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Oil equipment design teaching based on an *excellent engineers* training plan

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ABSTRACT: Oil equipment design, part of the process equipment and control engineering major, was selected as a pilot for the *Excellence Engineering Education Programme*, a major education reform programme initiated by the Ministry of Education in China. The reformed approach to teaching aims to improve the training of students in design and solving practical problems. This revised training covers process calculation, structural design and strength checks for equipment. Also, covered are such subjects as chemical engineering cartography and optimised design using process simulation software. The training provides the basis for students who wish to work in the petroleum and petrochemical industries. Based on the employability rates of the graduates trained according to the reformed approach, it is evident that the reform has contributed to their increased success in obtaining suitable jobs.

INTRODUCTION

Engineering higher education in China plays an important role in the country's economic development. There is a need to foster the development of a large number of high quality engineering and technical personnel with innovative ability, to satisfy the needs generated by the country's economic and social development. On 23 June 2010, the Chinese Ministry of Education held a meeting at Tianjin University on the *Excellence Engineering Education Programme*, which included relevant departments and industry associations, to discuss the carrying out of the education programme (hereinafter referred to as the *Excellence Programme* [1-4].

Since its launch, three batches of colleges and universities have been approved to implement the Excellence Programme. In 2011, Northeast Petroleum University was approved among the second batch to implement the Ministry of Education Excellence Programme. The process equipment and control engineering major at Northeast Petroleum University was chosen as the pilot for the Excellence Programme. Three years of reform have been carried out under the *excellent engineers for the petroleum and petrochemical industries* programme, which has affected personnel training.

Before the reforms, students' design ability was poor; they were unable to integrate theory with practice, and had a poor facility for engineering drawing. In order to solve these problems, and in line with the outstanding engineers' training goal set in 2013, the process equipment and control engineering course dealing with oil equipment design was reformed, starting with the junior students in 2014. The new training focuses on the design of actual equipment. This enables students to understand typical equipment design and to apply theoretical knowledge to solving practical engineering problems.

To make the training more closely reflect actual engineering practice, senior engineers of the Oil Field Design Institute were engaged to guide the students. They delivered lectures, taught process equipment design, and organised visits to oilfields and petrochemical plants. So far, there have been three cohorts of students who have experienced the new regime, and the results are positive. As a result, students' employability has been improved, and they have won a number of awards in college innovation contests. Also, teachers have gained the title of *outstanding teacher*. Outlined in this article are the new *oil equipment design* course details, which play an important role in developing students' overall ability, including that in scientific research and innovation.

OIL EQUIPMENT DESIGN OBJECTIVES

Oil equipment design from the major, process equipment and control engineering, was selected for the excellent engineers pilot. It involves basic theory and knowledge, as well as being important in training students to solve practical problems. The training includes structural design, strength checks of typical equipment, and class diagrams.

STUDY TOPICS AND GROUPS

Typical equipment considered on the oil equipment design course includes the heat exchanger, tower equipment and the reactor. The process equipment and control engineering course has three classes, with a total of 90 people divided into 30 co-operative learning groups of three people each. The 30 groups tackle 30 design topics, i.e. 10 heat exchanger topics, 10 tower equipment, and 10 reactor topics. Each group has a different design problem and the groups are supported by six teachers, two for each device type. The training is scheduled over four weeks.

TRAINING CONTENT

Typical Equipment Design

In order to develop students' understanding of process flow diagrams and their production, each student must draw and document a process flow diagram. Then, they must complete the calculations for typical process equipment in the design. Once it is completed, specific content is introduced, for example benzene-toluene continuous rectification tower design.

Design parameters: in continuous sieve plate column atmospheric distillation separation of benzene, the toluene mixture of 41% benzene requires the tower overhead distillate containing toluene to be not greater than 4%, and the toluene content in the tower bottom to be not less than 96% (the above are mass fractions). The benzene, toluene mixture capacity is 6 ton per hour (t/h). The material state is bubble point material. The operating reflux ratio is 1.8 times the minimum reflux ratio. The tower overhead pressure is 4 KPa. The heat source is low pressure saturated steam. The veneer pressure drop is not greater than 0.7 KPa.

The design steps - process calculation: use the process parameters and the graphical method for a theoretical plate number N_T, as shown in Figure 1, where N_T = 12 - 1 = 11 (not including the tower bottom). The rectifying section has five pieces and the stripping section has six. Operating conditions for the tower are obtained and the structural design is completed.

