

Teaching Reform for Curriculum Design of Mechanisms and Machines Theory Focusing on Students' Practice and Innovation Abilities *

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Abstract—In order to develop students' practice and innovation ability, the research are carried out on reformation of curriculum design of mechanisms and machines theory. Two attempts are recommended: ① Experiment teaching of mechanisms assembling and kinematic demonstrating should be adapted; ②based on virtual prototype technology, kinematics and dynamics analysis should be completed by use of software package ADAMS. The general goal and implementation plan of teaching reformation are given; the practical experience and effect of Northeastern University (NEU) in China are introduced. This teaching method can enhance students' initiative of study and improve their innovation ability, which has potential future to be extended in university education.

Keywords—Innovation ability; Curriculum design of mechanisms and machines theory; Teaching reform; ADAMS; Experiment teaching

I. INTRODUCTION

As a basic course of mechanical engineering in university education, the course of mechanisms and mechanics theory plays an important role in the development of the students' innovation design of mechanical system, comprehensive design ability, innovative consciousness and engineering consciousness^[1-3]. The course of mechanisms and mechanics theory is composed of two parts: theory teaching and Curriculum design, which are arranged in two semesters. Curriculum design is an important practical teaching process in the course system of mechanisms and machines theory. The process is based on the design practice, and it is an important method to develop the students' designing and innovation ability. Meanwhile, curriculum design is practical application

and test of the knowledges from theory teaching, which is highly appreciated by the teachers, and is also the focus of reform in education of mechanisms and machines theory. At present, four methods are adopted in the curriculum design in China: mechanisms analysis based on graphic method; analysis and calculation of mechanisms with C language program based on the analytical method; mechanisms kinematic synthesis by use of graphing method and kinematic scheme design of mechanisms. These courses are still in the teaching mode of "task-based", the objects of which are not closely set on the development of students' innovation ability. At present, it seems a little technically backward of graphic method based on "reversal method" or "half angle rotation method" and analytic method with the C programming language, which are commonly used in the curriculum design process. So it isn't beneficial for students to master modern analysis and design technology with computers and to learn popular large software packages which is commonly used in practical engineering. Especially for personnel training of innovative talents, the problems above need to be solved and improved.

II. THE GENERAL GOAL FOR REFORMATION OF CURRICULUM DESIGN

In order to develop students' innovation ability, add experiment teaching to curriculum design; students' initiative of study and intuitionistic image of the mechanism to be designed are enhanced through mechanisms assembling and kinematic demonstrating based on testing system; kinematics and dynamics analysis of the mechanism are completed with the software package ADAMS, it makes students learn virtual prototype software which is widely used in mechanical

engineering as early as possible. Finally, for the excellent students who have certain innovation ability in the process of curriculum design, they are encouraged to continue to improve the practice ability and innovation ability to solve practical problems through participation in technological production and related design competition.

III. THE IMPLEMENTATION PLANS FOR REFORMATION OF CURRICULUM DESIGN

The plan of the course is 40 hours, which includes 6 hours of theoretical teaching, 4 hours for experimental teaching and 30 hours of calculation and design on computers by students. Usually, it is arranged in two weeks to complete. The main design steps and procedures are as follows:

Step 1 Theoretical teaching: Introduce the purpose, requirements and methods of curriculum design, introduce simulation software ADAMS for Automatic Dynamic Analysis of Mechanical Systems and give self reference books and self-study area. According to the design requirements from the teachers, two kinds of mechanisms should be proposed.

Step 2 Experiment teaching: Based on testing system, assembling, kinematic demonstrating and related tests are accomplished for the two kinds of mechanisms above, which enhances students' intuitionistic image of the mechanism to be designed.

Step 3 Calculation and design on computers: determine an optimum one by the comprehensive comparison of the two kinds of mechanisms above. And then, achieve kinematics analysis, dynamic static analysis and rotary inertia of flywheel calculation by using ADAMS. Finally, write a copy of curriculum design instruction and bind in a volume.

Step 4 performaces evalutaion: The final score of the students' curriculum design is given mainly depends on usual performance, results of the experiment, quality of the instructions and question answering. For the talents who are encouraged to participate in technological production and related design competition, learning times and performaces evalutaion should be flexible and appropriate, and the final grade should be combined with the results of the competition.

