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Reform and Exploration of Case-Driven Graduate Course Teaching

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Abstract: This article takes linear motor fault diagnosis as a case carrier, constructs a knowledge system that integrates student theory and practice, guides students with key problems in fault diagnosis to cultivate their ability to solve engineering problems, demonstrates creative solutions to key core problems to strengthen students' cross-integration and innovation capabilities, and takes the craftsman spirit as the fundamental driving force to enhance students' scientific literacy. Through course practice testing, the course content, including case content, teaching process design, and assessment, has been optimized and updated to stimulate graduate students' interest in learning, enhance their enthusiasm for innovation, and strengthen their awareness of innovation.

Keywords: *Case Teaching, Cross-Integration Innovation, Teaching Reform, Linear Motor Fault Diagnosis*

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I. INTRODUCTION

Currently, enhancing the alignment between the disciplinary system and modernization/intelligentization, and building a healthy, robust, and sustainable AI industry ecosystem, requires synergistic development of hardware equipment and algorithm software, and is inseparable from core elements such as innovation leadership and talent support. The "Education Power Construction Plan Outline (2024–2035)" for the first time proposes establishing a sound strategic investment mechanism in education and building a collaborative education partnership that deeply integrates universities, enterprises, and society. Therefore, it is extremely urgent to increase the cultivation of digital talent, adapt to the needs of technological developments like artificial intelligence, establish a multi-level and multi-type digital talent training mechanism, deepen educational and teaching reforms, and focus on cultivating innovative, applied, and skilled talents. However, in the existing talent training models, the teaching philosophy often overemphasizes "theory" while neglecting "practice"; teaching case design prioritizes the "teaching plan" over the "student"; and teaching forms favor "lecturing" over "participation". The reasons for this are twofold: on the one hand, constraints such as student cohort size and teaching hardware conditions mean relevant courses primarily focus on theoretical instruction, leading to a disconnect from engineering practice; on the other hand, insufficient integration of industry and education prevents cutting-edge technologies from engineering practice from effectively entering the classroom, resulting in a failure to organically integrate and mutually reinforce theory and practice [1,2].

In view of this, the teaching case is based on the fault diagnosis and predictive maintenance of Permanent Magnet Switched Flux Linear Motors (PMFLSM), which are core power components in high-end equipment and intelligent manufacturing. It forms an open, systematic case teaching system encompassing linear motor parameter identification and system modeling, fault mechanism analysis, platform design, sensor placement optimization, signature feature extraction based on multi-modal fusion, and deep learning-based fault diagnosis and lifespan prediction. This system provides foundational material for academic degree postgraduates in control science conducting research in areas such as pattern recognition and intelligent systems, modern detection technology and automation devices, and intelligent control. It enables students to discuss, innovate, and make improvements, aiming to achieve a course teaching system that balances theoretical instruction with practice and integrates industry and education [3,4]. The implementation of this project will stimulate graduate students' interest in learning, enhance their enthusiasm for innovation, strengthen their innovative awareness, further improve their innovation capability and engineering practice ability, and help them develop the craftsman spirit of "persistence, focus, excellence, meticulousness, and pursuit of excellence" through practice, thereby laying the foundation for cultivating innovative, applied, and skilled talents for the industry [5].

II. INNOVATIVE IDEAS FOR CASE-BASED TEACHING REFORM

The linear motor drive system is a universal and key driving equipment in the field of intelligent manufacturing, primarily composed of windings and permanent magnets. Its safe and stable operation is crucial for ensuring the security and reliability of intelligent equipment. Fault diagnosis for linear motors involves fault mechanism analysis, sensor data acquisition, signature feature extraction, and AI-based fault classification. This case project collaborates with Shandong Atlas Intelligent Technology Co., to develop a fault diagnosis case for switched flux linear motors, ensuring the smooth implementation of case-based teaching. The main innovations of the case focus on four aspects: case content design, teaching mode, course assessment, and ideological and political integration [6].

(1) Guided by Engineering Needs, Restructuring and Updating the Teaching Content System

Addressing the requirements of practical engineering application tasks, the course integrates fundamental knowledge and algorithms related to engineering applications, data acquisition, feature extraction, and deep networks. It involves in-depth analysis of key core problems in practical engineering applications, designing engineering solutions, and highlighting the value of engineering applications. This approach guides students to establish the engineering thinking concept of "application safety and reliability," enhancing their engineering thinking ability. Considering the dialectical relationship between theory and practice, typical cases from engineering practice are integrated into the teaching. Using theory as a guide, the direction and goals of practice are clarified. Through methods like in-depth analysis and course seminars, practice is used to test and verify the correctness and effectiveness of theory. Encouraged by continuous feedback from practice, students are motivated to optimize engineering problem design schemes and solutions to key issues through literature review and teamwork, thereby improving their comprehensive ability and quality in solving practical engineering problems [7].

