



Practical Teaching Experience of Applied Mechanics Teaching with the Integration of Teaching Reform, Science Popularization and Ideology and Politics

Feng Wu^(✉) and Wanxie Zhong

Key Laboratory of Structural Analysis of Industrial Equipment, Department of Mechanics,
Faculty of Vehicle Engineering and Mechanics, Dalian University of Technology,
Dalian 116024, People's Republic of China
wufeng_chn@163.com, wxzhong@dlut.edu.cn

Abstract. Modern applied mechanics research has developed toward multidisciplinary cross discovery, and numerous branch courses have appeared in applied mechanics teaching, different courses are taught by using different methods, and the connection between them is less talked about in teaching. It is difficult for students to integrate the knowledge of different courses in a limited time, and the learning burden is increased while the academic vision and independent thinking ability are weakened. To this end, this paper studies a new model of applied mechanics teaching from the perspective of integrating teaching reform, science popularization and ideology and politics, and summarizes relevant practical teaching experience. This study can also provide useful reference for other engineering courses teaching.

Keywords: Applied mechanics · Teaching reform · Science popularization · thinking and politics · Theoretical system of public teaching

1 Introduction

Applied mechanics, also known as engineering mechanics, is a science that studies the motion law of macroscopic matter and its engineering application [1]. It is not only a branch of physics, but also a branch of engineering. Modern applied mechanics is developing in the direction of multidisciplinary cross. Its research involves a large number of new space air vehicle system, complex mechanical systems, intelligent equipment systems, micro-electromechanical systems and mechanical behaviors of new materials, etc., showing the characteristics of strong nonlinearity and multi-field coupling cross, and the mechanical research objects are extended to ultra-high temperature, ultra-high speed, ultra-high pressure and other unconventional environments [2]. In these contexts, how to cultivate high-level applied mechanics talents who have the ability of independent innovation and overcome the “bottleneck” common technical problems has become an

important issue. The expansion of applied mechanics in breadth and depth makes students learn more and more subjects and content, but the learning time is limited, which puts forward urgent requirements for applied mechanics teaching and textbook updating. By reviewing the teaching of applied mechanics, some problems can be found: analytical mechanics [3] is the foundation of applied mechanics, but it is rarely taught in teaching. Although control theory [4, 5] comes from mechanics, it is applied more and more widely, but it is rarely taught in the teaching of applied mechanics. Applied mechanics emerged a lot of branches of courses and these courses have a set of theoretical systems and methods. Interdisciplinary and connection are rarely taught in the teaching [6]. In fact, faced with the emergence of a large number of new interdisciplinary subjects, simply increasing the content of teaching will overburden students. The use of different teaching methods in different branches of courses is also not conducive to students' knowledge integration, and will greatly limit students' academic vision and their ability to think independently.

In this paper, we carries out research from three aspects: teaching, science popularization and ideology and politics, trying to provide methods to solve the above problems. In 2006, we obtained the support of education material and course construction of Duality System of Applied Mechanics from the graduate students teaching reform project of Dalian University of Technology, and began to explore the reform of applied mechanics teaching. In 2010, with the support of the undergraduate education reform project "Exploration of Applied Mechanics Curriculum Reform Based on Symplectic Mathematical Method" of Dalian University of Technology, we researched and established a teaching system of applied mechanics with symplectic dual system as the public theoretical system (hereinafter referred to as symplectic mechanics). In 2018, we obtained the support of "New Engineering" excellent undergraduate textbook construction and "Aerospace Science and Technology Textbook Publishing Project" from Dalian University of Technology, studied the teaching significance of ideology and politics for symplectic mechanics, and wrote related textbooks. In 2021, we got the graduate students education reform project "The Construction of Course Reserve in the Combination of Symplectic Mechanics and Ideological and Political Education" of Dalian University of Technology. Under the support of these projects, we have conducted in-depth research on the teaching reform of engineering applied mechanics and established a public theoretical system with the symplectic dual variable system as the applied mechanics teaching and used the symplectic ternary algebra as the basic tool to apply the characteristic of organically combined teaching, science popularization, ideology and politics to the teaching mode. This paper introduces this work in detail.

