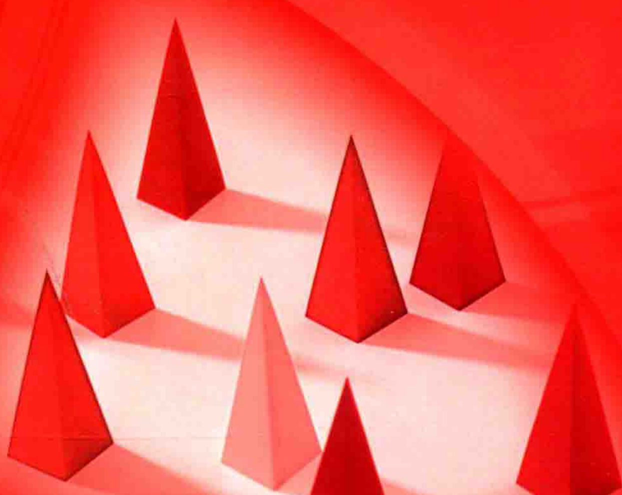
工业和信息化部“十二五”规划教材

Fundamental of Geometric Tolerance and Measurement Technology

几何量公差与测量技术基础(英文版)

张彦富　付求涯　王阿春　丛家慧　编著
徐文骥　曹国强　主审



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Abstract

This book is to meet the requirements of bilingual teaching and English teaching for foreign students of the course "interchangeability and technology measurement".

Contents include the basic terms and definitions, indication on drawing and application of limits and fits, geometrical tolerance, surface roughness. Also include rolling bearing, key and spline, screw thread, gear and other typical link together and selection, dimension chain and measuring technology foundation and inspection of plain workpiece dimension, etc.

In this book, the basic knowledge of geometric tolerance and measurement technology are systematically introduced, and the concept explain clearly, the difficulty contents are analyzed deeply. Appropriate amount questions and exercises are given after the chapter to deepen our understanding of the content and application of knowledge.

This book can be used as textbook or teaching reference book for bilingual teaching or English teaching which major is mechanical engineering or instrumentation in college, also as learning reference book to study fundamental of geometric tolerance and measurement technology for engineering and technical personnel whose major is mechanical design, manufacturing technology, standardization and metrology.

内容简介

本书是为了满足"互换性与技术测量"课程的双语教学和在我国就读的留学生英文授课的需要而编写。

内容包括极限与配合、几何公差(旧标准称为形状和位置公差)、表面粗糙度等的基本术语和定义、图样标注和选用等基础内容、滚动轴承、键和花键、螺纹、圆柱齿轮等典型连结的公差与配合及其选用、尺寸链以及测量技术基础和光滑工件尺寸检验等。

本书系统地介绍了几何量公差与测量技术的基础知识,概念阐述清楚,难点分析深入。各章均配置了适量的思考题和习题以使学生加深对所学内容的理解和应用。

本书可作为高等学校机械和仪表类各专业双语教学或全英文授课的教材或教学参考书,也可供需要掌握几何量公差与测试技术基础知识及应用的机械设计、制造工艺、标准化和计量测试工作的工程技术人员学习参考。

Foreword

The Interchangeability and Measurement technology is an important fundamental course to the students majored in mechanics, aircraft manufacturing and instrument engineering. The purpose of publishing this book is to meet the needs of bilingual education for Chinese students, more importantly, to meet the needs of international students education for foreign students studying in China.

This book is intended to introduce the national and international standardization and to harmonize the practices and methodology with the universal standards trend toward more efficient worldwide technical communication. Coordinating and integrating these techniques into and via computer graphics and other electronic data systems for design, manufacture, verification, and similar processes is also a prime objective.

This book may serve as an introduction to geometrical dimensioning and tolerance for students, and may also help practitioners in the fields of design, manufacturing and inspection. This book provides an instructional framework with which to expand graphics concepts into advanced undergraduate or graduate courses. It focus on variation enhances a student's ability to create an interpretable and producible product definition.

