Practice of CDIO in Course of *DC Motor Drive and Control System*

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ABSTRACT

DC Motor Drive and Control System is a primary course for Electrical Engineering and Automation. This course is a quite comprehensive and practical engineering course to be feasible to introduce the CDIO teaching mode. Based on the detailed analysis and revision of teaching syllabus and content, a third-level project is presented according CDIO standards 5, 7, 8 and 11. The main circuit and DC motor are provided by teachers. Students are responsible for the design and implement of control circuit. The major knowledge of this course together with other learned courses is sufficient to complete the project. This plan will help students improve their hands-on skills, integrate their comprehensive professional knowledge, stimulate students' motivations to use more professional and advanced design methods and apply them in the project.

Students are divided into groups and teams to perform the tasks as followed. Firstly, the project application report includes research theories, content, research goals, key subject problems, research plan, feasible analysis, and so on. Secondly, research report need to be completed, which includes regulator design results, drawings of all the designs, system simulation and PPT for final answer. Finally, manufacturing and function test. This part includes schematic diagram and PCB design, welding of hardware circuit, and function test and competition. The score of each student is given by teachers according to the implementation level, research report and attendance. The attendance will be checked strictly during the course. Students should join the project research on time. Absence without reason and early quit are forbidden. Extra score will be given to the outstanding student. Students carry out the project design and experiment, and finally accomplish scheduled tasks by means of test and answer. Through this practice of CDIO, students obtain important experience on hands-on skills, global vision and team work spirit.

KEYWORDS

DC Motor Drive and Control System, CDIO Teaching Mode, Teaching Reform, CDIO Standards: 5, 7, 8, 11

INTRODUCTIONS

DC Motor Drive and Control System is a primary course for electrical engineering and automation. The main content of this course is DC motor speed regulating system and design of industry regulator. This is an engineering course which will lead students put theoretical knowledge into practice. In tradition, this course is mainly taught theoretical knowledge, supplemented with some teaching experiments. As to such an engineering and practicable course, the traditional teaching mode cannot achieve the goal of learning to practice and need to be reformed.

With CDIO teaching mode (Zha Jianzhong, 2008), students learn knowledge with active and practical way and understand the connection between different courses by taking the whole

period from product development to achievement as carrier, which is very helpful to improve their engineering ability and foster their team work spirit.
DC Motor Drive and Control System involves many basic major course, it is a quite comprehensive and practical engineering course. Therefore, it is feasible to introduce the CDIO teaching mode into this course.
In this paper, the course system and traditional teaching mode of *DC Motor Drive and Control System* is analyzed firstly. The specific realization of CDIO in this course is introduced secondly. Finally, the actual result of the teaching reform is shown.

COURSE SYSTEM AND TRADITIONAL TEACHING MODE

Course System

The main topics of *DC Motor Drive and Control System* (Chen Boshi, 2007) is the design of DC motor speed regulating system, which requires a high level of comprehensive and systematic application. The prerequisite courses of *DC Motor Drive and Control System* are shown as Figure1. It can be seen that this course almost covers all of the basic courses of the major of electrical engineering and automation, especially *Power Electronics, Control Theory* and *Electromechanics*.

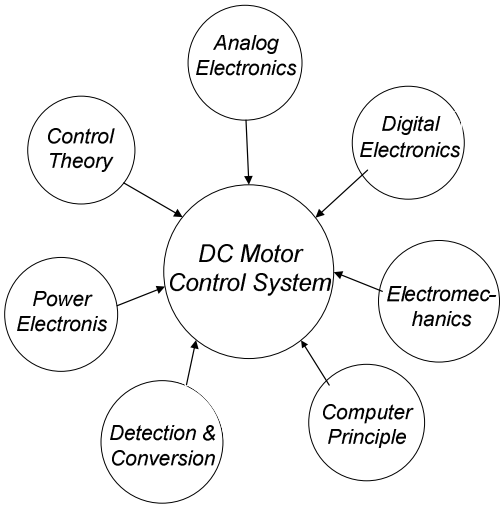

Figure 1. Prerequisite courses of *DC Motor Drive and Control System*

The subsequent courses of this course are shown as Figure 2. From Figure 1 and 2, it can be seen that *DC Motor Drive and Control System* is a center course.

