and upgrading of the manufacturing sector, advanced manufacturing has become a pivotal driver of economic development. The deep integration of next-generation information technologies—such as artificial intelligence, big data, and the Internet of Things—with traditional manufacturing has revolutionized production models, management paradigms, and product architectures. The smart manufacturing sector has exhibited marked trends of cross-domain convergence and intelligentization, fostering a surge in knowledge- and technology-intensive roles. This evolution demands unprecedented capabilities from manufacturing professionals: not only must they possess robust domain expertise, but also the engineering acumen to apply theoretical knowledge to real-world production scenarios and the innovative capacity to resolve complex technical challenges[1].

Under these circumstances, achieving precise alignment between talent cultivation systems and industrial requirements has become imperative. On-site engineers, who serve as critical intermediaries bridging technology R&D and practical production in advanced manufacturing, play an irreplaceable role. Beyond mastering production workflows—enabling equipment commissioning, operational maintenance, and quality control on the front lines—they must demonstrate proficiency in adopting emerging technologies to optimize and innovate manufacturing processes. Nevertheless, existing theoretical research on on-site engineer development remains underdeveloped[2], often constrained to superficial discussions. A systematic inquiry into competency frameworks, career progression patterns, and training mechanisms for such engineers is conspicuously absent, leaving a void in influential theoretical frameworks. This deficiency significantly undermines the scientific rigor and practical efficacy of current talent development programs. Consequently, conducting in-depth research and practice on cultivating on-site engineers through industry-education-research integration consortia holds both substantial practical relevance and theoretical significance.

2. DEMAND ANALYSIS OF ON-SITE ENGINEERS IN THE ADVANCED MANUFACTURING INDUSTRY

2.1 Development Trends of The Smart Manufacturing Industry

The intelligent manufacturing sector has deconstructed the traditional compartmentalization inherent in conventional manufacturing paradigms, achieving profound multidisciplinary integration across mechanical engineering, electronic information systems, computer science, and automation control. A salient manifestation of this integration is observed in the lifecycle of industrial robotics – spanning research, development, and deployment – which necessitates concurrent advancements in mechanical design precision, manufacturing engineering, embedded electronic control architectures, and machine learning algorithms. This technological symbiosis mandates that field engineers develop polycentric knowledge frameworks encompassing multiple disciplines, coupled with the capacity to synthesize and operationalize cross-domain expertise through coordinated workflows spanning disparate technical systems.

The pervasive implementation of artificial intelligence (AI), Industrial Internet of Things (IIoT), and big data analytics within manufacturing ecosystems has catalyzed exponential growth in production process intelligence. Modern smart factories employ distributed sensor arrays and IIoT-enabled communication protocols to establish pervasive machine-to-machine interconnectivity, enabling real-time data acquisition at sampling frequencies exceeding 1 kHz. These multidimensional data streams undergo systematic processing through cloud-native analytics platforms utilizing ensemble learning algorithms and digital twin simulations, thereby enabling predictive maintenance scheduling and self-optimizing production control strategies[3].

2.2 The Requirements for Talents in Knowledge- And Technology-Intensive Positions

On-site engineers require comprehensive foundational expertise spanning mechanical design, electronic circuits, automation control, and computer programming. In electrical automation systems, for instance, mastery of electrical principles, motor control theories, and PLC programming constitutes essential domain knowledge for executing equipment installation, commissioning, and maintenance tasks with technical efficacy.

Practical operational proficiency serves as the core professional competence for on-site engineers. This encompasses skilled equipment operation, rapid fault diagnosis and mitigation, and systematic process optimization. In automotive manufacturing contexts, engineers must demonstrate technical capabilities in calibrating and sustaining automated production lines to ensure efficient and stable operation with production yields exceeding 98%.

Within smart manufacturing ecosystems characterized by emergent technologies, engineers must exhibit innovative problem-solving capacities to address complex technical challenges. A representative case involves addressing poor cell consistency in new energy vehicle battery production, demanding innovative material processing techniques and electrochemical parameter optimization to achieve ≤3% cell voltage variance.

3. SPECIFIC MEASURES

3.1 The Construction of The Industry-college-Education Integration Community

Centered on the electrical automation technology discipline cluster within higher education institutions, an Industry-Education-Research Integrated Consortium has been collaboratively established with key industry enterprises (e.g., electrical equipment manufacturers, automation system integrators), research organizations, and industry associations. The consortium operates under a division-of-labor framework: Institutes furnish theoretical pedagogy and fundamental research support, enterprises provide practical training facilities, project cases, and field production expertise, research institutions advance technological innovation, while industry associations assume roles in policy guidance, standardization, and cross-platform knowledge dissemination.

