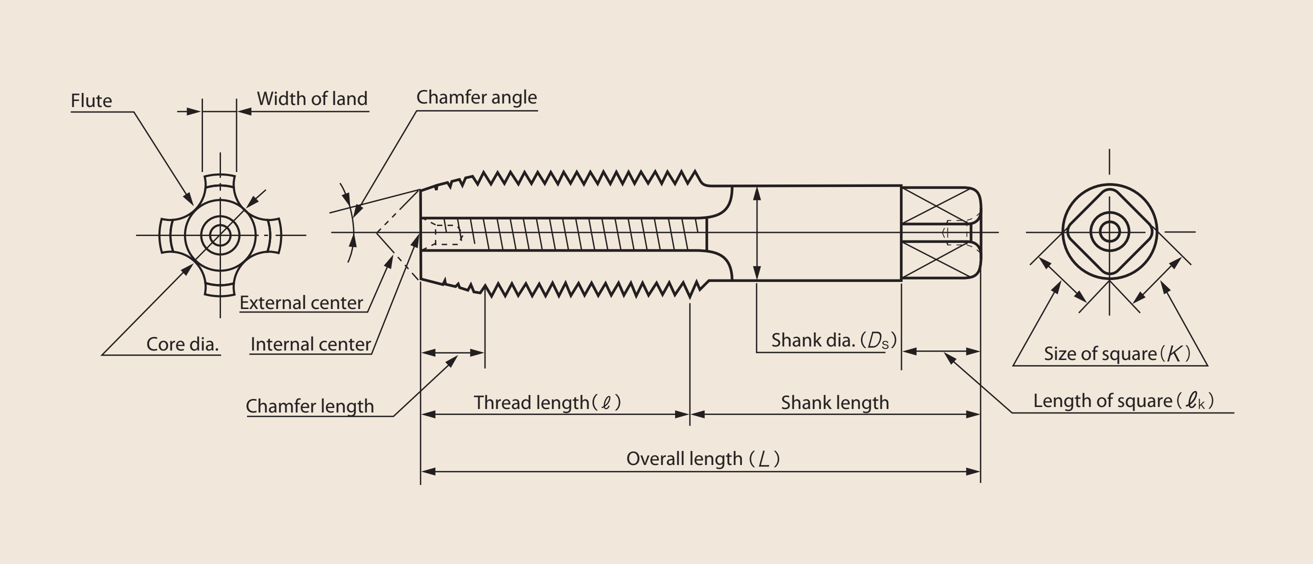
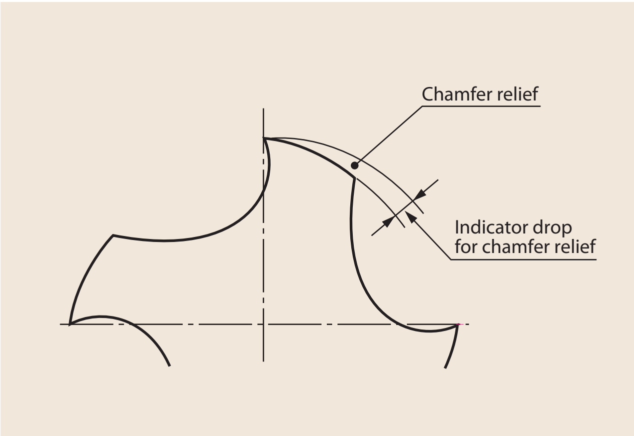
Technical Information

1. Terminology of Taps Technical-1
2. Flutes Technical-2
3. Edge angle and Cutting allowance of taps Technical-3
4. Recommended Tapping Speeds Technical-4
5. Tapping Speed and Revolution Technical-5
6. Tapping Torque Technical-6
7. Metric Thread and Gauge Profile Technical-9
8. Length of engagement Technical-11
9. Classes of Internal Threads and Classes of Taps Technical-13
10. Guide to Thread Forming Taps(Roll Taps) Technical-18
11. How to set the tap's oversize to meet with the coating margin of internal threads Technical-20
12. Recommended bored hole sizes Technical-21
13. Recommended Hole Sizes for Thread Forming Taps Technical-27
14. Bar diameter for external threads(for cutting type dies) Technical-28
15. Bar diameter of external screws(for thread rolling dies) Technical-31
16. Surface Treatment Technical-32
17. Carbide Taps Technical-35
18. Pipe Taps Standard Technical-37
19. Features of MC-Helical Thread Mills Technical-44
20. Selecting different tap holder combinations by machine feed system Technical-47
21 The common mechanics for a tap to cut oversize on an internal thread Technical-49
22. Trouble Shooting Technical-51
23. Center Drills Technical-55
24. Table of recommend centering condition Technical-56
25. Thread Series Technical-58
26. Basic profile of threads Technical-60
27. Symbols for Standard Threads Technical-62
28. Cross chart of thread cutting tool standard Technical-65
29. Hardness conversion table Technical-66
30. Conversion table from inch to millimeter Technical-67
31. Chemical Component table of work materials Technical-69
32. Materials used for Cutting Tools Technical-79
33. Design of taps and dies Technical-81
34. Design of center drills and centering tools Technical-83
35. Design of dies Technical-84
36. Design of taps for USA market and European market Technical-84

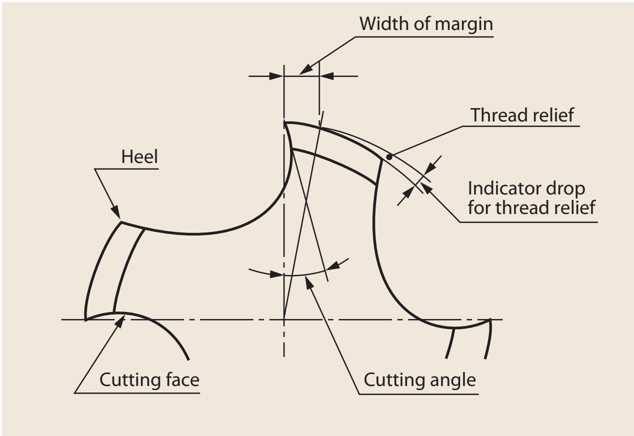
1. Terminology of Taps



■Chamfer relief

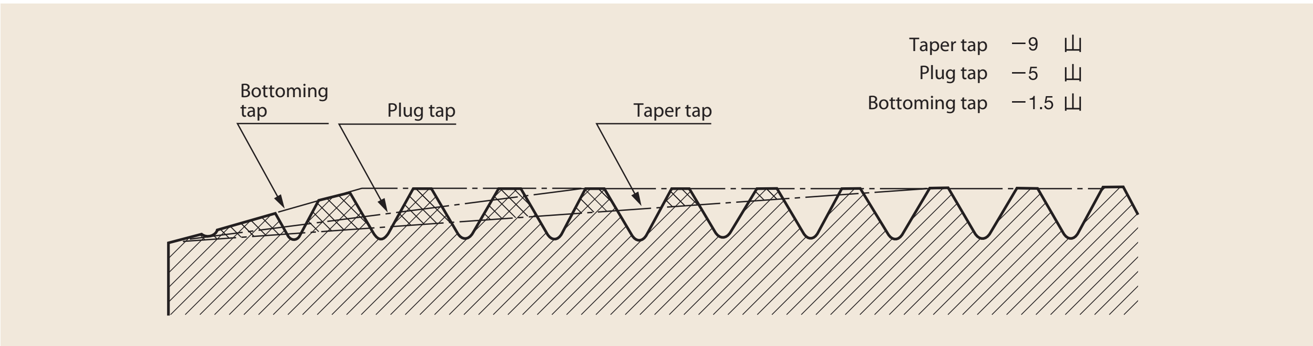


■Thread relief and cutting angle



Edge angle, including chamfer relief, thread relief, cutting angle and others, and heat treatment, have important functions affecting on workpiece shape, tool life, surface finish of internal screw thread, and so on.

■Chamfer of hand tap

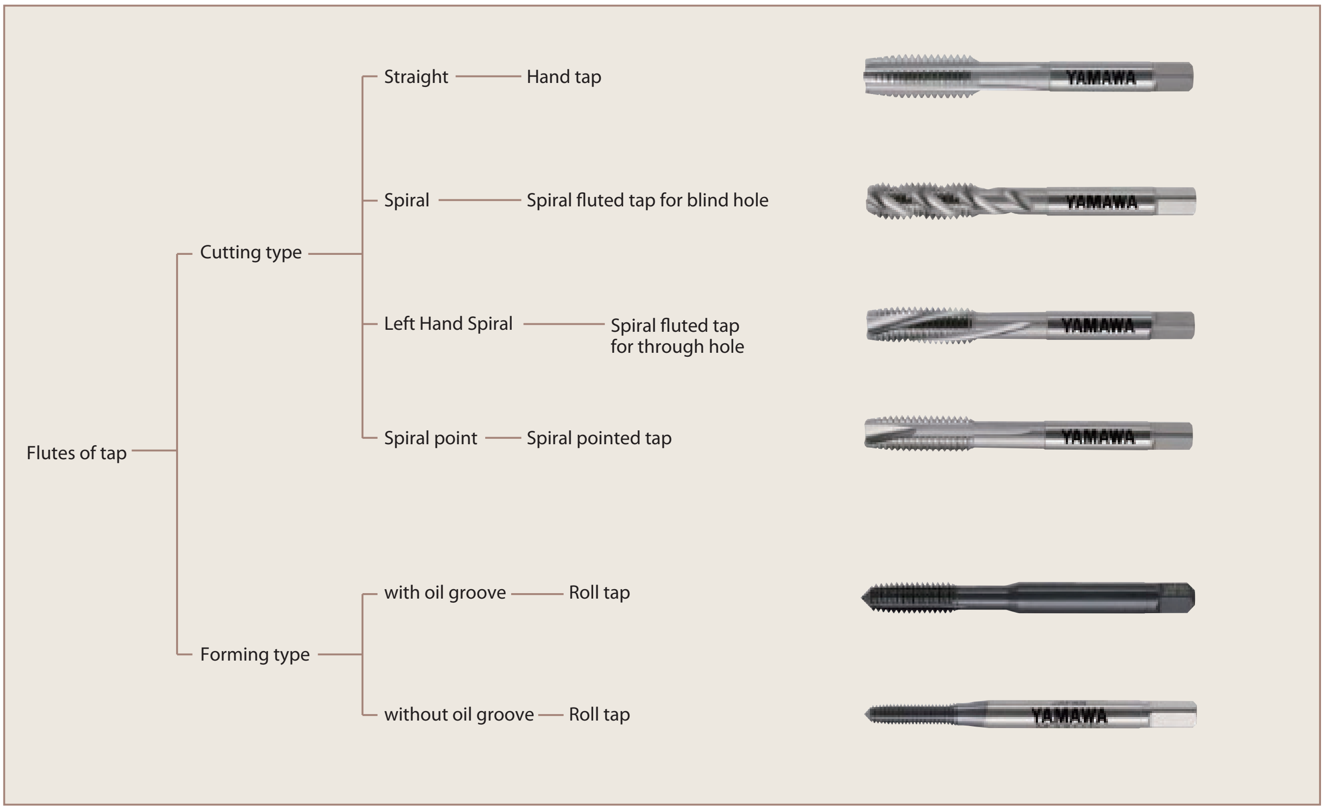


In general, tap chamfer is the most important part of taps to create internal thread. The function of full thread part of taps is to make a guidance.

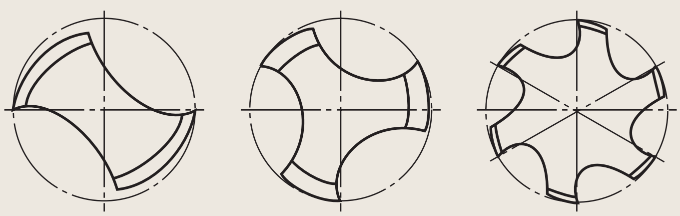
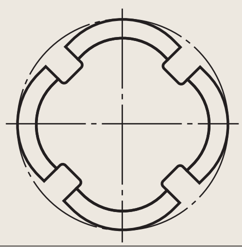
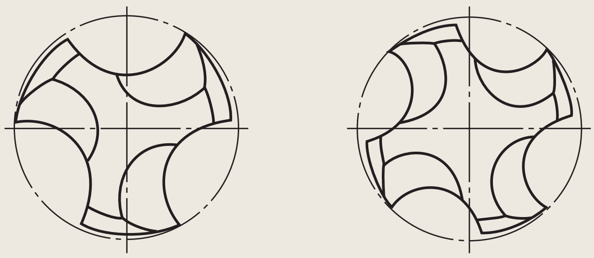
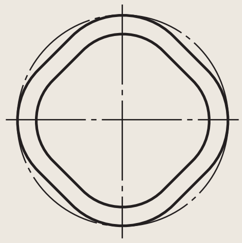
2. Flutes

■Major functions of flutes are :

1) Chips' pocket, 2) lubricant supply route, 3) rake angle formation, 4) to determine cutting amount in relation to the number of chamfer threads. And all are very important. Taps' flutes are classified into following groups by tapping methods, fluting method, tapping direction, and hand of screw thread.



■Type of Flute

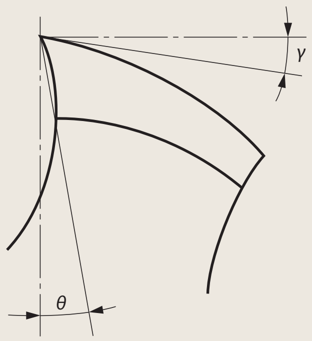
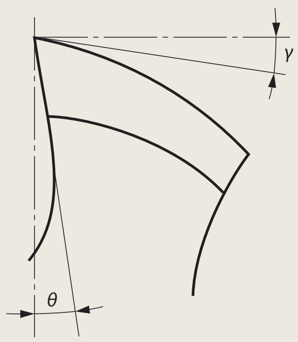
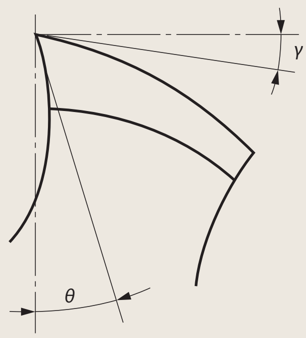
Type of Taps / Flute	Cutting type	Type of Taps / Flute	Forming type
Straight Flute Spiral Flute		With oil groove	
Spiral Point Flute		Without oil groove	

In general, the number of flutes for cutting type taps are usually increased as O.D. becomes larger. However, it is also influenced by tap's strength and regidity, the accomodation of chip, the amount of cutting, and lubricant supply system.

3. Edge angle and Cutting allowance of taps

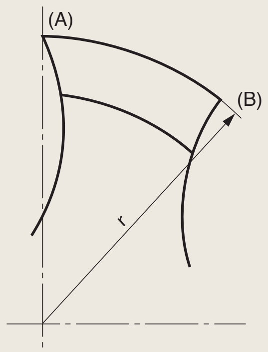
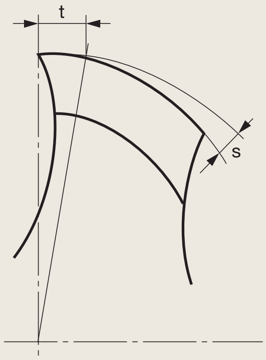
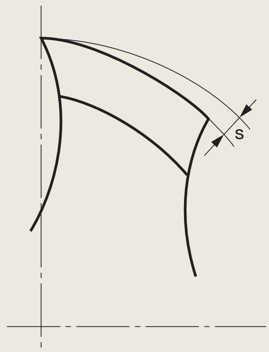
■Cutting angle and Chamfer relief

θ : Cutting angle γ : Chamfer relief

Chordal Hook Angle	Rake Angle	Tangential Hook Angle
		
Cutting angle of hook face. The angle between the center line passing the cutting edge and the straight line linking the cutting edge with the thread root.	Cutting angle of rake face. The angle between the center line passing the cutting edge and the straight line linking the cutting edge with thread root.	Cutting angle of hook face. The angle between the center line passing the cutting edge and the straight line tangent to the rake face on the cutting edge.

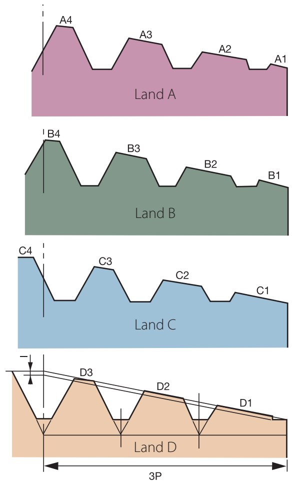
■Thread relief

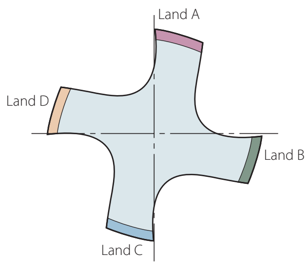
S : Thread relief

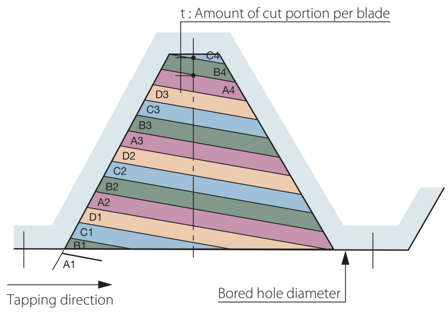
Concentric-unrelieved	Con-eccentric thread relief	Eccentric thread relief
		
No relief exists at land. Start (A) and heel (B) of thread land have same concentricy.	Radial relief in the thread form starts at the back of a concentric margin.	Radial relief in the thread form starts at the cutting edge and continues to the heel.

■The amount of cut portion

Please refer to the pictures shown.
In such taps as have 4 flutes and 3 thread chamfer, the cutting operation progresses in order from the edge of A1, B1, C1, D1…A2, B2…A4. Tap end is usually smaller than the size of bored hole, and A1 may not make any cutting operation.







4. Recommended Tapping Speeds

■Tapping Speeds

Following usage conditions affect tapping speeds : kind of taps, workpieces, number of chamfered threads, materials, hole condition and fluid. It is necessary to select the suitable tapping speed by paying attention to these conditions.
When work material has excellent workability, when there is a little depth of tapping, or when tapping fluid can be sufficient, select rather higher tapping speed. When workability of work material is unknown, to be safe, try nearly the lowest tapping speed at first, and then increase the speed gradually.

Unit : m/min

Workpiece Materials		Tapping Speed				
		Spiral Fluted	Spiral Pointed	Roll Taps	Straight Fluted	Cemented Carbide
Low Carbon Steels	SS400 S10C～S25C	8～15	10～20	8～15	6～10	—
Medium Carbon Steels	S25C～S45C	6～12	8～14	7～12	5～9	—
High Carbon Steels	S45C～S58C	5～10	8～12	5～10	5～8	—
Alloy Steels	SCM・SNCM	5～10	7～10	5～10	5～8	—
Heat treated Steels	20～45HRC	3～5	4～7	—	3～6	—
Stainless Steels	SUS	3～8	4～9	6～15	3～7	—
Tool Steels	SKD	5～8	6～10	—	5～9	—
Cast Steels	SC	6～10	8～13	—	6～10	—
Cast Irons	FC	—	—	—	12～17	15～25
Ductile Cast Irons	FCD	5～10	5～10	—	5～8	12～20
Coppers	Cu	8～12	8～13	25～35	7～11	15～33
Brass · Brass Casting	Bs・BsC	11～22	13～25	25～35	10～20	23～33
Phosphor Bronze · Phosphor Bronze Casting	PB・PBC	8～15	10～18	25～35	8～15	18～33
Wrought Aluminum	Al	15～25	20～25	25～35	15～20	23～40
Aluminum Alloy Castings	AC・ADC	11～22	12～24	15～25	10～20	15～25
Magnesium Alloy Castings	MC	7～15	10～20	—	7～15	12～20
Zinc Alloy Diecastings	ZDC	7～15	10～20	15～25	7～15	12～20
Thermosetting Plastic	Bakelite (Phenol-PF)	11～17	12～18	—	10～15	15～25
Thermoplastic resin	PVC, Nylon	11～17	12～18	—	10～15	15～25
Titanium Alloys	Ti-6Al-4Vetc	6～9	6～9	—	—	—
Nickel Base Alloys	Hastelloy, Inconel, Waspaloy	3～6	3～6	—	—	—

■Formula

Tapping Speed (Vc)

$$Vc = \frac{\pi \cdot Dc \cdot n}{1000} \text{ (m/min)}$$

n : Revolutionof tap (min^{-1})
π : 3.14
Dc : Nominal dia. of tap (mm)

