Teaching Reform of Fundamentals of Combustion for Energy and Power Engineering Majors in Agricultural Colleges and Universities in the Context of New Engineering Course

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Abstract The Fundamentals of Combustion course is an important compulsory course for Energy and Power Engineering Majors under the background of carbon peaking. According to the characteristics of teaching and scientific research at present, combined with the characteristics of complexity, interdisciplinary and rapid technology update of this course, this paper discusses the teaching content and teaching design of this course to meet the needs of talents of production, teaching and research under the background of new engineering course. It proposes more applicable teaching methods and practical means to broaden students' horizons, stimulate students' autonomous learning momentum, master the professional knowledge application ability, and cultivate innovative and competitive engineering professionals to adapt to the new energy strategy.

Key words New engineering course, Fundamentals of Combustion, Undergraduate education, Practice teaching, Curriculum reform

1 Introduction

China's energy structure has long been dominated by traditional fossil energy. China is the largest carbon emitter in the world, and the need for clean and low-carbon energy transformation is urgent. At the general debate of the 75th session of the United Nations General Assembly, general secretary Xi Jiping made a solemn commitment to the international community on "carbon peaking and carbon neutrality", and China will strive to achieve the peak of carbon dioxide emissions by 2030 and carbon neutrality by 2060. Energy combustion is the main source of carbon dioxide emissions in China, accounting for about 90% of all carbon dioxide emissions. Therefore, more and more attention has been paid to the technical problems related to energy, and it is urgent to train energy and power engineering professionals to adapt to the new situation. In the process of personnel cultivation, there are many problems in the traditional Energy and Power Engineering Majors in colleges and universities, such as the disconnection between theory and practice, the single teaching mode, the boring teaching, the failure to combine with the latest technological development in this field, and the slow updating of the original knowledge system[1]. As the core course of energy and power majors, Fundamentals of Combustion plays an important role in undergraduate education and teaching. Letting students master the fuel conversion process and combustion products control technology, understand the basic principles of combustion and advanced technology will help students to achieve the relevant planning objectives in the current curriculum standards, provide high-quality talents for the field of energy utilization, and realize the efficient training of key talents in the process of carbon emission reduction.

Based on the characteristics of the current curriculum and teaching of Fundamentals of Combustion in colleges and universities, combined with our teaching summary for many years, we came up with some new ideas for the optimization and reform of Fundamentals of Combustion teaching based on the "double carbon goal", in order to meet the urgent needs of colleges and universities in China to cultivate compound and dynamic professionals who are more suitable for the national strategy and development.

2 Three-dimensional construction of teaching mode

Due to the limitation of the current undergraduate teaching hours, it is difficult to explain the content of Fundamentals of Combustion textbooks completely and deeply only using the classroom teaching time. Based on this, we proposed the "three-in-one" comprehensive teaching mode. The teaching content is deepened from the foundation to the application layer by layer: the first is the theoretical basis, mainly the combustion aerodynamics and chemical reaction kinetics with the transfer of momentum, heat and mass as the core. The second is the basic principles and rules, fuel ignition theory, combustion process and characteristics of different fuels. The third is to inspire students to explore the hot scientific and technological propositions of combustion independently with the goal of achieving carbon peak, and to transform the theory into the application. A multi-dimensional evaluation system

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based on active learning (traditional closed-book examination, video learning and answer, scientific research practice and report) is constructed with three corresponding teaching modes (diversified classroom teaching, self-exploration and interactive answer based on MOOC and micro-video, and innovative training based on teachers' scientific research projects), so as to mobilize the enthusiasm of students, to form an organic whole of teaching content, learning methods and comprehensive evaluation to meet the needs of the times, encourage students to actively participate in teaching, combine teachers' key teaching with scientific research and innovation training to meet the requirements of carbon peak, promote each other and improve learning effect.

