A Comparative Study on the Training Mode of Doctoral Students in Mechanical Engineering between China and America

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Abstract: Under the background of China Manufacturing 2025 and intelligent manufacturing Chinese national needs, it is an important guarantee for our country's future development to cultivate doctoral students of mechanical engineering with strategic vision and international perspective. Taking Beihang University, Stanford University and Boston University as an example, this paper focuses on the cultivation mode of doctoral students in mechanical engineering, analyzes the characteristics of doctoral education concepts, degree type, selection and elimination, curriculum system, training links and incentive mechanism of Chinese and American, and think about the future development direction of the doctoral cultivation mode of mechanical engineering discipline in China.

Introduction

The doctor candidate training is the highest level of academic education. With the rapid development of economy society and the science and technology, a large number of high-level talents are urgently needed to drive for socialist modernization. The cultivation level of doctoral candidate is not only an important scale to measure the quality of higher education in a country, but also an important indicator of the development potential of national science and culture.

China is in a critical period of transform a big manufacturing country to a manufacturing power.[1] Considering the requirement of the national strategies combined with China Manufacturing 2025 and Intelligent Manufacturing, it is important to cultivate high-level mechanical engineering doctoral students with strategic vision and international perspective, strengthen the construction of high-level talent team in the field of intelligent manufacturing in China, and lay a solid foundation for reserve talents for the future industrial layout. It is an important strategic guarantee for China's future comprehensive national strength.

As an important basis and support for the quality of doctoral training, optimizing the mode of doctoral training has become an important task for the graduate schools and departments of contemporary universities to constantly think, explore and practice. The education of doctoral students in the United States started early. After years of reform and practice, it has created a relatively more mature cultivation model for doctoral students and achieved good results. Beihang university, Boston University and Stanford university rank top in mechanical engineering. They are representative training bases for doctor students in mechanical engineering, with this three university doctoral student cultivation model as a case, to summarize and analyze the characteristics of mechanical engineering disciplines doctoral cultivation mode of China and the United States, reference the American model in mechanical engineering disciplines has certain practical significance.

Overview of Sino-U.S. Doctoral Training Mode

The doctoral education in the United States has a long history of more than 150 years and rich

experience. China's doctoral education started in the 1980s and has been continuously improved for decades.

Connotation of Doctoral Student Training Mode.

Cultivation mode refers to the paradigm established in order to train students' specific knowledge, abilities and qualities, based on specific educational experience, guided by a certain teaching idea, and based on certain educational theories[2]. It is a standard style and operating method of the training process based on educational ideas and training goals, and its scope is greater than the teaching mode and less than the school running mode.

On the basis of the definition of the training mode, the doctoral training mode can be defined as the standard style and operation mode of the doctoral training process based on the doctoral education thoughts and training goals. According to the different types of doctoral student enrollment training, the doctoral student training model can be divided into two types: a continuous doctoral student training model, which is represented by the combination of master and doctoral students, advanced doctoral student training mode and direct doctoral student training mode, and segmented doctoral student training mode[3].

Overview of the Development Model of Doctoral Students in the United States.

American doctoral education originated in the middle of the 19th century. With the advocacy of scholars returning from Germany, Yale College borrowed from the German apprenticeship model for doctoral education and first established a doctoral program in 1947. Based on this prototype, in 1861, the first three doctorates were officially awarded, marking the official start of doctoral education in the United States.

With the advancement of the Industrial Revolution and the Westward Movement, there is an urgent need to train a group of high-level talents to participate in the national economic construction. At the end of the 19th century, the concept of American doctoral education was transformed from rationalism to pragmatism, and gradually formed America's own characteristic by improving the German model. The scale of doctoral education has gradually expanded. University of Pennsylvania, Harvard University, Johns Hopkins University and other famous universities have successively established graduate schools to train doctoral students. By 1900, 44 U.S. doctoral degrees were awarded to universities, and 382 doctoral degrees were awarded that year.

