Theoretical (Geometrical) Surface Roughness

Theoretical Surface Roughness at Turning indicates the minimum roughness value from the cutting conditions and it is shown by the formula as follows:

$$Rz(h) = \frac{f^2}{8R(r\epsilon)} \times 10^3$$

 $\begin{array}{l} {\sf Rz}(h): {\sf Theoretical Surface Roughness (\mu m)} \\ {\sf f}: {\sf Feed Rate (mm/rev)} \\ {\sf R}(r\epsilon): {\sf Corner Radius of Insert (mm)} \end{array}$

How to Obtain Surface Roughness Values

Туре	Symbol	How to Obtain	Explanation
Max. Height Roughness	Rz	Ry is obtained from the distance in micron meter between the highest peak and the lowest valley in the range of sampled reference length (<i>t</i>) to the direction of mean line of the roughness curve. Rz=Rp+Rv	
Ten Points Mean Roughness	Rz = Rp + Rv Rz is obtained from the total in micron meter of the mean value of the each distance between the mean line and 5 peaks (Yp) from the highest one, and the mean value of the each distance between the mean line and the 5 valleys (Yv) from the lowest one, of the roughness curve in the range of sampled reference length "t". $Rz_{JIS} = \frac{(Yp1+Yp2+Yp3+Yp4+Yp5) + (Yv1+Yv2+Yv3+Yw4+Yv5)}{5}$		$\begin{array}{c} & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & &$
Arithmetical Mean Roughness	Ra	Ra is obtained from the following formula in micron meter when the roughness curve is expressed by y=f(x), taking X-axis to the mean line direction and Y-axis to the vertical magnification of the roughness curve in the range of sampled reference length "t". $Ra = \frac{1}{e} \int_{t}^{t} \{f(x)\} dx$	



Relationship with Triangle Symbol

Arithmetical Mean Roughness Ra(µm)	Max. Height Roughness Rz(µm)	Ten PointsMean Roughness RzJIS(µm)	Note: (Relationship with Triangle)
0.025 0.05 0.1 0.2	0.1 0.2 0.4 0.8	0.1 0.2 0.4 0.8	$\forall \forall \forall \forall$
0.4 0.8 1.6	1.6 3.2 6.3	1.6 3.2 6.3	$\nabla \nabla \nabla$
3.2 6.3	12.5 25	12.5 25	\bigtriangledown
12.5 25	50 100	50 100	\bigtriangledown

Note: Finishing symbol (Triangle ▽and wave~) was abolished from JIS standard from 1994 Revision.

· How to Indicate

Example

①When Ra is 1.6µm→1.6µmRa

②When Rz is $6.3\mu m \rightarrow 6.3\mu m Rz$ ③When RzJIS is $6.3\mu m \rightarrow 6.3\mu m RzJIS$

Indication in JIS Standard

Example of Ra Indication		Example of Ry, (Rz) Indication				
①When indicating the upper limit only (when upper limit is 6.3μmRa)	6.3	①When indicating upper limit onlyIndicate surface roughness following the parameter symbol.	Rz6.3	R		
When indicating both lower and upper limit (when upper limit is 6.3µmRa, lower limit is 1.6µmRa)	6.3 1.6	When indicating both lower and upper limit Indicate surface roughness as (upper limit ~ lower limit) following the parameter symbol.	Rz6.3~1.6	A		

Note: The indications of Ra and Rz are different.

Surface Roughness Symbol Caution

The above information is based on JIS B 0601-2001. However, some symbols were revised as shown in the right table in accordance with ISO Standard from JIS B 0601-2001 version. Ten Points Mean Roughness (Rz) was eliminated from 2001 version but it still remains as RzJIS reference, since it was popular in Japan.

