Exploration and Practice of Curriculum Reform in Motion Control Systems

Jianqiang Su[1,2,*]
[1]*School of Electric Power, Inner Mongolia University of Technology, Hohhot, Inner Mongolia, China*
[2]*Inner Mongolia Key laboratory of Electrical and Mechanical Control, Inner Mongolia University of Technology, Hohhot, Inner Mongolia, China*
**Corresponding Author.*

Abstract: Motion control systems are a core course in the field of automation engineering. In light of the emergence of new technologies and industries, as well as the context of engineering education program accreditation, this course has faced a series of challenges, including outdated content, weakened skill development, low student engagement, and limited experimental opportunities. To address these issues and align with future industry trends, the curriculum for motion control systems has been redefined based on the three major principles of engineering accreditation. With a focus on professional training objectives, new standards for the motion control systems course have been established. Beneficial reforms and explorations have been conducted in three key areas: curriculum content, teaching methods, and experimental instruction. From a practical perspective, the results have been promising, with all course objectives being successfully achieved and noticeable improvements in students' abilities to analyze, design, and practically implement motion control systems.

Keywords: Engineering Education Accreditation; Motion Control Systems; Curriculum Reform; Experimental Instruction; Improvement of Student Capabilities

1. Introduction

The new wave of technological and industrial revolutions is flourishing, and engineering and technical talents, as the main force behind these revolutions, play a crucial role in determining China's position in future industries [1-2]. To align engineering talent development with international standards, China formally joined the Washington Accord in 2016, an agreement on mutual recognition of engineering education degrees. Domestic universities across China adhere to the basic principles of student-centered, outcome-oriented, and continuous improvement as they persistently advance professional engineering education accreditation [3-4]. Inner Mongolia University of Technology, in its automation program, aims to cultivate highly skilled applied engineering professionals who can engage in the analysis, design, development, operation, and management of control systems in fields such as electricity and energy industries. This goal is achieved through a scientifically designed curriculum, a multi-level practical teaching system, the establishment of collaborative training bases with industry partners, and the implementation of an in-house mentorship system. These measures emphasize the development of students' abilities to solve complex engineering problems and enhance the core competitiveness of the program. Please note that this translation is a general interpretation, and specific terms and context may vary depending on the intended audience and purpose of the translation [5-7].

As a core course in the Automation program at Inner Mongolia University of Technology, Motion Control Systems represents the final specialized course within the Electrical Drive and Control Systems curriculum module. This course encompasses fundamental knowledge in areas such as power electronics, motors and drives, automatic control principles, sensing technology, micro processing techniques, and more. Positioned as a core subject, the primary aim of the Motion Control Systems course goes beyond knowledge accumulation. It places a greater emphasis on cultivating students' abilities in systematic analysis, design, and practical hands-on skills. These objectives are critical in supporting the graduation goals of the Automation program [9-11].

This study aims to carry out pedagogical reforms and exploration in the context of the core curriculum of motion control systems within the field of automation. It underscores the imperative for engineering education to evolve and align with the demands of the new era marked by emerging technologies and industries. By adhering to the fundamental principles of student-centeredness, outcome-driven instruction, and continuous improvement, beneficial reforms and explorations have been conducted in three critical aspects: curriculum content, teaching methodologies, and experimental pedagogy. These efforts have proven effective in enhancing students' abilities in the analysis, design of motion control systems, and their practical skills. The findings and innovations presented in this paper hold significant implications not only for students within the field of automation but also for elevating the standards of engineering education. This will enable China to better adapt to the demands of future industries, thereby advancing its global standing in the competitive industrial landscape.

2. The Challenges Faced by the Motion Control Systems Course

The Motion Control Systems course is characterized by its strong comprehensiveness and close connection to practical applications. It not only requires students to have a comprehensive understanding of theoretical knowledge but also aims to cultivate their practical hands-on skills for conducting experiments. However, as new industries such as robotics, industrial robotic arms, electric vehicles, high-speed trains, wind power generation, and others continue to advance, motion control systems, serving as the underlying execution mechanism for these industries, face several new challenges in curriculum development. These challenges are not aligned with the three major principles of engineering education accreditation and make it difficult to meet the demands for training professionals in the field of automation.

