普通高等教育“十二五”规划教材

Electric Machinery

电机学（英汉双语）

◎ 刘慧娟　范瑜　主编

机械工业出版社
CHINA MACHINE PRESS

普通高等教育“十二五”规划教材

Electric Machinery

电 机 学

（英汉双语）

刘慧娟 范 瑜 主编

机 械 工 业 出 版 社

本书共分两大部分，第一部分为电机学的英文部分，第二部分为相应的中文部分，两部分内容基本一致。每部分包括6章：第0章为绪论；后面5章包括直流电机、变压器、交流电机的共同理论、感应电机和同步电机。在直流电机与感应电机两章中添加了电动机的机械特性、电动机的起动、制动和调速等“电力拖动”的内容。为加强学生对相关知识点的理解，各章中配有相应的例题；为便于学生学习，每一章后附有本章内容小结和相应数量的习题。

本书可作为普通高等院校电气工程及其自动化专业和其他电气类、自动化类等专业双语教学的教材，亦可供相关专业技术人员参考。

图书在版编目（CIP）数据

电机学 = Electric machinery：汉英对照/刘慧娟，范瑜主编．—北京：机械工业出版社，2014.4

普通高等教育“十二五”规划教材

ISBN 978-7-111-45221-8

Ⅰ.①电… Ⅱ.①刘… ②范… Ⅲ.①电机学—双语教学—高等学校—教材—汉、英 Ⅳ.①TM3

中国版本图书馆CIP数据核字（2013）第307205号

机械工业出版社（北京市百万庄大街22号 邮政编码100037）

策划编辑：王雅新 责任编辑：王雅新 王 琪

版式设计：常天培 责任校对：杜雨霏

封面设计：张 静 责任印制：李 洋

北京市四季青双青印刷厂印刷

2014年4月第1版第1次印刷

184mm×260mm · 22.75印张 · 576千字

标准书号：ISBN 978-7-111-45221-8

定价：45.00元

凡购本书，如有缺页、倒页、脱页，由本社发行部调换

电话服务 网络服务

社服务中心：(010)88361066 教材网：http://www.cmpedu.com

销售一部：(010)68326294 机工官网：http://www.cmpbook.com

销售二部：(010)88379649 机工官博：http://weibo.com/cmp1952

读者购书热线：(010)88379203 封面无防伪标均为盗版

前　言

随着世界经济一体化的不断发展，我国与世界经济、科技、文化的合作和交流日渐频繁，国际化的经济与科技环境对我国专业技术人员的国际化水平提出了更高的要求，特别是专业英语的交流应用能力。

近年来，国家教育部陆续颁发了一系列高等教育教学改革文件，要求推动双语教学课程建设，切实提高大学生的专业英语水平和使用英语从事科研的能力，并将双语教学列为高等院校教育质量评估中的一项重要指标。可见，培养既掌握专业知识又掌握专业外语的高素质复合型人才是目前中国高等教育发展的重要目标之一。

本书的主编在与美国、中国香港多所大学多年的合作研究与交流中，深切体会到专业英语的直接交流会极大地帮助我们发挥自身的科研潜能，增强科研竞争能力。同时，在北京交通大学的多年教学中，也发现国内本科生和研究生的专业英语的交流应用能力亟待提高。因此，坚持专业基础课程的双语教学，必将对提高我国专业技术人员的英语交流应用能力起到积极的推动作用。

本书是编者在总结多年电机学课程双语教学工作经验的基础上，结合电气工程及其自动化专业和电气类其他专业的电机学教学大纲，对多本英文原版电机学教材的教学内容和表述方法进行梳理、调整和更新，以适应21世纪我国教学改革的需要而编写的。

本书是高等院校电气工程及其自动化专业和其他电气类、自动化类等专业的主干课“电机学”双语教学的教材，内容涉及本学科一些最基本的理论和分析方法，是“电机学”和“电力拖动基础”两门课程主要内容的有机结合。

本书共分两大部分，第一部分为电机学的英文部分，第二部分为相应的中文部分，两部分内容基本一致。

本教材的主要特点是：

1）以直流电机、变压器、感应电机和同步电机4种典型通用电机为研究对象，着重讲解其工作原理和稳态运行特性，以及各类电机的共同性问题，突出本专业本科教学应掌握的基本概念、基本理论和基本分析方法，提高学生解决工程实际问题的能力。