A "Government-Institute-Enterprise-Industry-Research" collaborative model is implemented. Governments enact relevant policies and allocate funding to institutionalize industry-education-research integration. Institutes and enterprises formalize partnerships through agreements to co-develop talent cultivation programs, curricula, and teaching methodologies, while jointly delivering academic-practical hybrid pedagogy. Industry associations coordinate technical exchanges and skill-building initiatives to advance knowledge sharing. Research institutions collaborate with enterprises on R&D projects, translating innovations into industrial applications, while supplying cutting-edge case studies and experiential platforms for talent development.

3.2 The Talent Cultivation Model Based on the Apprenticeship System with Chinese Characteristics

A dual-mentor system is implemented throughout the talent cultivation process. Academic mentors (possessing theoretical expertise and pedagogical proficiency) oversee students' disciplinary instruction and scholarly guidance, while industry mentors (comprising frontline technical experts and senior engineers) deliver practical training and career counseling, imparting operational competencies, process expertise, and industry trends. For instance, during internships, industry mentors guide students through end-to-end project execution—from planning and design to installation and commissioning.

An alternating work-study pedagogy structures learning across academic-industrial contexts. During campus phases, students engage in foundational and core coursework (e.g., circuit theory, automation control) to establish theoretical mastery. Enterprise internships immerse students in production workflows, enabling application of knowledge while internalizing industrial management protocols and professional ethics. As a programmatic example, three-month internships are mandated during the latter sophomore and early junior years, allowing firsthand exposure to manufacturing processes that reinforce disciplinary comprehension.

3.3 Reforms of the Curriculum System and Teaching Contents

Guided by occupational position requirements, a work process-based curriculum system has been constructed. The courses within the electrical automation technology professional group are categorized into four modules: public basic courses, professional basic courses, professional core courses, and practical courses.

(1) Public basic courses focus on developing students' fundamental literacy and general competencies.

(2) Professional basic courses establish a solid theoretical foundation for students.

(3) Professional core courses align with the occupational competency requirements for field engineers, offering subjects such as Electrical Control System Design, PLC Programming and Application, and Industrial Robotics Technology.

(4) Practical courses include experiments, skill training, internships, and graduation projects, emphasizing the cultivation of practical and innovative abilities.

Industry-responsive teaching content updates ensure the integration of cutting-edge technologies and real-world production cases. For example:

(1) Courses now incorporate industrial internet platform applications and equipment remote monitoring and diagnosis to reflect advancements in industrial internet technology.

(2) Practical training embeds actual enterprise automation production line renovation projects, enabling students to master the latest technologies and methodologies through problem-solving.

(3) Collaborative development of school-enterprise textbooks integrates corporate production standards, process flows, and operational specifications, enhancing the practicality and relevance of teaching materials.

4. THE RESULTS OF THE CULTIVATION PRACTICE

Implementation of practice-oriented cultivation through the industry-education-research integration consortium has significantly enhanced students' disciplinary competence and operational proficiency. Graduates demonstrate rapid workforce adaptability, garnering widespread industry recognition. For instance, within the electrical automation technology discipline cluster, graduate employment rates have consistently exceeded 98% over the past three years, with 90%+ job-role alignment and enterprise satisfaction surpassing 95%.

An industry-aligned field engineer competency framework has been formalized through iterative refinement of educational outcomes against sector requirements. This framework codifies requisite knowledge domains, technical competencies, and professional attributes, while prescribing optimized curricula, pedagogical methodologies, and competency assessment protocols, establishing benchmarks for field engineer development.

5. CONCLUSIONS

Under the rapid advancement of advanced manufacturing, the cultivation of field engineers—key professionals bridging technology and production—has become strategically vital. By establishing industry-education-research integration consortia, leveraging China's distinctive apprenticeship system, and utilizing platforms such as the Electrical Automation Technology Discipline Cluster, these cultivation initiatives have effectively enhanced talent development quality, established standardized training frameworks, and yielded substantial outcomes in industry-academia collaboration.

This practice not only explores foundational principles for vocational education in nurturing engineering talent but also provides a replicable model for school-enterprise collaboration in cultivating field engineers. Moreover, it injects robust momentum into advancing advanced manufacturing. Looking ahead, efforts must further deepen industry-education-research integration, continuously refine the field engineer training system to align with the evolving talent demands of advanced manufacturing, and contribute more significantly to the transformation, upgrading, and high-quality growth of China's manufacturing sector.

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Design of a Multi-purpose Inner Circular Surface Machining Fixture and Machine Tool

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Abstract: In the military aerospace field, typical curved conical structures such as fire arrows, antenna covers, missile heads, etc. play a crucial role due to their large size, thin wall thickness, and geometric characteristics of conical rotors. These structures not only have a profound impact on national security and defense development, but also occupy an indispensable position in related fields. However, due to the fact that these structures are usually made of hard and brittle materials such as quartz ceramics and glass fibers, traditional metal chuck clamping methods are prone to material breakage during the processing. In addition, after the fixture is released, the workpiece often undergoes significant deformation, which directly affects the maintenance of dimensional accuracy. In view of this, a multifunctional fixture and machine tool suitable for inner circular surface machining have been designed, which has significant practical and strategic significance for achieving efficient clamping and precise positioning of conical parts, as well as improving machining accuracy and production efficiency.

