

Teaching reform of the *Introduction to Metal Cutting Machine Tools* course for the *Excellent Engineers Training Plan*

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ABSTRACT: Mechanical design, manufacturing and its automation is one of the key specialties in Shandong University of Technology, which is in the first list of *Excellent Engineers Training Plan* as authorised by the Education Ministry of the People's Republic of China. The *Introduction to Metal Cutting Machine Tools* course is one of the main subjects of this specialty. Its primary target is to imbue students with knowledge and the abilities to analyse requirements and select machine tools. The aim of the *Introduction to Metal Cutting Machine Tools* in the specialty of mechanical design, manufacturing and its automation is to develop technical talent in mechanical engineering that has innovation ability and meets the requirements of economic and social development. Explorations on the teaching reform for the *Excellent Engineers Training Plan* are summarised in this article, with importance attached to strengthening the training of students in engineering and innovative ability, and according to the practical teaching of the *Introduction to Metal Cutting Machine Tools* over the past few years.

INTRODUCTION

The *Excellent Engineers Training Plan* constituted by the Education Ministry of the People's Republic of China plays an important part in the medium- and long-term development of Chinese higher education and provides a major impetus for higher engineering education reform. After the kick-off meeting for the Excellent Engineers Training Plan held on 23 June 2010, many educators in Chinese universities explored teaching reform of various majors and courses.

The National Pilot School of Software at Harbin Institute of Technology has gradually developed an industrial education model with industry-oriented curricula and some best practices [1]. Ningbo University of Technology explored a *1234 Project Design Curriculum Innovation Model* as part of the *Excellent Engineers Training Plan*. Its notable feature is the combination of school and enterprise. Enterprises are deeply involved in all aspects of the teaching, such as developing project objectives, project type selection, teaching preparation and implementation [2]. Jiangsu University and Nanjing Automobile Groups established a college-enterprise practice training centre. Engineering and training projects were combined during the construction of the practice base to improve students' quality and practical ability [3].

Mechanical design, manufacturing and its automation is one of the key specialties in Shandong University of Technology, which is in the first list of Excellent Engineers Training Plans authorised by the Education Ministry of the People's Republic of China. *Introduction to Metal Cutting Machine Tools* is one of the main courses of this specialty. Its primary aim is to imbue students with knowledge and the ability to analyse requirements and select machine tools. This is necessary for students who enter the machine tool or manufacture industry and also for those who go into research or management. This is so because all kinds of machines, instruments and tools are needed by defence and in all branches of the national economy. Such equipment can only be manufactured by machine tools. The knowledge of metal cutting machine tools is the necessary essential foundation for the engineers, researchers and administrators of the manufacturing industry.

Educators all over the world have carried out reform of the teaching of metal cutting machine tools. Sanz A. et al used virtual reality in the teaching of manufacturing processes, with material removal in CNC (Computer Numerical Control) machine-tools [4]. Tsai Jo-Peng et al investigated the effect of the use of virtual reality on teaching machine tools operation [5]. Wang Shan and Wang Baohua explored the reform of the teaching of numerical control machine tools and programming in modern engineering education [6].

Introduction to Metal Cutting Machine Tools is a course with strong theoretical and practical features, which aims to cultivate comprehensive engineering and innovative abilities. Summarised here are some teaching reforms for the *Excellent Engineers Training Plan* combined with practical teaching experiences.

STRENGTHENING THE CULTIVATION OF STUDENTS' INNOVATIVE ABILITY

Innovative ability is the ability to develop new ideas, methods or inventions in science, art or technology, which have economic, social or cultural value. Innovation can occur in all kinds of practical fields where knowledge and theory are applied. Innovation sustains the progress of a nation; it is the inexhaustible energy for a country's prosperity. The competition in today's society is for talent with innovative ability rather than just talent itself.