Since the 20th century, the United States has ushered in the spring of doctoral education. The development of training concepts has been improved, the training objectives have been enriched, the training objects have been diversified, the training methods have been crossed, and the training perspective has been internationalized. The development of doctoral education in the United States has formed a flourishing scene. In 1940, the number of U.S. doctoral degree grants increased to 3,290, and the number of degree-granting institutions increased to 100.[4] The type of doctoral degree also changed from a single research-type doctoral degree to a professional-type doctoral degree.

The latest statistics show that in the academic year of 2013-2014, the number of doctoral degree awarding institutions in the United States increased rapidly to 4,724, and the number of doctoral degree awarding institutions in the academic year reached 177,580[5]. U.S. doctoral student training scale and quality rank first in the world, and the U.S. model has become the main model for countries in the world to learn from.

Overview of the Development of Doctoral Education in China.

The earliest origin of doctoral education in China originated in 1935. The Government of the Republic of China promulgated Article 12 of the Degree Granting Law, which divided higher education into three levels of doctoral, master, and bachelor degrees. This is a sign of the formal establishment of a modern degree system in China. However, for various reasons, no doctor's degree was awarded before the founding of new China in 1949.

After the founding of the People's Republic of China, a series of systems and measures were promulgated, such as the "Decision on Reforming the Academic System" in 1951, the "Interim

Measures for the Training of Postgraduates in Higher Education Institutions (Draft)" in 1953, and the "Opinions on Recruiting Postgraduates in Higher Education Institutions" in 1977. In the "Interim Measures on the Selection of Four-year Graduate Students in Relevant Key Institutions of Higher Education in China in 1980", the Ministry of Education has set clear requirements for the training goals of four-year graduate students. After the promulgation of the Degree Regulations, most of these four-year graduate students have awarded doctoral degrees, which is the embryonic form of doctoral education in New China[3].

Since the promulgation and implementation of the "Regulations on the Degree of the People's Republic of China" in 1981, great progress has been made in the development of doctoral education in China, and the scale of doctoral students has leapt to the forefront of the world. [6] In 1984, the Ministry of Education issued the "Notice on Master's Degree Programs for Advance Study of Doctoral Degrees", which signifies that the training mode for doctoral students in China has shifted from a single staged training mode to a continuous and staged coexistence mode. The Degree Committee of the State Council, the Ministry of Education, and the Ministry of Personnel jointly issued the "Notice on Carrying out a Survey of the Quality of National Doctoral Degrees" in 2007. The quality of doctoral education has gradually become the focus of educators. In 2013, the three ministries and commissions of the Ministry of Education, the Development and Reform Commission, and the Ministry of Finance jointly issued the "Opinions on Deepening the Reform of Graduate Education", and provided specific guidance on strengthening the ability to innovate and exploring distinctive graduate training models in the new situation. In 2015, a total of 74416 doctoral students were enrolled in China, with 326687 doctoral students and 53778 graduate doctoral students [7]. China has gradually formed a relatively perfect doctoral training model in many years of teaching practice.

Case Study of Doctoral Cultivation Mode

China and America have different national conditions, history and culture. In the long-term training of graduate students, they have formed the doctoral cultivation modes with their own characteristics.

Concepts of Doctoral Education.

After years of exploration, reform, practice and correction, American doctoral education training concept has experienced by rationalism, the rationalism and pragmatism coexist, then to the nascent nationalism process, the current American doctoral education concept focus from the emphasis on nationalism to internationalization, focus on training with international influence, high-level, interdisciplinary talents, to satisfy the needs of the production, the construction of compatible doctoral training patterns [8].

The process of cultivating doctoral students in China have fully implemented the basic task of cultivating talents with morality, insisted on training first-class students into first-class talents, optimized and formed a leading talent training system of coordinated development of "scientific basis, practical ability, humanistic quality and international vision", and achieved the goal of "emphasizing foundation, strengthening cross, expanding vision and promoting innovation" Training mode.

Types of Doctoral Education.

