GAODENG XUEXIAO ZHUANYE JIAOCAI

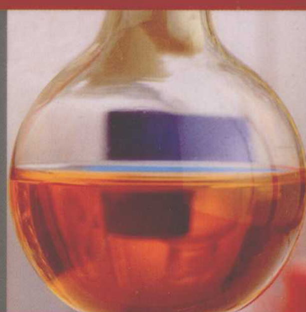
· 高等学校专业教材 ·

[高校教材]

化工设计简明双语教程

秦益民　编著

INTRODUCTION TO
CHEMICAL ENGINEERING DESIGN



中国轻工业出版社

高等学校专业教材

化工设计简明双语教程

Introduction to Chemical Engineering Design

秦益民　编著

中国轻工业出版社

图书在版编目(CIP)数据

化工设计简明双语教程 = Introduction to Chemical Engineering Design/秦益民编著. —北京:中国轻工业出版社,2010. 4

高等学校专业教材

ISBN 978-7-5019-7498-6

Ⅰ.①化… Ⅱ.①秦… Ⅲ.①化工过程－设计－双语教学－高等学校－教材 Ⅳ.①TQ02

中国版本图书馆 CIP 数据核字（2010）第 016316 号

责任编辑：涂润林

策划编辑：涂润林　　责任终审：劳国强　　封面设计：锋尚设计

版式设计：王超男　　责任校对：燕　杰　　责任监印：马金路

出版发行：中国轻工业出版社（北京东长安街 6 号，邮编：100740）

印　　刷：河北高碑店市德裕顺印刷有限责任公司

经　　销：各地新华书店

版　　次：2010 年 4 月第 1 版第 1 次印刷

开　　本：787 × 1092　1/16　　印张：10.25

字　　数：236 千字

书　　号：ISBN 978-7-5019-7498-6　　定价：20.00 元

邮购电话：010-65241695　传真：65128352

发行电话：010-85119835　85119793　传真：85113293

网　　址：http://www.chlip.com.cn

Email：club@chlip.com.cn

如发现图书残缺请直接与我社邮购联系调换

90184J1X101ZBW

前　　言

双语教学是通过用非母语的表达方式来解释和理解专业知识的概念、内容和思想的一种教学方式，其主要目的之一是培养学生熟练地用外语学习知识和思考问题，从“学外语”过渡到“用外语”。自2001年国家教育部颁发文件，明确要求高校在公共和专业课实行以汉语和英语为授课语言的双语教学开始，全国许多高校对双语教学进行了各种形式的尝试和实践，在培养学生使用外语、开阔学生的视野等方面起到了很好的成效。双语教学为学生提供了一个输出语言的机会，培养了学生用两种语言进行思维的能力。在双语教学中，学生开始把英语作为一种传播知识的媒介，而不是知识本身。从这一点上看，双语教学是学以致用的开始，对大学生综合素质的培养有着十分重要的作用。

双语教学的目的体现在知识目标、语言目标和思维目标上，即学生对学科知识的掌握、对英语的熟练应用、以及用英语的思维方式进行学习和思考。在双语教学的实施过程中，良好的教学效果受学生的英语水平、授课教师的综合素质、教学环境、办学设施、教材、课程设置、考试方式等因素的影响。在一系列制约双语教学质量的因素中，教材的质量尤为重要。目前国内高校普遍采用国外原版教材作为英文教材。在教学过程中发现，尽管这类教材内容丰富，但是作为本科教材，一些内容过于深奥，学生不易理解。另外，由于国情的不同，对于相同的专业知识，中文教材及英文教材中的一些内容差别比较大，容易使学生思想产生混淆，达不到很好的教学效果。

《化工设计》是一门综合应用性很强的专业基础课，是化工及相关类专业学生在掌握化工基础理论知识后，向工程技术领域转化的一个重要环节。它是对各门化工专业基础课程回顾和总结后，运用于工艺设计、工程设计的一门十分重要的应用课程，在化学、化工、材料、生化等技术领域的科研成果转化为现实生产力的过程中起到桥梁和纽带的作用。

