Exploration and Practice of General Problem in Different Curricula of Mechanical Engineering Major under the Background of New Engineering

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Abstract. Under the environment of new engineering construction, innovative talents should have excellent comprehensive qualities, a wide range of knowledge, a multi-disciplinary knowledge, and the ability to extract, transfer, and deepen the application of the learned knowledge. As for the curricula of Mechanical Engineering Major of Huzhou University, mass-damping-spring (m-c-k) system in "Theoretical Mechanics" curriculum and resistance-inductance-capacitance (R-L-C) system in "Electrical and Electronics" curriculum are scheduled respectively. However, each of the two systems is composed of one energy storage element and two energy dissipation elements similarly. And two systems are characterized by second-order differential equation. Thereby the problems related with the two systems can be classified into one general problem. Based on above-mentioned situation, a reform of exploration and practice of general problem in different curricula is proposed. General problems of different curricula are combined into one special lecture for senior undergraduate or graduate students. And the method of finding general problems, teaching means, requirements for the teacher are constructed. Moreover, an experiment for assessing the effective of the reform is designed and carried out. Two groups of students from two parallel classes of Mechanical Engineering major are chosen. One group learn the m-c-k and R-L-C systems intensively while the other group learn them separately at an interval of one month. The group’s average scores of learning the two systems intensively are 11.22 points higher than the group’s average scores of learning them separately at an interval of one month. Also, the method reported in this paper can be also expanded to other engineering majors.

Keywords: General problem, Mechanical Engineering Major, m-c-k and R-L-C systems, New Engineering

1 Introduction

Engineering education is an important component of higher education. Whether it is required by external reality of higher education or the logical development of higher education itself, taking reform is an important guarantee for achieving the sustainable development of higher engineering education in the future [1]. Faced with the strong impact of the new round of industrial revolution, artificial intelligence, big data, and the Internet of Things (IoT), governments around the world have launched and deployed a variety of strategies [2-4]. Following Germany's "Industry 4.0", the United State's "Industrial Internet Strategy", France's "New Industrial France strategy ", and Japan's "Japan Revitalization Strategy", China's "Made in China 2025" was introduced [5]. These strategies have a significant impact on the world's

ITEI 2023, November 24-26, Zhengzhou, People's Republic of China

DOI 10.4108/eai.24-11-2023.2343616

industrial reform and the development of engineering education. The deployments of these strategies mark the entry of traditional industry into an intelligent and digital era. The Ministry of Education organized a seminar on the development strategy of higher engineering education at Fudan University [6]. The participating universities discussed the connotation, characteristics, and construction path of the new engineering discipline. And they reached a consensus, including training science and technology persons in emerging fields, updating traditional engineering majors, cultivating innovative talents, and enhancing the national hard power. Thus, it is required that innovative talents have excellent comprehensive qualities, a wide range of knowledge, a multi-disciplinary knowledge, and the ability to extract, transfer, and deepen the application of the learned knowledge. Moreover, the teaching method of engineering majors of higher education institutions is required to keep up with the pace of the industrial revolution, where the of Mechanical Engineering Major bears the brunt.

According to the teaching syllabus of Mechanical Engineering Major of Huzhou University, the curricula "Electrical and Electronics", "Fundamentals of Control Engineering", and "Testing Technology and Sensors" are scheduled. Among them, a chapter of "Theoretical Mechanics" introduces the m-c-k second-order vibration system; a chapter of "Electrical and Electronics" introduces the R-L-C second-order electrical system. However, there is much more similarity between the two systems [7,8], e.g., damping of m-c-k and resistance of R-L-C are energy consuming components, “mass and spring” of m-c-k system and “inductance-capacitance” of R-L-C system are energy storage components, and the quality factor of the two systems has the same physical meaning. Moreover, in the practical teaching process, the m-c-k system is taken as a study object in mechanical system while R-L-C system is taken as a study object in electrical system. Consequently, students' understandings of the two systems are isolated and scattered. And the famous simulation software, such as Multisim, Spice, Matlab, and Cadence, can be used to analyze and optimize the system parameters of the R-L-C system [9-11]. While for the m-c-k system, the above software cannot be directly used for optimizing the system parameters. Academic competitions of mechanical engineering require parameter optimization of mechanical structures, such as intelligent cars and robotic arms. Whereas the two systems are introduced to students in different semesters, thus students cannot understand them fully, let alone the application and innovation based on the general problem existing in the two systems. Therefore, the reform of exploration and practice of general problem in different curricula is conducted in this paper.

