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Research on Teaching Reform of Additive Manufacturing Major Based on Industry-Education Integration

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Abstract: With the rapid advancement of advanced manufacturing, additive manufacturing (AM) has emerged as a core disruptive technology widely applied in aerospace, biomedical, and automotive industries, generating a surging demand for high-quality applied talents. Nevertheless, the traditional teaching model of AM major in Chinese universities generally suffers from outdated curriculum, insufficient practical training, and weak engineering competence of faculty, resulting in a mismatch between talent output and industrial requirements. Grounded in the concept of industry-education integration, this paper analyses the key dilemmas in current AM teaching, and proposes targeted reform strategies covering curriculum system, faculty development, training bases, teaching modes, and evaluation mechanisms. This study aims to provide references for improving AM talent cultivation quality and deepening the integration of higher education and industrial development.

1. Introduction

Additive manufacturing, or 3D printing, fabricates components layer-by-layer from digital models, representing a paradigm shift in conventional manufacturing [1]. In recent years, breakthroughs in selective laser melting (SLM), fused deposition modeling (FDM), and binder jetting have propelled AM from prototyping to mass production, making it a pillar of manufacturing transformation globally [2-3]. The global AM market maintains an annual growth rate above 20%, with expanding applications in precision aerospace parts, medical implants, lightweight automotive components, and cultural products.

The booming AM industry raises higher standards for talent quality. Enterprises increasingly demand compound talents proficient in equipment operation, process optimization, post-processing, and production management, rather than those with only theoretical knowledge of materials and mechanical design [4]. However, as a newly established program in most Chinese universities, AM major still follows the traditional engineering education framework, featuring a prominent emphasis on theory over practice and knowledge delivery over ability development. This gap has led to a

disconnection between graduates' knowledge structure and actual industrial demands.

Industry-education integration serves as a critical approach to align higher education with economic and social development, and offers a fundamental solution to the mismatch between talent cultivation and industrial needs [5-7]. Under the background of New Engineering Education reform and national policy support for industry-education collaboration, exploring AM teaching reform oriented by industrial demand and school-enterprise cooperation carries great practical significance [8]. This paper constructs a teaching reform system for AM major based on industry-education integration, and discusses its implementation paths and practical effects.

2. Current Dilemmas in Additive Manufacturing Major Teaching

2.1. Outdated Curriculum System Lagging Behind Industrial Progress

Most AM curriculum systems are extended from traditional mechanical or materials engineering disciplines, with excessive focus on basic theories such as material mechanics and engineering graphics. Cutting-edge technologies closely related to industrial practice, including metal AM process, topological optimization, quality inspection, and digital twin, are not fully integrated into courses. Moreover, curriculum content updates slowly, failing to keep pace with the rapid iteration of AM technologies. New processes, materials, and equipment widely adopted in enterprises have not been timely incorporated into teaching, leading to a disconnect between learning and application. The curriculum structure also lacks modular and elective pathways for different industrial segments, restricting students' personalized development.

2.2. Disconnection Between Practical Teaching and Industrial Production

Practical training is essential for cultivating engineering competence, yet it remains a weak link in AM education. Due to the high cost of AM equipment and consumables, many universities are only equipped with desktop FDM devices, lacking industrial-grade metal 3D printers, post-processing facilities, and testing instruments. Students can only complete simple model printing instead of experiencing real production workflows. Additionally, most practical courses consist of verification experiments following textbook instructions, with little integration of real engineering projects. Students operate step-by-step without independent problem-solving training, making it difficult to develop genuine engineering capabilities.

2.3. Shortage of Dual-Qualified Teaching Faculty

The majority of AM teachers enter academia directly after graduation, possessing solid academic backgrounds but limited industrial experience and engineering project competence. When teaching practical courses, they often rely on textbook descriptions rather than real production cases. Meanwhile, rigid university employment and assessment systems hinder the recruitment of senior enterprise engineers as full-time faculty. Part-time enterprise mentors also face constraints in teaching time and systematic pedagogical training, limiting their contribution to practical teaching.

