

金属材料 弯曲试验方法

1 范围

本标准规定了测定金属材料承受弯曲塑性变形能力的试验方法。

本标准适用于金属材料相关产品标准规定试样的弯曲试验,但不适用于金属管材和金属焊接接头的弯曲试验,金属管材和金属焊接接头的弯曲试验由其他标准规定。

2 规范性引用文件

下列标准所包含的条文,通过在本标准中引用而成为本标准的条文。凡是注日期的引用文件,其随后所有的修改单(不包括勘误的内容)或修订版均不适用于本标准,然而,鼓励根据本标准达成协议的各方研究是否可使用这些文件的最新版本。凡是不注日期的引用文件,其最新版本适用于本标准。

GB/T 2975 钢及钢产品 力学性能试验取样位置及试样制备(GB/T 2975—1998,eqv ISO 377:1997)

3 符号和说明

本标准使用的符号和说明见表1及图1、图2、图3和图B.1。

表1 符号和说明

符号	说 明	单 位
a	试样厚度或直径(或多边形横截面内切圆直径)	mm
b	试样宽度	mm
L	试样长度	mm
l	支辊间距离	mm
D	弯曲压头直径	mm
α	弯曲角度	(°)
r	试样弯曲后的弯曲半径	mm
f	弯曲压头的移动距离	mm
c	试验前支辊中心轴所在水平面与弯曲压头中心轴所在水平面之间的间距	mm
p	试验后支辊中心轴所在垂直面与弯曲压头中心轴所在垂直面之间的间距	mm

4 原理

弯曲试验是以圆形、方形、矩形或多边形横截面试样在弯曲装置上经受弯曲塑性变形,不改变加力方向,直至达到规定的弯曲角度。

弯曲试验时,试样两臂的轴线保持在垂直于弯曲轴的平面内。如为弯曲180°角的弯曲试验,按照相关产品标准的要求,可以将试样弯曲至两臂直接接触或两臂相互平行且相距规定距离,可使用垫块控制规定距离。

Metallic Materials

Bend Test

1. Scope

This Standard specifies the test method to measure the ability of the metallic materials to bear the plastic deformation after bend.

This Standard applies to the bend test of test pieces regulated in applicable product standard of metallic materials. However, it does not apply to the bend tests for the metallic pipes and welded joints of metal. Instead, the bend tests for the metallic pipes and welded joints of metal are regulated in other standards.

2. Normative References

The provisions containing in the following normative documents, through reference in this text, constitute provisions of this Standard. For any dated references, the subsequent amendments to (excluding corrections), or revisions of any of these publications do not apply. However, the related parties reaching agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. For any undated references, the latest edition of the referenced document applies.

GB/T 2975 Steel and Steel Products - Location and Preparation of Test Pieces for Mechanical Testing (GB/T 2975-1998, eqv ISO 377:1997)

3. Symbols and Designations

The symbols and designations applied in this Standard are shown in Table 1, Figure 1, Figure 2, Figure 3 and Figure B.1.

Table 1 Symbols and Designations

Symbol	Designation	Unit
a	Thickness or diameter of the test piece (or diameter of inscribed circle for the cross section of polygon)	mm
b	Width of test piece	mm
L	Length of test piece	mm
l	Distance between supporting rollers	mm
D	Diameter of press head	mm
α	Bending angle	(°)
r	Bending radius of the test piece after bending	mm
f	Displacement distance of press head	mm
c	Distance between the horizontal plane of the center shaft for the supporting roller and that for the press head before the test	mm
p	Distance between the vertical plane of the center shaft for the supporting roller and that for the press head after the test	mm

4. Principle

The bend test is to bend the test piece with round, quadrate, rectangular or polygonal cross section with bending device to form plastic deformation without change of force applying direction unit it reaches the specified bending angle.

In bend test, the axial line of two arms of the test piece shall keep in the plane perpendicular to the bending axis. For the bend test with bending angle of 180° , in accordance with the requirements of applicable product standard, bend the test piece until the two arms contact with each other or the two arms keep parallel at a specified distance which can be controlled by the spacer.