(2) Oriented by the OBE Concept, Constructing a New Case Teaching Method of "Flipped Classroom + SPOC"

Classroom teaching is extended into a "three-stage" teaching model comprising pre-class preparation, in-class flipping, and post-class extension. Before each class, specific content and course objectives are provided, encouraging students to utilize online resources for preliminary research and cultivating their exploratory skills. During instruction, a flipped classroom format is adopted, encouraging students to ask questions and participate in class discussions. The teaching team provides targeted instruction based on issues identified during these discussions. After class, students participate in discussions on the SPOC platform, proposing solutions to key problems based on acquired knowledge. By benchmarking against the case teaching plan, they explore algorithms and technologies from different fields and apply them to engineering through integrated innovation, effectively solving practical engineering problems. This deepens students' understanding of domain knowledge, broadens their perspective of related fields, and strengthens their wide-ranging, multi-level, and comprehensive integrated innovation capabilities, as well as the depth and breadth of their understanding of key core content [8]. This builds a new case teaching method of "Flipped Classroom + SPOC" based on the OBE concept.

(3) Focusing on Strengthening Innovation Capability, Establishing a New Teaching Model with Dual Closed-Loop Assessment and Case Updates

The assessment for the linear motor fault diagnosis case teaching is conducted based on three aspects: teaching assessment, ideological-political inspection, and teaching element evaluation. The teaching assessment system builds upon traditional student evaluation methods while incorporating an ideological-political element inspection plan to comprehensively assess students' technical literacy and political literacy. The supporting element evaluation comprehensively assesses the degree to which course-related elements support talent cultivation, while simultaneously optimizing the integration of ideological and political elements. Based on the assessment results, team members analyze and summarize findings, optimize the teaching assessment scheme, refine the methods and approaches for integrating ideological and political content, innovate the teaching model, and achieve updates in the dual closed-loop assessment and evaluation system, case updates, and updates in teaching participation elements.

(4) Based on Diverse Ideological-Political Theories, Constructing a New Model for Collaborative Integration of Diverse Ideological-Political Elements

Addressing the fundamental educational questions of "what kind of people to cultivate, how to cultivate them, and for whom to cultivate them," ideological and political elements permeate the entire case teaching process. The aim is to cultivate high-quality talent aligned with national development strategies, capable of supporting national economic construction, technological innovation, and social progress. Simultaneously, using the craftsman spirit, students are encouraged and guided to establish the value of "self-reliance through technology and a fulfilling life," to emulate master craftsmen, learn their character of pursuing technical excellence, and be motivated to grow into self-reliant and strengthening high-quality technical and skilled talents through technological learning. A new model for multi-perspective ideological-political integration is established.

III. CONTENT AND MEASURES OF CASE TEACHING REFORM

(1) Case content framework

Based on the relevant scientific research achievements from longitudinal projects such as the team's national general project "Research on Suspended Guidance Hybrid Excitation Linear Synchronous Motor for Ropeless Elevator" and Henan Provincial Science and Technology Key Project "Research on Key Technologies of Linear Motor Fault Diagnosis Based on Spatial Mapping and Data Fusion", as well as major horizontal projects from enterprises such as "Research and Development of Direct-Drive Motor for Intelligent Equipment", and combined with the team's teaching practical experience and teaching objectives, the content framework of the teaching case has been developed, covering topics such as linear motor fault simulation analysis and platform design, sensor data acquisition and analysis, data processing and feature extraction, online calibration based on CNN network, spatial attention of deep network, etc. The framework of the teaching case for switch flux linkage linear motor fault diagnosis is shown in Figure 1.