Туре	Symbol of JIS B 0601-1994	Symbol of JIS B 0601-2001				
Max. Height Roughness	Ry	_	÷	Rz		
Ten Points Mean Roughness	Rz	_	÷	(Rzjis)		
Arithmetical Mean Roughness	Ra	_	÷	Ra		

Technical

1. Varieties of Surface Roughness Indicators

Definitions and presentations of arithmetic average roughness(Ra), maximum height(Ry), 10 spot average roughness(Rz), average concave to convex distance(Sm), average distance between local peaks S and load length rate to are given as parameters indicating the surface roughness of an industrial product. Surface roughness is the arithmetical average of values at randomly extracted spots on the surface of an object. [Centerline average roughness(Ra75)is defined in the supplements to JIS B 0031 and JIS B 0601.]

Typical calculations of surface roughness

Arithmetic Average Roughness Ra

A portion stretching over a reference length in the direction in which the average line extends is cut out from the roughness curve. This portion is presented in a new graph with the X axis extending in the same direction as the average line and the Y axis representing the magnitude. Ra is represented by the equation shown at right, in microns(µm).

Maximum Height Ry

A portion stretching over a reference length in the direction in which the average line extends is cut out from the roughness curve. The gap between the peak line and the trough line is measured in the direction in which the magnitude axis extends, in microns(µm).

Reference A portion without an abnormally high peak or abnormally low trough, which may be regarded as a flaw, is cut out over the reference length.

Ten-spot Average Roughness Rz

A portion stretching over a reference length in the direction in which the average line extends is cut out from the roughness curve. The average of the levels(Yp)of the highest peak to the fifth highest peak as measured from the average line and the average of the levels(Yp)of the lowest trough to the fifth lowest trough similarly measured in the said portion are added together. Rz is this sum, in microns(um).



Yp1 + Yp2 + Yp3 + Yp4 + Yp5 + Yv1 + Yv2 + Yv3 + Yv4 + Yv5 Rz= Yp1, Yp2, Yp3, Yp4, Yp5 : Levels of the highest peak to the fifth highest peak in the said portion with the reference length ℓ . Yv1, Yv2, Yv3, Yv4, Yv5 : Levels of the lowest trough to the fifth lowest trough in the said portion with the reference length ℓ .

Reference Relation between Arithmetic Average Roughness(Ra)and Conventional Parameters

Ar	ithmetic Average Ra	Roughness	Maximum Height Ry	Ten-spot Average Roughness Rz	Reference Length of Ry(Rz)	Conventional Finish Symbol	
Standard Series	Cut-off Value c(mm)	Graphical Representation of Surface Texture	Standar	rd Series	ℓ(mm)		
0.012 a	0.08		0.05 s	0.05 z	0.08		
0.025 a	0.25	0.012 ~ 0.2	0.1 s	0.1 z	0.00	\bigtriangledown	
0.05 a	0.20		0.2 s	0.2 z	0.25		
0.1 a 0.2 a			0.4 S	0.4 2	0.25		
0.2 u			0.0 0	0.0 2			
0.4 a	0.8	04 / 16 /	1.6 s	1.6 z	0.8		
0.8 a			3.2 S	3.2 Z	0.0		
1.0 a			0.0 5	0.5 2			
3.2 a	25	3.2 / ~ 6.3 /	12.5 s	12.5 z			
6.3 a	2.0		25 s	25 z	2.5	• •	
12.5 a		125 /	50 s	50 z		<u></u>	
25 a	8		100 s	100 z		\checkmark	
50 a		50 / . 100 /	200 s	200 z	8		
100 a	_		400 s	400 z	-	~	

*Interrelations among the three types shown here are not precise, and are presented for convenience only. *Ra:The evaluation values of Ry and Rz are the cut-off value and the reference length each multiplied by five, respectively.

1. Positions of Auxiliary Symbols for Surface Symbol

A surface roughness value, cut-off value or reference length, machining method, grain direction, surface undulation, etc. are indicated around the surface symbol as shown in Fig. 1 below.

Fig. 1 Positions of Auxiliary Symbols



- a : Ra Value
- b : Machining Method
 - c : Cut-Off Value, Evaluation Length
 - c' : Reference Length, Evaluation Length
 - d : Grain Direction
 - f : Parameter other than Ra(tp:Parameter/Cut-Off Level)
 - g : Surface Undulation(JIS B 0610)
 - **Reference** These symbols except a and f are provided when they are needed.
- Reference Under ISO 1302, a finish range should be indicated as e in Fig. 1.