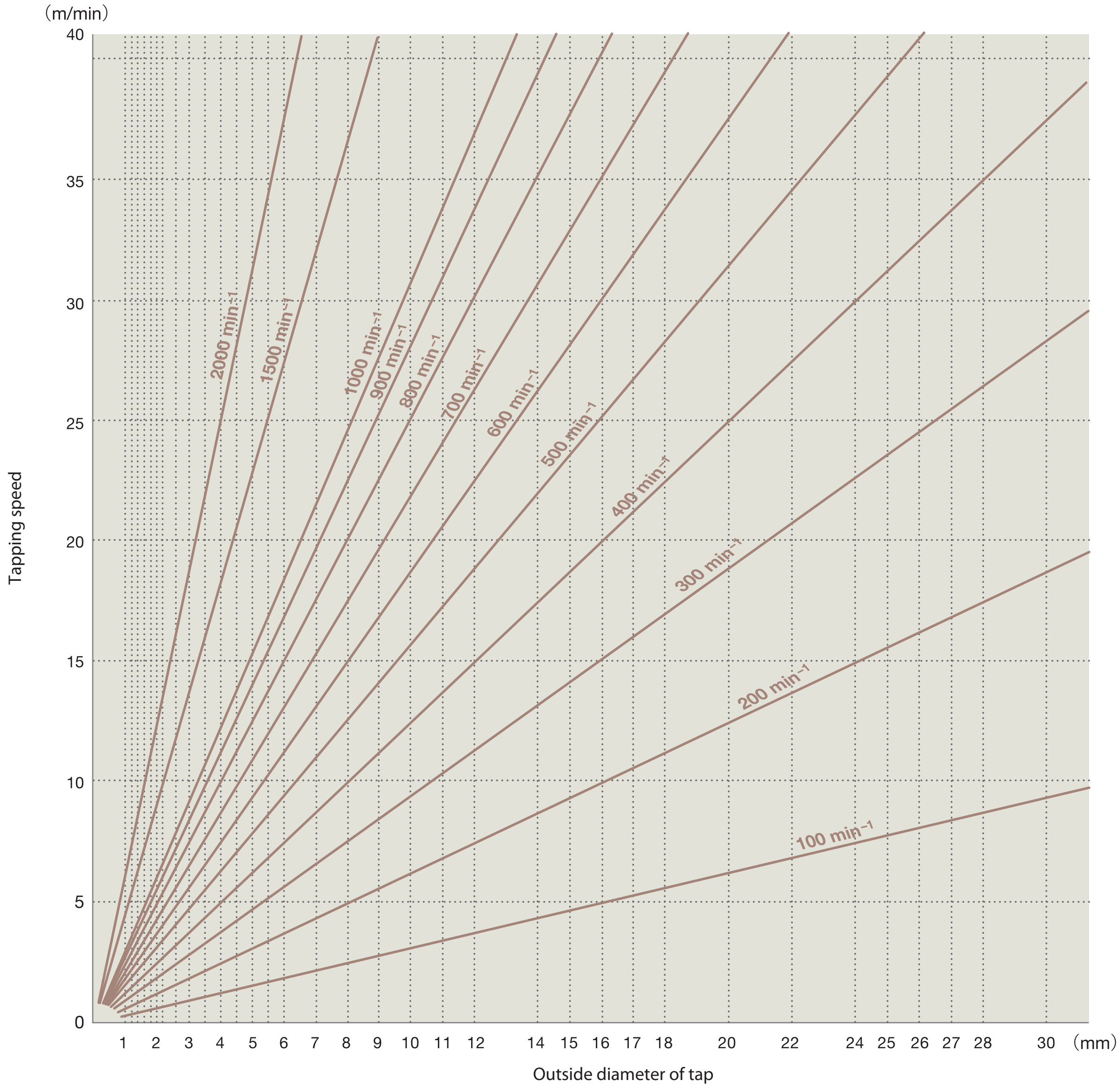
Revolution of tap (n)

$$n = \frac{1000 \cdot Vc}{\pi \cdot Dc} \text{ (}min^{-1}\text{)}$$

Vc : Tapping Speed (m/min)
Dc : Nominal dia. of tap (mm)
π : 3.14

5. Tapping speed and Revolution

■Conversion table



6. Tapping Torque

■Tapping Torque of Cutting type Taps

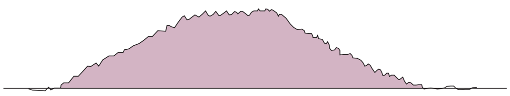
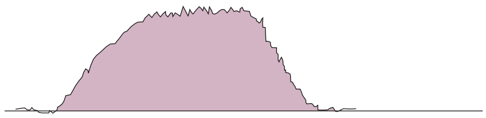
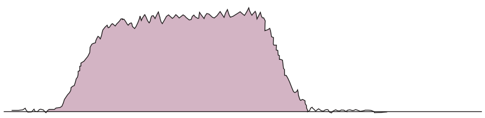
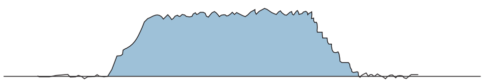
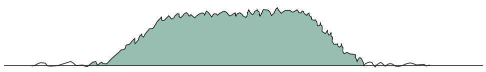
The torque starts increasing as the threads of chamfer enter the workpiece material. It becomes highest when all threads of chamfer cut into workpiece material, and is in plateau until the chamfer cuts through the workpiece. After that, the torque will decrease until the end of tapping.

■Cutting Torque Line

Cutting torque lines in the test of different kinds of taps, hand tap, spiral fluted tap, spiral pointed tap are shown below.

Tapping Condition

Tap : HSS P2 M8×1.25	Bored hole size : 6.8mm
Cutting speed : 6.1m/min	Cutting oil : Water insoluble oil
Workpiece material : S50C	Machine : Drilling machine
Tapping type : 10mm Through hole	Measurement equipment : Piezoelectric torque tester

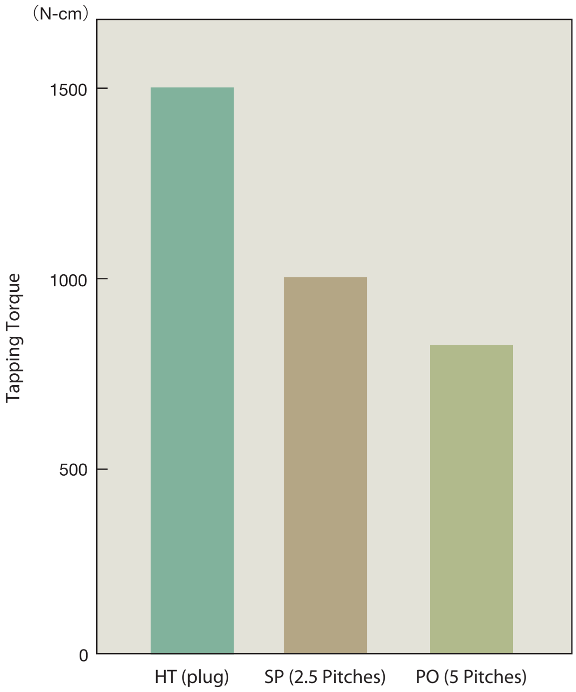
Type of tap		Torque lin es	Description
Hand tap (P2)	Taper tap (9 threads)		Gentle slope is observed because of less cutting by each cutting chamfer, but longer tapping time is taken than in the other hand taps.
	Plug tap (5 threads)		Plateau is observed since whole chamfer threads enter the workpiece material. Tapping time is much shorter than that of the taper tap.
	Bottoming tap (1.5 threads)		Plateu is also observed since whole short chamfer threads enter the workpiece material. Tapping process time is shorter than that of the plug tap.
Spiral fluted tap (P2, 2.5 threads)			Spiral fluted tap pulls out the chips, good choice for blind hole tapping. The cutting torque of spiral fluted taps is smaller than that of the hand taps.
Spiral pointed tap (P2, 5 threads)			Spiral pointed tap pushes out the chips forward. It is good choice for through hole use. Cutting torque is smallest in all taps.

The cutting torque will change depending on the kind of taps, cutting chamfer, number of flutes, workpiece materials and their hardness, lubrication types, and chips.

6. Tapping Torque

■Comparison of Cutting Torque by Different Type of Taps

Cutting torque of hand tap (HT), and spiral fluted tap (SP), and spiral pointed tap (PO) differs, shown in the chart below.



Tapping Condition

Tap :	HSS P2 M10×1.5
Cutting speed :	10m/min
Workpiece material :	S50C
Hole condition :	20mm through hole
Bored hole size :	ϕ8.5, drill
Lubrication :	Water insoluble oil
Machine :	Radial drilling machine
Measurement equipment :	Piezoelectric torque tester

If the cutting torque of hand tap is assumed as 100, the cutting torque of other taps is as follows :

Hand Tap : 100
Spiral fluted Tap : 70~75
Spiral Pointed Tap : 60~65

■Tapping Torque of Forming type Taps

■Calculation for Tapping Torque of Roll Taps

○It is hard to calculate tapping torque for roll taps because they contain more complicated factor than the cutting taps.
According to our experience, tapping torque of roll taps is twice or three times larger than that of the cutting taps in general.

○Major factors increasing or decreasing tapping torque of roll taps are :

(1) Mechanical characteristic of workpiece (Tensile strength, hardness, spring back feature, work hardening index) : As the tensile strength gets larger, the threading torque becomes larger.
(2) Size and length of bored hole: Bored hole size is usually defined to obtain 75% thread height of basic thread profile. Roll taps may be shuttered due to the excessive tapping torque when the bored hole size is made smaller to obtain higher thread height. Tapping torque gets larger as the efficient length of internal screw becomes longer because there is an increase in friction coefficient caused by spring back of workpiece material.
(3) Tapping process (tapping speed, lubricant, and rigidity of main spindle).
(4) Surface treatment of taps (oxidizing, nitriding, TiN, and TiCN coatings).

○Tapping Torque Equation for Forming Taps

Based on the tensile strength of workpiece material, we prepare following equation to obtain tapping torque of standard formig taps.
Condition : Effective length of internal screw is 1.5D,. Thread height is 75%.

Tapping Torque Equation for Forming Taps

$$T = Kf \times Dc \times P^2/1000$$

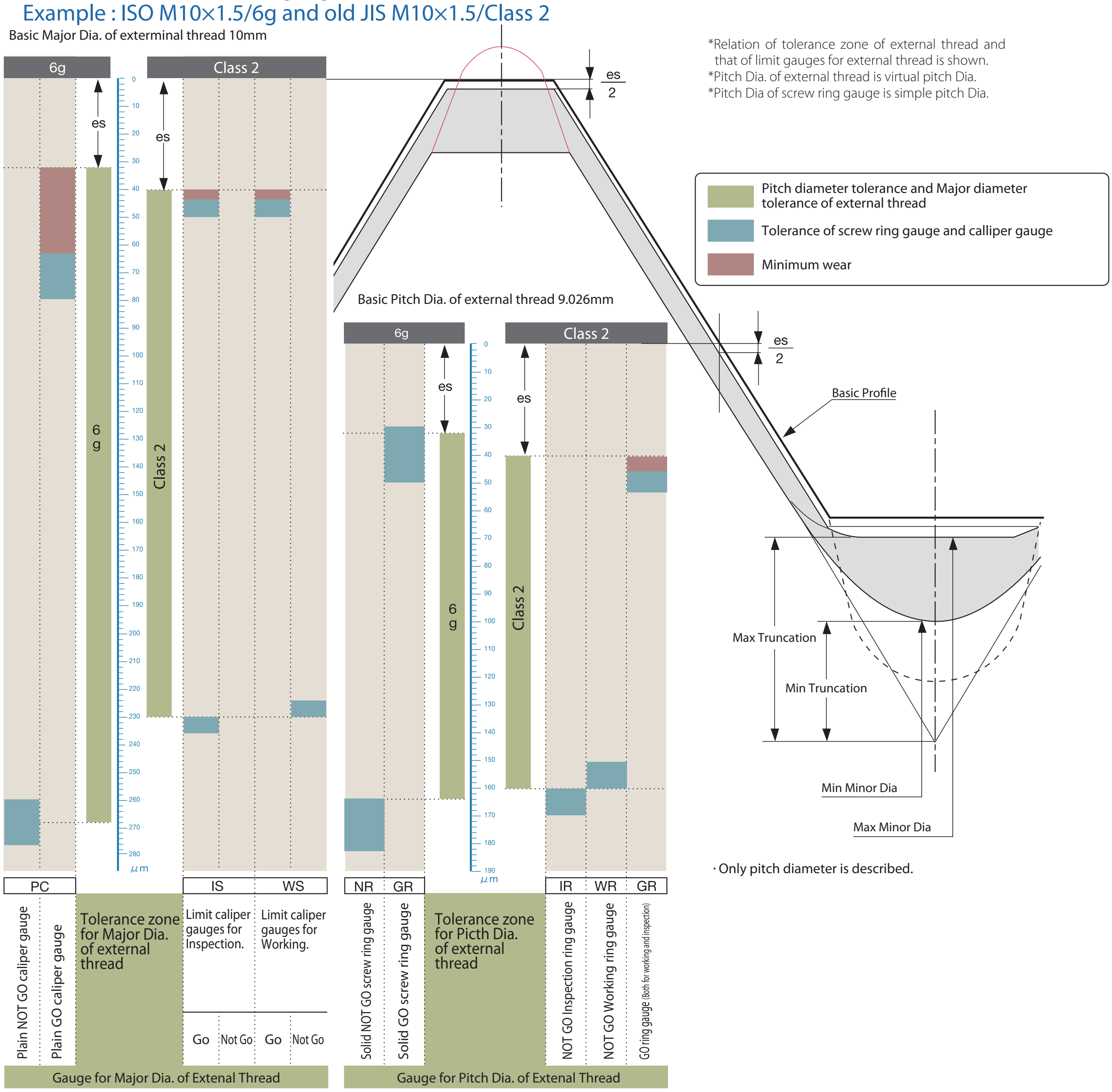
T : Tapping Torque (N-m)
Dc : Nominal Diameter of Tap (mm)
P : Pitch (mm)
Kf : Deforming resistance (Nmm^2)

Workpiece Materials	Deforming resistance (N/mm^2)
General Structure Steels, Low Carbon Steels	750~850
Medium Carbon Steels, Alloy Steels	1150~1350
Stainless Steels	1100~1300
Wrought Aluminum	250~350
Aluminum Die castings	380~530
Coppers, Wrought Copper Alloys	750~1050

7. Metric Thread and Gauge Profile

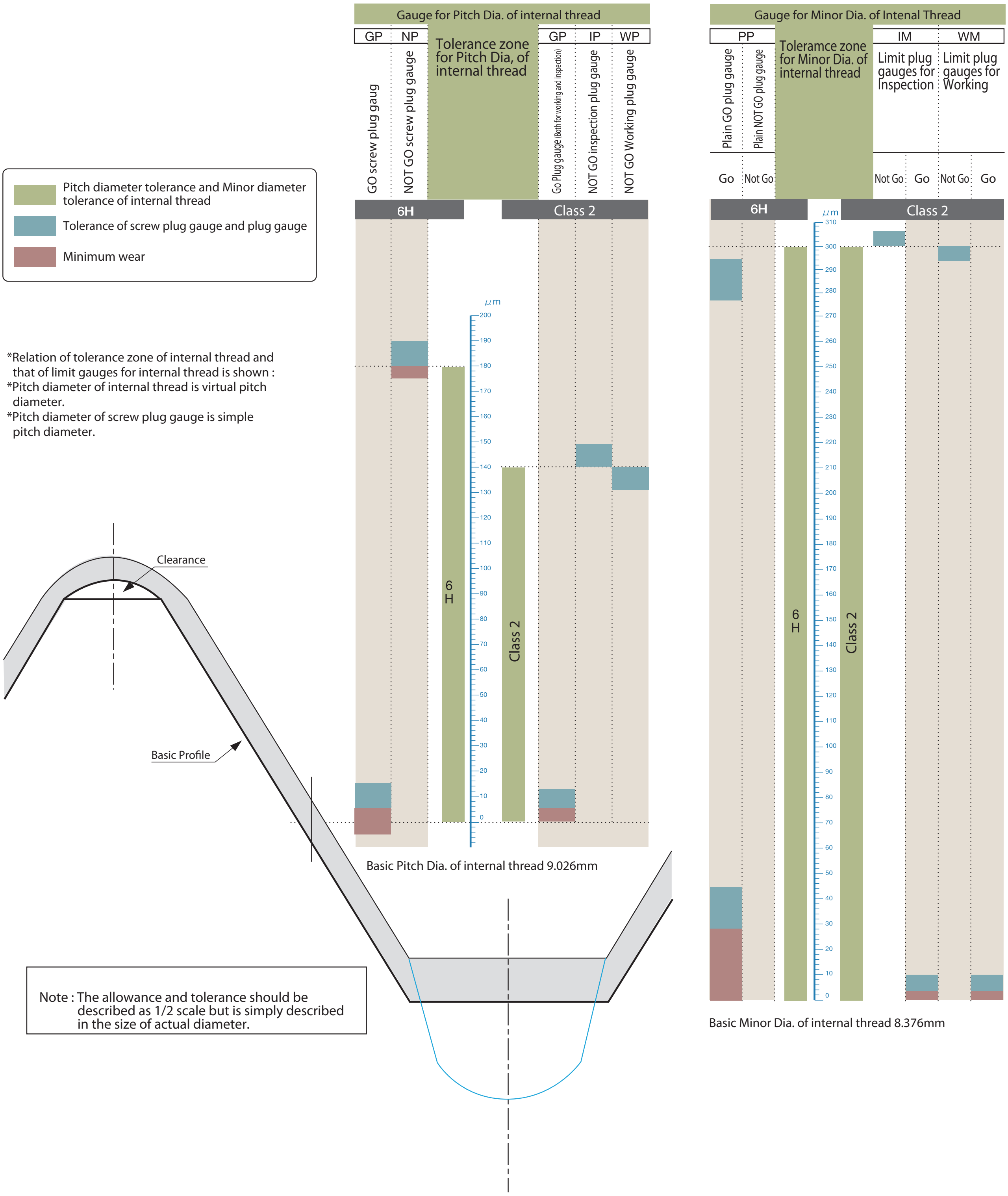
Relation of tolerance position between screw thread classes and thread gauge classes in ISO(new JIS) and old JIS standard.

■External threads and Limit gauges for external threads
Example : ISO M10×1.5/6g and old JIS M10×1.5/Class 2



· Only pitch diameter is described.

Internal threads and Limit gauges for internal threads
Example : ISO M10×1.5/6H and old JIS M10×1.5/Class 2



*Relation of tolerance zone of internal thread and that of limit gauges for internal thread is shown :
*Pitch diameter of internal thread is virtual pitch diameter.
*Pitch diameter of screw plug gauge is simple pitch diameter.

Note : The allowance and tolerance should be described as 1/2 scale but is simply described in the size of actual diameter.

- Limit gauges for screw threads
  JIS B 0251-2008

JIS B 0251-1975 Limit gauges for metric coarse threads Appendix

JIS B 0253-1985 Gauge for taper pipe threads

JIS B 0255-1975 Limit gauge for unified coarse threads

JIS B 0252-1996 Limit gauge for metric fine threads

JIS B 0254-1985 Gauge for parallel pipe threads

JIS B 0256-1975 Limit gauge for unified fine threads, Appendix

8. Length of engagement

■Length of engagement

Thread tolerance class is chosen in consideration of "engagement classification" and "engagement length". To realize the stable tapping, it is necessary to fully understand the relation between these factors and to choose the suitable tolerance class.

On "engagement calssification : middle", the tolerance class 6H is almost always chosen for standard internal threads. However, in case of "engagement length : L", tolerance class 7H can also be chosen.

On M12x1.75, the tolerance of 7H is 25% (50µm) larger than that of 6H. And this widens the selection range of the tolerance class for taps to customer's advantage.

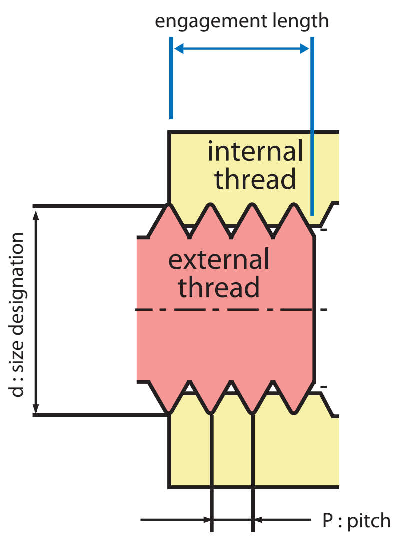
【M12x1.75】
6H Pitch diameter : 10.863 ~ 11.063mm (tolerance 0.200 mm)
7H Pitch diameter : 10.863 ~ 11.113mm (tolerance 0.250 mm)

1) Engagement classification

classification	application
fine	precise screw threads with a little allowance
middle	standard screw threads used for machines, apparatuses and constructions bodies
coarse	screw threads used for construction and building installation, and screw threads for which threading operation is very difficult such as threading of hot rolled steel bars.