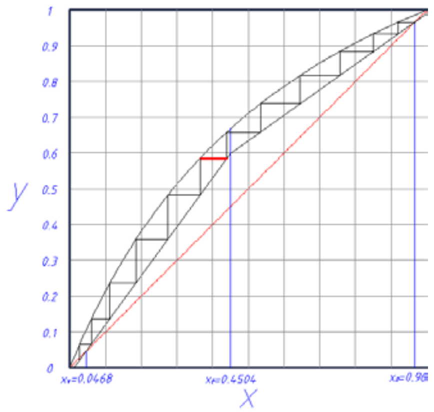


Figure 1: Graphical method - theoretical plate layers.

Equipment Structure Design

Students use relevant data and specifications to determine the type and size of various parts of the tower. After that, a check is made of the fluid mechanics on the tray, to obtain the plate load performance diagram, as shown in Figure 2.

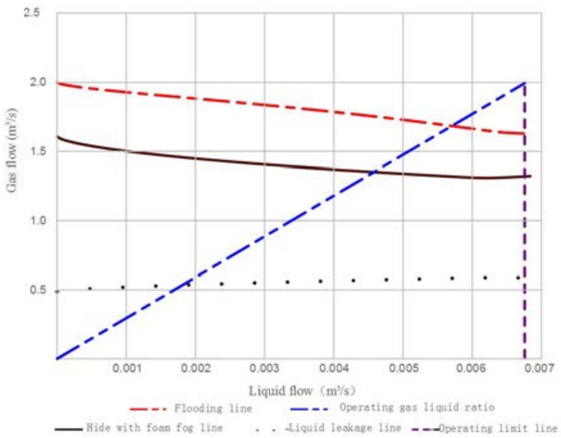


Figure 2: Load performance diagram for the rectifying section.

Equipment Strength Check

The design is checked for strength, the stiffness and the stability. An example is the dangerous section, shown in Figure 3 below. Then, students are expected to carry out the seismic moment, wind-bending moment calculations, for the 0-0 section, 1-1 section and 2-2 section.

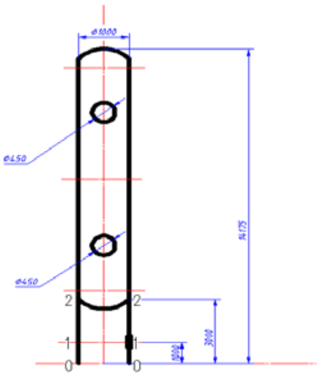


Figure 3: Dangerous sections.

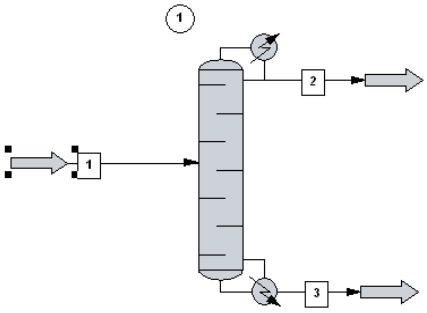


Figure 4: Calculation model - shortcut method.

The Calculation Manual

Through the calculation, structural design and strength checks, each student produces a design calculation manual.

APPLICATION OF CHEMICAL PROCESS SIMULATION SOFTWARE

The chemical process simulation system, CHEMCAD, was used to carry out the design and performance verification for the process parameters and the structural parameters of the tower. First, the distillation unit shortcut module was chosen, as shown in Figure 4 above, and the minimum theoretical plate number and relevant data calculated. Then, the CHEMCAD Strict calculation distillation simulation (SCDS) module was used to calculate the overhead and bottom components, so as to meet the given process condition. Relevant data are shown in Table 1 and Table 2.

Table 1: Strict calculation distillation simulation (SCDS) rigorous distillation summary 1.

Stream number	1	2	3
Temperature (℃)	100.6420	81.6614	109.1328
Pressure (MPa)	0.1040	0.1040	0.1040
Enthalpy (MJ/h)	5086.7	1720.2	1099.6
Vapour mole fraction	1.0000	0.00000	0.00000
Total (kmol/h)	69.9118	30.7032	39.2086
Total (kg/h)	6000.0000	2413.0434	3586.9562
Total streamed L (m^3/h)	6.8421	2.7300	4.1121
Total streamed V (m^3/h	1566.98	688.17	878.81
Benzene (%)	41.000000	95.999998	3.999999
Methylbenzene (%)	59.000003	4.000001	95.999998

Table 2: Strict calculation distillation simulation (SCDS) rigorous distillation summary 2.