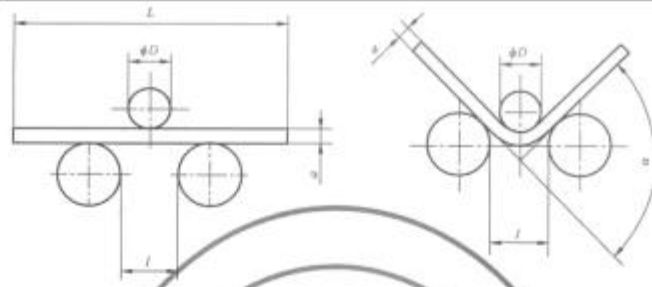


图 1



图 3

- 1—虎钳；
- 2—弯曲压头。

5 试验设备

5.1 一般要求

弯曲试验应在配备下列弯曲装置之一的试验机或压力机上完成：

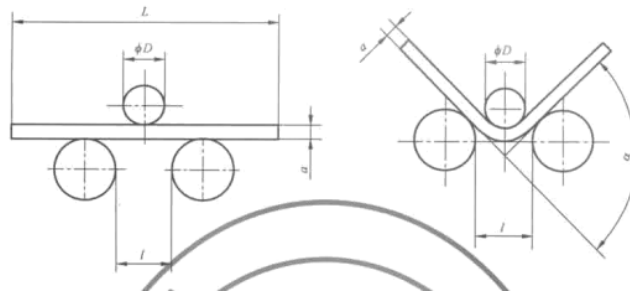


Figure 1

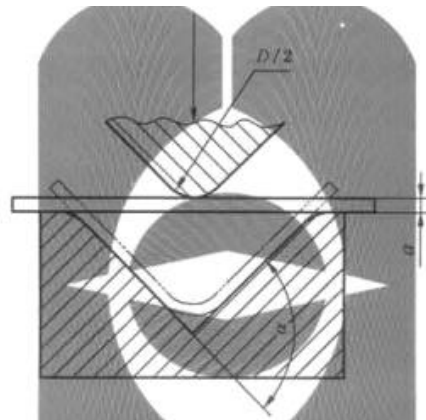
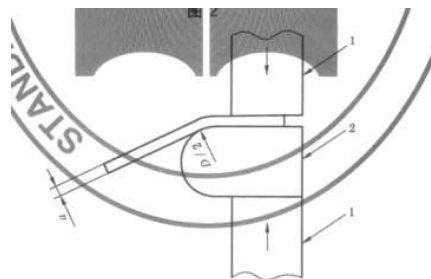


Figure 2



- 1 – Jaw vice;
- 2 – Press head

Figure 3

5. Test Equipment

5.1 General requirements

The bend test shall be completed by the testing machine or press machine equipped with any of the following bending devices:

a) 配有两个支辊和一个弯曲压头的支辊式弯曲装置,见图 1;

b) 配有一个 V 型模具和一个弯曲压头的 V 型模具式弯曲装置,见图 2;

c) 虎钳式弯曲装置,见图 3。

5.2 支辊式弯曲装置

5.2.1 支辊长度和弯曲压头的宽度应大于试样宽度或直径(见图 1)。弯曲压头的直径由产品标准规定。支辊和弯曲压头应具有足够的硬度。

5.2.2 除非另有规定,支辊间距离 l 应按公式(1)确定:

$$l = (D + 3a) \pm \frac{a}{2} \dots\dots\dots(1)$$

此距离在试验期间应保持不变。

注:此距离在试验前期保持不变,对于 180° 弯曲试样此距离会发生变化。

5.3 V 型模具式弯曲装置

模具的 V 形槽其角度应为 $(180^\circ - \alpha)$ (见图 2),弯曲角度 α 应在相关产品标准中规定。

模具的支承棱边应倒圆,其倒圆半径应为 $(1 \sim 10)$ 倍试样厚度。模具和弯曲压头宽度应大于试样宽度或直径并应具有足够的硬度。

5.4 虎钳式弯曲装置

装置由虎钳及有足够硬度的弯曲压头组成(见图 3),可以配置加力杠杆。弯曲压头直径应按照相关产品标准要求,弯曲压头宽度应大于试样宽度或直径。

由于虎钳左端面的位置会影响测试结果,因此虎钳的左端面(见图 3)不能达到或者超过弯曲压头中心垂线。

5.5 符合弯曲试验原理的其他弯曲装置(例如翻板式弯曲装置等)亦可使用。

6 试样

6.1 一般要求

试验使用圆形、方形、矩形或多边形横截面的试样。样坯的切取位置和方向应按照相关产品标准的要求。如未具体规定,对于钢产品,应按照 GB/T 2975 的要求。试样应去除由于剪切或火焰切割或类似的操作而影响了材料性能的部分。如果试验结果不受影响,允许不去除试样受影响的部分。

