



21世纪高等学校机械设计制造及其自动化专业系列教材

# 机电设计方法概论

(双语版)

Introductory Mechanical Design Tools

William Singhose 著  
Jeff Donnell

胡友民 译



华中科技大学出版社

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中国·武汉

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# 21 世纪高等学校 机械设计制造及其自动化专业系列教材

## 总 序

“中心藏之，何日忘之”，在新中国成立 60 周年之际，时隔“21 世纪高等学校机械设计制造及其自动化专业系列教材”出版 9 年之后，再次为此系列教材写序时，《诗经》中的这两句诗又一次涌上心头，衷心感谢作者们的辛勤写作，感谢多年来读者对这套系列教材的支持与信任，感谢为这套系列教材出版与完善作过努力的所有朋友们。

追思世纪交替之际，华中科技大学出版社在众多院士和专家的支持与指导下，根据 1998 年教育部颁布的新的普通高等学校专业目录，紧密结合“机械类专业人才培养方案体系改革的研究与实践”和“工程制图与机械基础系列课程教学内容和课程体系改革研究与实践”两个重大教学改革成果，约请全国 20 多所院校数十位长期从事教学和教学改革工作的教师，经多年辛勤劳动编写了“21 世纪高等学校机械设计制造及其自动化专业系列教材”。这套系列教材共出版了 20 多本，涵盖了机械设计制造及其自动化专业的所有主要专业基础课程和部分专业方向选修课程，是一套改革力度比较大的教材，集中反映了华中科技大学和国内众多兄弟院校在改革机械工程类人才培养模式和课程内容体系方面所取得的成果。

这套系列教材出版发行 9 年来，已被全国数百所院校采用，受到了教师 and 学生的广泛欢迎。目前，已有 13 本列入普通高等教育“十一五”国家级规划教材，多本获国家级、省部级奖励。其中的一些教材（如《机械控制基础》、《机电传动控制》、《机械制造技术基础》等）已成为同类教材的佼佼者。更难得的是，“21 世纪高等学校机械设计制造及其自动化专业系列教材”也已成为一个著名的丛书品牌。9 年前为这套教材作序的时候，我希望这套教材能加强各兄弟院校在教学改革方面的交流与合作，对机

机械工程类专业人才培养质量的提高起到积极的促进作用,现在看来,这一目标很好地达到了,让人倍感欣慰。

李白讲得十分正确:“人非尧舜,谁能尽善?”我始终认为,金无足赤,人无完人,文无完文,书无完书。尽管这套系列教材取得了可喜的成绩,但毫无疑问,这套书中,某本书中,这样或那样的错误、不妥、疏漏与不足,必然会存在。何况形势总在不断地发展,更需要进一步来完善,与时俱进,奋发前进。较之9年前,机械工程学科有了很大的变化和发展,为了满足当前机械工程类专业人才培养的需要,华中科技大学出版社在教育部高等学校机械学科教学指导委员会的指导下,对这套系列教材进行了全面修订,并在原基础上进一步拓展,在全国范围内约请了一大批知名专家,力争组织最好的作者队伍,有计划地更新和丰富“21世纪机械设计制造及其自动化专业系列教材”。此次修订可谓非常必要,十分及时,修订工作也极为认真。

“得时后代超前代,识路前贤励后贤。”这套系列教材能取得今天的成绩,是众多机械工程教育工作者和出版工作者共同努力的结果。我深信,对于这次计划进行修订的教材,编写者一定能在继承已出版教材优点的基础上,结合高等教育的深入推进与本门课程的教学发展形势,广泛听取使用者的意见与建议,将教材凝练为精品;对于这次新拓展的教材,编写者也一定能吸收和发展同类教材的优点,结合自身的特色,写成高质量的教材,以适应“提高教育质量”这一要求。是的,我一贯认为我们的事业是集体的,我们深信由前贤、后贤一定能一起将我们的事业推向新的高度!

尽管这套系列教材正开始全面的修订,但真理不会穷尽,认识决无终结,进步没有止境。“嚶其鸣矣,求其友声”,我们衷心希望同行专家和读者继续不吝赐教,及时批评指正。

是为之序。

中国科学院院士

fan

2009.9.9

# Translator's Preface

To cultivate the students' creative thinking and practical ability is the important goal of engineering education. Since there is few appropriate textbook for the theoretical and practical teaching of engineering design approaches, this book is a tutorial textbook translated and edited for the course, *Innovative Mechatronic Design Methods and Tools*. The course, *Creative Decisions and Designs*, in Georgia Tech has adopted the English edition of this book, which met with a favorable reception, as the prescribed book for the engineering students. This book mainly introduces a series of fundamental and practical design tools to engineering design novice, aiming to help them grasp the basic design methods and tools rather than some professional knowledge. Besides, it is also designed to help students to build the ability of creative thinking, teamwork and technical communication ability, providing a foothold for learners to further their professional knowledge as well as specializing in industry research and development. Featured with all-round content, simplified expression, this book is easy to understand, and therefore can be used for classroom teaching and self-study. Undoubtedly, it is a good introductory book for engineering design and tools.

