Planned Textbooks of Higher Education for Eleventh Five-year Plan

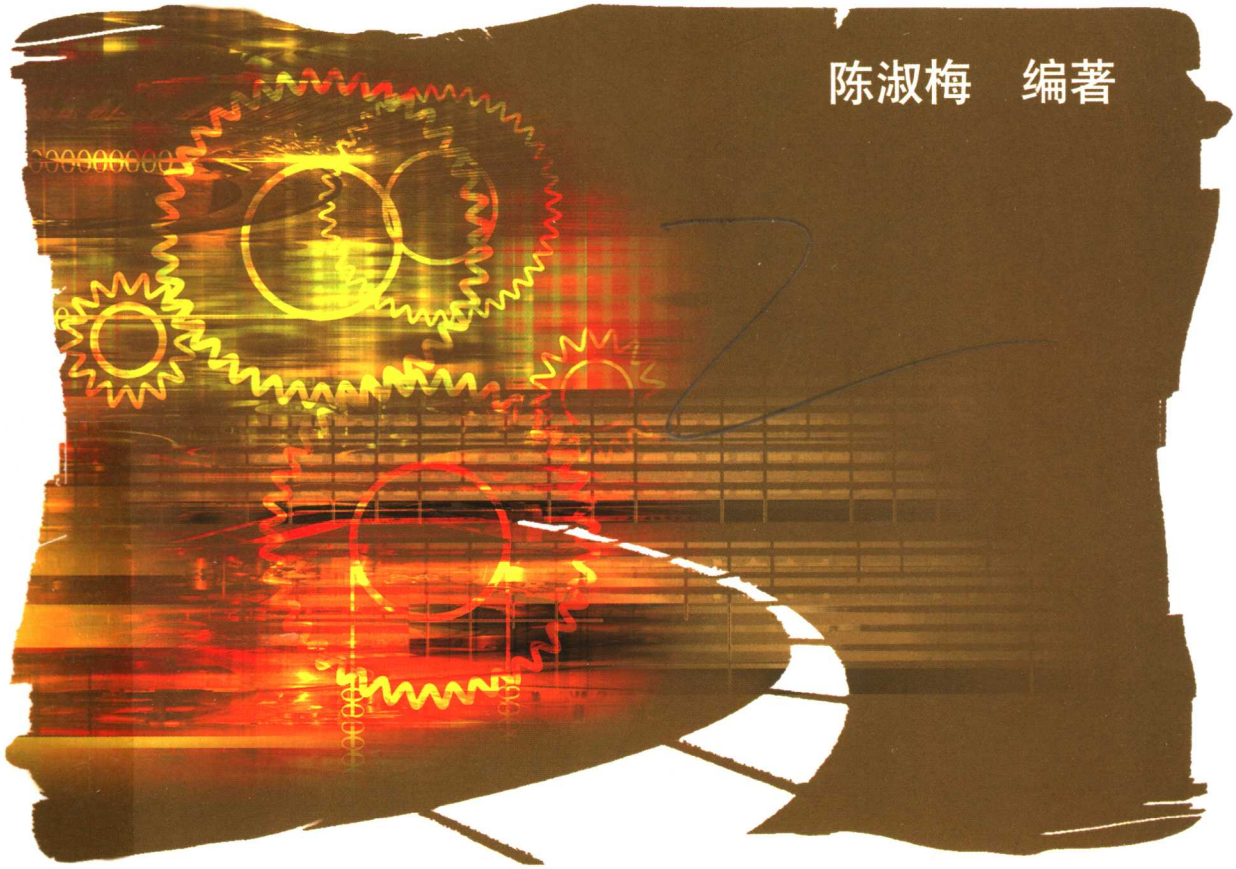
普通高等教育“十一五”规划教材

Hydraulic and Pneumatic Transmission

(English-Chinese Bilingual)

液压与气压传动

（英汉双语）



陈淑梅　编著

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本书为普通高等教育“十一五”规划教材，分为两篇（Part one and Part Two）共12章。1～9章为液压传动，10～12章为气压传动。与同类型教材相比不同点在于：全书采用英汉双语形式编写与排版，可作为高等院校机械设计制造及自动化、机械电子工程（机电一体化）、车辆工程、冶金、水利工程、材料成形及控制工程、模具设计与制造、轻工机械等机械工程类专业的英汉双语教材。

同时配套有英汉双语多媒体（CAI）电子教案（教师版）和各章节的练习题（英文版），可供教师在课堂授课和学生做课外练习题时与本教材配套使用。

本书还附有部分液压与气压传动专业词汇（英汉双语），供学生在自学本教材时更快地查阅并掌握专业英语术语。同时本教材也可以作为机械工程类研究生的专业英语辅助教材或阅读材料。

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Preface

Mechanical engineering and automation technology are advancing rapidly in our country. Therefore it is imperative to cultivate highly qualified application-oriented talents to meet the current needs, which requires new development in the higher education.