6.2 矩形试样的棱边

试样表面不得有划痕和损伤。方形、矩形和多边形横截面试样的棱边应倒圆,倒圆半径不能超过以下数值:

- 1 mm,当试样厚度小于 10 mm;
- 1.5 mm,当试样厚度大于或等于 10 mm 且小于 50 mm;
- 3 mm,当试样厚度不小于 50 mm。

棱边倒圆时不应形成影响试验结果的横向毛刺、伤痕或刻痕。如果试验结果不受影响,允许试样的棱边不倒圆。

6.3 试样的宽度

试样宽度应按照相关产品标准的要求,如未具体规定,应按照以下要求:

- a) 当产品宽度不大于 20 mm 时,试样宽度为原产品宽度;
- b) 当产品宽度大于 20 mm 时:
 - 当产品厚度小于 3 mm 时,试样宽度为 (20 ± 5) mm;
 - 当产品厚度不小于 3 mm 时,试样宽度在 20 mm~50 mm 之间。

6.4 试样的厚度

试样厚度或直径应按照相关产品标准的要求,如未具体规定,应按照以下要求:

- a) Bending device provided with two supporting rollers and one press head, as shown in Figure 1;
- b) Bending device provided with one V-shaped mould and one press head, as shown in Figure 2;
- c) Bending device provided with jaw vice, as shown in Figure 3.

5.2 Bending device provided with supporting rollers

5.2.1 The length of supporting roller and width of press head shall exceed the width or diameter of the test piece (as shown in Figure 1). The diameter of the press head is specified in the product standard. The supporting roller and press head shall be of

sufficient rigidity.

5.2.2 Unless otherwise specified, the distance between supporting rollers (l) shall be determined by formula (1):

$$l = (D + 3a) \pm \frac{a}{2} \quad (1)$$

The distance shall keep unchanged during testing.

Note: The distance keeps unchanged during the early stage of the test. For the test piece to be bent by 180°, the distance may change.

5.3 Bending device provided with V-shaped mould

The angle of V-shaped groove of the mould shall be $(180^\circ - \alpha)$ (as shown in Figure 2). The bending angle (α) shall be regulated in applicable product standard.

The supporting edge of the mould shall be of rounding and the rounding radius shall be (1~10) times of the test piece's thickness. The width of the mould and press head shall exceed the width or diameter of the test piece. And they shall be of sufficient rigidity.

5.4 Bending device with jaw vice

The device is composed of the jaw vice and press head with sufficient rigidity (as shown in Figure 3). In addition, the force-applying lever can be equipped additionally. The diameter of the press head shall meet the requirement in applicable product standard and its width shall exceed the width or diameter of the test piece.

As the position of the left end face of the jaw vice may influence the test result, it shall not reach or exceed the center vertical line of the press head (as shown in Figure 3).

5.5 The other bending devices (such as the bending device provided with reverse turning bed) meeting principle of bend test are available.

6. Test Piece

6.1 General requirements

In the test, test piece with round, quadrature, rectangular or polygonal cross section is adopted. The cutting position and direction of the rough sample shall meet the requirement of the applicable product standard. Where no specific provisions are

regulated, the test pieces for steel products shall meet the requirements in GB/T 2975. Remove the part influencing the material property caused by shearing, flame cutting or similar operation from the test piece. However, if such part does not influence the test result, the part is free from removal.

6.2 Edge of rectangular test piece

There shall be no scratch and damage on the surface of the test piece. The test pieces with quadrangle, rectangular or polygonal cross section shall be of rounding whose radius shall exceed the following numerical values:

- 1mm, in case the thickness of the test piece is less than 10mm;
- 1.5mm, in case the thickness of the test piece is more than or equal to 10mm but less than 50mm;
- 3mm, in case the thickness of the test piece is no less than 50mm.

In rounding of edge, there shall not appear such defects as transverse burr, scar or notch influencing the test result. However, if the test result is not influenced, the edge of the test piece is free from rounding.