Keywords: Inner Circular Surface; Fixtures and Fixtures; Machine Tool Design; Machining Accuracy; Industrial Ceramics

1. FIXTURE DESIGN

During flight, missiles and rockets are affected by air resistance, and the larger the contact area, the greater the resistance. Therefore, in order to minimize air resistance to the greatest extent possible, a conical structure is usually designed. However, conical structures are prone to rotation and shaking during clamping, and due to their hard and brittle material, they are prone to breakage and deformation during processing, which cannot guarantee dimensional accuracy and processing efficiency [1]. Therefore, in order to improve the processing efficiency and accuracy of conical structures, it is crucial to design a fixture system that can firmly clamp conical structures without causing them to break or deform. Numerical control machine tools should be designed with reasonable mechanical structures such as head box, center frame, and machine tailstock, and should be used in conjunction with the numerical control system to achieve three-axis linkage control, in order to achieve the machining of complex curved surfaces in deep hole cavities.

Fixture refers to a device used in the mechanical manufacturing process to fix workpieces, usually consisting of positioning elements, clamping devices, connecting elements, and fixtures[2]. During machine tool processing, in order to achieve the technical requirements of dimensional accuracy, geometric shape, and mutual position specified in the drawing, the workpiece must be positioned and clamped firmly before processing, so that the machine tool, cutting tool, and workpiece maintain a certain relative position and undergo processing and testing[3].

Currently, the iteration of aerospace products is rapid, and traditional rigid fixtures are no longer able to meet the demand for rapid clamping. Flexible fixtures, with their flexible, diverse, and fast sample changing characteristics, can effectively achieve a stable combination between workpieces, fixtures, and equipment, ensuring stable clamping of workpieces and enhancing the overall structural stability[4].

1.1 Fixture and Fixture Plate Design

The specific aterial of the clamp is cast iron, and the inner cavity is glued with the first and second tooling plates. The first tooling plate is 80-100mm away from the large end face of the cover body, and the second tooling plate is 100mm away from the small end face of the cover body. This can firmly clamp the cover body without damaging it.

The tooling plate is made of soft plastic material, and its center is designed with a through hole for easy clamping of the cover body. The inner walls of the holes of the two tooling plates are strictly according to the contour line of the cover body, and are precision machined by a CNC machine tool internal grinder in one go. The two inner hole walls maintain a certain degree of concentricity, and when clamping the cover body, they will tightly adhere without generating excessive stress or damaging the cover body.

The advantage of this fixture clamp design is that the plastic material fixture is easy to process, and it is also convenient for adhesive fixation and replacement, without damaging the clamp. The inner hole line of the tool plate processed by imitation can firmly clamp the cover without shaking, ensuring good inner surface roughness.

1.2 Specific Design of Clamp

The main structure of the fixture includes: fixture cap, plastic fixture plate, reinforcing ribs, and cone sleeve. When processing covers of different lengths, outer diameters, and sizes, there is no need to replace the clamp. Simply replace the plastic fixture according to the geometric dimensions of the cover, which can reduce processing costs. The function of the fixture cap is to increase the pre tightening force as the tightening force increases during the clamping of the cover, making the cover clamping more secure and preventing rotation and vibration during antenna cover processing.

Before clamping the cover body, it is necessary to conduct a visual inspection of the blank to ensure that its appearance meets the processing standards. Next, conduct a detailed inspection of the inner circle fixture to ensure that the runout of the fixture does not exceed 0.03mm. During the clamping process, the small end of the cover should not shake, while the shaking of the large end inside the fixture should be controlled within 0.02mm. At the same time, the runout of the inner circular grinding wheel should not exceed 0.02mm.

2. MACHINE TOOL DESIGN

Machine tool is a high-precision and high-efficiency automated equipment, usually composed of CNC device, bed, spindle box, tool holder feed system, tailstock, hydraulic system, cooling water, lubrication system, and chip removal system[5]. The FANUC CNC system is adopted, which has compensation functions for linear interpolation and arc interpolation. By equipping multiple types of cutting tools, the X, Z, and C axes are controlled in a coordinated manner, thereby enhancing machining capabilities and achieving the machining of complex curved surfaces and irregular arc conical structural parts [6].

2.1 Machine Tool Head Box Design

The main structure of the machine tool head box consists of a series of precision mechanical components such as clamps, center frames, fixture caps, slide rails, supports, fixed seats, and guide rails.

The center frame plays a role in clamping and positioning the fixture body, and can slide back and forth along the support seat, making the center frame move away from or close to the machine tool head frame[7]. The distance between the center frame and the machine head frame can be adjusted to meet the processing requirements of different lengths of covers, with strong versatility.