For filling in the widening gap between social needs and status quo of higher education, the Auditing and Editing Committee for "Planned Textbooks of Higher Education for 'Eleventh Five-year Plan'" is set up by the Machinery Electronics Committee, which subordinates to the China Machinery Education Association, and the China Machine Press, which aims to publish a series of practical textbooks based on the principle of "attaching more importance to basic theories and engineering application rather than the process of deduction". The main features of the series are:

(1) Scientific objective. The series is targeted for training all-round application-oriented talents and distinguished from other high-school teaching materials. It has high technicality emphasizing on engineering application and innovation.

(2) Selective categories. The series includes mechanics, hydraulic and pneumatic transmission, cartography, design, numerical control, practical training, materials, bilingual teaching, etc. tank are available for teachers to choose from.

(3) Multimedia teaching. Each volume of the series has related courseware and accessorial books and a discussion room on the Internet.

The China Machine Press, one of the earliest large-scale publishing houses and high-education textbooks bases, is a prestigious authority in publishing books in mechanical and electrical engineering. With concerted efforts from all circles this series of books will contribute greatly to bringing up high-qualified engineers for our country.

Peigen Li,
Academician
Director of the Machinery Electronics Teaching Committee
China Machinery Education Association
Huazhong University of Science and Technology

序

为了适应我国机械工程及自动化专业迅速发展的需要，培养大批素质高、应用能力与实践能力强的应用综合型人才已成为当务之急。这同时对高等教育的办学理念、体制、模式、机制和人才培养等方面提出了全新的要求。

为了打通新形势下高等教育和社会需求之间的瓶颈，中国机械工业教育协会机电类学科教学委员会和机械工业出版社联合成立了“普通高等教育‘十一五’规划教材”编审委员会，本着“重基本理论、基本概念，淡化过程推导，突出工程应用”的原则，组织教材编写工作，并力求使本套教材突出以下特点：

（1）定位科学。本套教材主要面向应用的综合型人才的培养。既不同于培养研究型人才的教材，也不同于一般应用型本科的教材；在保持高学术水准的基础上，突出工程应用，强调创新思维。

（2）品种齐全。这套教材设有“力学”、“液压与气压传动”、“制图”、“设计”、“数控”、“实训”、“材料”、“双语”等模块，方便学校选用。

（3）立体化程度高。每本教材均要求配备 CAI 课件和相关的教辅材料，并在网站上为本套教材开设研讨专栏。

机械工业出版社是我国成立最早、规模最大的科技出版社之一，是国家级优秀出版社，是国家高等教育的教材出版基地之一，在机电类教材出版领域具有很高的地位。相信这套教材在中国机械工业教育协会机电类学科委员会和机械工业出版社的精心组织下，通过全国几十所学校老师的仔细、认真的编写，一定能够为我国高等教育应用综合型人才的培养提供更好用、更适用的教材。

教育部机械工程及自动化专业分教学指导委员会主任
中国机械工业教育协会高等学校机械工程及自动化学科教学委员会主任
李培根院士
于华中科技大学

Foreword

Motivation of this book. The higher education in China is now entering a new era of reform which encourages bilingual teaching in foundation courses, technical foundation courses and specialist courses. The main objective of the reform is to promote the internationalization of higher education and to cultivate application-oriented talents with creativity and quality education. Bilingual teaching is thus becoming one of the ways to link our higher education to the world-facing various challenges of the new century and assure high-quality and comprehensive elitists. The reform in bilingual teaching is a strategic choice for our higher education in the 21st century. This book thus intends to provide a solid base for bilingual teaching and to meet the immediate needs of our higher education reform for interfacing with the world.

Arrangement of the material. This book was written following the *Basic Requirements in Teaching Descriptive Hydraulic and Pneumatic Course developed* by the Mechanical Engineering Advisory Committee for Higher Engineering Education. It is introduced based on the current practice and demands of education reform in teaching power engineering. It targets at fostering application-oriented talents for the 21st century. The development of the book is guided by advanced mechanical engineering techniques. It is focused on learning centered activities and aims at quality education. The contents of the book cover selected topics simplified and extracted for a wide range of readers. The book was written based on the characteristics of foundation courses. It inherits the essence of a traditional course content and integrates extensive teaching experience of the authors in the past years. It focuses on the presebt education needs in fostering talents with comprehensive quality education and creative thinking. This book exhibits following characteristics:

(1) Bilingual. The bilingual edition represents the achievements of higher education reform in teaching and curriculum development for the 21st century. It emphasizes on the training of application-oriented talents in the international context and quality education in basic engineering subjects.