6.3 Width of the test piece

The width of the test piece shall meet the requirements of applicable product standard. Where no specific provisions are regulated, the following requirements shall be met:

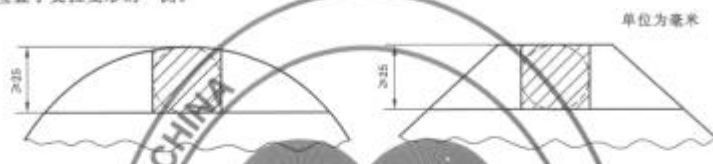
- a) In case the product width is not more than 20mm, the width of the test piece is the original width of the product;
- b) In case the product width is more than 20mm,
 - and the product thickness is less than 30mm, the width of the test piece is (20 ± 5) mm;
 - and the product thickness is not less than 30mm, the width of the test piece ranges from 20mm to 50mm.

6.4 Thickness of the test piece

The thickness or diameter of the test piece shall meet the requirements of applicable product standard. Where no specific provisions are regulated, the following requirements shall be met:

6.4.1 对于板材、带材和型材,试样厚度应为原产品厚度。如果产品厚度大于 25 mm,试样厚度可以机加工减薄至不小于 25 mm,并保留一侧原表面。弯曲试验时,试样保留的原表面应位于受拉变形一侧。

6.4.2 直径(圆形横截面)或内切圆直径(多边形横截面)不大于 30 mm 的产品,其试样横截面应为原产品的横截面。对于直径或多边形横截面内切圆直径超过 30 mm 但不大于 50 mm 的产品,可以将其机加工成横截面内切圆直径不小于 25 mm 的试样。直径或多边形横截面内切圆直径大于 50 mm 的产品,应将其机加工成横截面内切圆直径不小于 25 mm 的试样(见图 4)。试验时,试样未经机加工的原表面应置于受拉变形的一侧。



6.5 锻材、铸材和半成品的试样

对于锻材、铸材和半成品,其试样尺寸和形状应在交货要求或协议中规定。

6.6 大厚度和大宽度试样

经协议,可以按大于 6.3 条规定宽度和 6.4 条规定厚度的试样进行试验。

6.7 试样的长度

试样长度应根据试样厚度(或直径)和所使用的试验设备确定。

7 试验程序

特别提示:试验过程中应采取足够的安全措施和防护装置。

7.1 试验一般在 $10\text{--}35\text{ }^{\circ}\text{C}$ 的室温范围内进行。对温度要求严格的试验,试验温度应为 $(23\pm 5)\text{ }^{\circ}\text{C}$ 。

7.2 按照相关产品标准规定,采用下列方法之一完成试验:

- 试样在给定的力和力作用下弯曲至规定的弯曲角度(见图 1、图 2 和图 3)。
- 试样在力作用下弯曲至两臂相距规定距离且相互平行(见图 6)。
- 试样在力作用下弯曲至两臂直接接触(见图 7)。

7.3 试样弯曲至规定弯曲角度的试验,应将试样放于两支辊(见图 1)或 V 形模具(见图 2)上,试样轴线应与弯曲压头轴线垂直,弯曲压头在两支座之间的中点处对试样连续施加力使其弯曲,直至达到规定的弯曲角度。弯曲角度 α 可以通过测量弯曲压头的位移计算得出,见附录 B。

可以采用图 3 所示的方法进行弯曲试验。试样一端固定,按弯曲压头进行弯曲,可以绕过弯曲压头,直至达到规定的弯曲角度(详见 5.4)。

弯曲试验时,应当缓慢地施加弯曲力,以使材料能够自由地进行塑性变形。

当出现争议时,试验速率应为 $(1\pm 0.2)\text{ mm/s}$ 。

使用上述方法如不能直接达到规定的弯曲角度,可将试样置于两平行压板之间(见图 5),连续施加力压其两端使进一步弯曲,直至达到规定的弯曲角度。

7.4 试样弯曲至两臂相互平行的试验,首先对试样进行初步弯曲,然后将试样置于两平行压板之间(见图 5),连续施加力压其两端使进一步弯曲,直至两臂平行(见图 6)。试验时可以加或不加内置垫块。垫块厚度等于规定的弯曲压头直径,除非产品标准中另有规定。

7.5 试样弯曲至两臂直接接触的试验,首先对试样进行初步弯曲,然后将试样置于两平行压板之间,连续施加力压其两端使进一步弯曲,直至两臂直接接触(见图 7)。

6.4.1 For the plates, strips and proximate matters, the thickness of test piece shall be the original thickness of the product. In case the product thickness exceeds 25mm, the thickness of the test piece can be decreased to such extent as not less than 25mm by machining and one original surface is retained. In bend test, the surface retained shall be such face as bearing tensile deformation.