2 Teaching Reform of Applied Mechanics

The development trend of interdisciplinary is increasingly strengthened, and there are more and more branch courses of modern applied mechanics, and each branch course has its own set of theoretical system and methods of teaching, and the connection between courses is not enough. As a result, students' learning burden becomes heavier and heavier, and they cannot organize and integrate the knowledge learned in various courses well, which results in difficulties in solving practical engineering and scientific research problems. The research of teaching reform of applied mechanics is imperative.

2.1 Taking Symplectic Dual Variable System as the Public Theoretical System of Applied Mechanics Teaching

After years of teaching research, it is found that there exists a public theoretical system between some branch courses of applied mechanics - the system of symplectic-pairing variables [5–8]. Analytical mechanics and structural mechanics are the basic courses of applied mechanics, the former describes the controlling equations and evolution laws of mechanical systems in the time direction, and the latter describes the deformation laws of mechanical objects in the space dimension. However, there seems to be no connection between the contents and methods of teaching of these two courses, and analytical mechanics is rarely taught in mechanics lessons due to the obscure mathematical formulas. After research, it can be found that there is a simulated relationship between analytical mechanics and structural mechanics. Although the physical meaning of the equations of motion of single-degree-of-freedom spring-vibrator in analytical mechanics and the equations of tension rod control in structural mechanics are different, the equations are the same set of equations, only the positive and negative signs are different. From the simulation point of view, the equations of the least action variational principle of analytical mechanics and the minimum potential energy principle of structural mechanics are the same. The displacement and momentum of analytical mechanics are a pair of dual variables, while the displacement and force of structural mechanics are a pair of dual variables, and these two pairs of dual variables are subject to the same symplectic transformation. Speaking clearly about the simulation relationship between the two courses can easily tell the simulation relationship between the methods of different courses, and even induce students to use the methods of one course for the other course, and learn one course, they can easily learn the other course, promote the integration of knowledge, reduce the learning burden, and also improve the quality of learning. We have used the symplectic mathematical method to establish a public theoretical teaching system between the two courses - the symplectic dual variable system. Currently, we have established a public theoretical system based on symplectic dual variable system for the branch courses of applied mechanics, such as analytical mechanics, elastic mechanics, material mechanics, structural mechanics, theoretical mechanics, control theory, etc., and have extended the system to electromagnetism, water wave dynamics, phonon crystals, etc. [8–11].

2.2 Using Symplectic Ternary Algebra as the Basic Tool to Lecture the Symplectic Theory System of Applied Mechanics, Reducing the Learning Difficulty of Engineering Graduate Students

The major construction of “new engineering” is to cultivate excellent scientific and technical talents who will lead the development of future emerging technologies and industries, so as to accelerate the conquering of a number of “bottleneck” key core technologies and promote China’s global influence in the new round of scientific and technical revolution and international competition. Symplectic mechanics is a teaching direction that adapts to the needs of the times. Improving the teaching effectiveness of symplectic mechanics is related to the cultivating quality of innovative talents in the mechanics discipline. Therefore, we must treat the teaching of symplectic mechanics

from the height of talent cultivation strategy, prudently and creatively select appropriate teaching tools, and make the seemingly advanced symplectic mechanics theory in a more “digestible” form for engineering students. When explaining applied mechanics with symplectic dual variables as the public theoretical system, it is necessary to explain the symplectic mathematics, a preparatory mathematics course, clearly to students. However, the current symplectic mathematics books and works are mainly based on symplectic geometry as the frame, which requires a systematic study of the advanced mathematical theory of differential manifold and symplectic geometry, etc., so as to master symplectic mathematics [12]. Limited by time conditions and university foundation, it is very difficult for engineering graduate students to learn these mathematical knowledge systematically. In the undergraduate stage, the mathematics teaching of engineering graduate students mainly includes calculus, linear algebra and probability theory and symplectic mathematics is “desired but not practiced”. After years of development, symplectic mathematics has attracted many students with its advantages in applied mechanics and related interdisciplinary subjects, but the obscure symplectic mathematics makes many students daunted.