2.4. Single-Sided Talent Evaluation Mechanism

Traditional AM talent evaluation centers on written exam scores, prioritizing theoretical knowledge memorization while neglecting practical skills, problem-solving ability, and innovative thinking. This orientation drives students to focus on exam-oriented learning rather than improving comprehensive competencies. Furthermore, evaluation is dominated by university teachers, with

rare participation from enterprise mentors, so assessment results cannot truly reflect students' adaptability to industrial positions.

3. Teaching Reform Strategies Based on Industry-Education Integration

3.1. Co-Constructing Industrial Demand-Oriented Modular Curriculum

Universities should collaborate with leading AM enterprises to develop talent cultivation schemes and curriculum systems centered on industrial post competency. The curriculum can be divided into four modules: basic literacy, professional foundation, professional skills, and engineering practice. The professional skill and practice modules shall be co-developed by faculty and enterprise engineers, integrating the latest industrial standards, process specifications, and typical project cases. For instance, core courses on metal AM parameter optimization, post-processing technology, and quality control can be added, and real enterprise projects such as aerospace blade printing and medical implant development can be adopted as teaching cases. A dynamic curriculum update mechanism shall be established, with regular review by enterprise technical experts to ensure teaching content aligns with industrial technological progress.

3.2. Building Dual-Qualified Faculty through Industry-University Collaboration

A competent dual-qualified team is the foundation of industry-education integrated teaching. First, universities should establish regular enterprise practice programs for teachers, arranging 1–2 months of on-site training or temporary positions in partner enterprises annually to accumulate engineering experience. Second, implement an enterprise mentor program, recruiting senior technical experts and management elites as part-time lecturers to teach practical courses, guide training and graduation projects, and bring cutting-edge industrial experience into classrooms. Third, build joint teaching and research platforms to encourage collaborative research and teaching reform projects between faculty and enterprise technicians, enhancing the engineering literacy of both sides.

3.3. Co-Building Shared Production-Teaching Training Bases

Training bases are core carriers for practical education. Universities and enterprises should leverage respective strengths to build multi-functional bases integrating teaching, training, research, and production. On campus, universities can introduce enterprises to build "campus factories" through equipment donation, technology investment, or joint construction, deploying industrial-grade AM equipment and production lines to simulate real manufacturing environments. Students can complete process operation, product trial production, and quality testing in the base, integrating learning, training, and production. This work establishes "factory classrooms" in partner enterprises off campus with dedicated practice zones and student workstations, and arranges internships and on-the-job training under the guidance of enterprise mentors.

3.4. Implementing Project-Driven Task-Based Teaching

Replace the traditional teacher-centered model with project-driven and task-oriented teaching based on real enterprise projects. Teachers decompose actual industrial projects into sequential tasks: 3D modeling, process parameter design, equipment operation, post-processing, and performance testing. Students work in teams to complete tasks independently, with guidance from both faculty and enterprise mentors. Through the cycle of "project undertaking – problem analysis – scheme design – operation implementation – summary improvement", students integrate theoretical

knowledge with practical skills, fostering engineering thinking and problem-solving competence. Additionally, order-oriented talent training programs can be launched with enterprises, designing customized curricula according to specific post demands to realize seamless transition from graduation to employment.

3.5. Establishing Multi-Subject Diversified Evaluation System

This work reforms the exam-dominated evaluation model by building a diversified system combining process and outcome assessment, university and enterprise evaluation. In evaluation content, it increases the weight of practical operation, project quality, teamwork, and innovation awareness, focusing on comprehensive engineering literacy. In evaluation subjects, it implements a dual-assessment mechanism: university teachers evaluate theoretical mastery and academic performance, while enterprise mentors assess practical skills, post adaptability, and professional ethics based on internship and project performance. In evaluation methods, it adopts on-site operation assessment, project defense, work evaluation, and internship reports to comprehensively reflect students' actual abilities.

4. Conclusions

Industry-education integration is an inevitable path for AM major teaching reform to adapt to advanced manufacturing development and improve applied talent cultivation quality. Targeting the problems of outdated curriculum, theory-practice disconnection, faculty shortage, and rigid evaluation, universities should deepen school-enterprise cooperation and promote all-round integration of curriculum, faculty, training bases, teaching modes, and evaluation mechanisms. Future efforts should further expand the depth and breadth of cooperation, explore long-term win-win mechanisms, and continuously enhance the alignment between talent cultivation and industrial development, so as to provide strong talent support for the high-quality development of the AM industry.

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