INTERNATIONAL STANDARD

ISO 9013

Second edition
2002-09-15

Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances

Coupage thermique — Classification des coupes thermiques — Spécification géométrique des produits et tolérances relatives à la qualité

Reference number
ISO 9013:2002(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9013 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 8, *Equipment for gas welding, cutting and allied processes*.

This second edition cancels and replaces the first edition (ISO 9013:1992), which has been technically revised.

Annexes A and B of this International Standard are for information only.

Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances

1 Scope

This International Standard applies to materials suitable for oxyfuel flame cutting, plasma cutting and laser cutting. It is applicable to flame cuts from 3 mm to 300 mm, plasma cuts from 1 mm to 150 mm and to laser cuts from 0,5 mm to 40 mm. This International Standard includes geometrical product specifications and quality tolerances.

The geometrical product specifications are applicable if reference to this International Standard is made in drawings or pertinent documents, e.g. delivery conditions.

If this International Standard is also to apply, by way of exception, to parts which are produced by different cutting processes (e.g. high-pressure water jet cutting), this has to be agreed upon separately.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1101:1983, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings*

ISO 1302:2002, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation*

ISO 2553, *Welded, brazed and soldered joints — Symbolic representation on drawings*

ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO 8015, *Technical drawings — Fundamental tolerancing principle*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

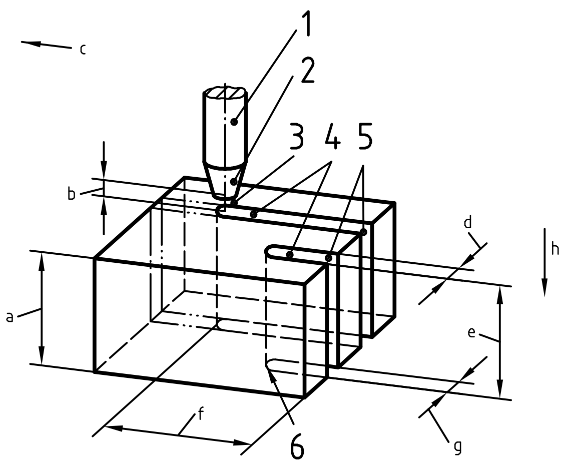
3.1 General

Nouns referring to the cutting operation will be formed by using the key word “cutting” (e.g. advance cutting direction); nouns referring to the cut carried out will be formed by using the key word “cut” (e.g. cut surface).

3.2 Terms and definitions explained by figures

NOTE Figure 1 indicates the terms related to the cutting process of the work piece after the cutting process has started, Figure 2 indicates the terms for the finished work piece. Figure 3 shows a straight cut and Figure 4 a contour cut.

3.2.1 Terms on the started work piece



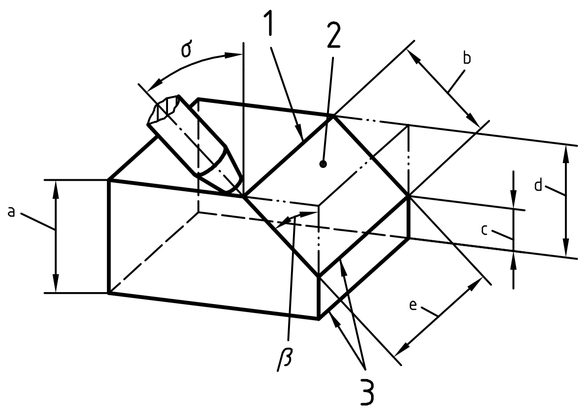
Key

1 Torch
2 Nozzle
3 Beam/flame/arc
4 Kerf
5 Start of cut
6 End of cut

[a] Work piece thickness
[b] Nozzle distance
[c] Advance direction
[d] Top kerf width
[e] Cut thickness
[f] Length of cut
[g] Bottom kerf width
[h] Cutting direction

Figure 1 — Terms related to the cutting process of the work piece

3.2.2 Terms on the finished work piece



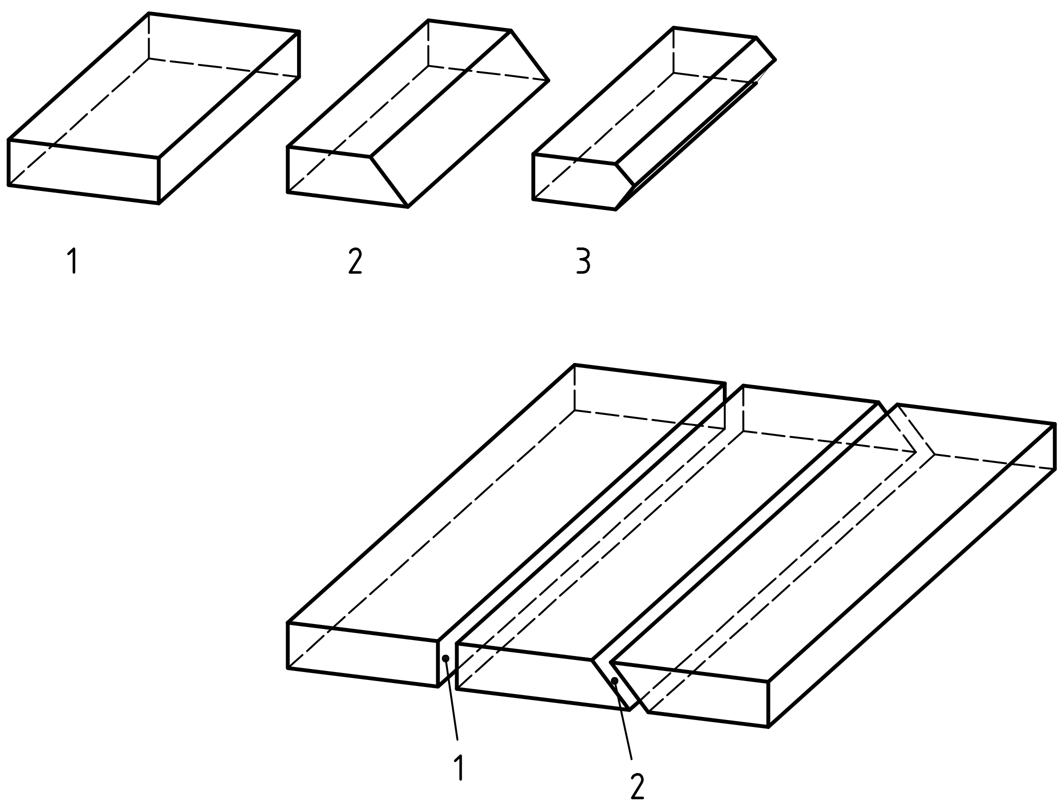
Key

1 Upper edge of cut
2 Cut surface
3 Lower edge of cut

a Work piece thickness
b Cut thickness (first possibility)
c Depth of root face/cut thickness (first possibility)
d Cut thickness (second possibility)
e Length of cut

Figure 2 — Terms on the finished work piece

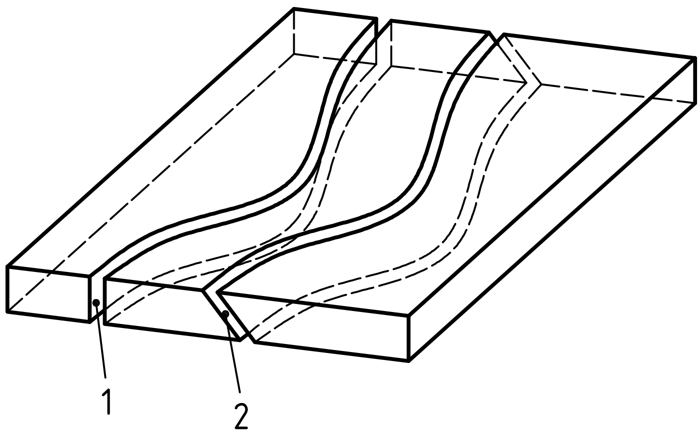
3.2.3 Cutting types



Key

1 Vertical cut
2 Bevel cut
3 Bevel cut (double)

Figure 3 — Straight cut



Key

1 Vertical cut

2 Bevel cut

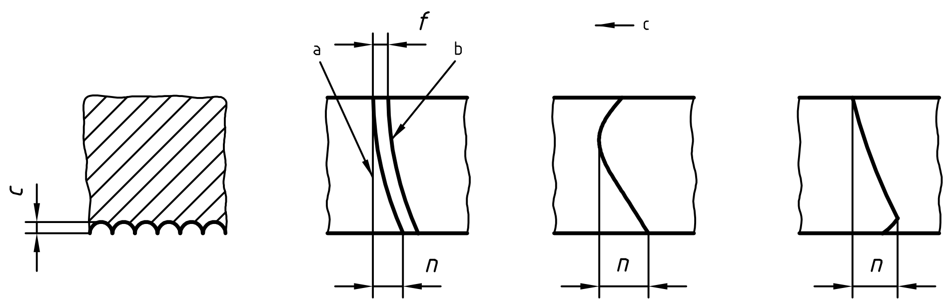
Figure 4 — Contour cut

3.3
cutting speed
relative speed between tool, e.g. flame blowpipe, and work piece

3.4
kerf width
distance of the cut surfaces at the upper edge of cut or with existing melting of top edge immediately below, as caused by the cutting jet

3.5
drag
n
projected distance between the two points of a drag line in the direction of cutting

See Figure 5.