(1) The curriculum content is outdated and struggles to meet the demands of industrial development. The previous Motion Control Systems teaching materials primarily focused on DC motor speed control, with AC speed control offered as an elective course. Due to its complexity, very few students opted for the AC speed control course, making it inaccessible to the majority of students. However, with advancements in control theory, power electronics, and microelectronics, it is an undeniable fact that AC speed control systems are gradually replacing DC speed control systems in the industrial sector. AC speed control systems are rapidly evolving towards higher voltage, greater capacity, enhanced performance, improved efficiency, environmental sustainability, and network integration. As leading institutions in technology and science, universities must promptly update their teaching content. Failure to do so can hinder their ability to effectively support talent development and meet the requirements of the industrial sector.

(2) The predominant focus on knowledge dissemination makes it challenging to meet the competence development requirements of engineering accreditation. Engineering accreditation places a stronger emphasis on cultivating students' capabilities and emphasizes outcome orientation. In the initial stages of the Motion Control Systems course, the emphasis is primarily on the application of the theoretical knowledge acquired in areas such as motors, power electronics, and control theory. This approach places a significant focus on teaching theoretical knowledge from textbooks but lacks the emphasis on developing students' analytical, design, and research skills for complex engineering problems, which are required by engineering accreditation standards.

(3) Low student engagement makes it challenging to effectively spark students' enthusiasm for learning. Engineering education program accreditation emphasizes teaching with the student at the center and aims to cultivate students' proactive learning, problem-solving abilities for complex engineering problems, and teamwork skills. The previous teaching model, due to the breadth and specialization of the course content, resulted in students being unwilling to engage deeply with the course material. Many students focused primarily on rote learning and solving problems to meet the immediate requirements without delving into a deeper understanding.

This approach led to a lack of enthusiasm for learning among students and made it more difficult to cultivate their self-learning abilities.
(4) The limited variety of experiments makes it challenging to meet the requirements for enhancing students' engineering practical skills. The previous set of experiments in the Motion Control Systems course relied on the Zhejiang Qiushi experimental platform and consisted of four DC speed control experiments completed within two weeks. Students followed the experiment manual step by step to conduct these experiments. The experimental setups were singular in function and enclosed in cabinets, making it difficult for students to seamlessly integrate theoretical knowledge with practical application. They had a superficial understanding of hardware concepts and often couldn't fully grasp the underlying principles behind the observed phenomena during the experiments. Consequently, students found it challenging to effectively develop their engineering practical skills through these experiments.

3. Reform of the Motion Control Systems Curriculum System

Based on the industry context, the three major principles of engineering accreditation, and the positioning of automation education goals, new course standards for Motion Control Systems have been developed. These standards consist of three course objectives for theoretical courses and four course objectives for practical courses. For theoretical courses, the course objectives are structured around three levels: analyzing, designing, and researching motion control systems. They aim to cultivate students' independent analytical skills, the ability to design automatic control systems, and the capability to solve complex engineering problems. In practical courses, the course objectives focus on four aspects: designing experiments and their implementation, data analysis, report writing, and teamwork. These objectives are designed to enhance students' practical skills. Building upon the formulation of course standards, reforms and explorations have been undertaken in three key areas: curriculum content, teaching methods, and laboratory instruction.

3.1 Curriculum Content Reform Based on Engineering Background

Taking into account the development of motion control systems, societal demands, the faculty team in the field of automation, student learning conditions, and the school's infrastructure, a comprehensive reform of the teaching content has been undertaken.
(1) While retaining the basic content structure of open-loop control, single-loop control, and double-loop control for DC speed control, some of the DC speed control content has been removed. In its place, content related to AC speed control has been introduced, focusing on variable voltage-variable frequency speed control based on steady-state models and vector control speed control based on dynamic models. Both DC and AC portions now occupy an equal share of course hours, with DC speed control serving as a foundation for AC speed control on one hand and meeting the requirements of new industries and complex engineering problems as stipulated in engineering accreditation on the other.
(2) In accordance with the graduation objectives outlined in engineering accreditation, adjustments have been made to the content of the Electrical Drive and Control Systems module within the curriculum. Within the framework of the module is course offerings, Motion Control Systems, as the final specialized course, has been adapted to complement the other supporting courses. For instance, in Power Electronics Technology, the content related to thyristor rectification has been reduced while content pertaining to PWM inverter control technology has been added to align with AC speed control. Additionally, in the course on Automatic Control Principles, a dedicated section on PID design for DC speed control systems has been included. These changes not only address the issue of insufficient teaching hours but also establish connections between courses within the module, creating an integrated system and collectively supporting the achievement of graduation objectives.
(3) In line with the industry background, additional project case teaching content has been incorporated. Motion control is a course that combines strong theoretical aspects with practical applications. To further strengthen the connection between course theory and engineering experiments and to ignite students' interest in learning, the classroom instruction has primarily included teaching cases related

to the control systems of high-speed rail electric drive, wind power control systems for doubly fed induction generators, artillery drive control systems, pure electric vehicle motor drive systems, and multi-degree-of-freedom robotic arm control systems, among others.