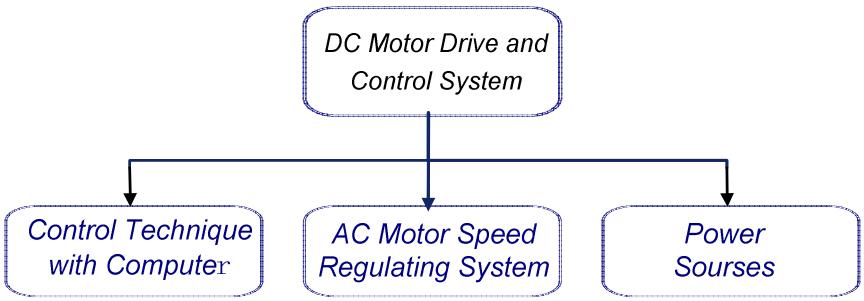

Figure 2. Subsequent Courses of *DC Motor Drive and Control System*

Traditional Teaching Mode

In teaching plan, the total class hours of *DC Motor Drive and Control System* are 56 hours. In traditional teaching mode, there are 50 hours for classroom teaching, in which students accept knowledge passively from teacher's instruction. There are 6 hours for experiments. These experiments are to verify the theoretical knowledge of classroom teaching. Students are led by experiment guidelines to connect wire and debug on the bench. There are very little design and research activities for students to complete on their own.
Furthermore, there are other defects with traditional teaching mode. For instance, basic courses are taught by teachers of different department. The organic connection of the courses is not understood by students validly and clearly. Students have not a total recognition of the major knowledge, so they have no ability to solve real engineering problem. As there is no chance to perform a real project, students generally lack engineering ability and team work spirit.
Teaching reform must be done to improve the students' engineering ability and develop their team work spirit.

PRACTICE OF CDIO IN *DC MORTOR DRIVE AND CONTROL SYSTEM*

Design of Third-level Project

CDIO teaching mode is introduced to reach this target of teaching reform. A third-level project is presented according to CDIO standards 5, 7, 8 and 11 (LIU Si-yuan,et al, 2012).
A complete DC motor speed regulating system is composed of main circuit, control circuit and DC motor with load. The key point of *DC Motor Drive and Control System* is the design of control circuit. However, the main circuit and DC motor are provided by teachers.
The major knowledge of this course together with other learned courses is sufficient to complete the project. Students are encouraged to apply more professional and advanced design method into the project by themselves in their spare time.
According to CDIO standard 5, there are two designs in the third-level project. One is design of an analog control circuit for basic level. The other is design of a digital control circuit for advanced level.
Students will be given detailed instruction after grouping. Firstly, they need to provide a project application. In the application, they should elaborate research theories, content, research goals, key subject problems, research plan and feasible analysis. The working base and condition, brief introduction of team members, and funds budget are also included in the application. Secondly, they need to complete a research report including regulator design results, drawings of all the designs, system simulation and PPT for final answer. Regulator design results are composed of steady and dynamic structure diagram, function norm analysis, regulator structure selection and parameter calculation, and verification. Finally is the manufacturing and function test. This part includes the schematic diagram and PCB design, welding of hardware circuit, and function test and competition.

Organization and Realization Scheme

Teaching team includes class teachers and guiding teachers. According to their speciality, teachers guide in different stages of the project.
The realization scheme is shown as Figure 3. The project applies competition mode. Firstly, students are divided into groups. Each group includes four or five students. Each group need

