TECHNICAL DATA

1. The International System of Units (SI) and its usage

1—1. Scope of application This standard specifies the International System of Units (SI) and how to use units under the SI system, as well as the units which are or may be used in conjunction with SI system units.

1—2. Terms and definitions The terminology used in this standard and the definitions thereof are as follows.

(1) **International System of Units (SI)** A consistent system of units adopted and recommended by the International Committee on Weights and Measures. It contains base units and supplementary units, units derived from them, and their integer exponents to the 10th power. SI is the abbreviation of System International d Unites (International System of Units).

(2) **SI units** A general term used to describe base units, supplementary units, and derived units under the International System of Units (SI).

(3) **Base units** The units shown in **Table 1** are considered the base units.

(4) **Supplementary units** The units shown in **Table 2** below are considered the supplementary units.

Table 1. Base Units

Measure	Unit name	Unit symbol	Definition
Length	Meter	m	A meter is the length of the path traveled by light in a vacuum during a time interval of $\frac{1}{299\ 792\ 458}$ of a second.
Mass	Kilogram	kg	A kilogram is a unit of mass (not weight or force). It is equal to the mass of the international prototype of the kilogram.
Time	Second	s	A second is the duration of 9, 192, 631, 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.
Electric flow	Ampere	A	An ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} Newtons per meter of length.
Thermodynamic temperature	Kelvin	K	A Kelvin is the fraction $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water.
Amount of substance	Mole	mol	A mole is the amount of substance of a system that contains as many elementary particles (1) or aggregations of elementary particles as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary particles must be specified.
Luminous intensity	Candela	cd	A candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of $\frac{1}{683}$ watts per steradian.

Note (1) The elementary particles here must be atoms, molecules, ions, electrons or other particles.

Table 2. Supplementary Units

Measure	Unit name	Unit symbol	Definition
Plane angle	Radian	rad	A radian is the plane angle between two radii of a circle that cuts off an arc on the circumference equal in length to the radius.
Solid angle	Steradian	sr	A steradian is the solid angle which, having its vertex in the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides equal in length to the radius of the sphere.

(5) **Derived Units** Units expressed algebraically (with mathematical symbols such as multiplication and division signs) using base units and supplementary units are considered to be derived units. Derived units with special names and symbols are shown in **Table 3**.

Example: Examples of SI Derived Units Expressed in Terms of Base Units

Measure	Derived unit	
	Name	Symbol
Surface area	Square meter	m^2
Volume	Cubic meter	m^3
Speed	Meters per second	m/s
Acceleration	Meter per second per second	m/s^2
Wave numbers	Per meter	m^{-1}
Density	Kilograms per cubic meter	kg/m^3
Current density	Amperes per square meter	A/m^2
Magnetic field strength	Amperes per meter	A/m
Concentration of substance	Moles per cubic meter	mol/m^3
Specific volume	Cubic meters per kilogram	m^3/kg
Luminance	Candelas per square meter	cd/m^2

Table 3. SI Derived Units with Special Names and Symbols

Measure	Derived unit		Derivation from basic unit or supplementary unit, or derivation from another derived unit
	Name	Symbol	
Frequency	Hertz	Hz	1 Hz =1 s^{-1}
Force	Newton	N	1 N =1 kg•m/s^2
Pressure, stress	Pascal	Pa	1 Pa =1 N/m^2
Energy, work, heat quantity	Joule	J	1 J =1 N•m
Work rate, process rate, power, electric power	Watt	W	1 W =1 J/s
Electric charge, quantity of electricity	Coulomb	C	1 C =1 A•s
Electric potential, potential difference, voltage, electromotive force	Volt	V	1 V =1 J/C
Electrostatic capacity, capacitance	Farad	F	1 F =1 C/V
Electric resistance	Ohm	Ω	1 Ω =1 V/A
Conductance	Siemens	S	1 S =1 $Ω^{-1}$
Magnetic flux	Weber	Wb	1 Wb =1 V•s
Magnetic flux density (magnetic induction)	Tesla	T	1 T =1 Wb/m^2
Inductance	Henry	H	1 H =1 Wb/A
Celsius temperature	Degrees Celsius or degrees	℃	1 t℃ =(t+273.15)K
Luminous flux	Lumen	lm	1 lm =1 cd•sr
Illumination	Lux	lx	1 lx =1 lm/m^2
Radioactivity	Becquerel	Bq	1 Bq =1 s^{-1}
Absorbed dose	Gray	Gy	1 Gy =1 J/kg
Dose equivalent	Sievert	Sv	1 Sv =1 J/kg

1—3. Integer exponents of SI units

(1) **Prefixes** The multiples, prefix names, and prefix symbols that compose **the integer exponents of 10 for SI units** are shown in **Table 4**.

Table 4. Prefixes

Multiple of unit	Prefix Name	Prefix Symbol	Multiple of unit	Prefix Name	Prefix Symbol	Multiple of unit	Prefix Name	Prefix Symbol
10^{18}	Exa	E	10^{2}	Hecto	h	10^{-9}	Nano	n
10^{15}	Peta	P	10	Deca	da	10^{-12}	Pico	p
10^{12}	Tera	T	10^{-1}	Deci	d	10^{-15}	Femto	f
10^{9}	Giga	G	10^{-2}	Centi	c	10^{-18}	Atto	a
10^{6}	Mega	M	10^{-3}	Milli	m			
10^{3}	Kilo	k	10^{-6}	Micro	μ			

2. Conversion table for conventional units that are difficult to convert to SI units

(The units enclosed by bold lines are the SI units.)

Force	**N**	dyn	kgf
	1	1×10^{5}	$1.019\ 72\times10^{-1}$
	1×10^{-5}	1	$1.019\ 72\times10^{-6}$
	9.806 65	$9.806\ 65\times10^{5}$	1

Viscosity	**Pa·s**	cP	P
	1	1×10^{3}	1×10
	1×10^{-3}	1	1×10^{-2}
	1×10^{-1}	1×10^{2}	1

Note: 1P=1dyn·s/cm²=1g/cm·s
1Pa·s=1N·s/m², 1cP=1mPa·s

Stress	**Pa** or **N/m²**	**MPa** or **N/mm²**	kgf/mm²	kgf/cm²
	1	1×10^{-6}	$1.019\ 72\times10^{-7}$	$1.019\ 72\times10^{-5}$
	1×10^{6}	1	$1.019\ 72\times10^{-1}$	$1.019\ 72\times10$
	$9.806\ 65\times10^{6}$	9.806 65	1	1×10^{2}
	$9.806\ 65\times10^{4}$	$9.806\ 65\times10^{-2}$	1×10^{-2}	1

Note: 1Pa=1N/m², 1MPa=1N/mm²

Kinematic viscosity	**m²/s**	cSt	St
	1	1×10^{6}	1×10^{4}
	1×10^{-6}	1	1×10^{-2}
	1×10^{-4}	1×10^{2}	1

Note: 1St=1cm²/s, 1cSt=1mm²/s

Pressure	**Pa**	**kPa**	**MPa**	bar	kgf/cm²	atm	mmH_2O	mmHg or Torr
	1	1×10^{-3}	1×10^{-6}	1×10^{-5}	$1.019\ 72\times10^{-5}$	$9.869\ 23\times10^{-6}$	$1.019\ 72\times10^{-1}$	$7.500\ 62\times10^{-3}$
	1×10^{3}	1	1×10^{-3}	1×10^{-2}	$1.019\ 72\times10^{-2}$	$9.869\ 23\times10^{-3}$	$1.019\ 72\times10^{2}$	7.500 62
	1×10^{6}	1×10^{3}	1	1×10	$1.019\ 72\times10$	9.869 23	$1.019\ 72\times10^{5}$	$7.500\ 62\times10^{3}$
	1×10^{5}	1×10^{2}	1×10^{-1}	1	1.019 72	$9.869\ 23\times10^{-1}$	$1.019\ 72\times10^{4}$	$7.500\ 62\times10^{2}$
	$9.806\ 65\times10^{4}$	$9.806\ 65\times10$	$9.806\ 65\times10^{-2}$	$9.806\ 65\times10^{-1}$	1	$9.678\ 41\times10^{-1}$	1×10^{4}	$7.355\ 59\times10^{2}$
	$1.013\ 25\times10^{5}$	$1.013\ 25\times10^{2}$	$1.013\ 25\times10^{-1}$	1.013 25	1.033 23	1	$1.033\ 23\times10^{4}$	$7.600\ 00\times10^{2}$
	9.806 65	$9.806\ 65\times10^{-3}$	$9.806\ 65\times10^{-6}$	$9.806\ 65\times10^{-5}$	1×10^{-4}	$9.678\ 41\times10^{-5}$	1	$7.355\ 59\times10^{-2}$
	$1.333\ 22\times10^{2}$	$1.333\ 22\times10^{-1}$	$1.333\ 22\times10^{-4}$	$1.333\ 22\times10^{-3}$	$1.359\ 51\times10^{-3}$	$1.315\ 79\times10^{-3}$	$1.359\ 51\times10$	1

Note: 1Pa=1N/m²

Work, energy, heat quantity	**J**	kW·h	kgf·m	kcal
	1	$2.777\ 78\times10^{-7}$	$1.019\ 72\times10^{-1}$	$2.388\ 89\times10^{-4}$
	$3.600\ \ \times10^{6}$	1	$3.670\ 98\times10^{5}$	$8.600\ 0\ \times10^{2}$
	9.806 65	$2.724\ 07\times10^{-6}$	1	$2.342\ 70\times10^{-3}$
	$4.186\ 05\times10^{3}$	$1.162\ 79\times10^{-3}$	$4.268\ 58\times10^{2}$	1

Note: 1J=1W·s, 1J=1N·m

Power process rate/power, heat flow	**W**	kgf·m/s	PS	kcal/h
	1	$1.019\ 72\times10^{-1}$	$1.359\ 62\times10^{-3}$	$8.600\ 0\ \times10^{-1}$
	9.806 65	1	$1.333\ 33\times10^{-2}$	8.433 71
	$7.355\ \ \times10^{2}$	$7.5\ \ \times10$	1	$6.325\ 29\times10^{2}$
	1.162 79	$1.185\ 72\times10^{-1}$	$1.580\ 95\times10^{-3}$	1

Note: 1W=1J/s, PS: French horsepower

Thermal conductivity	**W/(m·K)**	kcal/(m·h·℃)
	1	$8.600\ 0\times10^{-1}$
	1.162 79	1

Coefficient of heat transfer	**W/(m²·K)**	kcal/(m²·h·℃)
	1	$8.600\ 0\times10^{-1}$
	1.162 79	1

Specific heat	**J/(kg·K)**	kcal/(kg·℃) cal/(g·℃)
	1	$2.388\ 89\times10^{-4}$
	$4.186\ 05\times10^{-3}$	1

HARDENING AND HARDNESS TESTS

Heat Treatment for Steel Materials

Name	Vickers hardness (HV)	Hardening depth (mm)	Strain	Applicable materials	Typical materials	Remarks
Through hardening	Max. 750	All	Varies according to the material.	High-C steel C>0.45%	SKS3 SKS21 SUJ2 SKH51 SKS93 SK4 S45C	· Should not be used for long parts such as spindles or for precision parts.
Carburizing	Max. 750	Standard 0.5 Max. 2	Medium	Low-C steel C<0.3%	SCM415 SNCM220	· Localized hardening is possible. · Hardening depth must be specified on drawings. · Suitable for precision parts
Induction hardening	Max. 500	1～2	Large	Medium-C steel C 0.3～0.5%	S45C	· Localized hardening is possible. · Expensive in small volumes · Good fatigue resistance
Nitriding	900～1000	0.003～0.008	Small	Nitriding steel	SACM645	· Highest hardening hardness · Suitable for precision parts · Suitable for sliding bearing spindles
Tufftride®	Carbon steel 500 SUS 1000	0.01～0.02	Small	Steel materials	S45C SCM415 SK3 Stainless steel	· Good fatigue resistance and wear resistance · Same corrosion resistance as zinc plating · Not suitable for precision parts because polishing following the heat treatment is not possible. · Suitable for oil-free lubrication
Bluing				Wire rod	SWP—B	· Low temperature annealing · Enhances elasticity by removing internal stress during forming

Hardness Test Methods and Applicable Parts

Test method	Principle	Applicable heat-treated parts	Characteristics	Remarks
1. Brinell hardness	· A ball indenter (steel or carbide alloy) is used to indent the test surface. Hardness is given by dividing the test load by the surface area, which was found from the diameter of the indentation.	· Annealed parts · Normalized parts · Anchored materials	① Suitable for uneven materials and forged products because the indent is large. ② Not suitable for small or thin specimens	JIS Z 2243
2. Rockwell hardness	· The standard or test load is applied via a diamond or ball indenter, and the hardness value is read from the tester.	· Hardened parts and tempered parts · Carburized surfaces · Nitrided surfaces · Thin sheets of copper, brass, bronze, or similar materials ※Rockwell C scale (HRC) is not suitable for materials such as narrow pins and thin sheets.	① Hardness value can be obtained quickly. ② Suitable as an intermediate test of actual products ③ Caution is required because there are many types. ※ There are many types of Rockwell hardness testers, including the A scale (HRA), B scale (HRB), C scale (HRC), and D scale (HRD).	JIS Z 2245
3. Shore hardness	· The specimen is set on a table and a hammer is dropped from a set height. Hardness is determined based on how high the hammer bounces.	· Hardened parts and tempered parts · Nitrided parts · Large parts treated by carburizing or similar process	① Extremely easy to operate. Data can be obtained quickly. ② Suitable for large parts ③ Because indent is small and not noticeable, this test is suitable for actual products. ④ Compact and light-weight. Portable.	JIS Z 2246
4. Vickers hardness	· A diamond square pyramid indenter with a vertex angle of 136 degrees is used to create an indentation in the test surface. The hardness value is found from the test load and the surface area of the indent, computed from the length of the diagonal lines of the indent. (Conversion is performed automatically.)	· Materials with a thin hardened layer created by induction hardening, carburizing, nitriding, electroplating, ceramic coating, etc. · Hardened layer depth in carburized and nitrided parts	① Suitable for small and thin specimens ② Because the indenter is diamond, this test can be used with materials of any hardness.	JIS Z 2244

Approximate Conversion Values for Rockwell C Hardness Values of Steel (1)

(HRC) Rockwell C scale hardness	(HV) Vickers hardness	Brinell hardness (HB) 10 mm ball Load 3000 kgf		Rockwell Hardness (3)			Rockwell superficial hardness Diamond conical indenter			(Hs) Shore hardness	Tensile strength (approximate value) MPa (kgf/mm²) (2)	Rockwell C scale hardness (3)
		Standard ball	Tungsten carbide ball	(HRA) A scale Load 60kgf Diamond conical indenter	(HRB) B scale Load 100kgf Dia. 1.6mm (1/16 in.) ball	(HRD) D scale Load 100kgf Diamond conical indenter	15—N scale Load 15kgf	30—N scale Load 30kgf	45—N scale Load 45kgf			
68	940	—	—	85.6	—	76.9	93.2	84.4	75.4	97	—	68
67	900	—	—	85.0	—	76.1	92.9	83.6	74.2	95	—	67
66	865	—	—	84.5	—	75.4	92.5	82.8	73.3	92	—	66
65	832	—	(739)	83.9	—	74.5	92.2	81.9	72.0	91	—	65
64	800	—	(722)	83.4	—	73.8	91.8	81.1	71.0	88	—	64
63	772	—	(705)	82.8	—	73.0	91.4	80.1	69 9	87	—	63
62	746	—	(688)	82.3	—	72.2	91.1	79.3	68.8	85	—	62
61	720	—	(670)	81.8	—	71.5	90.7	78.4	67.7	83	—	61
60	697	—	(654)	81.2	—	70.7	90.2	77.5	66.6	81	—	60
59	674	—	(634)	80.7	—	69.9	89.8	76.6	65.5	80	—	59
58	653	—	615	80.1	—	69.2	89.3	75.7	64.3	78	—	58
57	633	—	595	79.6	—	68.5	88.9	74.8	63.2	76	—	57
56	613	—	577	79.0	—	67.7	88.3	73.9	62.0	75	—	56
55	595	—	560	78.5	—	66.9	87.9	73.0	60.9	74	2075 (212)	55
54	577	—	543	78.0	—	66.1	87.4	72.0	59.8	72	2015 (205)	54
53	560	—	525	77.4	—	65.4	86.9	71.2	58.6	71	1950 (199)	53
52	544	(500)	512	76.8	—	64.6	86.4	70.2	57.4	69	1880 (192)	52
51	528	(487)	496	76.3	—	63.8	85.9	69.4	56.1	68	1820 (186)	51
50	513	(475)	481	75.9	—	63.1	85.5	68.5	55.0	67	1760 (179)	50
49	498	(464)	469	75.2	—	62.1	85.0	67.6	53.8	66	1695 (173)	49
48	484	451	455	74.7	—	61.4	84.5	66.7	52.5	64	1635 (167)	48
47	471	442	443	74.1	—	60.8	83.9	65.8	51.4	63	1580 (161)	47
46	458	432	432	73.6	—	60.0	83.5	64.8	50.3	62	1530 (156)	46
45	446	421	421	73.1	—	59.2	83.0	64.0	49.0	60	1480 (151)	45
44	434	409	409	72.5	—	58.5	82.5	63.1	47.8	58	1435 (146)	44
43	423	400	400	72.0	—	57.7	82.0	62.2	46.7	57	1385 (141)	43
42	412	390	390	71.5	—	56.9	81.5	61.3	45.5	56	1340 (136)	42
41	402	381	381	70.9	—	56.2	80.9	60.4	44.3	55	1295 (132)	41
40	392	371	371	70.4	—	55.4	80.4	59.5	43.1	54	1250 (127)	40
39	382	362	362	69.9	—	54.6	79.9	58.6	41.9	52	1215 (124)	39
38	372	353	353	69.4	—	53.8	79.4	57.7	40.8	51	1180 (120)	38
37	363	344	344	68.9	—	53.1	78.8	56.8	39.6	50	1160 (118)	37
36	354	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	1115 (114)	36
35	345	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	1080 (110)	35
34	336	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	1055 (108)	34
33	327	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	1025 (105)	33
32	318	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	1000 (102)	32
31	310	294	294	65.8	(106.0)	48.4	75.6	51.3	32.7	43	980 (100)	31
30	302	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	950 (97)	30
29	294	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	930 (95)	29
28	286	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	910 (93)	28
27	279	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	880 (90)	27
26	272	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	860 (88)	26
25	266	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	840 (86)	25
24	260	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	825 (84)	24
23	254	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	805 (82)	23
22	248	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	785 (80)	22
21	243	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	770 (79)	21
20	238	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	760 (77)	20
(18)	230	219	219	—	96.7	—	—	—	—	33	730 (75)	(18)
(16)	222	212	212	—	95.5	—	—	—	—	32	705 (72)	(16)
(14)	213	203	203	—	93.9	—	—	—	—	31	675 (69)	(14)
(12)	204	194	194	—	92.3	—	—	—	—	29	650 (66)	(12)
(10)	196	187	187	—	90.7	—	—	—	—	28	620 (63)	(10)
(8)	188	179	179	—	89.5	—	—	—	—	27	600 (61)	(8)
(6)	180	171	171	—	87.1	—	—	—	—	26	580 (59)	(6)
(4)	173	165	165	—	85.5	—	—	—	—	25	550 (56)	(4)
(2)	166	158	158	—	83.5	—	—	—	—	24	530 (54)	(2)
(0)	160	152	152	—	81.7	—	—	—	—	24	515 (53)	(0)

Note (1) : Figures in blue are based on ASTM E 140, Table 1 (Jointly prepared by SAE, ASM and ASTM.)
(2) : The units and figures shown in parentheses (　　) following the listed value are the results of conversion from PSI figures by reference to JIS Z 8413 and Z8438 conversion tables.
1MPa = 1N/mm²
(3) : The figures in parentheses (　　) are in ranges not frequently used. They are given as reference data.