3.2 Teaching Method Reform Centered on Student-Centered Learning

The traditional teaching method for motion control systems places the teacher at the center of instruction, resulting in abstract course theory that is challenging for students to comprehend, leading to low levels of engagement. Engineering education program accreditation places a stronger emphasis on student-centered learning. Based on this, new teaching methods have been introduced alongside the existing ones to enhance the learning experience.

(1) Incorporation of student-led seminar-style teaching methods: Based on the case study content provided, students work in groups of three to select an application project, gather information, design a plan, write a design report, create a presentation, and present it in class. The primary participants in teaching are the students themselves, with the teacher playing a guiding role, facilitating student discussions, encouraging critical thinking, providing insights into the latest developments in the field, and illustrating the practical applications of course content. This approach nurtures students' proactive learning abilities, team spirit, and collaboration skills.

(2) Integration of the Rain Classroom platform into the curriculum: To further enhance student engagement, teachers send the next course content, PPT slides, and supplementary materials to the Rain Classroom platform prior to the class. During the class, the online testing feature of Rain Classroom is used to assess students' understanding in real-time. The teacher can address common issues promptly and facilitate interactive discussions. Additionally, after the class, students have the opportunity to ask questions and engage in discussions with the teacher through the platform. Modern teaching aids available in Rain Classroom, such as animations, videos, and other online resources, are used to present complex topics in motion control systems, such as static and dynamic characteristics and magnetic field orientation, in an intuitive manner, effectively capturing students' interest and improving the overall classroom teaching effectiveness.

(3) Addition of out-of-class project assignments: To enhance students' active self-learning, research skills, and exposure to cutting-edge knowledge in motion control systems, out-of-class project assignments have been introduced. These assignments include tasks such as the double-loop design of a DC-driven system for a tracked mobile robot and the design of a DC-driven system for a pure electric vehicle motor. Students are required to model and simulate these systems using MATLAB, analyze the results, and optimize design parameters. This approach not only encourages students to take initiative in self-study and research but also broadens their horizons by exposing them to advanced concepts related to motion control systems. Furthermore, the simulation aspect of the assignments bridges the gap between theory and experimentation, addressing the issue of a disconnect between the two. It also lays the groundwork for more comprehensive course design experiments.

3.3 Experiment Teaching Reform Based on Four-Level Design

In accordance with the requirements of engineering education program accreditation, the laboratory courses have closely integrated theory with experimentation and skill development. This reform departs from the traditional model of simply wiring circuits and collecting data during experiments and instead adopts a teaching approach that encompasses motor parameter testing, modeling and simulation, comprehensive system design, and experimental tuning. Firstly, students conduct parameter measurements on the controlled object, the motor, using the experimental platform. Subsequently, leveraging the earlier project assignments and utilizing the simulation model constructed, students adjust and refine the model based on the motor parameters collected during the foundational experiments, followed by simulation analysis. Next, they design PI controller parameters for current and speed loops in accordance with specific experimental requirements. Finally, the students carry out experiments on the platform, comparing and analyzing whether the simulation results, calculation results, and experimental results align. If the designed targets are not met, they iterate through a new cycle of simulation and design until the desired outcomes are achieved. Through this four-level experiment teaching reform encompassing parameter testing, theoretical design, simulation analysis, and comprehensive experimentation, students deepen their understanding of the static and dynamic characteristics of control systems. Particularly, in adjusting parameters for online asynchronous motor control, observing motor speed and flux waveforms, and gaining insights into variable frequency control of asynchronous motors, students significantly improve their engineering design capabilities. Furthermore, during the implementation of experiments, a group-based approach with individual assessments is employed. This approach not only effectively hones students' teamwork and communication skills but also ensures that each student can independently complete experiments, preventing instances of undue reliance on others.

