TEACHING MATERIALS
FOR COLLEGE STUDENTS
高等学校教材

# ENGINEERING GRAPHICS

# 工程制图

赵军友　主　编
陈福忠　曹清园　邹俊艳　赵海晖　副主编

中国石油大学出版社
CHINA UNIVERSITY OF PETROLEUM PRESS

# ENGINEERING GRAPHICS

# 工程制图

主　编　赵军友

副主编　陈福忠　曹清园　邹俊艳　赵海晖

中国石油大学出版社
CHINA UNIVERSITY OF PETROLEUM PRESS

图书在版编目(CIP)数据

工程制图 =Engineering graphics: 英文 / 赵军友主编. —东营: 中国石油大学出版社, 2014. 5

ISBN 978-7-5636-4407-0

Ⅰ. ①工… Ⅱ. ①赵… Ⅲ. ①工程制图－高等学校－教材－英文 Ⅳ. ① TB23

中国版本图书馆 CIP 数据核字(2014)第 105184 号

书　　名: 工程制图
作　　者: 赵军友

责任编辑: 袁超红(电话 0532－86981532)
封面设计: 青岛友一广告传媒有限公司

出 版 者: 中国石油大学出版社(山东 东营　邮编 257061)
网　　址: http://www.uppbook.com.cn
电子信箱: shiyoujiaoyu@126.com
印 刷 者: 青岛星球印刷有限公司
发 行 者: 中国石油大学出版社(电话 0532－86981532, 86983437)
开　　本: 185 mm × 260 mm　印张: 13. 5　字数: 346 千字
版　　次: 2014 年 9 月第 1 版第 1 次印刷
定　　价: 28. 00 元

# Preface

Engineering graphics, a basic course for the engineering specialties, possess a very important position in the education system structure for engineering. For a long time, the engineering graphics teaching is only for the Chinese national students, and there are few special English textbooks for the international students. Considering of more and more international exchange in education, we realize the more and more importance of the engineering graphics textbook in English, so we compiled this textbook which has its own characteristics.

This book is designed to meet "the Basic Teaching Requirements" of college specialties with different class hours and intended to provide a comprehensive engineering graphics textbook with innovative course system structure, so as to meet the requirements of engineering graphics teaching with English language. In addition, the book set is accompanied by the problem book, which give many typical problems and many of the problems come from oil field engineering. Its basic materials can be used as a common platform that is suitable for all specialties, petroleum engineering, civil engineering, electrical engineering, mechanical and non-mechanical specialties, and the specialties include the ones with more class hours and the ones with fewer class hours.

The author has studied and consulted various well-known engineering graphics textbooks from abroad, and has adopted up-to-date Chinese National Standards. This will undoubtedly make the book convenient to use for both instructors and students.

This book is edited by Mr. Zhao Junyou (赵军友) as chief editor, and Mr. Chen Fuzhong (陈福忠), Ms. Cao Qingyuan (曹清园), Ms. Zou Junyan (邹俊艳), Mr. Zhao Haihui (赵海晖) as associated editors in chief. The participants are as follows: Mr. Shu Qi (束奇), Mr. Sun Feng (孙峰), Mr. Zhang Zhenguo (张振国), Mr. Wang Xiuhui (王秀会), Mr. Wang Lei(王雷), Mr. Liu Xiangmeng (刘祥猛), Mr. Wan Fawei (万法伟), Mr. Zuo Peng(左鹏), Ms. Zhang Ruirui (张蕊蕊), and Mr. Lan Kai (兰凯), all of them are from China University of

Petroleum (East China).

During the process of compiling this book, Ms. Barbra (Technology English expert from New York, U.S.A), wrote some of the drafts and refined some translations. Dr. Cathleen, translation specialist from University of British Columbia, Canada, and Dr. Cristina, language specialist from Catholic University of Leuven, Belgium, gave the check and provided written comments. Professor Liu Yancong (刘衍聪), Niu Wenjie (牛文杰) and Sun Peixian (孙培先) gave us much support and help. The Industry Design Department colleagues, just the teamwork gave us the base of this compiling work. I wish to express my sincere thanks to them for their significant contributions.