[a] Reference line

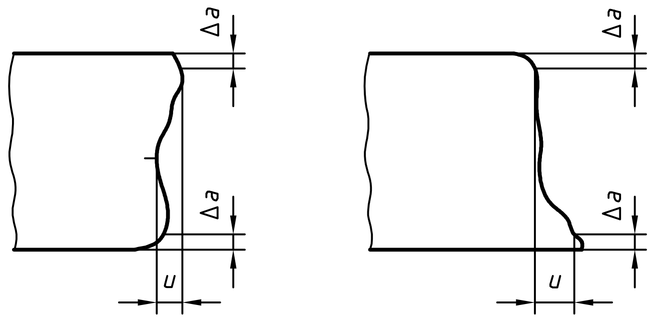
[b] Drag line

[c] Advance direction

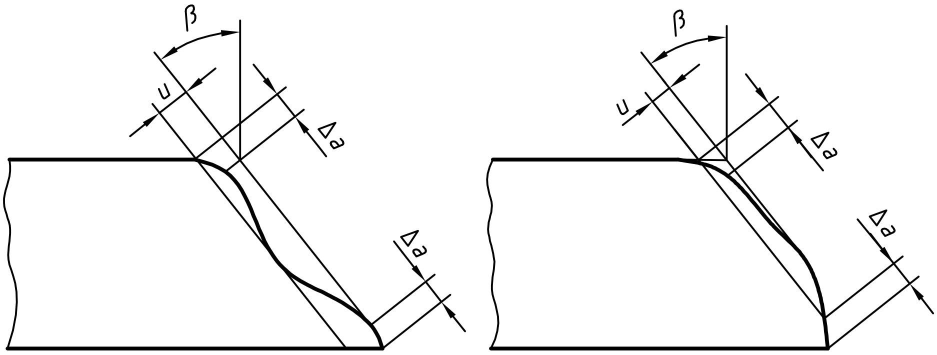
Figure 5 — Drag line

3.6
perpendicularity or angularity tolerance
u
distance between two parallel straight lines (tangents) between which the cut surface profile is inscribed, and within the set angle (e.g. 90° in the case of vertical cuts)

NOTE The perpendicularity or angularity tolerance includes not only the perpendicularity but also the flatness deviations. Figures 6 and 7 show the maximum effective deviations within the tolerance class.



a) Vertical cut



b) Bevel cut

Figure 6 — Perpendicularity and angularity tolerances

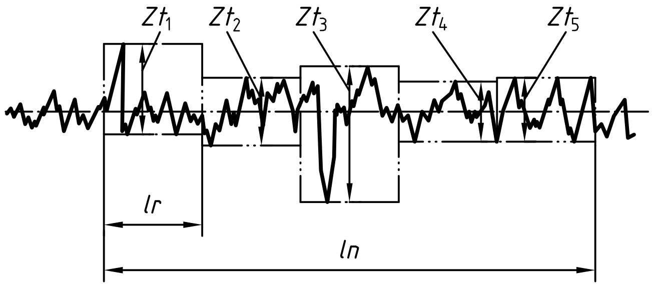
3.7
profile element height
Zt
sum of the height of the peak and depth of the valley of a profile element

[ISO 4287:1997]

3.8
mean height of the profile
*Rz*5
arithmetic mean of the single profile elements of five bordering single measured distances

See Figure 7.

NOTE The index 5 in *Rz*5 was added to distinguish the arithmetic mean and the maximum height of profile of the five single profile elements.



where

Zt_1 to Zt_5	represent single profile elements;
ln	is the evaluation length;
lr	is the single sampling length (1/5 of ln).

Figure 7 — Mean height of the profile

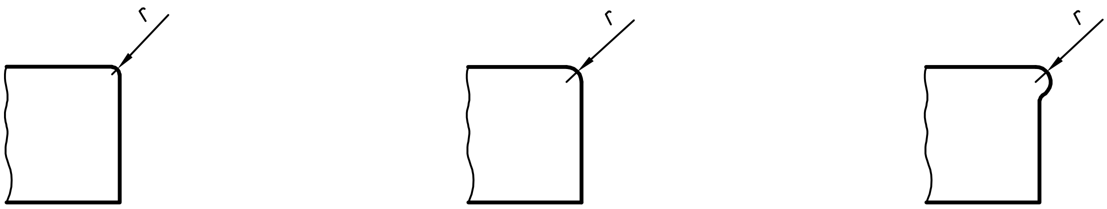
3.9
melting of top edge

r

measure characterizing the form of the upper edge of cut

NOTE The latter may be a sharp edge, a molten edge or cut edge overhang.

See Figure 8.



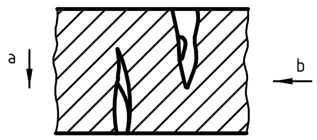
a) Sharp edge **b) Molten edge** **c) Cut edge overhang**

Figure 8 — Melting

3.10
gouging

scourings or kerves of irregular width, depth and shape, preferably in the direction of the cut thickness, which interrupt an otherwise uniform cut surface

See Figure 9.



a Cutting direction

b Advance direction

Figure 9 — Gouging

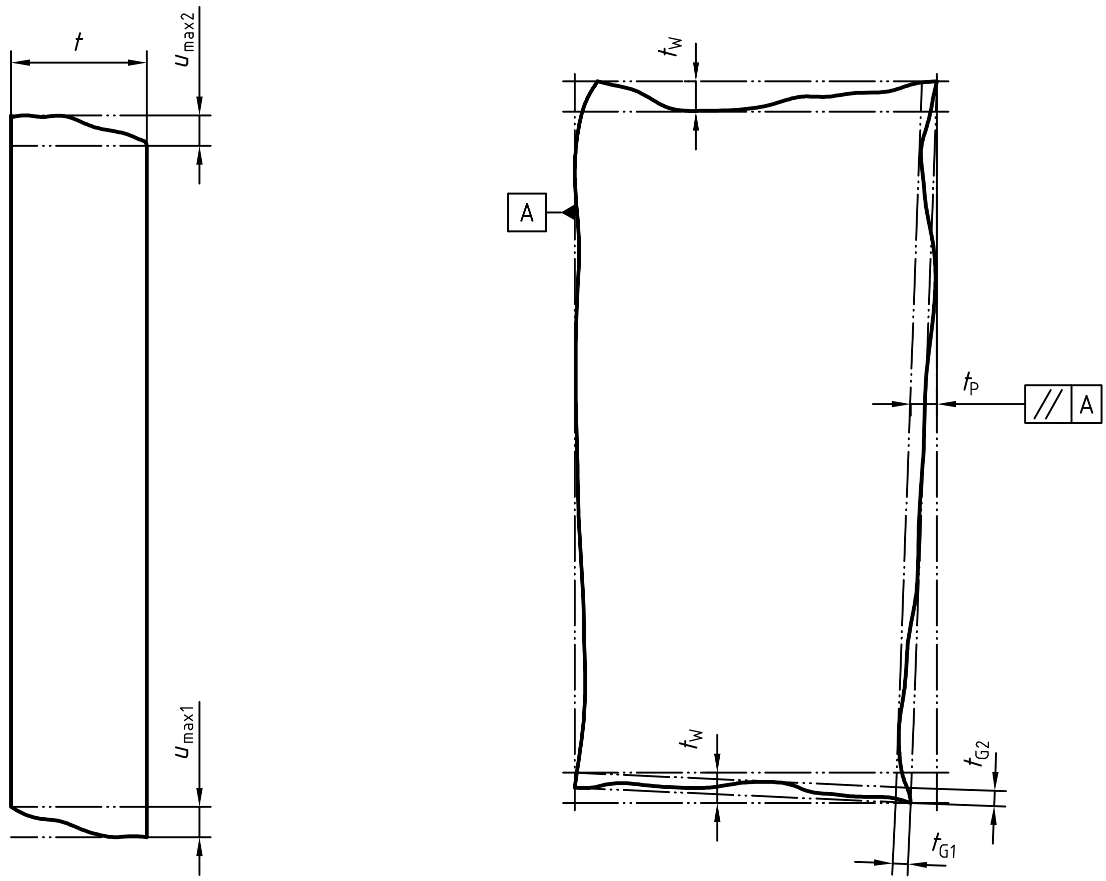
4 Symbols

For the purposes of this International Standard, the following symbols for dimensional indications apply.

