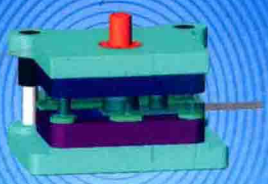

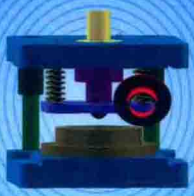

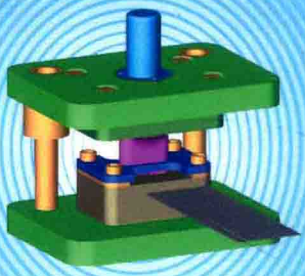

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COLD STAMPING DIE DESIGN
冷冲压模具设计（英文版）

Wang Xiufeng 王秀凤
Li Weidong 李卫东

北京航空航天大学出版社
BEIHANG UNIVERSITY PRESS

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Abstract

Based on the author's rich teaching and practical experience, this textbook is an accumulated effort to introduce the basic knowledge of cold or room temperature stamping die design systematically and comprehensively. For the most representative blanking die, the stamping die design process, structure type selection, design steps and the main process calculation are described in details, and then the characteristics of the bending die, drawing die and flanging die are explained further. In addition, common cold stamping die design data and standard parts for inspection were included in order to facilitate student curriculum design and to engineering personnel for reference.

This textbook is written for international students and domestic undergraduates majoring in mechanical engineering. The accompanying multimedia CAI courseware is made to assist teaching.

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Preface

In China, international student education has become an important new growth point in higher education development, and it is also a crucial part of China's international affairs. With the internationalization trend of higher education, many international students come to study in China's universities or colleges. Therefore, the internationalization process is greatly promoted in China. At the same time, the specialty teachers face challenges for teaching specialty courses in English, in which the supporting books are essential as the course materials.

With the rapid development of stamping die industry, stamping die design has become an independent industry, and it attracts more and more people's attention. In order to make students understand and master the basic knowledge of stamping die design in a limited time and obtain the basic capability of stamping die design, this textbook is written based on the author's rich teaching and practical experience. It focuses on the elaboration of basic knowledge and basic concept, and has the characteristics of academic terminology, easy to understand, clarity, coping well with quite complicated subjects and combining the theory with the practice. Therefore, the design and arrangement of this textbook are suitable for the teaching regularity and students' cognitive regularity, and help a coordinated development of students' knowledge, practical ability and personal quality. It divides into seven chapters in total, and the stamping die design process, structural type selection, design steps and the main process calculation are explained in details based on the most representative blanking die. Then, the characteristics of bending die, drawing die and flanging die are given further. In addition, in order to facilitate the student curriculum design and engineering reference, cold stamping die design commonly used data and standard parts for inspection were also contained in this textbook. Furthermore, there is a multimedia CAI courseware accompanying this textbook. It enhances the teaching effect and quality by manufacturing all kinds of vivid animation to easily learn and understand by AutoCAD, flash, Photoshop, Animationpro and virtual reality technology. Thus, the curriculum teaching is implemented lively and interestingly, and international students can obtain more knowledge and information in the limited teaching hours. At the same time, it can meet the requirements for both the international students teaching in English and the bilingual education to cultivate the international compound talents for Chinese students.

This textbook is written for the professional students of stamping die or related mechanical engineering with a reference time for 38 hours, and follow-up courses should be arranged with cold stamping die course design. This textbook can be used in accordance with the multimedia CAI courseware to assist teaching. At the same time, this textbook can also be used for relevant professional technical staff in the related institutes teaching, or scientific

research institutes.

This textbook is written by Wang Xiufeng, and Li Weidong, and proofread by Dr. Liu Junhua and Zheng Yang. The illustrations in this textbook are completed by Wang Zengqiang, Wang Peng, Liu Juan, Zhao Yanli, Wang Qiang, Shi Xin, Tong Zhenyu. The multimedia CAI courseware is made by Wang Xiufeng, Li Weidong, Cai Zhe, Guo Liyong, Wang Peng, Wang Dongzhao. This textbook was written by referring to some excellent textbooks and the related materials, and they played an important reference function, which we would like to show our appreciation. In addition, it is inevitable that there are some mistakes in this textbook, so all criticism and corrections from experts or readers are welcome.