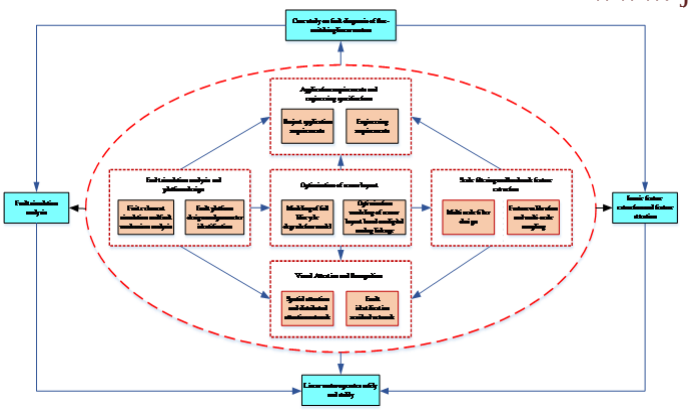

Figure 1 Framework of a teaching case on fault diagnosis of switched flux linear motors

The teaching case aims at the safe and stable operation of switched flux linear motors, with permanent magnet loss of excitation and winding short-circuit faults as the research objects. It relies on the major horizontal project of intelligent equipment direct-drive motor research and development (Dongguan Zhiying Intelligent Equipment Co., Ltd.), as well as the provincial and ministerial level project of key technology research on linear motor fault diagnosis based on spatial mapping and data fusion, for case construction and optimization. The main contents of case construction include:

1) Conduct finite element simulation and failure mechanism analysis of linear motors. This mainly involves the modeling of the finite element model of PMFSLM, the analysis of the generation mechanism of permanent magnet field loss and winding short-circuit faults, as well as the analysis of electromagnetic characteristics such as permanent magnet field, air gap magnetic density, leakage magnetic density, three-phase current, three-phase voltage, no-load back electromotive force, and thrust.
2) Design of fault diagnosis test platform. The content involves related mechanical structure design, primary module design for different proportions of permanent magnet loss of excitation and different proportions of winding short circuits, adjustable air gap, variable load design, parameter identification and system modeling of linear motors, etc.
3) Sensor placement optimization. The content involves modeling of a full-life cycle degradation model based on simulation data, and modeling of a sensor placement optimization model for digital-analog linkage.
4) Extracting characteristic features through multi-scale filtering. The content involves the design and optimization of spatially distributed filters based on the frequency domain, the optimization of parameters and structure of spatially distributed filters with frequency nonlinear mapping functions, and the suppression of associated harmonics.
5) Feature calibration and multi-scale sampling. The content involves data distribution drift suppression and multi-scale spatial data sampling.
6) Spatial attention and distributed attention. The content involves the design and optimization of network structures for spatial constraint feature extraction and distributed feature extraction based on visual attention, as well as the design and optimization of fault diagnosis models based on residual networks.