(2) Multimedia teaching. The accompanied CAI multimedia with case-based teaching materials, which animats and covers the complete contents of this book published simultaneously. Various powerful softwares have been used to make the videos which demonstrate the dynamic, static and continuous actions. For example, pressure characteristics of hydraulic oil display clearly the

oil flowing through the inner configuration of elements and system circuits, which represent clearly the operating principle of elements and flowing dynamic experience for system circuits. Therefore the two main features "pressure" and "motion" transmissions in hydraulic/pneumatic transmission system are represented visually. The large number of engineering models, animations, various function of multimedia, and intuitive presentation of live examples with visual virtual software effects are used to stimulate students studying interests, which will result in better efficacy.

(3) English exercises. This book has been prepared to provide students and users with well-connected English-Chinese bilingual exercises. It will enable students to think and solve problems in the English context. It covers various simple and complex questions that are suited for a wide range of students and enables students to grip professional vocabulary, ensuring students of international application on the subject of hydraulic and pneumatic transmission.

(4) Proving a re-edited CAI version. The electric CAI multimedia version prepared using Powerpoint is an open course material with a large benefit that it could be easily modified (insert, cancel and revision) by teachers to meet the needs of their own teaching.

Editors for this book. The editor of this book is Professor Shu Mei Chen from Fuzhou University, Fujian province of China. The participants are: Xiaoqin Xu, Xiaomei Chen, Kunquan Yang, Yuangui Chen and Tianyan Chen. This book is audited by Professor Ning Qin from University of Sheffield, Great Britain and by Professor Xinzhang Lin from College of Mechanical Engineering of Fuzhou University, China. The authors would sincerely appreciate and like specially to thank them for providing a thorough review and giving many invaluable suggestions. In addition, multimedia videos are also accomplished by Lichao Tian, Lingwei Wang, Xiaoteng Tang and Qiaodan Xu.

Readership of this book. Hydraulic and pneumatic transmission is one of the key technical foundation courses with wide application fields, such as mechanical design and manufacture, engineering machines, mining, metallurgy, light industry machines and so on. The authors thus feel that this book is suitable as a bilingual teaching material for mechanical engineering students such as mechatronics engineering, material fabricating molding and control engineering, mould design and manufacture, aerospace engineering, shipping machines and light industry. At the same time, it could be reading and supplementary materials for graduate students who are interested in the subject in the later years of their course of study. However a certain amount of background knowledge of mathematics and applied mechanics is required.

Acknowledgments. The book was written with the reference to some excellent books and teaching materials as shown in the section of references. The authors highly appreciate, especially Associate Professors Fuling Xu and Yaoming Chen of Huazhong University of Science and Technology and Professor Jianmin Zuo from Nanjing Institute of Technology. Thanks go to China machine press, college of mechanical engineering and educational administration of Fuzhou Vniversity. Thanks also go to many others who helped in the course of the publication of this book. Special support from Fuzhou University through Teaching Material Development Funds and Fujian province of China, Outstanding Courses Construction Funds are all gratefully acknowledged.

In addition, it is unavoidable that this book may still contain mistakes. All critics and corrections from experts and readers are welcome.

The authors
At Fuzhou University

前言

当前，我国的高等教育进入了新一轮的改革阶段：大力开展基础课、专业基础课和专业课的双语教学，加速推进我国高等教育的国际化和培养大批素质高、应用能力与实践能力强的应用综合型人才。因此，双语教学是我国高等教育与国际接轨的重要途径之一，是培养大批素质高、应用能力与实践能力强的应用综合型人才的有力保证；是迎接新世纪挑战和教育改革发展的必然趋势，也是中国高等教育在21世纪必须作出的战略选择。

本教材是依照高等学校工科“液压与气压传动”教学指导委员会制订的课程教学基本要求，结合近年来本课程的教学改革特点，围绕培养面向21世纪的素质高、应用能力与实践能力强的应用综合型人才进行编写的。它将面向现代机械工程技术，并紧紧围绕以“学”为中心、以“素质提高”为目的的指导思想，力求简明扼要、质量上乘、覆盖面广。另一方面，本教材将针对专业基础课程的特点，继承传统内容的精华，融入编者多年积累的教学经验，着眼于新时期对人才培养的要求，以加强对学生综合素质及创新能力的培养为出发点。本教材具有如下特点：