SURFACE ROUGHNESS

JIS B 0601 (1994)
Excerpts from JIS B 0031 (1994)

Varieties of Surface Roughness

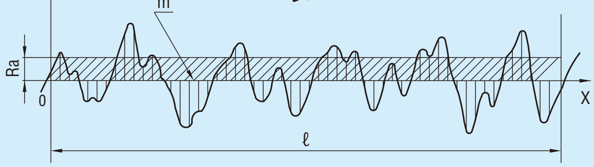
The definitions and notation are prescribed for the parameters which indicate the surface roughness of an industrial product, including the arithmetic average roughness (Ra), maximum height (Ry), 10-spot average roughness (Rz), average concave-to-convex distance (Sm), average distance between local peaks (S), and load length rate (tp). Surface roughness is the arithmetic average of values at randomly selected spots on the surface of an object.

[Center-line average roughness (Ra_{75}) is defined in the supplements to JIS B 0031 and JIS B 0601.]

Typical calculations of surface roughness

Arithmetical 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. When the roughness curve is represented by $y=f(\chi)$, Ra is the value in microns (μm) found from the formula shown at right.

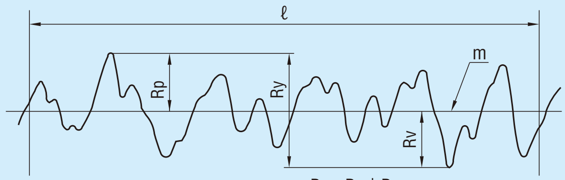


$$Ra=\frac{1}{\ell}\int_0^{\ell}|f(\chi)|\,d\chi$$

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 valley line in this portion is measured in the direction of the magnitude axis, and this value is indicated in microns (μm).

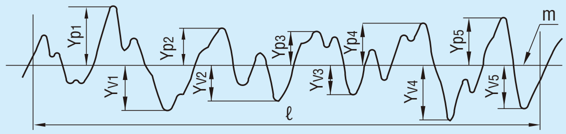
Note: When finding Ry, the reference length is selected from a portion which contains no abnormally high peaks or abnormally low valleys (locations which are likely flaws).



$Ry=Rp+Rv$

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. Within this portion, the average absolute value of the height (Yp) of the five highest peaks as measured from the average line and the average absolute value of the height (Yv) of the five lowest valleys are added together. Rz is this sum, in microns (μm).



$$Rz=\frac{|Yp_1+Yp_2+Yp_3+Yp_4+Yp_5|+|Yv_1+Yv_2+Yv_3+Yv_4+Yv_5|}{5}$$

$Yp_1, Yp_2, Yp_3, Yp_4, Yp_5$: Heights of the of top five peaks within the sampled portion of reference length ℓ

$Yv_1, Yv_2, Yv_3, Yv_4, Yv_5$: Heights of the five lowest valleys within the sampled portion of reference length ℓ

Reference: Relationship Between Arithmetic Average Roughness (Ra) and Previous Notation

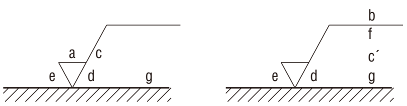
Arithmetical average roughness Ra			Max. height Ry	Ten-spot average roughness Rz	Ry·Rz reference length ℓ (mm)	Conventional finishing symbol
Standard sequence	Cut-off value λc (mm)	Drawing indication of surface texture	Standard sequence			
0.012 a	0.08	0.012 ∼ 0.2	0.05 s	0.05 z	0.08	▽▽▽▽
0.025 a	0.25		0.1 s	0.1 z		
0.05 a			0.2 s	0.2 z	0.25	
0.1 a	0.8		0.4 s	0.4 z		
0.2 a			0.8 s	0.8 z	0.8	
0.4 a		0.4 ∼ 1.6	1.6 s	1.6 z		▽▽▽
0.8 a			3.2 s	3.2 z		
1.6 a			6.3 s	6.3 z		
3.2 a	2.5	3.2 ∼ 6.3	12.5 s	12.5 z	2.5	▽▽
6.3 a			25 s	25 z		
12.5 a	8	12.5 ∼ 25	50 s	50 z		▽
25 a			100 s	100 z	8	
50 a		50 ∼ 100	200 s	200 z		∼
100 a	—		400 s	400 z	—	

※The relationships among the three varieties shown here are not precise, and are presented for convenience only.
※Ra: The evaluation lengths of Ry and Rz are the cut-off values and the reference length each multiplied by five.

Position of Auxiliary Symbols for Surface Symbols

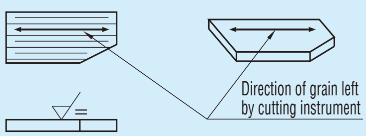
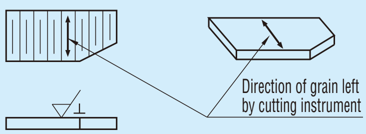
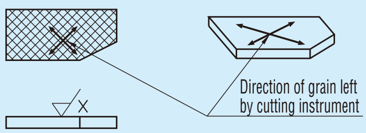
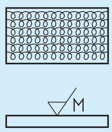
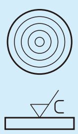
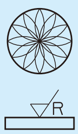
An auxiliary symbol indicating a surface roughness value, cut-off value or reference length, machining method, grain direction, surface undulation, etc. is placed around the surface symbol as shown in Fig. 1.

Fig. 1　Positions of Auxiliary Symbols



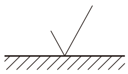
a: Ra value
b: Machining method
c: Cutoff value・Evaluation length
c´: Reference length・Evaluation length
d: Grain direction
f: Parameter other than Ra（when tp, this is parameter / cutoff level）
g: Surface undulation（according to JIS B 0610）
Remark　: Symbols other than a and f shall be entered when needed.

Reference　: In ISO 1302, a finish allowance is entered at the location of e in Figure 1.

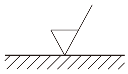
Symbol	Meaning	Diagram
=	Direction of grains left by the cutting instrument are parallel to the projection plane of the drawing where the symbol is entered. Example: Shaped surface	
⊥	Direction of grains left by the cutting instrument are perpendicular to the projection plane of the drawing where the symbol is entered. Examples: Shaped surface (side view), circular cut, cylindrical cut	
X	Direction of grains left by the cutting instrument intersect in 2 directions at angles to the projection plane of the drawing where the symbol is entered. Example: Honed surface	
M	Direction of grains left by the cutting instrument intersect in multiple directions or have no direction. Examples: Lapped surface, superfinished surface, and surface finished by front milling or end milling with cross feed	
C	Grains left by the cutting instrument are virtually concentric around the center of the projection plane of the drawing where the symbol is entered. Example: Facing surface	
R	Grains left by the cutting instrument are virtually radial with respect to the center of the projection plane of the drawing where the symbol is entered.	

■Examples of surface symbols

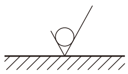
Surface symbol



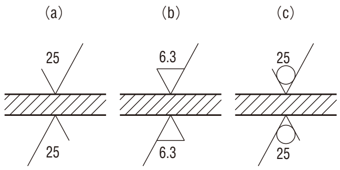
Symbol indicating a surface that requires a removal process



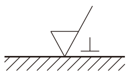
Symbol indicating a surface where removal processes are prohibited



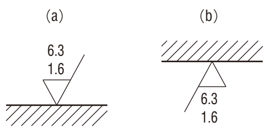
Examples of indicating the Ra upper limit



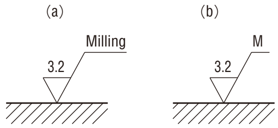
Example of indicating grain direction



Examples of indicating Ra upper limit and lower limit



Examples of indicating the machining method



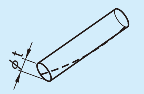
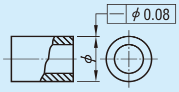
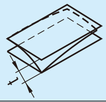
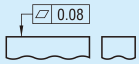
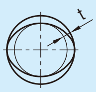
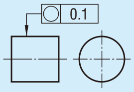
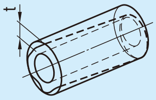
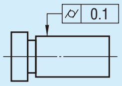
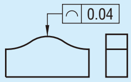
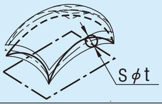
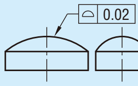
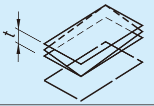
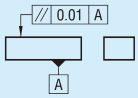
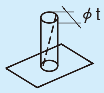
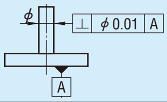
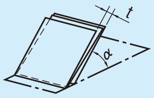
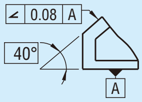
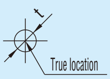
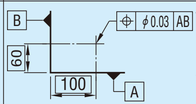
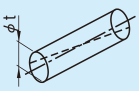
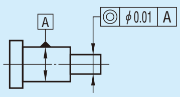
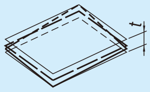
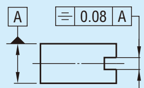
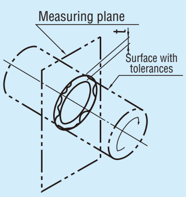
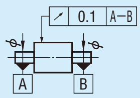
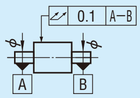
SURFACE ROUGHNESS BY DIFFERENT MACHINING METHODS

	Arithmetic average 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
Conventional notation for surface roughness	Max. height 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 value of reference length (mm)	0.25				0.8			2.5		8		25	
	Finishing symbol	▽▽▽▽				▽▽▽			▽▽		▽		—	
Machining methods	Forging								◄ Fine	►	◄	—	—	►
	Casting								◄ Fine	►	◄	—	—	►
	Die casting								◄	►				
	Hot rolling								◄	—	—	►		
	Cold rolling			◄	—	—	—	—	►					
	Drawing						◄	—	—	►				
	Extruding						◄	—	—	►				
	Tumbling		◄	—	—	►								
	Sandblasting								◄	—	►			
	Rolling				◄	—	►							
	Front milling						◄ Fine	►	◄	—	—	►		
	Planing								◄	—	—	►		
	Carving (including slotting)								◄	—	—	►		
	Milling						◄ Fine	►	◄	—	—	►		
	Precision boring				◄	—	—	►						
	Filing						◄ Fine	►	◄	—	►			
	Round grinding			◄ Fine	—	►	◄ High	►	◄ Medium	►	◄ Rough	—	—	►
	Boring						◄ Fine	►	◄	—	►			
	Drilling								◄	—	►			
	Reaming					◄ Fine	►	◄	—	►				
	Broach grinding					◄ Fine	►	◄	—	►				
	Shaving						◄	—	—	►				
	Grinding			◄ Fine ►	◄ High	►	◄ Medium	►	◄ Rough	—	►			
	Hone finishing			◄ Fine	►	◄	—	►						
	Super finishing	◄ Fine	►	◄	►									
	Buffing		◄ Fine	—	—	►	◄	—	►					
	Paper finishing			◄ Fine	►	◄	►							
	Lapping	◄ Fine	►	◄	►									
	Liquid honing			◄ Fine	►	◄	—	►						
	Burnishing				◄	—	►							
	Surface rolling				◄	—	►							
	Electric discharge carving						◄	—	—	—	►			
	WEDM (Wire electric discharge machining)							◄	—	►				
	Chemical polishing					◄ Fine	—	►	◄	►				
	Electrolytic abrasion	◄ Fine	—	—	►	◄	—	►						

INDICATIONS OF GEOMETRICAL TOLERANCE ON DRAWINGS

Excerpts from JIS B 0021 (1984)

■Types and symbols of geometrical tolerances

	Type of tolerance	Symbol	Definition of tolerance range		Examples of drawings and their interpretations	
Shape tolerances	Straightness tolerance	⏤		If the symbol φ is attached before the numerical value that indicates the tolerance range, this tolerance range is the range within a cylinder of diameter t.		If a tolerance frame is connected to a dimension that indicates the diameter of a cylinder, the axis line of the cylinder shall be contained within a cylinder of 0.08mm diameter.
	Flatness tolerance	⏥		The tolerance range is the area between two parallel planes separated by distance t.		This surface shall be contained within two parallel planes separated by 0.08mm.
	Circularity tolerance	○		The tolerance range in the considered plane is the area between two concentric circles separated by distance t.		The circumference in any section normal to the axis shall be contained between two concentric circles separated by 0.1mm on the same plane.
	Cylindricity tolerance	⌭		The tolerance range is the range contained between two coaxial cylinder surfaces separated by distance t.		The considered surface shall be contained between two coaxial cylinder surfaces separated by 0.1mm.
	Profile tolerance of line	⌒		The tolerance range is the range contained between the two envelope curves formed by a circle with diameter t, the center of which is situated on the theoretically correct profile curve.		In any cross-section parallel to the projection plane, the considered profile shall be contained between the two envelope curves formed by a 0.04mm diameter circle, the center of which is situated on the theoretically correct profile curve.
	Profile tolerance of surface	⌓		The tolerance range is the range contained between the two enveloping surfaces formed by a sphere with diameter t, the center of which is situated on the theoretically correct profile surface.		The considered surface shall be contained between the two enveloping surfaces formed by a 0.02mm diameter sphere, the center of which is situated on the surface containing the theoretically correct profile.
Orientation tolerances	Parallelism tolerance	∥		The tolerance range is the range contained between two planes parallel to the datum plane and separated by distance t.		The surface shown by the arrow of the indicator line shall be contained between two planes parallel to the datum plane A and separated by 0.01mm in the direction of the arrow of the indicator line.
	Perpendicularity tolerance	⊥		If symbol φ is attached before the numerical value indicating the tolerance range, this tolerance range is the range contained within a cylinder of diameter t that is perpendicular to the datum plane.		The axis of the cylinder shown by the arrow of the indicator line shall be contained within a cylinder of diameter 0.01mm that is perpendicular to the datum plane A.
	Angularity tolerance	∠		The tolerance range is the range contained between two parallel planes inclined at a specified angle to the datum plane and separated from each other by distance t.		The surface shown by the arrow of the indicator line shall be contained between two parallel planes which are inclined with theoretical exactness by 40 degrees to the datum plane A, and which are separated by 0.08mm in the direction of the arrow of the leader line.
Positional tolerances	Positional tolerance	⌖		The tolerance range is the range contained within a circle or sphere of diameter t with its center situated at the theoretically exact location of the considered point (hereafter referred to as the "true location").		The point shown by the indicator line shall be contained within a 0.03mm diameter circle with its center situated at the true location 60mm from datum line A and 100mm from datum line B.
	Coaxiality tolerance or concentricity tolerance	◎		If symbol φ is attached before the numerical value that indicates the tolerance, the tolerance range is the range within a cylinder of diameter t whose axis matches the datum axis line.		The axis of the cylinder shown by the arrow of the indicator line shall be contained within a cylinder of diameter 0.01mm whose axis matches datum axis line A.
	Symmetry	⌯		The tolerance range is the range contained between two parallel planes separated by distance t and arranged symmetrically with respect to the datum center plane.		The center plane shown by the arrow of the indicator line shall be contained between two parallel planes separated by 0.08mm and arranged symmetrically with respect to the datum center plane A.
Run-out tolerances	Circular run-out tolerance	↗		The tolerance range is the range contained between two concentric circles separated in the axial direction by distance t and the centers of which are situated on the datum axis line on any measuring plane normal to the datum axis line.		The radial run-out of the cylinder surface shown by the arrow of the indicator line shall not exceed 0.1mm on any measuring plane normal to the datum axis line when the cylinder is rotated by one rotation about the datum axis line A–B.
	Total run-out tolerance	⌰		The tolerance range is the range contained between two coaxial cylinders having axes agreeing with the datum axis line and separated from each other by distance t in the radial direction.		The total radial run-out of the cylinder surface shown by the arrow of the indicator line shall not exceed 0.1mm at any point on the cylinder surface when the cylindrical part is rotated about the datum axis line A–B.

The meanings of the lines used in the drawings in the "definition of tolerance range" column are as follows.
Thick solid or broken line: Shape Thin dash-dot line: Center line Thick dash-dot line: Datum
Thin alternating long and two short dashes line: Supplementary projection plane or section plane Thin solid or broken line: Tolerance range
Thick alternating long and two short dashes line: Projection of shape onto supplementary plane or section plane

BASIS OF SELECTION FOR FITS

Excerpts from "Product Manual (Accuracy Version)" in JIS "How to Use" series

			H6	H7	H8	H9	Applicable part	Functional classification		Application example
Parts can move relative to each other	Clearance fit	Loose fit				c9	Part which accommodates a particularly wide gap, or a moving part which requires a gap Part which accommodates a wide gap to facilitate assembly Part which requires an appropriate gap even at high temperatures	Part which for functional reasons requires a large gap { Expands. Large positional error. Long fitting length		Piston ring and piston ring groove Fitting by means of a loose set pin
		Loose roll fit			d9	d9	Part which accommodates a wide gap, or which requires a wide gap	Cost needs to be reduced. { Manufacturing cost Maintenance cost		Crank web and pin bearing (side) Exhaust valve box and spring bearing sliding part Piston ring and piston ring groove
				e7	e8	e9	Part which accommodates a fairly wide gap, or a moving part which requires a gap Fairly wide gap and well lubricated bearing Bearing subjected to high temperature, high speed, and high load (high-degree forced lubrication)	Regular rotating or sliding part (Must be well lubricated.)		Fitting of exhaust valve seat Main bearing for crankshaft Regular sliding part stripper bolt MSB (e9)
		Roll fit	f6	f7	f7 f8		Fitting which provides an appropriate clearance and permits movement (high-quality fitting). Regular normal-temperature bearing lubricated with grease or oil	Regular fitting part (is often disassembled)		Part where a cooled exhaust valve box is inserted Regular shaft and bushing Link device lever and bushing
		Tight roll fit	g5	g6			Continuously rotating part of a precision machine under light load Fitting with a narrow gap and which permits movement (spigot, positioning) High-precision sliding part	Part requiring precision motion with almost no gap		Link device pin and lever Key and key groove Precision control valve rod Guide lifter pin (g6)
Parts cannot move relative to each other.	Transition fit	Sliding fit	h5	h6	h7 h8	h9	Fitting which allows movement by hand when a lubricant is used (high-quality positioning) Special high-precision sliding part Unimportant stationary part	Difficult to disassemble without damaging the part.	Fitting force alone is insufficient for transmitting force	Fitting of rim and boss Fitting of gears in a precision gear device Dowel pin MSTH (h7)
		Push fit	h5 h6	js6			Installation part which is compatible with a very small tightening interference High-precision positioning which locks both parts in place while unit is in use Fitting which can be assembled/disassembled using a wooden or lead hammer			Fitting two coupling flanges Governor path and pin Fitting of gear rim and boss
		Striking	js5	k6			Fitting which requires an iron hammer or hand press for assembly/disassembly (A key or other device is required in order to prevent inter-part shaft rotation.) Precision positioning			Fitting of gear pump shaft and casing Reamer bolt
			k5	m6			Assembly/disassembly are the same as the above. Precision positioning which permits no gap at all			Reamer bolt Dowel pin MSTM (m6) Fastening of hydraulic device pistons and shafts Fitting of coupling flange and shaft
		Light press fit	m5	n6			Fitting which requires considerable force for assembly/disassembly Precision stationary fitting (A key or other device is required for high-torque transmission purposes.)		Fitting force along is sufficient for transmitting small force	Fitting of flexible shaft coupling and gear (passive side) Precision fitting Punch SPAS, etc. (m5) Insertion of suction valve and valve guide Die MHD, etc. (m5)
	Interference fit	Press fit	n5 n6	p6			Fitting which requires large force for assembly/disassembly (A key or other device is required for high-torque transmission purposes.) However, only light press-fitting force is required for press-fitting when both parts are non-ferrous parts. Fastened using the standard press-fitting for fastening a ferrous part to a ferrous, bronze, or copper part	Difficult to disassemble without damaging the part.		Insertion of suction valve and valve guide Straight die MSD, etc. (n5) Fixing a gear and shaft together (small torque) Dowel pin MST (p6) Flexible coupling shaft and gear (drive side)
			p5	r6			Assembly/disassembly are the same as the above. Shrinkage press fitting, cold press fitting or forced press fitting is required for large parts		Fitting force is capable of transmitting considerable force	Coupling and shaft
		Strong press fit, shrinkage press fit, cold press fit	r5	s6 t6 u6 x6			Permanent assembly in which parts are both tightly fastened together and will not be disassembled, and which requires shrinkage press fitting, cold press fitting, or forced press fitting. For light alloys, only ordinary press fitting is required.			Fitting and fixing a bearing bushing Insertion of suction valve and valve seat Fixing a coupling flange and shaft together (large torque) Fixing a drive gear rim and boss together Fitting and fixing a bearing bushing

The items printed in red in the Application example are press die parts presented in this catalog.

