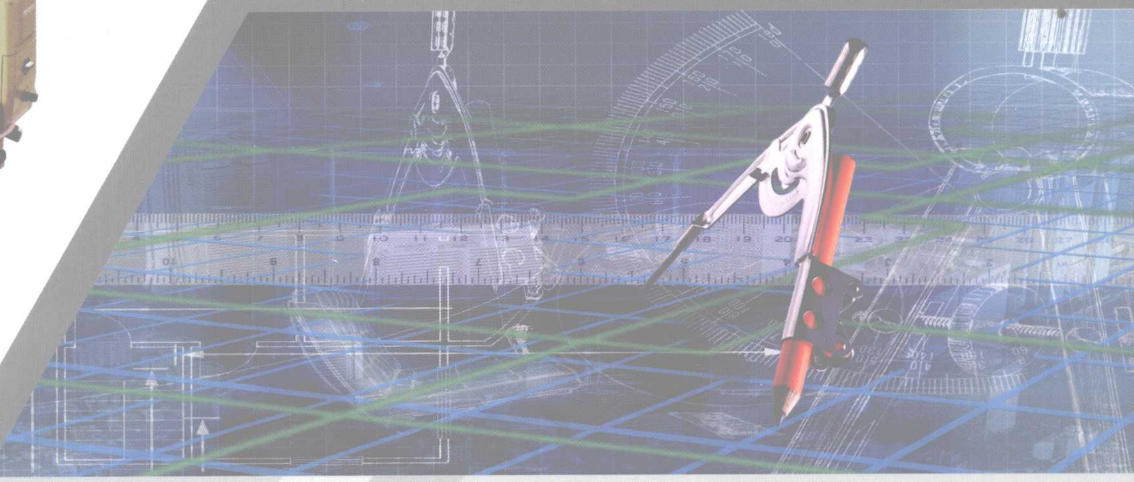
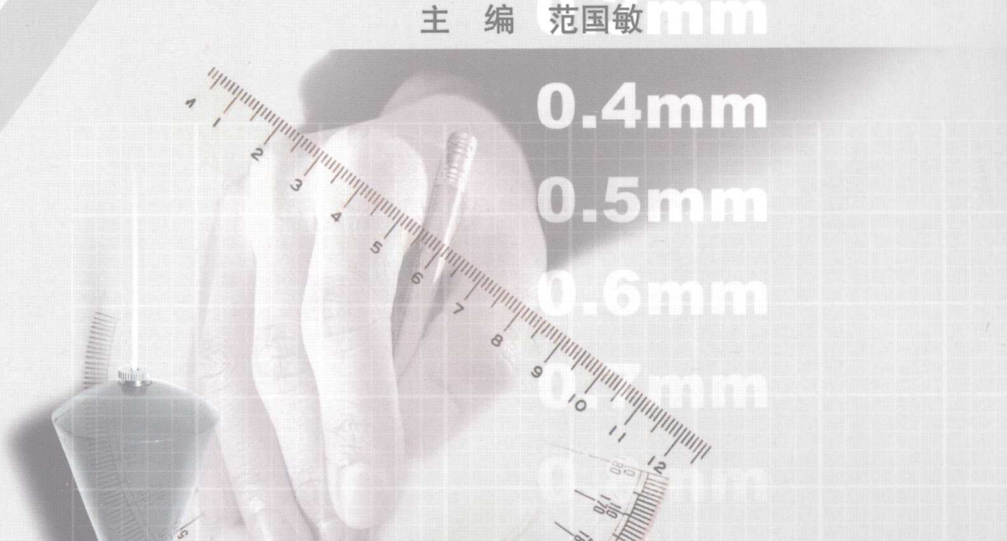
高等院校规划教材



互换性与技术测量

主　编　范国敏



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高等院校规划教材

Interchangeability & Measurement Technology

互换性与技术测量

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前　　言

互换性与技术测量是高等院校机械类和机电结合类各专业重要的专业技术基础课程。它是和机械工业发展紧密联系的基础学科，是切合当前教育改革需要，培养适应21世纪现代工业发展要求的机械类高级应用技术型人才的教材。

在机械产品的精度设计和制造过程中，如何正确地应用相关的国家标准和零件精度设计的原则、方法进行机械产品的精度设计，如何运用常规、现代的检测技术手段来保证机械零件加工质量是本课程教学的培养目标。结合多年的教学实践经验，组织编写了这本书。