Authors

January, 2018 in Beijing

Please download the multimedia CAI courseware by scanning the QR code as follow:

You can also download all the documents on the website https://pan.baidu.com/s/1zw7yttgMSqIn73Q7_20cMw. If you have any questions, please contact Beihang University Press via 010 - 82317036 or goodtextbook@126.com.

Contents

Chapter 1 Introduction

Stamping is a processing method that can produce parts by separating or deforming from sheet metal through stamping dies. When it is processing at room temperature, it is called cold stamping or stamping.

1.1 Concept and application of cold stamping die

Cold stamping die is the main equipment in the industrial production for the mass production of parts. Therefore, the die industry becomes the basic industry of the national economy.

Cold stamping die can ensure products with dimensional accuracy, stable quality and without damaging their surface during processing. By using the cheap rolled steel sheet or strip coming from metallurgical plants in large quantities to produce the parts and without heating, it has advantages of high efficiency, good quality, light weight, low cost, energy and raw materials savings. Therefore, any other processing methods cannot parallel it. The application of cold stamping die has become one of the most important means in modern industrial production and leads the development direction. Developing and improving the technical level of modern manufacturing industry depends largely on the development of cold stamping die industry.

At present, parts are often produced by cold stamping die to improve the production efficiency and quality. For a normal press, it can produce several or dozens of parts per minute. Furthermore, the production efficiency of a high-speed press is up to several hundreds or thousands per minute. Cold stamping die takes 37% of the total dies including cast die, plastic mould, forging die etc. According to incomplete statistics, about 60% of the parts in aircraft, automobile, tractor, motor, appliances, instrument, meter and others, about 90% of the parts used in bicycle, watch, washing machine, refrigerator, electric fan and other light industrial products, and the overall parts in household hardware, tableware and other items are produced by cold stamping die. Thus, the cold stamping die is one of the major equipments in the modern industrial production. Both the industrial production and development trends of new products are closely connected with each other. Die manufacturing technology represents the national development level of industrial manufacturing technologies. It is so special that more and more people gradually realize its critical role in the mass production.

1.2 History and situation of cold stamping die

The emergence of the cold stamping die can be traced back thousands of years ago, when the pottery parts were fired and the bronze parts were cast. With the development of modern industry, the cold stamping die is developed and applied in large-scale production. In the 19th century, with the development of arms industry, watch industry and radio industry, the cold stamping die began to be widely used. After World War Ⅱ, with the soaring of the world economy, cold stamping had become the best choice to produce various household appliances, automobiles, electronic equipment, cameras, watches and other parts in large quantities. From a global view, the advanced technologies were the stamping in the United States, the fine stamping in Switzerland, the cold extrusion in Germany and plastic processing research in the former Soviet Union. In the 1950s, the cold stamping die design was made to meet the requirements of production based on experience, reference drawing and perceptions, and the user's requirements, but the function of die parts were lack of understanding. From 1955 to 1965, stamping technology was developing rapidly by mathematical analysis on the function of the main parts of the cold stamping die and the force status acting on them, and the metal plastic processing technology and principle were deeply understood. Furthermore, the design principle of the cold stamping die was summarized to apply to the field of mechanical pressure, stamping materials, processing methods, die structure, die material, die manufacturing methods, automation devices and promoted stamping technology in practical production. In the 1970s, a variety of the multi-functional automatic cold stamping dies were manufactured with high efficiency, high accuracy and long life span. Their representatives were more than fifty-station progressive die and more than a dozen stations in multi-station transfer die. In the meantime, Japan became the most advanced country and manufactured the micron precision of cold stamping die. From the mid-1970s to now, the computer was gradually used in the whole process of cold stamping die production, which includes inputting parts drawing, calculating the blank size of the workpiece, nesting of the blank in the strip, determining the size and standard of the die shoes, drawing assembly and parts drawings, and outputting NC codes (for CNC machining centers and wire cutting processing), so the design level, processing precision and complexity of the cold stamping die were improved continually, and its manufacturing cycles were shorten greatly. The trends of current computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM) in the world are to develop a geometric system to satisfy the reqirements of complex parts and cold stamping dies, to establish an integrated production system (CIMS) based on CAD and CAM, to research on plastic forming simulation technology such as physical and mathematical simulation to improve process analysis and theoretical and practical level of die CAE, and develop the intelligent databases and distributed databases to improve the expert systems and intelligent

CAD, etc.