2.2 Machine Tool Tailstock Design

The machine tool tailstock is equipped with a grinding component, and a cleverly designed groove structure below it allows for flexible adjustment of the position of the grinding component according to the different lengths of the cover during the machining process, thereby achieving precise machining of the inner circle of the cover. The grinding tool component of the machine tool tailstock includes a diamond grinding wheel and a grinding rod. The grinding wheel rotates to achieve the grinding of the inner circle of the cover body [8].

During the grinding process, the spatial position of the grinding tool components is precisely controlled by precise CNC programming of the rotating motor, thereby achieving precise linkage in the front, back, left, and right directions to machine complex surfaces inside the cover.

2.3 Overall Design of Machine Tool

The overall design of a multi-purpose inner circular surface machining machine tool includes structures such as machine head frame, center frame, fixture, tail frame, and grinding tool components.

The conical structure inner circle fixture and machine tool have the advantages of strong machining adaptability, high machining accuracy, and simple operation. During the machining process, the application of flexible fixtures, the overall design of CNC machine tools, and the optimization of machining schemes can improve the machining quality and accuracy of the inner circle of conical structures.

3. FUTURE DEVELOPMENT TRENDS

3.1 Development Trends of Fixtures

The opening of the clamp should be increased to facilitate the clamping operation of the cover. At the same time, while ensuring the strength of the clamp, the requirements of energy conservation and consumption reduction should also be taken into account. From a safety perspective, it is necessary to ensure a safe distance between the workpiece and the tool, and prevent interference between the grinding rod shaft, tool, and cover [9].

The specific design of the clamp should have flexibility to improve versatility while ensuring a certain clamping force and compactness. The inner hole wall of the tooling plate needs to be processed strictly according to the numerical simulation program to prevent clamping deformation and vibration during the processing, thereby significantly improving the machining accuracy and efficiency of the cover body.

3.2 Development Trends of CNC Machine Tools

With the development demand of aerospace, science and technology, and precision parts, CNC machine tools have been widely used due to their advantages of high processing efficiency and precision [10]. The development trends of future CNC machine tools mainly include the following aspects:

(1) It has a high rotational speed and can achieve three-axis linkage control, meeting the requirements for machining the inner and outer surfaces of the irregular cover body;

(2) Has good vibration resistance and sufficient power, strength, and stiffness to meet the accuracy requirements of the workpiece;

(3) Featuring a simple and compact structure with low manufacturing costs; Good craftsmanship and easy maintenance and adjustment; The characteristics of smooth operation and low noise.

4. CONCLUSION

The multi-purpose inner circular curved surface fixture is designed as a specialized flexible fixture. The plastic fixture plate is glued to the fixture cavity, and according to the contour curve of the cover body, the CNC machine tool is used to machine the inner hole wall of the imitation fixture plate, making it closely fit with the fixture plate, thereby reducing the shaking of the cover body, improving the clamping stability, and ensuring the processing quality and accuracy of the product. The CNC machine tool ensures efficient and precise machining of the cover surface by designing exquisite core mechanical structures such as the head box, center frame, and machine tailstock, combined with advanced control methods of three-axis linkage. The design of multi-purpose inner circular surface fixtures and machine tools provides great convenience for the machining of inner circles in covers, and will develop towards high quality and high production efficiency in the future.

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"Crunchy" to Tough: a Study on the Cultivation Mechanism of Mental Toughness in Higher Vocational Students

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Abstract: Psychological Resilience, as the core ability of individuals to cope with adversity, has been proved to be positively correlated with academic achievement and career adaptability. However, in traditional higher vocational education, the cultivation of psychological resilience is often simplified as "frustration education" or fragmented psychological counseling activities, which lacks a systematic mechanism. Therefore, building a mental toughness cultivation mechanism that suits the characteristics of higher vocational students is a key path to realize the transformation from "brittle" to toughness.

Keywords: Mental toughness, Higher education, Students, Transformation, Pathways

1. THE REALISTIC DILEMMA AND CULTIVATION NECESSITY OF HIGHER VOCATIONAL STUDENTS' MENTAL TOUGHNESS

Students in higher vocational colleges and universities generally face multiple pressures, such as weak academic foundation, high requirements for skills practice, and fierce competition for employment, which leads to some students' "brittle" characteristics - they are prone to anxiety, self-denial, and even behavioral withdrawal in the face of setbacks. According to the research of Hebei University of Technology in 2024, 32% of the higher vocational students have lost control of their emotions due to academic pressure, and their mental toughness score is significantly lower than that of general undergraduate students. This phenomenon not only affects students' academic performance (e.g., increased failure rate, decreased participation in skill competitions), but may also induce mental health crises (e.g., depressive tendencies, social avoidance).