6.4.2 For the product with its diameter (round cross section) or that of inscribed circle (polygonal cross section) not more than 30mm, the cross section of the test piece shall be the original cross section of the product. For the product with its diameter or that of inscribed circle (polygonal cross section) exceeding 30mm but not more than 50mm,

the diameter of inscribed circle for the polygonal cross section of the test piece can be decreased to such extent as not less than 25mm by machining. For the product with its diameter or that of inscribed circle (polygonal cross section) exceeding 50mm, the diameter of inscribed circle for the polygonal cross section of the test piece can be decreased to such extent as not less than 25mm by machining (as shown in Figure 4). In test, the original surface retained of the test piece shall be such face as bearing tensile deformation.

Unit: mm

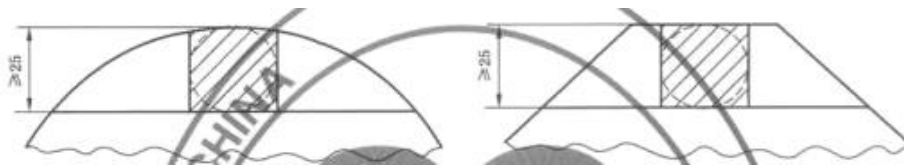


Figure 4

6.5 Test pieces of forgings, castings and semi-finished products

For the forgings, castings and semi-finished products, the dimension and shape of the test pieces shall be regulated within delivery requirements or in the agreement.

6.6 Test pieces with heavy thickness and large width

Upon agreement, it is permissible to apply the test pieces with the width exceeding that specified in 6.3 and the thickness exceeding that specified in 6.4 in test.

6.7 Length of the test piece

The length of the test piece shall be determined according to the thickness (or diameter) and the test equipment used.

7. Test Procedures

7.1 The test is always conducted under the ambient temperature of 10 °C~35 °C. With regard to the test having strict temperature requirement, the testing temperature shall be (23±5) °C.

7.2 In accordance with the applicable product standard, complete the test by any one of the following methods:

a) The test piece is bent to the bending angle under the given condition and the action of proper force (as shown in Figure 1, Figure 2 and Figure 3);

b) The test piece is bent to such extent as the two arms parallel to each other at the specified distance under the action of proper force (as shown in Figure 6);

c) The test piece is bent to such extent as the two arms contacting with each other under the action of proper force (as shown in Figure 7).

7.3 For the test in which the test piece is bent to the specified bending angle, place the test piece on the two supporting rollers (as shown in Figure 1) or V-shaped mould (as shown in Figure 2), keeping the axial line perpendicular to that of press head. The press head applies force to bend the test piece continuously at the midpoint of the two seats until the test piece bends to the specified bending angle (α) which can be determined by measuring the displacement of the press head, as shown in Appendix B.

It is available to conduct bend test by the method shown in Figure 3. Fix one end of the test piece and bend it by winding the press head until it reaches the specified bending angle. (For details, see 5.4)

In bend test, apply the bending force slowly so that the material can achieve plastic deformation freely.

In case of dispute, the test rate shall be (1 ± 0.2) mm/s.

Where the test piece cannot be bent to the specified bending angle directly by the mentioned method, place the test piece between the two parallel pressing plates (as shown in Figure 5) and apply the force to both ends continuously so that the test piece bends further until it reaches the specified bending angle.

7.4 For the test in which the test piece is bent to such extent as the two arms parallel to each other, bend the test piece initially. Then place the test piece between the two parallel pressing plates (as shown in Figure 5) and apply the force to both ends continuously so that the test piece bends further until its two arms get parallel to each other (as shown in Figure 6). In test, the built-in spacer can be either used or not. Unless otherwise regulated in applicable product standard, the thickness of the spacer is equal to the specified diameter of the press head.