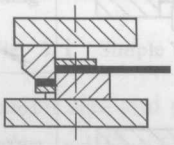
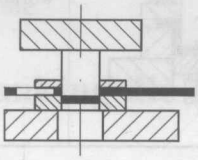
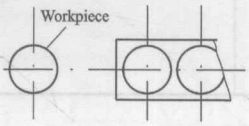
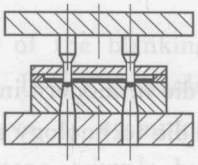
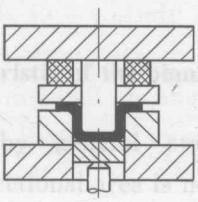
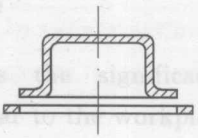
In a word, the die CAD, CAE and CAM should be combined together to achieve integrated, three-dimensional, intelligent and networked application. Furthermore, the users can realize the collaboration in a unified environment so that they give full play to their respective advantages and effectiveness, implement integrated management of information and sharing, support the whole process of cold stamping die design, manufacturing, assembly, inspection, testing and production management, and carry out the target of high-quality, high-efficient, low-cost products to suit the individual pursuit.

1.3 Classification of cold stamping die

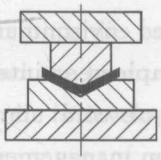
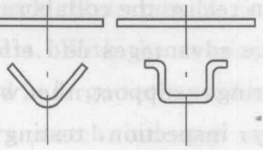
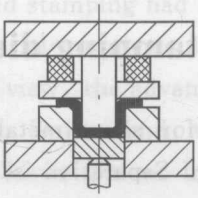
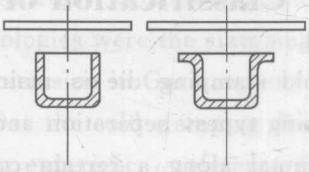
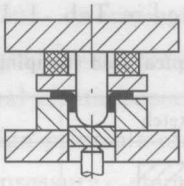
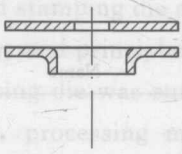
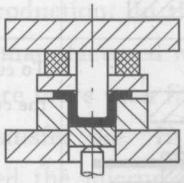
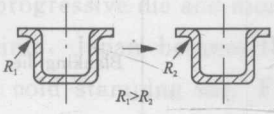
Cold stamping die is mainly used for sheet metal processing, and there are two processing types, separation and forming. Separation is to separate a workpiece from the sheet metal along a certain contour, while forming is to obtain the required shape and dimensional precision by plastic deformation without damaging the sheet metal.

The typical cold stamping dies are listed in Tab. 1.1.

Tab. 1.1 Typical cold stamping dies

Type	Name		Die sketch	Die characteristics
Separation	Shearing die			To cut sheet metal with the cutting line not closed.
	Blanking	Blanking die		To cut sheet metal along the closed line to obtain the cutting part as the workpiece. 
		Piercing die		To cut sheet metal along the closed line with the cutting part as the scrap. 
	Trimming die			To cut the excessive material of the workpiece boundary. 

(continued)

Type	Name	Die sketch	Die characteristics
Forming	Bending die		To bend sheet metal to a certain angle or shape. 
	Drawing die		To draw sheet metal into a hollow workpiece for arbitrary shape. 
	Flanging die		To form a hole on the sheet metal or the outer edge into a vertical straight wall. 
	Sizing die		To press uneven surface of the workpiece, and correct shape of the drawing workpiece or bent workpiece. 

Questions

1. What is the role of cold stamping die in modern industrial production?
2. Discuss the modern cold stamping die technology and its development status.
3. How many types do the cold stamping dies have?