Finally, all comments and suggestions from readers are cordially welcome and appreciated.

**Author**

**2014-05-30**

# Contents


Introduction ..... 1

Chapter 1 Basic Knowledge of Engineering Drawing ..... 4

1.1 General Provisions in National Standards ..... 4

1.2 Drawing Tools and Their Utilization ..... 12

1.3 Geometric Construction ..... 14

1.4 Analysis and Drawing of 2D Picture ..... 16

Chapter 2 Projection of Basic Elements ..... 18

2.1 Principles of Orthographic Projection ..... 18

2.2 Projection of Points ..... 20

2.3 Projection of Lines ..... 22

2.4 Projection of Planes ..... 27

Chapter 3 Basic Solids and Their Intersections ..... 32

3.1 Polyhedral Solids ..... 32

3.2 Curved Solids ..... 37

Chapter 4 Composite Solids ..... 50

4.1 Analysis of Composite Solids ..... 50

4.2 Drawing Method and Procedure of Composite Solids ..... 51

4.3 Axonometric Projection ..... 55

4.4 Reading Views of Composite Solids ..... 62

4.5 Dimensioning Composite Solids ..... 68

**Chapter 5 Representation Methods of Drawings ..... 74**

5.1 Views ..... 74
5.2 Sections ..... 77
5.3 Cuts and Other Representation ..... 85

**Chapter 6 Standard Parts and Commonly Used Parts ..... 91**

6.1 Threads ..... 91
6.2 Screw Fasteners ..... 98
6.3 Commonly Used Parts ..... 103

**Chapter 7 Detail Drawings ..... 115**

7.1 Detail Drawing Contents ..... 116
7.2 Manufacture Process Structure ..... 116
7.3 Technical Requirements ..... 119
7.4 Choosing Views and Dimensioning of a Part ..... 133
7.5 Part Measurement ..... 140
7.6 Detail Drawing Interpretation ..... 143

**Chapter 8 Assembly Drawings ..... 149**

8.1 Contents of Assembly Drawings ..... 149
8.2 Representation Methods of Assembly Drawings ..... 150
8.3 Rationality of Fitting Structures ..... 155
8.4 Interpreting Assembly Drawings ..... 157

**Chapter 9 Brief Introduction to AutoCAD ..... 162**

9.1 The User Interface ..... 162
9.2 Drawing and Editing Techniques ..... 165
9.3 Auxiliary Function ..... 171
9.4 Dimensioning ..... 181
9.5 Constructing 3D-solids Using AutoCAD ..... 185

**Appendices ..... 187**

**References ..... 210**

# Introduction

In the field of modern design and academic study, the ability of special imagination and drawings representation is emphasized in a significant position. Engineering graphics plays the very important role in cultivating the ability of special imagination, technical exchange and industrial production.

### Object of This Course

Projection method is extensively adopted in designing, conceiving and diagrammatizing special geometry problems. In the engineering activities, the structure, shape, size, material, standard and function of the machines, architectures, equipments, parts and other solids are always represented in drawings. These drawings are called engineering graphics. So engineering graphics is one of the tools used by human for the expression, conception, analysis and communication of technical information.

Engineering graphics is an application oriented subject that introduces the preparation representation and reading of engineering graphics. Considering scientific and technological level, engineering graphics, which is often called "the common technical language for engineers", is an important document in industry for design, manufacture, utilization and service.

This course mainly deals with the basic principles and methods of projection, establishing the process of "solid to drawing" and process of "drawing to solid", in other words, it studies the transition regulations from 2D to 3D. The theory and method of engineering graphics, are the scientific knowledge for constructing and reading the engineering graphics, in accordance with projection regulations and technical principles. As the important tool for solving engineering problems, these drawing principles and standards should be mastered by every engineer.