为了在《化工设计》课程中开展双语教学，本书用英语介绍了化工设计中涉及的原理、规范、程序和方法，包括化工设计项目的可行性研究、厂址选择、工艺流程设计、物料衡算和能量衡算、化工设备的设计和选型、车间布置设计等设计内容，以及化工工艺设计中涉及的安全、环境及经济评价等问题。本书在编者多年从事《化工设计》课程双语教学的基础上，把国外及国内关于化工设计的主要内容进行了整合，从概念设计开始到项目的经济评价，用英语完整地介绍了化工设计中各个阶段的设计内容、原理及方法。本书结合了编者在国外高科技公司多年从事新产品开发的经验，在书中加入了新产品开发过程的内容，与化工新工艺设计的内容整合后，可以使学生更好地理解《化工设计》课程的主要内容。

本书在用英文编制完整的教材的同时，对书中涉及的有关化工设计的主要英语词汇及短语用中文标出，在方便学生掌握学科知识的同时，达到双语教学的知识目标、语言目标和思维目标，真正使英语成为教与学的工具。

本书适合化工、材料、日化、生物工程、环境治理等相关专业的双语教学，可供化工及相关行业从事生产、科研、产品开发的工程技术人员阅读、参考。

由于化工设计涉及的领域广泛，内容深邃，而编著者的学识有限，故疏漏之处在所难免，敬请读者批评指正。

编著者

2009 年 9 月

CONTENTS(目录)

1 An overview of chemical engineering design(化工设计概况)

1.1 Chemical engineering design

Chemical engineering design(化工设计) is concerned with the design of equipment(设备), process(工艺), system(系统) and plants(车间) in which raw materials(原料) are turned into valuable chemical products. It involves many important factors, such as the economics of chemical product development(化工产品开发), cost estimation in building a chemical plant, profitability analysis, process selection, materials of construction, process control, plant location and safety issues. In order to fully understand the principles of chemical engineering design, students need to be familiar with thermodynamics(热力学), heat, mass and momentum transfer, inorganic and organic chemistry, chemical kinetics(化学动力学), reactor design and many other related subjects.

Chemical engineers design processes based upon physical and chemical changes. The processes may yield marketable items, such as gasoline or penicillin(青霉素), or non-commercial items, such as clean air or clean water. The processes are created by integrating principles from basic sciences, traditionally chemistry, physics, and mathematics, with consideration of economics, environmental impact(环境影响), and employee safety.

1.2 Historical background of chemical engineering

The chemical engineering profession, barely 100 years old, began as an interface(界面) between chemistry and mechanical engineering. The principal goal in the early days of chemical engineering was to commercialize(商业化) chemical reactions(化学反应) developed at a chemist's laboratory. In 1983, a list of the top ten achievements of chemical engineering was compiled on the occasion of the seventy-fifth anniversary of the American Institute of Chemical Engineers(AIChE)(美国化学工程师学会), a national organization(全国性组织) with approximately 60,000 members. The AIChE used two criteria to form this list, first, the degree to which the achievement was an innovative(创新性的) and creative(创造性的) response to a societal need(社会需要), and second, the historical impact of the process. These ten achievements are summarized as follows:

(1) Synthetic rubber(合成橡胶): Elastic materials(弹性材料), such as automobile tires and

drive belts, are an integral part of everyday life. The annual production(年产量) of rubber in 1983 was twenty-two billion pounds. Remarkably, this industry was developed in only two years, just in time to replace shortages of natural rubber during World War II.

(2) Antibiotics(抗生素): In 1918 an influenza epidemic(流行性感冒) killed two million people worldwide, one-half million in the United States alone. Venereal diseases (性病) were incurable. Until the 1950s, polio(小儿麻痹症) crippled millions. Discovering medicines was only part of the solution. After it was observed that a mold(霉菌) inhibited bacterial growth in a petri dish, chemical engineers developed the technology to ultimately produce millions of pounds per year of penicillin. Chemical engineering made possible the mass production(大规模生产) of medicines and the subsequent availability to people worldwide.