In the computer age, the solution of complex continuous problems mainly relies on discretization. The famous algorithm of computational dynamics, “symplecticity-preserving algorithm”, is proposed for the discrete format of dynamics integration, and adopts the expression of matrix vector. It is found that the symplectic mechanics theory and its engineering application can be explained systematically by using symplectic ternary algebras as the basic tool, and the connection between symplectic mechanics and the traditional mechanics theories such as finite element and the Hamilton’s least-action principle can be explained [13]. Symplectic ternary algebras [14] is taught by matrix vector language. Engineering graduate students who have studied calculus, linear algebra and probability theory in their undergraduate studies have enough mathematical reserves to understand the symplectic ternary algebras and symplectic mechanics dual system. Taking symplectic ternary algebras as the basic teaching tool, we put emphasis on college mathematics knowledge such as matrix, calculus, etc., reduce the mathematical reserve requirements for learning symplectic mechanics theory, and reduce the learning difficulty of students.

3 Science Popularization to Assist the Teaching of Symplectic Mechanics

On the role of science popularization, Comrade Xi Jinping once pointed out: “To be a scientist is the dream of countless Chinese children, we should make science and technology work become an attractive job, become a career that children respect and yearn for, give children’s dreams with the wings of science and technology, let the talents gather together in the future science and technology world of the motherland, let the stars shine in the future vast sky of science!”. Science popularization can attract not only primary and secondary school students, but also college students and graduate students, helping them to enhance their interest in learning, overcome difficulties in learning professional knowledge, expand the scope of knowledge, and improve innovative thinking ability.

The teaching of applied mechanics mainly focuses on formula derivation, example analysis and engineering application, which requires rigorous professional knowledge and strong logic, which is relatively unfamiliar to beginners, while the concept of symplectic mechanics is even stranger to engineering students. According to the author's decades of experience in scientific research, we have compiled science popularization books such as "Force, Work, Energy and Symplectic Mechanics", "Engineering Mathematics – Thoughts of Zu Chongzhi", and "Symplectic Breaking Cocoon", and recorded science popularization videos. With force, work and energy as the explaining objects of symplectic mathematics, we start from the simplest mechanical problems and express them with familiar concepts and languages, trying to return symplectic mathematics with the original physical appearance and break the mystery of "symplectic". For example, when telling the basic concept of "symplectic", we start with a spring, describe the linear relationship between the deformation, stiffness and force of the spring, and derive the basic concepts of applied mechanics such as stiffness matrix, symplectic matrix, state space, energy principle and group symmetries. Beginners can understand the concept of "symplectic" as long as they have learned physics knowledge in elementary school and know partial linear algebra knowledge, and then understand the basic mechanics knowledge of computational mechanics, structural mechanics and analytical mechanics, such as the principle of minimum potential energy, the variation principle of least action, finite element and Hamilton system, etc. In "Engineering Mathematics – Thoughts of Zu Chongzhi", we introduce the idea of integration by calculating PI using the circle-cutting technique, which introduces the concept of variational method in computational mechanics, and further introduce the time domain finite element method and symplectic conservation in dynamics problems, and the symplectic conservation method for the basic control equation in the differential-algebraic equation of robotics.