Content	Value	Content	Value
Equipment number	1	Estimate temperature 2 (℃)	81.0538
Number of stages	15	Effectiveness top stage	0.8500
1st feed stage	8	Effectiveness last stage	0.8500
Condenser mode	12	Top pressure (MPa)	0.1040
Condenser specification	0.0400	Calculation condenser duty (MJ/h)	-4057.4653
Condenser composition i position	2	Calculation reboiler duty (MJ/h)	1790.5458
Reboiler mode	12	Initial flag	6
Reboiler specification	0.0400	Calculation reflux mole (kmol/h)	100.3687
Reboiler composition i	1	Tray efficiency profile	1
Estimate distillation rate (kmol/h)	29.6521	Calculation reflux ratio	3.2690
Estimate reflux rate (kmol/h)	104.2926	Calculation reflux mass (kg/h)	7888.2334
Estimate temperature top (℃)	81.0059	Optimisation flag	1
Estimate temperature bottom (℃)	109.1335	Calculation tolerance	9.9740e-005

The benzene mole fraction of 95.999998% for the tower overhead meets the requirement from Table 1, and the number of plates is 15. The 8 plate is the location of the adding materials plate by simulation from Table 2. Finally, in using the sensitivity analysis of the optimisation method, with the material plate position as independent variable, and the reboiler heat load and the return quality as the dependent variables, curves are obtained for the reboiler heat load, and change in return quality by material plate location, as shown in Figure 5 and Figure 6, respectively.

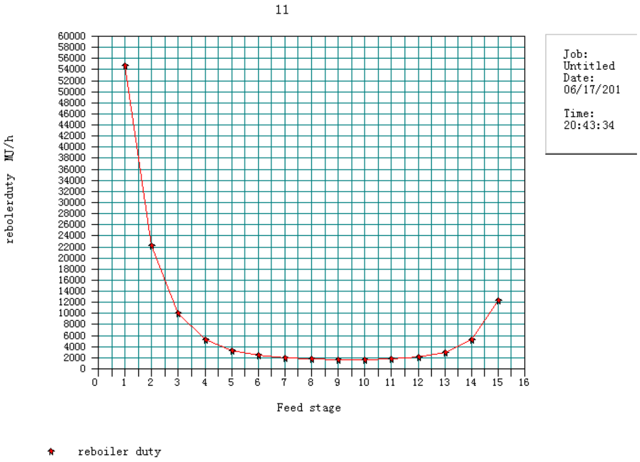


Figure 5: Curve of the reboiler heat load change with material plate location.

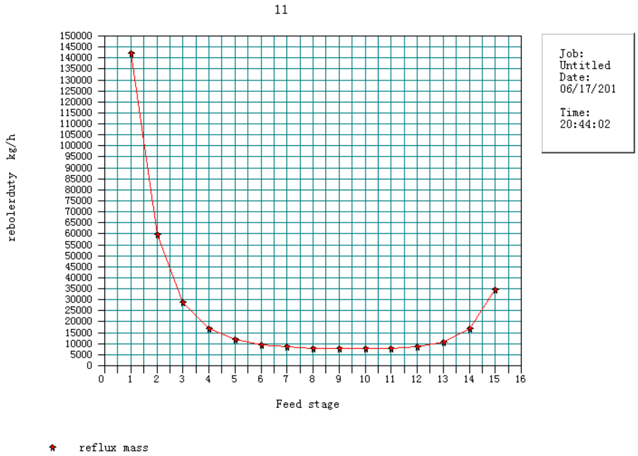
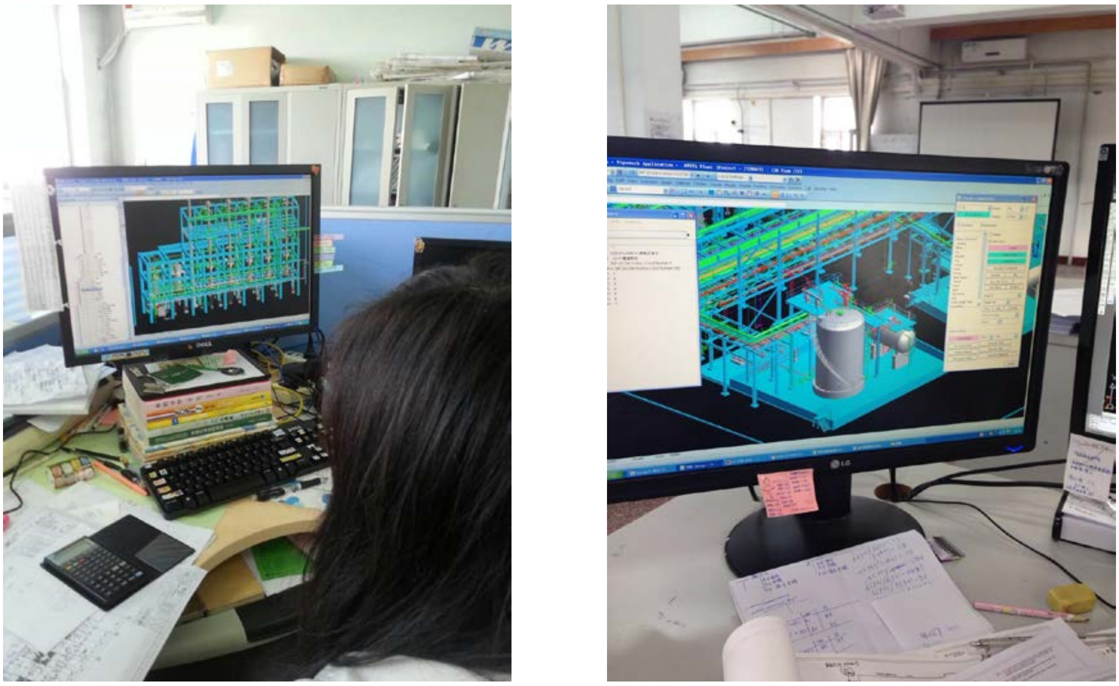