根据高等院校机械类和机电结合类各专业的培养目标及对毕业生的基本要求，本书本着注重理论与实践紧密联系的原则，既保证了必要、足够的理论知识内容，又增强了理论知识的应用性、实用性；既突出了常见几何参数及典型表面的公差要求的标注、查表、解释以及对几何量的常见检测方法和数据处理的内容，又适当地保证了对国家标准制定的基本原理的解释、分析，以贯穿本课程始终的实际例子，说明理论内容，尤其是重点化解难于理解的理论内容。

为了推进双语教学事业的发展，本书正文全部采用英文编写，教材后辅以中英文对照的单词表，以及常用的中文参数表格。

本书第1、2、3章由范国敏编写，第4章由蒋蓉编写，第5章由刘琛编写，第6章由郑笑红编写，单词表和附录由王续明编写。全书由范国敏统稿和定稿。

本书承蒙郑笑红教授主审，并提出了许多宝贵的意见和建议，在此表示感谢。同时，对徐卫红教授、梁为副教授及为本书编写出版工作提供帮助的所有人员表示衷心的感谢。

由于编者水平有限，时间仓促，书中难免有不足和错漏之处，恳请读者批评指正。

编　者

2008年3月

内 容 提 要

本书是为了适应现代生产和科学发展的需要、深化双语教学改革而编写的一本专业技术基础教材。本书共10章，结合工程实际对互换性原则、圆柱体结合的极限与配合、形状和位置公差，以及轴承和齿轮的精度设计等内容进行了具体介绍，从研究几何参数的精度设计方面解决机器使用要求与制造工艺之间的矛盾，用测量技术手段保证国家技术标准的贯彻实施，从而确保产品的质量。

本书是高等院校机械和机电类、材料、精密仪器和仪表类各专业的教学教材，也可供有关工程技术与管理人员使用、参考。

Contests

1 Manufacturing Considerations in Design

Objectives:

- Standardization
- Interchangeability
- Preferred Numbers

1.1 Standardization

1.1.1 Introduction

The purpose of standardization is to establish mandatory or obligatory norms or standards to which the different types, grades, parameters (e.g., dimensions), quality characteristics, test methods and rules of marking, packing, and storage of finished items, raw materials and semi-finished articles should conform. Its aim is to minimize variety so that the number of types, dimensions and sizes, etc., are limited to a definite number of models. Standardization is of great importance in mechanical Engineering in which a large variety of types and size of items in single quantities (heavy machine tools, presses, sewing machine, etc) exist, a wide range of materials used and a great number of diverse manufacturing processes adopted. Standardization helps in the manufacture of required machines comparatively quickly and economically despite this diversity.

1.1.2 There are two stages in standardization

(1) The creation of models in which the properties which a given item should possess are established.

(2) The reduction of the number of these items, processes and methods to a rational minimum.

1.1.3 In mechanical engineering the following items are included in standardization

(1) Rules of mechanical drawing, notation of technical units.

(2) Materials their chemical composition, basic mechanical properties and heat treatment.

(3) Shapes and dimensions of most widely used parts and units such as nuts bolts, studs, screws, washers, cotter pins, rivets, keys, dowels, belts, chains, couplings, rolling contact bearing, etc.

(4) Structural elements of the majority of machine element such as modules of gears and worm wheels, diameters and widths of pulleys, etc.

(5) Accuracy i.e. fits and tolerance and surface finish of machine elements.

Two terms closely related to “standardization” are “normalization” and “unification”.

Normalization is the standardization established by separate departments or plants. The aims of unification of the machine element and units are to minimize the types of the items, by eliminating the superfluous diversity of products and production materials, etc. This is achieved by utilizing units and parts common to machines of different dimensions and applications.

1.1.4 Standardization has got the following uses

(1) It makes the mass production possible, thereby, reducing the manufacturing costs and labor requirements.

(2) The standardization of specifications and methods of testing the machine elements helps in improving their quality and hence the service life.

(3) The repair and maintenance of the machines is simplified since the worn-out or damaged parts can easily be replaced by the standard ones.

(4) It reduces the time and efforts that needed to create and manufacture new machines since the standard elements and units can be used to assemble a new machine.

Standardization include GB, QB and JB etc.

1.2 Interchangeability

Notes:

(1) The tolerance of size is normally defined as the difference between the upper and lower dimensions.