IV. A CASE OF REFORMATION OF CURRICULUM DESIGN

A. Task requirements

Tile 8.31 "the design of swinging conveyer" in [4] is chosen as the task of curriculum design, take design data item 3 as the requirements, the optimal kinematics arrangements (Fig.1) of the mechanism is finally determined. As shown in Fig. 1, link mechanism is driven by the motor through a three-level gears system. Component 6 is the material trough, it makes straight reciprocating move. Component 7 is the materials, it can move with the material trough together when they move right because of its small acceleration. But when component 6 moves left, its acceleration is big enough, which causes the material trough and the materials slide to each other, thus the materials handling work is completed.

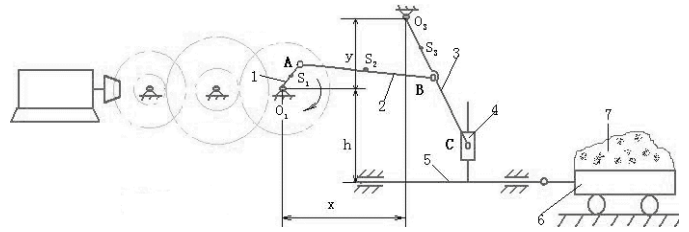


Fig. 1 kinematics arrangements of swinging conveyer

kinematics parameters are designed as: $l_{O1A}=0.09m, l_{AB}=0.302m, l_{O3C}=0.27m, l_{O3B}=0.16m, x=0.27m, y=0.112m, h=0.18m$. The locations of centroids are: $l_{O1S1}=0.0035m, l_{AS2}=0.11m, l_{O3S3}=0.0393m$. The mass and rotary inertia of each links are: $m_1=51kg, J_{S1}=0.3kgm^2, m_2=35.6kg, J_{S2}=0.55kgm^2, m_3=90kg, m_4=900kg, J_{S3}=1.14kgm^2, m_5+m_6=60kg, m_7=2800kg$. The equivalent rotary inertia is $J_{e1}=50kgm^2$, which is generated from the motor rotor and the gear transmission equivalent to the axis O_1 . The static and dynamic friction coefficients of the materials and the material trough are $f_0=0.45$ and $f=0.35$ respectively. The allowable value of non-uniformity coefficient of operating is $[\delta]=0.15$, and the swinging times of material trough is 57.5 times per minute.

B. The Practice of Reformation of Curriculum Design

According to the task requirements of curriculum design above, the author has carried out some attempts on the reformation of curriculum design of mechanisms and machines theory based on softwar ADAMS in school of mechanical engineering and automation Northeastern University. Some details will be partly introdeced about the students' completion of curriculum design. As shown in Fig. 2, a simplified virtual prototype model of the swinging conveyer is established under the software ADAMS which is in left limit position. A physical model is assembled based on testing system as shown in Fig. 3.