Figure 6: Curve of the return quality change with material plate location.

From Figure 5, at Plate 10, the reboiler heat load is least, and the heat load has only a small change from Plate 8 to Plate 11. From Figure 6, Plate 10 has the least return quality, while the return quality has only small changes from Plate 8 to Plate 11. The software simulation and the calculation differ slightly. The process is optimised by the software simulation to find the optimal material plates.

KNOWLEDGE LECTURES AND PRACTICE IN THE DESIGN INSTITUTE

Lectures to students on special topics were delivered by the senior engineer of Daqing Petrochemical Design Institute and Daqing Oilfield Company, to better integrate theory with practice. The lectures included the *Equipment and Piping Layout Project*; the *Pressure Vessel Design and Computer Aided Design Project*; the *Pressure Vessel and The Heat Exchanger Design Project*. The Design Institute was visited by students learning how to use the engineering software when designing chemical process equipment. The software was explained to the students by the design personnel. Figure 7 shows scenes from the visit.



a) b)

Figure 7: Visit and study at the Design Institute.

RESULTS AND DISCUSSION

Assessment has four components, viz. attendance accounts for 20%, chemical drawing 20%, process and equipment design 20%, and drawing 40%. Because it is group learning, students in a group will have similar results. Students in a group work and study together, which improves their team spirit.

The fifth session of the national college students' process equipment and innovation contest, leading to the award of *Outstanding Cup*, was held in 2014. Seven teams from the process equipment and control engineering major attended the competition. Students from the 2011 and 2012 cohorts participated and used the typical equipment design method and chemical process simulation software taught on the course. Ultimately, three groups won second prize, three groups won third prize, and two groups won an honourable mention. Two teachers won the outstanding instructor award. The first students who participated in this reformed teaching were the 2010 entry, who graduated in July 2014.

The employment rate for 2012, 2013 and 2014 graduates is shown in Table 3. It can be seen that the employment rate in 2014 is higher than that in 2012 or 2013.

Table 3: Employment rate for 2012, 2013 and 2014.

Year	Number of students	Employment rate %
2012	120	94.18
2013	88	93.56
2014	113	98.13

CONCLUSIONS

The 2010-2012 cohorts of students have received the revised training for oil equipment design. With four weeks of training, students learnt to design chemical process equipment, produce process flow diagrams, equipment assembly and other chemical drawings. In addition, they learnt to use chemical process simulation software, and learnt how to optimise a design, so as to reduce cost. This practice lays the foundation for the students to undertake petroleum and petrochemical design work, and is a good method for higher engineering education as evidenced by outcomes.

The authors are of the opinion that the reformed approach to training has contributed to students' success in securing suitable jobs.

ACKNOWLEDGEMENT

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