1.1 Fitting with regularly used hole adopted as reference

Reference hole	Shaft tolerance range class																
	Clearance fit							Transition fit			Close fit						
H6						g5	h5	js5	k5	m5							
					f6	g6	h6	js6	k6	m6	n6 *	p6 *					
H7					f6	g6	h6	js6	k6	m6	n6	p6 *	r6 *	s6	t6	u6	x6
				e7	f7		h7	js7									
H8					f7		h7										
				e8	f8		h8										
			d9	e9													
H9			d8	e8			h8										
		c9	d9	e9			h9										
H10	b9	c9	d9														

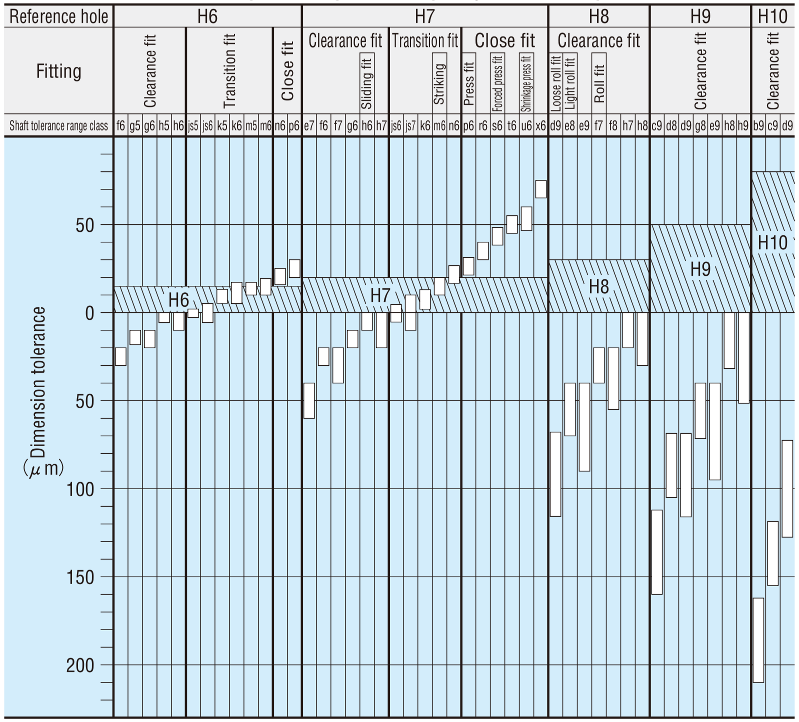
Note: ＊Exceptions for these fittings may arise depending on the dimensional sectioning scheme.

2.1 Fitting with regularly used shaft adopted as reference

Reference shaft	Hole tolerance range class																
	Clearance fit							Transition fit			Close fit						
h5							H6	JS6	K6	M6	N6 *	P6					
h6					F6	G6	H6	JS6	K6	M6	N6	P6 *					
					F7	G7	H7	JS7	K7	M7	N7	P7 *	R7	S7	T7	U7	X7
h7				E7	F7		H7										
					F8		H8										
h8			D8	E8	F8		H8										
			D9	E9			H9										
h9			D8	E8			H8										
		C9	D9	E9			H9										
	B10	C10	D10														

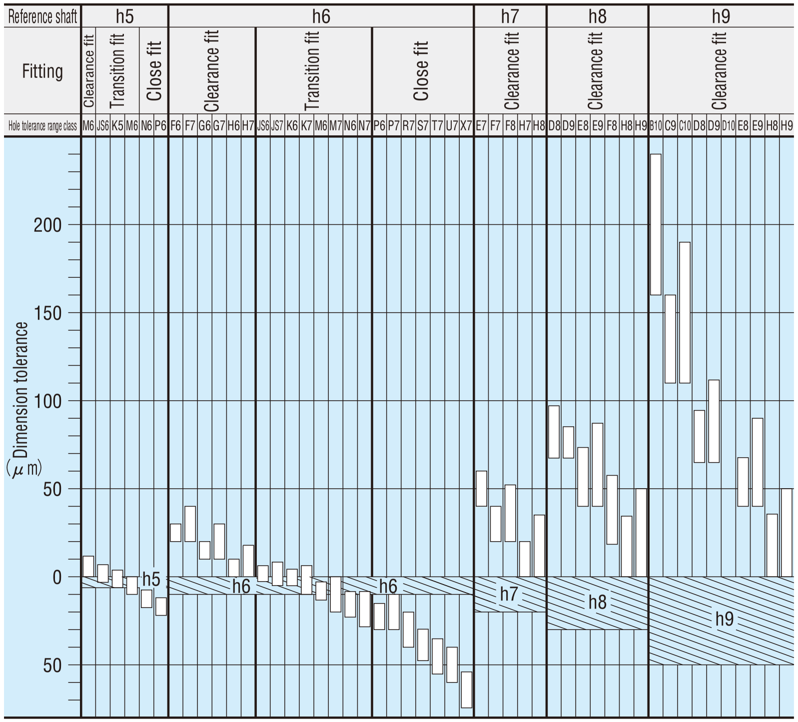
Note: ＊Exceptions for these fittings may arise depending on the dimensional sectioning scheme.

1.2 Correlation of tolerance ranges in fitting with the regularly used hole adopted as reference



＊ Cases in which the measurement exceeds the reference dimension in the above table (18mm) but does not exceed 30mm.

2.2 Correlation of tolerance ranges in fitting with the regularly used shaft adopted as reference



＊ Cases in which the measurement exceeds the reference dimension in the above table (18mm) but does not exceed 30mm.

[TECHNICAL DATA] TOLERANCES OF REGULARLY USED HOLE FITS

Excerpts from JIS B 0401 (1999)

Hole dimensional tolerances for regularly used fitting

Units: μm

Standard dimension (mm) More than	Not more than	B10	C9	C10	D8	D9	D10	E7	E8	E9	F6	F7	F8	G6	G7	H6	H7	H8	H9	H10	JS6	JS7	K6	K7	M6	M7	N6	N7	P6	P7	R7	S7	T7	U7	X7
–	3	+180 +140	+85 +60	+100 +60	+34 +20	+45 +20	+60 +20	+24 +14	+28 +14	+39 +14	+12 +6	+16 +6	+20 +6	+8 +2	+12 +2	+6 0	+10 0	+14 0	+25 0	+40 0	±3	±5	0 −6	0 −10	−2 −8	−2 −12	−4 −10	−4 −14	−6 −12	−6 −16	−10 −20	−14 −24	–	−18 −28	−20 −30
3	6	+188 +140	+100 +70	+118 +70	+48 +30	+60 +30	+78 +30	+32 +20	+38 +20	+50 +20	+18 +10	+22 +10	+28 +10	+12 +4	+16 +4	+8 0	+12 0	+18 0	+30 0	+48 0	±4	±6	+2 −6	+3 −9	−1 −9	0 −12	−5 −13	−4 −16	−9 −17	−8 −20	−11 −23	−15 −27	–	−19 −31	−24 −36
6	10	+208 +150	+116 +80	+138 +80	+62 +40	+76 +40	+98 +40	+40 +25	+47 +25	+61 +25	+22 +13	+28 +13	+35 +13	+14 +5	+20 +5	+9 0	+15 0	+22 0	+36 0	+58 0	±4.5	±7	+2 −7	+5 −10	−3 −12	0 −15	−7 −16	−4 −19	−12 −21	−9 −24	−13 −28	−17 −32	–	−22 −37	−28 −43
10	14	+220 +150	+138 +95	+165 +95	+77 +50	+93 +50	+120 +50	+50 +32	+59 +32	+75 +32	+27 +16	+34 +16	+43 +16	+17 +6	+24 +6	+11 0	+18 0	+27 0	+43 0	+70 0	±5.5	±9	+2 −9	+6 −12	−4 −15	0 −18	−9 −20	−5 −23	−15 −26	−11 −29	−16 −34	−21 −39	–	−26 −44	−33 −51
14	18																																		−38 −56
18	24	+244 +160	+162 +110	+194 +110	+98 +65	+117 +65	+149 +65	+61 +40	+73 +40	+92 +40	+33 +20	+41 +20	+53 +20	+20 +7	+28 +7	+13 0	+21 0	+33 0	+52 0	+84 0	±6.5	±10	+2 −11	+6 −15	−4 −17	0 −21	−11 −24	−7 −28	−18 −31	−14 −35	−20 −41	−27 −48	–	−33 −54	−46 −67
24	30																																−33 −54	−40 −61	−56 −77
30	40	+270 +170	+182 +120	+220 +120	+119 +80	+142 +80	+180 +80	+75 +50	+89 +50	+112 +50	+41 +25	+50 +25	+64 +25	+25 +9	+34 +9	+16 0	+25 0	+39 0	+62 0	+100 0	±8	±12	+3 −13	+7 −18	−4 −20	0 −25	−12 −28	−8 −33	−21 −37	−17 −42	−25 −50	−34 −59	−39 −64	−51 −76	–
40	50	+280 +180	+192 +130	+230 +130																													−45 −70	−61 −86	
50	65	+310 +190	+214 +140	+260 +140	+146 +100	+174 +100	+220 +100	+90 +60	+106 +60	+134 +60	+49 +30	+60 +30	+76 +30	+29 +10	+40 +10	+19 0	+30 0	+46 0	+74 0	+120 0	±9.5	±15	+4 −15	+9 −21	−5 −24	0 −30	−14 −33	−9 −39	−26 −45	−21 −51	−30 −60	−42 −72	−55 −85	−76 −106	–
65	80	+320 +200	+224 +150	+270 +150																											−32 −62	−48 −78	−64 −94	−91 −121	
80	100	+360 +220	+257 +170	+310 +170	+174 +120	+207 +120	+260 +120	+107 +72	+126 +72	+159 +72	+58 +36	+71 +36	+90 +36	+34 +12	+47 +12	+22 0	+35 0	+54 0	+87 0	+140 0	±11	±17	+4 −18	+10 −25	−6 −28	0 −35	−16 −38	−10 −45	−30 −52	−24 −59	−38 −73	−58 −93	−78 −113	−111 −146	–
100	120	+380 +240	+267 +180	+320 +180																											−41 −76	−66 −101	−91 −126	−131 −166	
120	140	+420 +260	+300 +200	+360 +200	+208 +145	+245 +145	+305 +145	+125 +85	+148 +85	+185 +85	+68 +43	+83 +43	+106 +43	+39 +14	+54 +14	+25 0	+40 0	+63 0	+100 0	+160 0	±12.5	±20	+4 −21	+12 −28	−8 −33	0 −40	−20 −45	−12 −52	−36 −61	−28 −68	−48 −88	−77 −117	−107 −147	–	–
140	160	+440 +280	+310 +210	+370 +210																											−50 −90	−85 −125	−119 −159		
160	180	+470 +310	+330 +230	+390 +230																											−53 −93	−93 −133	−131 −171		
180	200	+525 +340	+355 +240	+425 +240	+242 +170	+285 +170	+355 +170	+146 +100	+172 +100	+215 +100	+79 +50	+96 +50	+122 +50	+44 +15	+61 +15	+29 0	+46 0	+72 0	+115 0	+185 0	±14.5	±23	+5 −24	+13 −33	−8 −37	0 −46	−22 −51	−14 −60	−41 −70	−33 −79	−60 −106	−105 −151	–	–	–
200	225	+565 +380	+375 +260	+445 +260																											−63 −109	−113 −159			
225	250	+605 +420	+395 +280	+465 +280																											−67 −113	−123 −169			
250	280	+690 +480	+430 +300	+510 +300	+271 +190	+320 +190	+400 +190	+162 +110	+191 +110	+240 +110	+88 +56	+108 +56	+137 +56	+49 +17	+69 +17	+32 0	+52 0	+81 0	+130 0	+210 0	±16	±26	+5 −27	+16 −36	−9 −41	0 −52	−25 −57	−14 −66	−47 −79	−36 −88	−74 −126	–	–	–	–
280	315	+750 +540	+460 +330	+540 +330																											−78 −130				
315	355	+830 +600	+500 +360	+590 +360	+299 +210	+350 +210	+440 +210	+182 +125	+214 +125	+265 +125	+98 +62	+119 +62	+151 +62	+54 +18	+75 +18	+36 0	+57 0	+89 0	+140 0	+230 0	±18	±28	+7 −29	+17 −40	−10 −46	0 −57	−26 −62	−16 −73	−51 −87	−41 −98	−87 −144	–	–	–	–
355	400	+910 +680	+540 +400	+630 +400																											−93 −150				
400	450	+1010 +760	+595 +440	+690 +440	+327 +230	+385 +230	+480 +230	+198 +135	+232 +135	+290 +135	+108 +68	+131 +68	+165 +68	+60 +20	+83 +20	+40 0	+63 0	+97 0	+155 0	+250 0	±20	±31	+8 −32	+18 −45	−10 −50	0 −63	−27 −67	−17 −80	−55 −95	−45 −108	−103 −166	–	–	–	–
450	500	+1090 +840	+635 +480	+730 +480																											−109 −172				

Note: In each column, the upper figure is the upper dimensional tolerance, and the lower figure is the lower dimensional tolerance.

Dimensional tolerances for regularly used fitting shaft

Shaft tolerance range class — Units: μm

Standard dimension (mm) More than	Not more than	b9	c9	d8	d9	e7	e8	e9	f6	f7	f8	g5	g6	h4＊	h5	h6	h7	h8	h9	js5	js6	js7	k5	k6	m5	m6	n5＊	n6	p6	r6	s6	t6	u6	x6
—	3	−140 −165	−60 −85	−20 −34	−20 −45	−14 −24	−14 −28	−14 −39	−6 −12	−6 −16	−6 −20	−2 −6	−2 −8	0 −3	0 −4	0 −6	0 −10	0 −14	0 −25	±2	±3	±5	+4 0	+6 0	+6 +2	+8 +2	+8 +4	+10 +4	+12 +6	+16 +10	+20 +14	—	+24 +18	+26 +20
3	6	−140 −170	−70 −100	−30 −48	−30 −60	−20 −32	−20 −38	−20 −50	−10 −18	−10 −22	−10 −28	−4 −9	−4 −12	0 −4	0 −5	0 −8	0 −12	0 −18	0 −30	±2.5	±4	±6	+6 +1	+9 +1	+9 +4	+12 +4	+13 +8	+16 +8	+20 +12	+23 +15	+27 +19	—	+31 +23	+36 +28
6	10	−150 −186	−80 −116	−40 −62	−40 −76	−25 −40	−25 −47	−25 −61	−13 −22	−13 −28	−13 −35	−5 −11	−5 −14	0 −4	0 −6	0 −9	0 −15	0 −22	0 −36	±3	±4.5	±7	+7 +1	+10 +1	+12 +6	+15 +6	+16 +10	+19 +10	+24 +15	+28 +19	+32 +23	—	+37 +28	+43 +34
10	14	−150 −193	−95 −138	−50 −77	−50 −93	−32 −50	−32 −59	−32 −75	−16 −27	−16 −34	−16 −43	−6 −14	−6 −17	0 −5	0 −8	0 −11	0 −18	0 −27	0 −43	±4	±5.5	±9	+9 +1	+12 +1	+15 +7	+18 +7	+20 +12	+23 +12	+29 +18	+34 +23	+39 +28	—	+44 +33	+51 +40
14	18																																	+56 +45
18	24	−160 −212	−110 −162	−65 −98	−65 −117	−40 −61	−40 −73	−40 −92	−20 −33	−20 −41	−20 −53	−7 −16	−7 −20	0 −6	0 −9	0 −13	0 −21	0 −33	0 −52	±4.5	±6.5	±10	+11 +2	+15 +2	+17 +8	+21 +8	+24 +15	+28 +15	+35 +22	+41 +28	+48 +35	—	+54 +41	+67 +54
24	30																															+54 +41	+61 +48	+77 +64
30	40	−170 −232	−120 −182	−80 −119	−80 −142	−50 −75	−50 −89	−50 −112	−25 −41	−25 −50	−25 −64	−9 −20	−9 −25	0 −7	0 −11	0 −16	0 −25	0 −39	0 −62	±5.5	±8	±12	+13 +2	+18 +2	+20 +9	+25 +9	+28 +17	+33 +17	+42 +26	+50 +34	+59 +43	+64 +48	+76 +60	—
40	50	−180 −242	−130 −192																													+70 +54	+86 +70	
50	65	−190 −264	−140 −214	−100 −146	−100 −174	−60 −90	−60 −106	−60 −134	−30 −49	−30 −60	−30 −76	−10 −23	−10 −29	0 −8	0 −13	0 −19	0 −30	0 −46	0 −74	±6.5	±9.5	±15	+15 +2	+21 +2	+24 +11	+30 +11	+33 +20	+39 +20	+51 +32	+60 +41	+72 +53	+85 +66	+106 +87	—
65	80	−200 −274	−150 −224																											+62 +43	+78 +59	+94 +75	+121 +102	
80	100	−220 −307	−170 −257	−120 −174	−120 −207	−72 −107	−72 −126	−72 −159	−36 −58	−36 −71	−36 −90	−12 −27	−12 −34	0 −10	0 −15	0 −22	0 −35	0 −54	0 −87	±7.5	±11	±17	+18 +3	+25 +3	+28 +13	+35 +13	+38 +23	+45 +23	+59 +37	+73 +51	+93 +71	+113 +91	+146 +124	—
100	120	−240 −327	−180 −267																											+76 +54	+101 +79	+126 +104	+166 +144	
120	140	−260 −360	−200 −300	−145 −208	−145 −245	−85 −125	−85 −148	−85 −185	−43 −68	−43 −83	−43 −106	−14 −32	−14 −39	0 −12	0 −18	0 −25	0 −40	0 −63	0 −100	±9	±12.5	±20	+21 +3	+28 +3	+33 +15	+40 +15	—	+52 +27	+68 +43	+88 +63	+117 +92	+147 +122	—	—
140	160	−280 −380	−210 −310																											+90 +65	+125 +100	+159 +134		
160	180	−310 −410	−230 −330																											+93 +68	+133 +108	+171 +146		
180	200	−340 −455	−240 −355	−170 −242	−170 −285	−100 −146	−100 −172	−100 −215	−50 −79	−50 −96	−50 −122	−15 −35	−15 −44	0 −14	0 −20	0 −29	0 −46	0 −72	0 −115	±10	±14.5	±23	+24 +4	+33 +4	+37 +17	+46 +17	—	+60 +31	+79 +50	+106 +77	+151 +122	—	—	—
200	225	−380 −495	−260 −375																											+109 +80	+159 +130			
225	250	−420 −535	−280 −395																											+113 +84	+169 +140			
250	280	−480 −610	−300 −430	−190 −271	−190 −320	−110 −162	−110 −191	−110 −240	−56 −88	−56 −108	−56 −137	−17 −40	−17 −49	0 −16	0 −23	0 −32	0 −52	0 −81	0 −130	±11.5	±16	±26	+27 +4	+36 +4	+43 +20	+52 +20	—	+66 +34	+88 +56	+126 +94	—	—	—	—
280	315	−540 −670	−330 −460																											+130 +98				
315	355	−600 −740	−360 −500	−210 −299	−210 −350	−125 −182	−125 −214	−125 −265	−62 −98	−62 −119	−62 −151	−18 −43	−18 −54	0 −18	0 −25	0 −36	0 −57	0 −89	0 −140	±12.5	±18	±28	+29 +4	+40 +4	+46 +21	+57 +21	—	+73 +37	+98 +62	+144 +108	—	—	—	—
355	400	−680 −820	−400 −540																											+150 +114				
400	450	−760 −915	−440 −595	−230 −327	−230 −385	−135 −198	−135 −232	−135 −290	−68 −108	−68 −131	−68 −165	−20 −47	−20 −60	0 −20	0 −27	0 −40	0 −63	0 −97	0 −155	±13.5	±20	±31	+32 +5	+45 +5	+50 +23	+63 +23	—	+80 +40	+108 +68	+166 +126	—	—	—	—
450	500	−840 −995	−480 −635																											+172 +132				

Note: In each column, the upper figure is the upper dimensional tolerance, and the lower figure is the lower dimensional tolerance.