(1) Case teaching design

1) Construct a blended teaching model centered around case studies

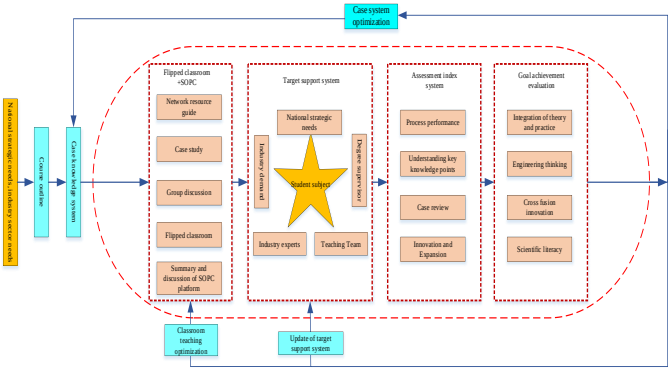

Figure 2: "Flipped Classroom + SOPC" Case Teaching Model Based on OBE Concept

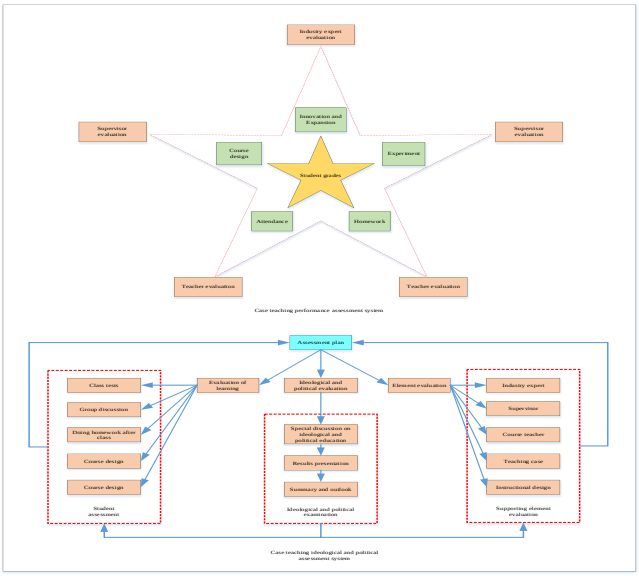

Figure 3: Case Teaching Assessment Mode

Construct a new case teaching method based on the OBE (Outcome-Based Education) concept, utilizing the "flipped classroom + SPOC (Small Private Online Course)" approach. Extend classroom teaching into a "three-stage" teaching model, encompassing pre-class preparation, classroom flipping, and post-class expansion. Leverage online resources and rely on the SPOC platform to implement the flipped classroom. Cultivate students' exploration abilities, transforming case teaching into a process of "examination + discussion", and promote the transformation of teaching mode through classroom flipping. After class, students participate in discussions on the SPOC platform, enhancing their depth and breadth of understanding of key core content. The design of the PMFSLM (Permanent Magnet Field Loss and Winding Short Circuit Fault Diagnosis) case is carried out from aspects such as teaching methods, assessment evaluation system, achievement of learning outcomes, and case updating and optimization. Explore a framework centered around students, aligned with national strategies and overall industry needs, coordinating various knowledge elements such as industry experts, teachers, and mentors to construct a three-in-one evaluation system for achieving learning outcomes. Establish a four-in-one student evaluation system based on process performance, understanding of key knowledge points, case evaluation, and innovative expansion. Evaluate the achievement of learning objectives from four aspects: integration of theory and practice, engineering thinking, cross-disciplinary innovation, and

scientific literacy. Combine the three-in-one achievement evaluation system to construct a dual closed-loop assessment evaluation system and a new case teaching model for case updating and optimization. The design of the "flipped classroom + SPOC" case teaching model based on the OBE concept is illustrated in Figure 2.

2) Case teaching assessment method

Course assessment is a crucial measure for evaluating the achievement of case teaching, and it serves as an important reference for optimizing the design of case library teaching schemes and teaching methods. It not only assesses students' learning outcomes and the achievement of teaching objectives but also examines and supervises relevant course elements. The assessment of case teaching on linear motor fault diagnosis is based on three aspects: teaching assessment, ideological and political examination, and teaching element evaluation. The teaching assessment system is based on traditional student assessment methods, while incorporating an ideological and political examination scheme to comprehensively assess students' technical and political literacy. The support element evaluation comprehensively assesses the support provided by relevant course elements to talent cultivation, while optimizing the integration of ideological and political elements to provide comprehensive support for talent cultivation. The assessment mode of case teaching is shown in Figure 3.

3) Integration of ideological and political elements

Figure 4: Integration of case knowledge points and ideological and political elements

By combining the core knowledge points of the case content with the ideological and political elements, students are aroused to a sense of urgency, foster a sense of nationalism, cultivate a deep patriotism, and clarify their mission and responsibility in the new era. Based on the case of linear motor fault diagnosis, guided by materialism, the concept of a community with a shared future for mankind, and the core values of socialism, and using practical testing as a means, the spirit of craftsmanship, characterized by "perseverance, dedication, meticulousness, and pursuit of excellence," is used as a driving force to cultivate students' core value pursuit of serving the people, serving the governance and administration of the Communist Party of China, serving the consolidation and development of the socialist system with Chinese characteristics, and serving the reform and opening up and socialist modernization. The integration of case knowledge points and ideological and political elements is shown in Figure 4.

CONCLUSION

The fault diagnosis case study of switched flux linear motors encompasses finite element simulation analysis and modeling of linear motors, a fault diagnosis platform, modeling of a full-life cycle degradation model based on simulation data, modeling of a sensor placement optimization model for digital-analog linkage, design of spatial filters, extraction of characteristic features, visual attention based on deep networks, and fault classification. It integrates theories and technologies related to mechanical structure design, simulation and modeling, and deep learning, providing a real-world engineering application example for the case study teaching of the "Frontiers of Electronic Information" course. Simultaneously, the construction of this case study offers insights for enterprises in theoretical innovation and technological advancement. The theories of sensor placement optimization driven by digital-analog linkage, spatial filter design techniques, and multi-scale feature sampling techniques proposed in the case study also provide technical references and support for enterprises to carry out fault diagnosis and life prediction in related fields.

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