2.1 Course design (i) The course of Fundamentals of Combustion has rich content, so it is necessary to distribute the teaching content reasonably. On the one hand, it ensures that the course content can be taught completely; on the other hand, it can also realize the combination of teachers' teaching, students' exploration and scientific research innovation, and achieve good teaching results. (ii) It is necessary to encourage students to learn and share in combination with MOOC and micro-video, implement group teaching mode, divide the work and cooperate in groups, find learning materials, actively discuss, and effectively guide teachers to evaluate and supervise the process of independent exploration. (iii) It is necessary to promote learning and training through scientific research and innovation. By participating in teachers' related topics, literature reading and scientific research practice, students are encouraged to actively find problems and solve them effectively, so as to improve their understanding of combustion-related fields.

2.2 Course implementation According to the teaching content, it is feasible to design the contents of lesson preparation, teaching and after-class practice. It can focus on the teaching of definitions, mechanisms, technical principles and other knowledge that are difficult to understand and important in textbooks. For example, when explaining combustion calculation, it is mainly through the recall of chemical equations to master the calculation methods of combustion air volume, flue gas volume, oxygen consumption and other calculation formulas, not just the mechanical memory of the formulas. In the basic part of fuel theory, it is not necessary to memorize the derivation process of combustion law, but to master the combustion law and combustion theory. For various theoretical models, it also focuses on understanding and explanation, and weakens derivation process. Besides, according to the advanced technology of Fundamentals of Combustion under the carbon peak, the use of video and other modes are introduced, and students are also taught to explore self-learning through the Internet. In addition, according to the characteristics of undergraduates, hot topics are selected to explore the frontier of scientific research and innovation. Through literature review and practical training, students can understand the latest combustion technologies (such as microgravity combustion, oxygen-enriched combustion), energy storage and clean combustion technologies, and guide students to explain and optimize new technologies from the perspective of combustion principles.

3 Diversified practice of teaching methods

3.1 Strengthening basic concepts and highlighting key and difficult points Combustion process is a complex process of coupling of chemical thermodynamics and thermal science, which produces many basic knowledge of the integration of phase change reaction and chemical reaction, such as nonlinear dynamic characteristics of combustion, flame structure, flame propagation speed, flame stability and fluctuation, ignition, extinction, explosion, *etc.* The following difficulties may occur in the teaching process.

(i) Difficulties in understanding abstract chemical processes and physical nature such as chemical reaction kinetics, transport phenomena, and Arrhenius law.

(ii) Students lack intuitive understanding of laminar premixed flame, jet flame, diffusion flame, droplet flame, turbulent flame and so on, and it is difficult for students to understand and visualize in the process of classroom teaching.

(iii) The theory of ignition and extinction, flame propagation and stability, including the variation of combustion of different fuels, flame propagation, ignition forms and conditions, *etc.*

In view of the above difficulties, in the course of teaching, we should help students to supplement the relevant basic concepts in time, through the association method and analogy method, we can compare and repeat the combustion law with the relevant laws of heat transfer and engineering thermodynamics, so as to help students gain new insight through restudying of old material, and increase their understanding and memory.

3.2 Carrying out heuristic teaching in connection with practical cases In the teaching process of Fundamentals of Combustion course, we should closely combine with other professional basic courses such as fluid mechanics, thermodynamics, heat transfer and so on, combine the teaching content organically, explain the profound in simple terms, and combine the basic principle with practical application. The demand for high efficiency, energy saving and emission reduction of traditional power devices further promotes the innovation and development of basic combustion elements such as fuel, combustion theory and combustion devices. Combined with the background of carbon peak and carbon neutralization, domestic and foreign fuel technologies, new combustion devices and technologies can be taken as the key updated contents of course teaching and practice. The practical application of various burners, such as jet burner, swirl burner, tangential combustion boiler, *etc.*, is analyzed to help students understand the different physical and chemical processes of gas, liquid and solid combustion, understand the key factors and control methods of combustion process, and combine with the strategic requirements of carbon peak and energy saving and emission reduction, so as to understand the characteristics of the combustion process, the formation mechanism of combustion products and control methods. For another example, solid waste disposal-waste incineration

also plays its role in the goal of double carbon, becoming a new star of environmental carbon sequestration. It is also a new trend of current research to use industrial practical cases, such as the popular AI industrial brain, to precisely control the waste incineration process and flue gas treatment. Thus, compared with Fundamentals of Combustion traditional teaching cases, under the new policy background, providing students with more research results and cases in emerging fields can not only integrate knowledge, but also inspire students to master more new methods and technologies in learning, and broaden their horizons of exploration, enhance students' sense of mission and responsibility to study hard, innovate constantly and break through difficult problems.