Symbol	Term
a	Cut thickness
Δa	Thickness reduction
B_z	Machining allowance
c	Groove depth
f	Pitch of drag line
G_o	Upper limit deviation
G_u	Lower limit deviation
ln	Evaluation length
lr	Single sampling length
n	Drag
r	Melting of top edge
$Rz5$	Mean height of the profile
t	Work piece thickness
t_G	Straightness tolerance
t_P	Tolerance of parallelism
t_W	Perpendicularity tolerance
u	Perpendicularity or angularity tolerance
Zt	Profile element height
β	Angle of bevel of cut
σ	Nozzle (setting) angle

5 Form and location tolerances

Figure 10 shows the maximum deviations within the tolerance zone.



a) Through thickness

b) Flat

where

- u is the perpendicularity tolerance (see 14.8 of ISO 1101:1983) in cutting direction;
- t_W is the perpendicularity tolerance (see 14.8 of ISO 1101:1983) for cut width referred to A;
- t_P is the parallelism tolerance (see 14.7 of ISO 1101:1983) for cut width referred to A on sheet level;
- t_{G1} is the straightness tolerance (see 14.1 of ISO 1101:1983) for cut length;
- t_{G2} is the straightness tolerance (see 14.1 of ISO 1101:1983) for cut width.

Figure 10 — Form and location tolerances shown by the example of a sheet plate

6 Determination of the quality of cut surfaces

6.1 General

These requirements serve the purpose of indicating measuring procedures and measuring instruments by means of which it is possible to determine and evaluate the characteristic values of cut surfaces.

When choosing the measuring instruments, care has to be taken that the error limits are not above 20 % of the values of the characteristic values to be measured. Tables 1 and 2 indicate the precision and coarse measuring instruments for the characteristic values.

Table 1 — Precision measuring instruments

Symbol	Precision measuring instruments	
	Error limits	Examples
u	0,02 mm	Guide device in the direction of the cut thickness and of the nominal angle with dial gauge Contact stylus point angle ⩽ 90° Contact stylus point radius ⩽ 0,1 mm
$Rz5$	0,002 mm	Precision measuring instrument, e.g. electric contact stylus instrument for continuous scanning in cutting direction
n	0,05 mm	Measuring microscope with crosswires and cross-slide of sufficient adjustability
r	0,05 mm	Special device for scanning the profile of the cut upper edge by a dial gauge
Straightness	0,2 mm	Steel wire with max. 0,5 mm diameter, feeler gauge

Table 2 — Coarse measuring instruments

Symbol	Coarse measuring instruments	
	Error limits	Examples
u	0,1 mm	Tri-square (workshop square with a degree of precision 1 or 2), for bevel cuts, bevel gauge or set square set to the nominal angle of bevel of cut or set angle, for this purpose depth gauge with sensing point, measuring wire, feeler gauge
$Rz5$	—	—
n	0,2 mm	Tri-square (workshop square) for bevel cuts, sliding square or set square, for this purpose caliper gauge with nonius or graduated ruler with nonius. Bevel gauge with conversion table from the drag angle to the drag length
r	0,1 mm	Convex gauge (radius gauge)
Straightness	0,2 mm	Steel wire with max. 0,5 mm diameter, feeler gauge

6.2 Measuring

6.2.1 Measuring conditions

Measurements shall be carried out on brushed, free-from-oxides cuts outside areas including imperfections.

As reference element, the upper and lower sides of the thermally-cut work piece are taken. They shall be even and clean.

For defining the straightness, the reference element and the straight measuring line shall be aligned to one another so that the maximum distance between the straight measuring lines and the real surface equals a minimum. The minimum condition is explained in detail in 3.7 of ISO 1101:1983.

6.2.2 Measuring point

6.2.2.1 General

The number and location of the measuring points depend on the shape and size of the work piece and sometimes also on the intended use. The following indications may serve as a guideline.

The cut surfaces are classified in the tolerance fields according to the maximum measured values. Therefore, the measuring points shall be located where the maximum measured values are to be expected. When choosing the measuring points due consideration shall be given to the fact that the maximum values of the mean height of the profile and of the perpendicularity or angularity tolerance may be found at different points of the cut. If measured values are located at the lower limit of a tolerance field, additional measurements should be carried out due to the uncertainty of the visual selection of the point with the expected maximum measured value. If measured values are located at the upper limit of the tolerance field or if there are any doubts regarding some measuring results, supplementary measurements shall be carried out on the same number of additional measuring points.

6.2.2.2 Number of the measuring points

The number and location of the measuring points shall be defined by the manufacturer.

If no requirement is specified, carry out:

u two times three measurements at a distance of 20 mm each on each meter of the cut;

$Rz5$ one time one measurement on each meter of the cut.

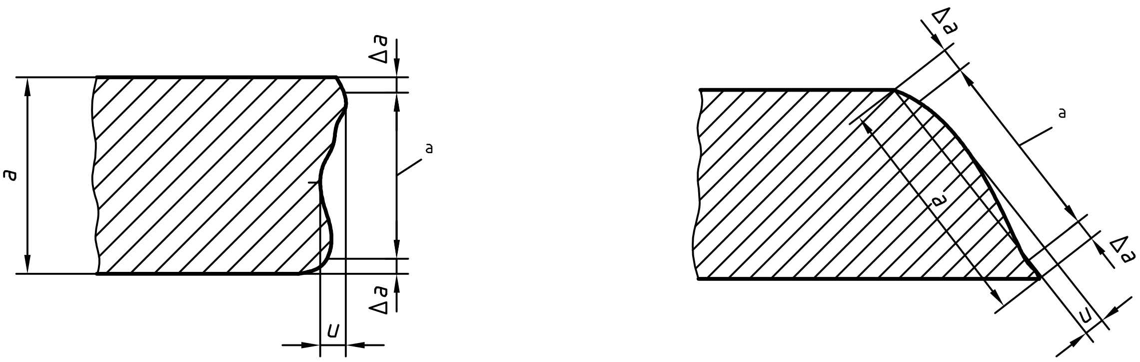
6.2.2.3 Location of the measuring points

The characteristic value of perpendicularity or angularity tolerance u only will be determined in a limited area of the cut surface. The area shall be reduced by the dimension Δa according to Table 3 from the upper and the lower cut surface edges (see Figure 11).

The reason for the reduced cut face profile is to allow for the melting of the top edge.

Table 3 — Dimensions for Δa

Cut thickness, a mm	Δa mm
$\leqslant 3$	$0{,}1a$
$> 3 \leqslant 6$	0,3
$> 6 \leqslant 10$	0,6
$> 10 \leqslant 20$	1
$> 20 \leqslant 40$	1,5
$> 40 \leqslant 100$	2
$> 100 \leqslant 150$	3
$> 150 \leqslant 200$	5
$> 200 \leqslant 250$	8
$> 250 \leqslant 300$	10



a) Vertical cut

b) Bevel cut

[a] Area for determination of the perpendicularity and angularity tolerances

Figure 11 — Definition of the measuring range for perpendicularity and angularity tolerances

For cut thicknesses below 2 mm, the measuring procedure to determine the perpendicularity or angularity tolerance specifically has to be agreed upon.