Chapter 2 Blanking Die Design

Blanking die is the die used to separate a workpiece from the piece, the strip or semi-finished products along a predetermined outline. Usually it refers to the blanking die and the piercing die.

Simple blanking die is shown in Fig. 2.1.

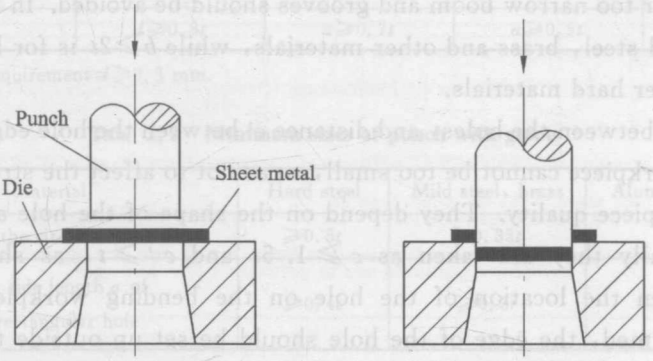


Fig. 2.1 Simple blanking die

Based on different requirements on size and precision of workpiece, the blanking die can be classified into general blanking die and fine blanking die. The following is about general blanking die, known as blanking die.

2.1 Foundation of blanking die design

2.1.1 Technological characteristics of the blanking workpiece

Technological characteristics of the blanking workpiece focus on the fitness of the blanking workpiece for stamping. It is a technological requirement on product design that put forward from the perspective of stamping. A good process has little material consumption, few numbers of steps, simple but long-life die structure, stable product quality and simple operation.

1. Structure technological characteristic of the blanking workpiece

The workpiece produced by general stamping shows the significant regional characteristics because its cross-sectional area is not perpendicular to the workpiece surface. When the workpiece is produced by blanking die with suitable clearance, its bright region can

be up to 30% of the workpiece thickness with an obvious fillet angle on the side of die, a height of burrs on the side of punch less than 0.05 mm and the shape doming to a certain degree. The above features are unique of the general stamping, and it must be considered when selecting the stamping process. When the shape of a blanking workpiece is designed, the following issues should be considered.

① The shape of the blanking workpiece should be simple and regular to get the minimum waste in the nesting.

② Sharp corners must be avoided. If there are some special requirements, $R>0.25t$ rounded transition should be allowed.

③ Too long or too narrow boom and grooves should be avoided. In Fig. 2.2, the width $b\geqslant 1.5t$ is for mild steel, brass and other materials, while $b\geqslant 2t$ is for high-carbon steel or alloy steel and other hard materials.

④ Distance c between the holes, and distance c' between the hole edge and the boundary of the blanking workpiece cannot be too small, so as not to affect the strength of the die and the blanking workpiece quality. They depend on the shape of the hole and thickness of the sheet metal. Usually they are taken as $c\geqslant 1.5t$ and $c'\geqslant t$, as shown in Fig. 2.2. Furthermore, when the location of the hole on the bending workpiece or the drawing workpiece is confirmed, the edge of the hole should be set up outside two interface radius regions to protect the punch edge from damage and a small punch from break due to side pressure with asymmetry acting on the punch during the piercing process. Usually the distance l between the hole edge and the wall of workpiece is taken as $l\geqslant R+0.5t$, as shown in Fig. 2.3.

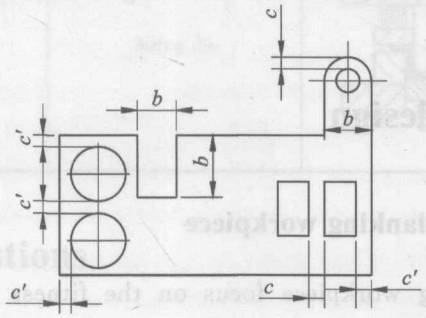


Fig. 2.2 Blanking workpiece shape

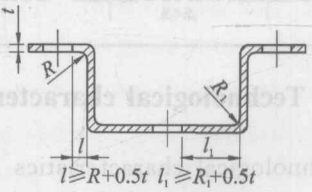
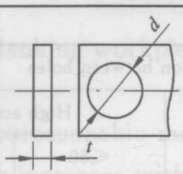
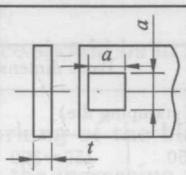
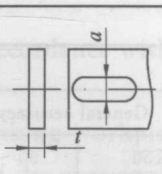
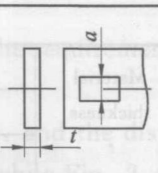