American doctorate can be divided into two types: research doctorate and professional doctorate. The vast majority are research doctorates, mainly referring to PhDs. Professional doctorates are divided into 23 types according to research content, including doctor of arts (DFA), doctor of education (EdD), doctor of engineering (DEng), and so on. Doctors of law (JD) and doctors of medicine (MD) are generally not professional doctoral degrees [9].

The vast majority of doctoral degrees awarded by Chinese universities are research doctorates, which are divided into six major categories: liberal arts, science, engineering, agriculture, medicine, and military. The mechanical engineering discipline of Beihang University also has a professional

doctorate degree. Relying on major national science and technology projects, combining cutting-edge technology and development trends in the industry, training high-level specialized talents who are application-oriented, composite, and highly innovative, making them leaders and organizers of engineering technology innovation, and high-level technology and management talents [10].

Elimination of Doctoral Education.

There are some differences in the selection mechanism of doctoral candidates between Chinese and the U.S. universities. The United States admissions for doctoral students usually determine the quality and potential of students based on the applicant's average undergraduate credit score GPA, GRE test scores, TOEFL test scores, recommendation letters, CV and PS. Chinese universities take doctoral graduate admission test results as the most important basis requirements, the overall quality of the students will be examined through interviews.

The Chinese and American doctoral programs are open to undergraduates and postgraduates, and the specific operation methods are different. There are two ways to accept doctoral students in the United States. One is to directly enroll in a doctoral program for undergraduate graduates, and it usually takes about 6 years to graduate. The other is to accept a master's degree into a doctoral program, which usually takes about 4 years to graduation. Boston University stipulates that no matter whether it is a bachelor's degree or a master's degree, a doctoral dissertation must be completed within 5 years. Stanford University also requires that the master's degree dissertation should not exceed 5 years. Beihang University enrolls doctoral students including post-graduate doctoral programs, as well as three types of doctoral student training modes: "Master-Docter combined program", "Advance in Ph.D." and "Direct Ph.D.". All doctoral students must complete within 8 years.

Chinese and American universities have corresponding requirements for the study and research work of doctoral students in the school, and they will be eliminated automatically if they fail to meet the basic requirements. In order to assess the scientific research quality of doctoral students in a timely manner, students who are not suitable for PhD students should be eliminated as soon as possible to avoid wasting time. Most American universities, including Boston University and Stanford University, organize a Qualification Exam within one year of admission. Take Stanford University 's PhD students in mechanical engineering as an example. Each spring and autumn holds a doctoral qualification exam. Each student has two opportunities to take the exam. Once they pass, they can be transferred from PhD Student to PhD Candidate status. If they fail in both examinations, they will be eliminated from the PhD training program. Stanford University's examination process is organized by oral examination. Each student chooses 3 directions of interest. Each direction is evaluated by 2 professors. Candidates need to answer the questions of 6 professors carefully. All the questions are derived from the curriculum and scientific research. Deeply analyze the candidates' knowledge and the ability of theory to connect with practice. In addition, doctoral students who failed to pass the open question defense within 5 years were eliminated directly in Stanford. Doctoral students who failed the Boston University Mathematics exam were eliminated directly. Those who failed the courses in Chinese and American universities would be eliminated.

Doctoral Course System.

China and the United States have similarities in the construction of the doctoral curriculum system. They both give curriculum weight by credit, both require minimum credits, both distinguish between compulsory courses and elective courses, and both develop course learning plans under the guidance of instructors. However, in the course of training doctoral students in American universities, emphasis is placed on the cultivation of writing ability, and there are credit requirements for scientific research. Course spans and freedom of choice are greater, and even a large platform course model that connects undergraduate and graduate courses is adopted.