The characteristic value of the mean height of the profile *Rz*5 only will be determined in a limited area of the cut surface. The measurement is carried out at the point of the maximum surface roughness of the cut thickness, in accordance with ISO 4288. For oxyfuel flame cutting as well as for plasma cutting, the measurement typically takes place at a distance of 2/3 of the cut thickness from the upper cut edge; for laser cutting in the upper third from the upper cut edge. For cut thicknesses below 2 mm, the measurement is carried out at a distance of 1/2 of the cut thickness from the upper cut edge.

6.2.3 Procedure

The characteristic values for the cut surfaces will be determined, according to the type of measurement, by means of the corresponding instruments listed in Tables 1 and 2.

The mean height of the profile *Rz*5 shall be measured at 15 mm from the cut length in the advance direction. The measurement will take place in accordance with ISO 4288 using a tester as described in ISO 3274.

If a measuring wire or sensor for coarse measurement of the perpendicularity or angularity tolerance cannot be introduced in the gap between shifting square and cut surface, a depth gauge with sensing point shall be used. In the case of molten edges with unfinished projection, the latter will be considered in the perpendicularity or angularity tolerance.

7 Quality of the cut surface

7.1 Characteristic values

The quality of the cut surfaces of thermally cut materials is described by the following characteristic values:

a) perpendicularity or angularity tolerance, u;

b) mean height of the profile, *Rz*5.

The following characteristic values may be used in addition:

c) drag, n;

d) melting of top edge, r;

e) possibly occurrence of dross or melting drops on the lower edge of the cut.

7.2 Measuring ranges

7.2.1 General

For quality, the ranges for perpendicularity or angularity tolerance, u, and mean height of the profile, $Rz5$, shall be indicated in the order u, $Rz5$. Where no value is fixed, a “0” (zero) shall be indicated.

As far as the laser cutting is concerned, the quality classification is based on the results obtained with unalloyed steels.

Isolated faults, such as gouges, the unavoidable formation of melting beads on the lower edge of the cut at the start of cuts, or oxide remainders on the cut surface have not been considered when defining the quality values of this International Standard.

At multi-flank cuts, such as Y, double V or double HV seams (see ISO 2553), each cut surface shall be evaluated separately.

7.2.2 Perpendicularity or angularity tolerance, u

The ranges for the perpendicularity or angularity tolerance, u, are shown in Table 4 and in Figure 12.

Table 4 — Perpendicularity or angularity tolerance, u

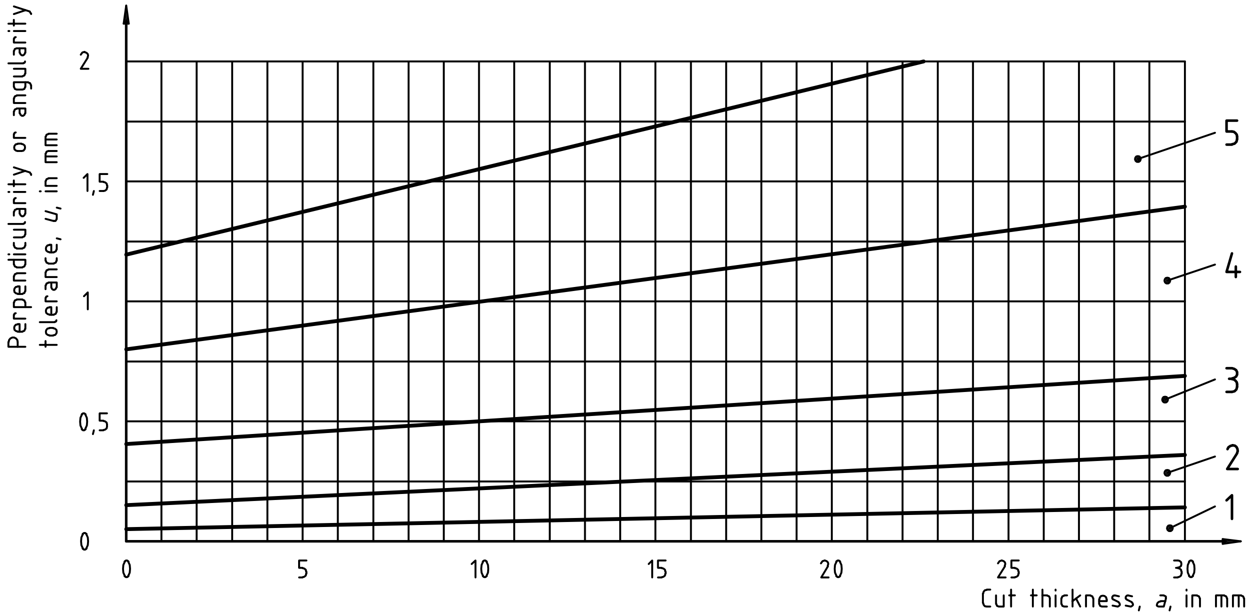
Range	Perpendicularity or angularity tolerance, u mm
1	$0{,}05 + 0{,}003a$
2	$0{,}15 + 0{,}007a$
3	$0{,}4 + 0{,}01a$
4	$0{,}8 + 0{,}02a$
5	$1{,}2 + 0{,}035a$

7.2.3 Mean height of the profile, $Rz5$

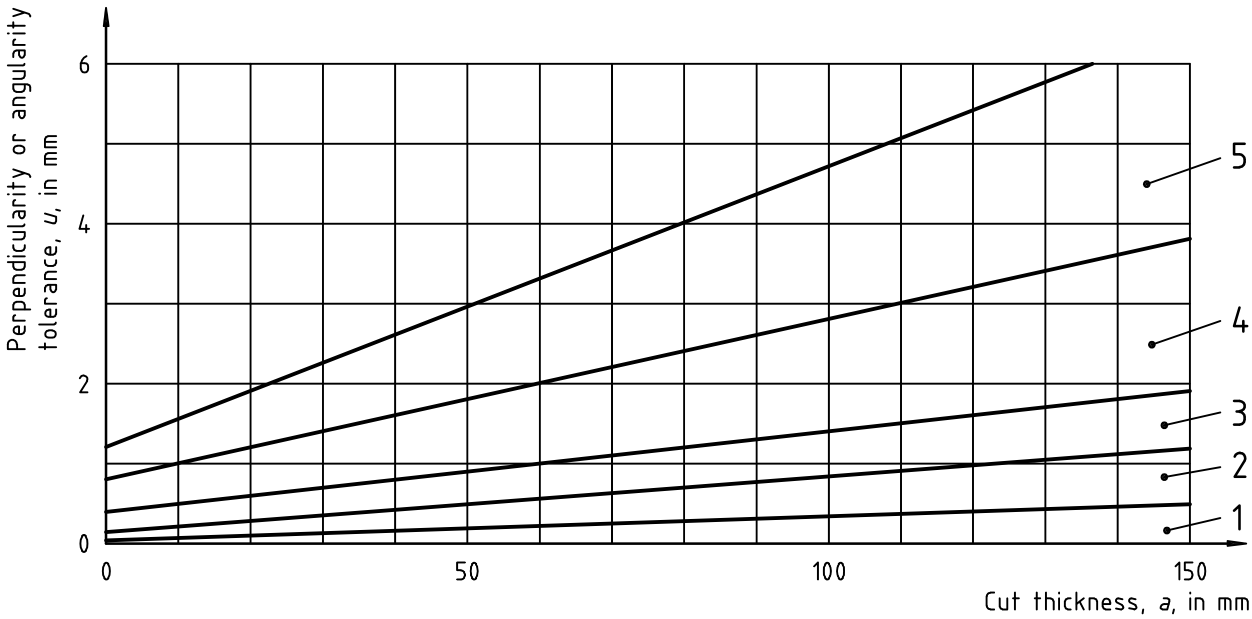
The ranges for the mean height of the profile $Rz5$ are shown in Table 5 and in Figure 13.