2) Classification of engagement length

symbol	classification	limit size
S	short	up to and including $2.24Pd^{0.2}$
N	normal	over $2.24Pd^{0.2}$ up to and including $6.7Pd^{0.2}$
L	long	over $6.7Pd^{0.2}$



3) Selection rule of internal threads and external threads
Selection rule of the tolerance class of internal threads

tolerance position	H		
engagement length / engagement classification	S	N	L
fine	4H	5H	6H
middle	5H	6H	7H
coarse	-	7H	8H

Selection rule of the tolerance class of external threads

tolerance position	h			g		
engagement length / engagement classification	S	N	L	S	N	L
fine	(3h4h)	4h	(5h4h)	-	-	-
middle	(5h6h)	6h	(7h6h)	(5g6g)	6g	(7g6g)
coarse	-	-	-	-	8g	(9g8g)

4) engagement length

Unit : mm

size	pitch	S	N		L
		up to and including	over	up to and including	over
M1	0.25	0.6	0.6	1.7	1.7
M1	0.2	0.5	0.5	1.4	1.4
M1.1	0.25	0.6	0.6	1.7	1.7
M1.1	0.2	0.5	0.5	1.4	1.4
M1.2	0.25	0.6	0.6	1.7	1.7
M1.2	0.2	0.5	0.5	1.4	1.4
M1.4	0.3	0.7	0.7	2	2
M1.4	0.2	0.5	0.5	1.4	1.4
M1.6	0.35	0.8	0.8	2.6	2.6
M1.6	0.2	0.5	0.5	1.5	1.5
M1.8	0.35	0.8	0.8	2.6	2.6
M1.8	0.2	0.5	0.5	1.5	1.5
M2	0.4	1	1	3	3
M2	0.25	0.6	0.6	1.9	1.9
M2.2	0.45	1.3	1.3	3.8	3.8
M2.2	0.25	0.6	0.6	1.9	1.9
M2.5	0.45	1.3	1.3	3.8	3.8
M2.5	0.35	0.8	0.8	2.6	2.6
M3	0.5	1.5	1.5	4.5	4.5
M3	0.35	1	1	3	3
M3.5	0.6	1.7	1.7	5	5
M3.5	0.35	1	1	3	3
M4	0.7	2	2	6	6
M4	0.5	1.5	1.5	4.5	4.5
M4.5	0.75	2.2	2.2	6.7	6.7
M4.5	0.5	1.5	1.5	4.5	4.5
M5	0.8	2.5	2.5	7.5	7.5
M5	0.5	1.5	1.5	4.5	4.5
M5.5	0.5	1.5	1.5	4.5	4.5
M6	1	3	3	9	9
M6	0.75	2.4	2.4	7.1	7.1
M7	1	3	3	9	9
M7	0.75	2.4	2.4	7.1	7.1
M8	1.25	4	4	12	12
M8	1	3	3	9	9
M8	0.75	2.4	2.4	7.1	7.1
M9	1.25	4	4	12	12
M9	1	3	3	9	9
M9	0.75	2.4	2.4	7.1	7.1

size	pitch	S	N		L
		up to and including	over	up to and including	over
M10	1.5	5	5	15	15
M10	1.25	4	4	12	12
M10	1	3	3	9	9
M10	0.75	2.4	2.4	7.1	7.1
M11	1.5	5	5	15	15
M11	1	3	3	9	9
M11	0.75	2.4	2.4	7.1	7.1
M12	1.75	6	6	18	18
M12	1.5	5.6	5.6	16	16
M12	1.25	4.5	4.5	13	13
M12	1	3.8	3.8	11	11
M14	2	8	8	24	24
M14	1.5	5.6	5.6	16	16
M14	1	3.8	3.8	11	11
M15	1.5	5.6	5.6	16	16
M15	1	3.8	3.8	11	11
M16	2	8	8	24	24
M16	1.5	5.6	5.6	16	16
M16	1	3.8	3.8	11	11
M17	1.5	5.6	5.6	16	16
M17	1	3.8	3.8	11	11
M18	2.5	10	10	30	30
M18	2	8	8	24	24
M18	1.5	5.6	5.6	16	16
M18	1	3.8	3.8	11	11
M20	2.5	10	10	30	30
M20	2	8	8	24	24
M20	1.5	5.6	5.6	16	16
M20	1	3.8	3.8	11	11
M22	2.5	10	10	30	30
M22	2	8	8	24	24
M22	1.5	5.6	5.6	16	16
M22	1	3.8	3.8	11	11
M24	3	12	12	36	36
M24	2	8.5	8.5	25	25
M24	1.5	6.3	6.3	19	19
M24	1	4	4	12	12

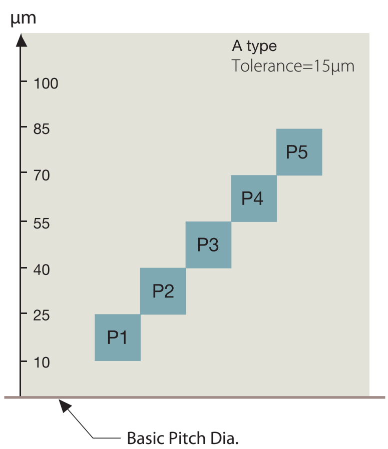
9. Classes of Internal Threads and Classes of Taps

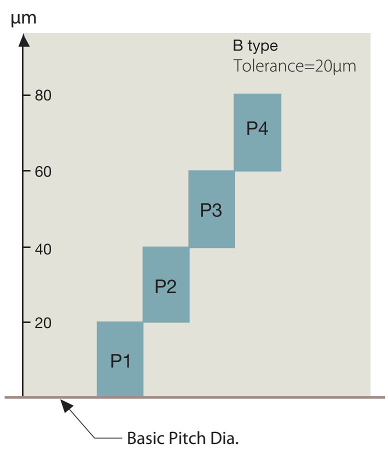
1. YAMAWA P Class System

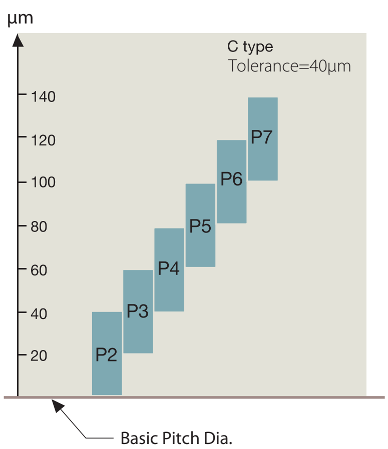
YAMAWA P Class system for thread limits is specified in accordance with JSCTA (The Japan Solid Cutting Tools' Association). Pitch diameter tolerance zone for normal size M1～M52 (U,W up to 2") are shown in the table below. Depending on pitch diameter tolerance and tolerance position, pitch diameter tolerance zones are classified into three types, A , B and C.
(1) A type : 15μm tolerance. The tolerance of P1, P2, P3… is defined as basic +10～+25μm, +25～+40μm, +40～+55μm and so on, respectively.
(2) B type : 20μm tolerance. The tolerance of P1, P2, P3… is defined as basic +0～+20μm, +20～+40μm, +40～+60μm and so on, respectively.
(3) C type : 40μm tolerance. The tolerance of P2, P3, P4… is defined as basic +0～+40μm, +20～+60μm, +40～+80μm and so on, respectively.
YAMAWA P class system is made in a step form. It can be used to select depending on the tapping conditions.

■ Pitch Tolerance zone for P Class with Nominal size and Pitch

Pitch \ Nominal Size	1mm≦Size≦24mm (7/8)	24mm (7/8)＜Size≦30mm	30mm (11/4)＜Size≦52mm (2)
≦0.6mm	A type	B type	B type
0.6mm＜Pitch≦1.75mm	B type	B type	B type
1.75mm＜Pitch≦2mm	B type	B type	C type
2mm＜Pitch≦5mm	B type	C type	C type

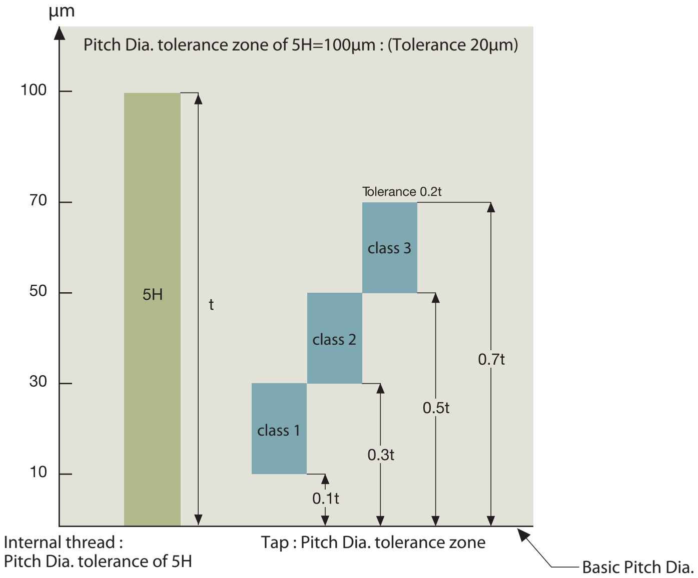






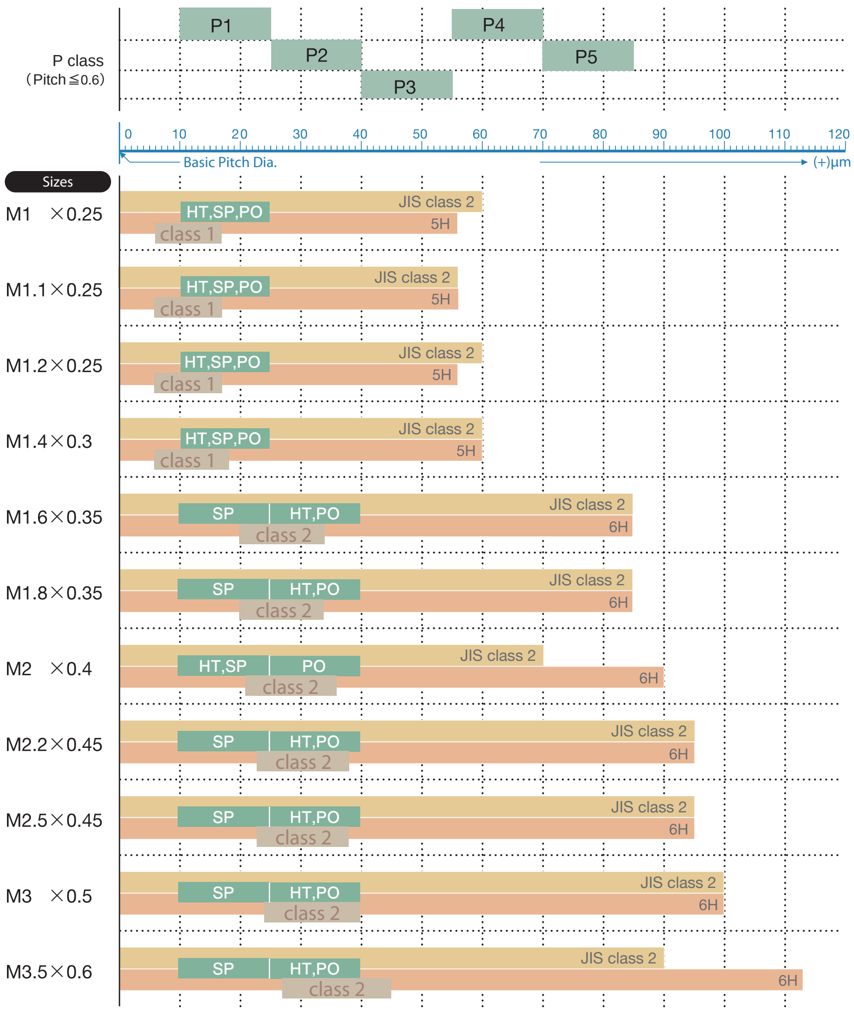
2. JIS Limit

Thread limits of taps for metric threads : Today the thread limits of ISO2857 are specified in the main book of JIS, and those of old 1st class, 2nd class and 3rd class are specified in JIS Appendix. In the thread limits of 1st, 2nd and 3rd classes (old JIS), the pitch diameter tolerances change depending on nominal size and pitch even if the class is same. On the other hand, in the thread limit of ISO2857 (current JIS), the pitch diameter tolerance is same and only the tolerance position changes as far as the nominal size is same.
The tolerance, as shown in the next picture (Page 669), is specified as X% of internal thread tolerance and it changes depending on nominal diameter and pitch. Thread classes of the main book of JIS will be said to be a system located in the middle of YAMAWA P class and old JIS class. To show clearly, thread limit classification is called Class 1, Class 2 and Class 3 in current JIS, and 1st class, 2nd class and3rd class in old JIS.



3. Comparison of pitch diameter tolerance zone for the classes of internal thread and tap.

Following graph shows :
In metric coarce threads
(1) Tap limit classes of YAMAWA P class.
(2) Pitch diameter tolerance zone of 2nd class (Tap) of JIS Appendix (old JIS) and that of class 2 (Tap) <class 1 for M1.4 and smaller> of the main book of JIS (current JIS).
(3) Pitch diameter tolerance zone of old JIS 2nd class (Internal thread) and that of JIS 6Hclass (Internal thread) <5H class for M1.4 and smaller>
(4) Pitch diameter tolerance zone of standard classes of YAMAWA P class.



P class
Pitch diameter tolerance zone of recommended class for YAMAWA P class

SP
Standard class of YAMAWA Spiral Fluted Tap

PO
Standard class of YAMAWA Spiral Pointed Tap

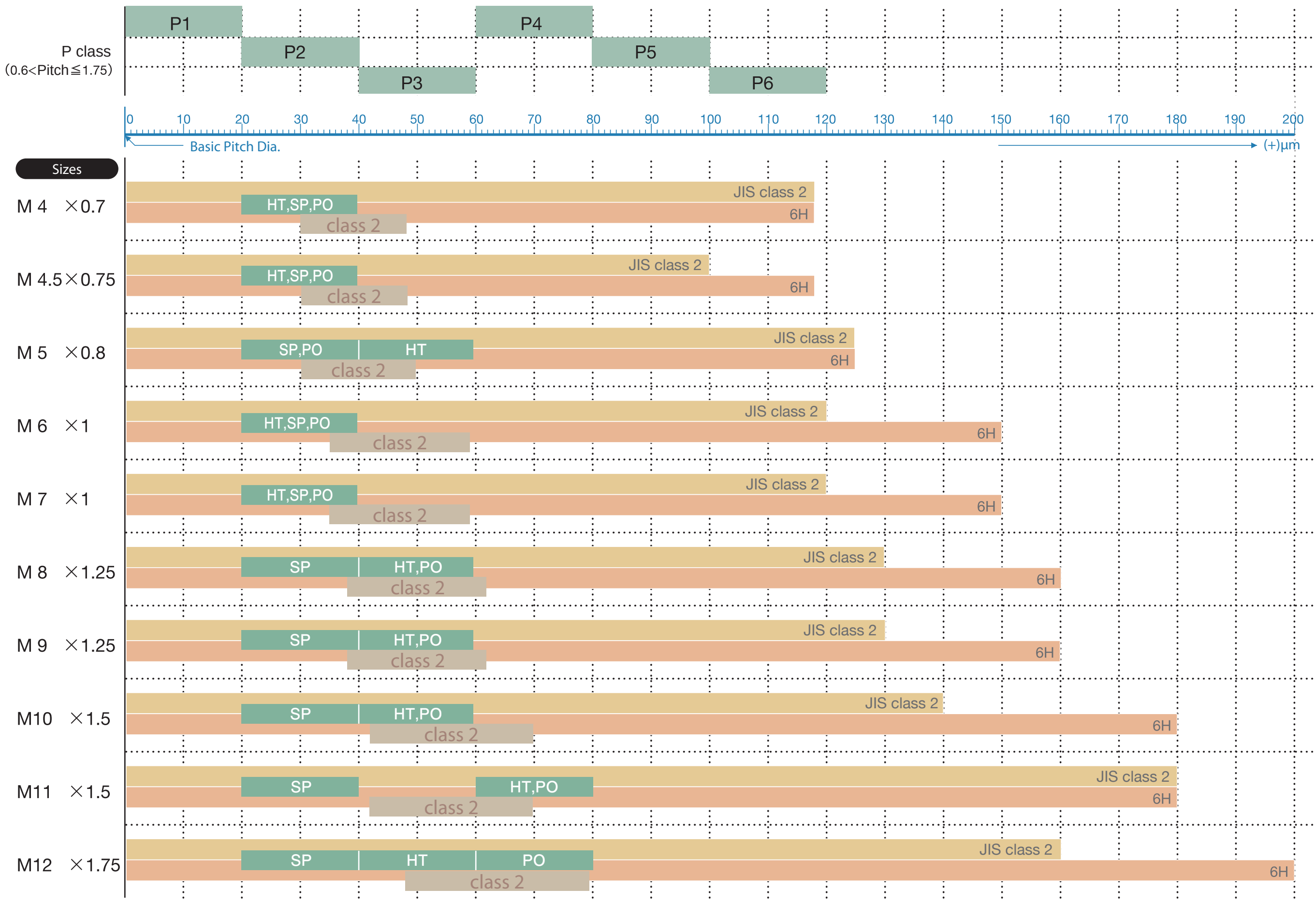
HT

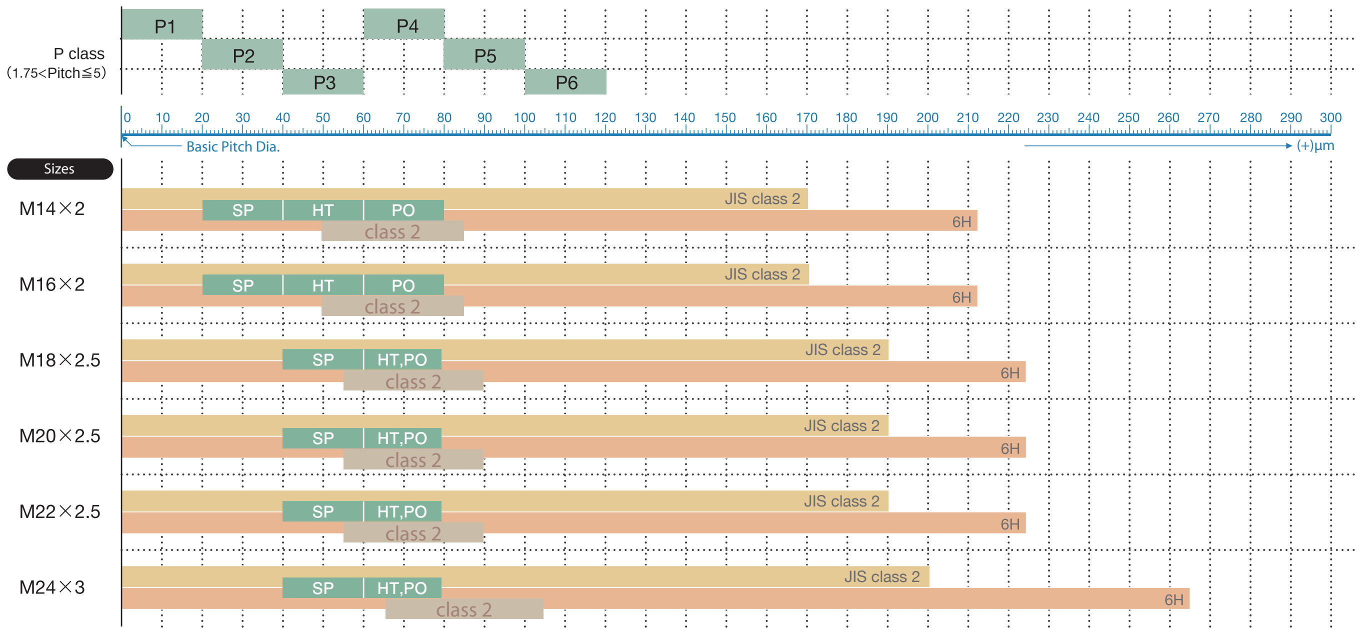
class
Pitch diameter tolerance zone of tap in the main book of JIS (current JIS).
Class 1 for M1.4 and smaller, class 2 for M1.6 and larger

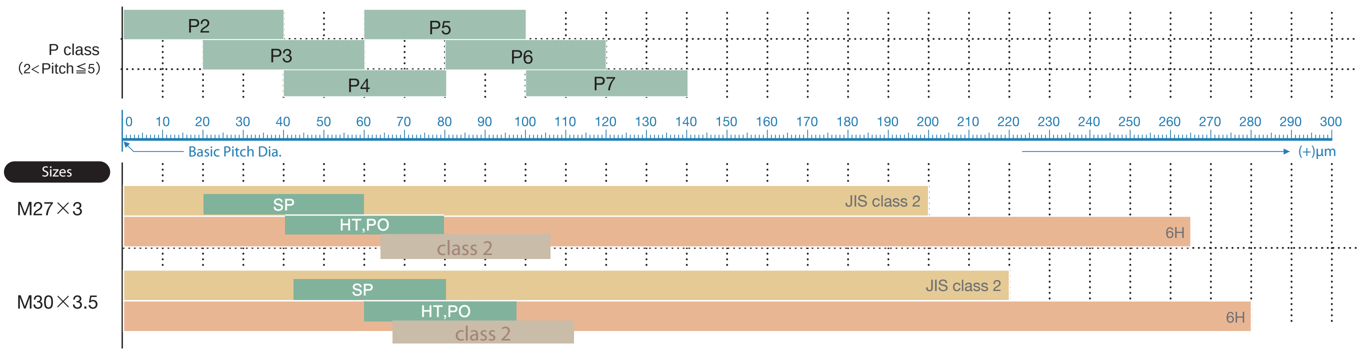
Pitch diameter tolerance zone of internal threads in old JIS class 2.

Pitch diameter tolerance zone of internal thread in current JIS (ISO)
Class 5H for M1.4 and smaller, class 6H for M1.6 and larger

9. Classes of Internal Threads and Classes of Taps







4. Standard Class and Oversize

The standard class of the tap which we have been manufacturing for general use is JIS 2nd class. This JIS 2nd class is basically defined as the thread limit of the tap which can cut the internal thread of old JIS 2nd class. With technical innovation such as various tap classification, high precision tapping machines, workpiece materials and diversity of workpieces' dimension, conventional products having JIS 2nd class could not always satisfy customers requirement due to following situations.

(1) In cutting taps, the shape of flutes influences the thrust of axial direction. We explain about oversize cutting tendency caused by the thrust force of axial direction by referring to that of Straight fluted hand taps as a basic. Spiral pointed taps have little tendency of oversize cutting, but Spiral fluted taps have a tendency of oversize cutting.

(2) Due to the relation between pitch diameter of JIS 2nd class tap and that of GO thread plug gauge for the internal thread of old JIS 2nd class, if the cutting edge of tap wears normally, the taps will become gauge out quickly resulting in short tool life.

(3) Due to the material or shape of workpiece, the material can shrink. In these cases, it would be better to use oversized taps to compensate for shinkage after tapping.

(4) When plating is to be applied to internal threads after threading, we should use oversized taps to compensate for the thickness amount of plating.

(5) Where little tendency of oversize cutting is expected, but large wear in tools is expected during tapping operation, it is better to consider using oversized taps as much as possible.

From these situations, in spiral pointed taps, spiral fluted taps and various types of special purpose taps, YAMAWA has adopted the P class limit system which is explained in previous pages. Depending on the type and designation of taps, YAMAWA has selected from the P class system the tap's thread limit which the tap manufacturer recommends for general tapping operation. From the reason of (1) stated above, even in the same tap designation, the recommendation for spiral pointed taps is different from that for spiral fluted taps. Especially in the standard products of spiral pointed taps and spiral fluted taps, YAMAWA has specified the recommendation differently in the relation to oversize cutting tendency. Oversize taps mean the taps of which thread limits are oversize above the recommendation. This is due to the reasons (3), (4) and (5) stated above. Usually for oversize taps, YAMAWA recommends the taps which thread tolerance classes are one or two steps above the standard recommendation.

As you can see in the picture drawn in previous pages, the recommendation can be used for cutting JIS (ISO) 6H internal threads.