### Characteristics of This Course

Engineering graphics, are not only a foundation subject for a specific major, but also a part

in the entire spectrum of engineering education. It also provides theories and methodologies for all engineering; talents to express their spatial and visual imagination. The course mainly studies the basic theories and methods for the preparation and reading of engineering graphics as well as related national standards on mechanical drawing and technical drawing. The main features of the book are the following:

(1) It is a foundation subject for other engineering-related subjects and education and provides a basis for studying other subjects afterwards.

(2) It is a cross disciplinary subject that integrates geometry, projection theory, basic engineering knowledge, basic engineering specifications and standards, and advanced drawing techniques.

(3) It is an engineering subject which has a close connection with body and shape construction, analysis and representation and requires continuous integration with engineering regulations and methodologies.

(4) It is a widely used practical subject integrating both theoretical and engineering practices.

(5) It provides a method covering engineering, visual imagination that could effectively train students with the ability in comprehensive special imagination and analysis.

(6) It is a common engineering language applicable to different regions, different disciplines, different languages.

**Tasks of This Course**

Engineering graphics is the study for the representation and communication of products and processes. It is a carrier of engineering and product information and the communication language in engineering and industry. The course is based on rigorous theoretical and highly practical materials that are important to train students with scientific thinking and innovation. It is an important technical foundation of undergraduate course for general higher education in universities and colleges.

The tasks of this course are as following:

(1) To study the basic theory and applications of orthographic projection and train students with abilities in design and innovation.

(2) To train students with a balanced skill in hand drawing, instrument drawing and computer assisted drawing as well as the ability in reading mechanical drawings.

(3) To train students with abilities in spatial and logical thinking, visual imagination, conceptualization, exploration and innovation.

(4) To train students with serious working attitude, meticulous working style and their persistence in complying with related national standards.

**Study Methodologies of This Course**

The course consists of projection theory and engineering practices. Different methodologies may be applied when studying different parts of this course.

(1) When studying the projection theory, one should understand the basic concepts and basic rules. It should integrate projection analysis and geometry drawing techniques with their spatial imagination, logic reasoning and analytics judgment and establish the corresponding relationship between plane drawing and spatial shape. To improve one's spatial imagination is a step-by-step process and requires repeated studies from spatial shapes to planar representations and vise versa.

(2) When studying the representation of composite and parts, one should master the theory and methodologies of shape and body analysis and line and plane analysis through attending lectures or self learning. One should be skilled in simplifying complicated problems so that the problem could be solved with minimum effort. One should also ensure careful observation, profound thinking, persistent trying and exercises and thus continuously improve his/her ability in spatial analysis and conceptualization.

(3) When studying drawing techniques, attention should be paid to proper usage of tools, mastery of methods and skills in hand drawing. All drawings must comply with related national standards. Skilled drawing, using AutoCAD requires comprehensive exercise on computers and practice. Further attention should also be paid with added care to exploration, observation, and practice for producing a quality drawing.

(4) When learning reading drawings, one should participate in real engineering work and accumulate knowledge through practice. One should try to apply the knowledge in practice and thus develop ability in making observation, thinking, conclusion, application and skills in problem solving. In the process of drawing, reading and exercises, try to learn from duplication, revision, exploration and creative thinking. One must be able to complete this subject through typical examples and continued synthesis of exercises and practices.

(5) To learn this course well, the more important methods are: preview before class, review after class and do enough exercises timely.

Above all, one can master and consolidate the knowledge of this course through the integration of learning and practice, carefulness, seriousness, and hardness.

# Chapter 1 Basic Knowledge of Engineering Drawing

As a common language of engineering, the drawing is used to direct the production and make the technical interchange. Therefore, it is necessary to specify, in a unified way, drafting practices. The national standards are considered the most authoritative guiding documents to uniform drafting practices in China. This chapter is about basic knowledge of engineering drawing for further studies. Contents in this chapter include national standards related, drawing tools and their utilization, and basic techniques in drawing geometrical construction.