The book is composed of eleven majorchapters. They are: Introduction, Limits and fits, Fundamentals of Geometrical Quantity Measurement, Geometrical Tolerance, Surface roughness, Measurement of Plain Workpieces, Tolerances and fits of rolling bearings, Tolerances and measurement of cylinder screw, Tolerances and fits of Keys and Spline, Accuracy Design of Cylindrical Involute Gear, and Dimension chain. For individuals with adequate knowledge of both geometric dimension and tolerancing and measurement, many of the chapters can be read separately.

The chief editor of this book is by Zhang Yanfu and Fu Qiuya, and vice editor is Wang Achun and Cong Jiahui. Chapter 1 is written by Shan Baofeng who worked in Shenyang Aerospace University, Chapter 2 is written by Zhang Yanfu and Liu Ping who worked in Shenyang Aerospace University, Chapter 3 and Chapter 6 is written by Fu Qiuya who worked in Jiangxi University of Science and Technology, Chapter 4 is written by Zhang Yanfu who worked in Shenyang Aerospace University,Chapter 5 and Chapter 7 is written by Cong Jiahui who worked in Shenyang Aerospace University, Chpater 8 is written by Ma Ning who worked in Shenyang Aerospace University, Chpater 9 and Chapter 10 is written by Wang Achun who worked in Shenyang Aerospace University, and Chpater 11 is written by Wang Xia who worked in Shenyang Aerospace University. This book is reversed by Xu Wenji professor who worked in Dalian University of Technology and Cao Guoqiang professor who worked in Shenyang Aerospace University.

This book has proudly acquired special financial support from the Textbook Publishing Fund of Shenyang Aerospace University. We gratefully announce our sincerely acknowledgements.

Due to the limitation of our knowledge, there must be mistakes and errors in this book. Please oblige me with your valuable comments.

E-mail: zhyfln@163.com

Editors

2015.9

Contents

Chapter 1 Introduction

1.1 Interchangeability

The performance and cost of production is always considered by engineers (designer, manufacturer and inspector), however, usually the performance is higher, and the cost is higher. And at same performance, the cost is higher, and then the competitiveness in market is lower. How to ensure a production with high performance and low cost is key problem for engineers, one answer is to design a mechanical component with interchangeability.

1.1.1 Interchangeability and its advantages

During daily life, there are a lot of devices with interchangeability. Such as when a bulb is fail, to buy a new one and replace the old one, then the light can be continue serve for us; a component is fail in bicycle or watch, to buy a same specification and to replace it, the bicycle and watch can be used again.

In the mechanical engineering, there are more devices with interchangeability. Shown in Fig. 1 - 1, the nuts, bolts and rolling bearing are all manufactured and assembly according to interchangeability principle.

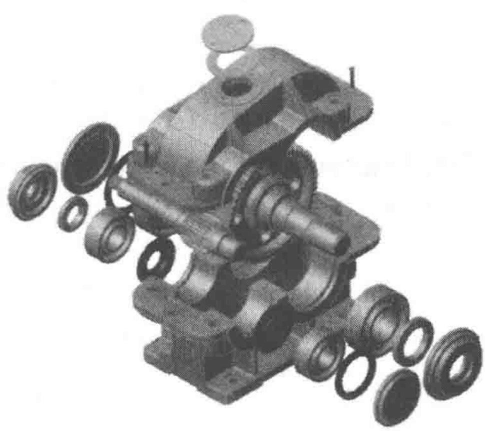

Fig. 1 - 1 Examples of Interchangeability

1. Definition

Interchangeability is the ability of one product, process or service to be used in place of another to fulfill the same requirements. In the mechanical manufacturing, interchangeability refers to fabricate workpiece respectively according to specified tolerances of geometric, physical, and mechanical performance parameters, and then during assembly and repairing one such workpiece can freely replace another, without further machine or custom fitting (such as filing).

The interchangeability of one workpiece has two aspects, one is functional interchangeability and another is dimensional interchangeability. The mechanical parameters (such as strength, stiffness and hardness) and physical parameters (such as voltage, rotate speed, lighting) belongs to functional interchangeability. The geometrical parameters (such as size, form and surface texture) belong to dimensional interchangeability. Dimensional interchangeability is concerned with geometrical properties. In this book, only the dimensional interchangeability are discussed.