2 Fundamental Implementation of General Problem in Different Curricula

Based on the requirements of new engineering and innovative talents, the characteristics of the Mechanical Engineering Major was explored. And the general problems in different curricula, concrete cases of general problems, faculty of teaching general problems, and moral education are constructed and practiced. A closed-loop system was developed for continuous improvement. Finally, innovative talents are cultivated. The implementation scheme is shown in Fig. 1.

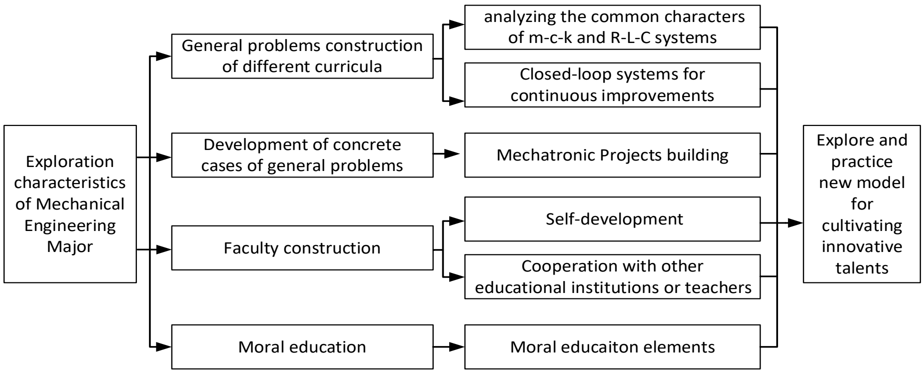

Fig. 1 Implementation scheme of general problem in different curricula

2.1 Construction of general problems in different curriculum

The m-c-k and R-L-C systems is taken as classical example for demonstrating how to construct the general problem of different curricula (Table 1). A thematic teaching and learning are adopted for integrating the general problem of the two systems. First, the teachers should create a thematic handbook that is designed for senior undergraduate or graduate students. The handbook should present the general problems across different courses in a well-organized manner, allowing students being interested in theoretical knowledge. Moreover, the cases in the handbook should be derived from real-life and visible as well as tangible, which enables students to build models, extract characteristic parameters, and solve problems. Additionally, the cases should reflect China's major scientific research or technological achievements in recent years, which fosters students' identification of the socialist new era with Chinese characteristics. Secondly, the teaching methods are crucial. The traditional approach of mainly focusing on theoretical teaching should be transformed into a balanced approach that includes theory, discussion, exploration, and demonstrations of knowledge application in practical scenarios. Especially, emphasis should be placed on the application of general problems in emerging digital industries, such as the IOT, artificial intelligence, and big data. Finally, corresponding assignments and experiments should be designed to assess students' mastery of the knowledge points. Students should be encouraged to complete these tasks and engage in innovation in their spare time, thereby cultivating their abilities to analyze and solve problems.

Table 1: Parameters comparison between m-c-k and R-L-C systems

Mechanical system (m-c-k)		Electrical system (R-L-C)		Relationship between parameters
Force	F	Voltage	V	/
Velocity	v	Current	I	/
Stiffness	k	Capacitance	C	$C=\eta^2/k$ [a]
Mass	m	inductance	L	$L=m/\eta^2$
Damping	c	Resistance	R	$R=c/\eta^2$

[a] η denotes transformation coefficient

Students are encouraged to actively participate in research projects, engineering practices, and academic competitions to develop their ability to solve practical problems. By applying the theoretical knowledge learned in class to actual research work, students can deal with engineering problems and undergo a transformation from passive learners to active researchers. Scientific research feeds back to teaching by integrating research and teaching organically, which strengthens student’s training and research-oriented learning. Case studies from research projects should be transformed into experiment projects of curricula. For instance, the analysis methods of the m-c-k system can be provided for analyzing the overall system of intelligent robots in engineering practice and innovation competitions. As a result, the intelligent robot's ability for maintaining stability and resisting vibrations are improved, so do the students' practical innovation capabilities.