Table 5 — Mean height of the profile, $Rz5$

Range	Mean height of the profile, $Rz5$ µm
1	$10 + (0{,}6a$ mm)
2	$40 + (0{,}8\ a$ mm)
3	$70 + (1{,}2a$ mm)
4	$110 + (1{,}8a$ mm)



a) Perpendicularity or angularity tolerance, u — Work piece thickness up to 30 mm

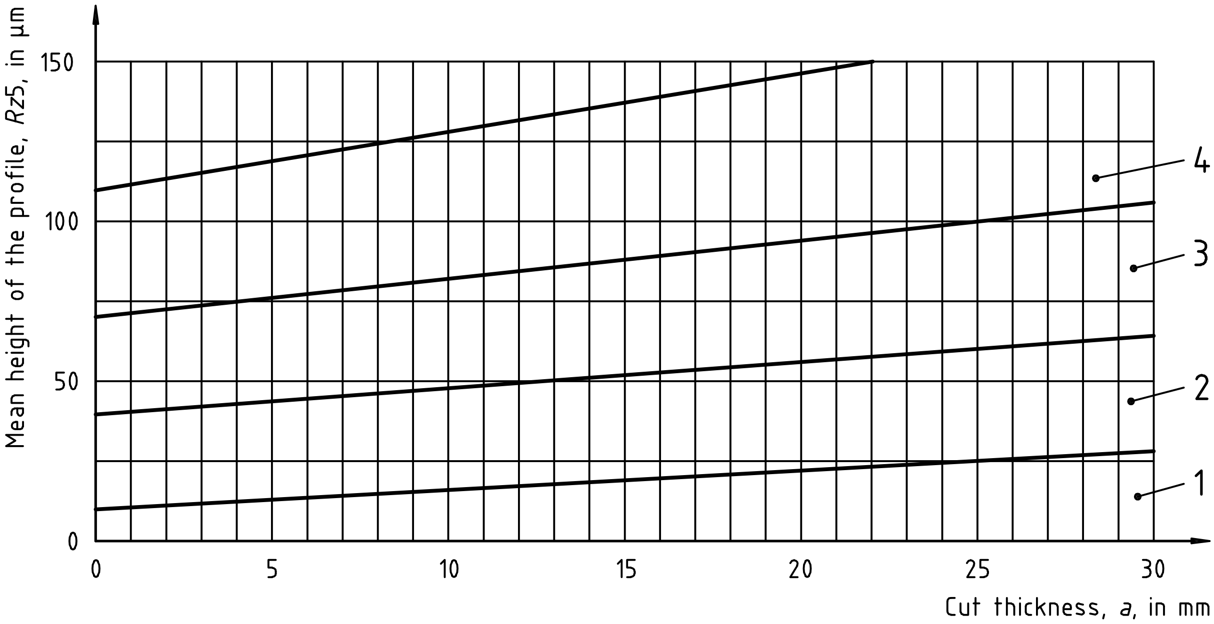


b) Perpendicularity or angularity tolerance, u — Work piece thickness up to 150 mm

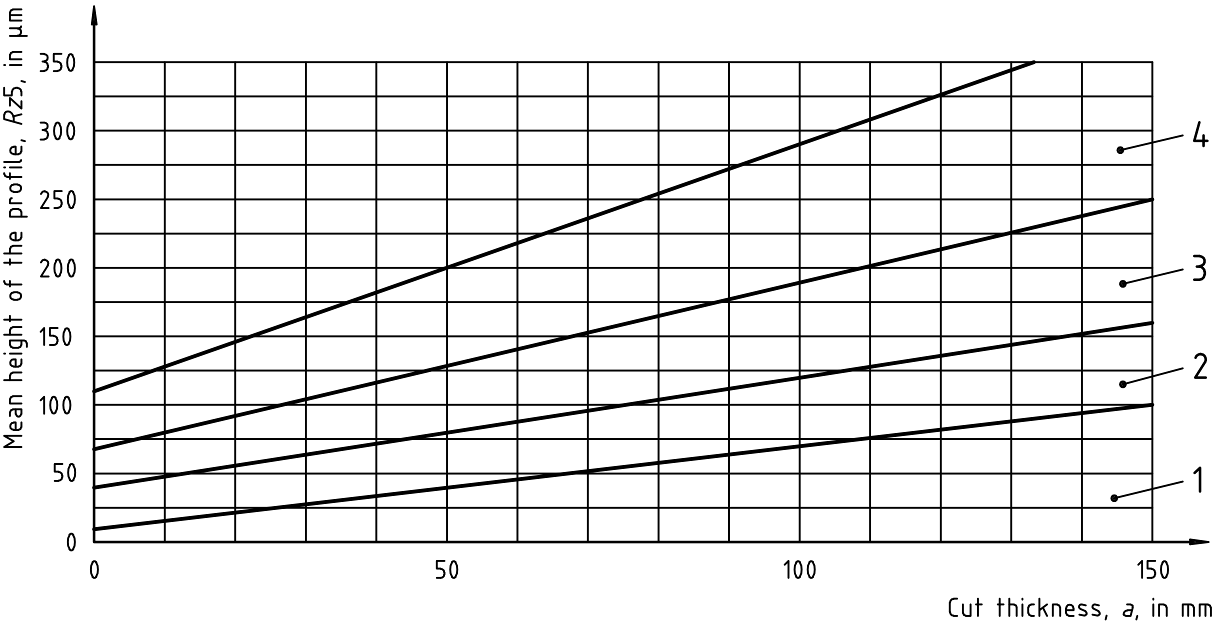
Key

1 to 5 Range (see Table 4)

Figure 12 — Perpendicularity or angularity tolerance, u



a) **Mean height of the profile, *Rz*5 — Work piece thickness up to 30 mm**



b) **Mean height of the profile, *Rz*5 — Work piece thickness up to 150 mm**

Key

1 to 4 Range (see Table 5)

Figure 13 — Mean height of the profile, *Rz*5

8 Dimensional tolerances

8.1 General

The dimensions in the drawings shall be taken to be the nominal dimensions, the actual dimensions being determined on the clean surfaces of the cut. The limit deviation specified in Tables 6 and 7 shall apply to dimensions without tolerance indications, where reference is made to this International Standard on drawings or in other documents (e.g. delivery conditions).

They are only applicable to flame cuts and plasma cuts on work pieces with a length to width ratio (length:width) not exceeding 4:1 and for lengths of cut (circumference) of not less than 350 mm.

For work pieces cut by flame and plasma cutting with a length to width ratio greater than 4:1, the limit deviations shall be specified by the manufacturer following the principles set out in this International Standard.

For laser cutting, the maintainable dimensional tolerances depend essentially on the geometry and the pre-treatment condition of the work piece.

If necessary, the limit deviations shall be agreed upon separately.

The limit deviations for the cut surface quality (perpendicularity or angularity tolerance) are treated separately from the limit deviations for the dimensional deviations of the work piece in order to emphasize the different influences on the work piece.

The definitions for the limit deviations are based on the independence principle described in ISO 8015, according to which the dimensional, form and geometrical tolerances apply independent of one another. The limit deviations do **not** include the deviations from perpendicularity or angularity.

As the definitions for the limit deviations are based on the independence principle, it was deemed not to be necessary to explain this fact once again by the additional indication of the tolerance according to ISO 8015 on the drawing. This avoids any misunderstandings with regard to a possible elimination of the independence principle if there is no reference to ISO 8015.

If other form and location tolerances, e.g. straightness tolerance, perpendicularity tolerance in cut length and cut width direction, shall be maintained, they have to be agreed upon separately.