Note ＊: h4 and n5 are old JIS standards, however they are listed here because they apply to a large number of Misumi products.

1. General dimension tolerance for parts formed by press working from sheet metal JIS B 0408—1991—

Table 1. General dimension tolerances of punching

Units: mm

Standard dimension		Grade		
		Grade A	Grade B	Grade C
	No more than 6	±0.05	±0.1	±0.3
More than 6	No more than 30	±0.1	±0.2	±0.5
More than 30	No more than 120	±0.15	±0.3	±0.8
More than 120	No more than 400	±0.2	±0.5	±1.2
More than 400	No more than 1000	±0.3	±0.8	±2
More than 1000	No more than 2000	±0.5	±1.2	±3

Note Grade A, B, and C are equivalent to tolerance grades f, m, and c in JIS B 0405.

Table 2. General dimensional tolerances of bending and drawing

Units: mm

Standard dimension		Grade		
		Grade A	Grade B	Grade C
	No more than 6	±0.1	±0.3	±0.5
More than 6	No more than 30	±0.2	±0.5	±1
More than 30	No more than 120	±0.3	±0.8	±1.5
More than 120	No more than 400	±0.5	±1.2	±2.5
More than 400	No more than 1000	±0.8	±2	±4
More than 1000	No more than 2000	±1.2	±3	±6

Note Grade A, B, and C are equivalent to tolerance grades f, m, and c in JIS B 0405.

2. General tolerances for parts formed by shear from metal plates JIS B 0410—1991—

Table 1. General dimensional tolerances of cut widths

Units: mm

Standard dimension		Material thickness (t) class							
		$t≦1.6$		$1.6<t≦3$		$3<t≦6$		$6<t≦12$	
		Grade							
		Grade A	Grade B	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
	No more than 30	±0.1	±0.3	—	—	—	—	—	—
More than 30	No more than 120	±0.2	±0.5	±0.3	±0.5	±0.8	±1.2	—	±1.5
More than 120	No more than 400	±0.3	±0.8	±0.4	±0.8	±1	±1.5	—	±2
More than 400	No more than 1000	±0.5	±1	±0.5	±1.2	±1.5	±2	—	±2.5
More than 1000	No more than 2000	±0.8	±1.5	±0.8	±2	±2	±3	—	±3
More than 2000	No more than 4000	±1.2	±2	±1.2	±2.5	±3	±4	—	±4

Table 2. General tolerances of straightness

Units: mm

Nominal dimension of cut length		Material thickness (t) class							
		$t≦1.6$		$1.6<t≦3$		$3<t≦6$		$6<t≦12$	
		Grade							
		Grade A	Grade B	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
	No more than 30	0.1	0.2	—	—	—	—	—	—
More than 30	No more than 120	0.2	0.3	0.2	0.3	0.5	0.8	—	1.5
More than 120	No more than 400	0.3	0.5	0.3	0.5	0.8	1.5	—	2
More than 400	No more than 1000	0.5	0.8	0.5	1	1.5	2	—	3
More than 1000	No more than 2000	0.8	1.2	0.8	1.5	2	3	—	4
More than 2000	No more than 4000	1.2	2	1.2	2.5	3	5	—	6

Table 3. General tolerances for perpendicularity

Units: mm

Nominal length of short side		Material thickness (t) class					
		$t≦3$		$3<t≦6$		$6<t≦12$	
		Grade					
		Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
	No more than 30	—	—	—	—	—	—
More than 30	No more than 120	0.3	0.5	0.5	0.8	—	1.5
More than 120	No more than 400	0.8	1.2	1	1.5	—	2
More than 400	No more than 1000	1.5	3	2	3	—	3
More than 1000	No more than 2000	3	6	4	6	—	6
More than 2000	No more than 4000	6	10	6	10	—	10

[TECHNICAL DATA] STANDARD MACHINING TOLERANCES

Excerpts from JIS B 0405 (1991)
JIS B 0419 (1991)

1. Regular cut dimension tolerance JIS B 0405 —1991—

Tolerances for length excluding chamfered portion Units: mm

Tolerance class		Standard dimension range							
Symbol	Description	Over 0.5 (1) to 3 incl.	Over 3 to 6 incl.	Over 6 to 30 incl.	Over 30 to 120 incl.	Over 120 to 400 incl.	Over 400 to 1000 incl.	Over 1000 to 2000 incl.	Over 2000 to 4000 incl.
		Tolerance							
f	Precision grade	±0.05	±0.05	±0.1	±0.15	±0.2	±0.3	±0.5	—
m	Medium class	±0.1	±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±2
c	Coarse class	±0.2	±0.3	±0.5	±0.8	±1.2	±2	±3	±4
v	Very coarse class	—	±0.5	±1	±1.5	±2.5	±4	±6	±8

Note (1): Tolerances for standard dimensions of less than 0.5 mm shall be specified individually.

2. Tolerance for length of chamfered portion (radius of rounding for edges and edge chamfering dimension)

Units: mm

Tolerance class		Standard dimension range		
Symbol	Description	Over 0.5 (2) to 3 incl.	Over 3 to 6 incl.	Over 6
		Tolerance		
f	Precision grade	±0.2	±0.5	±1
m	Medium class			
c	Coarse class	±0.4	±1	±2
v	Very coarse class			

Note (2): Tolerances for standard dimensions of less than 0.5 mm shall be specified individually.

3. Angle tolerance

Tolerance class		Length of shorter side of angle (Units: mm)				
Symbol	Description	10 or less	Over 10 to 50 incl.	Over 50 to 120 incl.	Over 120 to 400 incl.	Over 400
		Tolerance				
f	Precision grade	±1°	±30′	±20′	±10′	± 5′
m	Medium class					
c	Coarse class	±1° 30′	± 1°	±30′	±15′	±10′
v	Very coarse class	±3°	± 2°	± 1°	±30′	±20′

4. Regular perpendicularity tolerance JIS B 0419 —1991—

Units: mm

Tolerance class	Nominal length on shorter side			
	100 or less	Over 100 to 300 incl.	Over 300 to 1000 incl.	Over 1000 to 3000 incl.
	Perpendicularity tolerance			
H	0.2	0.3	0.4	0.5
K	0.4	0.6	0.8	1
L	0.6	1	1.5	2

5. Regular straightness and flatness tolerance JIS B 0419 —1991—

Units: mm

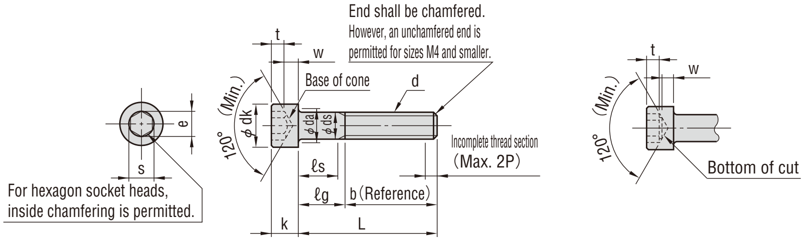
Tolerance class	Nominal length					
	10 or less	Over 10 to 30 incl.	Over 30 to 100 incl.	Over 100 to 300 incl.	Over 300 to 1000 incl.	Over 1000 to 3000 incl.
	Straightness and flatness tolerance					
H	0.02	0.05	0.1	0.2	0.3	0.4
K	0.05	0.1	0.2	0.4	0.6	0.8
L	0.1	0.2	0.4	0.8	1.2	1.6

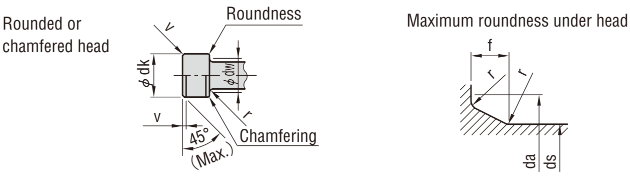
6. Regular symmetry tolerance

Units: mm

Tolerance class	Nominal length			
	100 or less	Over 100 to 300 incl.	Over 300 to 1000 incl.	Over 1000 to 3000 incl.
	Symmetry tolerance			
H	0.5			
K	0.6		0.8	1
L	0.6	1	1.5	2

1. Names of parts





$f\ (Max.) = 1.7r\ (Max.)$

$r\ (Max.) = \dfrac{da\ (Max.) - ds\ (Max.)}{2}$

r (Min.) = As shown in provided table

Units: mm

Thread nominal (d) (2)		M3	M4	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30
Thread pitch (P)		0.5	0.7	0.8	1	1.25	1.5	1.75	2	2	2.5	2.5	2.5	3	3	3.5
b	Reference	18	20	22	24	28	32	36	40	44	48	52	56	60	66	72
d_k	Max. (standard dimension) *	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36	40	45
	Max. **	5.68	7.22	8.72	10.22	13.27	16.27	18.27	21.33	24.33	27.33	30.33	33.39	36.39	40.39	45.39
	Min.	5.32	6.78	8.28	9.78	12.73	15.73	17.73	20.67	23.67	26.67	29.67	32.61	35.61	39.61	44.61
d_a	Max.	3.6	4.7	5.7	6.8	9.2	11.2	13.7	15.7	17.7	20.2	22.4	24.4	26.4	30.4	33.4
d_s	Max. (standard dimension)	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
	Min.	2.86	3.82	4.82	5.82	7.78	9.78	11.73	13.73	15.73	17.73	19.67	21.67	23.67	26.67	29.67
e	Min.	2.87	3.44	4.58	5.72	6.86	9.15	11.43	13.72	16.00	16.00	19.44	19.44	21.73	21.73	25.15
f	Max.	0.51	0.60	0.60	0.68	1.02	1.02	1.45	1.45	1.45	1.87	2.04	2.04	2.04	2.89	2.89
k	Max. (standard dimension)	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
	Min.	2.86	3.82	4.82	5.70	7.64	9.64	11.57	13.57	15.57	17.57	19.48	21.48	23.48	26.48	29.48
r	Min.	0.1	0.2	0.2	0.25	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1	1
s	Nominal (standard dimension)	2.5	3	4	5	6	8	10	12	14	14	17	17	19	19	22
	Min.	2.52	3.02	4.02	5.02	6.02	8.025	10.025	12.032	14.032	14.032	17.050	17.050	19.065	19.065	22.065
	Max. (1) Section 1	2.580	3.080	4.095	5.140	6.140	8.175	10.175	12.212	14.212	14.212	17.230	17.230	19.275	19.275	22.275
	Max. (1) Section 2	2.560	3.080	4.095	5.095	6.095	8.115	10.115	12.142	14.142	14.142					
t	Min.	1.3	2	2.5	3	4	5	6	7	8	9	10	11	12	13.5	15.5
v	Max.	0.3	0.4	0.5	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.7	3
d_w	Min.	5.07	6.53	8.03	9.38	12.33	15.33	17.23	20.17	23.17	25.87	28.87	31.81	34.81	38.61	43.61
w	Min.	1.15	1.4	1.9	2.3	3.3	4	4.8	5.8	6.8	7.7	8.6	9.5	10.4	12.1	13.1

Note (1): Section 1 for "s (Max.)" applies to bolts with strength class 8.8 and 10.9 and property class A2—50 and A2—70. Section 2 applies to bolts with strength class 12.9. However, based on agreement between the parties involved in the delivery, Section 1 may be applied to bolts with strength class 12.9.
s (Max.) for bolts of nominal size M20 or larger applies to bolts of all strength classes and property classes.

Note (2): Nominal sizes shown in ( ) should not be used whenever possible.

Remarks
1. Add a straight knurl or diamond knurl (refer to JIS B 0951 (KNURLING)) to the sides of the head.In this case, d_k (Max.) is the value marked by ** in this table.
   If a bolt without knurling is required, it shall be specified by the ordering party. However the d_k (Max.) is the value marked by * in this table.
2. The recommended length (ℓ) for the nominal thread size shall be enclosed in a bold line.
   For cases in which L is shorter than the position of the dotted line, full thread shall be used and the length of the incomplete thread part under the head shall be approximately 3P.
3. ℓg (Max.) and ℓs (Min.) for cases of a nominal length (ℓ) longer than the position of the dotted line shall be determined by the following formula.

   ℓg (Max.) = Nominal length (ℓ) − b

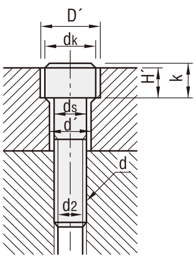
   ℓs (Min.) = ℓg (Max.) − 5P

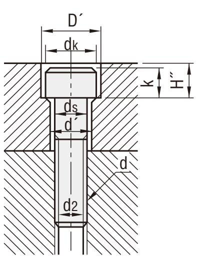
2. L, ℓs, and ℓg of hexagon socket head cap screws

Units: mm

Thread nominal (d)			M3		M4		M5		M6		M8		M10		M12		(M14)		M16		(M18)		M20		(M22)		M24		(M27)		M30	
L			ℓs Min. and ℓg Max.																													
Nominal length	min.	max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓs max.	ℓs min.	ℓg max.
5	4.76	5.24																														
6	5.76	6.24																														
8	7.71	8.29																														
10	9.71	10.29																														
12	11.65	12.35																														
16	15.65	16.35																														
20	19.58	20.42																														
25	24.58	25.42	4.5	7																												
30	29.58	30.42	9.5	12	6.5	10	4	8																								
35	34.5	35.5			11.5	15	9	13	6	11																						
40	39.5	40.5			16.5	20	14	18	11	16	5.75	12																				
45	44.5	45.5					19	23	16	21	10.75	17	5.5	13																		
50	49.5	50.5					24	28	21	26	15.75	22	10.5	18																		
55	54.4	55.6							26	31	20.75	27	15.5	23	10.25	19																
60	59.4	60.6							31	36	25.75	32	20.5	28	15.25	24	10	20														
65	64.4	65.6									30.75	37	25.5	33	20.25	29	15	25	11	21	4.5	17										
70	69.4	70.6									35.75	42	30.5	38	25.25	34	20	30	16	26	9.5	22										
80	79.4	80.6									45.75	52	40.5	48	35.25	44	30	40	26	36	19.5	32	15.5	28	11.5	24						
90	89.3	90.7											50.5	58	45.25	54	40	50	36	46	29.5	42	25.5	38	21.5	34	15	30	9	24		
100	99.3	100.7											60.5	68	55.25	64	50	60	46	56	39.5	52	35.5	48	31.5	44	25	40	19	34		
110	109.3	110.7													66.25	74	60	70	56	66	49.5	62	45.5	58	41.5	54	35	50	29	44	20.5	38
120	119.3	120.7													75.25	84	70	80	66	76	59.5	72	55.5	68	51.5	64	45	60	39	54	30.5	48
130	129.2	130.8															80	90	76	86	69.5	82	65.5	78	61.5	74	55	70	49	64	40.5	58
140	139.2	140.8															90	100	86	96	79.5	92	75.5	88	71.5	84	65	80	59	74	50.5	68
150	149.2	150.8																	96	106	89.5	102	85.5	98	81.5	94	75	90	69	84	60.5	78
160	159.2	160.8																	106	116	99.5	112	95.5	108	91.5	104	85	100	79	94	70.5	88
180	179.2	180.8																			119.5	132	115.5	128	111.5	124	105	120	99	114	90.5	108
200	199.05	200.95																					135.5	148	131.5	144	125	140	119	134	110.5	128
220	219.05	220.95																											139	154	130.5	148
240	239.05	240.95																											159	174	150.5	168
260	258.95	261.05																											179	194	170.5	188
280	278.95	281.05																											199	214	190.5	208
300	298.95	301.05																											219	234	210.5	228

Reference: Dimensions of counterbore and bolt holes for hexagon socket head cap screws





Units: mm

Thread nominal (d)	M3	M4	M5	M6	M8	M10	M12	M14	M16	M18	M20	M22	M24	M27	M30
ds	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
d´	3.4	4.5	5.5	6.6	9	11	14	16	18	20	22	24	26	30	33
dk	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36	40	45
D´	6.5	8	9.5	11	14	17.5	20	23	26	29	32	35	39	43	48
k	3	4	5	6	8	10	12	14	16	18	20	22	24	27	30
H´	2.7	3.6	4.6	5.5	7.4	9.2	11	12.8	14.5	16.5	18.5	20.5	22.5	25	28
H˝	3.3	4.4	5.4	6.5	8.6	10.8	13	15.2	17.5	19.5	21.5	23.5	25.5	29	32
d2	2.6	3.4	4.3	5.1	6.9	8.6	10.4	12.2	14.2	15.7	17.7	19.7	21.2	24.2	26.7

TABLE OF HOLE SIZES BEFORE THREADING

1. Metric coarse thread

Nominal thread size	Minimum dimension	Maximum dimension	
	Grade 2 / Grade 3	Grade 2	Grade 3
M 1×0.25	0.73	0.78	—
M 1.1×0.25	0.83	0.89	—
M 1.2×0.25	0.93	0.98	—
M 1.4×0.3	1.08	1.14	—
M 1.6×0.35	1.22	1.32	—
M 1.7×0.35	1.33	1.42	—
M 1.8×0.35	1.42	1.52	—
M 2×0.4	1.57	1.67	—
M 2.2×0.45	1.71	1.84	—
M 2.3×0.4	1.87	1.97	—
M 2.5×0.45	2.01	2.14	—
M 2.6×0.45	2.12	2.23	—
M 3×0.5	2.46	2.60	2.64
M 3.5×0.6	2.85	3.01	3.05
M 4×0.7	3.24	3.42	3.47
M 4.5×0.75	3.69	3.88	3.92
M 5×0.8	4.13	4.33	4.38
M 6×1	4.92	5.15	5.22
M 7×1	5.92	6.15	6.22
M 8×1.25	6.65	6.91	6.98
M 9×1.25	7.65	7.91	7.98
M 10×1.5	8.38	8.68	8.75
M 11×1.5	9.38	9.68	9.75
M 12×1.75	10.11	10.44	10.53
M 14×2	11.84	12.21	12.31
M 16×2	13.84	14.21	14.31
M 18×2.5	15.29	15.74	15.85
M 20×2.5	17.29	17.74	17.85
M 22×2.5	19.29	19.74	19.85
M 24×3	20.75	21.25	21.38
M 27×3	23.75	24.25	24.38
M 30×3.5	26.21	26.77	26.92
M 33×3.5	29.21	29.77	29.92
M 36×4	31.67	32.27	32.42
M 39×4	34.67	35.27	35.42
M 42×4.5	37.13	37.80	37.98
M 45×4.5	40.13	40.80	40.98
M 48×5	42.59	43.30	43.49