3.3 Attaching importance to practice teaching and cultivating engineering concept In practice teaching, especially in the background of carbon neutralization and carbon peak, the traditional experimental content can not enable students to obtain the latest research results in an innovative manner, resulting in low professional understanding of practical problems when undergraduates graduate, and they can not use systematic professional theoretical knowledge to solve practical engineering problems. At present, most of the teachers are responsible for scientific research and teaching. Therefore, in the process of teaching, teachers should integrate innovative scientific research achievements into teaching, guide students to establish innovative thinking, and improve the ability of effective transformation of knowledge. For example, traditional fuels are divided into gaseous fuels, liquid fuels and solid fuels, and direct combustion of a large number of solid fuels is the main cause of air pollution in China. Under the background of carbon peak, the proportion of hydropower, nuclear power and new energy will increase, but in China, the traditional energy structure dominated by coal is still the mainstream. Therefore, the choice of fuel and the related practical teaching of new combustion technology are particularly important in the teaching design. Among the gaseous fuels, natural gas is the focus of current research. Through the study of the textbook, students can master the basic principles of natural gas combustion, and at the same time, they can apply the traditional Bunsen burner experiment to help students master the ignition, combustion, and gas laminar combustion characteristics. For the contents related to natural gas combustion, such as the basic working principle of gas turbine combustion, conversion characteristics, and the combined application of gas turbine-steam turbine, it is necessary to give a thorough explanation. At this time, the traditional experiment can not meet the demand, through the extracurricular practice teaching, the establishment of school-enterprise joint training mode can provide students with extracurricular field learning opportunities, will be more helpful for students to master the combustion and application of gaseous fuels. In liquid fuel, it is feasible to build an experimental platform, self-made atomization burner, use a series of experiments such as the preparation and combustion of biomass liquid fuel to expand the content of the textbook, and better help students understand the current hot issues of Fundamentals of Combustion such as liquid atomization and droplet combustion. Compared with traditional experiments, these new experimental and practical teaching processes are more helpful for students to cultivate engineering concepts in the process of double carbon goals, energy saving and emission reduction, and new energy utilization. Based on the theoretical knowledge of specialized courses and combined with the new progress of Fundamentals of Combustion research, the design of comprehensive and innovative experimental projects suitable for undergraduate knowledge system is the key to the integration of theory and experiment and the improvement of students' application ability and innovation ability.

4 Proper selection of teaching means

The Fundamentals of Combustion course involves chemical thermodynamics, chemical kinetics and other basic contents. There are many basic concepts, complex mathematical formulas and abstract calculation content. The traditional teaching mode is mainly based on teachers' dictation and blackboard writing, which makes it difficult to attract students' attention and achieve the desired teaching effect. In recent years, with the vigorous development of network technology, multimedia teaching based on rain classroom and MOOC has become an increasingly important teaching method in the teaching process, which can actively mobilize students' interest in learning. For example, liquid fuels such as biomass fuel oil, as an alternative to fossil fuels with zero carbon emissions, are also important research objects in the double carbon goal. In traditional teaching, the combustion process of liquid fuel is mainly introduced. In this context, the use of new biomass liquid fuels for teaching can help students more easily form awareness of alternative energy use. Teachers can use animation to simulate the atomization and combustion process of liquid fuel spray combustion in internal combustion engines, high-pressure atomizing nozzles, burners and other equipment to help students master the atomization, evaporation, mixing, ignition and combustion stages of liquid fuel. For the basic and important teaching contents, especially the basic concepts and formulas, such as the derivation of the calculation equation of air quantity and combustion product quantity, the traditional blackboard writing method is still used, which can not only improve the students' attention to the knowledge points, but also enable the students to clearly understand the association and logical relationship between the knowledge points[4]. In addition, it also advocates the use of computer-aided teaching to solve the problem that the investment of Fundamentals of Combustion experimental equipment is high and it can not meet the needs of purchasing experimental equipment in large quantities. CFD experimental resources can be used to set up numerical simulation computer-aided teaching experimental courses, through classroom demonstration, students are encouraged to understand complex combustion problems in depth through classroom and after-class self-study, deepen their understanding of efficient combustion and emission control in the combustion process, and cultivate innovative thinking.