2. THE SPECIFIC MANIFESTATIONS OF WEAK MENTAL TOUGHNESS OF HIGHER VOCATIONAL STUDENTS

The weak psychological resilience of higher vocational students has evolved from an episodic phenomenon to a group characteristic, which is specifically manifested in the systematic vulnerability of the four dimensions of cognition, behavior, emotion, and social adaptation, which profoundly affects the development of individuals and the quality of education[1].

2.1 Cognitive Dimensions: Negative Attribution and Goal Collapse

Higher vocational students generally have the tendency of "learned helplessness", attributing their academic or skill training difficulties to their own unchangeable deficiencies (e.g., "I was born unsuitable for learning technology"). According to the survey, 65% of the students who failed the first practical training had the cognition of "ability curing" and gave up the opportunity of subsequent practice. This cognitive bias further leads to low-order goal setting: 82% of students take "not failing" as their core academic goal, and only 7% take the initiative to participate in skill competitions or innovation and entrepreneurship projects[2]. A case study of a numerical control program in a higher vocational college shows that when facing the selection of provincial competitions, more than half of the students directly abstained from the competition for fear of "losing face if they do not perform well", reflecting the active avoidance of challenging goals.

2.2 Behavioral Dimension: Homogenization of Frustration Coping Strategies

Students mostly adopt the "avoidance-alternative" behavior pattern when facing pressure. Observations in the practical training classroom revealed that 42% of the students chose to play with their cell phones for a long time to divert their anxiety rather than seeking guidance from the teacher when they made successive mistakes in equipment operation[3], and 27% avoided the practical training class by fabricating reasons for taking a leave of absence. In the academic field, some students use "bad social" (e.g., posting "high school bad daily life" videos on social media) to compensate for their psychological problems, forming a vicious cycle of "behavioral withdrawal - self-stigmatization". The vicious cycle of "behavioral withdrawal - self-stigmatization". Statistics from a school's psychological counseling center show that 89% of the cases of academic crisis caused by procrastination are directly related to the lack of stress resistance[4].

2.3 Emotional Dimension: Dysfunctions in Emotional Regulation

Higher vocational students' mood swings are characterized by "high frequency and low tolerance".

Psychological assessment shows that 56% of students need more than 24 hours to recover emotional stability after being criticized, which is much higher than the 38% in undergraduate colleges and universities. Typical performance: when the practical training teacher points out the operation error, students are prone to violent emotional reactions (such as slamming tools, suddenly leaving the field). The percentage of self-injurious behaviors triggered by failing to meet the standard of coursework in the 2023 crisis intervention cases of a school reached 34%, highlighting the serious failure of the emotion regulation mechanism. Social media analysis further revealed that negative emotional labels such as "emo" and "broken defense" were used 2.3 times more frequently on average per day in the online community of higher vocational students than in the undergraduate group.

2.4 Social Adaptation Dimension: Low Utilization of Support Networks

Despite the general establishment of psychological counseling systems in higher vocational colleges and universities, less than 15% of students take the initiative to seek help. According to the questionnaire survey, 68% of the students think that they will be looked down upon if they reveal their vulnerability, and they prefer to vent their emotions on anonymous social platforms. In teamwork, those with weak mental toughness often show "pseudo-collaboration": they participate in group tasks on the surface, but in fact avoid core responsibilities. The tracking of an e-commerce team showed that 32% of the members avoided the pressure of practical work by "nodding participation" (only completing marginal work such as data collection), which led to a decline in team effectiveness.

3. THE MULTIDIMENSIONAL ATTRIBUTION OF WEAK MENTAL TOUGHNESS IN HIGHER VOCATIONAL STUDENTS

3.1 Individual Traits: Cognitive Biases and Self-Efficacy Deficits

The phenomenon of "skill-based low self-esteem" is common among higher vocational students, that is, they overly deny their own potential due to their unsatisfactory performance in the college entrance examination. Research shows that these students tend to attribute their failure to "lack of ability" rather than "lack of effort", resulting in low self-efficacy. For example, a student majoring in mechanics at a higher vocational college gave up participating in a provincial skills competition because he was afraid of the complexity of CNC programming, reflecting his negative response to challenges.

3.2EDUCATIONAL ENVIRONMENT: IMBALANCE BETWEEN PRESSURE TO PRACTICE AND SUPPORT SYSTEMS

Higher vocational education emphasizes practical skills, but some colleges and universities have the tendency of "emphasizing skills over psychology". In practical training courses, students need to complete high-precision operations within a limited time, teachers often focus on technical standards and ignore the psychological guidance. A survey of higher vocational colleges and universities in the Yangtze River Delta region shows that 78% of practical training teachers have not received training in mental toughness guidance, resulting in a lack of emotional adjustment support for students facing operational errors.

3.3 SOCIAL PERCEPTION: PROFESSIONAL PREJUDICE AND IDENTITY CRISIS

The labeling of higher vocational education as "inferior education" has aggravated students' identity anxiety. Some students are questioned by their friends and relatives that "there is no future in higher vocational education", and fall into the psychological dilemma of "the theory of the futility of effort". This phenomenon is particularly prominent among students from less developed regions, forming a vicious cycle of "external denial - internal dissolution".