5. Classes of Taps for European market, and PD tolerance zone of taps.

Unit : μm

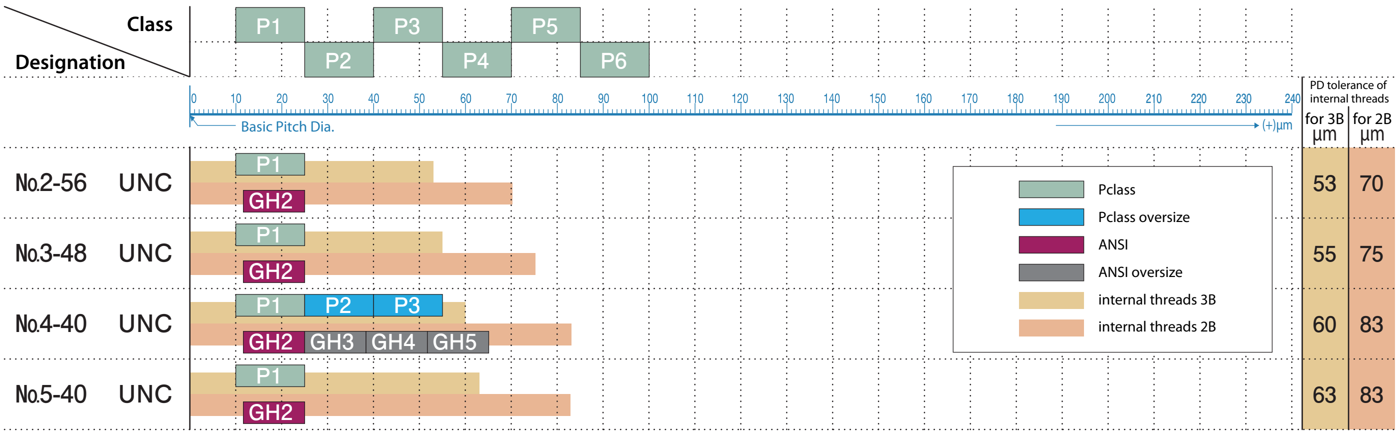
UNC	2B
Nr. 1 - 64	+28～+12
Nr. 2 - 56	+30～+13
Nr. 3 - 48	+32～+14
Nr. 4 - 40	+34～+16
Nr. 5 - 40	+35～+16
Nr. 6 - 32	+38～+18
Nr. 8 - 32	+39～+18
Nr.10 - 24	+42～+20
Nr.12 - 24	+43～+20
1/4 - 20	+46～+22
5/16 - 18	+49～+23
3/8 - 16	+53～+25
7/16 - 14	+56～+27
1/2 - 13	+58～+28
9/16 - 12	+60～+29
5/8 - 11	+63～+30
3/4 - 10	+66～+31
7/8 - 9	+70～+33
1 - 8	+73～+35

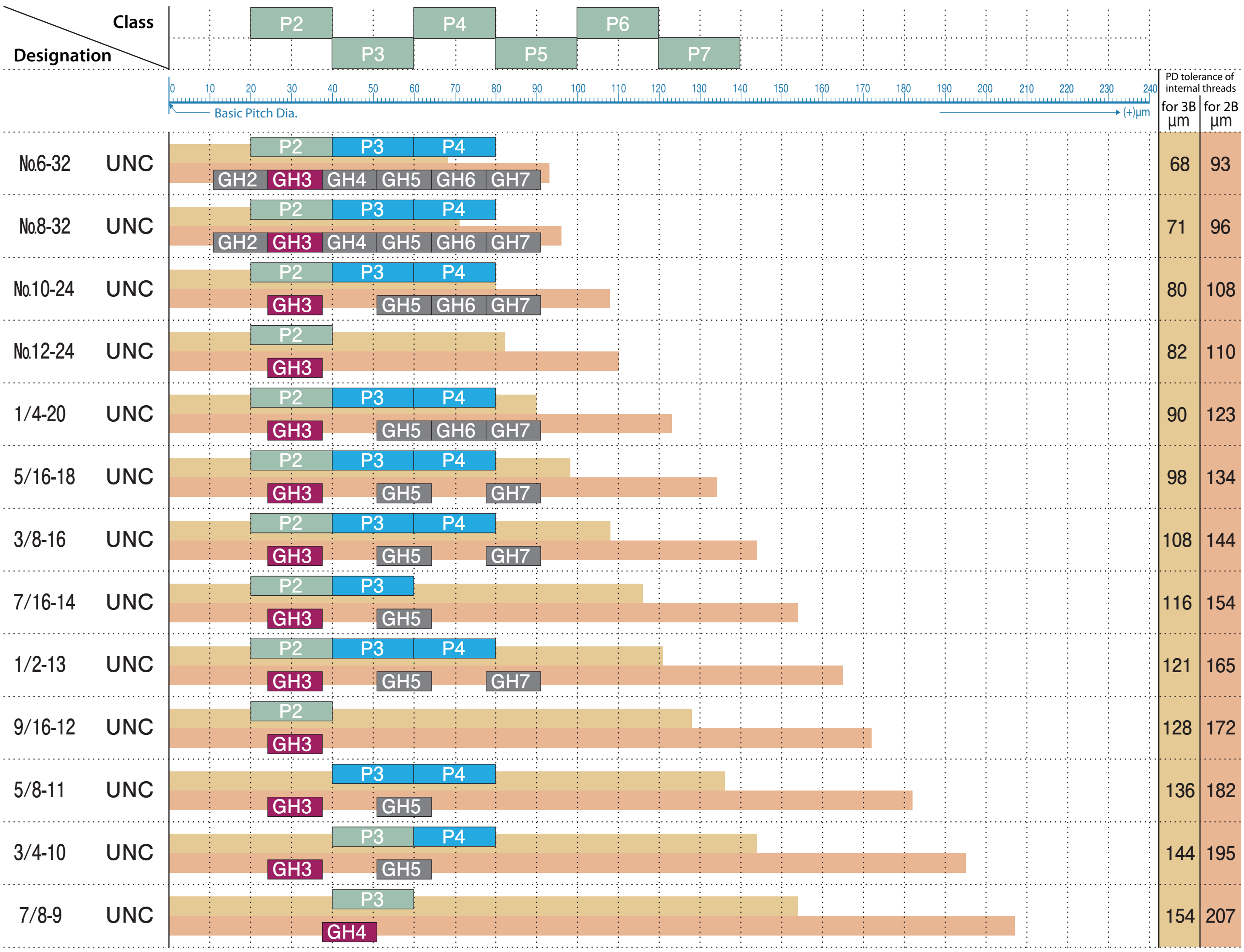
UNF	2B
Nr. 0 - 80	+26～+11
Nr. 1 - 72	+28～+12
Nr. 2 - 64	+29～+12
Nr. 3 - 56	+31～+13
Nr. 4 - 48	+32～+14
Nr. 5 - 44	+34～+15
Nr. 6 - 40	+36～+16
Nr. 8 - 36	+38～+17
Nr.10 - 32	+40～+18
Nr.12 - 28	+42～+19
1/4 - 28	+43～+19
5/16 - 24	+46～+20
3/8 - 24	+48～+20
7/16 - 20	+51～+22
1/2 - 20	+52～+23
9/16 - 18	+54～+23
5/8 - 18	+56～+23
3/4 - 16	+60～+25
7/8 - 14	+64～+27
1 - 12	+67～+29

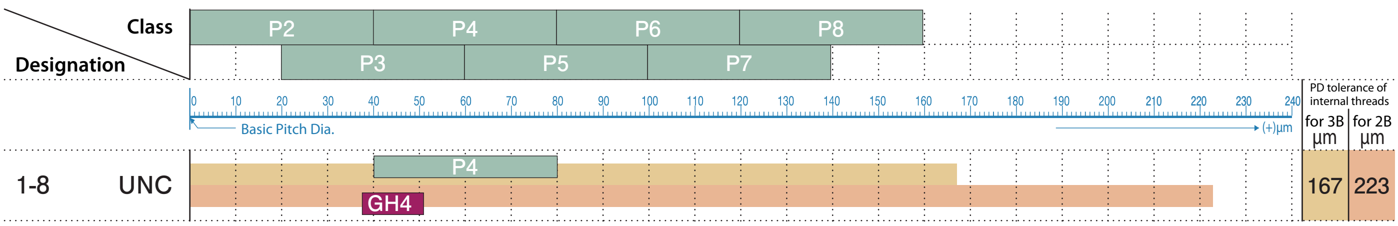
BSW	—
1/16 ×60	+28～+13
3/32 ×48	+32～+15
1/8 ×19	+35～+15
5/32 ×32	+40～+18
3/16 ×24	+44～+21
1/4 ×20	+46～+23
5/16 ×18	+49～+23
3/8 ×16	+51～+25
7/16 ×14	+56～+28
1/2 ×12	+61～+30
9/16 ×12	+61～+30
5/8 ×11	+63～+30
3/4 ×10	+69～+33
7/8 × 9	+69～+33
1 × 8	+74～+36
1 1/8 × 7	+79～+38
1 1/4 × 7	+79～+38
1 3/8 × 6	+83～+41
1 1/2 × 6	+84～+40
1 5/8 × 5	+90～+45
1 3/4 × 5	+92～+46
1 7/8 × 4.5	+95～+48
2 × 4.5	+96～+48

G	—
1/8 - 28	+43～+21
1/4 - 19	+50～+25
3/8 - 19	+50～+25
1/2 - 14	+57～+28
5/8 - 14	+57～+28
3/4 - 14	+57～+28
1 - 11	+72～+36
1 1/4 - 11	+72～+36
1 1/2 - 11	+72～+36

6. Comparison table of tap's classes for American market and PD tolerance for ANSI unified internal threads.







10. Guide to Thread Forming Taps (Roll Taps)

Thread Forming Taps are the tools used for producing internal threads by a thread forming process. Currently, YAMAWA's Thread Forming Taps have a good reputation by being used in large area. They are widely used along with the diversity of workpieces and with the change into miniaturization of workpieces. Followings are the characteristics and features of Thread Forming Taps (Roll Tap) which cutting type taps do not have.

<Features of Roll Taps>

○**Tapping without producing chips.** They are suitable for blind hole tapping. In producing internal threads with no chips, they save you a time for chip disposal.

○**Roll taps are stronger than cutting taps due to their design.** The effect of fluteless design gives a large cross-section area to the tap, which effectively eliminates the problem of chip jamming and thus make Roll taps very strong.

○**Roll taps produce excellent pitch diameter well within pitch diameter tolerances.** Material deformation process produces the internal threads with good surface finish as well as precise pitch diameter.

○**High efficiency and tool life** The configuration of the lobes at the crests of the tap threads make high speed tapping possible and extends tool life compared with cutting type taps. The addition of a supplemental tap surface treatment, such as Oxide, Nitride, TiN, and TiCN can extend tool life 2 to 20 times over an uncoated (bright) taps performance.

<Points to note during a Roll tapping operation>

○Tapping torque is 2 to 3 times larger than that of cutting type taps.

○Roll tapping is only applicable to stringy materials.

○The deviation of hole size before tapping should be about 5% of pitch. The control of hole size before tapping should be more severe than that of cutting type taps.

○The selection of lubricants is important to prevent sticking or welding.

○Burrs at the face of an internal thread are larger than those produced by cutting type taps, in some cases it is necessary to take additional counter-sink processing at the top of hole.

○In the minor diameter of internal thread, U-shape form (Tine form) at the hole entrance can be seen. U-shape form is never seen when using cutting type taps.

<Selection of YAMAWA Roll Taps>

○**Types of Roll Taps** YAMAWA produces various types of Roll Taps which include General purpose taps, Special purpose taps for non-ferrous and steel, as well as special purpose taps with surface treatment for the specified applications. To provide for longer tool life, specially developed premium materials are also used together with physical vapor deposition (PVD) such as TiN and TiCN. In particular, OL-RZ is superior product developed for dry machining with good regards to tapping environment and performance.

○**Tap Materials** YAMAWA's standard tap material is SKH58 designed for improving torque, superior anti-friction properties as well as toughness. To extend tool life, we use SKH56, or SKH10(Powder HSS) which is the best tap material for antifriction.

○**Tolerance Class** Using the datum 12.7μm in a step form, in accordance with ANSI standard GH class, we made up YAMAWA's G class system. The differences in materials being Roll tapped, as well as hole size, contribute to differences in thread forming. YAMAWA offers 2 to 3 oversized tap tolerance classes in order to achieve the most suitable internal thread pitch diameter size.

○**Chamfer length** Chamfer lengths : 2 pitches for blind hole use and 4 pitches for through hole use. Basically 4 pitches have longer tool life than 2 pitches because force applied on one blade at 4 pitch chamfer is smaller than that at 2 pitch chamfer. However, it is difficult to say about tool life in a few words because each different tapping condition influences the tool life.

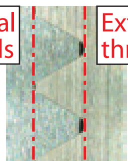
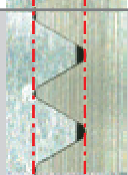
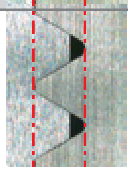
<Shape of internal threads and the ratio of thread engagement affected by bored hole diameter>

Compared with the basic height of thread engagement, the actual height of the thread engagement is called "thread engagement ratio" in percentage.

Depending on the bored hole diameter, internal threads and thread engagement ratio will change.

In tapping, the tapping condition must be chosen by refering to the thread engagemet ratio.

In tapping, it can reduce cutting space and forming space to make bored hole diameters as large as possible. This, through reducing the load on taps, can restrict tap's wear and damage.

S50C, minor diameter of threads cut M24x3 minor dia tolerance of internal threads ϕ20.752~ϕ21.252	
【S50C internal threads cut ①】 M24x3 bored hole size : ϕ20.652 minor dia tolerance of internal threads NG thread engagement ratio : 103.1%	
【S50C internal threads cut ③】 M24x3 bored hole size : ϕ21.000 minor dia tolerance of internal threads: Middle thread engagement ratio : 92.4%	
【S50C internal threads cut ⑤】 M24x3 bored hole size : ϕ21.352 minor dia tolerance of internal threads NG thread engagement ratio : 81.5%	

Aluminum, minor diameter of threads formed M25x2 minor dia tolerance of internal threads ϕ22.835~ϕ23.210	
【Aluminum, internal threads formed ①】 M25x2 bored hole size : ϕ23.903 minor diameter of finished internal threads : 22.723mm minor dia tolerance of internal threads NG thread engagement ratio : 105.2%	
【Aluminum, internal threads formed ③】 M25x2 bored hole size : ϕ24.042mm minor diameter of finished internal threads : 23.067mm minor dia tolerance of internal threads : Middle thread engagement ratio : 89.3%	
【Aluminum, internal threads formed ⑤】 M25x2 bored hole size : ϕ24.240mm minor diameter of finished internal threads : 23.462mm minor dia tolerance of internal threads NG thread engagement ratio : 71.0%	

Think threads with YAMAWA

<Condition of use>

○Relation between tapping speed and tapping lubricant depending on work materials.

Work Material		Tapping Speed (m/min)	Tapping lubricant*
Aluminum and Aluminum Alloy	Die Cast Materials	15～25	Sulfer-chlorinated Mineral oil Chlorinated non-soluble oil Non-soluble oil
	Cold Drawn, Cold Forged, Cast	25～35	
Zinc and Zinc Alloy	Die Cast Materials	15～25	
	Cold Drawn, Cold Forged, Cast	25～35	
Copper	Cold Forged, Cast	25～35	
Brass	Cold Drawn, Cold Forged	25～35	
Steel	Mild Steel, Medium Carbon Steel, Stainless Steel	6～15	Chlorinated non-soluble oil
	Free Cutting Steel, Soft Magnetic Iron	15～25	

*Basis of selection of JIS symbols

Note : It is necessary to carefully select a suitable tapping speed taking into consideration : machining conditions, style of tap, number of tap chamfered threads, work piece design, material being tapped, hole condition and type of tapping fluid.

<Accuracy of roll taps>

■YAMAWA G class system Thread Forming Taps

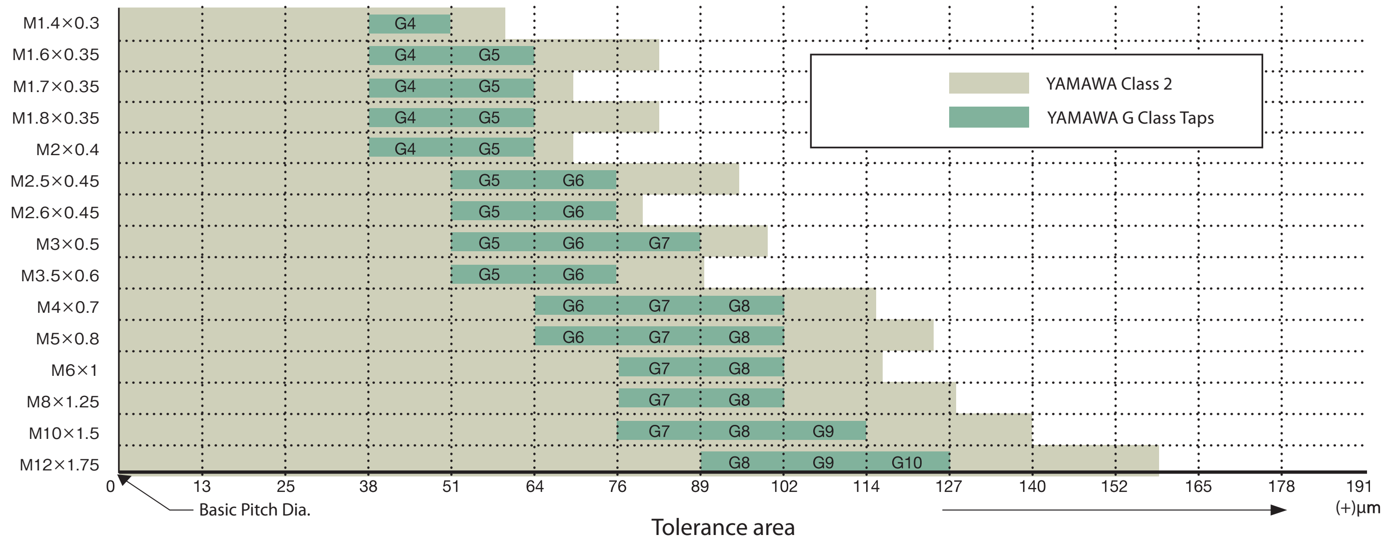
○YAMAWA G class system is made by using the datum 0.0005 inch (12.7μm) in a step form in accordance with ANSI standard GH class.

○The upper deviation of G class is decided by rounding off the grade No.× 12.7 to 1 decimal.

○The lower deviation of G class is specified in the same upper tolerance of one lower step.

○The tolerances are either 12 μm or 13μm.

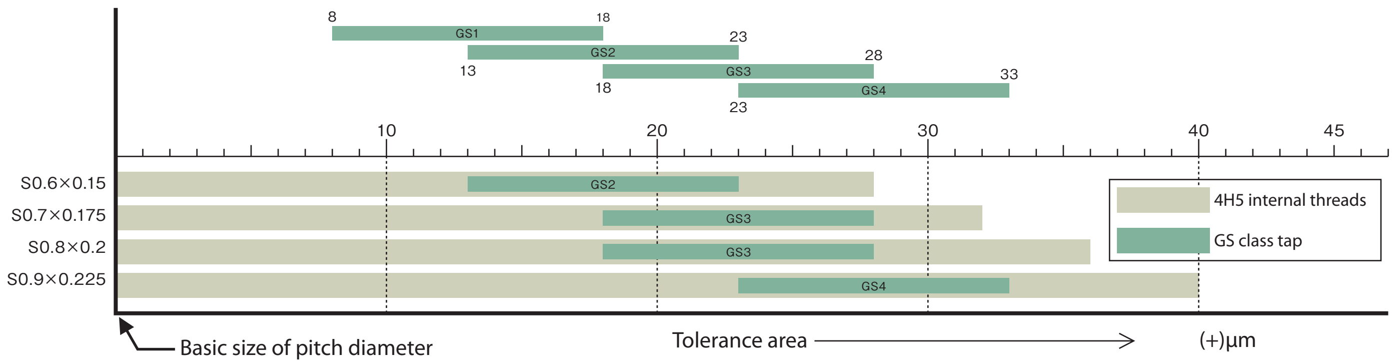
■Comparison of pitch tolerance zone between class 2 internal threads and recommended Roll Taps G Class.



■Roll taps for miniature threads, Accuracy GS class

○GS class is the accuracy class special for roll taps for miniature threads.

Comparison table of PD tolerance of GS class of roll taps for miniature threads and 4H5 internal threads.



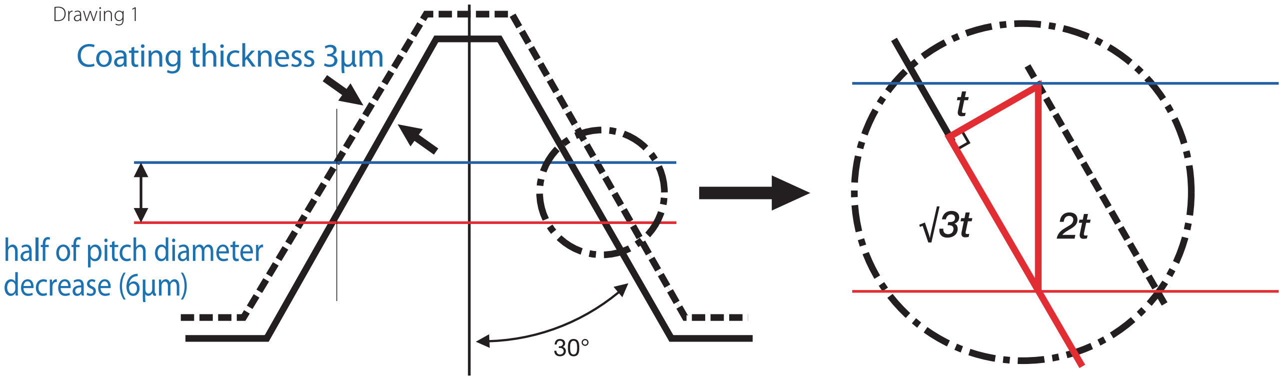
11. How to set the tap's oversize to meet with the coating margin of internal threads

1) Relation between coating thickness and pitch diameter when applied with coating

Dwg.1 shows the relation between coated internal thread and pitch diameter

* Thickness of coating is measured at right angle to flank face. Pitch diamete is measured at right angle to axis (radially).