（1）突出英汉双语的特色。本教材采用英汉对照编排形式，体现高等教育面向21世纪教学内容和课程体系改革的成果，立足于国际接轨的综合型人才培养的特点，重视基本工程素质教育。

（2）多媒体教学。与本教材配套的多媒体CAI电子教案光盘与本书同时出版，更加增强了本教材的感观效果。该CAI课件覆盖教材的全部内容，运用各种软件的功能，灵活地将视频的动态、间断和连续动作等表现手法进行有机结合，结合了液/气压传动系统回路压力的变化特性，将液压油（流体介质）在各种液压元件及各种控制回路中的流动形式可视化地描述，从而剖析了各种液压元件的结构特征和工作原理以及各种复杂液压回路的实现过程。这种采用大量反映实物模型的动画演示可激发学生的学习兴趣，将会取得较好的教学效果。

（3）英语练习题。练习题以英文形式出现，进一步培养学生在专业英语环境下进行本课程的思考与练习。练习题型博采众长，由浅入深，覆盖面宽，难度适宜，兼顾典型性和通用性，为培养学生掌握液压与气压传动专业英语词汇，进一步从事国际化的液压与气压传动设计的能力培养打下基础。

（4）配套的CAI课件可编辑性强。该课件采用较易掌握的Powerpoint工具软件编制，为开放式课件。其最大的好处是：可由任课教师根据课程需要及教学习惯，方便地自行增加、删减或重组有关内容，或按自己的风格和特色进行改编，以满足个性化教学的要求。

本书由福州大学机械工程及自动化学院陈淑梅教授编著，参编者有：许晓勤、陈小梅、杨坤全、陈元贵和陈天炎。全书由英国设菲尔德（Sheffield）

大学机械工程系覃宁教授和福州大学机械工程及自动化学院林信彰教授审核，编者对两位专家、教授所给予的大力支持和提出的宝贵建议深表感谢。另外参加本教材多媒体动画制作的还有田立超、王玲玮、唐晓腾，许乔丹。

液压与气压传动课程是机械工程的一门专业基础主干课程，具有很强的工程应用背景（如机械设计与制造、工程机械、矿山机械、冶金机械和轻工机械等）。本书可作为高等院校机械设计制造及自动化、机械电子工程（机电一体化）、车辆工程、材料成形及控制工程、模具设计与制造、轻工机械等机械工程类专业的英汉双语教材，同时也可以作为机械工程类研究生的专业英语辅助教材或阅读材料，具有广泛的适用面。学习者在学习本教材之前需要掌握一定的高等数学和应用流体力学的基础知识。

在本书的编写过程中我们参考和引用了国内外优秀的同类参考书籍，详见本教材的参考文献。在此特别对华中科技大学许福玲和陈尧明副教授、左健民教授以及其他所有参考书籍的作者表示衷心的感谢。在本教材的编写过程中还得到机械工业出版社、福州大学机械工程及自动化学院和教务处等有关部门的大力支持，并得到福州大学教材建设基金和福建省精品课程建设基金的资助，在此表示由衷的感谢；同时对所有关心和帮助本书出版的各界人士表示真诚的谢意！

由于编者水平有限，书中难免有错误和疏漏，敬请各位专家及广大读者批评指正。

编者

于福州大学

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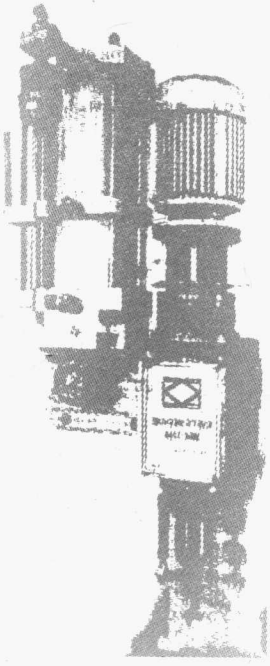
Part One

Hydraulic Transmission



Chapter 1 Introduction to Hydraulic and Pneumatic Transmission

1.1 Study on Hydraulic and Pneumatic Transmission

Hydraulic and pneumatic transmissions are a discipline that is based on fluid medium energy of compressive fluid (pressure oil or compressive air) to accomplish mechanical transmission and automatic control. Hydraulic and pneumatic transmissions are similar in operating principle and control means. Special sub-circuits built by various hydraulic (or pneumatic) components are used to build up particular hydraulic/pneumatic transmission systems to realize energy transfer and control. Having a sound grip of knowledge in physical performances and static/dynamic characters of fluid, operating principle and construct several hydraulic element and sub-circuit and hydraulic/pneumatic system designs are the best way to study power (hydraulic/pneumatic) transmission and control technology.