## 1.1 General Provisions in National Standards

Engineering drawing is an important documentation used during the process of design and manufacturing. For the sake of convenience in communication, all drawings should comply with the national standards. National standards are abbreviated as "GB" with a code. For example, GB/T 14689—2008 is the standard for defining drawing sheet size and layout. Here, GB/T is the abbreviation of the National Standard (GB—GUO JIA BIAO ZHUN, T—TUI JIAN in chinese). The code 14689 is a serial number of the standard. The code 2008 indicates the year when the standard was published.

### 1.1.1 Standard drawing sheets with layout (GB/T 14689—2008)

#### *1. Standard sheets*

While producing the drawing, one should usually adopt the standard sheets and layout illustrated in Table 1-1. There are five standard sheets, namely A0, A1, A2, A3 and A4. A3 and A4 are often used during the study. If it is necessary, one may also use extended sheets of larger size specified in the standard.

#### *2. Layout of standard sheets*

One must use solid lines to draw the border. There are two layouts to follow, i. e. with or without space for book binding. The dimensions for each of the layouts for the five standard

sheets are shown in Table 1-1. For A4 paper, one usually adopts a vertical layout. While for A3, one usually adopts a horizontal layout. However, one may use a different layout in case of certain products.

**Table 1-1 Standard drawing sheets** mm

| Sheets | A0 | A1 | A2 | A3 | A4 |
|---|---|---|---|---|---|
| $B \times L$ | 841 × 1 189 | 594 × 841 | 420 × 594 | 297 × 420 | 210 × 297 |
| $a$ | 25 | | | | |
| $c$ | 10 | | | 5 | |
| $e$ | 20 | | 10 | | |

### *3. Title block*

One must draw a title block on each drawing sheet. The position of the title block should be located on the lower right corner of the sheet as shown in Fig. 1-1 and Fig. 1-2.

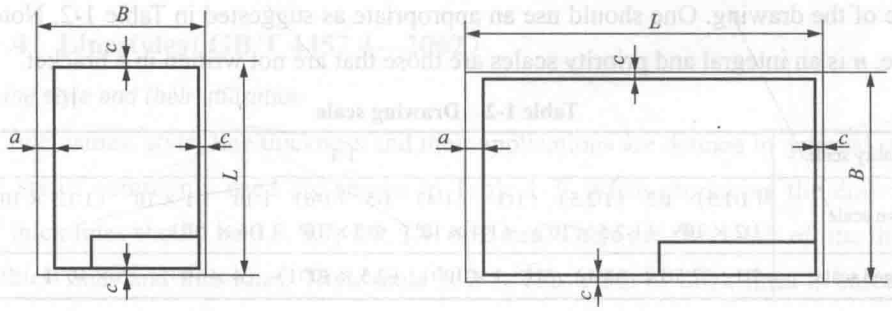



**Fig. 1-1** Drawing sheets with binding area

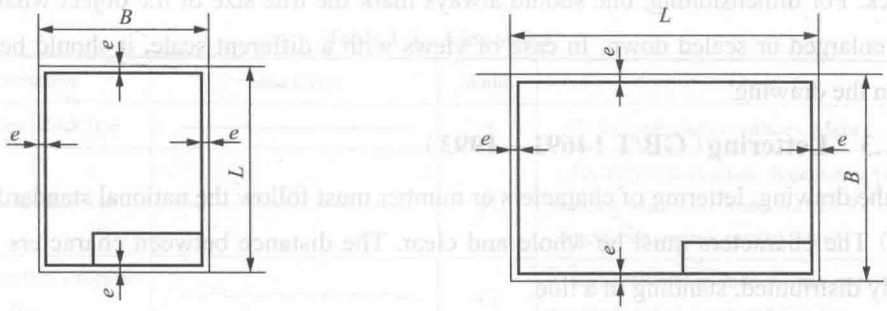



**Fig. 1-2** Drawing sheets without binding area

The layout and size of the title block should also follow the national standard GB/T 10609. 1—2008. Title block on exercise drawings used in this course can be simplified and a recommendation is illustrated in Fig. 1-3.