The geometrical properties are defined as deviations from geometrical ideal elements (usually called features in the documents related to geometrical production specifications) of the workpieces (machine elements). Geometrical ideal elements are parts of the entire workpiece surface, which have geometrical, unique and nominal form as e. g. planes, cylinders, spheres, cones and tori. They can also be derived as, for example, axes, section lines, generator lines of highest points and edges.

2. Advantages of a part with interchangeability

This interchangeability allows easy assembly of new devices, and easier repair of existing devices, while minimizing both the time and skill required of the person doing the assembly or repair. If a machine element with interchangeable, the machine element can be used as possible as it can, so it is designed as standard workpiece or common workpiece, then can be manufactured as mush as possible, then the following advantages can be obtained.

In the design aspect, the drawing and calculation jobs will be decreased, the designing time is saved and computer aided design can be used.

In the manufacture aspect: large numbers of standard machine elements can be made, then distributional manufactures can be adopted and automatic manufacture lines can be used, result to the cost of these standard machine elements is lower.

In the repairing aspect: a machine element can be replaced as quickly as possible when the machine element is interchangeable, so the repairing time and cost are decreased, whole machine is efficiency and long life.

3. Classification

According to the interchange extent, interchangeability can be divided into two types, i. e., complete interchangeability and incomplete interchangeability.

Complete interchangeability: in an assembly, any auxiliary options and repair are not needed.

Incomplete interchangeability: in an assembly, selection (pre-grouping) before assembly and adjustment during assembly is permitted.

Incomplete interchangeability is adopted only the assembly precision is very high, and it is hard to fabricate or very expensive to fabricate, or even not able to fabricate. In this case, the tolerance of workpieces is specified big value during machining these workpieces, and after fabricated, the workpieces are grouped according to the actual size through measure. So the difference of the workpieces actual size is very small in same group, then the workpieces are assembled according to the corresponding group (that is the big holes fit with the big shafts, and the small holes fit with small holes).

Usually the complete interchangeability is adopted during cooperate between different factories and incomplete interchangeability is adopted during workpieces are assembled and machined in same factory.

Reference information about interchangeability:

The beginning of the nineteenth century, a crude form of the mass-production assembly techniques was developed by Eli Whitney when he received an order from the U. S. government for 10 000 rifles, which had to be manufactured in a short period of time. The components of each rifle were manufacturing separately by different workers. Each worker was assigned the task of manufacturing a large number of the same component. Meanwhile, the dimensions of those components were kept within certain limits, so that they could possibly replace each other and their mating counterparts. By doing so, Eli Whitney established very important concepts, on which modern mass production was based, namely, interchangeability and fits.

—from Wikipedia item "Interchangeable Part".

1.2 Standardization

1.2.1 Standard and standardization

Standardization is defined by ISO/IEC Guide 2 as "the development and implementation of concepts, doctrines, procedures and designs to achieve and maintain the required levels of compatibility, interchangeability or commonality in the operational, procedural, material, technical and administrative fields to attain interoperability."

Standardization includes all the active process of formulating, publishing and implementation, and implementation if the key process. Moreover, standardization is an active process of continuous improvement through revision.

Standardization is one of the important means of modern organization of production, the premise of professional collaboration of production, and important part of scientific management.

A standard maybe developed privately or unilaterally, for example by corporation, regulatory body, military, etc. Standards can also be developed by groups such as trade union, and trade associations. Standard organizations often have more diverse input and usually develop voluntary standards: these might become mandatory if adopted by government, business contract, etc.

The standards adopted in mechanicalindustry mainly are international standard, national standards (such as GB(National Standards of the People's Republic of China), DEC, JIS, ANSI), local area standards, and industrial standards. All international standards are with code ISO (International Standard Organization). Chinese standards are with code GB, Germany standards are with code DEC, Japanese standards are with code JIS, etc.

In order to achieve interchangeability of production, it is necessary to ensure unity in technology between decentralized local branches of production and production links in mechanical manufacturing industry. While standardization is the important means to establish technology unity in modern production. So standardization is the technical basis for the implementation of the interchangeability of production.