Drawing 1

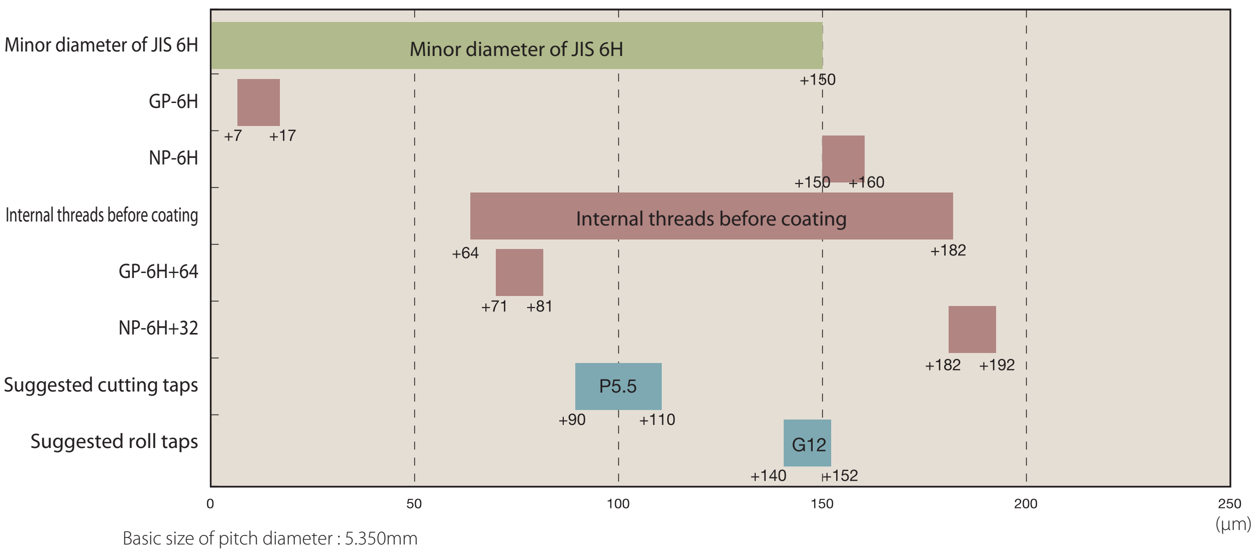


Where t (coating thickness) equals 3μm, by using following formula, oversize is roughly caluculated.
Pitch diameter decrease 2t×2 (both side of threads) = 3μm×2×2 =12 μm (rough over size)

2) How to specify taps for coating

1. We suppose the accuracy of finished internal threads is 6H class, and inspection is done with GP-6H and NP-6H.
2. We suppose the disperse of coating thickness is controlled within the tolerance of 8~16μm.
   The disperse of coating thickness, when it is exchanged into pitch diameter, will become the disperse of 32~64μm.
3. Accuracy of internal threads before coating is the thread accuray which GP-6H goes through (OK), even when max coating (64μm) is applied.
   And this accuracy is the thread accuray which NP-6H does not go through (OK), when min coating (32μm) is applied.
4. We propose followings for inspecting the accuracy of internal threads before coating :
   GO gauge before coating : GP-6H+64
5. Next, based on GO gauge before coating and NOT GO gauge before coating, we study to specify the suitable accuracy of the tap before coating.

M6×1 How to specify the accuracy of tap before coating (Coating thickness 8~16μm)



Basic size of pitch diameter : 5.350mm

M6×1 Basic size of pitch diameter	: 5.350mm		
Internal thread tolerance 6H	: 0~+150μm (Tolerance : 150μm)		
Accuracy GP-6H	: +7~+17μm	Accuracy NP-6H	: +150~+160μm
Internal thread tolerance before coating	: +64~+182μm (Tolerance : 118μm)		
Accuracy GP-6H+64	: +71~+81μm	Accuracy NP-6H+32	: +182~+192μm
Accuracy of suggested cutting taps (P5.5)	: +90~+110μm		
Accuracy of suggested roll taps (G12)	: +140~+152μm		

12. Recommended bored hole sizes

■For Metric Threads

Unit : mm

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
M1 ×0.25	(0.785)	(0.729)	0.75
M1 ×0.2	(0.821)	(0.783)	0.80
M1.1×0.25	(0.885)	(0.829)	0.85
M1.1×0.2	(0.921)	(0.883)	0.90
M1.2×0.25	(0.985)	(0.929)	0.95
M1.2×0.2	(1.021)	(0.983)	1.00
M1.4×0.3	(1.142)	(1.075)	1.10
M1.4×0.2	(1.221)	(1.183)	1.20
M1.6×0.35	1.321	1.221	1.25
M1.6×0.2	(1.421)	(1.383)	1.40
※M1.7×0.35	1.421	1.321	1.35
※M1.7×0.2	1.521	1.483	1.50
M1.8×0.35	1.521	1.421	1.45
M1.8×0.2	(1.621)	(1.583)	1.60
M2 ×0.4	1.679	1.567	1.60
M2 ×0.25	(1.785)	(1.729)	1.75
M2.2×0.45	1.838	1.713	1.75
M2.2×0.25	(1.985)	(1.929)	1.95
※M2.3×0.4	1.979	1.867	1.90
※M2.3×0.25	2.085	2.029	2.05
M2.5×0.45	2.138	2.013	2.1
M2.5×0.35	2.221	2.121	2.2
※M2.6×0.45	2.238	2.113	2.2
※M2.6×0.35	2.321	2.221	2.3
M3 ×0.5	2.599	2.459	2.5
M3 ×0.35	2.721	2.621	2.7
M3.5×0.6	3.010	2.850	2.9
M3.5×0.35	3.221	3.121	3.2
M4 ×0.7	3.422	3.242	3.3
M4 ×0.5	3.599	3.459	3.5
M4.5×0.75	3.878	3.688	3.8
M4.5×0.5	4.099	3.959	4.0
M5 ×0.8	4.334	4.134	4.2
M5 ×0.5	4.599	4.459	4.5
M5.5×0.5	5.099	4.959	5.0
M6 ×1	5.153	4.917	5.0
M6 ×0.75	5.378	5.188	5.3
※M6 ×0.5	5.599	5.459	5.5
M7 ×1	6.153	5.917	6.0

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
M7 ×0.75	6.378	6.188	6.3
※M7 ×0.5	6.599	6.459	6.5
M8 ×1.25	6.912	6.647	6.8
M8 ×1	7.153	6.917	7.0
M 8×0.75	7.378	7.188	7.3
※M 8×0.5	7.599	7.459	7.5
M 9×1.25	7.912	7.647	7.8
M 9×1	8.153	7.917	8.0
M 9×0.75	8.378	8.188	8.3
M10×1.5	8.676	8.376	8.5
M10×1.25	8.912	8.647	8.8
M10×1	9.153	8.917	9.0
M10×0.75	9.378	9.188	9.3
※M10×0.5	9.599	9.459	9.5
M11×1.5	9.676	9.376	9.5
M11×1	10.153	9.917	10.0
M11×0.75	10.378	10.188	10.3
※M11×0.5	10.599	10.459	10.5
M12×1.75	10.441	10.106	10.3
M12×1.5	10.676	10.376	10.5
M12×1.25	10.912	10.647	10.8
M12×1	11.153	10.917	11.0
※M12×0.5	11.599	11.459	11.5
M14×2	12.210	11.835	12.0
M14×1.5	12.676	12.376	12.5
M14×1	13.153	12.917	13.0
M15×1.5	13.676	13.376	13.5
M15×1	14.153	13.917	14.0
M16×2	14.210	13.835	14.0
M16×1.5	14.676	14.376	14.5
M16×1	15.153	14.917	15.0
M17×1.5	15.676	15.376	15.5
M17×1	16.153	15.917	16.0
M18×2.5	15.744	15.294	15.5
M18×2	16.210	15.835	16.0
M18×1.5	16.676	16.376	16.5
M18×1	17.153	16.917	17.0
M20×2.5	17.744	17.294	17.5

The recommended tap drill sizes indicated above are for JIS 6H (Class 2) Metric Threads.
• D1: Minor diameter of JIS 6H (Class 2) internal thread. The Minor diameters D1 shown in ( ) are of 5H (Class 2) for coarse threads and of 4H • 5H (Class 1) for fine threads.
• ※Marked sizes have been eliminated from JIS.

Unit : mm

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
M20×2	18.210	17.835	18.0
M20×1.5	18.676	18.376	18.5
M20×1	19.153	18.917	19.0
M22×2.5	19.744	19.294	19.5
M22×2	20.210	19.835	20.0
M22×1.5	20.676	20.376	20.5
M22×1	21.153	20.917	21.0
M24×3	21.252	20.752	21.0
M24×2	22.210	21.835	22.0
M24×1.5	22.676	22.376	22.5
M24×1	23.153	22.917	23.0
M25×2	23.210	22.835	23.0
M25×1.5	23.676	23.376	23.5
M25×1	24.153	23.917	24.0
M26×1.5	24.676	24.376	24.5
M27×3	24.252	23.752	24.0
M27×2	25.210	24.835	25.0
M27×1.5	25.676	25.376	25.5
M27×1	26.153	25.917	26.0
M28×2	26.210	25.835	26.0
M28×1.5	26.676	26.376	26.5
M28×1	27.153	26.917	27.0
M30×3.5	26.771	26.211	26.5
M30×3	27.252	26.752	27.0
M30×2	28.210	27.835	28.0
M30×1.5	28.676	28.376	28.5
M30×1	29.153	28.917	29.0
M32×2	30.210	29.835	30.0
M32×1.5	30.676	30.376	30.5
M33×3.5	29.771	29.211	29.5
M33×3	30.252	29.752	30.0
M33×2	31.210	30.835	31.0
M33×1.5	31.676	31.376	31.5
M35×1.5	33.676	33.376	33.5
M36×4	32.270	31.670	32.0
M36×3	33.252	32.752	33.0
M36×2	34.210	33.835	34.0
M36×1.5	34.676	34.376	34.5

• D1: Minor diameter of JIS 6H (Class 2) internal thread.

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
M38×1.5	36.676	36.376	36.5
M39×4	35.270	34.670	35.0
M39×3	36.252	35.752	36.0
M39×2	37.210	36.835	37.0
M39×1.5	37.676	37.376	37.5
M40×3	37.252	36.752	37.0
M40×2	38.210	37.835	38.0
M40×1.5	38.676	38.376	38.5
M42×4.5	37.799	37.129	37.5
M42×4	38.270	37.670	38.0
M42×3	39.252	38.752	39.0
M42×2	40.210	39.835	40.0
M42×1.5	40.676	40.376	40.5
M45×4.5	40.799	40.129	40.5
M45×4	41.270	40.670	41.0
M45×3	42.252	41.752	42.0
M45×2	43.210	42.835	43.0
M45×1.5	43.676	43.376	43.5
M48×5	43.297	42.587	43.0
M48×4	44.270	43.670	44.0
M48×3	45.252	44.752	45.0
M48×2	46.210	45.835	46.0
M48×1.5	46.676	46.376	46.5
M50×3	47.252	46.752	47.0
M50×2	48.210	47.835	48.0
M50×1.5	48.676	48.376	48.5

12. Recommended bored hole sizes

■For Unified Threads

Unit : mm

Nominal size	Minor diameter of internal threads (D_1) Max.	Minor diameter of internal threads (D_1) Min.	Drill Size
No. 0 - 80UNF	1.305	1.182	1.25
No. 1 - 64UNC	1.582	1.425	1.55
No. 1 - 72UNF	1.612	1.474	1.55
No. 2 - 56UNC	1.871	1.695	1.80
No. 2 - 64UNF	1.912	1.756	1.85
No. 3 - 48UNC	2.146	1.941	2.1
No. 3 - 56UNF	2.197	2.025	2.1
No. 4 - 40UNC	2.385	2.157	2.3
No. 4 - 48UNF	2.458	2.271	2.4
No. 5 - 40UNC	2.697	2.487	2.6
No. 5 - 44UNF	2.740	2.551	2.7
No. 6 - 32UNC	2.895	2.642	2.8
No. 6 - 40UNF	3.022	2.820	2.9
No. 8 - 32UNC	3.530	3.302	3.4
No. 8 - 36UNF	3.606	3.404	3.5
No.10 - 24UNC	3.962	3.683	3.9
No.10 - 32UNF	4.165	3.963	4.1
No.12 - 24UNC	4.597	4.344	4.5
No.12 - 28UNF	4.724	4.496	4.6
No.12 - 32UNEF	4.826	4.623	4.7
1/4 - 20UNC	5.257	4.979	5.1
1/4 - 28UNF	5.588	5.360	5.5
1/4 - 32UNEF	5.689	5.487	5.6
5/16 - 18UNC	6.731	6.401	6.6
5/16 - 24UNF	7.035	6.782	6.9
5/16 - 32UNEF	7.264	7.087	7.1
3/8 - 16UNC	8.153	7.798	8.0
3/8 - 24UNF	8.636	8.382	8.5
3/8 - 32UNEF	8.864	8.662	8.7
7/16 - 14UNC	9.550	9.144	9.4
7/16 - 20UNF	10.033	9.729	9.9
7/16 - 28UNEF	10.337	10.135	10.2
1/2 - 13UNC	11.023	10.592	10.9
1/2 - 20UNF	11.607	11.329	11.5
1/2 - 28UNEF	11.938	11.710	11.8
9/16 - 12UNC	12.446	11.989	12.2
9/16 - 18UNF	13.081	12.751	12.9
9/16 - 24UNEF	13.385	13.132	13.2
5/8 - 11UNC	13.868	13.386	13.6
5/8 - 18UNF	14.681	14.351	14.5
5/8 - 24UNEF	14.986	14.732	14.8
3/4 - 10UNC	16.840	16.307	16.6
3/4 - 16UNF	17.678	17.323	17.5
3/4 - 20UNEF	17.957	17.679	17.8
7/8 - 9UNC	19.761	19.177	19.6
7/8 - 14UNF	20.675	20.270	20.5
7/8 - 20UNEF	21.132	20.854	21.0
1 - 8UNC	22.606	21.971	22.3
1 - 12UNF	23.571	23.114	23.3
1 - 14UNS	23.825	23.445	23.6
1 - 20UNEF	24.307	24.029	24.1
1 1/8 - 7UNC	25.349	24.638	25.0
1 1/8 - 8UN	25.781	25.146	25.5
1 1/8-12UNF	26.746	26.289	26.5
1 1/8-18UNEF	27.381	27.051	27.2
1 1/4 - 7UNC	28.524	27.813	28.2
1 1/4 - 8UN	28.956	28.321	28.5
1 1/4-12UNF	29.921	29.464	29.6
1 1/4-18UNEF	30.556	30.226	30.3
1 3/8 - 6UNC	31.115	30.353	30.8
1 3/8 - 8UN	32.131	31.496	31.8
1 3/8-12UNF	33.096	32.639	32.8
1 3/8-18UNEF	33.731	33.401	33.5
1 1/2 - 6UNC	34.290	33.528	34.0
1 1/2 - 8UN	35.306	34.671	35.0
1 1/2-12UNF	36.271	35.814	36.0
1 1/2-18UNEF	36.906	36.576	36.7
1 5/8 - 8UN	38.481	37.846	38.1
1 5/8-12UN	39.446	38.989	39.1
1 5/8-18UNEF	40.081	39.751	39.8
1 3/4 - 5UNC	39.827	38.964	39.5
1 3/4 - 8UN	41.656	41.021	41.3
1 3/4-12UN	42.621	42.164	42.3
2 - 4 1/2UNC	45.593	44.679	45.2
2 - 8UN	48.006	47.371	47.8
2 - 12UN	48.971	48.514	48.6

• The recommended tap drill sizes indicated above are for JIS Class 2B UNC & UNF threads, and ANSI B1.1 Class 2B UNEF, UN & UNS threads.

For Metric Threads Using with Helical Coil Wire Inserts

Unit : mm

Nominal size	Bored hole size		Drill Size
	Max.	Min.	
M 2 ×0.4	2.16	2.10	2.13
M 2.5×0.45	2.68	2.6	2.6
M 2.6×0.45	2.78	2.7	2.7
M 3 ×0.5	3.20	3.12	3.15
M 4 ×0.7	4.30	4.17	4.2
M 5 ×0.8	5.33	5.16	5.2
M 6 ×1	6.42	6.25	6.3
M 8 ×1.25	8.52	8.31	8.4
M10 ×1.5	10.62	10.37	10.5
M10 ×1.25	10.52	10.31	10.4
M10×1	10.42	10.25	10.3
M12×1.75	12.73	12.43	12.6
M12×1.5	12.62	12.37	12.5
M12×1.25	12.52	12.31	12.4

Nominal size	Bored hole size		Drill Size
	Max.	Min.	
M14×2	14.83	14.49	14.7
M14×1.5	14.62	14.37	14.5
M14×1.25	14.52	14.31	14.4
M16×2	16.83	16.49	16.7
M16×1.5	16.62	16.37	16.5
M18×2.5	19.04	18.58	18.9
M18×1.5	18.62	18.37	18.5
M20×2.5	21.04	20.58	20.9
M20×1.5	20.62	20.37	20.5
M22×2.5	23.04	22.58	22.9
M22×1.5	22.62	22.37	22.5
M24×3	25.25	24.70	25.1
M24×1.5	24.62	24.37	24.5

• The figures listed above are according to the data provided by helical coil wire insert manufacturers.

Pipe Thread (Rc, PT)

Unit : mm

Nominal size	Drill Size		Internal Thread Minor Dia. On [Min.] Length of Useful Thread	Internal Thread Minor Dia. On [Min.] Gauge Length
	With Reaming Before Tapping	Without Reaming Before Tapping		
Rc 1/16 - 28	6.1	6.2	6.244	6.384
Rc 1/8 - 28	8.1	8.2	8.249	8.388
Rc 1/4 - 19	10.7	11.0	10.962	11.174
Rc 3/8 - 19	14.2	14.5	14.448	14.658
Rc 1/2 - 14	17.6	18.0	17.979	18.263
Rc 3/4 - 14	23.0	23.5	23.378	23.663
Rc 1 - 11	29.0	29.5	29.459	29.822
Rc 1 1/4 - 11	37.5	38.0	37.976	38.339
Rc 1 1/2 - 11	43.4	44.0	43.869	44.232
Rc 2 - 11	54.9	55.5	55.412	55.844

For Whitworth Coarse Threads

Unit : mm

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
※W 1/8 - 40	(2.591)	(2.362)	2.55
※W 3/16 - 24	(3.744)	(3.406)	3.70
W 1/4 - 20	5.204	4.914	5.1
W 5/16 - 18	6.670	6.340	6.6
W 3/8 - 16	8.113	7.733	8.0
W 7/16 - 14	9.508	9.048	9.4
W 1/2 - 12	10.830	10.310	10.7
W 9/16 - 12	12.418	11.898	12.3
W 5/8 - 11	13.817	13.257	13.7
W 3/4 - 10	16.778	16.178	16.6
W 7/8 - 9	19.691	19.031	19.5
W 1 - 8	22.514	21.814	22.3

• D1: Minor diameter of JIS Class 2 internal thread.
• Whitworth Threads have been eliminated from JIS.
• ※Marked sizes are in accordance with BSW.

For Sewing Machine Threads

Unit : mm

Nominal size	Minor diameter of internal threads (D_1)		Drill Size
	Max.	Min.	
1/8 SM44	2.605	2.485	2.5
9/64 SM40	2.948	2.818	2.9
11/64 SM40	3.742	3.612	3.7

12. Recommended bored hole sizes

■Pipe Thread

○Rp, PS

Unit : mm

Nominal size	Minor Diameter of JIS internal thread (D1)		Drill Size
	Max.	Min.	
Rp 1/16 - 28	6.632	6.490	6.5
Rp 1/8 - 28	8.637	8.495	8.5
Rp 1/4 - 19	11.549	11.341	11.4
Rp 3/8 - 19	15.054	14.846	14.9
Rp 1/2 - 14	18.773	18.489	18.6
Rp 3/4 - 14	24.259	23.975	24.0
Rp 1 - 11	30.472	30.110	30.2
Rp 1 1/4-11	39.133	38.771	38.8
Rp 1 1/2-11	45.026	44.664	44.7
Rp 2 - 11	56.837	56.475	56.5

○G, PF

Unit : mm

Nominal size	Minor Diameter of JIS internal thread (D1)		Drill Size
	Max.	Min.	
G 1/16 - 28	6.843	6.561	6.7
G 1/8 - 28	8.848	8.566	8.7
G 1/4 - 19	11.890	11.445	11.7
G 3/8 - 19	15.395	14.950	15.2
G 1/2 - 14	19.172	18.631	19.0
G 5/8 - 14	21.128	20.587	21.0
G 3/4 - 14	24.658	24.117	24.5
G 7/8 - 14	28.418	27.877	28.2
G 1 - 11	30.931	30.291	30.6
G 1 1/8-11	35.579	34.939	35.2
G 1 1/4-11	39.592	38.952	39.2
G 1 1/2-11	45.485	44.845	45.0
G 1 3/4-11	51.428	50.788	51.0
G 2 - 11	57.296	56.656	57.0

■American Standard Pipe Thread

Unit : mm

Nominal size	Tap Drill Size					
	NPT				NPSC	
	With Reaming Before Tapping		Without Reaming Before Tapping			
	mm	inch	mm	inch	mm	inch
1/16 - 27	5.94	0.234	6.15	0.242	6.35	0.250
1/8 - 27	8.33	0.328	8.43	0.332	8.74	0.344
1/4 - 18	10.72	0.422	11.13	0.438	11.13	0.438
3/8 - 18	14.27	0.562	14.27	0.562	14.68	0.578
1/2 - 14	17.48	0.688	17.86	0.703	18.26	0.719
3/4 - 14	22.63	0.891	23.01	0.906	23.42	0.922
1 - 11 1/2	28.58	1.125	28.98	1.141	29.36	1.156
1 1/4-11 1/2	37.31	1.469	37.69	1.484	38.10	1.500
1 1/2-11 1/2	43.26	1.703	43.66	1.719	44.45	1.750
2 - 11 1/2	55.17	2.172	55.58	2.188	56.36	2.219
2 1/2 - 8	65.48	2.578	66.27	2.609	67.46	2.656

・The drill sizes are according to ANSI/ASME B1.20.1-1983 PIPE THREADS, GENERAL PURPOSE (INCH) (partial listing).