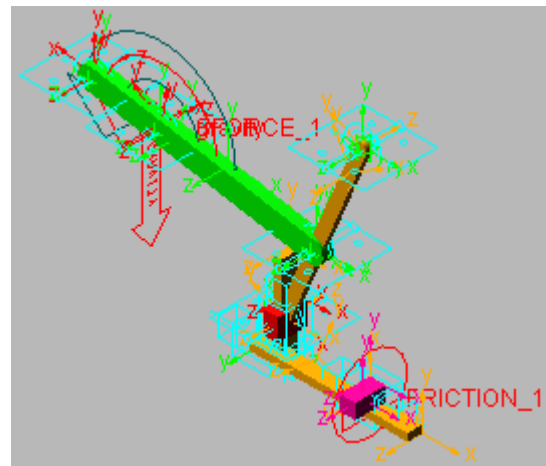


Fig. 2 A simplified virtual prototype model of the swinging conveyer

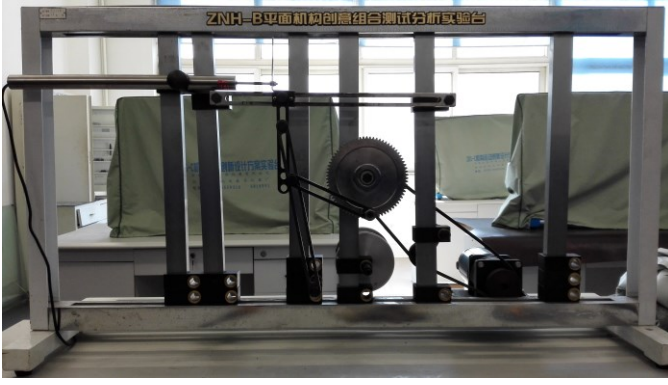


Fig. 3 A physical model of the swinging conveyor

C. Kinematic Analysis of the Mechanism

Using the simulation function of ADAMS, the position, velocity and acceleration curves of the material trough are obtained as shown in Fig. 4. The position, velocity and acceleration curves of the materials are shown in Fig. 5. The velocity and acceleration comparisons of materials and material trough are shown in Fig. 6. As shown in Fig. 6, the materials begins to separate from the material trough when the inertia force of the materials is bigger than the friction ($t = 0.49s$). When $t = 0.77s$ i.e. the velocity of materials is equal to the velocity of material trough (at this time, some materials has been thrown out of the trough), materials and material trough begin to move together as the same velocity and acceleration until the next separation process.

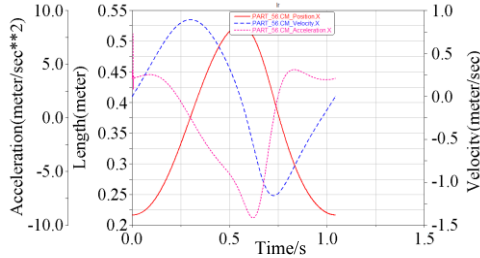


Fig. 4 the position, velocity and acceleration curves of the material trough

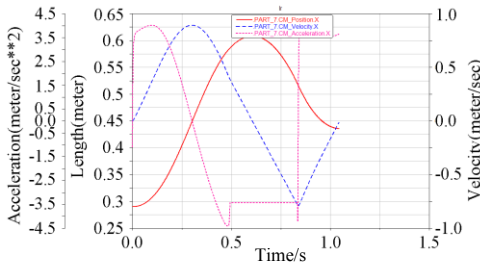


Fig. 5 The position, velocity and acceleration curves of the materials

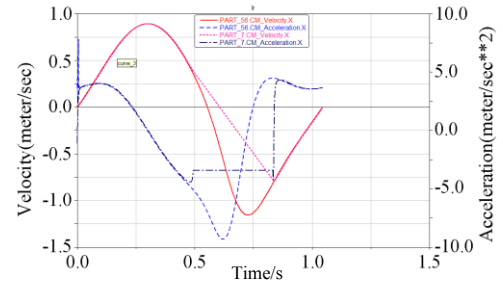


Fig. 6 The velocity and acceleration comparisons of materials and material trough

D. Force Analysis of the Mechanism

- Reaction force analysis of fixed hinge

The reaction forces in horizontal and vertical directions of the O_1 and O_3 points of the fixed hinge are obtained in ADAMS, the results are saved as Numeric Data format and inputed into the Origin6.0 software, the diagram of reaction force vectors are drawn in Fig. 7 and Fig. 8 respectively.

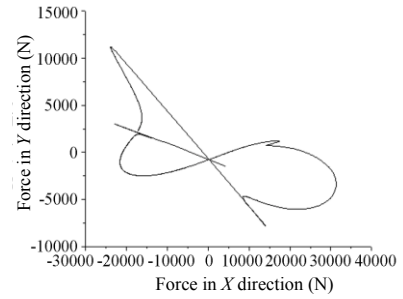


Fig. 7 the diagram of reaction force vectors at O_1

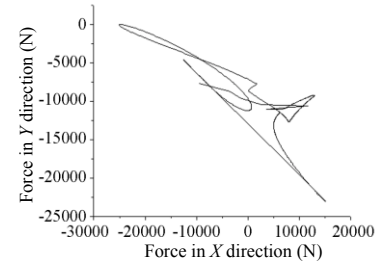


Fig. 8 the diagram of reaction force vectors at O_3

- The analysis of equilibrium torque

Using the simulation function of ADAMS, the equivalent equilibrium torque T_b of the crank is obtained as shown in Fig. 9, and the average value of equivalent equilibrium torque is calculated with ADAMS i.e. $T_{bv}=245.2(N \cdot m)$.