5 Organic integration of ideological and political elements

In classroom teaching, ideological and political elements can also be integrated to further strengthen students' feelings of home and country and sense of mission. For example, after years of exploration and development, China's manned space industry has made considerable progress. In this process, the development of various technologies related to combustion can not be separated from the hard work of generations of scientists. The developers of the "two bombs and one satellite" relied on their own efforts and worked arduously. In an extremely difficult environment, they used limited means of scientific research and testing, fought tenaciously, broke through one technical difficulty after another, linked their personal ideals with the destiny of the motherland and the rejuvenation of the nation, and finally achieved breakthroughs in cutting-edge technologies such as the atomic bomb, the hydrogen bomb, and the artificial satellite. There are also breakthroughs and innovations in the key technologies of liquid fuel combustion in large aircraft independently developed by China, which are also the result of the outstanding efforts of scientists. All kinds of fuels currently used, as a substitute for future energy, also have very important practical significance. In the study of the course, teachers should infiltrate the education of professional accomplishment and ideological morality, cultivate students' meticulous and serious work style, cultivate students' professional ethics, and improve students' safety awareness. Combining with the actual situation of the course, the ideological and political teaching reform is carried out in the aspects of content design, teaching methods, management and implementation, and course evaluation and assessment. When formulating teaching plans, curriculum standards and teaching plans, teachers should integrate ideological and political education elements such as professional ideals, craftsman spirit, moral education, values education and legal meaning education, and combine professional characteristics, teaching content, students' characteristics, social and enterprise requirements to carry out teaching research, specific design and reasonable evaluation, so as to achieve the effect of "moistening things silently". It is necessary to establish and improve the evaluation system of ideological and political courses, effectively enhance the attention of professional teachers to ideological and political courses, optimize and reform the content of lesson preparation, and also allow teachers of ideological and political courses to participate in the teaching of professional courses, think about the teaching of "ideological and political courses" of professional courses, and put forward relevant opinions. Through the establishment of a mechanism, the integration of ideological and political teachers and professional teachers, it is expected to explore the construction of a "collaborative education" team of teachers.

6 Optimized design of assessment mechanism

In the process of course assessment, combined with the three-in-one teaching mode, the comprehensive performance of students in the classroom performance, practical skills, independent exploration and other learning processes in and out of class is examined, the traditional way of taking the final examination results as the main way is changed, and the cumulative scoring method is adopted to avoid students merely paying attention to the final written examination and memorizing the knowledge points by rote. In the process of teaching, make full use of the teaching mode of flipped classroom[5], students can be grouped into dormitories. After the teaching of each course module, students can consult relevant information in groups, discuss the latest scientific issues involved in the module in class, and teachers can score the group performance into the final grade. Efforts should be made to cultivate students' interest and ability in scientific research, to take students' active learning and participation in scientific research practice projects as the content of investigation, and to encourage students to cultivate their professional qualities by improving their ability to consult literature and practical skills, so as to better meet the needs of employment and further education in the future.

7 Conclusions

As an important professional basic course of Energy and Power Engineering Majors, Fundamentals of Combustion is the comprehensive application and intersection of engineering thermodynamics, heat transfer, fluid mechanics and other knowledge. In view of the demand orientation of active professionals under the background of carbon peak in China, corresponding measures should be taken to improve the teaching effect of Fundamentals of Combustion teaching process. By using the "three-in-one" teaching mode, we should attach importance to the practice teaching of advanced combustion technology and equipment while paying attention to the teaching of basic principles and basic theories, constantly update the teaching content, optimize the teaching mode, strengthen the students' practical ability and independent exploration ability, and cultivate innovative and competitive engineering professionals to adapt to the new energy strategy.

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