The coverage of mechanical engineering courses in American universities is quite extensive. The mechanical engineering disciplines of Stanford University include design, fluid mechanics, thermodynamics, and solid mechanics. Among them, design includes product design, industrial

design, design and manufacturing, mechatronics, control, and robotics. Subdivided disciplines such as dynamics, biomechanics, etc., Boston University's mechanical engineering disciplines are biased towards basic research, including mechanical manufacturing, materials engineering, computer engineering, etc., Beihang University has three national key first-class disciplines: mechanical engineering, aerospace science and technology, and materials science. In recent years, it has also gradually transformed into a major mechanical engineering discipline. On the original basis, it has added a design and shipbuilding and marine engineering. Chinese and American universities use the course number to distinguish the type and difficulty of the course, and they encourage cross-disciplinary and infiltration integration. The addition of interdisciplinary course credits in the training plan requires the improvement of the knowledge system of doctoral students.

There are many types of courses in American universities. There is a large choice and online course selection. The Boston University doctoral program implements a trial auditing system. After the audition, you can withdraw from the course within the prescribed time limit. Stanford University requires at least 135 credits for a continuous doctoral degree while a doctoral student at the master's degree is required to complete 90 credits, including no less than 27 credits for professional courses and at least 63 credits for scientific research. Boston University requires that full-time PhD students must complete 64 credits, of which at least 32 credits are required for professional courses, and scientific research credits must not be less than 16 credits. Students with advanced degrees need to complete 32 credits, including at least 8 credits scientific research. Beihang University requires at least 38 credits for PhD student of which no less than 6 credits are required for integrated practice, and at least 16 credit hours are required for PhD students at the master's level, and no less than 3 credits for integrated practice.

Segment of Doctoral Education.

Chinese and American universities carry out scientific research training for doctoral students through scientific research projects, and use seminars as an important interactive method of teaching and research. American universities also use Laboratory Rotation as an important way to cultivate scientific research interests of doctoral students [11]. Stanford University and Boston University doctoral students in the discipline of mechanical engineering both implement a weekly seminar system to make multi-level and multi-angle interactions to the greatest extent through academic reports, deepen knowledge understanding, and promote academic exchanges. At the same time, authoritative professors of related disciplines from universities are often invited to make reports. Students can learn about the latest academic developments through intensive academic report meetings, and can often participate in various international conferences. In recent years, Chinese universities have attached great importance to internationalization, and doctoral students have more and more opportunities to participate in academic reports and international academic conferences. In the past five years, the number of graduate students of mechanical engineering disciplines of Beihang University has continued to increase, with 37 graduate students going abroad in 2013. It has increased to 62 in 2016. In line with international standards, they are committed to international academic frontier research. It has become a common consensus for doctoral education in domestic universities.

The doctoral education in the United States implements a combination of supervisor and doctoral steering committees. Unlike domestic universities that determine the supervisor for doctoral admissions examinations, students only contact the intended supervisor when applying for a doctoral program in the United States. The supervisor is determined before the qualification exam. Boston University doctoral students in mechanical engineering usually find a supervisor at the end of the first semester, and some students change their supervisor after conducting a period of research. In order to make it easier for doctoral students to understand the research directions of different supervisor and find their own points of interest, Stanford University recommends but does not obligate doctoral students to rotate supervisors. Doctoral students conduct research for 3 months under the guidance of each supervisor according to their own research work, usually only after rotating 2-3 supervisor to determine their research direction. After the qualification examination,

students and their supervisors negotiate to establish a steering committee for doctoral dissertations, which is generally composed of 3 or more expert professors, and is responsible for the guidance and defense of doctoral dissertation writing. The doctoral dissertation of Chinese universities is generally supervised by a supervisor or a teacher of the same research group. The opening, interim, and defense of graduation thesis are jointly reviewed by the defense committee, but the experts of the defense committee do not participate in the guidance of the doctoral dissertation writing process.

Chinese universities have clear requirements for doctoral students to publish journal articles. The discipline of mechanical engineering at Beihang University requires each doctoral student to publish at least 3 papers, including at least 1 SCI paper. American universities have less stringent requirements for journal papers. There is no specific provision in the Boston university journal articles published requirements. Stanford University's doctoral students in mechanical engineering generally require the publication of 2-3 journal papers, but it is not a mandatory requirement. The graduation standards mainly judged according to the scientific research level of the students.