A closed-loop system is constructed based on the teaching experience of the entire process m-c-k and R-L-C systems, including exploring, discussing, implementing, evaluating, and continuously improving the general problem. As for exploring general problem, collective wisdom, literature reviews, interdisciplinary communication among teachers and innovative activities between students can be used. In terms of discussion, a quarter of all students are be chosen to explore the flaws and provide suggestions during the process of teaching. After completing the teaching and evaluation, continuous improvements should be made to address shortcomings. Finally, the closed-loop system ultimately is developed.

2.2 Development of concrete cases of general problems

A well-chosen example is very important for students to understanding the general problems fully. And for the Mechanical Engineering Major, the chosen example would be better a mechatronics device that includes two domains at least, mechanical domain and electric domain. As a result, a general problem could exist. Then, the mechatronics device is analyzed in different domain for students, respectively. Finally, the general problem is extracted from the different domains.

Piezoelectric micromachine ultra transducer (PMUT) (Fig. 2), is taken as classical example for demonstrating how to develop a well-chosen example. The PMUT includes three domains, mechanical domain, electrical domain, and acoustic domain.

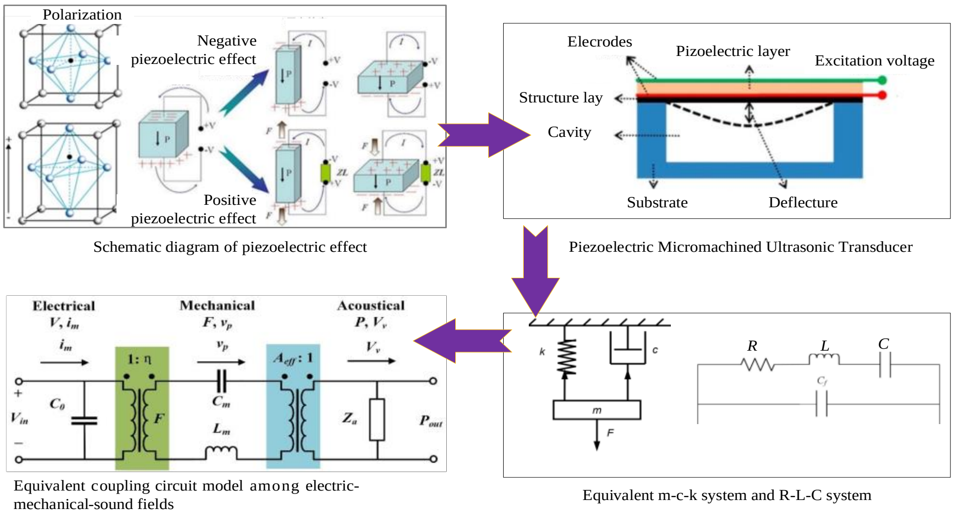

Fig. 2 Schematic diagram of extracting general problem from PMUT

First, Piezoelectric effect is introduced. Piezoelectric effect is a phenomenon in which mechanical energy and electrical energy are mutually converted in dielectric materials. And dielectric materials with piezoelectric effect are also called piezoelectric materials. Typically, piezoelectric materials have a crystalline structure. From a micro perspective, the piezoelectric effect originates from the disturbance of charge balance inside the crystal by an external field, which results in polarization and electric field. Stress applied to a piezoelectric crystal changes the distance between the positive and negative charge center, which resulted in macroscopic polarization measured as an open-circuit voltage on the surface of the crystal. On the other hand, the external electric field acts on the positive and negative charge center positions inside the crystal, resulting in elastic strain and size change of the crystal structure. That is known as the inverse piezoelectric effect. The piezoelectric effect can be seen as a linear interaction between mechanical and electrical domains.