■Dryseal American Standard Pipe Thread

Unit : mm

Nominal size	Tap Drill Size					
	NPT				NPSC	
	With Reaming Before Tapping		Without Reaming Before Tapping			
	mm	inch	mm		mm	inch
1/16 - 27	5.94	0.234	6.15	0.242	6.25	0.246
1/8 - 27	8.33	0.328	8.43	0.332	8.61	0.339
1/4 - 18	10.72	0.422	11.13	0.438	11.13	0.438
3/8 - 18	14.27	0.562	14.27	0.562	14.68	0.578
1/2 - 14	17.48	0.688	17.86	0.703	17.86	0.703
3/4 - 14	22.63	0.891	23.01	0.906	23.42	0.922
1 - 11 1/2	28.58	1.125	28.98	1.141	29.36	1.156
1 1/4-11 1/2	37.31	1.469	37.69	1.484		
1 1/2-11 1/2	43.26	1.703	43.66	1.719		
2 - 11 1/2	55.17	2.172	55.58	2.188		
2 1/2 - 8	65.48	2.578	66.27	2.609		

・The drill sizes are according to ANSI B1.20.3-1976 Dryseal Pipe Threads (Inch) (partial listing).

■Percentage of Thread Engagement & Relation between Percentage of Thread Height and Area Removed at A Thread Height

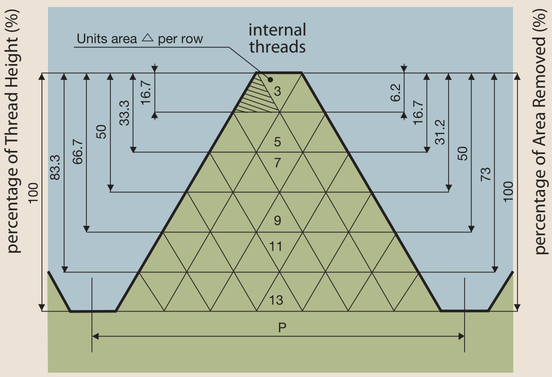
Percentage of Thread Engagement

$$\frac{\text{Basic Major Dia.} - \text{Hole Size Before Tapping}}{2\times(\text{Basic Thread Overlap})} \times 100$$

Basic Thread Overlap

Metric & Unified Thread	0.5413P
Whitworth Thread	0.5664P
Pipe Thread (Rc, Rp, G, PT, PS, PF)	0.6403P

P=Pitch



As shown above, when the thread height increases, the amount of material to be removed increases rapidly, so it is an advantage to tap users to keep the hole size (thread minor diameter) as large as possible.

13. Recommended Hole Sizes for Thread Forming Taps

■For Metric Threads

Unit : mm

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
M1 ×0.25	G4	0.92	0.89
M1.2×0.25	G4	1.11	1.09
M1.4×0.3	G4	1.30	1.26
M1.6×0.35	G4	1.47	1.43
M1.7×0.35	G4	1.57	1.52
M1.8×0.35	G4	1.67	1.62
M2 ×0.4	G4	1.84	1.79
M2 ×0.25	G4	1.91	1.89
M2.2×0.45	G5	2.04	1.98
M2.3×0.4	G4	2.14	2.09
M2.5×0.45	G5	2.34	2.27
M2.5×0.35	G5	2.38	2.34
M2.6×0.45	G5	2.44	2.37
M3 ×0.5	G5	2.82	2.75
M3 ×0.35	G5	2.87	2.82

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
M 3.5×0.6	G5	3.27	3.19
M 3.5×0.35	G5	3.37	3.32
M 4 ×0.7	G6	3.72	3.65
M 4 ×0.5	G6	3.83	3.76
M 5 ×0.8	G6	4.67	4.59
M 5 ×0.5	G6	4.83	4.76
M 6 ×1	G7	5.59	5.49
M 6 ×0.75	G6	5.69	5.61
M 7 ×1	G7	6.59	6.48
M 7 ×0.75	G7	6.70	6.62
M 8 ×1.25	G7	7.49	7.36
M 8 ×1	G7	7.59	7.48
M 8 ×0.75	G7	7.70	7.62
M10 ×1.5	G7	9.34	9.22
M10 ×1.25	G7	9.49	9.35

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
M10×1	G 7	9.59	9.48
M12×1.75	G 8	11.23	11.09
M12×1.5	G 8	11.34	11.22
M12×1.25	G 9	11.50	11.36
M12×1	G 7	11.58	11.47
M14×2	G10	13.14	12.98
M14×1.5	G 9	13.35	13.22
M14×1	G 8	13.59	13.48
M16×2	G10	15.14	14.97
M16×1.5	G 9	15.34	15.22
M16×1	G 8	15.59	15.48
M18×2.5	G11	16.93	16.73
M18×1.5	G10	17.35	17.23
M20×2.5	G11	18.92	18.72
M20×1.5	G10	19.35	19.22

・According to the ductility, hardness and dimension of the workpiece to be tapped, the recommended hole sizes for thread forming tapping may have to be altered.
The values listed above should only be used as an aid in selecting suitable drills when using thread forming taps, the correct hole sizes should be decided based on test result.
Further, the values listed above are suitable for 0.5D~2D threading length in relatively ductile materials (D : thread major diameter).

■For Unified Threads

Unit : mm

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
No.0 - 80UNF	G5	1.45	1.39
No.1 - 64UNC	G5	1.76	1.68
No.1 - 72UNF	G5	1.77	1.70
No.2 - 56UNC	G4	2.04	1.96
No.2 - 64UNF	G4	2.06	1.98
No.3 - 48UNC	G4	2.35	2.25
No.3 - 56UNF	G4	2.37	2.29
No.4 - 40UNC	G5	2.64	2.54
No.4 - 48UNF	G5	2.68	2.59
No.5 - 40UNC	G5	2.97	2.87

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
No. 5 - 44UNF	G5	2.99	2.90
No. 6 - 32UNC	G5	3.22	3.11
No. 6 - 40UNF	G5	3.29	3.19
No. 8 - 32UNC	G6	3.89	3.78
No. 8 - 36UNF	G5	3.91	3.81
No.10 - 24UNC	G6	4.44	4.30
No.10 - 32UNF	G6	4.53	4.44
No.12 - 24UNC	G6	5.07	4.96
No.12 - 28UNF	G6	5.13	5.03
1/4 - 20UNC	G7	5.86	5.73

Nominal size	Tolerance Class of Tap	Recommended Hole Size Max.	Recommended Hole Size Min.
1/4 - 28UNF	G7	6.00	5.91
5/16 - 18UNC	G7	7.38	7.23
5/16 - 24UNF	G7	7.53	7.42
3/8 - 16UNC	G7	8.89	8.72
3/8 - 24UNF	G7	9.10	8.99
7/16 - 14UNC	G8	10.40	10.20
7/16 - 20UNF	G8	10.62	10.48
1/2 - 13UNC	G8	11.92	11.70
1/2 - 20UNF	G8	12.20	12.06

・According to the ductility, hardness and dimension of the workpiece to be tapped, the recommended hole sizes for thread forming tapping may have to be altered.
The values listed above should only be used as an aid in selecting suitable drills when using thread forming taps, the correct hole sizes should be decided based on test result.
Further, the values listed above are suitable for 0.5D~2D threading length in relatively ductile materials (D : thread major diameter).

14. Bar diameter for external threads (for cutting type dies)

■Tolerable limit size and tolerance of outside diameter for metric external screws

Unit : mm

size designation	pitch	outside diameter of external screws					
		ISO			old JIS		
	P	$d$max	$d$min	T_d	$d$max	$d$min	T_d
M1	0.25	1.000	0.933	0.067	0.985	0.940	0.045
	0.2	1.000	0.944	0.056	0.980	0.930	0.050
M1.1	0.25	1.100	1.033	0.067	1.100	1.033	0.067
	0.2	1.100	1.044	0.056	1.100	1.044	0.056
M1.2	0.25	1.200	1.133	0.067	1.185	1.140	0.045
	0.2	1.200	1.144	0.056	1.180	1.130	0.050
M1.4	0.3	1.400	1.325	0.075	1.380	1.320	0.060
	0.2	1.400	1.344	0.056	1.380	1.330	0.050
M1.6	0.35	1.581	1.496	0.085	1.581	1.496	0.085
	0.2	1.583	1.527	0.056	1.583	1.527	0.056
M1.8	0.35	1.781	1.696	0.085	1.781	1.696	0.085
	0.2	1.783	1.727	0.056	1.783	1.727	0.056
M2	0.4	1.981	1.886	0.095	1.980	1.890	0.090
	0.25	1.982	1.915	0.067	1.980	1.930	0.050
M2.2	0.45	2.180	2.080	0.100	2.180	2.080	0.100
	0.25	2.182	2.115	0.067	2.182	2.115	0.067
M2.5	0.45	2.480	2.380	0.100	2.480	2.380	0.100
	0.35	2.481	2.396	0.085	2.481	2.396	0.085
M3	0.5	2.980	2.874	0.106	2.980	2.874	0.106
	0.35	2.981	2.896	0.085	2.980	2.880	0.100
M3.5	0.6	3.479	3.354	0.125	3.470	3.360	0.110
	0.35	3.481	3.396	0.085	3.480	3.380	0.100
M4	0.7	3.978	3.838	0.140	3.978	3.838	0.140
	0.5	3.980	3.874	0.106	3.970	3.860	0.110
M4.5	0.75	4.478	4.338	0.140	4.470	4.340	0.130
	0.5	4.480	4.374	0.106	4.470	4.360	0.110
M5	0.8	4.976	4.826	0.150	4.976	4.826	0.150
	0.5	4.980	4.874	0.106	4.970	4.860	0.110
M5.5	0.5	5.480	5.374	0.106	5.470	5.360	0.110
M6	1	5.974	5.794	0.180	5.970	5.820	0.150
	0.75	5.978	5.838	0.140	5.970	5.850	0.120
M7	1	6.974	6.794	0.180	6.970	6.820	0.150
	0.75	6.978	6.838	0.140	6.970	6.850	0.120
M8	1.25	7.972	7.760	0.212	7.960	7.790	0.170
	1	7.974	7.794	0.180	7.970	7.830	0.140
	0.75	7.978	7.838	0.140	7.970	7.830	0.140
M9	1.25	8.972	8.760	0.212	8.960	8.790	0.170
	1	8.974	8.794	0.180	8.970	8.830	0.140
	0.75	8.978	8.838	0.140	8.970	8.830	0.140
M10	1.5	9.968	9.732	0.236	9.960	9.770	0.190
	1.25	9.972	9.760	0.212	9.960	9.810	0.150
	1	9.974	9.794	0.180	9.970	9.820	0.150
	0.75	9.978	9.838	0.140	9.978	9.838	0.140
M11	1.5	10.968	10.732	0.236	10.968	10.732	0.236
	1	10.974	10.794	0.180	10.970	10.820	0.150
	0.75	10.978	10.838	0.140	10.978	10.838	0.140
M12	1.75	11.966	11.701	0.265	11.950	11.760	0.190
	1.5	11.968	11.732	0.236	11.960	11.790	0.170
	1.25	11.972	11.760	0.212	11.972	11.760	0.212
	1	11.974	11.794	0.180	11.960	11.810	0.150
M14	2	13.962	13.682	0.280	13.950	13.740	0.210
	1.5	13.968	13.732	0.236	13.960	13.790	0.170
	1	13.974	13.794	0.180	13.960	13.810	0.150
M15	1.5	14.968	14.732	0.236	14.960	14.790	0.170
	1	14.974	14.794	0.180	14.960	14.810	0.150

size designation	pitch	outside diameter of external screws					
		ISO			old JIS		
	P	$d$max	$d$min	T_d	$d$max	$d$min	T_d
M16	2	15.962	15.682	0.280	15.950	15.740	0.210
	1.5	15.968	15.732	0.236	15.960	15.790	0.170
	1	15.974	15.794	0.180	15.960	15.810	0.150
M17	1.5	16.968	16.732	0.236	16.968	16.732	0.236
	1	16.974	16.794	0.180	16.974	16.794	0.180
M18	2.5	17.958	17.623	0.335	17.950	17.710	0.240
	2	17.962	17.682	0.280	17.950	17.650	0.300
	1.5	17.968	17.732	0.236	17.950	17.780	0.170
	1	17.974	17.794	0.180	17.960	17.810	0.150
M20	2.5	19.958	19.623	0.335	19.950	19.710	0.240
	2	19.962	19.682	0.280	19.950	19.650	0.300
	1.5	19.968	19.732	0.236	19.950	19.780	0.170
	1	19.974	19.794	0.180	19.960	19.810	0.150
M22	2.5	21.958	21.623	0.335	21.950	21.710	0.240
	2	21.962	21.682	0.280	21.950	21.650	0.300
	1.5	21.968	21.732	0.236	21.950	21.780	0.170
	1	21.974	21.794	0.180	21.960	21.810	0.150
M24	3	23.952	23.577	0.375	23.940	23.680	0.260
	2	23.962	23.682	0.280	23.940	23.640	0.300
	1.5	23.968	23.732	0.236	23.950	23.780	0.170
	1	23.974	23.794	0.180	23.960	23.810	0.150
M25	2	24.962	24.682	0.280	24.940	24.640	0.300
	1.5	24.968	24.732	0.236	24.950	24.780	0.170
	1	24.974	24.794	0.180	24.960	24.810	0.150
M26	1.5	25.968	25.732	0.236	25.950	25.780	0.170
M27	3	26.952	26.577	0.375	26.940	26.680	0.260
	2	26.962	26.682	0.280	26.962	26.682	0.280
	1.5	26.968	26.732	0.236	26.950	26.780	0.170
	1	26.974	26.794	0.180	26.974	26.794	0.180
M28	2	27.962	27.682	0.280	27.940	27.640	0.300
	1.5	27.968	27.732	0.236	27.950	27.780	0.170
	1	27.974	27.794	0.180	27.960	27.810	0.150
M30	3.5	29.947	29.522	0.425	29.940	29.660	0.280
	3	29.952	29.577	0.375	29.952	29.577	0.375
	2	29.962	29.682	0.280	29.940	29.640	0.300
	1.5	29.968	29.732	0.236	29.950	29.780	0.170
	1	29.974	29.794	0.180	29.960	29.810	0.150
M32	2	31.962	31.682	0.280	31.940	31.640	0.300
	1.5	31.968	31.732	0.236	31.950	31.780	0.170
M33	3.5	32.947	32.522	0.425	32.940	32.660	0.280
	3	32.952	32.577	0.375	32.952	32.577	0.375
	2	32.962	32.682	0.280	32.962	32.682	0.280
	1.5	32.968	32.732	0.236	32.950	32.780	0.170
M35	1.5	34.968	34.732	0.236	34.950	34.780	0.170
M36	4	35.940	35.465	0.475	35.930	35.630	0.300
	3	35.952	35.577	0.375	35.952	35.577	0.375
	2	35.962	35.682	0.280	35.940	35.640	0.300
	1.5	35.968	35.732	0.236	35.950	35.780	0.170
M38	1.5	37.968	37.732	0.236	37.950	37.780	0.170
M39	4	38.940	38.465	0.475	38.930	38.630	0.300
	3	38.952	38.577	0.375	38.952	38.577	0.375
	2	38.962	38.682	0.280	38.962	38.682	0.280
	1.5	38.968	38.732	0.236	38.968	38.732	0.236
M40	3	39.952	39.577	0.375	39.952	39.577	0.375
	2	39.962	39.682	0.280	39.940	39.640	0.300
	1.5	39.968	39.732	0.236	39.950	39.780	0.170

ISO tolerance area Class 6g (M1.6 and larger) 6h (M1.4 and smaller) old JIS 2nd class
old JIS 2nd class

- ISO : from table 2 JIS B0209-2 and from table 1 JIS B0209-3
- Old JIS : from the tolerable limit size and the tolerance of metric coarse threads (for 2nd class external threads, JIS B 0209-1982 appendix 1, appendix 1 attachment 4. from the tolerable limit size and the tolerance of metric fine threads (for 2nd class external threads), JIS B 0211-1982 appendix, appendix attachiment 4

14. Bar diameter for external threads (for cutting type dies)

Unit : mm

size designation	pitch	outside diameter of external screws					
		ISO			old JIS		
	P	$d$max	$d$min	T_d	$d$max	$d$min	T_d
M42	4.5	41.937	41.437	0.500	41.930	41.610	0.320
	4	41.940	41.465	0.475	41.940	41.465	0.475
	3	41.952	41.577	0.375	41.952	41.577	0.375
	2	41.962	41.682	0.280	41.940	41.640	0.300
	1.5	41.968	41.732	0.236	41.950	41.780	0.170
M45	4.5	44.937	44.437	0.500	44.930	44.610	0.320
	4	44.940	44.465	0.475	44.940	44.465	0.475
	3	44.952	44.577	0.375	44.952	44.577	0.375
	2	44.962	44.682	0.280	44.940	44.640	0.300
	1.5	44.968	44.732	0.236	44.950	44.780	0.170
M48	5	47.929	47.399	0.530	47.930	47.590	0.340
	4	47.940	47.465	0.475	47.940	47.465	0.475
	3	47.952	47.577	0.375	47.952	47.577	0.375
	2	47.962	47.682	0.280	47.940	47.640	0.300
	1.5	47.968	47.732	0.236	47.950	47.780	0.170

■Tolerable limit size and tolerance of outside diameter for unified external screws (for 2A thread)

Unit : mm

size designation	outside diameter of external screws		
	$d$max	$d$min	T_d
No0-80UNF	1.511	1.431	0.080
No.1-64UNC	1.838	1.743	0.095
No.1-72UNF	1.838	1.751	0.087
No.2-56UNC	2.169	2.066	0.103
No.2-64UNF	2.169	2.073	0.096
No.3-48UNC	2.496	2.383	0.113
No.3-56UNF	2.496	2.393	0.103
No.4-40UNC	2.824	2.695	0.129
No.4-48UNF	2.827	2.713	0.114
No.5-40UNC	3.154	3.026	0.128
No.5-44UNF	3.157	3.036	0.121
No.6-32UNC	3.484	3.333	0.151
No.6-40UNF	3.484	3.356	0.128
No.8-32UNC	4.142	3.991	0.151
No.8-36UNF	4.145	4.006	0.139
No.10-24UNC	4.800	4.618	0.182
No.10-32UNF	4.803	4.651	0.152
No.12-24UNC	5.461	5.279	0.182
No.12-28UNF	5.461	5.296	0.165
1/4-20UNC	6.322	6.117	0.205
1/4-28UNF	6.324	6.160	0.164
5/16-18UNC	7.907	7.687	0.220
5/16-24UNF	7.909	7.727	0.182
3/8-16UNC	9.491	9.254	0.237
3/8-24UNF	9.497	9.315	0.182
7/16-14UNC	11.076	10.816	0.260
7/16-20UNF	11.079	10.874	0.205
1/2-13UNC	12.661	12.386	0.275
1/2-20UNF	12.666	12.462	0.204
9/16-12UNC	14.246	13.958	0.288
9/16-18UNF	14.251	14.031	0.220
5/8-11UNC	15.834	15.528	0.306
5/8-18UNF	15.839	15.619	0.220
3/4-10UNC	19.004	18.677	0.327
3/4-16UNF	19.011	18.774	0.237
7/8-9UNC	22.176	21.824	0.352
7/8-14UNF	22.184	21.923	0.261
1-8UNC	25.349	24.969	0.380
1-12UNF	25.354	25.065	0.289
1 1/8-7UNC	28.519	28.103	0.416
1 1/8-12UNF	28.529	28.240	0.289
1 1/4-7UNC	31.694	31.278	0.416
1 1/4-12UNF	31.704	31.415	0.289
1 3/8-6UNC	34.864	34.402	0.462
1 3/8-12UNF	34.876	34.588	0.288
1 1/2-6UNC	38.039	37.577	0.462
1 1/2-12UNF	38.051	37.763	0.288
1 3/4-5UNC	44.381	43.861	0.520
2-4 1/2UNC	50.726	50.168	0.558

・from table 4 JIS B0210 and table 4 JIS B0212

■Tolerable limit size and tolerance of outside diameter for sewing machine screw external screws (for 2nd thread)

Unit : mm

thread designation	outside diameter of external screws		
	*d*max	*d*min	*Td*
1/16 SM80	1.588	1.518	0.070
5/64 SM64	1.984	1.904	0.080
3/32 SM56	2.381	2.286	0.095
3/32 SM100	2.381	2.306	0.075
1/8 SM40	3.175	3.045	0.130
1/8 SM44	3.175	3.055	0.120
1/8 SM48	3.175	3.065	0.110
9/64 SM40	3.572	3.442	0.130
11/64 SM40	4.366	4.236	0.130
3/16 SM24	4.762	4.602	0.160
3/16 SM28	4.762	4.602	0.160
3/16 SM32	4.762	4.602	0.160
7/32 SM32	5.556	5.396	0.160
15/64 SM28	5.953	5.773	0.180
1/4 SM24	6.350	6.170	0.180
1/4 SM40	6.350	6.220	0.130

・from table 2 JIS B 0226 (void in 2001)

■Pipe taper threads (R, PT)

Unit : mm

Designation	bar diameter (ref.)	
	Straight	taper (dia of thread end)
R 1/16	7.9	7.5
R 1/8	9.9	9.5
R 1/4	13.4	12.8
R 3/8	16.9	16.3
R 1/2	21.3	20.5
R 3/4	26.8	25.9
R 1	33.7	32.7
R 1・1/4	42.3	41.2
R 1・1/2	48.2	47.1
R 2	60.1	58.7

■Pipe pararell threads (G, PF)

Unit : mm

Designation	outside diameter of external screws	
	*d*max	*d*min
G 1/16	7.723	7.509
G 1/8	9.728	9.514
G 1/4	13.157	12.907
G 3/8	16.662	16.412
G 1/2	20.955	20.671
G 5/8	22.911	22.627
G 3/4	26.441	26.157
G 7/8	30.201	29.917
G 1	33.249	32.889
G 1・1/4	41.910	41.550
G 1・1/2	47.803	47.443
G 2	59.614	59.254

15. Bar diameter of external screws (for thread rolling dies)

Production data

○NRS-D recommendation for bar diameter for metric external screws

Unit : mm

designation	recommended bar diameter	
	Max	Min
M3×0.5	2.64	2.62
M4×0.7	3.54	3.52
M5×0.8	4.40	4.38
M6×1	5.30	5.28
M8×1.25	7.10	7.07

○RS-D recommendation for bar diameter for metric external screws

Unit : mm

designation	recommended bar diameter	
	Max	Min
M1×0.25	0.808	0.785
M1.1×0.25	0.918	0.891
M1.2×0.25	1.007	0.984
M1.4×0.3	1.168	1.142
M1.6×0.35	1.332	1.300
M1.7×0.35	1.432	1.401
M1.8×0.35	1.530	1.498
M2×0.4	1.699	1.669
M2×0.25	1.796	1.771
M2.2×0.45	1.863	1.827

designation	recommended bar diameter	
	Max	Min
M2.3×0.4	1.998	1.968
M2.3×0.25	2.096	2.071
M2.5×0.45	2.162	2.126
M2.5×0.35	2.228	2.196
M2.6×0.45	2.262	2.226
M2.6×0.35	2.318	2.278
M3×0.5	2.627	2.589
M3×0.35	2.718	2.677
M4×0.5	3.607	3.561
M5×0.5	4.606	4.560

○MS-RS-D recommendation for bar diameter for metric external screws

Unit : mm

designation	recommended bar diameter	
	Max	Min
S0.5×0.125	0.410	0.396
S0.6×0.15	0.494	0.479
S0.7×0.175	0.575	0.559
S0.8×0.2	0.658	0.640
S0.9×0.225	0.741	0.720

16. Surface Treatment

The best surface treatment is applied to each tap depending on the tapping purpose.
Characteristics and effectiveness of surface treatment are introduced at next section.