Table 6 — Limit deviations for nominal dimensions tolerance class 1

Dimensions in millimetres

Work piece thickness	Nominal dimensions							
	> 0 < 3	⩾ 3 < 10	⩾ 10 < 35	⩾ 35 < 125	⩾ 125 < 315	⩾ 315 < 1 000	⩾ 1 000 < 2 000	⩾ 2 000 < 4 000
	Limit deviations							
> 0 ⩽ 1	± 0,04	± 0,1	± 0,1	± 0,2	± 0,2	± 0,3	± 0,3	± 0,3
> 1 ⩽ 3,15	± 0,1	± 0,2	± 0,2	± 0,3	± 0,3	± 0,4	± 0,4	± 0,4
> 3,15 ⩽ 6,3	± 0,3	± 0,3	± 0,4	± 0,4	± 0,5	± 0,5	± 0,5	± 0,6
> 6,3 ⩽ 10	—	± 0,5	± 0,6	± 0,6	± 0,7	± 0,7	± 0,7	± 0,8
> 10 ⩽ 50	—	± 0,6	± 0,7	± 0,7	± 0,8	± 1	± 1,6	± 2,5
> 50 ⩽ 100	—	—	± 1,3	± 1,3	± 1,4	± 1,7	± 2,2	± 3,1
> 100 ⩽ 150	—	—	± 1,9	± 2	± 2,1	± 2,3	± 2,9	± 3,8
> 150 ⩽ 200	—	—	± 2,6	± 2,7	± 2,7	± 3	± 3,6	± 4,5
> 200 ⩽ 250	—	—	—	—	—	± 3,7	± 4,2	± 5,2
> 250 ⩽ 300	—	—	—	—	—	± 4,4	± 4,9	± 5,9

Table 7 — Limit deviations for nominal dimensions tolerance class 2

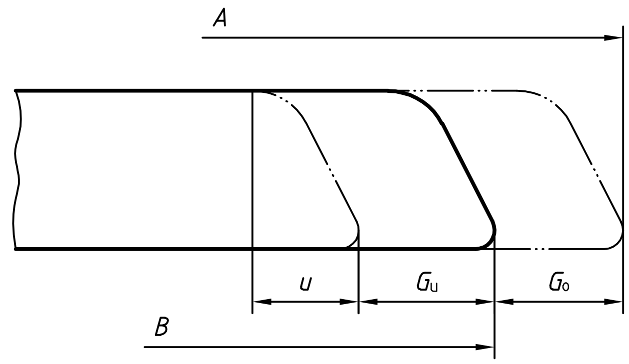
Dimensions in millimetres

Work piece thickness	Nominal dimensions							
	> 0 < 3	⩾ 3 < 10	⩾ 10 < 35	⩾ 35 < 125	⩾ 125 < 315	⩾ 315 < 1 000	⩾ 1 000 < 2 000	⩾ 2 000 < 4 000
	Limit deviations							
> 0 ⩽ 1	± 0,1	± 0,3	± 0,4	± 0,5	± 0,7	± 0,8	± 0,9	± 0,9
> 1 ⩽ 3,15	± 0,2	± 0,4	± 0,5	± 0,7	± 0,8	± 0,9	± 1	± 1,1
> 3,15 ⩽ 6,3	± 0,5	± 0,7	± 0,8	± 0,9	± 1,1	± 1,2	± 1,3	± 1,3
> 6,3 ⩽ 10	—	± 1	± 1,1	± 1,3	± 1,4	± 1,5	± 1,6	± 1,7
> 10 ⩽ 50	—	± 1,8	± 1,8	± 1,8	± 1,9	± 2,3	± 3	± 4,2
> 50 ⩽ 100	—	—	± 2,5	± 2,5	± 2,6	± 3	± 3,7	± 4,9
> 100 ⩽ 150	—	—	± 3,2	± 3,3	± 3,4	± 3,7	± 4,4	± 5,7
> 150 ⩽ 200	—	—	± 4	± 4	± 4,1	± 4,5	± 5,2	± 6,4
> 200 ⩽ 250	—	—	—	—	—	± 5,2	± 5,9	± 7,2
> 250 ⩽ 300	—	—	—	—	—	± 6	± 6,7	± 7,9

8.2 Dimensional tolerances on parts without finishing

8.2.1 The work piece shall fit into an assembly. The nominal dimension of the part to be cut results from the nominal dimensions of the finished part (= drawing dimension), reduced by the limit deviation (see Figure 14). The real dimension of a component produced by a thermal cutting process always corresponds to the greatest dimension at outside dimensions and to the smallest dimension at inside dimensions.

NOTE This kind of tolerance is normally required at welding joint preparation, as the work piece has to fit into an assembly.



where

A is the nominal dimension of finished part;

B is the nominal dimension of cutting part;

G_o is the upper limit deviation;

G_u is the lower limit deviation.

Figure 14 — Dimensional tolerances on parts without finishing

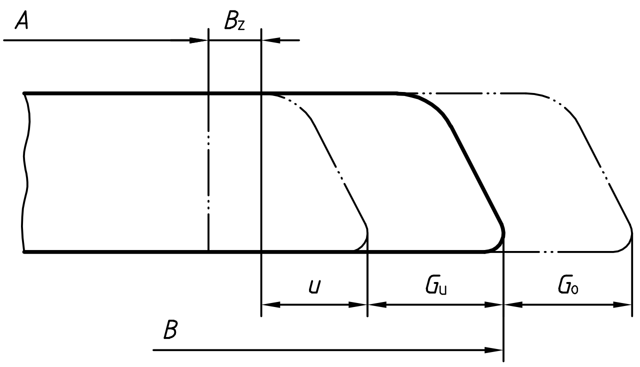
8.2.2 The work piece shall not fit into an assembly. The nominal dimension of the part to be cut results from the nominal dimension of the finished part (drawing dimension).

8.3 Dimensional tolerances on parts with finishing

8.3.1 General

In order to be able to maintain the nominal dimensions at the finished part, it is necessary, for outside dimensions of work pieces with a machining finishing allowance B_z, to add the perpendicularity or angularity tolerance as well as the lower limit deviation and, for inside dimensions of work pieces with a machining finishing allowance B_z, to subtract the perpendicularity or angularity tolerance as well as the lower limit deviation (see Figure 15).

The effective material to be removed depends on the machining allowance, the perpendicularity or angularity tolerance and the mean height of the profile for the relevant cutting process.



where

A is the nominal dimension of finished part;

B is the nominal dimension of cutting part;

B_z is the machining allowance;

G_o is the upper limit deviation;

G_u is the lower limit deviation.

Figure 15 — Dimensional tolerances on parts with finishing

8.3.2 Machining allowance

If the drawing does not bear any indication to this effect, in practice a machining allowance depending on the sheet thickness will be provided for according to Table 8.

Table 8 — Machining allowance, B_Z

Dimensions in millimetres

Cut thickness, a	Machining allowance for each cut surface, B_Z
$\geqslant 2 \leqslant 20$	2
$> 20 \leqslant 50$	3
$> 50 \leqslant 80$	5
> 80	7

9 Designation

A thermal cut of the perpendicularity or angularity tolerance range 1, of the mean height of the profile range 3 and of the limit deviations for nominal dimensions tolerance class 2 (see Table 7) is designated as follows:

Thermal cut ISO 9013-132

10 Information in technical documentation

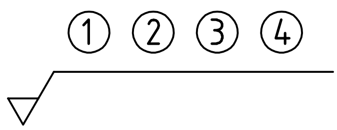
10.1 Indications of size

The dimensional indications in the drawings are referred to the cut work piece. In the technical documentation, standards, etc., dimensional symbols according to this International Standard shall be used.

10.2 Indication of quality of cut surface and of tolerance class

10.2.1 On technical drawings

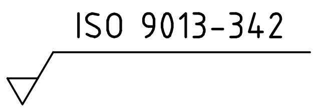
The quality and tolerance classes required in connection with thermal cutting shall be indicated using the following symbol in accordance with ISO 1302 as follows:



Key

1 Indication of the main number of this International Standard
2 Indication of the perpendicularity or angularity tolerance, u, according to 7.2.2
3 Indication of the mean height of the profile, $Rz5$, according to 7.2.3
4 Indication of the tolerance class according to clause 8

EXAMPLE — The quality with the symbol 34 (range 3 for *u*, range 4 for *Rz*5) and the limit deviations for nominal dimensions tolerance class 2 (see Table 7) are required.



10.2.2 Title block of technical documentation

The required cut quality and the required tolerance class shall be indicated as follows, referring to the main number of this International Standard:

EXAMPLE — The quality with the symbol 34 (range 3 for *u*, range 4 for *Rz*5) and the limit deviations for nominal dimensions tolerance class 2 (see Table 7) are required.

ISO 9013-342

Annex A
(informative)

Achievable cutting qualities for different cutting processes

This International Standard considers the principle used to describe the quality of thermal cuts indepently from the process, e.g. oxyfuel flame cutting, plasma cutting, laser cutting.

Not any quality tolerance and any geometrical product specification can be obtained by any process and any material.