(3) Polymers(高分子): Plastics, such as PVC, nylon, polyester, and polyethylene, are the predominant materials for consumer products. Plastics have replaced wood, metal, and glass in many applications because of their superior strength/weight ratio, chemical resistance, and mechanical properties.

(4) Synthetic fibers(合成纤维): Methods to produce fine threads of polymers allow us to rely less on exploiting plants and animals for clothing, carpets and fabrics.

(5) Cryogenic separation(低温分离) of air into O_2 and N_2. The present production is about 10^{12} cubic feet per year. N_2 is a key reagent for fertilizer and is used as a cryogen(冷冻剂). O_2 is used in medicine and metal processing.

(6) Separation of nuclear isotopes(同位素): Isotopically enriched uranium changed the world for better and for worse in 1945. Nuclear energy(核能) continues to be a viable supplement to fossil fuels(有机燃料). Medical research, diagnostics, and treatments require isotopically enriched elements.

(7) Catalytic cracking(催化裂解) of crude oil: Crude oil was once distilled into light and heavy fractions (kerosene, gasoline, lubicating oil); the range of oil products was limited by the physical mixture of the raw material. Catalytic cracking systematically decomposes(分解) oil molecules into molecular building blocks that may be used to construct complex chemicals. The ability to make high octane(辛烷) fuel was a crucial factor in the Battle of Britain and World War II.

(8) Pollution control(污染控制): Chemical engineers can work to design processes with minimal offending by-products(副产品) and devise strategies(设计策略) to restore polluted sites.

(9) Fertilizers(化肥): New fertilizers have improved agricultural productivity and helped to feed the world.

(10) Biomedical engineering(生物医学工程): Chemical engineering principles(化工原理) have been used to model the processes of the human body as well as to develop artificial organs (人造器官), such as the kidney, heart and lungs.

The contribution of chemical engineers influenced the evolution of modern society. Most of the top ten achievements listed above came during the heyday of engineering, when it seemed that society's needs could be met by technology, with engineers being the purveyors(供应商) of technology. Around the mid 1950s, however, technology came to be perceived as dangerous by people in the industrialized countries. People began to feel that society and the environment were dominated by technology, even victimized by technology. This perception(看法) remains today.

1.3 Contemporary chemical engineering

Contemporary(当代的) chemical engineers are increasingly involved in services(服务), compared to the historical emphasis on manufacturing(制造). This trend will probably continue as chemical engineers are enlisted to remedy environmental contamination(环境污染) and modify existing processes to meet modern business and manufacturing agendas. Some frontier areas of chemical engineering include:

Production of novel materials(特种材料的生产): Chemical engineers will design processes to produce ceramic parts for engines, high temperature super conductors, polymer composites(复合物) for structural components, and speciality chemicals produced in small amounts to exacting specifications(规格). Chemical processes will shift from the traditional area of petrochemicals to inorganic compounds, from liquids to solids, and from large scale to small scale.

Biotechnology(生物技术): Chemical engineers will improve methods of isolating bioproducts, design processes for chemical production from biomass, and capitalize on advances in genetic engineering(基因工程) to produce drugs, foods, and materials. Whereas chemical engineering has traditionally sought new reaction paths to produce established chemical commodities, biotechnology will seek ways to produce new chemicals, such as secondary metabolites and so-called fancy proteins. Whereas chemical processes are typically continuous(连续性的), where reactants constantly enter and products constantly leave, bioprocesses tend to be batch operations(间歇式操作). Finally, whereas traditional chemical processes(传统的化工工艺), such as petrochemicals, tolerate rough separation, bioproducts(生物制品) will require more rigorous isolation.