The science popularization book is a creative attempt by the author to cultivate interdisciplinary talents and popularize the application of computational science based on the collation of decades of practical experience in scientific research. It aims to guide readers to get started through the basic knowledge of computational science and lead them to solve problems in mechanics, control, electromagnetic waveguide, nano, etc. by the method of symplectic mathematics. Many students and scholars in China and abroad have learned about the concept of "symplectic" mechanics through our science popularization books. We also show the way of thinking and the spark of wisdom of the masters such as von Neumann, Euler, Hardy, Hilbert, etc. in our science popularization books, so that students can understand the masters' problem-solving methods, taste the beauty of symplectic mechanics, enhance their curiosity about new knowledge and technology, and improve their interest in learning and their own problem-solving ability.

4 Integration of Curriculum Ideology and Politics and Applied Mechanics Teaching

General Secretary Xi Jinping pointed out that higher education "should make efforts to cultivate patriotism, so that the spirit of patriotism is firmly rooted in the hearts of students" and "should guide students to set up high aspirations and cultivate the spirit of responsibility and unremitting struggle". "Only by impressing students can we guide

them. The feelings shown by teachers in the classroom is the most impressive and can even affect students for the rest of their lives. True faith is the only way to have true feelings, and true feelings are the only way to infect people; A good teachers should be an active disseminator of the common ideal of socialism with Chinese characteristics and the Chinese dream of the rejuvenation of the Chinese nation, helping students to build their dreams, pursue their dreams and fulfill their dreams, so that generations of young people can become the positive energy to realize our national dream.” Combined with this idea, the author excavates “ideology and politics factors” in the existing teaching of symplectic mechanics, integrates patriotic ideas into the teaching, integrates the ideology and politics factors into the teaching of professional courses, and tries to teach the students by example in the teaching process, so as to realize the ideological and political education in a subtle way.

The characteristics of the discipline of applied mechanics are as follows: 1) There are many Chinese masters of applied mechanics. After the founding of the country, a number of great scientists emerged in China, such as Qian Xuesen, Qian Weichang, Guo Yonghuai, Qian Lingxi, Mao Yisheng, etc., contributing to the national defense and engineering construction, and many of these scientists are applied mechanics. For example, Qian Xuesen was the chairman of China’s first mechanics committee, and Qian Lingxi was the chairman of the second mechanics committee. Mao Yisheng is a bridge expert, but also a master of engineering mechanics at the same time. The fighting spirit and patriotism of these mechanics provide excellent materials for the ideological and political education of applied mechanics. 2) Applied mechanics is closely integrated with national needs. The design, manufacture and maintenance of national major industrial equipment cannot be separated from applied mechanics. From early missile satellite to Shenzhou and Tiangong, from Wuhan Yangtze River Bridge to Hong Kong-Zhuhai-Macau Bridge, from Liujiaxia Hydropower Station to Three Gorges Dam, from automobiles to precision machine tools, from sketch design to computer-aided engineering design, applied mechanics has always played an important role. 3) Applied mechanics has inheritance. The calculation result of applied mechanics is an important means to guarantee the safety of engineering design, and the calculation is an important content of applied mechanics teaching. In ancient China there were many large-scale projects and many great engineers and masters of computational mathematics, such as Zu Chongzhi and Qin Jiushao et.al, who made great achievements in computation.

Combined with the above characteristics, the ideological and political materials of applied mechanics are abundant, and effective methods should be adopted to integrate these ideological and political materials into teaching. In the practice of ideological and political teaching of applied mechanics, the author combines contemporary hot issues with professional knowledge to increase the introduction of mechanics algorithm and the “bottleneck” problem – CAE software engineering. In particular, the author introduces the hard work and achievements of Dalian University of Technology in solving this problem, so as to enhance students’ patriotism, sense of danger and crisis and sense of social responsibility. In the course design, a special case analysis of Zu Chong’s circle cutting technique is established. Through the analogy relationship between circle cutting technique and the professional knowledge such as least action of mechanics, the geodesic lines, the symplecticity-preserving algorithm, etc., the advanced mechanics