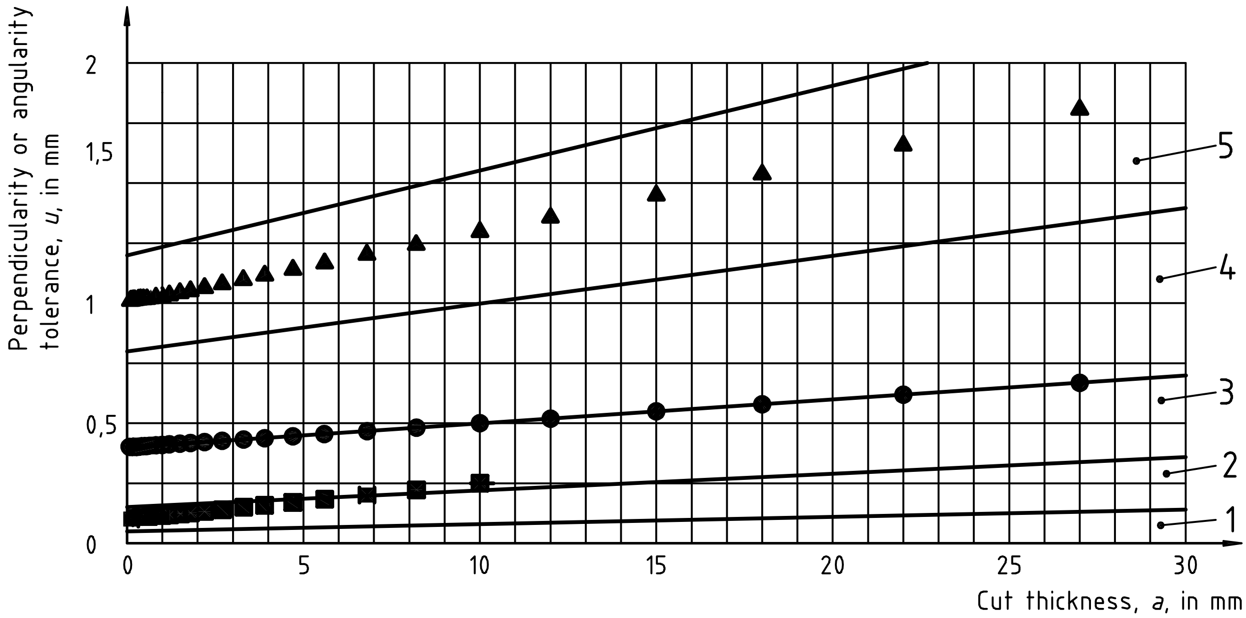
On cut surfaces of work pieces of aluminium, titanium, magnesium and their alloys as well as brass, as a function of the alloy's granular structure, rippled surfaces result on which it is not possible to determine the mean height of the profile and to evaluate it in accordance with this International Standard. Values approximately four times as high, with respect to this International Standard, may be expected for aluminium and aluminium alloys.

Limit deviations for nominal dimensions

	old	new
oxyfuel flame cutting	Class A	Class 1
oxyfuel flame cutting	Class B	Class 2

With regard to the oxyfuel flame cutting as well as to the plasma cutting, the perpendicularity or angularity tolerance does not apply to the beginning of the cut, the end of the cut, small radii and sharp angles.

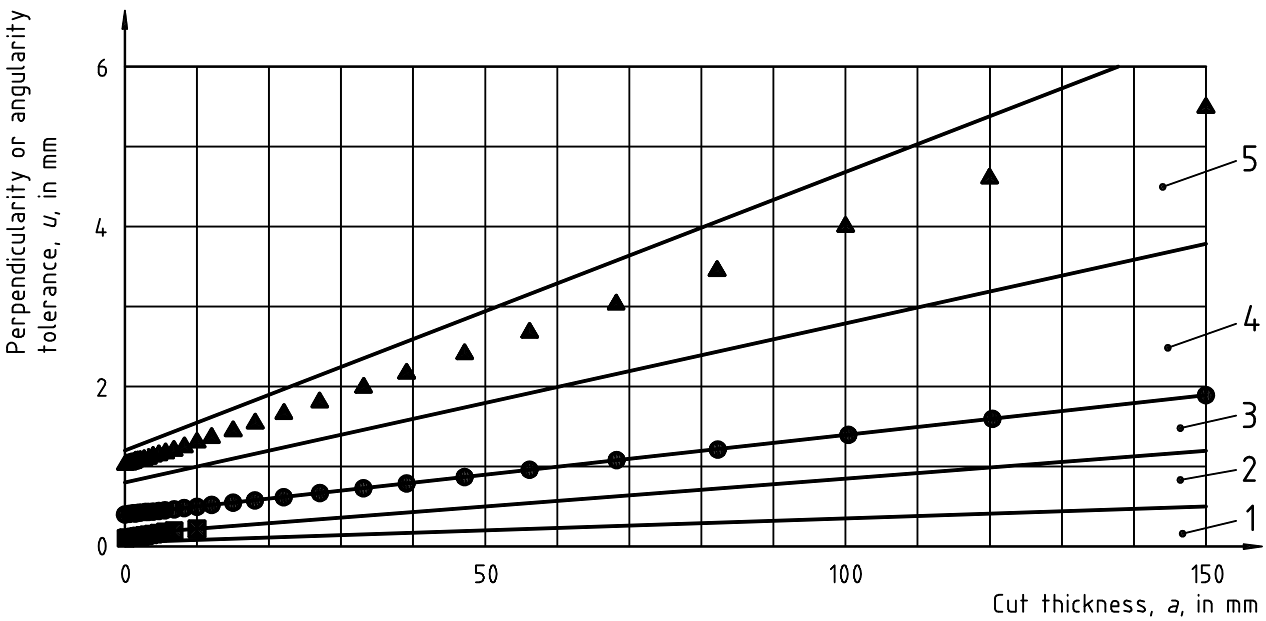
Figures A.1 to A.4 show average qualities achievable using the different cutting processes mentioned. However, depending on service conditions and used technology, qualities significantly different can be obtained.



Key

- ● Oxyfuel flame cutting
- ▲ Plasma cutting
- ■ Laser cutting
- 1 to 5 Range (see Table 4)

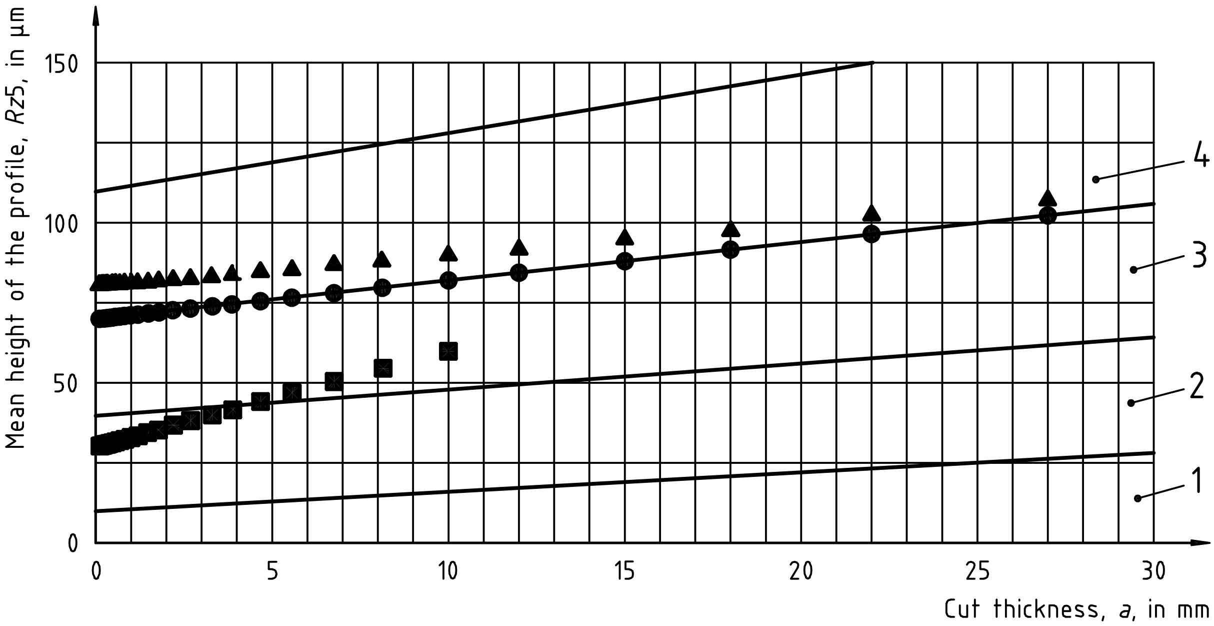
Figure A.1 — Typical cutting qualities achievable with perpendicularity or angularity tolerance, *u* — Work piece thickness up to 30 mm