2. Metric fine thread

Nominal thread size	Minimum dimension	Maximum dimension	
	Grade 2 / Grade 3	Grade 2	Grade 3
M 2.5×0.35	2.12	2.22	—
M 3×0.35	2.62	2.72	—
M 3.5×0.35	3.12	3.22	—
M 4×0.5	3.46	3.60	3.64
M 4.5×0.5	3.96	4.10	4.14
M 5×0.5	4.46	4.60	4.64
M 5.5×0.5	4.96	5.10	5.14
M 6×0.75	5.19	5.38	5.42
M 7×0.75	6.19	6.38	6.42
M 8×1	6.92	7.15	7.22
M 8×0.75	7.19	7.38	7.42
M 9×1	7.92	8.15	8.22
M 9×0.75	8.19	8.38	8.42
M 10×1.25	8.65	8.91	8.98
M 10×1	8.92	9.15	9.22
M 10×0.75	9.19	9.38	—
M 11×1	9.92	10.15	10.22
M 11×0.75	10.19	10.38	10.42
M 12×1.5	10.38	10.68	10.75
M 12×1.25	10.65	10.91	10.98
M 12×1	10.92	11.15	11.22
M 14×1.5	12.38	12.68	12.75
M 14×1	12.92	13.15	13.22
M 15×1.5	13.38	13.68	13.75
M 15×1	13.92	14.15	14.22
M 16×1.5	14.38	14.68	14.75
M 16×1	14.92	15.15	15.22
M 17×1.5	15.38	15.68	15.75
M 17×1	15.92	16.15	16.22
M 18×2	15.84	16.21	16.31
M 18×1.5	16.38	16.68	16.75
M 18×1	16.92	17.15	17.22
M 20×2	17.84	18.21	18.31
M 20×1.5	18.38	18.68	18.75
M 20×1	18.92	19.15	19.22
M 22×2	19.84	20.21	20.31
M 22×1.5	20.38	20.68	20.75
M 22×1	20.92	21.15	21.22
M 24×2	21.84	22.21	22.31
M 24×1.5	22.38	22.68	22.75
M 24×1	22.92	23.15	23.22
M 25×2	22.84	23.21	23.31
M 25×1.5	23.38	23.68	23.75
M 25×1	23.92	24.15	24.22
M 26×1.5	24.38	24.68	24.75
M 27×2	24.84	25.21	25.31
M 27×1.5	25.38	25.68	25.75
M 27×1	25.92	26.15	26.22
M 28×2	25.84	26.21	26.31
M 28×1.5	26.38	26.68	26.75
M 28×1	26.92	27.15	27.22
M 30×3	26.75	27.25	27.38
M 30×2	27.84	28.21	28.31
M 30×1.5	28.38	28.68	28.75
M 30×1	28.92	29.15	29.22
M 32×2	29.84	30.21	30.31
M 32×1.5	30.38	30.68	30.75
M 33×3	29.75	30.25	30.38
M 33×2	30.84	31.21	31.31
M 33×1.5	31.38	31.68	31.75
M 35×1.5	33.38	33.68	33.75
M 36×3	32.75	33.25	33.38
M 36×2	33.84	34.21	34.31
M 36×1.5	34.38	34.68	34.75
M 38×1.5	36.38	36.68	36.75
M 39×3	35.75	36.25	36.38
M 39×2	36.84	37.21	37.31
M 39×1.5	37.38	37.68	37.75
M 40×3	36.75	37.25	37.38
M 40×2	37.84	38.21	38.31
M 40×1.5	38.38	38.68	38.75
M 42×4	37.67	38.27	38.42
M 42×3	38.75	39.25	39.38
M 42×2	39.84	40.21	40.31
M 42×1.5	40.38	40.68	40.75
M 45×4	40.67	41.27	41.42
M 45×3	41.75	42.25	42.38
M 45×2	42.84	43.21	43.31
M 45×1.5	43.38	43.68	43.75
M 48×4	43.67	44.27	44.42
M 48×3	44.75	45.25	45.38
M 48×2	45.84	46.21	46.31
M 48×1.5	46.38	46.68	46.75
M 50×3	46.75	47.25	47.38
M 50×2	47.84	48.21	48.31
M 50×1.5	48.38	48.68	48.75

■Axial tightening force and fatigue limit when fastening with bolts

- When calculating the suitable axial tightening force for bolt tightening, the maximum force shall be 70% of the standard proof strength using the torque control method, and the force shall be within the elastic range.
- Bolt fatigue strength under repeated load must not exceed the maximum allowable value.
- The bolt and nut seat must not cause any depression in the fastened part.
- Tightening must not cause any damage to the fastened part.

> Methods of bolt tightening include the torque control method, torque gradient control method, rotation angle control method, and extension measurement method. The torque control method is most commonly used, due to its simplicity.

■Calculation of axial tightening force and tightening torque

The relationship of axial tightening force Ff is shown by Formula (1).

$Ff = 0.7 \times \sigma y \times As$ ······ (1)

Tightening torque T_{fA} is found from Formula (2).

$T_{fA} = 0.35k(1+1/Q)\,\sigma y \cdot As \cdot d$······ (2)

k : Torque coefficient
d : Bolt nominal diameter [cm]
Q : Tightening coefficient
σy : Proof strength (112 kgf/mm^2 for strength class 12.9)
As : Bolt effective cross-section area [mm^2]

■Sample calculation

Find the suitable torque and axial force when using an M6 hexagon socket head cap screw (strength class 12.9) to fasten soft steel to soft steel, and tightening with oil lubrication.

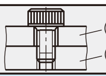
- The suitable torque is found by Formula (2), as shown below.

$T_{fA} = 0.35k(1+1/Q)\,\sigma y \cdot As \cdot d$
$= 0.35 \cdot 0.17(1+1/1.4)\,112 \cdot 20.1 \cdot 0.6$
$= 138$ [kgf·cm]

- Axial force Ff is found from Formula (1), as shown below.

$Ff = 0.7 \times \sigma y \times As$
$0.7 \times 112 \times 20.1$
1576 [kgf]

■Torque coefficient based on the combination of bolt surface treatment, tightened parts, and internal thread material

Bolt Surface treatment Lubrication	Torque coefficient k	Combination Tightened part material—Female screw material (a) (b) 
Steel bolt Black oxide coating Not lubricated	0.145	SCM—FC FC—FC SUS—FC
	0.155	S10C—FC SCM—S10C SCM—SCM FC—S10C FC—SCM
	0.165	SCM—SUS FC—SUS AL—FC SUS—S10C SUS—SCM SUS—SUS
	0.175	S10C—S10C S10C—SCM S10C—SUS AL—S10C AL—SCM
	0.185	SCM—AL FC—AL AL—SUS
	0.195	S10C—AL SUS—AL
	0.215	AL—AL
Steel bolt Black oxide coating Not lubricated	0.25	S10C—FC SCM—FC FC—FC
	0.35	S10C—FC SCM—S10C SCM—SCM FC—S10C FC—SCM
	0.45	S10C—S10C SCM—S10C AL—S10C AL—SCM
	0.55	SCM—AL FC—AL AL—AL

S10C: Non-heat-treated soft steel SCM: Heat treated steel (35HRC) FC: Cast iron (FC200) AL: Aluminum SUS: Stainless steel (sus304)

■Standard value for tightening coefficient Q

Tightening coefficient Q	Tightening method	Surface condition: Bolt	Surface condition: Nut	Lubrication
1.25	Torque wrench	Manganese phosphate	Untreated or phosphate	Not lubricated or MoS2 paste
1.4	Torque wrench Torque wrench with torque limiter	Untreated or phosphate		
1.6	Impact wrench			
1.8	Torque wrench Torque wrench with torque limiter	Untreated or phosphate	Untreated	Not lubricated

Indicating the strength class
Example: 12.9
- Proof strength (yield stress): 90% of minimum tensile strength
- Minimum tensile strength is 1220 N/mm^2 {124kgf/mm^2}

10.9
- Proof strength (yield stress): 90% of minimum tensile strength
- Minimum tensile strength is 1040 N/mm^2 {106kgf/mm^2}

■Initial tightening force and tightening torque

Nominal thread size	Effective cross-section area As mm^2	12.9 Yield load kgf	12.9 Initial tightening force kgf	12.9 Tightening torque kgf·cm	10.9 Yield load kgf	10.9 Initial tightening force kgf	10.9 Tightening torque kgf·cm	8.8 Yield load kgf	8.8 Initial tightening force kgf	8.8 Tightening torque kgf·cm	4.8 Yield load kgf	4.8 Initial tightening force kgf	4.8 Tightening torque kgf·cm
M 3×0.5	5.03	563	394	17	482	338	15	328	230	10	175	122	5
M 4×0.7	8.78	983	688	40	842	589	34	573	401	23	305	213	12
M 5×0.8	14.2	1590	1113	81	1362	953	69	927	649	47	493	345	25
M 6×1	20.1	2251	1576	138	1928	1349	118	1313	919	80	697	488	43
M 8×1.25	36.6	4099	2869	334	3510	2457	286	2390	1673	195	1270	889	104
M10×1.5	58	6496	4547	663	5562	3894	567	3787	2651	386	2013	1409	205
M12×1.75	84.3	9442	6609	1160	8084	5659	990	5505	3853	674	2925	2048	358
M14×2	115	12880	9016	1840	11029	7720	1580	7510	5257	1070	3991	2793	570
M16×2	157	17584	12039	2870	15056	10539	2460	10252	7176	1670	5448	3814	889
M18×2.5	192	21504	15053	3950	18413	12889	3380	12922	9045	2370	6662	4664	1220
M20×2.5	245	27440	19208	5600	23496	16447	4790	16489	11542	3360	8502	5951	1730
M22×2.5	303	33936	23755	7620	29058	20340	6520	20392	14274	4580	10514	7360	2360
M24×3	353	39536	27675	9680	33853	23697	8290	23757	16630	5820	12249	8574	3000

Note: • Tightening condition: Tightened by torque wrench. (Surface oil lubrication Torque coefficient k=0.17 Tightening coefficient Q=1.4)
• Because the torque coefficient varies depending on the conditions of use, use this table only as an approximate guide.
• This table consists of edited excerpts from the Catalog of Kyokuto MFG Co Ltd.

[TECHNICAL DATA] STRENGTH OF BOLTS, SCREW PLUGS, AND DOWEL PINS

■Bolt strength

1) When bolt is subjected to tensile load

$Pt = \sigma t \times As$…… (1)

$= \pi d^2 \sigma t/4$… (2)

Pt	: Tensile load in axial direction [kgf]
σb	: Bolt yield stress [kgf/mm^2]
σt	: Bolt maximum allowable stress [kgf/mm^2] ($\sigma t = \sigma b$/(safety factor α))
As	: Bolt effective cross-section area [mm^2] $As = \pi d^2/4$
d	: Bolt effective diameter (root diameter) [mm]

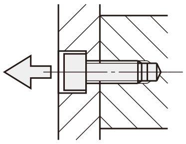
Example: Find a suitable size for a single hexagon socket head cap screw that will be subjected to repeated (pulsating) tensile loads of P=200 kgf. (Hexagon socket head cap screw material: SCM435, 38~43 HRC, strength class 12.9)

From formula (1):

$As = Pt/\sigma t$

$= 200/22.4$

$= 8.9$ [mm^2]



∴ Finding the effective cross-section area larger than this value from the table at right shows that a 14.2 [mm^2] M5 cap screw should be selected.

With additional consideration for the fatigue strength, and based on the strength class of 12.9 in the table, we select an M6 screw with maximum allowable load of 213 kgf.

2) For stripper bolts and others which are subjected to tensile impact loads, the selection is made based on the fatigue strength. (The bolt is subjected to 200 kgf loads in the same way. Stripper bolt material: SCM 435 33~38 HRC, strength class 10.9.)

From the table at right, for a strength class of 10.9 and a maximum allowable load of 200 kgf, the suitable bolt is a 318 [kgf] M8. Therefore we select a 10 mm MSB10 with a M8 thread section. When the bolt is subjected to shear load, also use a dowel pin.

■Unwin safety factor α based on tensile strength

M	Static load	Repeated load: Pulsating	Repeated load: Alternating	Impact load
Steel	3	5	8	12
Cast iron	4	6	10	15
Copper, soft metals	5	5	9	15

Shear stress $= \frac{\text{Standard strength}}{\text{Safety factor } \alpha}$ Standard strength: For ductile materials=Yield stress; For brittle materials=Fracture stress

Yield stress for strength class 12.9 $\sigma b = 112$ [kgf/mm^2]
Maximum allowable stress $\sigma t = \sigma b$/(safety factor)
(From table above, safety factor=5)
$= 112/5$
$= 22.4$ [kgf/mm^2]

■Bolt fatigue strength (For threads: fatigue strength = count of 2 million)

Nominal thread size	Effective cross-section area As mm^2	12.9 Fatigue strength* kgf/mm^2	12.9 Maximum allowable load kgf	10.9 Fatigue strength* kgf/mm^2	10.9 Maximum allowable load kgf
M 4	8.78	13.1	114	9.1	79
M 5	14.2	11.3	160	7.8	111
M 6	20.1	10.6	213	7.4	149
M 8	36.6	8.9	326	8.7	318
M10	58	7.4	429	7.3	423
M12	84.3	6.7	565	6.5	548
M14	115	6.1	702	6	690
M16	157	5.8	911	5.7	895
M20	245	5.2	1274	5.1	1250
M24	353	4.7	1659	4.7	1659

Fatigue strengths* have been excerpted from "Estimated values of fatigue limits for metal threads of small screws, bolts, and nuts" (Yamamoto) and modified.

■Screw plug strength

Find the maximum allowable load P when a MSW30 screw plug is subjected to impact load. (MSW30 material: S45C, tensile strength σb at 34~43 HRC 65 kgf/mm^2)

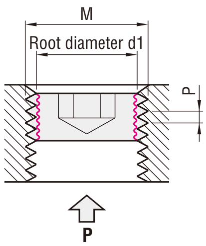
Assuming fracture due to shear occurs at the MSW root diameter location, the maximum allowable load $P = \tau t \times A$.

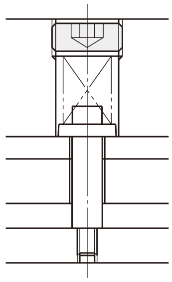
$= 3.9 \times 107.4$

$= 4190$ [kgf]

When the tap is a soft materials, find the maximum allowable shear from the inside thread root diameter.

Shear cross-section area A=Root diameter $d_1 \times \pi \times L$
(Root diameter $d_1 \fallingdotseq M - P$)
$A = (M-P)\pi L = (30-1.5)\pi \times 12$
$= 1074$ [mm^2]
Yield stress ≒ 0.9 × Tensile strength $\sigma b = 0.9 \times 65 = 58.2$
Shear stress ≒ 0.8 × Yield stress
$= 46.6$
Maximum allowable shear stress τt = Shear stress / (Safety factor 12)
$= 46.6/12 = 3.9$ [kgf/mm^2]





■Dowel pin strength

Find a suitable size for a single dowel pin which is subjected to repeated (pulsating) shear loads of 800 kgf. (Dowel pin material: SUJ2 hardness 58 HRC or higher)

$P = A \times \tau$

$= \pi D^2 \tau/4$

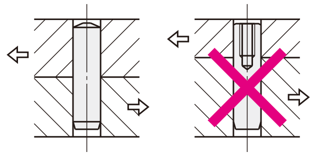
$D = \sqrt{(4P)/(\pi \tau)}$

$= \sqrt{(4 \times 800)/(3.14 \times 19.2)}$

$\fallingdotseq 7.3$

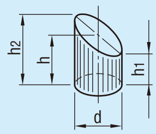
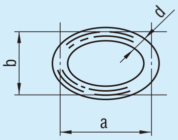
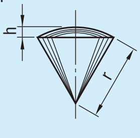
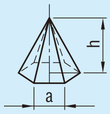
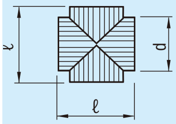
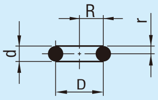
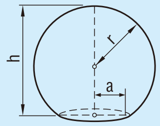
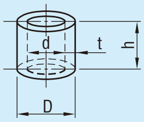
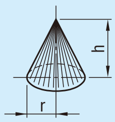
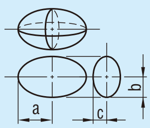
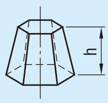
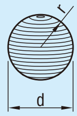
SUJ2 yield stress capability $\sigma b = 120$ [kgf/mm^2]
Maximum allowable shear strength $\tau = \sigma b \times 0.8$/(Safety factor α)
$= 120 \times 0.8/5$
$= 19.2$ [kgf/mm^2]

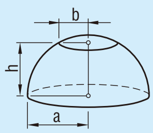
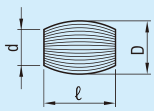
∴ For an MS dowel pin, select a size of D8 or larger.
In addition, selecting a single size for all dowel pins makes it possible to reduce items such as tools and inventory.



Do not use in such a way that load is applied to the threads.

The information provided here is only an example of calculating the strength. For actual selections, it is necessary to consider the hole pitch accuracy, hole perpendicularity, surface roughness, true roundness, plate material, parallelism, use of hardening, accuracy of the press machine, product production volume, tool wear, and various other conditions. Therefore the strength calculation value should be used only as a guide. (It is not a guaranteed value.)

3D shape	Volume V	3D shape	Volume V	3D shape	Volume V
Truncated cylinder 	$V=\frac{\pi}{4}d^2h$ $=\frac{\pi}{4}d^2\left(\frac{h_1+h_2}{2}\right)$	Ellipsoidal ring 	$V=\frac{\pi^2}{4}d^2\sqrt{\frac{a^2+b^2}{2}}$	Conical section of sphere 	$V=\frac{2}{3}\pi r^2h$ $=2.0944r^2h$
Pyramid 	$V=\frac{h}{3}A=\frac{h}{6}arn$ A=Bottom surface area r=Radius of inscribed circle a=Length of 1 side of regular polygon n=Number of regular polygon sides	Crossing cylinders 	$V=\frac{\pi}{4}d^2(\ell+\ell' \frac{d}{3})$	Circular ring 	$V=2\pi^2Rr^2$ $=19.739Rr^2$ $=\frac{\pi^2}{4}Dd^2$ $=2.4674Dd^2$
Spherical crown 	$V=\frac{\pi h^2}{3}(3r-h)$ $=\frac{\pi h}{6}(3a^2+h^2)$ a is the radius.	Hollow cylinder (tube) 	$V=\frac{\pi}{4}h(D^2-d^2)$ $=\pi th(D-t)$ $=\pi th(d+t)$	Cone 	$V=\frac{\pi}{3}r^2h$ $=1.0472r^2h$
Ellipsoidal body 	$V=\frac{4}{3}\pi abc$ In the case of a rotating ellipsoidal body (b=c): $V=\frac{4}{3}\pi ab^2$	Truncated pyramid 	$V=\frac{h}{3}(A+a+\sqrt{Aa})$ A,a=Surface area of each end	Sphere 	$V=\frac{4}{3}\pi r^3=4.1888r^3$ $=\frac{\pi}{6}d^3=0.5236d^3$

3D shape	Volume V
Zone of sphere 	$V=\frac{\pi h}{6}(3a^2+3b^2+h^2)$
Barrel shape 	When curve has circumference that is an arc: $V=\frac{\pi\ell}{12}(2D^2+d^2)$ When curve has circumference that is a parabola $V=0.209\ell(2D^2Dd+1/4d^2)$

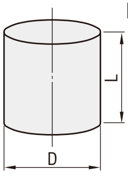
■Physical properties of metal materials

M	Density [g/cm³]	Young's modulus E [kgf/mm²]	Coefficient of thermal expansion [M10⁻⁶ /°C]
Soft steel	7.85	21000	11.7
SKD11	7.85	21000	11.7
Powdered high-speed steel (HAP40)	8.07	23300	10.1
Carbide V30	14.1	56000	6.0
Cast iron	7.3	7500 ~ 10500	9.2 ~ 11.8
SUS304	8.0	19700	17.3
Oxygen-free copper C1020	8.9	11700	17.6
6/4 brass C2801	8.4	10300	20.8
Aluminum A1100	2.7	6900	23.6
Duralumin A7075	2.8	7200	23.6
Titanium	4.5	10600	8.4

$1kgf/mm^2=9.80665\times10^6$ Pa

■Finding the weight

Weight W[g]=Volume[cm³]×Density



[Example] Material: Soft steel

Weight when D=ϕ16 and L=50 mm is found as follows.