Solid wastes(固体废物): Chemical engineers will invent methods to treat landfills as well as to remedy contaminated sites. Chemical engineers will also design alternatives for waste, such as incineration(焚烧), biological decomposition(生物降解), and recycling(回收). Whereas the reactants entering traditional chemical processes are well characterized and invariable from day to day, processing wastes requires designs that accept reactants with ill-defined composition that may change daily.

Pollution control(污染控制): Chemical engineers will continue to reduce pollution at its sources, for example, by recycling intermediate(中间体) outputs, redesigning chemical reactors, and reengineering entire processes. Gone are the days when a public waterway was designated "for industrial use". Waste water today sometimes exceeds the purity of the public water way it enters. Chemical engineers will design processes that not only meet current regulations(法规) but anticipate future regulations. Chemical engineers will aspire to the ultimate goal of "zero emission"

(零排放).

Energy: Chemical engineers will continue to improve the efficiency of present energy sources as well as develop new sources.

Process control(工艺控制): Chemical engineers will develop and implement better sensor for temperature, pressure, and chemical composition. Processes will be designed to integrate artificial intelligence(人工智能) for process control, monitoring and safety.

1.4 Ethics of chemical engineering design

As more and more emphasis is placed on safety and environmental protection, chemical engineers need to apply an increasingly higher standard to the design of their plants, both technically(技术上) and ethically(道义上). In 1954, the National Society of Professional Engineers(NSPE) in the United States adopted the following statement, known as the Engineers' Creed(工程师信条):

As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare.

I pledge:

To give the utmost performance;

To participate in none but honest enterprise;

To live and work according to the laws of man and the highest standards of professional conduct;

To place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations;

In humility and with need for Divine Guidance, I make this pledge.

The above statement is to do with ethics(道德), also called moral philosophy, which is derived from the Greek ethika, meaning character. Ethics deals with standards of conduct or morals. This conduct of behavior has obligations to (1) self, (2) employer and/or client, (3) colleagues and co-workers, (4) public, and (5) environment. The following is the Code of Ethics(道德规范) adopted by the American Institute of Chemical Engineers(AIChE):

Members of the American Institute of Chemical Engineers shall uphold and advance the integrity(完整性), honor(荣誉), and dignity(尊严) of the engineering profession by: being honest and impartial(公正的) and serving with fidelity(忠实) their employers, their clients, and the public; striving to increase the competence(能力) and prestige(影响力) of the engineering profession; and using their knowledge and skill for the enhancement of human welfare. To achieve these goals, members shall:

(1) Hold paramount the safety, health, and welfare of the public in performance of their professional duties.

(2) Formally advise their employers or clients (and consider further disclosure, if warranted) if they perceive that a consequence of their duties will adversely affect the present or future

health or safety of their colleagues or the public.

(3) Accept responsibility for their actions and recognize the contributions of others; seek critical review of their work and offer objective criticism of the work of others.

(4) Issue statements and present information only in an objective and truthful manner.

(5) Act in professional matters for each employer or client as faithful agents or trustees, and avoid conflicts of interest.

(6) Treat fairly all colleagues and co-workers, recognizing their unique contributions and capabilities.

(7) Perform professional services only in areas of their competence.

(8) Build their professional reputations on the merits of their services.

(9) Continue their professional development throughout their careers, and provide opportunities for the professional development of those under their supervision.

1.5 Outline of the present book

The design of a chemical engineering process(化工工艺) is a complex activity involving many different disciplines(学科) over a considerable period of time. The design may also go through many stages from the original research and development phases, through conceptual design(概念设计), detailed process design(工艺设计) and onto detailed engineering design(工程设计) and equipment selection. Many varied and complex factors including safety, health, the environment, economic and technical issues may have to be considered before the design is finalized.