The teaching aims of *Introduction to Metal Cutting Machine Tools* is to enable the students to master the range, transmission principles and transmission structure of all kinds of machine tools. The course is based on a series of foundation lessons, which lay the basis for further studies of the design of metal cutting machine tools and the technology of mechanical manufacturing. During the teaching process, attention was paid to guiding students to rethink, query and improve on existing machine structures and to also query the content of textbooks. This helps cultivate the innovative thinking and ability of students. Two teaching cases are shown below.

Teaching Case 1:

In the feed transmission chain of a CA6140 model lathe, the transmission ratio $\frac{64}{100} \times \frac{100}{97} \times \frac{25}{36}$ of change gears is adopted to approximate $\frac{7\pi}{48}$ when turning the modular system thread. The transmission ratio $\frac{63}{100} \times \frac{100}{75} \times \frac{36}{25}$ of change gears is adopted to approximate $\frac{25.4}{21}$ when turning an inch denominated thread. Students are guided to analyse the errors of the above approximate values.

It can be found that the approximate value of π is 3.1487531 in the first case and the approximate value of the conversion coefficient 25.4 between inches and millimetres is 25.4016 in the second case. These errors would be too large to meet the requirement when the lead screw of long length was turned using existing change gears [7]; and there are speed increasing gear sets in the above change gears, which are prone to leading to an increase in noise [8].

Students were required to optimise the above two groups of change gears to improve precision. The students found more than ten methods to optimise the numbers of gear teeth by literature searching and exploratory research. These methods include simple addition and subtraction, small numerical approximate fraction, separation fraction, fractional values addition, successive division, prime factor reduction, prime factor adjustment, prime factor adjustment multiplication, fractional difference division, adjusted fraction multiplication, conjugation fraction proportion addition, a programming method and using a look-up table.

Through the comparison of different optimisation results, it was found that the approximation error was least and there were no speed increasing gear sets, which can reduce the noise of gear transmission when $\frac{95}{96} \times \frac{64}{96} \times \frac{25}{36}$ was taken to approximate $\frac{7\pi}{48}$ and $\frac{82}{88} \times \frac{64}{71} \times \frac{36}{25}$ was taken to approximate $\frac{25.4}{21}$. The students' abilities of literature searching, self-learning and innovation were improved by such training.

Teaching Case 2:

The low speed transmission route in the transmission chain of a CA6140A model lathe is shown in Figure 1.

$$- \text{III} - \left\{ \begin{array}{c} 20 \\ 80 \\ 50 \\ 50 \end{array} \right\} - \text{IV} - \left\{ \begin{array}{c} 20 \\ 80 \\ 51 \\ 50 \end{array} \right\} - \text{V} - \frac{26}{58} - \text{M}_2 \text{ (Move to the right)} - \text{VI (Principal axis)}$$

Figure 1: The low speed transmission route in the transmission chain of a CA6140A model lathe.

During the teaching process, students were guided to ask questions, such as why the sum of gear teeth of three of the gear pairs is 100, while the gear teeth sum of another is 101 in the above transmission route? The students understood the reason after exploratory thought.

As shown in Figure 2, the low speed transmission mechanism in the main transmission chain of a CA6140A model lathe is also the mechanism of expand-screw-pitch when machining using the lathe. The screw pitch of the thread turned by the lathe can be expanded by 4 and 16 times when the two duplicate gears in the transmission route are of the engagement states $\frac{80}{20} \times \frac{50}{50}$ and $\frac{80}{20} \times \frac{80}{20}$ respectively. If the $\frac{51}{50}$ gears were changed to $\frac{50}{50}$ the transmission ratio of the expand-screw-pitch transmission mechanism would be 1 when the lathe operator makes the two duplicate gears to

be in the engagement state $\frac{50}{50} \times \frac{50}{50}$, which is the same as the occasion when the expand-screw-pitch transmission mechanism was not adopted. But the expand-screw-pitch transmission mechanism makes the transmission route longer and the machining error larger. In order to prevent the lathe operator wrongly choosing such a transmission route, the gear pair between axis VI and axis V was designed to be $\frac{51}{50}$. If the lathe operator chooses the transmission route $\frac{50}{51} \times \frac{50}{50}$, the thread cannot be turned. The students' abilities to apply knowledge from several courses and to innovate were improved through such training.