$W=\frac{\pi}{4}D^2\times L\times\text{Density}$

$=\frac{\pi}{4}\times1.6^2\times5\times7.85$

$\fallingdotseq79$[g]

■Finding dimensional changes resulting from thermal expansion

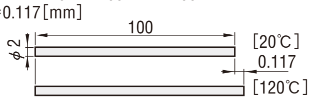
Example: Material: SKD11

Example: The amount of dimensional change δ which occurs when a pin of D=ϕ2, L=100 mm is heated to 100℃ is the following.

δ=Coefficient of thermal expansion×Total length×Temperature change

$=11.7\times10^{-6}\times100\text{ mm}\times100℃$

$=0.117$[mm]



■Finding dimensional changes resulting from Young's modulus E

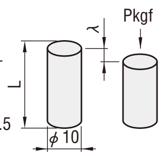
Example: Find strain λ when load P=1000 kgf is applied to a ϕ10×L60 pin. (Material: SKD11)

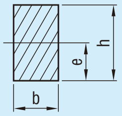
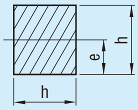
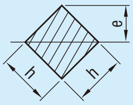
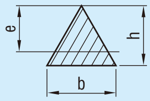
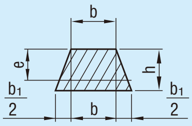
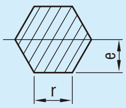
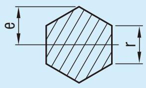
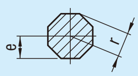
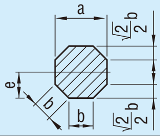
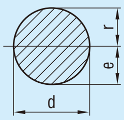
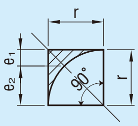
$E=\frac{PL}{A\lambda}$

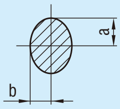
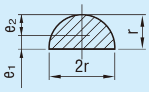
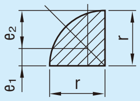
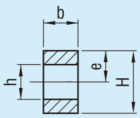
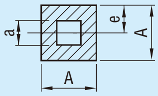
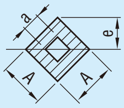
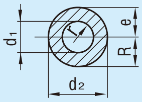
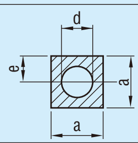
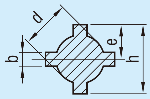
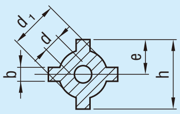
$\lambda=\frac{PL}{AE}=\frac{1000\times60}{78.5\times21000}$

$\fallingdotseq0.036$mm

Cross-section area $A=\frac{\pi}{4}D^2=78.5$



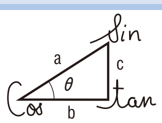
Cross section	Cross section area A	Distance of center of gravity e	Geometrical moment of inertia I	Cross section modulus Z=I/e
	bh	$\frac{h}{2}$	$\frac{bh^3}{12}$	$\frac{bh^2}{6}$
	h^2	$\frac{h}{2}$	$\frac{h^4}{12}$	$\frac{h^3}{6}$
	h^2	$\frac{h}{2}\sqrt{2}$	$\frac{h^4}{12}$	$0.1179\ h^3=\frac{\sqrt{2}}{12}h^3$
	$\frac{bh}{2}$	$\frac{2}{3}h$	$\frac{bh^3}{36}$	$\frac{bh^2}{24}$
	$(2b+b_1)\frac{h}{2}$	$\frac{1}{3}\times\frac{3b+2b_1}{2b+b_1}h$	$\frac{6b^2+6bb_1+b_1^2}{36(2b+b_1)}h^3$	$\frac{6b^2+6bb_1+b_1^2}{12(3b+2b_1)}h^2$
	$\frac{3\sqrt{3}}{2}r^2$ $=2.598\ r^2$	$\sqrt{\frac{3}{4}}r=0.866\ r$	$\frac{5\sqrt{3}}{16}r^4=0.5413\ r^4$	$\frac{5}{8}r^3$
		r		$\frac{5\sqrt{3}}{16}r^3=0.5413r^3$
	$2.828\ r^2$	$0.924\ r^2$	$\frac{1+2\sqrt{2}}{6}r^4$ $=0.6381\ r^4$	$0.6906r^3$
	$0.8284\ a^2$	$b=\frac{a}{1+\sqrt{2}}$ $=0.4142\ a$	$0.0547\ a^4$	$0.1095a^3$
	$\pi r^2=\frac{\pi d^2}{4}$	$\frac{d}{2}$	$\frac{\pi d^4}{64}=\frac{\pi r^4}{4}$ $=0.0491\ d^4$ $≒0.05\ d^4$ $=0.7854\ r^4$	$\frac{\pi d^3}{32}=\frac{\pi r^3}{4}$ $=0.0982d^3$ $≒0.1\ d^3$ $=0.7854\ r^3$
	$r^2\left(1-\frac{\pi}{4}\right)$ $=0.2146r^2$	e_1 $=0.2234\ r$ e_2 $=0.7766\ r$	$0.0075r^4$	$\frac{0.0075\ r^4}{e_2}$ $=0.00966r^3$ $≒0.01r^3$

Cross section	Cross section area A	Distance of center of gravity e	Geometrical moment of inertia I	Cross section modulus Z = I/e
	πab	a	$\frac{\pi}{4}ba^3 = 0.7854\ ba^3$	$\frac{4}{\pi}ba^2 = 0.7854\ ba^2$
	$\frac{\pi}{2}r^2$	$e_1 = 0.4244\ r$ $e_2 = 0.5756\ r$	$\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)r^4$ $= 0.1098\ r^4$	$Z_1 = 0.2587\ r^3$ $Z_2 = 0.1908\ r^3$
	$\frac{\pi}{4}r^2$	$e_1 = 0.4244\ r$ $e_2 = 0.5756\ r$	$0.055\ r^4$	$Z_1 = 0.1296\ r^3$ $Z_2 = 0.0956\ r^3$
	$b(H-h)$	$\frac{H}{2}$	$\frac{b}{12}(H^3-h^3)$	$\frac{b}{6H}(H^3-h^3)$
	A^2-a^2	$\frac{A}{2}$	$\frac{A^4-a^4}{12}$	$\frac{1}{6}\frac{A^4-a^4}{A}$
	A^2-a^2	$\frac{A}{2}\sqrt{2}$	$\frac{A^4-a^4}{12}$	$\frac{A^4-a^4}{12\ A}\sqrt{2}$ $= \frac{0.1179(A^4-a^4)}{A}$
	$\frac{\pi}{4}(d_2^2-d_1^2)$	$\frac{d_2}{2}$	$\frac{\pi}{64}(d_2^4-d_1^4)$ $= \frac{\pi}{4}(R^4-r^4)$	$\frac{\pi}{32}\left(\frac{d_2^4-d_1^4}{d_2}\right)$ $= \frac{\pi}{4} \times \frac{R^4-r^4}{R}$
	$a^2 - \frac{\pi d^2}{4}$	$\frac{a}{2}$	$\frac{1}{12}\left(a^4 - \frac{3\pi}{16}d^4\right)$	$\frac{1}{6a}\left(a^4 - \frac{3\pi}{16}d^4\right)$
	$2b(h-d)$ $+\frac{\pi}{4}d^2$	$\frac{h}{2}$	$\frac{1}{12}\left\{\frac{3\pi}{16}d^4 + b(h^3-d^3) + b^3(h-d)\right\}$	$\frac{1}{6h}\left\{\frac{3\pi}{16}d^4 + b(h^3-d^3) + b^3(h-d)\right\}$
	$2b(h-d)+$ $\frac{\pi}{4}(d_1^2-d^2)$	$\frac{h}{2}$	$\frac{1}{12}\left\{\frac{3\pi}{16}(d_1^4-d^4) + b(h^3-d_1^3) + b^3(h-d_1)\right\}$	$\frac{1}{6h}\left\{\frac{3\pi}{16}(d_1^4-d^4) + b(h^3-d_1^3) + b^3(h-d_1)\right\}$

[TECHNICAL DATA] CONVERSION CHART OF TRIGONOMETRICAL FUNCTIONS

θ (theta)	When deg (angle)=0° 00' ~ 11° 50'				
deg (angle°)	sin θ value	cos θ value	tan θ value	cot θ value	
0° 00'	.0000	1.0000	.0000	∞	90° 00'
10	.0029	1.0000	.0029	343.77	50
20	.0058	1.0000	.0058	171.89	40
30	.0087	1.0000	.0087	114.59	30
40	.0116	0.9999	.0116	85.940	20
50	.0145	.9999	.0145	68.750	10
1° 00'	.0175	.9998	.0175	57.290	89° 00'
10	.0204	.9998	.0204	49.104	50
20	.0233	.9997	.0233	42.964	40
30	.0262	.9997	.0262	38.188	30
40	.0291	.9996	.0291	34.368	20
50	.0320	.9995	.0320	31.242	10
2° 00'	.0349	.9994	.0349	28.636	88° 00'
10	.0378	.9993	.0378	26.432	50
20	.0407	.9992	.0407	24.542	40
30	.0436	.9990	.0437	22.904	30
40	.0465	.9989	.0466	21.470	20
50	.0494	.9988	.0495	20.206	10
3° 00'	.0523	.9986	.0524	19.081	87° 00'
10	.0552	.9985	.0553	18.075	50
20	.0581	.9983	.0582	17.169	40
30	.0610	.9981	.0612	16.350	30
40	.0640	.9980	.0641	15.605	20
50	.0669	.9978	.0670	14.924	10
4° 00'	.0698	.9976	.0699	14.301	86° 00'
10	.0727	.9974	.0729	13.727	50
20	.0756	.9971	.0758	13.197	40
30	.0785	.9969	.0787	12.706	30
40	.0814	.9967	.0816	12.251	20
50	.0843	.9964	.0846	11.826	10
5° 00'	.0872	.9962	.0875	11.430	85° 00'
10	.0901	.9959	.0904	11.059	50
20	.0929	.9957	.0934	10.712	40
30	.0958	.9954	.0963	10.385	30
40	.0987	.9951	.0992	10.078	20
50	.1016	.9948	.1022	9.7882	10
6° 00'	.1045	.9945	.1051	9.5144	84° 00'
10	.1074	.9942	.1080	9.2553	50
20	.1103	.9939	.1110	9.0098	40
30	.1132	.9936	.1139	8.7769	30
40	.1161	.9932	.1169	8.5555	20
50	.1190	.9929	.1198	8.3450	10
7° 00'	.1219	.9925	.1228	8.1443	83° 00'
10	.1248	.9922	.1257	7.9530	50
20	.1276	.9918	.1287	7.7704	40
30	.1305	.9914	.1317	7.5958	30
40	.1334	.9911	.1346	7.4287	20
50	.1363	.9907	.1376	7.2687	10
8° 00'	.1392	.9903	.1405	7.1154	82° 00'
10	.1421	.9899	.1435	6.9682	50
20	.1449	.9894	.1465	6.8269	40
30	.1478	.9890	.1495	6.6912	30
40	.1507	.9886	.1524	6.5606	20
50	.1536	.9881	.1554	6.4348	10
9° 00'	.1564	.9877	.1584	6.3138	81° 00'
10	.1593	.9872	.1614	6.1970	50
20	.1622	.9868	.1644	6.0844	40
30	.1650	.9863	.1673	5.9758	30
40	.1679	.9858	.1703	5.8708	20
50	.1708	.9853	.1733	5.7694	10
10° 00'	.1736	.9848	.1763	5.6713	80° 00'
10	.1765	.9843	.1793	5.5764	50
20	.1794	.9838	.1823	5.4845	40
30	.1822	.9833	.1853	5.3955	30
40	.1851	.9827	.1883	5.3093	20
50	.1880	.9822	.1914	5.2257	10
11° 00'	.1908	.9816	.1944	5.1446	79° 00'
10	.1937	.9811	.1974	5.0658	50
20	.1965	.9805	.2004	4.9894	40
30	.1994	.9799	.2035	4.9152	30
40	.2022	.9793	.2065	4.8430	20
50	.2051	.9787	.2095	4.7729	78° 10
	cos θ value	sin θ value	cot θ value	tan θ value	deg (angle°)
	When deg (angle)=78° 10' ~ 90° 00'				θ (theta)

θ (theta)	When deg (angle)=12° 00' ~ 23° 50'				
deg (angle°)	sin θ value	cos θ value	tan θ value	cot θ value	
12° 00'	.2079	.9781	.2126	4.7046	78° 00'
10	.2108	.9775	.2156	4.6382	50
20	.2136	.9769	.2186	4.5736	40
30	.2164	.9763	.2217	4.5107	30
40	.2193	.9757	.2247	4.4494	20
50	.2221	.9750	.2278	4.3897	10
13° 00'	.2250	.9744	.2309	4.3315	77° 00'
10	.2278	.9737	.2339	4.2747	50
20	.2306	.9730	.2370	4.2193	40
30	.2334	.9724	.2401	4.1653	30
40	.2363	.9717	.2432	4.1126	20
50	.2391	.9710	.2462	4.0611	10
14° 00'	.2419	.9703	.2493	4.0108	76° 00'
10	.2447	.9696	.2524	3.9617	50
20	.2476	.9689	.2555	3.9136	40
30	.2504	.9681	.2586	3.8667	30
40	.2532	.9674	.2617	3.8208	20
50	.2560	.9667	.2648	3.7760	10
15° 00'	.2588	.9659	.2679	3.7321	75° 00'
10	.2616	.9652	.2711	3.6891	50
20	.2644	.9644	.2742	3.6470	40
30	.2672	.9636	.2773	3.6059	30
40	.2700	.9628	.2805	3.5656	20
50	.2728	.9621	.2836	3.5261	10
16° 00'	.2756	.9613	.2867	3.4874	74° 00'
10	.2784	.9605	.2899	3.4495	50
20	.2812	.9596	.2931	3.4124	40
30	.2840	.9588	.2962	3.3759	30
40	.2868	.9580	.2994	3.3402	20
50	.2896	.9572	.3026	3.3052	10
17° 00'	.2924	.9563	.3057	3.2709	73° 00'
10	.2952	.9555	.3089	3.2371	50
20	.2979	.9546	.3121	3.2041	40
30	.3007	.9537	.3153	3.1716	30
40	.3035	.9528	.3185	3.1397	20
50	.3062	.9520	.3217	3.1084	10
18° 00'	.3090	.9511	.3249	3.0777	72° 00'
10	.3118	.9502	.3281	3.0475	50
20	.3145	.9492	.3314	3.0178	40
30	.3173	.9483	.3346	2.9887	30
40	.3201	.9474	.3378	2.9600	20
50	.3228	.9465	.3411	2.9319	10
19° 00'	.3256	.9455	.3443	2.9042	71° 00'
10	.3283	.9446	.3476	2.8770	50
20	.3311	.9436	.3508	2.8502	40
30	.3338	.9426	.3541	2.8239	30
40	.3365	.9417	.3574	2.7980	20
50	.3393	.9407	.3607	2.7725	10
20° 00'	.3420	.9397	.3640	2.7475	70° 00'
10	.3448	.9387	.3673	2.7228	50
20	.3475	.9377	.3706	2.6985	40
30	.3502	.9367	.3739	2.6746	30
40	.3529	.9356	.3772	2.6511	20
50	.3557	.9346	.3805	2.6279	10
21° 00'	.3584	.9336	.3839	2.6051	69° 00'
10	.3611	.9325	.3872	2.5826	50
20	.3638	.9315	.3906	2.5605	40
30	.3665	.9304	.3939	2.5386	30
40	.3692	.9293	.3973	2.5172	20
50	.3719	.9283	.4006	2.4960	10
22° 00'	.3746	.9272	.4040	2.4751	68° 00'
10	.3773	.9261	.4074	2.4545	50
20	.3800	.9250	.4108	2.4342	40
30	.3827	.9239	.4142	2.4142	30
40	.3854	.9228	.4176	2.3945	20
50	.3881	.9216	.4210	2.3750	10
23° 00'	.3907	.9205	.4245	2.3559	67° 00'
10	.3934	.9194	.4279	2.3369	50
20	.3961	.9182	.4314	2.3183	40
30	.3987	.9171	.4348	2.2998	30
40	.4014	.9159	.4383	2.2817	20
50	.4041	.9147	.4417	2.2637	66° 10
	cos θ value	sin θ value	cot θ value	tan θ value	deg (angle°)
	When deg (angle)=66° 10' ~ 78° 00'				θ (theta)