7.5 For the test in which the test piece is bent to such extent as the two arms contact with each other, bend the test piece initially. Then place the test piece between the two

parallel pressing plates and apply the force to both ends continuously so that the test piece bends further until its two arms contact with each other (as shown in Figure 7).

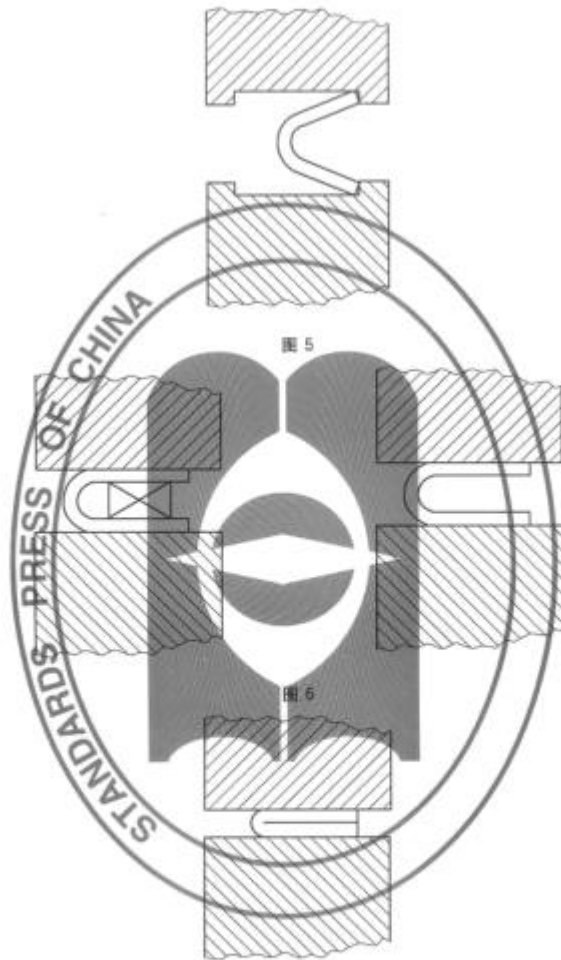


图 7

8 试验结果评定

8.1 应按照相关产品标准的要求评定弯曲试验结果。如未规定具体要求，弯曲试验后不使用放大仪器观察，试样弯曲外表面无可见裂纹应评定为合格。

8.2 以相关产品标准规定的弯曲角度作为最小值；若规定弯曲压头直径，以规定的弯曲压头直径作为最大值。

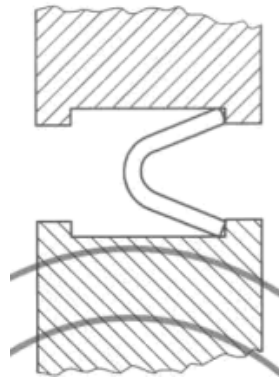


Figure 5

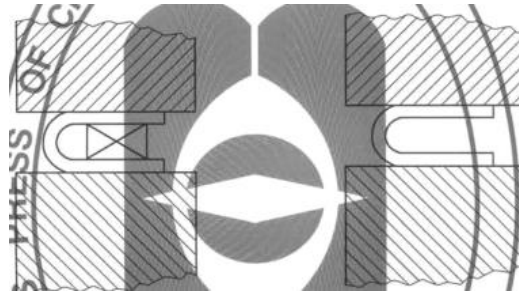


Figure 6

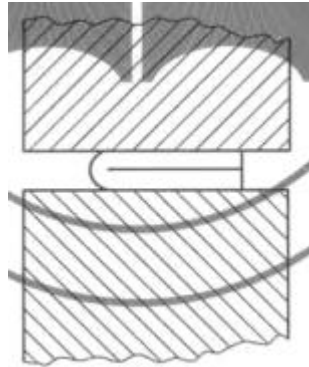


Figure 7

8. Judgment of Test Results

8.1 Judge the test results in accordance with the requirements of applicable product standard. Where no specific provisions are regulated, do not observe the test piece with amplifier after bend test. And it is judged to be qualified only if there is no visible crack on the bent surface of the test piece.

8.2 Define the bending angle specified by the applicable product standard as the minimum value. Where the diameter of press head is specified, it is defined as the maximum value.