(2) The need for tolerances to be identified on drawings is vital to allow assembly of parts in the desired way and interchangeability of parts as require in modern manufacturing methods.

1.2.1 The definition of interchangeability

Definition of interchangeability: A condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves, or of adjoining items, except for adjustment, and without selection for fit and performance. See also compatibility.

1.2.2 ISO GB and the function of interchangeability

(1) ISO is the International Standardization Organization.

(2) The principle of interchangeability is an important principle in industry.

(3) The important signification of interchangeability in modern industry.

1.2.3 There are two different ways to ensure interchangeability of the parts in the machinery

(1) The first way is to produce the parts individually for each specific machine and with absolute accuracy. This is a rather complex and uneconomic way.

(2) The second way is to divide the full series of standard diameters into a number of groups.

The arithmetical mean diameter of each group postulates the tolerances and deviations for all diameters in this group.

Notes:

(1) The two ways are now approved by the international standard and ensures interchangeability of parts produced all over the world.

(2) Interchangeability of parts depends on the production accuracy which in turn is

characterized by: limits of sizes reached in production.

1.2.4 The classification of interchangeability

Interchangeable parts are components of any device designed to specifications which insure that they will fit within any device of the same types. This streamlines the manufacturing process, since all pieces are guaranteed to fit with all other, and it similarly creates the opportunity for replacement parts.

The classification of interchangeability:

(1) Complete interchangeability.

(2) Incomplete interchangeability.

(3) Outside interchangeability.

(4) Inside interchangeability.

1.3 Preferred Numbers

The use of preferred numbers is to reduce unnecessary variation in the sizes of an article and thus minimizing the variety of production and of materials. These are specially recommended values and these specify the proportions of items and structures, power, capacities, speed and all other parameters used in production and expressed numerically. Supposing a machine is to be built in several sizes with different capacities of power. It becomes necessary to decide the capacities which will cover a certain range efficiently and with a minimum number of sizes. Now it has been established by experience that a certain range can be covered efficiently with a minimum number of sizes by the use of geometrical progression with constant ratio. In our decimal system, it is easy and convenient to select a series of numbers from 10 to 100, The following series have been established:

Coarse series with the ratio, $r=\sqrt[5]{10}=1.6$ and written as $R5$.

$R5$: 1.00, 1.60, 2.50, 4.00, 6.30, 10.00

Example: If our design constraints tell us that the two screws in our gadget can be spaced anywhere between 32 mm and 55 mm apart, we make it 40 mm, because 4 is in the $R5$ series of preferred numbers.

Example: If you want to produce a set of nails with the lengths between roughly 15 mm, and 300 mm, then the application of the $R5$ series would lead to a product repertoire of 16 mm, 25 mm, 40 mm, 63 mm, 100 mm, 160 mm, and 250 mm long nails.

The second series with the ratio, $r=\sqrt[10]{10}=1.26$ and written as $R10$.

If a finer resolution is needed, another five numbers are added to the series, one after each of the original $R5$ numbers, and we end up with the $R10$ series:

$R10$: 1.00, 1.25, 1.60, 2.00, 2.50, 3.15, 4.00, 5.00, 6.30, 8.00, 10.00

Where an even finer grading is needed, the $R20$, $R40$, and $R80$ series can be applied:

The third series with the ratio, $r=\sqrt[20]{10}=1.12$ and written as $R20$.

And the last series with the ratio $r=\sqrt[40]{10}=1.06$ and written as $R40$.

These four series are called "Basic Series". The other series known as "derived series", can be obtained simply by multiplying the base size by 10, 100, etc., or be dividing the base sizes by 10, 100, etc. The preferred numbers in the series $R5$ are. 1, 1.6, 2.5, 4.0, 6.3 and 10. The numbers have been rounded. As an application of preferred numbers, supposing tractors are to be produced in five types to fulfill all the need of design. The power needed for the tractors is to be established. Using series *R*5, the powers will be 10, 16, 25, 40 and 63 etc. Using series *R*10, the powers will be 12.5, 20, 31.5, 50 and 80 etc. According to the preferred numbers, the load carrying capacities of automobiles should be 1.6, 2.5, 4.0, 6.3 and 10 tones; and of dump lorries; 4.0, 6.3, 10, 16, 25, 40 and 63 tones.