1.2.2 Related standards on geometrical interchangeability

In this book, only geometrical interchangeability is studied. All standards on geometrical interchangeability are included in GPS (Geometrical Production Specifications) standard matrix.

GPS is the system used to define the geometrical requirements of workpieces in engineering specifications, and the requirements for their verification. GPS is also a system which is used to describe certain work-piece characteristics through some of the different stages of its life cycle (design, manufacture, inspection, etc).

GPS is concerned with geometrical characteristics such as size, location, orientation, form, surface texture etc (it is not concerned with other properties such as hardness, chemical composition, crystal structure, color etc).

For each geometrical characteristic, it is necessary to be able to define a specification for that characteristic, it is necessary to be able to measure the characteristic, and it is necessary to be able to compare the measurement with the specification. The GPS standards relating to these requirements are defined as a series of 7 links in each chain of standards. The 7 links are: ①Symbols and indications. ②Tolerance zones and parameters. ③Feature characteristics. ④Comparison and compliance. ⑤Measurement. ⑥Measurement equipment. ⑦Calibration.

Some manufacturing processes, such as casting and welding, have requirements which are specific to that process. Standards which deal with specific processes are grouped in a further 7 chains of standards.

Some machine elements, such as screw threads and gears, have requirements which are specific to those machine elements. Standards which deal with specific machine elements are grouped in a further 4 chains of standards.

In this book, the fundamental GPS standards and some complementary GPS standards are introduced. The fundamental GPS standards introduced in this book include *Limits and fits* (ISO 286 or GB 1800 series standards), *Geometrical Tolerancing-Tolerances of Form, Orientation, Location and Runout* (ISO 1101 or GB 1182) and *Surface texture: Profile* *method-Terms, Definition, and Surface Parameters* (ISO 7287 and GB 3505). Some complementary GPS standards introduced are machine element geometrical tolerance standard, they are: *Rolling bearing-Radial-Tolerance* (ISO 492), *Shaft and Housing fit with Rolling Bearing* (GB/T 275), *General purpose metrical screw thread-Tolerance* (ISO 965.3 and GB 2516) and *Cylindrical gear-ISO system of accuracy* (ISO 1328 and GB 10095).

1.3 Series of Preferred Values

Whilst it is possible to buy custom passive components with any desired value, standard parts are manufactured in ranges of preferred values. The reason behind this is that the manufacture method of many components results in a spread of characteristics and it is expensive to make/select the accurate values, whilst most components will work adequately with loose tolerance parts. It makes good economic sense to make and stock only a limited range of values.

In industrial design, preferred numbers (also called preferred values) are standard guidelines for choosing exact product dimensions within a given set of constraints. Product developers must choose numerous lengths, distances, diameters, volumes, and other characteristic quantities. While all of these choices are constrained by considerations of functionality, usability, compatibility, safety or cost, there usually remains considerable leeway in the exact choice for many dimensions.

Preferred numbers serve two purposes:

Using preferred numbers increases the probability of compatibility between objects designed at different times by different people. In other words, it is one tactic among many in standardization, whether within a company or within an industry and it is usually desirable in industrial contexts. The opposite motive can also apply, if it is in a manufacturer's financial interest: for example, manufacturers of consumer products often have a financial interest in lack of compatibility, in planned obsolescence, and in selling name-brand and model-specific replacement parts.

They are chosen such that when a product is manufactured in many different sizes, these will end up roughly equally spaced on a logarithmic scale. They therefore help to minimize the number of different sizes that need to be manufactured or kept in stock.

In the 1870s, a French army officer, Colonel Charles Renard, tried to rationalize the procurement of ropes for use with military balloons. He derived a preferred number system (the Renard system) using a geometric progression based on the number 10. The numbers created from the 5th (10th, 20th, 40th, 80th……) root of 10, rounded off to one/two decimal places, created the R5 (R10, R20, R40, R80) series. R5, R10, R20, and R40 are the basic series, and R80 is the additional series.

Series of preferred values are the decimal geometric series and their common ratio can be