2）本书在讲述电机理论的基础上，加入了交、直流电动机的电力拖动内容，为学习后续课程和解决今后遇到的工程问题打下了相应的基础。

3）将“磁路”等电机分析的基础知识放在绪论中，供读者学习参考。

4）本书的每一章之后都有本章小结和相应的习题，以帮助读者加强对本章内容的理解和掌握。

5）各章的内容具有相对独立性，可根据实际需要和学时决定取舍，各章的次序在具体讲授时也可以改变。

本书的编写方针是结合国情、博采众长、削枝强干、推陈出新，目标是编写一本取材精、科学性强、概念清、便于教学的简明电机学双语教学教材。

本书的英文部分由美国俄亥俄州立大学 Longya Xu 教授和香港理工大学的傅为农博士主审，中文部分由哈尔滨理工大学汤蕴璆教授主审。全书由北京交通大学范瑜教授、刘慧娟副教授、刘瑞芳副教授、张威老师、郭芳老师和桂俊峰老师共同编写。刘慧娟、范瑜担任主编，全书内容由刘慧娟统稿和策划。具体分工为：范瑜编写中英文绪论；刘慧娟编写中英文的第 1 章；桂俊峰编写中英文的第 2 章，张威编写中英文的第 3 章；刘瑞芳编写中英文的第 4 章；郭芳编写中英文的第 5 章。Longya Xu 教授、傅为农博士与汤蕴璆教授对全书做了非常仔细的审阅，并提出了许多宝贵的修改意见和建议，在此表示衷心的感谢！

本书的编写得到了北京交通大学电气学院领导的关怀和支持，得到了各位同仁的热心帮助，在此一并表示谢意。

由于编者水平有限，编写时间仓促，书中难免有不妥和错漏之处，恳请读者提出宝贵意见，以便在再版中修正。

编　者

CONTENTS

中文部分

Chapter 0 Introduction

0.1 The role of electrical machines in our lives

Electrical energy is the most widely used secondary energy and it is suitable for mass production, centralized management, long-distance transmission, flexible allocation and automatic control. Electrical machines are mechanical energy conversion machineries associated with production, transformation, distribution, utilization and the control of electrical energy; it plays an important role in various areas of the national economy.

1. Electrical machines are the main equipment in the production, transmission and distribution of electrical energy

In power plants, the rotation of rotors in generators is driven by steam turbines, hydraulic turbines, diesel or other power machineries. Rotors are used to convert mechanical energy, which has been converted from primary energies (fuel combustion heat, the potential energy of the water, the nuclear fission of atomic energy, wind energy, solar energy and tidal energy, etc) to electrical energy. Since the generator plays a critical role in the production of electricity, it is the most important electrical equipment in the power systems. In general, power plants are far away from load centers; therefore, high-voltage transmission is adopted in order to transmit power to remote places economically. Voltage of generators ranges from 10.5kV to 20kV and the typical transmission voltages are 110kV, 220kV, 330kV, 500 kV or higher. So step-up transformers are needed to increase the generator voltages before transmission. In China, the common values of high transmission voltage are 110kV, 220kV and 500kV. It can even go up to 1000kV. When electricity power reaches the load center, for the safety reason, various step-down transformers are needed to reduce the transmission voltages. The total capacity of transformers required by the power system usually is 7 to 8 times of the total capacity of the power generation equipment. Therefore, generators and transformers are the main electrical equipment in power plants and substations in the electric power industry.

2. Electrical machines are the motive equipment of the production machines and equipment

Various types of electrical machines are widely used in industry, agriculture, transportation and everyday life to drive production machines and equipment. In the machinery industry, for example, workhorses are driven and controlled by one or more electrical motors of different capacities. Grinder motors have a rotational speed of several tens of thousands per minute or even higher. Some machine tools need multi-speed motors. In the metallurgy industry, blast furnaces, converters and open-hearth-furnaces need more than one motor to drive. A large rolling mill may need a 5000 kW DC motor or even higher powered motors for proper functioning. Almost all machines in the world need a variety of AC and DC motors to be prime movers today. Machines can be used for different purposes

such as power irrigation, sideline products processing in agriculture, blowers, crane, transportation and transfer in enterprises, mining and more transport equipments, urban rail transport, Maglev, high speed train traction, electric vehicles, papermaking machinery, medical equipment, as well as household appliances.