concept is explained in a simple way. Students can understand the inheritance relationship between ancient Chinese science and modern science while learning professional knowledge, enhance cultural confidence and national pride. We combine contemporary hot issues with professional knowledge and add the introduction of mechanics algorithms and the “bottleneck” problem – CAE software engineering, and in particular, we introduce Dalian University of Technology’s efforts and achievements in solving this problem, so as to enhance students’ patriotism, sense of danger and crisis and sense of social responsibility. When we talk about the symplecticity-preserving algorithm, we tell our students, “Chinese people don’t have to have the sense of inferiority; keep up your spirits, take the initiative, carry out research on your own basis, and strive for a place in the world and have confidence that they will achieve something. Let’s do it!” When we encourage students to cultivate the striving spirit, we told students “Actions are made in thinking, but destroyed in following. If you always follow others, can you produce original results? It’s not right, is it? Originality is to be broken out, not to be followed.” When discussing the direction of scientific research, we pointed out that “the most important thing for scientific research is to adapt to the needs of the times, and the direction and ideas should not be mistaken.” When describing the development of symplectic mechanics, we especially pointed out that “ancient Chinese mathematicians also had brilliant achievements. We should go through the process of excavation, inheritance, taste, refinement, integration of modern mathematics, and then carry forward” [15]. We have also compiled the profiles of 15 Chinese scientists involved in symplectic mechanics, showing the important role of Chinese scientists in the development of mechanics, inspiring students’ learning enthusiasm, national confidence and cultural confidence, and encouraging students to strive for the realization of the dream of becoming a powerful country in science and technology.

5 Conclusion

Adhering to the teaching practice of applied mechanics, which integrates teaching reform, science popularization, ideology and politics, has played a positive role in the cultivation of engineering applied mechanics graduate students. At present, there are more and more graduate students studying symplectic mechanics and researchers engaged in symplectic mechanics after graduation, with a total of 5,465 literatures on the subject of symplectic algorithm and Hamilton system (CNKI data), and the research fields include more than 30 fields such as mechanics, mathematics, physics, computer, astronomy and geology.

Our science popularization books and textbooks have been highly praised by readers on mainstream e-commerce websites, such as Amazon.com and Dangdang.com, where readers evaluate “Force, Work, Energy and Symplectic Mechanics” as “a rare good book in China”, “dedicated to demystifying symplectic mechanics and easy to understand”, “A masterpiece... It is well worth reading”, “A simple and easy discussion of the relationship between force, work, energy and symplectic mechanics.”, and “After reading it, I feel very rewarding,...Long aftertaste.” The evaluation for the “Symplectic Breaking Cocoon” is “Advocating innovation and national spirit”. The evaluation of “The Symplectic Method of Applied Mechanics” is “suitable for entry, and from the perspective

of combining applied mechanics dual system and elastic mechanics to solve the new system, it is a great harvest"; "I hope this book and the readers of this book will contribute more to the motherland"; "This is a monograph handed down by Academician Zhong.... It is a must-read work for those engaged in mechanics research."

The teaching deeds of the second author have been reported by many domestic authoritative media, such as CCTV, CNR.cn, GMW.cn, people.cn, ScienceNet.cn, Sina.com.cn, etc., and have attracted millions of attention. Netizens from ScienceNet.cn evaluated that "He is a typical teacher who puts all he can into the growth of every student without reservation", "he is a real scholar"; Netizens on Sina.com described his lectures as "humorous, informative and fluent". "True educator", "Teaching for ideals and beliefs", "esteemed academician, pillar of the country, a model for our generation, the spirit of great work."; GMW.cn users described him as a "national treasure!" "The backbone of the country, the fortune of the country, the hope of the nation. A role model for teenagers to admire!"; "This is a respectable teacher," said netizens on CNR.cn. The teaching scene was also shown as the title of a promotional film by the Ministry of Education "Establishing morality and cultivating people, casting soul and educating people – the first anniversary of the construction of the National curriculum ideology and politics construction". These results show that the three-dimensional integration of teaching reform, science popularization, ideology and politics is a teaching model worth promoting.

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