Thinking and Inspiration

The cultivation mode for doctoral students in the discipline of mechanical engineering in universities in China is constantly reforming, developing, and progressing. The concept of doctoral degree training gradually transforms to a strategic height, the training plan is further adjusted and improved, the scope of the curriculum system is gradually spreading to major mechanical engineering disciplines, the doctoral degree training links are solidified, the doctoral degree incentive mechanism is complete, the students' international perspective is rapidly expanding, breakthroughs in direction research, academic level and international influence continue to increase.

Through a comparative analysis of the doctoral training mode of the mechanical engineering disciplines of representative universities in China and the United States, it has been found that Chinese and American universities have reached a high degree of consensus on the diversification of doctoral degree types, the elimination mechanism for doctoral students, the strict training process, the training of writing skills, and the form of financial incentives. Although there are differences in the methods for selecting doctoral students between the two countries, both can choose the most reasonable method that suits their country according to the actual situation. While seeking common ground while reserving differences, it is found that there is still room for improvement in China's doctoral training mode by referring to the doctoral training mode of American universities.

A Flexible Doctoral Supervisor System.

Strengthen the interaction between professors and students before doctoral students enter school, two-way selection of mentors based on a thorough understanding, optimize the dual-selection mechanism of mentors, reform the mode of determining mentors when enrolling, and use the method of determining mentors after enrolling in doctoral students in the United States, which can make the students have sufficient time to understand and recognize their research interests. Implement the supervisor group system and set up a doctoral thesis steering committee to provide students with more guidance ideas and research ideas. It can also avoid the troubles caused by doctoral supervisor's business trips or being too busy.

Improve the Quality of Course Teaching.

American college courses cover a wide range of subject areas, a large number of courses, a good degree of penetration and openness in graduate courses, and there are no strict boundaries for this master's and master's degree program. In contrast, the doctoral program system of mechanical engineering in Chinese universities is complete, but the reform cycle is relatively long in keeping up with the international frontier hot spot. The research on emerging interdisciplinary and hot issues is generally conducted under the guidance of the mentor. There are fewer related courses, less freedom for students to choose courses, less classic textbooks, and less choice of original foreign textbooks. It is of great significance to expand the curriculum area, encourage outstanding teachers

to devote themselves to teaching, develop more and better updated courses, and introduce or compile better teaching materials.

Strengthen the Relationship between Theory and Practice.

The theoretical curriculum of American universities through curriculum assignments and enterprise project research and development to improve curriculum requirements, deepen students 'knowledge and solidity, and cultivate students' ability to integrate theory with practice. There is still a phenomenon of disconnected theory and practice in the setting of doctoral courses in Chinese universities. The practical ability of doctoral students is generally cultivated outside the theoretical curriculum. The practical links of doctoral students should be further pre-positioned. The practical concepts and practical links should be embedded at the beginning of admission, to realize the simultaneous penetration and integration of theoretical learning and practical ability.

Stimulate Students' Scientific Research Interest.

The doctoral students of the mechanical engineering disciplines in China's universities have made great progress in original innovation. The number of SCI and EI papers has grown exponentially. Among them, there are many top-level journal papers such as Nature. However, the major breakthroughs in the thesis still largely depend on the rigid requirements of the training plan. The willingness to innovate and the motivation to write a dissertation for doctoral students are insufficient. It is necessary to further strengthen the guidance in stimulating students 'scientific research interest and cultivating doctoral students' initiative innovation consciousness.

Under the environment of "double-firstclass" university construction, the training mode for doctoral students of mechanical engineering disciplines in China's universities learns the advanced experience of world-class universities and combines the actual conditions of China's universities to make great strides on the road to world-class universities. But the doctoral training model of China and the United States is not completely the same. After long-term development, China and the United States have formed their own distinctive and mature doctoral training model systems. Chinese colleges and universities must learn from the advanced practices of the American model and cannot fully copy the American model. We should complement each other's strengths and integrate development in order to achieve long-term sustainable and healthy development of doctoral students in mechanical engineering.

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