Fig. 2.3 Hole location on the bending workpiece

⑤ A hole that big enough should be designed to avoid damaging punch. Its minimum size depends on its shape, material type, thickness of sheet metal, and the guide device during the punch operation. The minimum sizes of punch without guide are listed in Tab. 2.1, while the minimum sizes of punch with guide are listed in Tab. 2.2. The latter is less than the former because it increases the stability of the punch operation.

Tab. 2.1 Minimum sizes of punch without guide

Material				
Steel σ_b>700 MPa	$d \geqslant 1.5t$	$a \geqslant 1.35t$	$a \geqslant 1.1t$	$a \geqslant 1.2t$
Steel σ_b=400~700 MPa	$d \geqslant 1.3t$	$a \geqslant 1.2t$	$a \geqslant 0.9t$	$a \geqslant 1.0t$
Steel σ_b<400 MPa	$d \geqslant 1.0t$	$a \geqslant 0.9t$	$a \geqslant 0.7t$	$a \geqslant 0.8t$
Brass, copper	$d \geqslant 0.9t$	$a \geqslant 0.8t$	$a \geqslant 0.6t$	$a \geqslant 0.7t$
Aluminum, zinc	$d \geqslant 0.8t$	$a \geqslant 0.7t$	$a \geqslant 0.5t$	$a \geqslant 0.6t$

Note: Normal requirement $d \geqslant 0.3$ mm.

Tab. 2.2 Minimum sizes of punch with guide

Material	Hard steel	Mild steel, brass	Aluminum, zinc
d of the circular hole	$\geqslant 0.5t$	$\geqslant 0.35t$	$\geqslant 0.3t$
Short side length a of the rectangular hole	$\geqslant 0.4t$	$\geqslant 0.3t$	$\geqslant 0.28t$

Note: Normal requirement $d \geqslant 0.3$ mm.

2. Dimensional precision and cross-sectional roughness of the blanking workpiece

When we calculate the dimension of the punch and die, if there is no dimensional tolerances noted on the drawing of workpiece, they are chosen by GB 1800—1979 IT14 level as shown in Tab. 7.9. The dimensional accuracy, the dimensional tolerance between two holes' centers, the dimensional tolerance between the hole's center and the edge of the sheet metal, the angle deviation of the blanking workpiece and the approximate surface roughness of shear section that the inner and outer shapes of the normal blanking workpiece can achieve are shown in Tab. 2.3 ~ Tab. 2.7.

Tab. 2.3 Dimensional accuracies of the blanking workpiece

Unit: mm

Material thickness t	Basic dimension				
	≤3	3~6	6~10	10~18	18~500
≤1	IT12~IT13			IT11	
1~2	IT14	IT12~IT13			IT11
2~3	IT14			IT12~IT13	
3~5	—	IT14			IT12~IT13

Tab. 2.4 Dimensional tolerances between two holes' centers

Unit: mm

Material thickness t	Basic dimension between holes					
	General accuracy (stamping die)			High accuracy (stamping die)		
	≤50	50～150	150～300	≤50	50～150	150～300
≤1	±0.1	±0.15	±0.2	±0.03	±0.05	±0.08
>1～2	±0.12	±0.2	±0.3	±0.04	±0.06	±0.1
>2～4	±0.15	±0.25	±0.35	±0.06	±0.08	±0.12
>4～5	±0.2	±0.3	±0.40	±0.08	±0.10	±0.15

Note: 1. Piercing two holes at the same time;

2. General precision of stamping die: dimensional tolerance of the die edge is up to IT8, back angle of the die is 15′～30′;

3. High precision of stamping die: dimensional tolerance of the die edge is up to or higher than IT7, back angle of the die is less than 15′.