One should note the following: The outline of the title block must be drawn with solid lines. The right-side and the base line should be in coincidence with the frame border. Other inner lines should be drawn with thin lines.

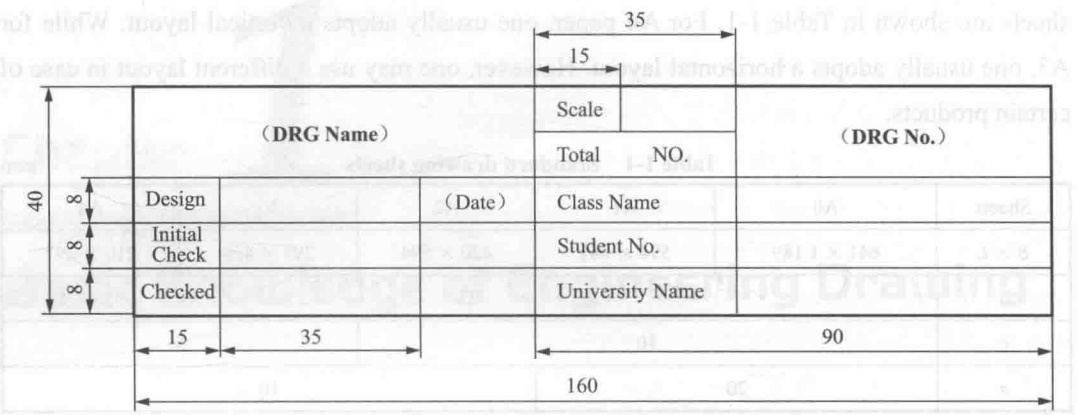



**Fig. 1-3** Suggested contents for a simplified title block

### 1.1.2 Scale (GB/T 14690—1993)

The ratio between the dimension on the drawing and features of the actual object is called the scale of the drawing. One should use an appropriate as suggested in Table 1-2. Note that in this table, $n$ is an integral and priority scales are those that are not written in a bracket.

**Table 1-2 Drawing scale**

| | |
|---|---|
| Originality scale | 1:1 |
| Down scale | (1:1.5) 1:2 (1:2.5) (1:3) (1:4) 1:5 (1:6) 1:10 $1:1\times10^n$ $(1:1.5\times10^n)$ $1:2\times10^n$ $(1:2.5\times10^n)$ $(1:4\times10^n)$ $1:5\times10^n$ $(1:6\times10^n)$ |
| Enlarged scale | 2:1 (2.5:1) (4:1) 5:1 $1\times10^n:1$ $(2.5\times10^n:1)$ $(4\times10^n:1)$ $5\times10^n:1$ |

One should adopt the same scale in one drawing and the scale should be marked in the title block. For dimensioning, one should always mark the true size of the object whatever the scale is enlarged or scaled down. In case of views with a different scale, it should be marked clearly in the drawing.

### 1.1.3 Lettering (GB/T 14691—1993)

In the drawing, lettering of characters or number must follow the national standards.

(1) The characters must be whole and clear. The distance between characters must be uniformly distributed, standing in a line.

(2) The font for Chinese characters should be the "Fang Song" and the standard simplified Chinese characters should be used. The height of characters should not be less than 3.5 mm and the width should be $h/\sqrt{2}$ ($h$ is the height).

(3) The number of characters is the height of the characters, such as 1.8, 2.5, 3.5, 5, 7, 14, 20 mm.

(4) The font for all characters can be in italic font or normal/straight font. The width of the strokes should be about one tenth or one fourteenth of the character height. The italic font characters should be inclined towards the right with an angel 75° with respect to horizontal lines. In general, italic font is used for all tapes of drawings.

(5) The number of characters for subscripts, fractions, the limit symbol, and notes is usually one less compared with full size fonts used in the drawing.