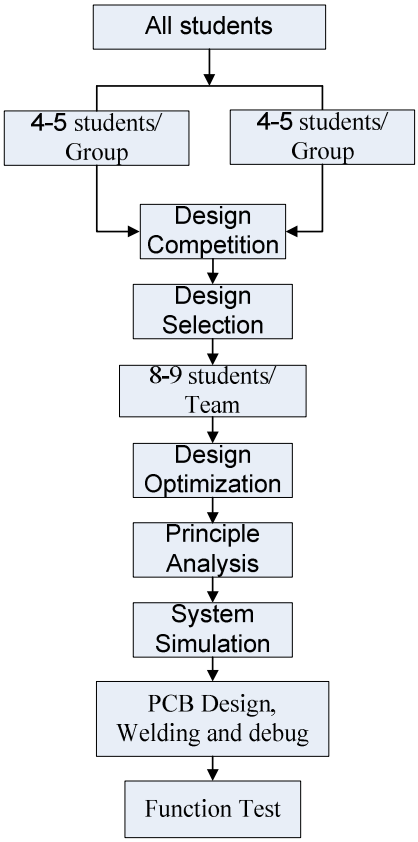

Figure 3. Realization scheme of third-level project

to propose an initial design. Secondly, the initial design competition should be carried out by two groups. The winner design becomes selected design to continue to the next process of the project. The two groups are combined into one team. Team leader will be the person who proposed the winner design. Finally, the team leader leads his team to accomplish the project.

Team members work in cooperation with a due division of labor. Each team member is not only responsible for his own work, but also needs to know the overall progress. Among the teams, evaluation, comparison and assistance to each other is much important to form valid competition and cooperation. Discussion and progress report should be held at regular intervals to solve problems and prevent mistakes.

The third-level project should be assigned at the beginning of the course. Students finish the project by schedule. The project needs 42 class hours, while 20 hours occupy the classroom teaching and other 22 hours are extracurricular time. The schedule together with project progress is shown as Table 1.

Examination Mode and Assessment Standard of Score

The project score is given by teachers according to the implementation level, research report and attendance. The attendance will be checked strictly during the course. Students should join the project research on time. Absence without reason and early quit are forbidden. Extra score will be given to the outstanding student.

The assessment standard of project score is drawn up according to CDIO standard 11.The project score is including two parts. One part is the team score. The team score is decided

Table 1. Schedule

Schedule	project progress	remarks
1st~4th h	Whole composition of DC motor speed regulating system	In class
5th~8th h	Engineering Indices of dynamic and steady feature of DC motor speed regulating system	In class
9th~12th h	Demo of regulator design	In class
13th~16th h	Structure and parameter optimization of regulator	Out of class
17th~20th h	Evaluation and competition of initial design	In class
21th~24th h	Simulation	Out of class
25th~34th h	PCB design, welding and debug	Out of class
35th~38th h	Test and contest	Out of class
39th~42nd h	answer	In class

by the degree of project design and manufacturing, test result and research report. This score is the average score of the team members. The other part of the project score is flexible score. The flexible score is given by team leader according to personal contribution to the project of each member. The flexible score would be positive or negative, which should be agreed by all members. The final project score of each member is the team score plus flexible score.The assessment standard of team score is shown as Table 2.

Table 2. Assessment standard of team score

Content	Standard
Project design, manufacturing and debug	25%
Test and competition	25%
Research report	30%
Final answer	20%

Results of Third-level Project

All of the teams finish third-level project. As for the basic level, design of analog control circuit, students applied analog IC as control unit together with operational amplifiers, resistors and capacitors. One PCB of analog design by students is shown as Figure 4.

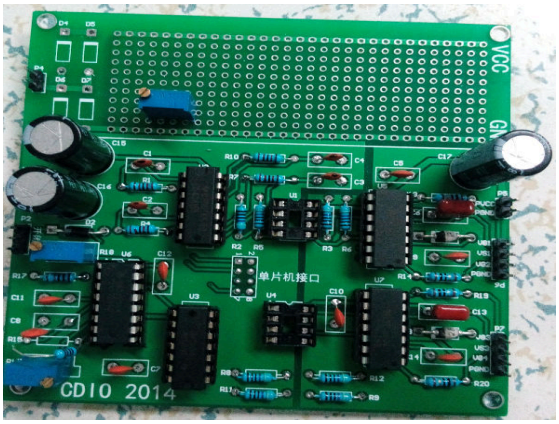

Figure 4. PCB of analog design by students

As for the advanced level, design of digital control circuit, students applied microcontrollers like single chip microcomputer (SCM) and digital signal processor (DSP) as control unit together with peripheral circuits. One DSP control circuit design by students is shown as Figure 5.