■Oxidizing

○This treatment was processed by using HOMO furnace being made by LEED AND NORTHUP company USA in 1938, and it is called HOMO treatment. This treatment is also called vapor treatment and steam treatment. Through this treatment, Fe304 layer of blue black color is produced over the tool surface.

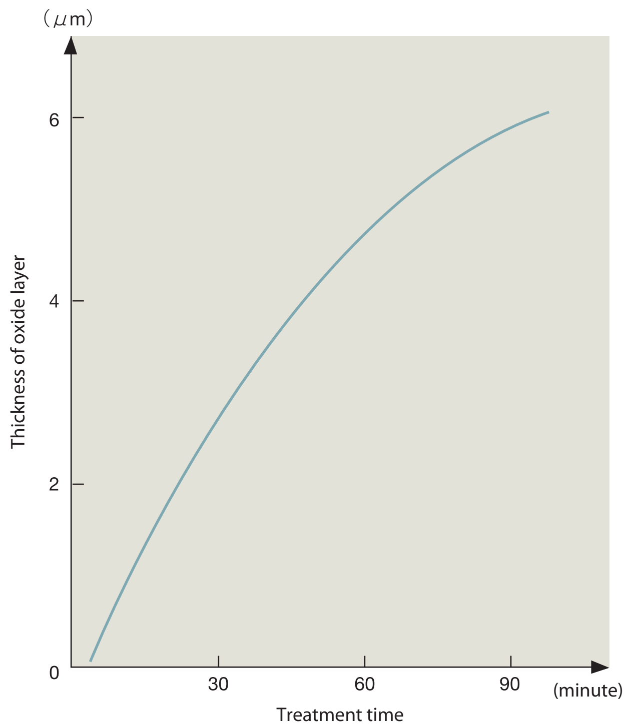
○Oxidization treatment produces porous layer on tool's surface. This porous layer works as oil pocket to reduce friction, to avoid welding and to improve the surface roughness of internal screw. Moreover, longer tool life is expected because the treatment reduces the remaining stress of HSS tools.

○This treatment does not increase the hardness on tool surface. Using the furnace of YAMAWA original design and choosing the proper treatment time, we have marked good result of oxidizing for YAMAWA HSS tools.

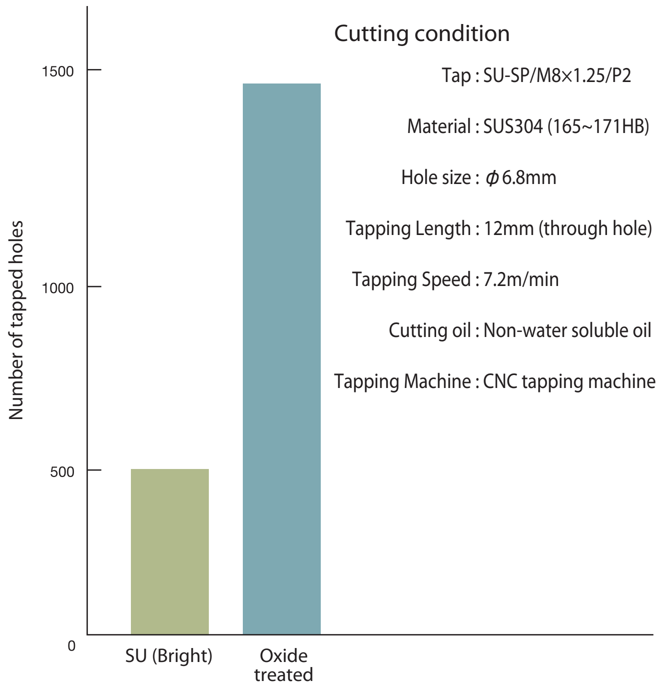
○Stainless steel and low carbon steel are the materials that are easy to get welding. We are applying this treatment to the special purpose taps for these materials to get good result. Further due to the reduction of friction resistance, this treatment has good result for wide range of steel type material.

○We combine oxidizing with nitriding for the taps designed for such steel and alloy tool steel. This double treatment wins good reputation of the market.

■Thickness of oxide layer and the time of treatment



■Efficiency of oxide treatment



■Nitriding

○In this treatment, we have Nitrogen and Carbon soak into the surface of HSS tools, and react with chemical of HSS material to produce hard nitride. There are 3 method in the treatment, as composition gas method, salt bath nitride method and ion nitride method.

○Salt bath nitride treatment is shifted into gas nitride treatment method because of cyanic environmental pollution.

○The temperature of treatment is 500 to 550 degree. Hardness and depth of the treatment can be controlled by active nitrogen concentration and reaction time.

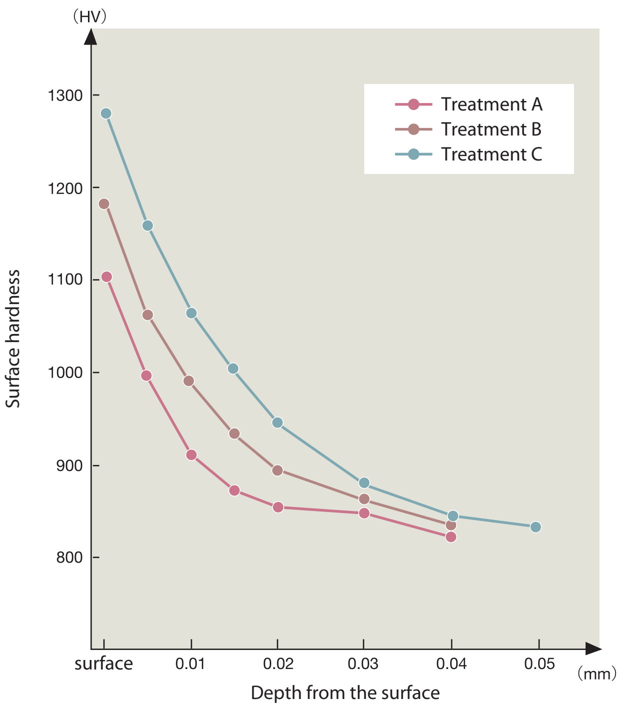
○The high hardness of tool surface minimizes chemical attraction. Result is less welding and friction resistance. Great improvement is expected in tool's performance.

○We have found out the best combinations of hardness and toughness through our treatment technology

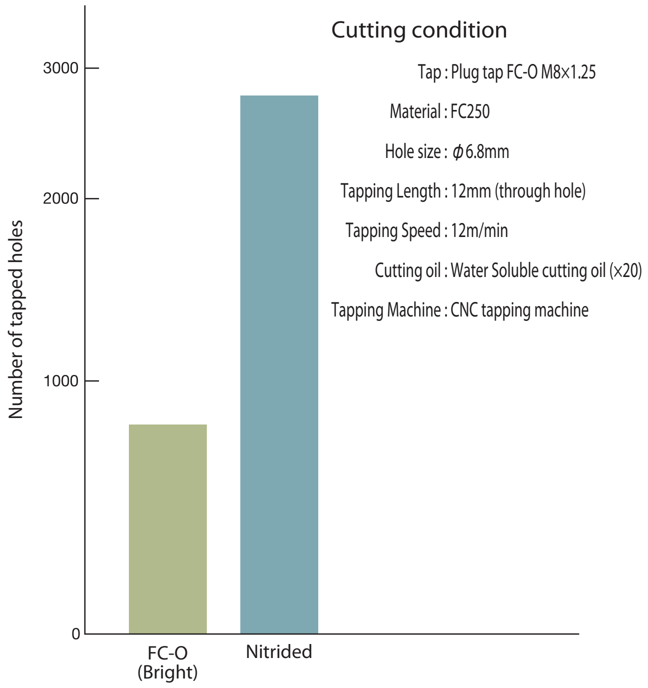
○The nitriding treatment will be widely applicable to workpiece materials such as gray cast irons, special cast irons, aluminum diecastings with higher silicone content, copper alloys, and resinoids (plastics), these materials produce small segmental chips and are very abrasive.

○We combine nitrogen and oxidizing for comparatively sticky material such as high carbon steel and refined alloy steel. This double treatment improves the chipping resistance and have won good reputation.

■Depth and hardness of Nitride Surface Treatment



■Efficiency of Nitride Treatment



■Hard coating

High speed cutting and hard-to-machine cutting are the recent technology. To meet this tendency, the hard layer coating by vapor deposition over tool's surface has become popular. There are two coating methods, CVD and PVD. PVD is mainly used for tap.

■Physical Vapor Deposition

○Inside of the container of high vacuum, are heat vapor deposition materials. And we vapor deposit particles ionized by electric discharge on tool's surface.

○Due to its low reaction temperature (lower than 500˚C), PVD makes little change in shape and hardness of HSS tools.

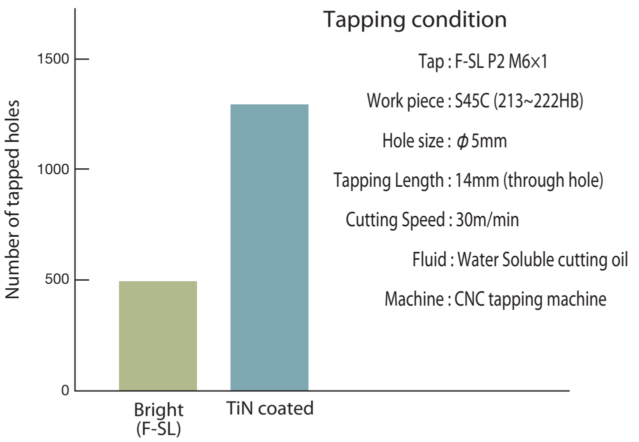
○We have adopted iron plating method, and are coating thin layer (1-4um) over our HSS and carbide tools. This layer processed by this method is very high in its adherence and its wear resistance.

■The features and classification of coating

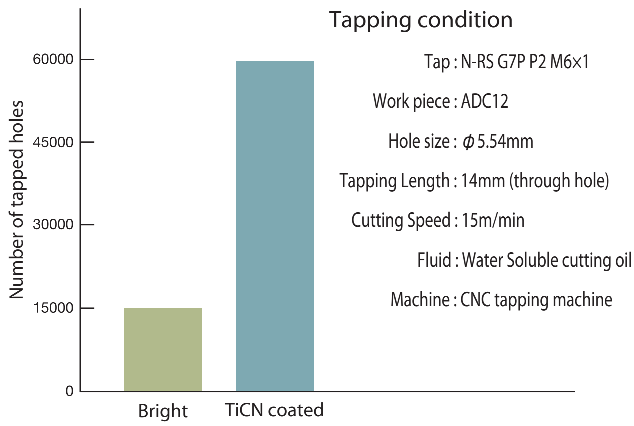
Features \ Classification	Titanium nitride (TiN)	Titanium carbonitride (TiCN)	Titanium nitride aluminum (TiAIN)	Hard chromium plating (CrN)
Vickers Hardness	2000～2400	3000～3500	2300～2700	1800～2200
Wear resistance	Good	Excellent	Excellent	Normal
Welding resistance	Good	Good	Good	Excellent
Heat resistance	Good	Normal	Excellent	Excellent
Acid resistance	Good	Normal	Excellent	Good
Slippery	Good	Excellent	Good	Excellent
Color	Gold	Blue Dray Violet	Violet	Silver
Workpiece materials	Carbon Steels Aluminum forging	Carbon Steels Hard Steels Stainless Steels Aluminum forging Cast Irons Brass・Bronze	Stainless Steels Cast Irons	Copper

Note: Evaluation (tri-level) of characteristic features is just comparative of these four coatings, TiN, TiCN, TiAIN, and CrN, in the table. These coatings have great advantages of wear resistance, welding resistance, and reduced friction resistance. The values of vickers hardness are also higher than the heat treatment or nitriding of HSS cutting tools from the table.

■The efficiency of TiN coating



■The efficiency of TiCN coating



17. Carbide Taps

Technological advances in machining automation and CNC machines and machining centers have helped improve the overall tapping process. YAMAWA was quick to respond to evolving customer needs resulting from technological innovations.
We can now recommend carbide taps, which provide tremendous improvements in mass-production and in reducing costs. It is estimated that carbide taps have 50 times more durability than HSS in tapping, when used properly. YAMAWA engineering believes the best carbide materials suitable for taps are ultramicro grain tungsten carbide, or ultrafine grain carbide made of high cobalt.

■Features of Carbide Taps

(1)Excellent durability with high toughness is obtainable.
(2)High anti-friction features are provided by the material's high hardness and comparatively high stringyness, which ultimately results in a longer tool life.
(3)Specially designed cutting angle and other dimensional features produce the internal threads with high tolerance accuracy and consistency.
(4)Under certain tapping condition, YAMAWA carbide taps can be used even for tapping hard-to-machine materials.

■Points to note during tapping with Carbide taps:

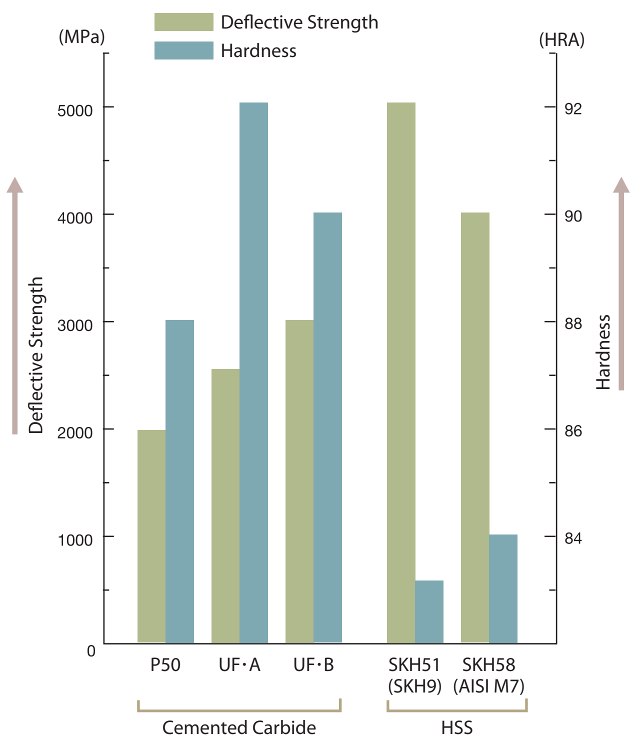
(1) Machine vibration, or run-out, can lead to Carbide tap chipping and premature failure. Tapping vibrations need to be kept to a minimum.
(2) Tap holder should be a rigid type for a Carbide tap. A holder attachment with axial float, or radial float tends to promote Carbide tap breakage and chipping.
(3) The hole to be tapped must be located correctly and on center ; any centering off or non-straight drilled hole tends to cause Carbide tap breakage due to deflection. Select correct hole depth with respect to tapping length (for blind hole only). It is especially important to prevent tap damage from chip packing and bottom thrusting in blind hole tapping.
(4) Cutting lubricants - select grade of lubricant. Improper flow of coolant, or lack of sufficient amount of lubricant, or cooling can increase the likelihood of Carbide tap chipping due to work material welding. Caution must be taken during dry machining to prevent chip welding to the tap.
(5) Work pieces - we provide Carbide taps with increased toughness, but Carbide taps are inferior to High Speed Steel (HSS) in the area of toughness. As a matter of fact Carbide taps have limited application due to this difference in toughness to HSS.

■Commonly used material and cutting conditions.

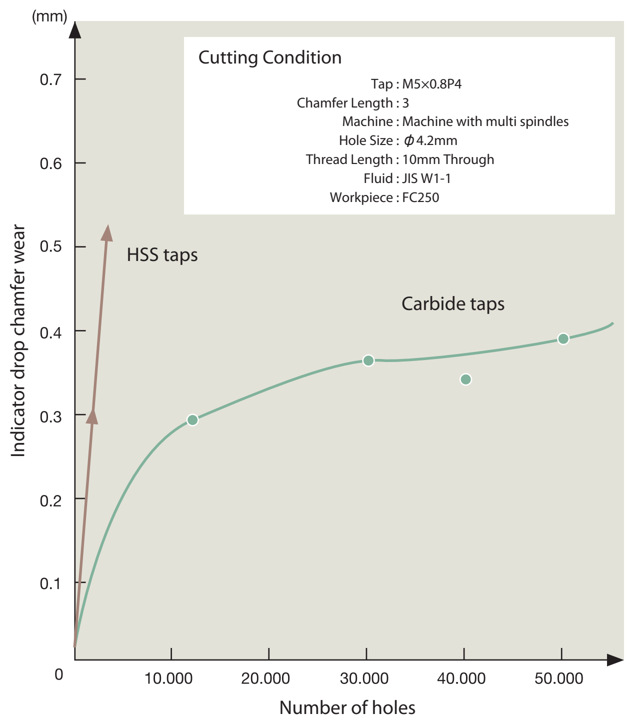
Work Material		Cutting Speed (m/min)	Cutting Fluid (General recommendation)	Cutting Fluid (JIS recommendation)
Cast Iron	Ordinary	15～25	Dry, light oil, water soluble oil	Un-soluble oil, 2nd kind No.11 and 13 Water soluble oil, W 1st kind No.1, W 2nd kind No.1
	Nodular Graphite	10～20	Light oil, water soluble oil	
	Malleable	10～20	Water soluble oil	
Aluminum		20～40	Light oil, water soluble oil	Un-soluble oil, 1st kind No.4-6 Un-soluble oil, 2nd kind No. 5-6 Water soluble oil, W 1st kind No.1
Copper		15～30	Light oil, water soluble oil	
Copper Alloy	Brass	20～30	Light oil, water soluble oil	
	Phosphor Bronze	15～30	Light oil, water soluble oil	
Die-Cast	Aluminum Alloy	15～25	Mixed oil of lard oil and kerosene	Un-soluble oil, 2nd kind No. 5-6 Water soluble oil, W 1st kind No.1
	Zinc Alloy	12～20	Mixed oil of lard oil and kerosene	
Plastic	Thermosetting	15～25	Water soluble oil, air	Water soluble oil, W 2nd kind No.3
	Thermo Plastic	15～25	Water soluble oil, air	
Hard Rubber		15～30	Dry, air	

Note : The table shows only general conditions. As for actual cutting operation, please consider the following points : (1) Machine Capacity, (2) Work piece(s), (3) Work Shape, (4) Setup (5) other factors.

■Toughness and Hardness of Cemented Carbide and HSS



■Chamfer wear and number of holes of Carbide taps and HSS taps



■Carbide Taps examples and comparison of tool life

Classification	Size	M2×0.4	M8×1.25	M6×1	M8×1.25	M10×1.25
Workpiece	Material	Plastic with glass fibre	ADC12	FC250	FC250	FC250
	Part's name	Electric Parts	Car Parts	Electric Parts	Car Parts	Car Parts
Thread Condition	Tapping Hole. condition	ϕ1.6 Through	ϕ6.7 Blind	ϕ5.0 Blind	ϕ6.7 Blind	ϕ8.7 Blind
	Tapping Length	4mm	18mm	10mm	16mm	18mm
Condition of Use	Machine	Special Machine	Special Machine	4Spindles Machine	Spindles Machine	Special Machine
	Cutting Speed	6.3m/min	8.5m/min	8m/min	6m/min	5.7m/min
	Fluid	Dry	Water soluble	Water soluble	Water soluble	Water soluble
Number of Holes	CT Tap	10.000	75.400	53.000	18.860	38.500
	HSS Tap	200	1.000	1.000	300	500
	Comparison of Life	50	75.4	53	62.9	77

Note : In above all situations, HSS taps are used standard ones. To use CT properly is capable of a long tool life.
These datum have come from customers are useing CT taps.

18. Pipe Taps Standard

1. JIS Pipe Taps

The pipe thread standard (JIS B 0202,0203) was revised in 1982 to meet ISO standard. In the same year, JIS B 4445 (straight pipe thread taps) and JIS B 4446 (taper pipe thread taps) were also revised.