$$\text{Principal axis} - \left\{ \frac{58}{26} - \text{V} - \frac{80}{20} - \text{IV} - \begin{array}{c} (4:1) \\ \left\{ \frac{50}{50} \right. \\ \left. \frac{80}{20} \right\} \\ (16:1) \end{array} - \text{III} - \frac{44}{44} - \text{VIII} - \frac{26}{58} \right\} - \text{IX} -$$

Figure 2: The transmission route of expand-screw-pitch in the CA6140A model lathe.

STRENGTHENING THE CULTIVATION OF STUDENTS' ENGINEERING ABILITY

The aim of the *Excellent Engineers Training Plan* is to meet the future needs of the industry and to target social demands using engineering technology. It seeks to improve students' engineering consciousness, engineering diathesis and engineering practical capacity.

Introduction to Metal Cutting Machine Tools is a speciality course rooted in engineering practice and serves to cultivate the engineering ability of students who will work in practical engineering fields. The course teaching plan was designed in co-operation with engineering enterprises. Homework was developed through communication with technical experts in the enterprises. For example, when studying the two-way multiple-piece clutch in a main-axis system and an overrunning clutch in a feeding system in a CA6140A model lathe, the following exercises were designed in collaboration with the production engineers at an enterprise to help students understand their working principles and apply them flexibly in engineering practice.

Teaching Case 3:

Question: the speed of the main axis decreases to zero as the tool begin to cut into the piece of work when using the CA6140A model lathe for rough machining. What is the reason? How can you solve this problem?

Solution: this is because the pressure of a two-way multiple-piece clutch decreases due to the abrasion of friction pieces. It can be solved as follows: press the spring pin and screw the nut on the press block until the nut crimps the friction pieces of the clutch. After the nut is adjusted to the proper position, let the spring pin block the gap in the nut again to prevent the nut from loosening due to rotation.

Teaching Case 4:

Question: the feed rod of a CA6140A model lathe can rotate when its main axis rotates forward, but only the rapid vertical and horizontal movement can be switched on; the self-acting feed cannot be switched on. What is the reason? How to solve this problem?

Solution: this is because the elasticity of the spring in the overrunning clutch is too small or the pin was worn out. It can be solved by changing the spring or the pin in the overrunning clutch.

Enterprises were investigated to determine actual engineering problems encountered in the production process and students were required to solve them using knowledge from the course. For example, when hobbing helical cylindrical gears, whether the gear is dextrorotary or levorotary, the dextrorotary hob will be adopted in production. But the workers in the workshop found that tool collision accidents occurred often and that the surface roughness of the teeth cannot meet requirements when the levorotary gear was hobbled using a dextrorotary hob. In reaction to the above phenomenon, the following exercise was designed:

Teaching Case 5:

Question: should a levorotary or dextrorotary hob be preferably chosen when using a gear hobbing machine to hob a levorotary cylindrical gear of big helical angle? Why?

Solution: the levorotatory hob should be preferably chosen. Because the setting angle of the hob equals the helical angle of helical gears minus the helical angle of hob, when the hob and gear are of the same helical sense, the setting angle is smaller and the hob is easy to install. Second, the tangential cutting force is in the same direction as the rotation of a worktable when the hob and gear are not of the same helical sense. This makes the tangential cutting force drive the worktable and leads to a gap of the indexing worm wheel and a drop of process precision and surface finish.

The students' engineering abilities were improved through such training. They can understand and master theoretical knowledge more deeply.

CONCLUSIONS

The implementation of the *Excellent Engineers Training Plan* is still something of a work in progress. In reaction, explorations of teaching reform were carried out during teaching. First, during teaching, attention was paid to guiding students to rethink, query and improve existing machine structures and the content of textbooks; hence, cultivating the innovative thinking and ability of students. Second, homework through communications with technical experts in enterprises had a good effect on the teaching and improved the students' innovative and engineering ability.

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