$a = \dfrac{b}{\cos\theta}$, $\dfrac{c}{\sin\theta}$

$b = a \cdot \cos\theta$, $\dfrac{c}{\tan\theta}$

$c = a \cdot \sin\theta$, $b \cdot \tan\theta$

θ (theta)	When deg (angle)=24° 00' ~ 35° 50'				
deg(angle°)	sin θ value	cos θ value	tan θ value	cot θ value	
24° 00'	.4067	.9135	.4452	2.2460	66° 00'
10	.4094	.9124	.4487	2.2286	50
20	.4120	.9112	.4522	2.2113	40
30	.4147	.9100	.4557	2.1943	30
40	.4173	.9088	.4592	2.1775	20
50	.4200	.9075	.4628	2.1609	10
25° 00'	.4226	.9063	.4663	2.1445	65° 00'
10	.4253	.9051	.4699	2.1283	50
20	.4279	.9038	.4734	2.1123	40
30	.4305	.9026	.4770	2.0965	30
40	.4331	.9013	.4806	2.0809	20
50	.4358	.9001	.4841	2.0655	10
26° 00'	.4384	.8988	.4877	2.0503	64° 00'
10	.4410	.8975	.4913	2.0353	50
20	.4436	.8962	.4950	2.0204	40
30	.4462	.8949	.4986	2.0057	30
40	.4488	.8936	.5022	1.9912	20
50	.4514	.8923	.5059	1.9768	10
27° 00'	.4540	.8910	.5095	1.9626	63° 00'
10	.4566	.8897	.5132	1.9486	50
20	.4592	.8884	.5169	1.9347	40
30	.4617	.8870	.5206	1.9210	30
40	.4643	.8857	.5243	1.9074	20
50	.4669	.8843	.5280	1.8940	10
28° 00'	.4695	.8829	.5317	1.8807	62° 00'
10	.4720	.8816	.5354	1.8676	50
20	.4746	.8802	.5392	1.8546	40
30	.4772	.8788	.5430	1.8418	30
40	.4797	.8774	.5467	1.8291	20
50	.4823	.8760	.5505	1.8165	10
29° 00'	.4848	.8746	.5543	1.8040	61° 00'
10	.4874	.8732	.5581	1.7917	50
20	.4899	.8718	.5619	1.7796	40
30	.4924	.8704	.5658	1.7675	30
40	.4950	.8689	.5696	1.7556	20
50	.4975	.8675	.5735	1.7437	10
30° 00'	.5000	.8660	.5774	1.7321	60° 00'
10	.5025	.8646	.5812	1.7205	50
20	.5050	.8631	.5851	1.7090	40
30	.5075	.8616	.5890	1.6977	30
40	.5100	.8601	.5930	1.6864	20
50	.5125	.8587	.5969	1.6753	10
31° 00'	.5150	.8572	.6009	1.6643	59° 00'
10	.5175	.8557	.6048	1.6534	50
20	.5200	.8542	.6088	1.6426	40
30	.5225	.8526	.6128	1.6319	30
40	.5250	.8511	.6168	1.6212	20
50	.5275	.8496	.6208	1.6107	10
32° 00'	.5299	.8480	.6249	1.6003	58° 00'
10	.5324	.8465	.6289	1.5900	50
20	.5348	.8450	.6330	1.5798	40
30	.5373	.8434	.6371	1.5697	30
40	.5398	.8418	.6412	1.5597	20
50	.5422	.8403	.6453	1.5497	10
33° 00'	.5446	.8387	.6494	1.5399	57° 00'
10	.5471	.8371	.6536	1.5301	50
20	.5495	.8355	.6577	1.5204	40
30	.5519	.8339	.6619	1.5108	30
40	.5544	.8323	.6661	1.5013	20
50	.5568	.8307	.6703	1.4919	10
34° 00'	.5592	.8290	.6745	1.4826	56° 00'
10	.5616	.8274	.6787	1.4733	50
20	.5640	.8258	.6830	1.4641	40
30	.5664	.8241	.6873	1.4550	30
40	.5688	.8225	.6916	1.4460	20
50	.5712	.8208	.6959	1.4370	10
35° 00'	.5736	.8192	.7002	1.4281	55° 00'
10	.5760	.8175	.7046	1.4193	50
20	.5783	.8158	.7089	1.4106	40
30	.5807	.8141	.7133	1.4019	30
40	.5831	.8124	.7177	1.3934	20
50	.5854	.8107	.7221	1.3848	54° 10
	cos θ value	sin θ value	cot θ value	tan θ value	deg(angle°)
	When deg (angle)=54° 10' ~ 66° 00'				θ (theta)

θ (theta)	When deg (angle)=36° 00' ~ 45° 00'				
deg(angle°)	sin θ value	cos θ value	tan θ value	cot θ value	
36° 00'	.5878	.8090	.7265	1.3764	54° 00'
10	.5901	.8073	.7310	1.3680	50
20	.5925	.8056	.7355	1.3597	40
30	.5948	.8039	.7400	1.3514	30
40	.5972	.8021	.7445	1.3432	20
50	.5995	.8004	.7490	1.3351	10
37° 00'	.6018	.7986	.7536	1.3270	53° 00'
10	.6041	.7969	.7581	1.3190	50
20	.6065	.7951	.7627	1.3111	40
30	.6088	.7934	.7673	1.3032	30
40	.6111	.7916	.7720	1.2954	20
50	.6134	.7898	.7766	1.2876	10
38° 00'	.6157	.7880	.7813	1.2799	52° 00'
10	.6180	.7862	.7860	1.2723	50
20	.6202	.7844	.7907	1.2647	40
30	.6225	.7826	.7954	1.2572	30
40	.6248	.7808	.8002	1.2497	20
50	.6271	.7790	.8050	1.2423	10
39° 00'	.6293	.7771	.8098	1.2349	51° 00'
10	.6316	.7753	.8146	1.2276	50
20	.6338	.7735	.8195	1.2203	40
30	.6361	.7716	.8243	1.2131	30
40	.6383	.7698	.8292	1.2059	20
50	.6406	.7679	.8342	1.1988	10
40° 00'	.6428	.7660	.8391	1.1918	50° 00'
10	.6450	.7642	.8441	1.1847	50
20	.6472	.7623	.8491	1.1778	40
30	.6494	.7604	.8541	1.1708	30
40	.6517	.7585	.8591	1.1640	20
50	.6539	.7566	.8642	1.1571	10
41° 00'	.6561	.7547	.8693	1.1504	49° 00'
10	.6583	.7528	.8744	1.1436	50
20	.6604	.7509	.8796	1.1369	40
30	.6626	.7490	.8847	1.1303	30
40	.6648	.7470	.8899	1.1237	20
50	.6670	.7451	.8952	1.1171	10
42° 00'	.6691	.7431	.9004	1.1106	48° 00'
10	.6713	.7412	.9057	1.1041	50
20	.6734	.7392	.9110	1.0977	40
30	.6756	.7373	.9163	1.0913	30
40	.6777	.7353	.9217	1.0850	20
50	.6799	.7333	.9271	1.0786	10
43° 00'	.6820	.7314	.9325	1.0724	47° 00'
10	.6841	.7294	.9380	1.0661	50
20	.6862	.7274	.9435	1.0599	40
30	.6884	.7254	.9490	1.0538	30
40	.6905	.7234	.9545	1.0477	20
50	.6926	.7214	.9601	1.0416	10
44° 00'	.6947	.7193	.9657	1.0355	46° 00'
10	.6967	.7173	.9713	1.0295	50
20	.6988	.7153	.9770	1.0235	40
30	.7009	.7133	.9827	1.0176	30
40	.7030	.7112	.9884	1.0117	20
50	.7050	.7092	.9942	1.0058	10
45° 00'	.7071	.7071	1.0000	1.0000	45° 00'
	cos θ value	sin θ value	cot θ value	tan θ value	deg(angle°)
	When deg (angle)=45° 00' ~ 54° 00'				θ (theta)

Finding the trigonometrical function value from the conversion chart

When deg (angle) is 0° 00' ~ 45° 00'

① Select the θ column on the left side of the conversion chart and find the deg (angle°).
② After verifying the type of trigonometrical function listed at the top of the conversion chart, determine the value of the target deg (angle°).

ex.) sin 5° =0.0872
cos5° =0.9962
tan 5° =0.0875
cot 5° =11.430

When deg (angle) is 45° 00' ~ 90° 00'

① Select the θ column on the right side of the conversion chart and find the deg (angle°).
② After verifying the type of trigonometrical function listed at the bottom of the conversion chart, determine the value of the target deg (angle°).

ex.) sin 85° =0.9962
cos85° =0.0872
tan 85° =11.430
cot 85° =0.0875

If the deg (angle°) includes figures after the decimal point, covert to a value of degrees (°) and minutes (').
Ex.: 5.5° becomes 5° 30' (5 degrees, 30 minutes). (1 degree=60 minutes)

Carbon Steels and Alloy Steels for Machine Structural Use

Japan Industrial Standards		Steel types in foreign standards					
Standard No. Name	Symbol	ISO 683/1,10,11[5)]	AISI SAE	BS 970 Part1,3 BS EN 10083−1,2	DIN EN 10084 DIN EN 10083−1,2	NF A35−551 NF EN 10083−1,2	ГОСТ 4543
JIS G 4051 Carbon steels for machine structural use	S10C	C10	1010	040A10 045A10 045M10	C10E C10R	XC10	—
	S12C	—	1012	040A12	—	XC12	—
	S15C	C15E4 C15M2	1015	055M15	C15E C15R	—	—
	S17C	—	1017	—	—	XC18	—
	S20C	—	1020	070M20 C22 C22E C22R	C22 C22E C22R	C22 C22E C22R	—
	S22C	—	1023	—	—	—	—
	S25C	C25 C25E4 C25M2	1025	C25 C25E C25R	C25 C25E C25R	C25 C25E C25R	—
	S28C	—	1029	—	—	—	25Г
	S30C	C30 C30E4 C30M2	1030	080A30 080M30 C30 C30E C30R	C30 C30E C30R	C30 C30E C30R	30Г
	S33C	—	—	—	—	—	30Г
	S35C	C35 C35E4 C35M2	1035	C35 C35E C35R	C35 C35E C35R	C35 C35E C35R	35Г
	S38C	—	1038	—	—	—	35Г
	S40C	C40 C40E4 C40M2	1039 1040	080M40 C40 C40E C40R	C40 C40E C40R	C40 C40E C40R	40Г
	S43C	—	1042 1043	080A42	—	—	40Г
	S45C	C45 C45E4 C45M2	1045 1046	C45 C45E C45R	C45 C45E C45R	C45 C45E C45R	45Г
	S48C	—	—	080A47	—	—	45Г
	S50C	C50 C50E4 C50M2	1049	080M50 C50 C50E C50R	C50 C50E C50R	C50 C50E C50R	50Г
	S53C	—	1050 1053	—	—	—	50Г
	S55C	C55 C55E4 C55M2	1055	070M55 C55 C55E C55R	C55 C55E C55R	C55 C55E C55R	—
	S58C	C60 C60E4 C60M2	1059 1060	C60 C60E C60R	C60 C60E C60R	C60 C60E C60R	60Г
	S09CK	—	—	045A10 045M10	C10E	XC10	—
	S15CK	—	—	—	C15E	XC12	—
	S20CK	—	—	—	—	XC18	—

ISO: International Organization for Standardization
AISI: American Iron and Steel Institute
SAE: Society of Automotive Engineers
BS: British Standards

Japan Industrial Standards		Steel types in foreign standards					
Standard No. Name	Symbol	ISO 683/1,10,11[5)]	AISI SAE	BS 970 Part1,3 BS EN 10083−1,2	DIN EN 10084 DIN EN 10083−1,2	NF A35−551 NF EN 10083−1,2	ГОСТ 4543
JIS G 4102 Nickel chromium steels	SNC236	—	—	—	—	—	40XH
	SNC415	—	—	—	—	—	—
	SNC631	—	—	—	—	—	30XH3A
	SNC815	15NiCr13	—	655M13	15NiCr13	—	—
	SNC836	—	—	—	—	—	—
JIS G 4103 Nickel chromium steels	SNCM220	20NiCrMo2 20NiCrMoS2	8615 8617 8620 8622	805A20 805M20 805A22 805M22	20NiCrMo2 20NiCrMoS2	20NCD2	—
	SNCM240	41CrNiMo2 41CrNiMoS2	8637 8640	—	—	—	—
	SNCM415	—	—	—	—	—	—
	SNCM420	—	4320	—	—	—	20XH2M (20XHM)
	SNCM431	—	—	—	—	—	—
	SNCM439	—	4340	—	—	—	—
	SNCM447	—	—	—	—	—	—
	SNCM616	—	—	—	—	—	—
	SNCM625	—	—	—	—	—	—
	SNCM630	—	—	—	—	—	—
	SNCM815	—	—	—	—	—	—
JIS G 4104 Chromium steels	SCr415	—	—	—	17Cr3 17CrS3	—	15X 15XA
	SCr420	20Cr4 20CrS4	5120	—	—	—	20X
	SCr430	34Cr4 34CrS4	5130 5132	34Cr4 34CrS4	34Cr4 34CrS4	34Cr4 34CrS4	30X
	SCr435	34Cr4 34CrS4 37Cr4 37CrS4	5132	37Cr4 37CrS4	37Cr4 37CrS4	37Cr4 37CrS4	35X
	SCr440	37Cr4 37CrS4 41Cr4 41CrS4	5140	530M40 41Cr4 41CrS4	41Cr4 41CrS4	41Cr4 41CrS4	40X
	SCr445	—	—	—	—	—	45X
JIS G 4105 Chromium molybdenum steels	SCM415	—	—	—	—	—	—
	SCM418	18CrMo4 18CrMoS4	—	—	18CrMo4 18CrMoS4	—	20XM
	SCM420	—	—	708M20	—	—	20XM
	SCM421	—	—	—	—	—	—
	SCM430	—	4131	—	—	—	30XM 30XMA
	SCM432	—	—	—	—	—	—
	SCM435	34CrMo4 34CrMoS4	4137	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	35XM
	SCM440	42CrMo4 42CrMoS4	4140 4142	708M40 709M40 42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	—
	SCM445	—	4145 4147	—	—	—	—
	SCM822	—	—	—	—	—	—

DIN: Deutsches Institut für Nörmung
EN: European Standards
NF: Norme Francaise
ГOCT: National standard of the former USSR

Japan Industrial Standards		Steel types in foreign standards					
Standard No. Name	Symbol	ISO 683/1,10,11 5)	AISI SAE	BS 970 Part1,3 BS EN 10083—1,2	DIN EN 10084 DIN EN 10083—1,2	NF A35—551 NF EN 10083—1,2	ГОСТ 4543
JIS G 4106 Manganese steels and manganese chromium steels for machine structural use	SMn420	22Mn6	1522	150M19	—	—	—
	SMn433	—	1534	150M36	—	—	30Г2 35Г2
	SMn438	36Mn6	1541	150M36	—	—	35Г2 40Г2
	SMn443	42Mn6	1541	—	—	—	40Г2 45Г2
	SMnC420	—	—	—	—	—	—
	SMnC443	—	—	—	—	—	—
JIS G 4202 Aluminum chromium molybdenum steels	SACM645	41CrAlMo74	—	—	—	—	—
JIS G 4052 Structural steels with specified hardenability bands	SMn420H	22Mn6	1522H	—	—	—	—
	SMn433H	—	—	—	—	—	—
	SMn438H	36Mn6	1541H	—	—	—	—
	SMn443H	42Mn6	1541H	—	—	—	—
	SMnC420H	—	—	—	—	—	—
	SMnC443H	—	—	—	—	—	—
	SCr415H	—	—	—	17Cr3 17CrS3	—	15X
	SCr420H	20Cr4 20CrS4	5120H	—	—	—	20X
	SCr430H	34Cr4 34CrS4	5130H 5132H	34Cr4 34CrS4	34Cr4 34CrS4	34Cr4 34CrS4	30X
	SCr435H	34Cr4 34CrS4 37Cr4 37CrS4	5135H	37Cr4 37CrS4	37Cr4 37CrS4	37Cr4 37CrS4	35X
	SCr440H	37Cr4 37CrS4 41Cr4 41CrS4	5140H	41Cr4 41CrS4	41Cr4 41CrS4	41Cr4 41CrS4	40X
	SCM415H	—	—	—	—	—	—
	SCM418H	18CrMo4 18CrMoS4	—	—	18CrMo4 18CrMoS4	—	—
	SCM420H	—	—	708H20	—	—	—
	SCM435H	34CrMo4 34CrMoS4	4135H 4137H	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	34CrMo4 34CrMoS4	—
	SCM440H	42CrMo4 42CrMoS4	4140H 4142H	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	42CrMo4 42CrMoS4	—
	SCM445H	—	4145H 4147H	—	—	—	—
	SCM822H	—	—	—	—	—	—
	SNC415H	—	—	—	—	—	—
	SNC631H	—	—	—	—	—	—
	SNC815H	15NiCr13	—	655H13	15NiCr13	—	—
	SNCM220H	20NiCrMo2 20NiCrMoS2	8617H 8620H 8622H	805H17 805H20 805H22	—	20NCD2	—
	SNCM420H	—	4320H	—	—	—	—

Japan Industrial Standards		Steel types in foreign standards					
Standard No. Name	Symbol	ISO 683/1,10,11 5)	AISI SAE	BS 970 Part1,3 BS EN 10083—1,2	DIN EN 10084 DIN EN 10083—1,2	NF A35—551 NF EN 10083—1,2	ГОСТ 4543
JIS G 4107 Alloy steel bolting materials for high temperature service	SNB5	—	501	—	—	—	—
	SNB7	42CrMo4 42CrMoS4	4140 4142 4145	708 40 709M40 42CrMo4 1)	42CrMo4 2)	42CrMo4 4)	—
	SNB16	—	—	40CrMoV4-6 1)	40CrMoV47 3)	40CrMoV4-6 4)	—
JIS G 4108 Alloy steel bars for special application bolting materials	SNB21—1～5	—	—	40CrMoV4-6 1)	40CrMoV47 3)	40CrMoV4-6 4)	—
	SNB22—1～5	42CrMo4 42CrMoS4	4142H	—	42CrMo4 2)	—	—
	SNB23—1～5	—	E4340H	—	—	—	—
	SNB24—1～5	—	4340	—	—	—	—

Notes 1) BS EN 10259
2) DIN 1654 Part 4
3) DIN 17240
4) NF EN 10259
5) ISO683—1, 10, and 11 have been translated into JIS as JIS G 7501, G 7502, and G 7503.

Tool steel name

Rolled steel for general structures	SS400	Steel, Structure, 400 N/mm²
Carbon steel for mechanical structures	S45C	Steel, 0.45% C
Chrome molybdenum steel	SCM435	Steel, Cr, Mo 435
Nickel chrome molybdenum steel	SNCM220	Steel, Ni, Cr, Mo, 220
Carbon tool steel	SK105 .... (formerly SK3)	Steel, Tool, 105
Alloy tool steel	SKS3	Steel, Tool, Special, Type 3
Alloy tool steel	SKD11	Steel, Tool, Dies, Type 11
High—speed tool steel	SKH51	Steel, Tool, High Speed, Type 51
High carbon chrome bearing steel	SUJ2	Steel, Use, Bearing, Type 2
Stainless steel	SUS304..........	Steel, Use, Stainless, Type 304
Gray cast iron	FC250	Ferrum (Iron), Cast, 250 N/mm²