3.4 Comparative Analysis of Teaching Reform Effects

After two years of teaching reform and exploration across two grade levels, the reform approach for this course has demonstrated notable improvements in both teaching effectiveness and student satisfaction.

The planned course objectives have all been achieved, with a significant enhancement in students' abilities to analyze problems and design motion control systems. The Table 1. presents the results of the most recent assessment of the attainment of course objectives for theoretical and practical teaching in the Motion Control Systems course. The data is based on a sample of 62 students from two classes.

Table 1. Survey on the Attainment of Course Objectives in Motion Control Systems Theory and Laboratory Teaching

Serial Number	Survey Questions (Course Objectives)	Evaluation of Course Objectives Attainment				
		Achieved	Achieved Well	Achieved Moderately	Achieved Adequately	Not Achieved
		100~ 90	89~ 80	79~ 70	69~ 60	Below 59
Theory Teaching	Course Objectives 1	5	20	27	10	0
	Course Objectives 2	4	17	32	9	0
	Course Objectives 3	2	15	31	14	0
Laboratory Teaching	Course Objectives 4	8	40	11	3	0
	Course Objectives 5	7	36	14	5	0
	Course Objectives 6	9	39	12	2	0
	Course Objectives 7	10	38	11	3	0

4. Conclusions

Combining engineering education program accreditation, a profound reconsideration and constructive teaching reform practices and exploration have been applied to the Motion Control Systems course. These efforts are guided by three fundamental principles: student-centricity, outcome-driven, and continuous improvement. Emphasis has been placed on reform and exploration across three key areas: course content, teaching methodologies, and experimental instruction, with the goal of thoroughly honing students' problem-solving abilities for complex engineering challenges in motion control systems. Throughout this process of teaching reform and exploration, it is deeply recognized that curriculum reform must closely align with the industrial and technological development landscape to nurture highly skilled, application-oriented engineering and technical talents capable of adapting to the demands of the new era.

Acknowledgments

This paper is supported by Inner Mongolia Science and Technology Research Project (2021GG0256), Inner Mongolia Natural Science Foundation Project (2022LHMS06007).

References

[1] Lin Jian. Engineering Education Accreditation and Engineering Education Reform and Development. Higher Engineering Education Research, 2015, 3: 10-19.

[2] Deng Miaolei. Research on the Construction of Teaching Quality Assurance System in Higher Education Institutions Based on Engineering Education Professional Certification: Review of Research on Teaching Quality Assurance System in Local Undergraduate Colleges in China. Education Theory and Practice, 2020, 40 (2): 2.

[3] Fan Yiyang, Yi Jingyi. Implications of the Washington Accord for Higher Engineering Education in China. Chinese Higher Education Research, 2014, 8: 45-49.

[4] Qi Shuyu, Li Guoxiang The Quality Regulations for Graduates under the Washington Agreement and Their Implications for the Training of Engineering Talents in Local Universities. Journal of Higher Education Management, 2018,12 (01): 48-53.

[5] Wang Daojun, Guo Wenan. Education. 3rd edition. Beijing: People's Education Press, 2016.

[6] Fan Qigao, Shen Yanxia, Zhu Yixin, et al. Research on the Teaching of Motion Control System under the Needs of First-Class Curriculum Construction. Journal of Electrical and Electronics Teaching, 2021, 43 (04): 94-98.

[7] Zhang Jun, Yue Qianqian. The Construction of Smart Classroom in Experimental Teaching under the Guidance of Golden Course. Journal of Jiangsu Institute of Technology, 2020,26 (04): 115-122.

[8] Ruan Yi, Yang Ying, Chen Boshi. Motion Control System. 5th Edition. Beijing: Mechanical Industry Press, 2019.

[9] Zhao Wenxiang, Ji Jinghua, Liu Guohai, et al. Reform of Simulation Experiment Teaching in the Motion Control Course. Laboratory Research and Exploration, 2013, 32(8): 130-133.

[10] Kuai Songyan, Heng Fengping, Cui Xin, Tan Guojun, Deng Xianming. Teaching Reform of the Motion Control System Course Based on Matlab. Journal of Electrical and Electronic Education, 2016, 38(1): 29-31.

[11] Yu Wei, Wang Fei, Lin Meijin. Application of Blended Learning in the Motion Control System Classroom Teaching. Western Quality Education, 2020, 14: 123-133.