At each stage it is important that the personnel involved have the correct combination of technical competencies and experience in order to ensure that all aspects of the design process are adequately addressed. The process design will often be an iterative process(迭代过程) with many different options being investigated and tested before a process is selected. In many occasions a number of different options may be available and final selection may depend upon a range of factors. Detailed mechanical, structural, civil and electrical design of equipment comes after the initial process design which covers the steps from the initial selection of the process to be used, through to the issuing of process flow sheets(工艺流程图). Such flowsheets will include the selection, specification and chemical engineering design of the equipment.

In addition to meeting various technical requirements, a chemical engineering design project(化工设计项目) should also take account of the relevant codes and standards(规范和标准). In this respect, modern engineering codes and standards cover a wide range of areas including material properties and compositions, testing procedures, design methods and inspection, codes of practice for plant operation and safety, etc. During the design process, it is important to ensure that consideration has been given to the appropriate standards and codes of practice developed by legislators(立法者), regulators(监督者), professional institutions and trade associations. For any equipment that is installed, it is also important to ensure that the operating procedures, testing regimes and maintenance strategies meet or exceed these requirements in terms of safety performance.

This book focuses on the key aspects of chemical engineering design. As an introductionary course in the teaching of chemical engineering design, this book describes the critical areas of chemical engineering design including site selection(厂址选择), process flow sheet design, mass and energy balances, equipment selection(设备选型), plant layout(车间布置), safety and environmental protection issues. In addition, students can learn the design processes used in multinational companies for managing product and process development.

In short, this is a concise textbook which can be useful as a course material in bilingual teaching courses(双语教学课程) for chemical engineering design.

2 An introduction to chemical product development(化工产品开发简介)

2.1 Product development in the chemical industry

Since chemical processes(化工工艺) are designed and developed to produce chemical products (化工产品), process design(工艺设计) and product design(产品设计) are closely related. In a market economy, product development is about developing technical solutions(技术答案) to meet market needs(市场需求). In the chemical industry(化工行业), market needs vary widely from petrochemicals(石化产品), food additives(食品添加剂), synthetic fibers(合成纤维), to pharmaceuticals(药品), cosmetics(化妆品) and many others. Once a product is developed, it is then necessary to produce it on a commercial scale, and chemical engineers are required to design the plant to convert the relevant raw materials into the product with defined specifications(规格). In this sense, chemical process design is a part of the overall product design process.

In a modern market economy(市场经济), product development is critical to a company's long term success. More and more emphases are now placed on developing novel and innovative products that can effectively suit customer needs. In order to understand the nature of product development, it would be useful to have an overall understanding of the industry(行业) where typically five principal types of players are involved.

Buyers(买方): For product development to be successful, a product must satisfy the needs of the potential buyers. For a company developing chemical products, whether large scale commodity chemicals(大宗化学品) or small scale fine chemicals(精细化学品), the product must have defined characteristics as would be required by its downstream users.

Suppliers(供应商): In order to fulfill its business functions, a chemical company needs many types of suppliers. Apart from the usual business suppliers such as accountancy firms and legal firms, the main suppliers to chemical companies are raw material and technical service(技术服务) providers. Research contractors are another type of suppliers in addition to the suppliers for components and equipments.

Industry rivals(行业竞争者): The nature of market economy means that in any industry, there are many firms making the same or similar products. These rivals compete with each other on the quality and price of their products. For a company to have competitive advantage(竞争优势) over its rivals, it needs to develop cutting edge technologies and manufacturing capability(制造能力) so that its products can have superior performances manufactured at a low cost.

Substitutes(替代品): Many chemicals have similar properties and they can be used in a similar way for the same end uses. These so-called substitute products compete with each other on quality and prices.

New entrants(新进入者): In any industry that is highly profitable, more investment would be attracted because of the high return on investment(投资回报). Chemical companies therefore should prevent new entrants to enter into their business area by creating barrier to entry, such as by patent protection(专利保护) or by developing novel manufacturing technologies.