4. CORE CONSTRUCTION PATH OF MENTAL TOUGHNESS TRAINING MECHANISM

4.1 Creating A Dynamic And Balanced "Supportive-Challenging" Educational Ecology

4.1.1 embedded design for mental toughness in practical skills training

Step-by-step task setting: Complex skills are broken down into small progressive goals to enhance self-efficacy through the accumulation of "micro-successes". For example, the CNC machining course can be designed as a three-stage task of "basic parts programming-complex assembly machining-enterprise real project simulation", with an immediate feedback mechanism for each stage.

Fault-tolerant evaluation system: Students are allowed to experience controlled failures in practical training and turn setbacks into learning resources through instructor-led review (e.g., "error attribution analysis form").

4.1.2 reinventing campus culture

We have reconstructed the narrative of role models, explored cases of outstanding graduates (such as national technical experts and entrepreneurial models), and broken the cognitive shackles of "academic determinism" through thematic documentaries and alumni sharing sessions. Meanwhile, a peer support network has been established, and a dual mentor system of "skill masters and psychologists" has been set up, with winners of senior skills competitions providing technical guidance and psychologists organizing regular pressure release workshops (such as positive thinking meditation and group sand tray).

4.2 Constructing a "Cognitive-Emotional-Behavioral" Trinity Curriculum System

4.2.1 cognitive restructuring module

Strengthening growth mindset training and helping students understand brain plasticity through "brain science + case study" lessons. For example, we have introduced the "neuron connection strengthening experiment" visualization teaching to explain how repeated practice can enhance skill proficiency. Meanwhile, the program also focuses on guiding vocational values and integrating the cultivation of craftsmanship into the professional curriculum. An intelligent manufacturing program has launched a series of activities on the theme of "Interviews with Great Master Craftsmen", combining enterprise mentors to explain the correlation between technical excellence and mental toughness.

4.2.2 emotional empowerment module

Practical training in emotion regulation techniques was conducted, and a VR situational simulation system was developed to allow students to practice their emotion management skills in scenarios such as virtual workplace conflicts and skill test failures. Research has shown that after 8 weeks of training, students' scores on the anxiety scale dropped by 27%. We have the conditions to carry out artistic expression therapy, and through interdisciplinary projects such as the "emotional sculpture" workshop for industrial design majors and the "stress visualization animation production" for digital media majors, we can realize the integration of emotional catharsis and skills training.

4.2.3 behavioral reinforcement module

We organize resilience challenges and design activities such as the "24-hour innovation marathon" and "extreme skills competition", which require teams to complete designated tasks under resource constraints to strengthen problem-solving and collaboration skills. Simultaneously carry out social service practice, organizing students to participate in rural revitalization technical assistance, community equipment maintenance and other public welfare projects, so as to enhance their sense of self-worth through real social contribution.

4.3 ESTABLISHMENT OF A COLLABORATIVE "HOME-SCHOOL-SCHOOL-ENTERPRISE-SCHOOL-SOCIETY" SUPPORT NETWORK

4.3.1 empowering transformation of family education

Developed a "Parental Mental Toughness Workshop" to guide parents to shift from "accountability for results" to "process accompaniment". For example, role-playing exercises on "how to respond to a child's frustration in practical training" are used to reduce "other people's children" comparisons.

4.3.2 involvement of business mentors throughout the process

Invite the technical backbone of enterprises to serve as "career resilience mentors", through the sharing of real cases (such as emergency treatment of production line failures) to convey the concept of career resilience, "failure is a learning opportunity".

4.3.3 integrated utilization of community resources

In cooperation with local trade unions, it has set up "Psychological Stations for Young Craftsmen", providing free psychological counseling and vocational skills certification tutoring, and building a dual support system of "psychology and skills".

5. CONCLUSION

The cultivation of mental toughness of higher vocational students needs to go beyond the perspective of "psychological repair" to "developmental empowerment". Through the reconstruction of educational ecology, curriculum innovation and collaborative network construction, the qualitative leap from "brittle" to toughness can be realized. Future research should further explore the application of artificial intelligence (e.g., emotion recognition technology) in resilience assessment, as well as the "skill-psychology" dual teacher training model, and ultimately form a symbiotic paradigm of personality growth and skill refinement with higher vocational characteristics.

6. ACKNOWLEDGMENT

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Formation and Growth of Crystals in Solid-liquid Suspension

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Abstract: The literature survey mainly shows that solid-liquid mixing process and the suspension stability. Crystallization is briefly descripted. In this study, a computational fluid dynamics (CFD) model was developed for solid liquid mixing .Computational fluid dynamics is a useful tool to analyze a system involving fluid flow through mathematical modeling and simulation by means of a computer based program. Most of the earlier work on solid suspension focuses on identifying critical impeller speed for just suspension of solids (Njs). In this study, apart from Njs, aspects like cloud height and liquid phase mixing in solid liquid suspensions were also studied.