1.2 Operating Principles of Hydraulic Transmission

There is an important physics law, i. e., the Pascal's law in the hydraulic pressure. In the seventeenth century (1620), Blaise Pascal, a French physicist formulated the fundamental law on which modern hydraulics is based. Pascal's law states "pressure exerted on a confined liquid is transmitted undiminished in all directions and acts with equal force on all equal areas".

Operating principle (such as hydraulic jack) is shown in the Fig. 1-1.

In Fig. 1-1, the jack contains a hand-operated pump, which draws oil from a reservoir. When one pulls up the lever 2, the small piston is moved up, the volume enlarges and becomes vacuum in the volume below in the small actuator 1 and non-return valve 7 is shut. Oil in the reservoir 6 is pumped past a non-return valve 8 into the bottom of the linear actuator under atmospheric pressure. When you apply force to the lever and press down the lever, it compresses the oil in the small actuator, which increases the oil force. Here, non-return valve 8 is shut; the oil in the bottom small actuator is pumped past a non-return valve 7 into the bottom of the big linear actuator 4; the oil flowing into the actuator forces the big piston to move heavy load. By pulling up and pushing down the lever alternately the heavy load 3 will be moved up continuously. If lever is stopped working, the non-return valve 7 will be shut and the big piston together with heavy load will be locked on the position of moving up. If the check valve 5 is opened, the oil on the bottom of big piston will flow back into the reservoir, which makes the big piston move down to its original position under deadweight.

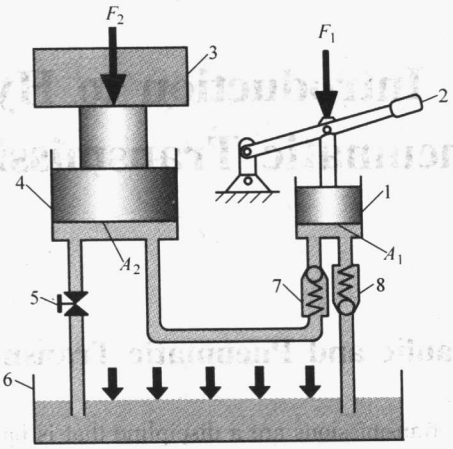


Fig. 1-1 Operating principle of hydraulic jack（液压千斤顶工作原理图）

1-Small actuator（小液压缸） 2-lever（杠杆） 3-Heavy load（重物）

4-Big actuator（大液压缸） 5-Check valve（截止阀） 6-Reservoir（油箱）

7，8-Non-return valve（单向阀）

From this operating principle of a hydraulic jack, it has been stated that the processing of drawing oil into and out from small actuator 1 is performed by the small actuator 1, non-return valves 7 and 8, which is transforming mechanical energy to hydraulic pressure energy, and this setup is called hand-operated hydraulic pump. The big piston and actuator 4 called lifting hydraulic actuator is transforming the hydraulic pressure energy to mechanical energy and moving up the heavy load. Both small and big hydraulic actuators constitute the simplest hydraulic transmission system, which accomplishs the two transmissions: power transmission and motion transfer.

To accomplish the power transmission and motion transfer, there are two properties of oils that constitute the basic elements of hydraulics. The first property is that oils are nearly incompressible. The second oil may be used to multiply forces.

1. Power transmission

Let's note the piston area of actuator as A_2, the total thrust on it as F_2, ($\uparrow$) then the hydraulic pressure in the actuator p_2,

$$p_2 = \frac{F_2}{A_2} \tag{1-1}$$

According to Pascal's law, here that is $p_1 = p_2 = p$, the oil displacement pressure is called the hydraulic system pressure.

It is important here to overcome the heavy load for moving the actuator, and taking the thrust on the small piston of pump as F_1,

$$F_1 = pA_1 = p_1A_1 = p_2A_1 = (\frac{A_1}{A_2})F_2 \tag{1-2}$$

where A_1 is the piston area of pump (small actuator).

The heavier the load is, the higher the hydraulic pressure is needed under a given A_1 and A_2, which illuminates the close relationship between the hydraulic system and outside load. Thus the