3. Electrical machines are an important element in the automatic control systems

With the development of science and technology, the level of automation in industry, agriculture and national defense facilities has continued to rise. Various control motors are used as detectors, amplifiers and solver components. Such motors are usually with small power, wide variety of output and high precision. Artillery and radar automatic positioning, satellite launch and flight control, the ship rudder automatic control, automatic control of the machining, the operation control of the computer, automatic recording instruments monitoring all depend on various control motors. Therefore precision control motors of different capacities are important elements in the whole automatic control systems.

An electrical machine is an electromechanical energy conversion device. When it is used to convert mechanical energy to electrical energy, it is called a generator. When it is used to convert electrical energy to mechanical energy, it is called a motor. Since all electrical machines can convert one type of energy to another, they can be either generators or motors.

In an electrical machine, there are magnetic circuits and electrical circuits that produce induction electromotive force and torque according to the electromagnetic induction law and the law of electromagnetic force to achieve electromechanical energy conversion.

0.2 Types of electrical machines

Electrical machines can be classified into four types according to their functions.

1) Generator: a device that can convert mechanical energy to electrical energy.

2) Motor: a device that can convert electrical energy to mechanical energy.

3) Transformer, phase shifter, frequency machine, variable flow machine: devices that can convert electrical energy to other forms of electrical energy, namely voltage, phase, frequency, and current of electrical power.

4) Control motor: part of the automatic control systems. It is used to generate and transmit signals. It can also be used as a servo element.

Depending on the type of applied current, rotating electrical machines can be divided into two types: DC machines and AC machines. AC machines can be further divided into three types: synchronous machines, induction machines (also called asynchronous machines) and AC commutator machines.

0.3 Materials used in internal structure of electrical machines

Materials used in electrical machines can be classified into the following four categories.

1) Electrically conductive materials: They are used in the electrical circuit system of the elec-

trical machines. In order to reduce line losses, conductive materials of small resistivity are used. The most commonly used materials are copper and aluminum.

2) Magnetically permeable (ferromagnetic) materials: They are used in the magnetic circuit system of the electrical machines. In order to produce a strong magnetic field and reduce the iron losses, the magnetically permeable materials should have a high magnetic permeability and low iron loss coefficient. Silicon steel is commonly used in AC magnetic circuit while steel plate and cast steel are used in DC magnetic circuit.

3) Insulating materials: They are used as the isolation bodies between conductors and iron cores. High dielectric strength and high heat-resistant strength are essential qualities of the materials. Insulating materials of electrical machines are divided into five insulation grades: A, E, B, F, and H. Their maximum working temperatures are 105℃, 120℃, 130℃, 155℃, 180℃ respectively.

4) Structural materials: They are used to support and connect all members of the machine. Materials with good mechanical strength, and light weight and easy to process are used, which are commonly cast steel, cast iron, steel, aluminum and engineering plastics.

0.4 Magnetic circuits

0.4.1 Magnetic fields

Magnetic fields are the fundamental mechanism by which energy is converted from one form to another in all electrical machines.

There are four basic principles to describe how magnetic fields are used in electrical machines:

1) A current-carrying wire can produce a magnetic field in the area around it.

2) A time-changing magnetic field can induce an *Induction Electromotive Force* (emf) in a coil of wire when it passes through the coil. (Transformers are based on this principle.)

3) A current-carrying wire experiences an induced force in the presence of magnetic field. (Motors are based on this principle.)

4) A moving wire experiences an *Induced Electromotive Force* (emf) in the presence of magnetic field. (Generators are based on this principle.)

Some specific quantities are used to describe magnetic fields, such as flux density $\boldsymbol{B}$ [Tesla, T], magnetic field intensity $\boldsymbol{H}$ [Ampere per meter, A/m], magnetic flux $\boldsymbol{\Phi}$ [Weber, Wb], magnetomotive force (mmf) $\boldsymbol{F}$ [Ampere turn, A], magnetic reluctance R_m [Ampere-turns per Weber, A/Wb, H^{-1}], magnetic conductance (permeance) Λ_m [Henry, H], and magnetic flux linkage Ψ [Weber-turn].

1. Specific quantities used in magnetic fields

(1) Flux density $\boldsymbol{B}$ [Tesla, T]

A current-carrying wire can produce a magnetic field in the area around it, and the flux density is used to describe the strength and the direction of the magnetic fields.

(2) Magnetic field intensity $\boldsymbol{H}$ [Ampere per meter, A/m]