Keywords: Solid-liquid Mixing; Suspension; Crystallization; CFD; Cloud Height.

1. INTRODUCTION

1.1 Solid-liquid Mixing

Mixing is one of the most widely used unit operations in polymer processing, fine chemicals, petrochemicals, biotechnology, agrichemicals, pharmaceuticals, paints and automotive finishes, cosmetics and consumer products, food, drinking water and wastewater treatment, pulp and paper, and mineral processing. It is carried out in mechanically agitated vessels for a variety of objectives, including for homogenizing multiple phases in terms of concentration gradient[1]. Among various mixing processes (e.g., viscous liquid, liquid liquid, gas liquid, solid liquid), solid liquid mixing is one of the most important mixing operations because it plays a crucial role in many unit operations such as suspension polymerization, solid-catalyzed reaction, dispersion of solids, dissolution and leaching, crystallization and precipitation, adsorption, desorption, and ion exchange [2,3].The primary objectives of solid liquid mixing are to avoid solid accumulation in the agitated vessel, to maximize the contacting area between the solids and liquid, and to ensure the system is homogeneous or solids particles are uniformly distributed throughout the vessel[4].

1.2 Solid-liquid Suspension

In most of the solid liquid processes, the solid particles are completely suspended. However, solid particles might not be distributed uniformly throughout the vessel. The performances of some processes such as crystallizers and heterogeneous photocatalytic reactors are affected by lack of the uniform distribution of solid particles. Therefore, a good understanding of the distribution of solid particles throughout the vessel is essential for design, process development, and scale up of the solid liquid mixing systems. Some researchers have adopted a general practice for evaluation of solid liquid mixing in agitated vessels through experimental investigation[5,6].

2. STUDY OF SOLID-LIQUID MIXING IN AGITATED TANKS THROUGH COMPUTATIONAL FLUID

Computational fluid dynamics (CFD) is a useful tool to analyze a system involving fluid flow through mathematical modeling and simulation by means of a computer based program. CFD is emerging as a design tool for the development of new processes at a fraction of the cost and time of the traditional experimental and pilot-plant approaches. Using the CFD technique to explore the effect of impeller type, particle size, impeller speed, specific gravity of solid particles, impeller off-bottom clearance, and power on the degree of homogeneity for the solid liquid mixing.

The computational fluid dynamics (CFD) modeling was successfully employed to explore the effect of operating conditions and design parameters on the mixing quality for the solid−liquid mixing operations. This technique provided in-depth details about the distribution of the solid phase within the mixing vessel. The impeller torque and cloud height calculated by the CFD model were in good agreement with the experimentally determined values. The average solid concentration at the bottom of the tank as a function of the impeller speed was determined through CFD to estimate the just suspended impeller speed (Njs), which was close to that predicted by the Zwietering’s correlation [7].The validated CFD model was then utilized to obtain the axial solid concentration profiles by which the degree of homogeneity was quantified as a function of the impeller power/speed, impeller type, impeller off-bottom clearance, particle size, and specific gravity of solid particles. As expected, the homogeneity of the system increased with an increase in impeller power/speed. Once the homogeneity reached the maximum, any further increase in impeller power/speed was not beneficial but detrimental due to the formation of the regions with low solid concentrations inside the circulation loops at higher impeller speed. The CFD results for the degree of homogeneity were in good agreement with those measured by the electrical resistance tomography. It was found that the A100 impeller was more efficient in terms of homogeneity than the A310 and A200 impellers and that the optimum impeller clearance was T/3 for the solid suspension systems. The CFD results also showed that the physical properties of the solid particles such as the particle size and the specific gravity significantly affect the degree of homogeneity in solid-liquid mixing operations.

3. THE QUALITY OF SUSPENSION

3.1 Stability Characteristics of Suspension

Stirred tanks are widely used in chemical process industries for catalytic reactions, dissolution of solids, crystallization, and so on. The quality of suspension in slurry reactors is a very crucial parameter in designing and optimizing in such processes. Conventionally, solid suspension in stirred reactors is character-ized by the “just suspension impeller” speed required for a just off-bottom suspension (Njs). This Njs is the speed at which all particles are lifted up from bottom of the vessel and not spending more than 1 or2sonthe bottom of the vessel [8]. Though the concept of Njs was introduced fifty years ago (after the work of Zwietering in 19581), it is still used as a primary design parameter even today. An attempt has been made to characterize suspension quality using cloud height, liquid phase mixing time, and liquid phase circulation time in solid liquid stirred vessels using conventional as well as advanced methods.

3.2 Factors Affect the Quality Sususpension

An attempt has been made here characterize suspension quality using cloud height, liquid phase mixing time, and liquid phase circulation time in solid liquid stirred vessels using conventional as well as advanced methods.