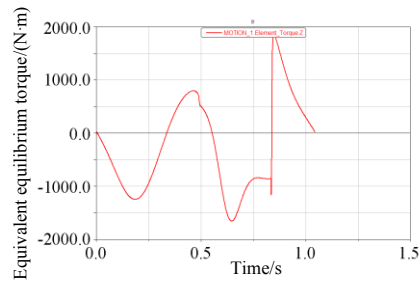


Fig. 9 the equivalent equilibrium torque of crank

• Calculation of flywheel rotary inertia

Step 1 The selection of motor: Power calculation expression of motor is $N = T_{bv} \times \omega / \eta_s$, total efficiency value is got depend on the mean values of bevel and spur gears in the transmission system, $\eta = 0.9 \times 0.93 \times 0.93 = 0.7784$, so $N \approx 2(\text{KW})$ and final selection of the motor model is Y132S-6.

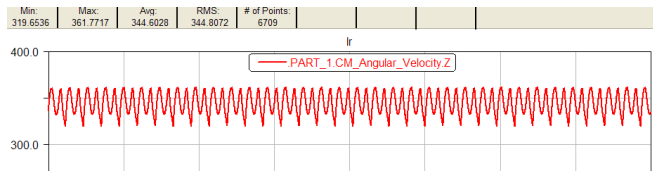


Fig. 10 angular velocity of the crank in the stable operation stage in ADAMS

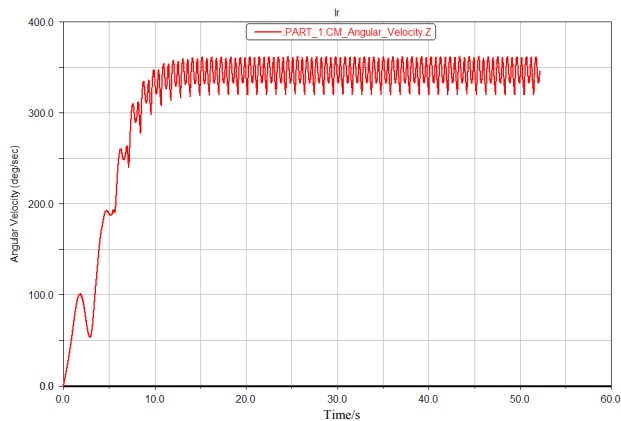


Fig. 11 angular velocity of the crank in the starting stage and the stable operation stage in ADAMS

Step 2 Calculation of rotary inertia of flywheel: In ADAMS, the motor is equivalent to the average equivalent equilibrium torque T_{bv} , which means a torque $T_{bv} = 245.2$ acts on the crank. Rotary inertia value of the crank is continuously increased in ADAMS by manual, when the

rotary inertia of flywheel is set in $J_f = 250(\text{kg} \cdot \text{m}^2)$, as shown in Fig. 10, the average, maximum and minimum values of angular velocity of the crank are $\omega_{\text{avg}} = 344.60 \text{ s}^{-1}$, $\omega_{\text{max}} = 361.77 \text{ s}^{-1}$ and $\omega_{\text{min}} = 319.65 \text{ s}^{-1}$ respectively when the crank works in a stable operation stage according to the simulation results with ADAMS. And then, non-uniformity coefficient of machinery operation is less than the allowable value i.e. $\delta = 0.122 < [\delta] = 0.150.15$, which meets the requirements. At the same time, angular velocity of the crank is drawn when it works in the starting stage and the stable operation stage by using the simulation function of ADAMS, which is shown in Fig. 11.

V. CONCLUSIONS

Experiment teaching is added in the curriculum design of mechanisms and machines theory, which enhances students' initiative of study and intuitionistic image of the mechanism to be designed. Kinematics and dynamics analysis of the mechanism are accomplished with the software package ADAMS, modern design methods are taught and foundation of engineering are built for students during the process of curriculum design. The author completed several rounds of practical reforms about curriculum design of mechanisms and machines theory in NEU, which shows that: students' initiatives of study are enhanced and their innovation abilities are improved. In the following related design contests such as mechanical innovative design competition for college students in China, The author's students won some provincial awards as first prize, second prize and third prize.

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