Stainless Steels, Heat Resistant Steels

JIS		International standards	Foreign standards						Europe standard	
Standard No./name (stainless steel code)	JIS	ISO TR 15510 L·No.	USA UNS	USA AISI	UK BS	Germany DIN	France NF	Russia (former USSR) ГOCT	EN Type	EN No.
JIS G 4303～	SUS 201	12	S20100	201			Z12CMN17−07Az		X12CrMnNiN17−7−5	1.4372
4305	SUS 202		S20200	202	284S16			12X17Г9AH4	X12CrMnNiN18−9−5	1.4373
Bars, hot rolled and	SUS 301	5	S30100	301	301S21	X12CrNi17 7	Z11CN17−08	07X16H6	X5CrNi17−7	1.4319
cold rolled plates,	SUS 301L	4				X2CrNiN18−7			X2CrNiN18−7	1.4318
sheets, and strips	SUS 301J1					X12CrNi17 7				
JIS G 4308～	SUS 302		S30200	302	302S25		Z12CN18−09	12X18H9		
4309	SUS 302B		S30215	302B						
Wires and rods	SUS 303	13	S30300	303	303S21	X10CrNiS18 9	Z8CNF18−09		X8CrNiS18−9	1.4305
	SUS 303Se		S30323	303Se	303S41			12X18H10E		
	SUS 303Cu									
JIS G 4313～	SUS 304	6	S30400	304	304S31	X5CrNi18 10	Z7CN18−09	08X18H10	X4CrNi18−10	1.4301
4315	SUS 304L	1	S30403	304L	304S11	X2CrNi19 11	Z3CN19−11	03X18H11	X2CrNi19−11	1.4307
		2								1.4307
Strips and wires for	SUS 304N1	10	S30451	304N			Z6CN19−09Az		X2CrNi18−9	1.4306
springs, wires for	SUS 304N2		S30452							
cold heading/forging	SUS 304LN	3	S30453	304LN		X2CrNiN18 10	Z3CN18−10Az		X2CrNiN18−10	1.4311
JIS G 4317～	SUS 304J1									
4320	SUS 304J2									
Hot rolled equal leg angles,	SUS 304J3		S30431	S30431						
cold finished bars,	SUS 305	8	S30500	305	305S19	X5CrNi18 12	Z8CN18−12	06X18H11	X4CrNi18−12	1.4303
blooms/billets for forgings,	SUS 305J1									
cold−formed sections	SUS 309S	X6CrNi23−14	S30908	309S			Z10CN24−13			
	SUS 310S	X6CrNi25−21	S31008	310S	310S31		Z8CN25−20	10X23H18	X6CrNi25−20	
	SUS 315J1									
	SUS 315J2									
	SUS 316	26	S31600	316	316S31	X5CrNiMo17 12 2	Z7CND17−12−02		X4CrNiMo17−12−2	1.4401
	SUS 316F	27				X5CrNiMo17 13 3	Z6CND18−12−03		X4CrNiMo17−13−3	1.4436
	SUS 316L	19	S31603	316L	316S11	X2CrNiMo17 13 2	Z3CND17−12−02		X2CrNiMo17−12−2	1.4404
		20				X2CrNiMo17 14 3	Z3CND17−13−03	03X17H14M3	X2CrNiMo17−13−3	1.4432
									X2CrNiMo18−14−3	1.4435
	SUS 316N		S31651	316N						
	SUS 316LN	22	S31653	316LN		X2CrNiMoN17 12 2	Z3CND17−11Az		X2CrNiMoN17−11−2	1.4406
		23				X2CrNiMoN17 13 3	Z3CND17−12Az		X2CrNiMoN17−13−3	1.4429
	SUS 316Ti	28	S31635			X6CrNiMoTi17 12 2	Z6CNDT17−12	08X17H13M2T	X6CrNiMoTi17−12−2	1.4571
	SUS 316J1									
	SUS 316J1L									
	SUS 317		S31700	317	317S16					
	SUS 317L	21	S31703	317L	317S12	X2CrNiMo18 16 4	Z3CND19−15−04		X2CrNiMo18−15−4	1.4438
	SUS 317LN	24	S31753				Z3CND19−14Az		X2CrNiMoN18−12−4	1.4434
	SUS 317J1								X2CrNiMoN17−13−5	1.4439
	SUS 317J2									
	SUS 317J3L									
	SUS 836L		N08367							
	SUS 890L	31	N08904	N08904	904S14		Z2NCDU25−20		X1CrNiMoCuN25−25−5	1.4539
	SUS 321	15	S32100	321	321S31	X6CrNiTi18 10	Z6CNT18−10	08X18H10T	X6CrNiTi18 10	1.4541
	SUS 347	17	S34700	347	347S31	X6CrNiNb18 10	Z6CNNb18−10	08X18H12Б	X6CrNiNb18 10	1.4550
	SUS 384	9	S38400	384			Z6CN18−16			
	SUS XM7	D26(1)	S30430	304Cu	394S17		Z2CNU18−10		X3CrNiCu18−9−4	1.4587
	SUS XM15J1		S38100				Z15CNS20−12		X1CrNiSi18−15−4	1.4381
	SUS 329J1		S32900	329						
	SUS 329J3L	33	S39240	S31803			Z3CNDU22−05Az	08X21H6M2T	X2CrNiMoN22−5−3	1.4462
	SUS 329J4L	34	S39275	S31260			Z3CNDU25−07Az		X2CrNiMoCuN25−6−3	1.4507

JIS		International standards	Foreign standards						Europe standard	
Standard No./name (stainless steel code)	JIS	ISO TR 15510 L·No.	USA UNS	USA AISI	UK BS	Germany DIN	France NF	Russia (former USSR) ГOCT	EN Type	EN No.
	SUS 405	40	S40500	405	405S17	X6CrAl13	Z8CA12		X6CrAl13	1.4002
	SUS 410L						Z3C14			
	SUS 429		S42900	429						
	SUS 430	41	S43000	430	430S17	X6Cr17	Z8C17	12X17	X6Cr17	1.4016
	SUS 430F	42	S43020	430F		X7CrMoS18	Z8CF17		X6CrMoS17	1.4105
	SUS 430LX	44	S43035			X6CrTi17	Z4CT17		X3CrTi17	1.4510
						X6CrNb17			X2CrTi17	1.4520
	SUS 430J1L						Z4CNb17		X3CrNb17	1.4511
	SUS 434	43	S43400	434	434S17	X6CrMo17 1	Z8CD17−01		X6CrMo17−1	1.4113
	SUS 436L		S43600	436					X1CrMoTi16−1	1.4513
	SUS 436J1L									
	SUS 444	46	S44400	444			Z3CDT18−02		X2CrMoTi18−2	1.4521
	SUS 445J1									
	SUS 445J2									
	SUS 447J1		S44700							
	SUS XM27		S44627				Z1CD26−01			
	SUS 403		S40300	403						
	SUS 410	48	S41000	410	410S21	X10Cr13	Z13C13		X12Cr13	1.4006
	SUS 410S	39	S41008	410S	403S17	X6Cr13	Z8C12	08X13	X6Cr13	1.4000
	SUS 410F2									
	SUS 410J1		S41025							
	SUS 416	49	S41600	416	416S21		Z11CF13		X12CrS13	1.4005
	SUS 420J1	50	S42000	420	420S29	X20Cr13	Z20C13	20X13	X20Cr13	1.4021
	SUS 420J2	51	S42000	420	420S37	X30Cr13	Z33C13	30X13	X30Cr13	1.4028
	SUS 420F		S42020	420F			Z30CF13		X29CrS13	1.4029
	SUS 420F2									
	SUS 429J1									
	SUS 431	57	S43100	431	431S29	X20CrNi17 2	Z15CN16−02	20X17H2	X19CrNi17 2	1.4057
	SUS 440A		S44002	440A			Z70C15		X70CrMo15	1.4109
	SUS 440B		S44003	440B						
	SUS 440C		S44004	440C			Z100CD17	95X18	X105CrMo17	1.4125
	SUS 440F		S44020	S44020						
	SUS 630	58	S17400	S17400			Z6CNU17−04		X5CrNiCuNb16−4	1.4542
	SUS 631	59	S17700	S17700		X7CrNiAl17 7	Z9CNA17−07	09X17H7 IO	X7CrNiAl17−7	1.4568
	SUS 632J1									
JIS G 4311～	SUH 31				331S42		Z35CNWS14−14	45X14H14B2M		
4315	SUH 35	X53CrMnNi21 4 (2)			349S52		Z52CMN21−09Az			
Heat resisting steel bars,	SUH 36		S63008		349S54	X53CrMnNi21 9	Z55CMN21−09Az	55X20Г9AH4		
plates, and	SUH 37		S63017		381S34					
sheets	SUH 38									
	SUH 309		S30900	309	309S24		Z15CN24−13			
	SUH 310		S31000	310	310S24	CrNi2520	Z15CN25−20	20X25H20C2		
	SUH 330		N08330	N08330			Z12NCS35−16			
	SUH 660		S66286				Z6NCTV25−20			
	SUH 661		R30155							
	SUH 21					CrAl1205				
	SUH 409	37	S40900	409	409S19	X6CrTi12	Z6CT12			
	SUH 409L	36					Z3CT12		X2CrTi12	1.4512
	SUH 446	X15CrN26(2)	S44600	446			Z12C25	15X28		
	SUH 1	X45CrSi9−3(2)	S65007		401S45	X45CrSi9 3	Z45CS9			
	SUH 3						Z40CSD10	40X10C2M		
	SUH 4				443S65		Z80CSN20−02			
	SUH 11	X50CrSi18−2(2)						40X 9C2		
	SUH 600							20X12BHMБфг		
	SUH 616		S42200							

Notes:
1. ISO: ISO TR 15510: 1997. Symbols are the same as EN. (1) ISO 4954, (2) ISO 683−15.
2. US: UNS registration numbers and the AISI Steel Manual
3. Europe standard: EN10088−1:1995.
4. European countries: BS, DIN, NF, others. These national standards are to be abolished in favor of EN.
5. OCT: 5632.

Tool Steels

JIS Standard No./name	JIS Symbol	ISO	AISI ASTM	BS	DIN VDEh	NF	ГОСТ
JIS G 4401 Carbon tool steels	SK140 (formerly SK1)	TC140	—	—	—	C140E3U	Y13
	SK120 (formerly SK2)	TC120	W1—11 1/2	—	—	C120E3U	Y12
	SK105 (formerly SK3)	TC105	W1—10	—	C105W1	C105E2U	Y11
	SK95 (formerly SK4)	TC 90	W1— 9	—	—	C 90E2U	Y10
	SK85 (formerly SK5)	TC 90 TC 80	W1— 8	—	C 80W1	C 90E2U C 80E2U	Y8Г Y9
	SK75 (formerly SK6)	TC 80 TC 70	—	—	C 80W1	C 80E2U C 70E2U	Y8
	SK65 (formerly SK7)	—	—	—	C 70W2	C 70E2U	Y7
JIS G 4403 High speed tool steels	SKH 2	HS18—0—1	T 1	BT 1	—	HS18—0—1	P18
	SKH 3	HS18—1—1—5	T 4	BT 4	S18—1—2—5	HS18—1—1—5	—
	SKH 4	HS18—0—1—10	T 5	BT 5	—	HS18—0—2—9	—
	SKH10	HS12—1—5—5	T15	BT15	S12—1—4—5	HS12—1—5—5	—
	SKH51	HS 6—5—2	M2	BM 2	S 6—5—2	HS 6—5—2	—
	SKH52	—	M3—1	—	—	—	—
	SKH53	HS 6—5—3	M3—2	—	S 6—5—3	HS 6—5—3	—
	SKH54	—	M4	BM 4	—	HS 6—5—4	—
	SKH55	HS 6—5—2—5	—	BM35	S 6—5—2—5	HS 6—5—2—5HC	P6M5K5
	SKH56	—	M36	—	—	—	—
	SKH57	HS10—4—3—10	—	BT42	S10—4—3—10	HS10—4—3—10	—
	SKH58	HS 2—9—2	M7	—	—	HS 2—9—2	—
	SKH59	HS 2—9—1—8	M42	BM42	S 2—10—1—8	HS 2—9—1—8	—
JIS G 4404 Alloy tool steels	SKS11	—	F2	—	—	—	XB4
	SKS 2	105WCr1	—	—	105WCr6	105WCr5	XBГ
	SKS21	—	—	—	—	—	—
	SKS 5	—	—	—	—	—	—
	SKS51	—	L6	—	—	—	—
	SKS 7	—	—	—	—	—	—
	SKS 8	—	—	—	—	C140E3UCr4	13X
	SKS 4	—	—	—	—	—	—
	SKS41	—	—	—	—	—	—
	SKS43	TCV105	W2—9 1/2	BW2	—	100V2	—
	SKS44	—	W2—8	—	—	—	—
	SKS 3	—	—	—	—	—	9XBГ
	SKS31	105WCr1	—	—	105WCr6	105WCr5	XBГ
	SKS93	—	—	—	—	—	—
	SKS94	—	—	—	—	—	—
	SKS95	—	—	—	—	—	—
	SKD 1	210Cr12	D3	BD3	X210Cr12	X200Cr12	X12
	SKD11	—	D2	BD2	—	X160CrMoV12	—
	SKD12	100CrMoV5	A2	BA2	—	X100CrMoV5	—
	SKD 4	30WCrV5	—	—	—	X32WCrV3	—
	SKD 5	30WCrV9	H21	BH21	—	X30WCrV9	—
	SKD 6	—	H11	BH11	X38CrMoV51	X38CrMoV5	4X5M C
	SKD61	40CrMoV5	H13	BH13	X40CrMoV51	X40CrMoV5	4X5M 1C
	SKD62	—	H12	BH12	—	X35CrWMoV5	3X3M3
JIS G 4404 (Continued)	SKD 7	30CrMoV3	H10	BH10	X32CrMoV33	32CrMoV12—18	—
	SKD 8	—	H19	BH19	—	—	—
	SKT 3	—	—	—	—	55CrNiMoV4	—
	SKT 4	55NiCrMoV2	—	BH224/5	55NiCrMoV6	55NiCrMoV7	5XHM

Special Purpose Steels

JIS Standard No./name	JIS Symbol	ISO	AISI SAE	BS	DIN	NF	ГОСТ
JIS G 4801 Spring steels	SUP 3	—	1075 1078	—	—	—	75 80 85
	SUP 6	59Si7	—	—	—	60Si7	60C2
	SUP 7	59Si7	9260	—	—	60Si7	60C2Г
	SUP 9	55Cr3	5155	—	55Cr3	55Cr3	—
	SUP 9A	—	5160	—	—	60Cr3	—
	SUP10	51CrV4	6150	735A51,735H51	50CrV4	51CrV4	XϕA50XГϕA
	SUP11A	60CrB3	51B60	—	—	—	50XГP
	SUP12	55SiCr63	9254	685A57,685H57	54SiCr6	54SiCr6	—
	SUP13	60CrMo33	4161	705A60,705H60	—	60CrMo4	—
JIS G 4804 Free cutting carbon steels	SUM11	—	1110	—	—	—	—
	SUM12	—	1108	—	—	—	—
	SUM21	9 S20	1212	—	—	—	—
	SUM22	11SMn28	1213	(230M07)	9 SMn28	S250	—
	SUM22L	11SMnPb28	12L13	—	9 SMnPb28	S250Pb	—
	SUM23	—	1215	—	—	—	—
	SUM23L	—	—	—	—	—	—
	SUM24L	11SMnPb28	12L14	—	9 SMnPb28	S250Pb	—
	SUM25	12SMn35	—	—	9 SMn36	S300	—
	SUM31	—	1117	—	15S10	—	—
	SUM31L	—	—	—	—	—	—
	SUM32	—	—	210M15,210A15	—	(13MF4)	—
	SUM41	—	1137	—	—	(35MF6)	—
	SUM42	—	1141	—	—	(45MF6.1)	—
	SUM43	44SMn28	1144	(226M44)	—	(45MF6.3)	—
JIS G 4805 High carbon chromium bearing steels	SUJ 1	—	51100	—	—	—	—
	SUJ 2	B1 or 100Cr6	52100	—	100Cr6	100Cr6	ЩX15
	SUJ 3	B2 or 100CrMnSi4—4	ASTM A 485 Grade 1	—	—	—	—
	SUJ 4	—	—	—	—	—	—
	SUJ 5	—	—	—	—	—	—

■COMPARISON OF DIE STEEL BY MANUFACTURERS

Type	Symbols in foreign standards				Hitachi Metals	Aichi Steel	Kobe Steel	Sanyo Special Steel	Daido Steel	Nippon Koshuha Steel Group	Nachi-Fujikoshi Corp	Riken Seiko	Uddeholm (Sweden)	Bohler (Germany)
	JIS	AISI	DIN	ISO										
Carbon tool steels	SK105 (formerly SK3)	W1-10		TC105	YC3	SK3		QK3	YK3	K3				K990
Alloy tool steel	SKS93				YCS3	SK301		QKSM	YK30	K3M	SK3M			
	SKS3				SGT	SKS3		QKS3	GOA	KS3	SKS3	RS3	ARNE	K460
	SKD1	D3		X210Cr12	CRD	SKD1		QC1	DC1	KD1			SVERKER3	K100 K107
	SKD11	D2	X210Cr12	X210Cr12W12	SLD	SKD11		QC11	DC11	KD11	CDS11	RD11	SVERKER21	K105 K110
	SKD11 (modified)				SLD8 SLD10	AUD15		QCM8 QCM10	DC53	KD11S KD21	MDS9		SLEIPNER	K340
	Matrix group CrSKD				ARK1	SXACE		QCM7	DCX					
	SKD12			X100CrMoV5	SCD	SKD12			DC12	KD12			RIGOR	K305
	Pre-hardened 40 HRC	A2			HPM2T				GO40F	KAP65			IMPAX	
	Pre-hardened 50 HRC or more				PRE2				CX1	RC55				
	Flame-hardened steel				HMD5 HMD1	SX105V SX4		QF3	GO5	FH5			FERNO	
	Low temperature air-cooled steel				ACD37	AKS3			GO4	KSM				
	Impact resistant steel				YSM	AKS4		QF1	GS5	KTV5	SRS6		PREGA COMPAX	K630
	Others				ACD8	AUD11 SX5 SX44					ICS22 MCR1		CALMAX VIKING ELMAX VANADIS4 VANADIS6 VANADIS10	K190
High-speed tool steel	SKH51	M2	H6.5.2	HS6—5—2	YXM1			QH51	MH51	H51	SKH9	RHM1		S600
	SKH55 group		S6.2.5	HS6—5—2—5	YXM4				MH55	HM35	HM35 HS53M	RHM5		S705
	SKH57 group		S10—4—3—10	HS10—4—3—10	XVC5				MH8	MV10	HS93R HS98M FM38V	RHM7		S700
	Matrix group				YXR33 YXR3 YXR7			QHZ	MH85 MH88	KXM KMX2 KMX3	MDS1 MDS3 MDS7 MATRIX2 ATM3			
Powdered high-speed tool steel	SKH40			HS6—5—3—8	HAP40		KHA30		DEX40		FAX38		ASP30	S590
	Matrix group				HAP5R		KHA3VN		DEX—M1 DEX—M3					
	Others				HAP10									S690
							KHA32	SPM23	DEX21		FAX31		ASP23	S790
					HAP50				DEX60					S390
									DEX61		FAX55			
					HAP72		KHA60	SPM60	DEX80		FAXG1		ASP60	
							KHA77				FAX18			
											FAXG2			
							KHA30N							
							KHA33N							
							KHA3NH							
							KHA5NH							

Reference material: Special Steels Nov. 2001 edition

Matrix group: Tool steels which reduce the amount of large carbides, a cause of accelerated tool wear and reduced toughness during cutting, in order to improve cutting performance and increase tool toughness

HARDNESS OF PRIMARY STEEL MATERIALS AND THE CORRESPONDING TOOLS

Machining method		Equipment name	Tools required
Cutting	Machining holes on sides and bottom	General purpose milling cutter	Drills
		NC milling cutter	Reamers
			End mills
		Machining center	Cutting tools
	Machining holes	Drilling machine	Drills
		Boring machine	Taps
		Boring machine	Reamers
		Jig borer	Cutting tools
	Machining cylinders	General purpose lathe	Drills
		NC lathe	Reamers
			Taps
		Turning center	Cutting tools
Grinding		Surface grinder	Grindstones
		Cylindrical grinder	
		Jig grinder	
		Profile grinder	
		Forming grinder	
Electric discharge		EDM	Electrode master
		WEDM	Wire

M

Tool material	Tool material	Parts material
Drills	High-speed steel	SKH—
Reamers	Carbide	Wn—Co
Taps	High-speed steel	SKH—
	Carbide	Wn—Co
End mills	High-speed steel	SKH—
	Carbide	Wn—Co
Cutting tools	Boron	CBN
	Diamond	D
Grindstones	White fused alumina	WA
	Brown fused alumina	A
	Pink fused alumina	PA
	Green silicon carbide	GC
	Black silicon carbide	C
	ED boron	CBN
	ED diamond	D
Electrode master	Electrolytic copper, brass	CU—
	Copper tungsten, silver tungsten	—Wn
Wire	Brass	CU—Zn
	Tungsten	Wn

Machined material	Non-ferrous metal	Untreated	Heat treated	Hardened/tempered
Press die materials	(Al)	(Al—alloy) SS400 (SS41) SKD11 S45C S50C DC53	(Be—Cu) SCM435 HPM2T	DC53 (Carbide) S45C SKS3 SKD11 SUJ2 SKH51
Plastic mold material	CU BsBM2	SKD61 STAVAX ESR RIGOR (SKD12 group)	HPM7 PX5 HPM38 S—STAR STAVAX ESR NAK55 HPM1 NAK80 HPM50 FDAC DH2F	(Electroforming-outside) (Electroforming-inside) ORAVAR SUPREME (Age-hardened) MAS1C SKD61 HPM38 S—STAR STAVAX ESR RIGOR (SKD12 group)
HRC		10 20	30 40	50 60 70