The choice of a particular series will depend upon the quantity of production. The greater the quantity of production, the greater can be the number of typical sizes. For limited quantities, the series *R*5 is used and as the production increases, change over is made to the series *R*10, *R*20 and *R*40, an international standard for preferred numbers is shown in Table 1.1.

Table 1.1 Preferred number

Series of preferred numbers				Data
*R*5	*R*10	*R*20	*R*40	
1.00	1.00	1.00	1.00	1.0000
			1.06	1.0593
		1.12	1.12	1.1220
			1.18	1.1885
	1.25	1.25	1.25	1.2589
			1.32	1.3335
		1.40	1.40	1.4125
			1.50	1.4962
1.60	1.60	1.60	1.60	1.5849
			1.70	1.6788
		1.80	1.80	1.7783
			1.90	1.8836
	2.00	2.00	2.00	1.9953
			2.12	2.1135
		2.24	2.24	2.2387
			2.36	2.3714
2.50	2.50	2.50	2.50	2.5119
			2.65	2.6607
		2.80	2.80	2.8184
			3.00	2.9854
	3.15	3.15	3.15	3.1623
			3.35	3.3497
		3.55	3.55	3.5481
			3.75	3.7584
4.00	4.00	4.00	4.00	3.9811
			4.25	4.2170
		4.50	4.50	4.4668
			4.75	4.7315
	5.00	5.00	5.00	5.0119

Table 1.1 (Continued)

Series of preferred numbers				Data
*R*5	*R*10	*R*20	*R*40	
			5.30	5.3088
		5.60	5.60	5.6234
			6.00	5.9566
6.30	6.30	6.30	6.30	6.3096
			6.70	6.6834
		7.10	7.10	7.0795
			7.50	7.4989
	8.00	8.00	8.00	7.9433
			8.50	8.4140
		9.00	9.00	8.9125
			9.50	9.4406
10.00	10.00	10.00	10.00	10.0000

2 The Limit and Fit of Smooth Cylindricality

Objectives:

- Apply english and metric tolerances to dimensions
- Calculate standard tolerances for precision fits
- Apply tolerances using basic shaft and basic hole systems

Content:

- Introduction
- Basic Principle of Tolerance
- Tolerance Dimensions
- Tolerance Terms
- Basic Hole System
- Basic Shaft System
- Cylindrical Fits
- Chain Versus Datum Dimensions
- Tolerance Notes

2.1 Introduction

1. *Geometric dimensioning and tolerance* (*GD&T*)

Geometric dimensioning and tolerance (GD&T) is a language used on mechanical engineering drawings composed of symbols that are used to efficiently and accurately communicate geometry requirements for associated features on components and assemblies. GD&T is, and has been, successfully used for many years in the automotive, aerospace, electronic and the commercial design and manufacturing industries.

In today's modern and technically advanced design, engineering and manufacturing world, effective and accurate communication is required to ensure successful end products.

Success oriented industries and organizations, which require accurate and common lines of communications between engineering, design, manufacturing and quality, should consider geometric dimensioning and tolerance (GD&T) as their mechanical drawing standard.

2. *Some advantages of GD&T* (*geometric dimensioning and tolerance*)

(1) Provides a clear and concise technique for defining a reference coordinate system (datums) on a component or assembly to be used throughout the manufacturing and inspection processes.

(2) Proper application of geometric dimensioning closely dovetails accepted and logical mechanical design process and design for manufacturing considerations.

(3) Geometric dimensioning dramatically reduces the need for drawing notes to describe

complex geometry requirements on a component or assembly by the use of standard symbology that accurately and quickly defines design, manufacturing and inspection requirements.

GD&T concepts such as MMC (maximum material condition) when applied properly will facilitate and simplify the design of cost saving functional check gages, manufacturing fixtures and jigs.