Tab. 2.5 Dimensional tolerances between the hole's center and the edge of the sheet metal

Unit: mm

Material thickness t	Basic dimension of the hole's center and the edge of the sheet metal			
	≤50	50～120	120～220	220～360
≤2	±0.5	±0.6	±0.7	±0.8
>2～4	±0.6	±0.7	±0.8	±1.0
>4	±0.7	±0.8	±1.0	±1.2

Note: First blanking and then piercing.

Tab. 2.6 Angle deviations of the blanking workpiece

Accuracy level	Length of the short side/mm												
	1～3	3～6	6～10	10～18	18～30	30～50	50～80	80～120	120～180	180～260	260～360	360～500	>500
High accuracy	±2°30′	±2°	±1°30′	±1°15′	±1°	±50′	±40′	±30′	±25′	±20′	±15′	±12′	±10′
General accuracy	±4°	±3°	±2°30′	±2°	±1°30′	±1°15′	±1°	±50′	±40′	±30′	±25′	±20′	±15′

Tab. 2.7 Surface roughness of shear section

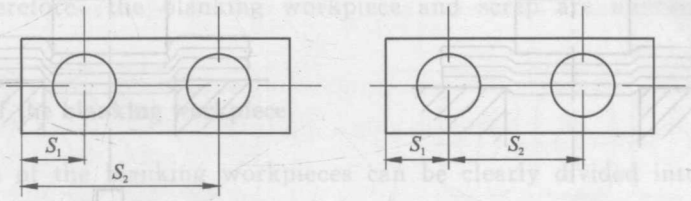
Material thickness t/mm	≤1	1～2	2～3	3～4	4～5
Surface roughness of shear section Ra/μm	3.2	6.3	12.5	25	50

Note: If the surface roughness of shear section of the blanking workpiece is higher than the corresponding value in Tab. 2.7, the extra sizing process is needed. Therefore, the surface roughness of shear section of different materials are 0.4 μm for brass, 0.4～0.8 μm for mild steel and 0.8～1 6 μm for hard steel.

3. Size marking of the blanking workpiece

Size marking of the blanking workpiece should be in accordance with the requirements of stamping process.

Fig. 2.4 (a) shows unreasonable marking of the blanking workpiece, and the distance between two holes' centers increases with the increasing of die abrasion, while Fig. 2.4 (b) shows reasonable marking of the blanking workpiece, and the distance between two holes' centers cannot change with the increasing of die abrasion, so the dimension tolerance can be reduced.



(a) Unreasonable marking (b) Reasonable marking

Fig. 2.4 Size marking of the blanking workpiece

2.1.2 Analysis of the blanking process

1. Force analysis of the sheet metal during the blanking

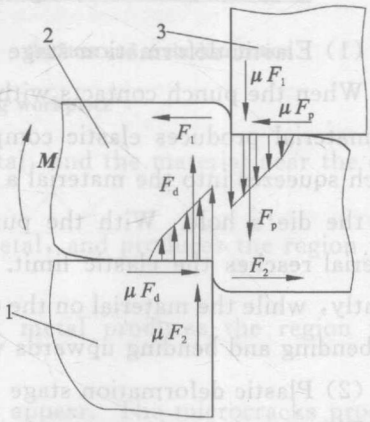
In the blanking process without blankholder, the forces acting on the sheet metal are shown in Fig. 2.5, where

F_p、F_d——Vertical resultant acting on the sheet metal produced by the punch or die;

F_1、F_2——Horizontal pressure force acting on the sheet metal produced by the punch or die;

μF_p、μF_d——Friction between the end surface of the punch or die and the sheet metal, they are perpendicular to F_p and F_d respectively, and generally point to the die or punch edge (μ is the friction coefficient, same as follows);

μF_1、μF_2——Friction between the side surface of punch or die and the sheet metal, they are perpendicular to F_1 and F_2 respectively, and generally point to the die or punch edge.



1—Die; 2—Sheet metal; 3—Punch

Fig. 2.5 Forces acting on the sheet metal

In Fig. 2.5, the sheet metal bends due to the moment of couple produced by the end