Second, characterization of different domains of the mechatronics device and relationship between different domains are presented. PMUT converts energy between electrical, mechanical, and acoustic fields. The characteristic parameters in the electrical field are voltage and current, in the mechanical field are force and velocity, and in the acoustic field are pressure and velocity. The electrical current in the electrical field can be converted into velocity in the mechanical field through the electromechanical coupling coefficient. The structure of the piezoelectric micro-mechanical ultrasound transducer comprises an active piezoelectric layer, a passive structural layer, and electrode layers distributed on the upper and lower surfaces of the piezoelectric layer. By applying alternating electric fields (in the vertical direction) to the upper and lower electrodes, the piezoelectric material generates lateral stresses (in the horizontal direction) due to the inverse piezoelectric effect, which causes a stress mismatch between the piezoelectric layer and the structural layer. The stress mismatch between these two layers forces the thin film to deform and bend at the neutral plane, resulting in vibration and achieving the conversion of electrical energy-mechanical energy-acoustic energy. The vibration frequency is also the same as the frequency of the alternating electric field. When the PUMT is operated in the receive mode, it undergoes bending vibration under the excitation of external sound waves, and realizes the conversion of acoustic energy-mechanical energy-electrical energy through the direct piezoelectric effect. To ensure efficient transmission and reception of ultrasonic waves, the thickness between different layers must be controlled to ensure that the neutral layer of the vibrating diaphragm falls outside the piezoelectric layer, otherwise the opposite-polarity charge regions in the piezoelectric layer will cancel each other out.

Third, application of PMUT is introduced, which will stimulate students' interest. PMUT can be applied in a variety of fields. (1) Distance measurement is one of the most important applications of ultrasonic devices. High-frequency ultrasound has strong anti-interference ability and can propagate over long distances, making it very suitable for distance measurement applications. It can be used to achieve vehicle blind zone detection without exceeding the cost of existing reverse radar systems, and can even be used to build a complete surround ultrasound imaging system to assist intelligent driving systems. (2) Improvements of imaging can be made in current ultrasound examinations. When a person is examined by B-mode ultrasound, the person needs to be applied a thick greasy substance, and the diagnostic process requires the ultrasound probe to scan back and forth, which leads to a poor experience. (3) Fingerprint recognition is also an important application. The main advantage of ultrasonic fingerprint sensors is that they can detect the fingerprint in the true dermis layer. This means that ultrasonic fingerprint sensors can recognize fake fingerprints made of resin. And the sensor can also enable individuals to successfully read their damaged fingerprints due to mechanical wear. (4) The advantages of PMUT can surpass existing technologies in the field of industrial non-destructive testing. PMUT array full-focusing imaging also has the potential to achieve 3-dimentional (3D) imaging. It can meet the requirements of the industrial sector for non-destructive testing, including portability and low power consumption.

2.3 Construction of faculty of teaching general problems

Cultivating teachers' mastery of different course content in the mechanical field can be achieved from the following aspects. First, teachers can enhance their understanding and mastery of various courses in the mechanical field through independent learning. They can refer to relevant textbooks, research articles, and practical cases, or participate in professional training and seminars to improve their level of professional knowledge. Second, teachers can participate in systematic training and further education courses to deepen their understanding and application ability of mechanical courses. They can attend academic conferences, seminars, or apply for training courses offered by relevant schools or institutions to obtain new knowledge and latest developments. Third, teachers can consolidate and apply their knowledge of mechanical disciplines by actively participating in engineering practices. They can engage in collaborative projects, laboratory research, or engineering practice activities within or outside the school, and enhance their professional competence through practical experience. Fourth, teachers can establish good cooperative relationships with other educational institutions or teachers to discuss course content and teaching methods. They can participate in academic conferences, teaching seminars, and other activities to exchange ideas and share experiences with experts and colleagues in the industry, learning from their practices. Fifth, teachers can regularly update and organize teaching materials and resources to keep up with the industry's development and changes. They can collect new teaching cases, experimental materials, and practical training resources to adapt to the evolving needs and demands of mechanical courses. In summary, cultivating teachers' mastery of different course content in the mechanical field requires continuous learning and improvement on the part of the teachers themselves. And maintaining communication and collaboration with peers ensure the updating and adaptability of professional knowledge.