Key

- ● Oxyfuel flame cutting
- ▲ Plasma cutting
- ■ Laser cutting
- 1 to 5 Range (see Table 4)

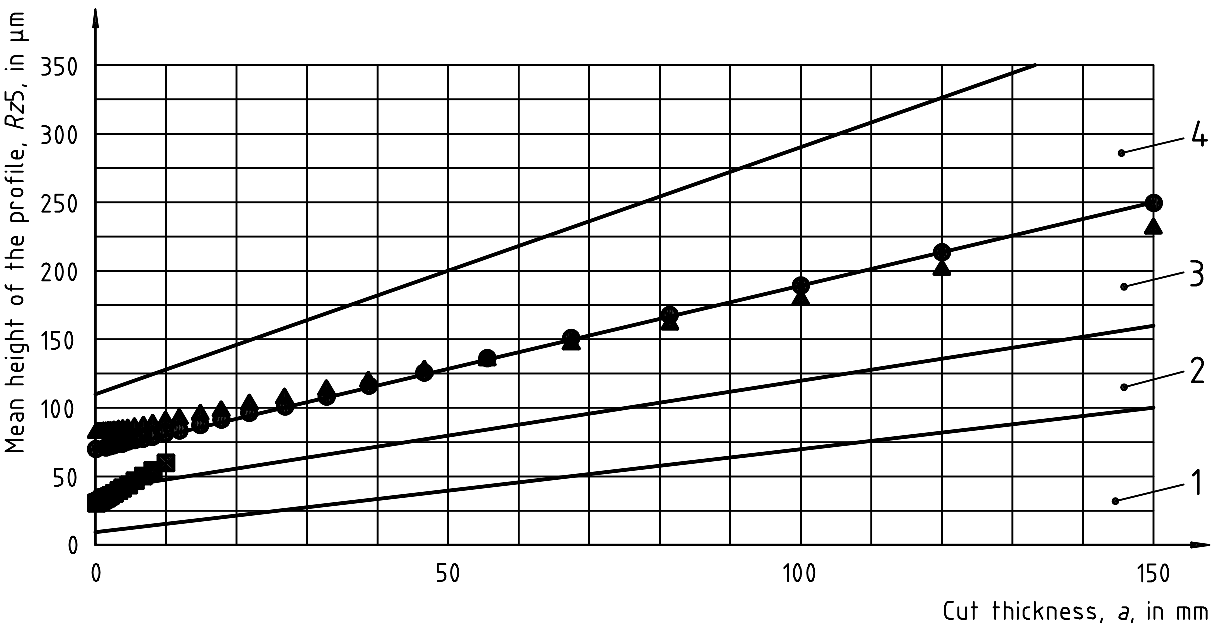
Figure A.2 — Typical cutting qualities achievable with perpendicularity or angularity tolerance, *u* — Work piece thickness up to 150 mm



Key

- ● Oxyfuel flame cutting
- ▲ Plasma cutting
- ■ Laser cutting
- 1 to 4 Range (see Table 5)

Figure A.3 — Typical cutting qualities achievable with mean height of the profile, *Rz*5 — Work piece thickness up to 30 mm



Key

- ● Oxyfuel flame cutting
- ▲ Plasma cutting
- ■ Laser cutting
- 1 to 4 Range (see Table 5)

Figure A.4 — Typical cutting qualities achievable with mean height of the profile, *Rz*5 — Work piece thickness up to 150 mm

Annex B
(informative)

Principles of process

B.1 General

This annex explains the principles of the process.

Thermal cutting processes may be classified according to the physics of the cutting process and according to the energy source acting externally on the work piece. All processes applied in practice are mixed forms of these. They are classified according to the predominant process of burning, melting or sublimation. The reaction process continues always into the depth and, on movement, in the feed direction.

B.2 Classification according to the physics of the cutting process

B.2.1 Oxyfuel flame cutting

Oxyfuel flame cutting is a thermal cutting process in which the kerf is produced by substantial oxidation of the material, the resulting products being blown out from the kerf by a high speed oxygen jet.

B.2.2 Fusion cutting

Fusion cutting is a thermal cutting process in which the kerf is produced by substantial melting of the material in that area, the resulting products being blown out from the kerf by a high speed gas jet.

B.2.3 Sublimation cutting

Sublimation cutting is a thermal cutting process in which the kerf is produced by substantial evaporation of the material in that area, the resulting products being blown out from the kerf by expansion or by a high speed gas jet.

B.3 Processes

B.3.1 Oxyfuel flame cutting

Oxyfuel flame cutting is the thermal cutting done with a fuel gas/oxygen flame and cutting oxygen. The heat released by the heating flame and the heat produced during the combustion permit continuous combustion by the cutting oxygen. The oxides produced, mixed with some molten metal, are driven out by the kinetic energy of the cutting oxygen jet. By this action, the kerf is produced.

Oxyfuel flame cutting is feasible if the following conditions are satisfied:

— the ignition temperature of the material to be cut is lower than its fusion temperature;

— the fusion temperature of the combustion products produced and of the metallic oxides, is lower than the fusion temperature of the material to be cut;

— the process produces such a quantity of heat that the material areas in the cutting direction are heated at least up to ignition temperature;

- the heat supply through the heating flame and the combustion of the material in the kerf exceed the heat dissipation through the heat discharge into the material and to the environment;
- the cutting slag is in such a liquid state that it can be driven out from the kerf by the cutting oxygen jet.

B.3.2 Plasma cutting

Plasma cutting is a thermal cutting process in which a constricted arc is used. Polyatomic gases dissociate in the arc and partially ionize; monoatomic gases partially ionize. The plasma beam thus generated has a high temperature and kinetic energy. It melts or partially vaporizes the material and blows it away. Thereby the kerf is produced.

The sheet thickness which can be cut is limited since for plasma cutting the whole heat required to liquefy the material has to be made available by the plasma cutting. With plasma cutting a difference is made between transferred and non-transferred arc. For the plasma cutting process, the material to be cut shall be electrically conducting since it forms part of the electrical circuit. This process is suitable for low and high cutting performance, i.e. cutting of thin and thick metal sheets. The plasma gas which is used as function of the material to be cut and of the cutting thickness, is of decisive importance for the energy transfer. On plasma cutting with non-transferred arc, the material is not placed within the electrical circuit. Therefore, electrically non-conducting materials may also be cut by this process. Plasma cutting with non-transferred arc only is suitable for low-cutting performance values as the cutting nozzle serves as anode.

B.3.3 Laser cutting

Laser cutting is a thermal cutting process in which the focused laser beam supplies the energy required for the cutting, this energy then being converted into heat. The cutting process is supported by a gas jet. With laser beam cutting a difference is made between laser oxyfuel flame cutting, laser fusion cutting and laser sublimation cutting.

B.4 Materials

B.4.1 Oxyfuel flame cutting

The prerequisites indicated in B.3.1 are satisfied in the case of iron, unalloyed steel and certain alloyed steels as well as titanium and some titanium alloys. The cutting process is made more difficult by alloying and accompanying elements — except for manganese — the difficulties increasing with rising content, e.g. of chromium, carbon, molybdenum and silicon. Therefore, among others, high-alloyed chromium-nickel or silicon steels and cast iron cannot be flame cut without applying special measures. These materials may be processed by different thermal cutting processes, e.g. by metal powder cutting or plasma cutting.

B.4.2 Plasma cutting

Nearly all fusible, electrically conducting metals, such as unalloyed and low-alloy steels, nickel based materials, copper alloys, titanium alloys, aluminium alloys and others are suitable for cutting.

B.4.3 Laser cutting

The material is suitable for laser cutting if its properties are affected in the cut areas only to such an extent that the component maintains at least the properties required for the intended use. Suitable for cutting are unalloyed and alloyed steels, nickel based materials, titanium alloys, aluminium alloys and others.

Bibliography

[1] ISO 17658, *Welding — Imperfections in oxyfuel flame cuts, laser beam cuts and plasma cuts — Terminology*

ICS 25.160.10

Price based on 25 pages