The author Dr. William Singhose, who graduated from Massachusetts Institute of Technology, is the associate professor of mechanical engineering department of Georgia Tech. He has been working on the research of dynamics and control of flexible structures for several years, and has made a series of achievements. Besides, Dr. Singhose's research also focuses on the engineering education approaches. The course, *Creative Decisions and Designs*, run by Dr. Singhose in Georgia Tech, is very popular among students and is admitted as one of the most influential courses in the industry. In 2011, Dr. Singhose came to the SMSE (School of Mechanical Science and Engineering) of HUST (Huazhong University of Science and Technology), and carried out the in-depth communication with faculties over the creative engineering and education problems. He will come to HUST again to teach the course, *Innovative Mechatronic Design Methods and Tools* in 2012. We are indebted to Dr. Singhose's dedication of providing the

copyright of this book freely. We, thereby, are permitted to publish the Chinese version of this book to help Chinese teachers and students to bring forth the innovative engineering education.

The translation and publishing of this book have been supported by the High-quality Textbook Publication Foundation of HUST. Cheng Yao engaged in the translation of this book, while Wang Xiaochen also took part in the proofreading of some manuscripts of the translation. Meanwhile, HUSTP(Huazhong University of Science and Technology Press) offered gracious assistance for the publication of this book. Thus, we would like to express our heartfelt thanks for all of them!

Owing to the limitation of the translators, there must be mistakes and errors in the book. It is hoped that readers will kindly point out our errors, we are obliged with your valuable comments.

**Hu Youmin**



# 译者序

培养工科学生创新思维与动手能力是工程教育的重要目标。在工程设计方法理论与实践教学活动中一直以来都缺少一本合适的教材,为此我们组织翻译了本书,将其作为“机电创新设计方法与工具”课程的试用教材。本书英文版多年来一直作为美国佐治亚理工学院工程类学生“创新决策与设计”课程的教材,受到使用者的广泛好评。本书主要介绍了一系列基本实用设计工具以帮助初学工程设计的人员学习基本的设计方法和设计工具而不是某些专业知识,旨在培养学生创新思维、团队合作和技术交流能力,为学习者以后继续学习专业知识或从事专业研究与开发打下必要的基础。本书内容全面,讲述深入浅出,便于理解,可用于课堂教学与自学,是很好的工程设计方法与工具入门教材。

本书作者 William Singhose 博士毕业于麻省理工学院,现为美国佐治亚理工学院机械工程系副教授。Singhose 博士多年来一直从事柔性机械的动力学与控制方面的研究,并取得一系列的成果。除研究工作之外, Singhose 博士还致力于工程教育方法研究,近年来他主持的“创新决策与设计”课程是该校工程类课程中最受学生欢迎和在业界最有影响力的课程之一。Singhose 博士曾于 2011 年来到华中科技大学机械学院与该院师生就工程创新与教育问题进行过深入交流。2012 年,他将再次来到华中科技大学,亲自为该校本科学生讲授“机电创新设计方法与工具”课程。Singhose 博士应我们的要求决定出版本书中译本,以帮助中国教师和学生更好开展工程创新教育,并无偿提供了版权,对此我们表示衷心的感谢。

本书的翻译和出版得到了华中科技大学精品教材出版基金的资助。程瑶参与了本书的翻译工作,王小岑参与校对部分译稿。本书的出版得到了华中科技大学出版社的大力协助。在此向他们致以诚挚的谢意!

由于译者的水平有限,书中错误在所难免,敬请读者指正,译者在此先致感谢之意。

胡友民

# Acknowledgements

This book was developed for the introductory mechanical design course at Georgia Tech. The course, *Creative Decisions and Designs*, requires beginning engineering students to work in teams to design and build a computer-controlled machine. Such a bold objective requires the course to provide the students with machine tools, computer controllers, actuators, sensors, pneumatics, and numerous miscellaneous supplies. These items require a substantial investment that is beyond the reach of most courses. We were very fortunate over the years to obtain sponsorship from numerous individuals and companies that shared our vision for such a demanding and rewarding course. Their support has made this book, this course, and this outstanding educational experience possible.