An investigation of the required stirrer speed and stirrer dimensions for the suspending of solid particles in a low viscosity liquid has been carried out. The results are given in dimensionless form. By means of these empirical correlations the design for this operation can be carried out in many simple cases. For more complicated systems it will probably be better to carry out trial experiments. Rules for scaling are discussed. As a criterion for complete suspension the condition is chosen that no solid matter rests on the bottom of the stirred vessel; the homogeneity of the suspension throughout the whole vessel is not especially examined. The results are compared with data from literature. Theoretical consideration for the mechanism underlying the lifting of the particles from the bottom are not given, but research into this mechanism will be continued[9]. New graphical data are presented for determining the impeller speeds at which particle suspension occurs in turbine agitated vessels using the basic correlation of Zwietering. However, contrary to the findings of Zwietering for this particular impeller it is shown that the suspension speed is a function of impeller clearance, as too is the fluid flow pattern and the distribution of particles throughout the vessel[10]. Cloud height is not strongly dependent on impeller type or solid physical properties, except for extremely rapidly-settling particles. However, it is dependent on the impeller diameter to tank diameter ratio (D/T), impeller off-botiom clearance to tank diameter ratio (C/T), and solids loading. The use of multiple impellers allows solids to be suspended to higher levels in tall batches. An intermediate impeller separation leads to optimal performance in terms of the power requirement to achieve a desired cloud height. Lower impeller separations do not yield significant performance improvements over a single impeller, while higher impeller separations lead to poor performance caused by “zoning” between the impellers[11].At higher solid loading (on and above 3% v/v), cloud height measurements indicated different stages of suspension. Cloud height was found to decrease with increase in impeller speed under certain conditions. Interaction of incompletely suspended solids, bed of unsuspended solids at the bottom and impeller pumping action causes such nonmonotonic variation of cloud height with the impeller speed.

3.3 Synthesis

The experimental determination of cloud height (the height to which solids are suspended par; in an agitated slurry as a function of the agitation intensity, solid physical properties, impeller type (pitched-blade or high efficiency), and system geometry. Cloud height is not strongly dependent on impeller type or solid physical properties, except for extremely rapidly-settling particles. However, it is dependent on the impeller diameter to tank diameter ratio (D/T), impeller off-botiom clearance to tank diameter ratio (C/T), and solids loading. The use of multiple impellers allows solids to be suspended to higher levels in tall batches[12]. An intermediate impeller separation leads to optimal performance in terms of the power requirement to achieve a desired cloud height. Lower impeller separations do not yield significant performance improvements over a single impeller, while higher impeller separations lead to poor performance caused by “zoning” between the impellers.

Mixing time (θmix) was found to depend on cloud height and on solid loading (when solid loading is above 3% v/v). Characteristics circulation time estimated from wall pressure fluctuations can provide useful indications on mixing time in suspension regimes where there is no significant clear liquid region above the solids cloud.

4. FORMATION OF CRYSTAL CRYSTALLIZATION

The phenomenology of crystallization is satisfactorily interpreted within the concepts of the formation and evolutionary structuring of precrystallization associates (quatarons). Evidence of their formation in overcooled (supersaturated) melts is synthesis of structural elements (anionic groups), which stably exist only in the crystal lattice and are modified in liquid phase under the change of cation-anion arrangement and lack of restrictions on symmetry.

The principal difference of a liquid-phase medium from a crystalline one is its isotropy, lack of local symmetry and a long-range order in the arrangement of components. The most important consequences of this are as follows: Electrostatic interaction between genenions is poorly compensated by neighboring similar ions, at least, for most compact gegenion configurations. This leads to a decrease in contacting distances in these configurations and reduction of coordination number[13]. On the other hand, owing to this fact, compact gegenion configurations coexist with the assembly of ions with greater (compared to the crystal) fluctuating coordination numbers. Because of the lack of limitations on symmetry and unsaturability of ionic bonds, the most advantageous coordination in the liquid-phase medium will be determined by the ratio of ionic radii of its components.

5. CONCLUSIONS

We think that in molten crystallization media differing from crystal ones only in position disordering (systems with the same type of interatomic interaction) there is no need for the formation of precrystallization associates. On cooling, in this type of medium, fluctuations in mutual arrangement will form a structure with the least internal energy (e.g., crystalline) whose perfection will depend on the rate of temperature decrease. Results of studies, for example [14], show that in crystallization media with different atomic interactions (e.g., ionic and covalent) quasistable cation–anion groupings (CAG) form, which principally differ from coordination polyhedra (primary structural modules) of crystal structure. In this case precrystallization associates must form invariably and their main function is, we think, to transform liquid-phase CAG into “crystalline” structural modules. This kind of transformation is possible during cooperative interaction of corresponding crystallization medium components, which changes the configuration of CAG and their translational mutual arrangement forming crystal structure topology.

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