In addition to the above five types of players, industrial regulators are becoming increasingly important in many industries. Without regulatory approval, many chemical products cannot be legally sold in almost any part of the world. Industrial regulators develop product standards(产品标准) and environmental and safety rules that company must comply with. Since chemical products cannot be legally sold without a regulatory approval, the regulators are a powerful force in the chemical industry.

2.2 Product development process

Figure 2.1 shows the product value chain(价值链) from the beginning of the product development process when an idea is formed, to the point when customers can use the product. All novel products begin with an idea to serve a particular customer needs. The product development process then goes through research, development, manufacturing, marketing, sales and customer services.

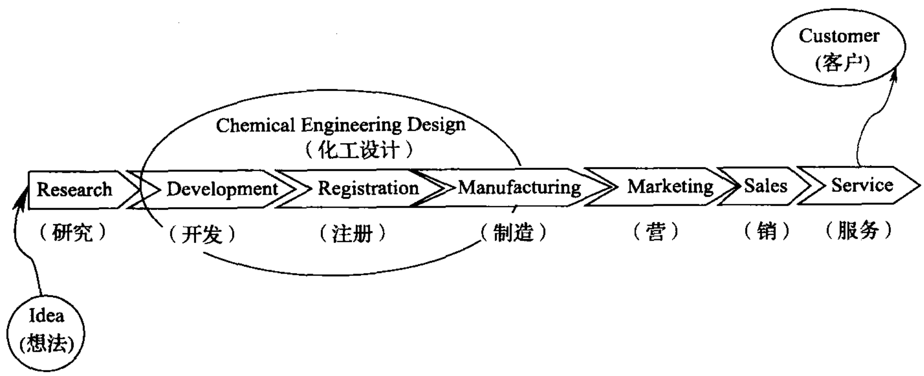


Figure 2.1 The product value chain

It should be pointed out that due to its uncertain nature, product development is often a risky venture. On average, for every 100 projects that go into development, 63 get killed before the final stage, 12 become commercial failure and only 25 become commercial successes. Therefore, during the development of chemical products, the need to develop a truly innovative product should always be balanced with the costs associated with failures at the later stages of the development cycle. A staged new product development (NPD, 新产品开发) process with go/kill points is a useful way to offer the formal review for controlling design inputs and outputs. These could be in the form of a five stage NPD process. In each of the stages, objectives can be set and pass/fail criteria can be defined. A documented stage review(阶段评审) should be held after every stage of the development work. A project may proceed or terminate by the results of each stage review.

By applying strict reviews at the end of each stage, the staged NPD process ensures that only the truly successful project can proceed to the full scale manufacturing, by which time, a large amount of capital(资本) should have been invested.

In the staged NPD process, the product development process can be divided into the following five stages:

(1) Concept formation(概念的形成)

(2) Initial exploration(初步探索)

(3) Development(开发)

(4) Product realization(产品实现)

(5) Product launch(产品上市)

Various issues are addressed during each stage. A project manager(项目经理) is responsible for ensuring that at the end of each stage, reviews are held at appropriate times with appropriate personnel. The outcome of these reviews should be a decision to either abandon, put on hold, or progress the project. If the project is to be progressed then a plan is set for the next stage. This plan must detail the major tasks to be completed, target timescale, and allocate responsibility for completion to an appropriate individual.

In all the stages of a design and development project, input is required from a number of relevant departments within the company, i. e., representatives of corporate management, finance, sales and marketing, design, development, quality control/assurance, regulatory affairs and manufacturing. The designated project manager ensures that appropriate consultation is maintained within the company at all times and establishes interfaces with customers or external advisers as required.

The concept formation stage aims to assess the validity(正确性) of a new product development concept. The following issues are considered:

- target market(目标市场)
- relevant standards/regulations(相关的标准和法规)
- relevant patents(相关的专利)
- competitive products(竞争产品)
- manufacturing process(制造工艺)

The initial exploration stage explores a product or process concept in order to assess its commercial potential. The areas considered include:

- product or process definition