# 致 谢

本书是为佐治亚理工大学的机电设计方法概论课程编写的。“创新决策与设计”这门课程需要刚接触工程类的学生以团队合作的形式设计和构建一台由计算机控制的机器。要实现如此大胆的目标是需要有一门课向学生提供机床、计算机控制器、制动器、传感器、充气轮胎,以及大量其他各种设备的。此项目需要大量的经费,其数目是超过大多数课程的。这些年,我们非常幸运地获得了许多个人和公司的资助,他们和我们一样,对这门要求高、效果好的课程非常看好。他们的支持使得这本书的出版、这门课的教学以及这些杰出教育经验的传授成为可能。

# Preface

When students take their first course in engineering design, they must adjust to an unusual educational experience. Most engineering students were the best in their class in high school. They take pride in working on their own to achieve the correct answer, which they place neatly at the end of their calculations in a nice square box. However, most design courses require students to work on problems that do not have a single, best answer. Design problems have a limitless number of good, satisfactory, and poor solutions. The idea of seeking a good solution, rather than the best solution can be very frustrating for top students.

Furthermore, design requires teamwork. So, the straight-A students must acclimate to conditions where their grade depends, at least in part, on the work of other students. This is a scary situation for many good students. They can respond to this challenge by trying to do all the work themselves, without coordinating with their teammates. Or, each team member may assume control over one subsystem and work tirelessly to make their part the best. This can lead to a fractured, disconnected design that does not function well on the whole.

Even if the team works well together, it is pointless to create a good design if the functions, components, and performance cannot be conveyed to other people. No successful company will pay to develop or produce a product that they do not fully understand. Therefore, technical communication is an essential component of design. It not only helps to convey the final design, but it is also important throughout the design process at team meetings and design reviews.

This book provides a set of simple tools to aid novice designers. The tools address elementary design, teamwork, and technical communication. Chapter 1 provides a very brief introduction to design that discusses the phases and qualities of design. Chapter 2 provides methods for understanding a design problem. This, of course, focuses on understanding the customer needs. Chapter 3 introduces function trees and functional decomposition so that students can think clearly about

the necessary functions and catalog them in a graphical format. Chapter 4 discusses specification sheets that list specific performance targets for a design. These design criteria will, of course, evolve and change throughout the design process as the problem and its possible solutions are better understood. Chapter 5 addresses conceptual design generation and evaluation. Chapter 6 presents some general safety guidelines. Techniques for detailed design of products are not covered in this book.

To aid in the teamwork aspect of design, Chapter 7 provides management and planning tools. Chapter 8 addresses team optimization, communication, and evaluation. Chapter 9 discusses the use of images in technical communication. Chapter 10 provides tools for generating technical reports. Chapter 11 describes the processes for documenting sources. Chapter 12 addresses details of presentations, with special attention to computer-based presentations. Appendices give sample technical reports and details on the mechanics of technical communication.

# 前 言

当学生们第一次聆听工程设计这门课时,他们将要准备适应一段不同寻常的教育历程。大多数工程类学生在高中时都是他们班里最优秀的学生。他们以依靠自己的力量解出正确的答案而自豪,他们常常把正确答案干净整洁地展示在计算的末尾。然而,大多数设计课程都不需要学生致力于得出唯一的、最佳的答案,设计问题有无限的解决方案,好的、满意的和差的,可谓五花八门。寻找好的解决方案而不是最佳的解决方案,这个理念可能会让成绩优秀的学生感到沮丧。

此外,设计需要团队合作。那么,全优学生必须适应这一规则:他们的成绩,至少是一部分成绩将取决于组内其他学生的工作。对于成绩优秀的学生,这可能会引起他们的不安。应对这一挑战,他们可能选择不与其他成员合作,独自完成整个小组的全部工作。或者,每个小组成员负责一个子系统,他们将付出不懈的努力以使各自的部分做得最好。但这样会产生一个断裂的、不连贯的设计,总的来说,系统不会运行得很好。

即使团队合作得很好,但如果不能把设计的功能、元件和性能很好地向别人展示,这是没有意义的。一个成功的公司不会在他们没有完全理解产品的情况下着手投资开发或生产一个产品。因此,技术沟通是设计中一个必要的环节。它不仅帮助我们将最后的设计成品向别人展示,而且对整个设计过程中的小组、设计评价都是十分重要的。

本书介绍了一系列简单工具以帮助初学设计者。这些工具强调初步设计、团队合作和技术交流。第1章对有关设计步骤及品质进行了简单介绍。第2章列出了理解设计问题的方法,当然,其重点在于了解客户需求。第3章介绍功能树和功能分解,以使学生能清楚地思考产品的必要功能,且能在一个图形格式里将其编成目录。第4章介绍列出了具体性能目标的产品设计说明书。随着在设计过程中对问题及其可能的解决方法的更好理解,这些设计标准也会随之改进和完善。第5章着重介绍概念设计的生成和评价。第6章列出了一些普遍的安全方针。产品的细节



设计技术在本书中不做讨论。

为了在设计团队合作方面给予帮助,第7章提供管理和规划工具。第8章讲述队伍优化、沟通和评价。第9章讨论在技术交流中图像的使用。第10章提供生成技术报告的工具。第11章讲述记录来源的过程。第12章对报告的细节,特别是基于计算机报告的细节予以着重介绍。附录列出了技术报告样例和机械技术交流的细节。



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