2.4 Moral education

Cultivating talents focus on not only “teaching” but also “education”. And thus the course contains moral education elements: "scientific spirit, family and country feelings, craftsman sprit, and great country style". “Eddy Current Tuned Mass Passive Damper” of Shanghai Tower is taken as an example to interpret the moral educaiton. The principle of a damper is like a person standing on a swaying suspension bridge. The balance is maintained by moving their body in the opposite direction of the bridge’s sway. When strong winds blow from a certain direction, the damper acts like a large pendulum and swings in the direction of the wind as well as creats a force opposite to the wind’s direction. This helps to reduce the degree of building sway and counteract the effects of the strong wind. With the use of this device, the acceleration exerted on the building by strong winds can be reduced by around 40%. As a result, even in the face of strong winds, the occupants inside the building can hardly perceive the building’s movements. Additionally, the Shanghai Tower, for the first time, adopted an eddy current tuned mass damper, which is a self-developed innovative technology in China. The maximum single-sided swing amplitude of the damper in the Shanghai Tower is 1 meter. During the impact of Typhoon “Lekima” in 2019, the damper’s single-sided swing amplitude exceeded 50 centimeters and the instantaneous peak reached 70 centimeters, which set a new record since the Tower’s completion. Essentially, the damper system is a second-order system that consists of a mass-spring-damper. The optimal design of the system parameters and its stability determine the wind resistance level of the building. The integration of a damper in the Shanghai Tower helps students to truly understand the importance of scientific knowledge in the development of our country, which fosters a greater passion and dedication towards scientific exploration. It guides students to develop a sense of historical mission and to enhance their professional qualities. It also instills the belief that today’s learning is for the better construction of tomorrow’s China. Students are encouraged to cultivate the spirit of craftsmanship, which includes the pursuit of excellence, a commitment to quality, and a customer-oriented service mindset. As a result, the example helps cultivate self-confidence in students. And this will contribute to the development of a modern, civilized, and prosperous world.

3 Comparative Analysis of Data Before and After the Reform

The comparative analysis of the score before and after the reform is depicted in Table 2. The results demonstrate that following the afore-mentioned reform, there was an average score improvement of 11.22 points, rising from 70.51 to 81.73. And about 86.36% of the students’ exam scores were more than 70 points in group A (with reform), while in group B only 68.19% of the students’ scores were more than 70 points. Moreover, students spend an average 45 minutes and 32 minutes to master the m-c-k and R-L-C second-order systems, respectively. While students spend 60 minutes to master the m-c-k and R-L-C second-order system. Thus there was an average learning efficiency improvement of 28.33 percent. Additionally, the students’ participating enthusiasm increased significantly compared to previous teaching method. Teaching assessment methods and standards, the requirements of teachers to students, teachers' attitude towards the course and students' recognition of teaching methods all have a great impact on the teaching effect.

More importantly, there are multiple general problems in different curricula of the "Mechanical Engineering Major", but the general problems are not clearly pointed out in the training plan and teaching outline. Therefore, it is necessary to conduct research, exploration, and practice on the general problems in the cross curricula during the teaching process.

Table 2: Comparison of exam scores of before and after reform

Final Exam Scores	Group A (with reform)	Group B (without reform)
90-100	9.09%	4.55%
80-90	36.36%	31.82%
70-80	40.91%	31.82%
60-70	9.09%	18.18%
0-60	4.55%	13.64%

4 Conclusion

A reform of exploring and practicing of general problem in different curricula was proposed. Based on the reform concept, the method of finding general problem, teaching means, requirements for the teacher are constructed. Moreover, the effectiveness of the proposed reform has been practiced in two groups of students. The group's exam average scores of learning the general problem intensively are 11.22 points higher than the group's average exam scores of learning them separately at an interval of one month. Meanwhile, in the context of the construction of "new engineering", general problems focus on the mechanical and electrical integration, which improves students' scientific research and engineering practice ability. Active tuned mass damper of Shanghai Tower is taken as a practical application example, which enhances the scientific spirit, practice belief of the students. The reform reported in this paper can be also expanded to other engineering majors.

Acknowledgments: This work was supported by the Research and Construction Fund of "Four New" Education and Teaching Reform (Grant No. JG202250),

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