3. *Example application* (*Fig.*2.1)

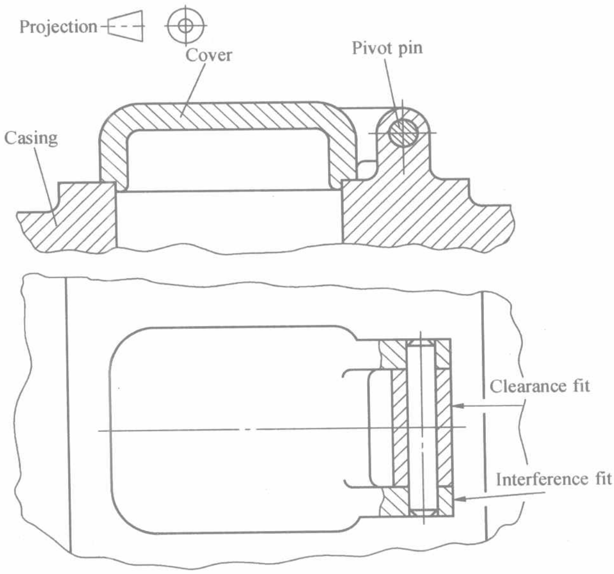

Fig. 2.1

Dimensioning parts within a required range of variation is called **tolerance.**

The tolerance may be specified as a factor or percentage of the nominal value, a maximum deviation from a nominal value, an explicit range of allowed values, be specified by a note or published standard with this information, or be implied by the numeric accuracy of the nominal value. Tolerance can be symmetrical, as in 40 ± 0.1, or asymmetrical, such as $40^{+0.2}_{-0.1}$.

It is good engineering practice to specify the largest possible tolerance while maintaining proper functionality. Closer or tighter tolerances are more difficult, and hence costly, to achieve. Conversely, larger or looser tolerances may significantly affect the operation of the device. Example Fig.2.2.

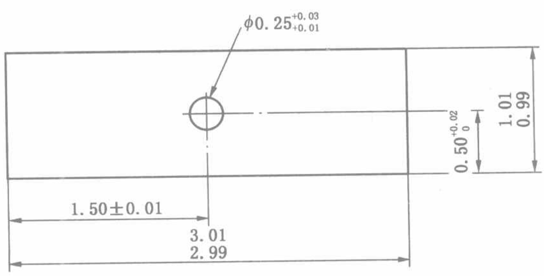

Fig. 2.2

2.1.1 What is a dimensional tolerance

When manufacturing or constructing an item it is virtually impossible to achieve precisely the required size of the item. The error permissible in manufacture is called the tolerance; this is normally given on the drawing of the item. Tolerances which affect the size of an object or features on it are referred to as **dimensional tolerances**. They are also used to tolerance the size of locating features on an item or one item in relation to another. For example, the required length (or basic length) of part of a plastic pen clip, shown, is 10 mm. This size could vary, however, between 9.5 mm and 10.5 mm and still fit in the slot provided for it on the pen. A tolerance of 1 mm, normally stated as ±0.5 mm, could therefore be applied to this dimension without affecting the function of the part. The length of this part of the clip could then be manufactured to any size between 9.5 mm and 10.5 mm and still be acceptable.

2.1.2 The need for dimensional tolerances

In a manufacturing or construction situation it is never possible to make an item to a precise dimension with absolute accuracy due to inaccuracies introduced through the manufacturing and construction process. This would not be a major problem if:

(1) Each part did not interface or interact with any other parts.

(2) The time and resources were available to further work each part until it interfaced as desired with mating parts.

In reality these conditions are rarely met, or are they desirable. Modern technological advancement, mass production and the drive towards even higher levels of productivity has led to increased demand for manufacturing accuracy. This can only be achieved through the appropriate use of tolerances. For example the accuracy with which a door hinge is manufactured will affect the ease of movement of the hinge, in other words it can be too tight or too slack. By specifying appropriate dimensional tolerances for the hinge the "feel" of the hinge can be controlled without requiring time consuming fitting and adjustment, parts not made to the required tolerances either being rejected as scrap or reworked.

The European aerospace industry provides excellent examples of how technological and political progress has dictated an ever increasing need for accuracy. The Airbus, for example, which is made up of parts (wings, fuselage, tail section etc) made in various European countries before being shipped to France for assembly. Without the tolerance the successful assembly of such a complex piece of machinery would not be possible.

There is a similar need for tolerances in the construction industry, for example large power station cooling towers 100 m or so in diameter, may have a shell thickness of only 100 or 120 mm. Obviously very careful attention must be paid according to the tolerance to ensure a successful construction. On the other hand building tolerances are sometimes specified to allow for adjustment during construction, especially when the precise size of a mating part is not known, for example when a new building is being erected against the party wall of an existing house, the latter may not be plumb or square.

2.1.3 The use of dimensional tolerances

Tolerances are used in both the engineering and construction industries to specify limits on sizes and location on products as diverse as motorway flyovers, oil tankers, motor cars and digital watches.