Code	Meaning	Illustration	Examples of Graphical Representation of Surface Texture				
_	The trace left by a cutting instrument is parallel to the projection plane in the drawing. Ex. Shaped Surface	Trace Left by a Cutting Instrument	Surface Symbol				
⊥	The trace left by a cutting instrument is perpendicular to the projection plane in the drawing. Ex. Shaped Surface(Side View) Circular Cut, Cylindrical Cut	Trace Left by a Cutting Instrument	Removal of Material is Prohibited				
X	The pattern left by a cutting instrument diagonally crosses the projection plane in the drawing. Ex. Honed Surface	Trace Left by a Cutting Instrument	Upper Limit of Ra (a) (b) (c) 25 - 6.3 - 25 - 7.5				
Μ	The pattern left by a cutting instrument crosses in various directions or has no grain direction. Ex. Lapped Surface, Superfinished Surface and Surface Finished with a Front Mill or End Mill	₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩	Grain Direction				
С	The pattern left by a cutting instrument is virtually concentric around the center of the plane in the drawing. Ex. Faced Surface		Upper and Lower Limits of Ra (a) (b) 6.3 1.6 6.3 6.3 6.3 6.3 1.6 6.3 1.6				
R	The pattern left by a cutting instrument is virtually radial around the center of the plane in the drawing.		Machining Method (a) (b) Milled 3.2 				

(Technical Data) Surface Roughness by Different Processing Methods

(Technical Data)	
Indications of Geometrical T	olerance on Drawings

Excerpt from JIS B 0021(1984)

Arithmetical mean roughness Ra		0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50	100
Former designations of surface roughness	Maximum peak Ry Rmax.	0.1 -S	0.2 S	0.4 S	0.8 S	1.6 —S	3.2 —S	6.3 —S	12.5 —S	25 S	50 S	100 -S	200 -S	400 -S
	Standard values of standard length (mm)	0.25			I	0.8		2.5		8		25		
	Triangular indication													_
	Forging								Prec	ision _				
	Casting								_ Prec	ision ,				
	Die casting									,				
	Hot rolling											,		
	Cold rolling			·					,					
	Drawing													
	Extruding									,				
	Tumbling					,								
	Sandblasting													
	Rolling						<u> </u>							
	Face cutter grinding						, Prec	ision _				,		
	Planing								. <u> </u>			,		
	Carving (Slotting)											,		
	Cutter grinding						, Prec	ision ,				,		
	Precision boring							,						
	Filing						, Prec	ision ,			,			
Working	Round grinding				Precisior	,	, Fine		. Med	ium,		Rough		
method	Boring						, Prec	ision ,						
	Drilling													
	Reaming					Prec	ision ,			,				
	Broach grinding					. Prec	ision ,							
	Shaving									,				
	Grinding			Precision .	Fine		, Mec	lium		Rough				
	Hone finishing			. Prec	ision ,									
	Super finishing	_ Prec	ision ,	·	,									
	Buffing			Prec	ision				,					
	Paper finishing			. Prec	ision ,	•								
	Lapping	. Prec	ision ,	·	,									
	Liquid honing			, Prec	ision ,	·		,						
	Burnishing						,							
	Surface rolling						,							
	Electric discharge carving													
	Wire cut electric spark													
	Chemical polishing					•	Precisior	.						
	Electrolytic abrasion		Prec	ision	,	•								

Kinds and Symbols of Geometrical Tolerances

Lines used in the drawings in the column of " definition of tolerance zone " indicate the following meanings Thick solid line or broken line · Feature Thick alternate long and short dash line: Datum Thin solid line or broken line: Tolerance zone

Thin alternate long and short dash line: Center line

Thin alternate long and two short dashes line: Supplementary projection plane or sectional plane

Thick alternate long and two short dashes line: Projection of a feature to supplementary Projection plane or sectional plane