Several examples are shown in Fig. 1-4.

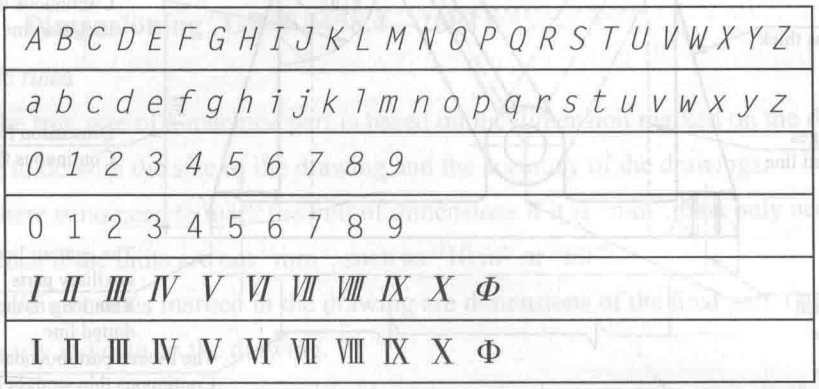



**Fig. 1-4** Examples of characters

### 1.1.4 Linestyles (GB/T 4457.4—2002)

#### *1. Line style and their utilization*

All line names, style, line thickness and their applications are defined in national standard. The line styles commonly used are shown in Table 1-3. When producing the drawing, the width of thick lines should be 0.5, 0.7, 1.0, 1.4, or 2 mm. There are two kinds of line thickness, namely thick lines and thin lines. Their scale is 2:1. The width of thick lines is based on the dimension and structure of the drawing. Fig. 1-5 illustrates the applications of the various line styles.

**Table 1-3 Line styles**

| Description | Line styles | Width | Usage |
|---|---|---|---|
| Continuous thick line | | *d* | To indicate visible outlines, edges |
| Continuous thin line | | *d*/2 | For fictitious outlines, dimensions, projection hatching and leader lines, also for the outline of coincidence section, root of thread |
| Continuous thin irregular line | | *d*/2 | Part sectional boundary lines or to terminate a part view, and for short break line |
| Continuous thin straight line with intermittent zigzags | | *d*/2 | To show a break on an adjacent member to which a component is attached |
| Thin dashed lines | | *d*/2 | Hidden edges, hidden outline |
| Thin dashed dotted line | | *d*/2 | Axis line, symmetrical center lines, etc. |
| Thin long dashed double dotted line | | *d*/2 | To indicate adjacent parts alternative and extreme positions of moving parts, also to indicate imaginary line |
| Thick dashed dotted line | | *d* | To indicate a cutting plane for sectional views |