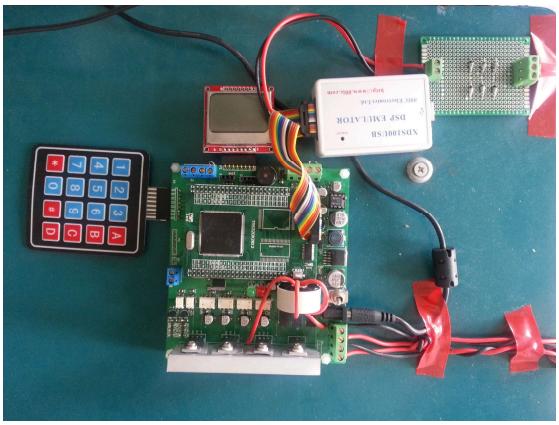
Figure 5. DSP control circuit design by students

It is worth mentioning of regulator design. With the design method from the course, there must be overshoot in dynamic regulating progress of motor speed, which is not accepted in some tough conditions. Some students found out better solution to avoid the overshoot shown as Figure 6. This is a result of active learning.

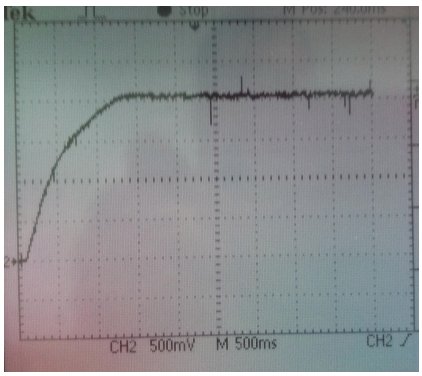

Figure 6. Experimental waveform of no overshoot regulator design by students

EFFECT OF CDIO PRACTICE

This CDIO practice was carried out at the spring term of 2014. The goal of teaching reform was reached. Through the third-level project research, good effect was obtained.

Active Learning

The modern teaching idea of teachers as the guide and students as the main body is well behaved in CDIO teaching mode. Students' activity was encouraged. In the practice of CDIO, an apparent effect is the high attendance rate. Classroom atmosphere was very animated. Teachers and students interacted very well.

In traditional teaching mode, teacher did not grasp students' knowledge structure because actual ability is hard to show at classroom. So, teacher only launched teaching activities by experience. In CDIO teaching mode, students were encountered with many practical problems they had never met. Students must solve these problems by themselves. Most of these problems were solved through data access in library or internet. A few problems were put into discussion class and solved by debate and assistance from other teams. This is one effect of active learning.

The design method in the course is neither the only one nor the best. Some students applied other methods by reading reference out of the course and achieved better function, which was mentioned above. This is another effect of active learning.

From the project design result, this practice reached the CDIO standards 8 very well.

Comprehensive Study

In traditional teaching mode, students only grasp fragmental pieces of knowledge. When they meet real engineering problem, they have no overall concept and comprehensive knowledge. In the progress of project research, students learned how to synthesize their fragmental knowledge into integrity. This comprehensive study mode forces them to find everything fresh and new. Overall concept was established in first step.

For example, in regulator design, verification is much important. In traditional teaching mode, students always neglected the final verification because they had never met a real engineering project of verification. In the third-level project, they came to realize the importance of verification because they had found that design results might not reached technique index without verification. Thus, students finally understood how to finish a total design. This also reached CDIO standards 7.

Team Work Spirit

Before the CDIO practice, students were not aware of team cooperation. They were used to doing it alone. In the design of third-level project, students understood that a whole practical engineering project cannot be accomplished by one person. They realized the importance of sharing the work and cooperating with one another. Team work spirit was improved.

CONCLUSIONS

Through the practice of CDIO on *DC Motor Drive and Control System*, students' ability of hands-on skills and global vision are formed and improved. Students realize the importance of team work spirit. Compared with the classes without CDIO, excellence rate and passing rate are all obviously higher in final examination. The teaching reform of CDIO practice reaches its goal.

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