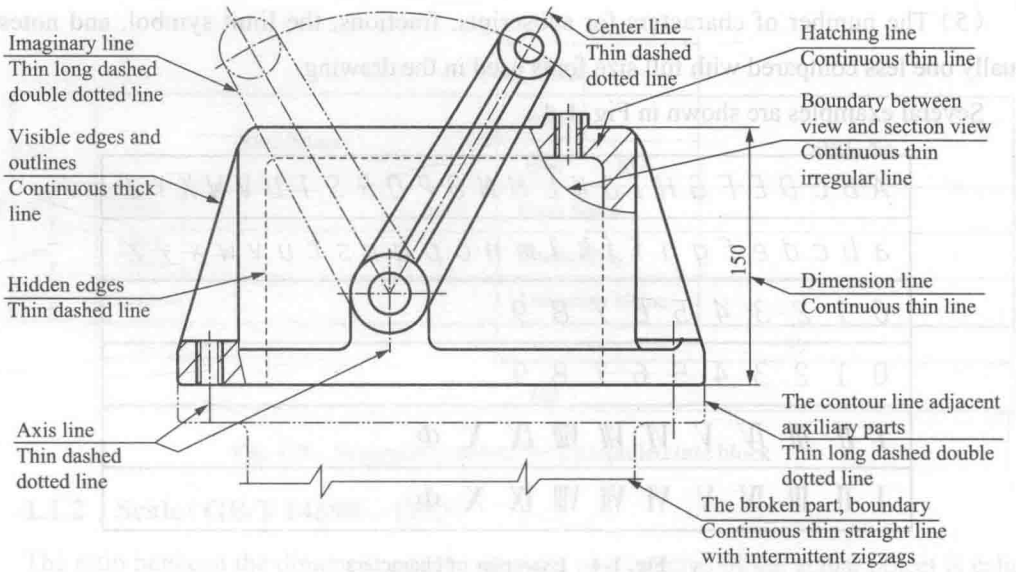



**Fig. 1-5** Example of drawing lines

### *2. Further notes for drawing lines*

(1) In the same drawing, one should use the same line width for the same type of lines, and also they should be the same respectively for the length and the gap of dashed lines, dashed dotted lines, dashed double dotted lines.

(2) The distance between two parallel lines should not be less than the width of two continuous thick lines. The limit distance must be not less than 0.7 mm.

(3) The center line should be longer from 2 to 5 mm than the drawing frame; the end line should be long dot, but not short dot. And the center of a circle is the intersection point of long dash. When it is difficult to draw dot line or double dot line in small drawing, it can be replaced by continuous thin line, as shown in Fig. 1-6.

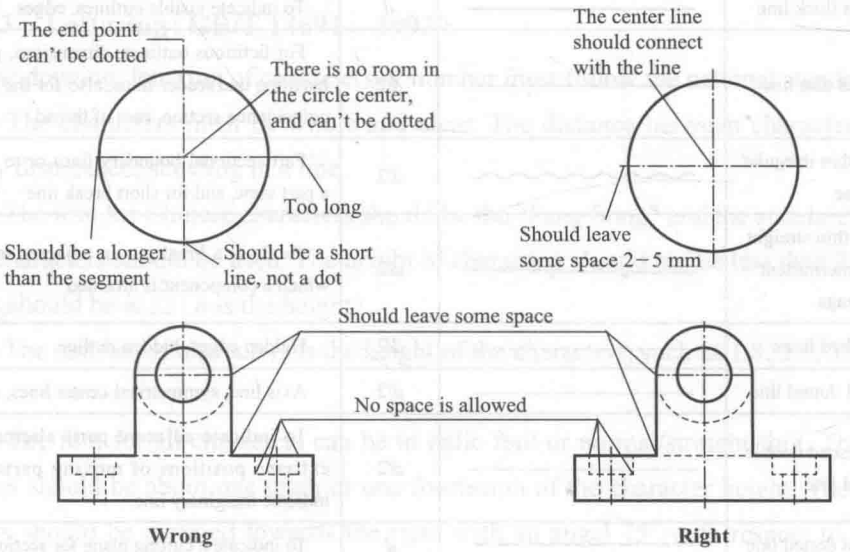



**Fig. 1-6** Example of drawing line

(4) When two thin dashed lines meet together, the line segments should meet (not space). When a thin dashed line is an extension of a continuous line, a little space should be kept at the intersection position, as shown in Fig. 1-6.

### 1.1.5 Dimensioning (GB/T 4458.4—2003)

#### *1. Basic rules*

(1) The true size of a machine part is based on the dimension marked on the drawing and has nothing to do with the size of the drawing and the accuracy of the drawings.

(2) There is no need to mark the unit of dimensions if it is "mm". One only needs to mark the dimensions if the units are not "mm", such as "10 m" or "60°".

(3) All dimensions marked in the drawing are dimensions of the final part. Otherwise one needs to clearly indicate on the drawing.

(4) Each dimension of the part should mark on the drawing only once. It should also be marked on a drawing that most clearly represents the corresponding structures.

#### *2. Dimension construction*

A complete dimension is shown in Fig. 1-7 and is composed of an extension line, a dimension line, terminal features and text.

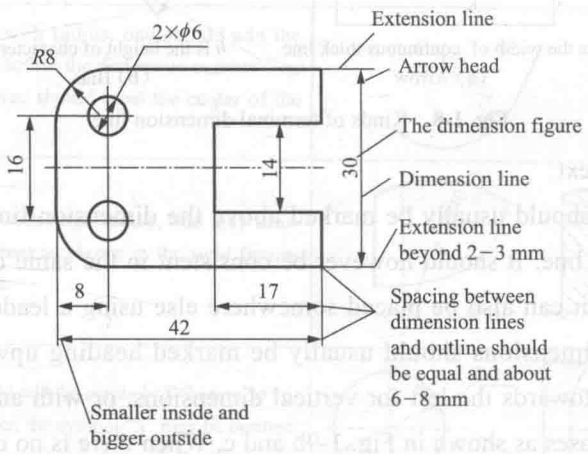



**Fig. 1-7** Dimensioning elements

(1) Extension line.

An extension line is drawn with a continuous thin line and it illustrates the scope of the corresponding dimension. An extension line originates from a feature outline, an axis line, or a symmetrical center line, and which can also be used as an extension line.

Extension line is usually drawn perpendicular to the dimension lines and the extension lines should extend beyond the terminal of dimension line for about 2−3 mm. If necessary, extension line may also have a different inclination angle with the dimension lines.

(2) Dimension line.

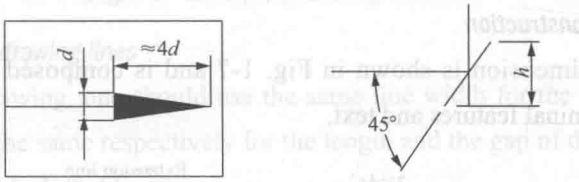
① A dimension line must be drawn using thin solid line and cannot be replaced by

existing lines in the drawing. It can not be in coincidence with any existing lines or be drawn as extension of any existing lines.

② For linear dimension, the dimension line must be parallel to line segment being dimensioned. It should be about 6−8 mm for the distance between the dimension line and the nearest feature and the distances between two neighboring dimension lines. A small size dimension is usually placed inside and a big one is usually placed outside, as shown in Fig. 1-7.

(3) Dimension line terminal.

A dimension line may have two types of terminals, as shown in Fig. 1-8, arrowhead or oblique line. For the same drawing, one should use the same type of terminals and usually the arrowhead is used. It should be noticed that the tip of the arrowhead should just get in touch with the extension lines, but not longer or shorter. When an oblique line is adopted for dimension line terminals, the dimension line and the extension lines must be mutually perpendicular from each other and the oblique line should be a thin solid line.



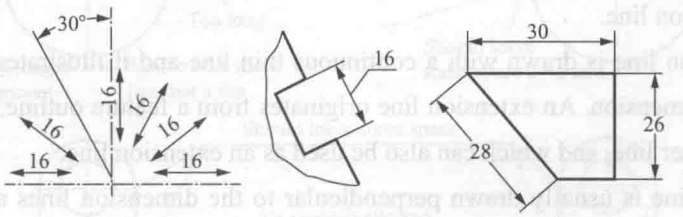

*d* is the width of continuous thick line (a) Arrow

*h* is the height of characters (b) Bias

**Fig. 1-8** Kinds of terminal dimension line

(4) Dimension text.

Dimension text should usually be marked above the dimension line or in the breaking space of a dimension line. It should however be consistent in the same drawing. When there is not enough space, it can also be placed somewhere else using a leader line. As shown in Fig. 1-9, all linear dimensions should usually be marked heading upwards for horizontal dimensions, heading towards the left for vertical dimensions, or with an inclination heading upwards for general cases as shown in Fig. 1-9b and c. When there is no confusion, dimension text can also be entered in the breaking space of the dimension line as shown in Fig. 1-9c.




(a) (b) (c)

**Fig. 1-9** Text orientations for dimensioning