○A part of the pipe thread standard was revised in 1966 to meet ISO, but in the 1982 revision, the ISO standard was defined in the main book of JIS and the old 1966 standard was defined in JIS Appendix. For Pipe Threads, which are specified in the main book of JIS and JIS Appendix, thread symbols are different but the nominal size 1/8 to 6 inch are same. In the 1998 revision, the contents of the main book of JIS and JIS Appendix are not changed.

○ISO tap standard for pipe threads is different from the JIS tap standard in style, size and thread limit. Like the pipe thread standard, in JIS tap standards for pipe threads, style, size and thread limits of ISO standard are specified in the main book of JIS and those of old JIS standard are in the JIS Appendix. For ISO standard (style and size), please refer to the next page.

○Thread limits of Rp and G taps are the same as the ISO standard. The thread limit of Rc taps is the same as the JIS class 2 of PT taps shown in JIS Appendix because Rc is not specified in the ISO standard. Therefore, both Rc taps and PT taps can be used interchangeably. For the relation between thread limit of internal threads and tap thread limit, please refer to the table below.

○Pipe Taps standard was revised in 1987. And tap designations shown in JIS Appendix were changed to Parallel Pipe Thread Taps for PF, Taper Pipe Thread Taps for PT, Parallel Pipe Thread Taps for PS.

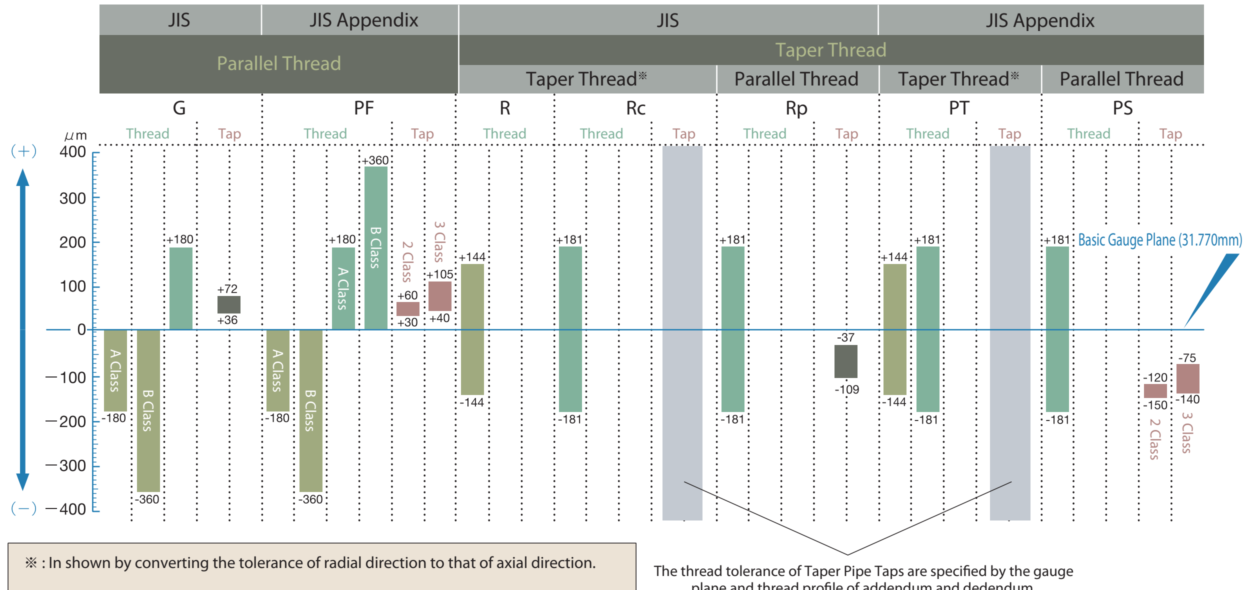
■Symbol of Pipe threads

Type	Classification		Standard	JIS (ISO)	JIS Appendix
Taper Thread	Taper Thread	Internal Thread	JIS B 0203—1982	Rc	PT
		External Thread		R	PT
	Parallel Thread	Internal Thread		Rp	PS
		External Thread		—	—
Parallel Thread	Parallel Thread	Internal Thread	JIS B 0202—1982	G	PF, A class
				—	PF, B class
		External Thread		G, A class	PF, A class
				G, B class	PF, B class

■Relation of pitch diameter tolerance zone between thread and tap

Example.1-11

Parallel Pipe Thread : JIS B 0202 Straight Pipe Thread Taps : JIS B 4445
Taper Pipe Thread : JIS B 0203 Taper Pipe Thread Taps : JIS B 4446

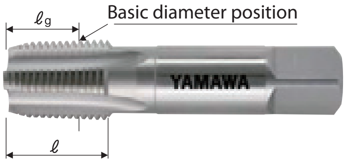


※ : In shown by converting the tolerance of radial direction to that of axial direction.

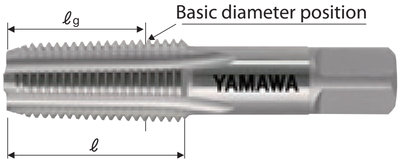
Internal Thread External Thread

■Comparison of the thread limit of taper pipe tap

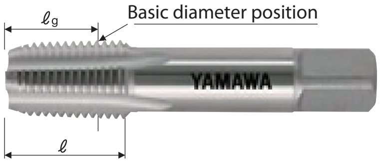
Rc



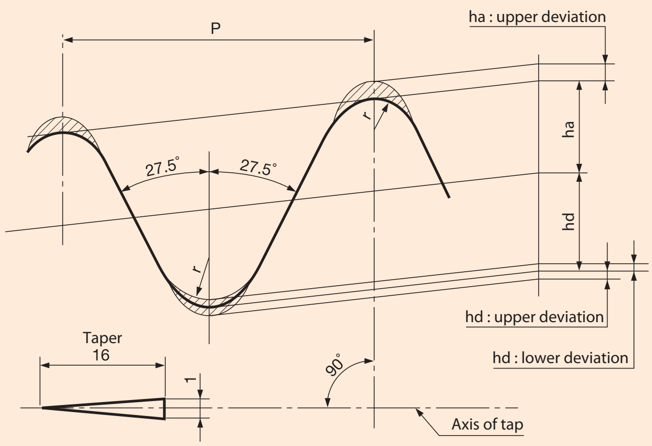
PT



S-PT



P = 25.4/n
n = Number of thread



Unit : mm

Norminal Size	Basic major Dia. of Gauge Plane	Number of Threads※	ISO (Rc)		Appendix (PT)				Thread Limit			
					PT Thread		S-PT Thread		ha		hd	
			Thread Length ℓ	Basic Diameter Postion ℓg	Thread Length ℓ	Basic Diameter Postion ℓg	Thread Length ℓ	Basic Diameter Postion ℓg	Basic Size	Tolerance (μm)	Basic Size	Tolerance (μm)
1⁄16	7.723	28	14	10.1	—	—	—	—	0.291	0～+30	0.291	±15
⅛	9.728	28	15	10.1	19	13	16.5	10.5	0.291	0～+30	0.291	±15
¼	13.157	19	19	15	28	21	19.5	12.5	0.428	0～+40	0.428	±20
⅛	16.662	19	21	15.4	28	21	21	14	0.428	0～+40	0.428	±20
½	20.955	14	26	20.5	35	25	27	17	0.581	0～+50	0.581	±25
¾	26.441	14	28	21.8	35	25	29	19	0.581	0～+50	0.581	±25
1	33.249	11	33	26	45	32	35	22	0.740	0～+60	0.740	±30
1 ¼	41.910	11	36	28.3	45	32	37.5	24.5	0.740	0～+60	0.740	±30
1 ½	47.803	11	37	28.3	45	32	38.5	25.5	0.740	0～+60	0.740	±30
2	59.614	11	41	32.7	50	35	42.5	27.5	0.740	0～+60	0.740	±30
2 ½	75.184	11	45	37.1	—	—	—	—	0.740	0～+60	0.740	±30
3	87.884	11	48	40.2	—	—	—	—	0.740	0～+70	0.740	±35
4	113.030	11	53	46.2	—	—	—	—	0.740	0～+70	0.740	±35

Note : JIS standard has 2 types of Taper pipe thread, PT and S-PT taps ISO standard has one type of Taper pipe thread Rc, which can substitute, PT and S-PT taps

※ : Threads per inch

■Comparison of the thread limit for straight pipe taps

Unit : μm

Norminal Size	Number of Threads※	Pitch (mm)	The Thread Limit of ISO (G)								The Therad Limit of Appendix of PF							
			Major Dia		Pitch Dia				Minar Dia		Major Dia		Pitch Dia				Minar Dia	
			Basic Size (mm)	LT (+)	Basic Size (mm)	UT (+)	LT (+)	Tolerance	Basic Size (mm)	UT	Basic Size (mm)	LT (+)	Basic Size (mm)	UT (+)	LT (+)	Tolerance	Basic Size (mm)	UT (+)
1/16	28	0.9071	7.723	32	7.142	43	21	22	6.561	Not Specified	—		—				—	
1/8	28	0.9071	9.728	32	9.147	43	21	22	8.566		9.728	65	9.147	40	20	20	8.566	40
1/4	19	1.3368	13.157	37	12.301	50	25	25	11.445		13.157	90	12.301	50	25	25	11.445	50
3/8	19	1.3368	16.662	37	15.806	50	25	25	14.950		16.662	90	15.806	50	25	25	14.950	50
1/2	14	1.8143	20.955	43	19.793	57	28	29	18.631		20.955	115	19.793	55	25	30	18.631	55
5/8	14	1.8143	22.911	43	21.749	57	28	29	20.587		22.911	115	21.749	55	25	30	20.587	55
3/4	14	1.8143	26.441	43	25.279	57	28	29	24.117		26.441	115	25.279	55	25	30	24.117	55
7/8	14	1.8143	30.201	43	29.039	57	28	29	27.877		30.201	115	29.039	55	25	30	27.877	55
1	11	2.3091	33.249	54	31.770	72	36	36	30.291		33.249	145	31.770	60	30	30	30.291	60
1 1/8	11	2.3091	37.897	54	36.418	72	36	36	34.939		37.897	145	36.418	60	30	30	34.939	60
1 1/4	11	2.3091	41.910	54	40.431	72	36	36	38.952		41.910	145	40.431	65	30	35	38.952	65
1 1/2	11	2.3091	47.803	54	46.324	72	36	36	44.845		47.803	145	46.324	65	30	35	44.845	65
1 3/4	11	2.3091	53.746	54	52.267	72	36	36	50.788		53.746	145	52.267	65	30	35	50.788	65
2	11	2.3091	59.614	54	58.135	72	36	36	56.656		59.614	150	58.135	75	35	40	56.656	75
2 1/4	11	2.3091	65.710	65	64.231	87	43	44	62.752									
2 1/2	11	2.3091	75.184	65	73.705	87	43	44	72.226									
2 3/4	11	2.3091	81.534	65	80.055	87	43	44	78.576									
3	11	2.3091	87.884	65	86.405	87	43	44	84.926									
3 1/2	11	2.3091	100.330	65	98.851	87	43	44	97.372									
4	11	2.3091	113.030	65	111.551	87	43	44	110.072									

※ : Threads per inch
UT : The upper deviation
LT : The lower deviation

■Comparison of the thread limit of taper pipe taps

Unit : μm

Norminal Size	Number of Threads※	Pitch (mm)	The Thread Limit of ISO (Rp)								The Therad Limit of Appendix of PS									
			Major Dia		Pitch Dia				Minar Dia		Major Dia			Pitch Dia				Minar Dia		
			Basic Size (mm)	LT (−)	Basic Size (mm)	UT (−)	LT (−)	Tolerance	Basic Size (mm)	UT	Basic Size (mm)	UT	LT (−)	Basic Size (mm)	UT (−)	LT (−)	Tolerance	Basic Size (mm)	UT	LT (−)
1/16	28	0.9071	7.723	43	7.142	14	43	29	6.561	Not Specified	—			—				—		
1/8	28	0.9071	9.728	43	9.147	14	43	29	8.566		9.728	+10	50	9.147	30	50	20	8.566	+10	50
1/4	19	1.3368	13.157	63	12.301	21	63	42	11.445		13.157	+ 5	75	12.301	50	75	25	11.445	+ 5	75
3/8	19	1.3368	16.662	63	15.806	21	63	42	14.950		16.662	+ 5	75	15.806	50	75	25	14.950	+ 5	75
1/2	14	1.8143	20.955	86	19.793	29	86	57	18.631		20.955	- 25	115	19.793	85	115	30	18.631	- 25	115
3/4	14	1.8143	26.441	86	25.279	29	86	57	24.117		26.441	- 25	115	25.279	85	115	30	24.117	- 25	115
1	11	2.3091	33.249	109	31.770	37	109	72	30.291		33.249	- 50	150	31.770	120	150	30	30.291	- 50	150
1 1/4	11	2.3091	41.910	109	40.431	37	109	72	38.952		41.910	- 50	150	40.431	115	150	35	38.952	- 50	150
1 1/2	11	2.3091	47.803	109	46.324	37	109	72	44.845		47.803	- 50	150	46.324	115	150	35	44.845	- 50	150
2	11	2.3091	59.614	109	58.135	37	109	72	56.656		59.614	- 45	145	58.135	105	145	40	56.656	- 45	145
2 1/2	11	2.3091	75.184	130	73.705	43	130	87	72.226											
3	11	2.3091	87.884	130	86.405	43	130	87	84.926											
4	11	2.3091	113.030	130	111.551	43	130	87	110.072											

※ : Threads per inch
UT : The upper deviation
LT : The lower deviation

2. American Pipe Thread Taps

American standard pipe thread has various types and are complicated. We show their symbols and engagement of threads as follows.

■Pair groups of external thread and internal thread.

Standard	Symbol	Internal Thread	Maiting Thread	External Thread	Maiting Thread
Pipe Threads, General Purpose (ANSI/ASME B1.20.1)	American Standard Taper Pipe Thread for General Use	NPT	NPT	NPT	NPT NPSC
	American Standard Straight Pipe Thread in Pipe Couplings	NPSC	NPT	–	–
	American Standard Taper Pipe Threads for Railing Joints	NPTR	NPTR	NPTR	NPTR
	American Standard Straight Pipe Thread for Free-Fitting Mechanical Joints for Fixtures	NPSM	NPSM	NPSM	NPSM
	American Standard Straight Pipe Thread for Loose-Fitting Mechanical Joints with Locknuts	NPSL	NPSL	NPSL	NPSL
	American Standard Straight Pipe Threads for Loose-Fitting Mechanical Joints for Hose Couplings	NPSH	NPSH	NPSH	NPSH
Dryseal Pipe Threads (ANSI B1.20.3)	Dryseal American Standard Taper Pipe Thread	NPTF	NPTF PTF-SAE-SHORT	NPTF	NPTF,NPSF,NPSI PTF-SAE-SHORT
	Dryseal SAE Short Taper Pipe Thread	PTF-SAE-SHORT	NPTF	PTF-SAE-SHORT	NPTF NPSI
	Dryseal American Standard Fuel Internal Straight Pipe Thread	NPSF	NPTF	–	–
	Dryseal American Standard Intermediate Internal Straight Pipe Thread	NPSI	NPTF PTF-SAE-SHORT	–	–

Note : These symbols correspond to the name of American pipe thread.

These threads are
(1) Thread angle is 60˚
(2) Taper of Taper Thread is 3/4" per foot.
(3) Fundamental height of triangle : H=Height of triangle thread profile H=0.866025P
(4) The difference between American Standard Pipe Thread for general use and Dryseal American Standard Pipe
- Crests and roots truncation of thread is different.
- The length of engagement for pipe thread is different by types.
- With regard to standard, Dryseal American Standard Pipe Thread is available in right hand.

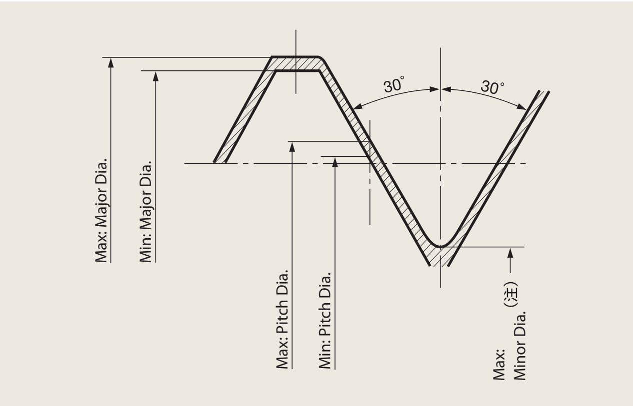
In accordance with ANSI B 94.9, 4 types of pipe thread are specified in American Pipe Thread Standard.
Please refer to next page about the relation between taps and threads and about thread tolerance.

○Classification of American pipe thread taps

Designation	Symbol	Class	Material	Threads to be cut	Range
Straight Pipe Thread Tap	NPS	Ground Thread	HSS	NPSC,NPSM	⅛~1
Dryseal Straight Pipe Thread Tap	NPSF	Ground Thread	HSS	NPSF	⅛~¾
Taper Pipe Thread Tap	NPT	Ground Thread	HSS	NPT	1⁄16~2
Dryseal Taper Pipe Thread Tap	NPTF	Ground Thread	HSS	NPTF	1⁄16~2

■Thread limit of American Pipe Thread Taps

○Straight pipe thread taps for (NPS) G Class



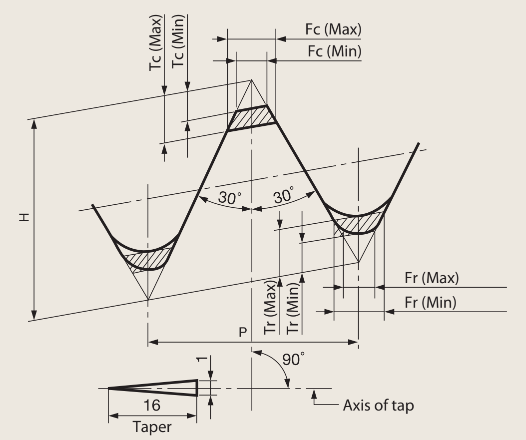
Unit : mm

Nominal Size	Major diameter			Pitch diameter			Minor diameter※
	Max : Major Dia.	Min : Major Dia.	Tolerance	Max : Pitch Dia.	Min : Pitch Dia.	Tolerance	Max : Minor Dia.
NPS 1/8 - 27	10.241	10.216	0.025	9.527	9.515	0.012	M−0.653
NPS 1/4 - 18	13.606	13.582	0.024	12.542	12.530	0.012	M−1.019
NPS 3/8 - 18	17.045	17.021	0.024	15.981	15.969	0.012	M−1.019
NPS 1/2 - 14	21.226	21.202	0.024	19.840	19.828	0.012	M−1.334
NPS 3/4 - 14	26.560	26.536	0.024	25.186	25.162	0.024	M−1.334
NPS 1 - 11 1/2	33.215	33.178	0.037	31.526	31.502	0.024	M−1.644

※ : Above dimensions change depending on actually measured.

○Taper pipe thread taps (NPT) G Class

p = 25.4/n
n = Number of thread
H = 0.866025P

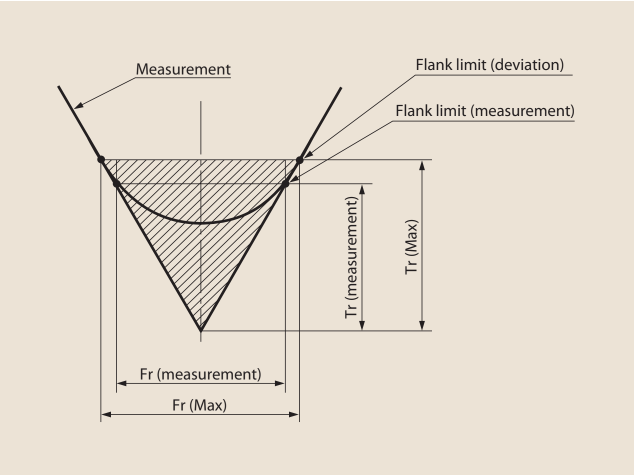


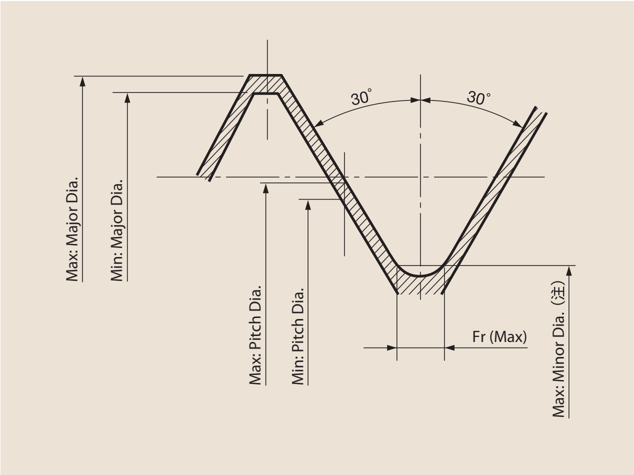
Unit : μm

Nominal Size	Crest				Root			
	Tc		Fc		Tr		Fr	
	Max	Min	Max	Min	Max	Min	Max	Min
NPT 1/16 - 27	68	32	78	37	80	32	92	37
NPT 1/8 - 27	68	32	78	37	80	32	92	37
NPT 1/4 - 18	92	48	106	56	101	48	116	56
NPT 3/8 - 18	92	48	106	56	101	48	116	56
NPT 1/2 - 14	106	61	122	71	118	61	136	71
NPT 3/4 - 14	106	61	122	71	118	61	136	71
NPT 1 - 11 1/2	120	74	138	85	134	74	154	85
NPT 1 1/4-11 1/2	120	74	138	85	134	74	154	85
NPT 1 1/2-11 1/2	120	74	138	85	134	74	154	85
NPT 2 - 11 1/2	120	74	138	85	134	74	154	85
NPT 2 1/2 - 8	147	105	169	122	173	105	199	122
NPT 3 - 8	147	105	169	122	173	105	199	122

■Thread limit of Dryseal American Pipe Thread Taps

○Straight pipe thread taps (NPSF) G Class



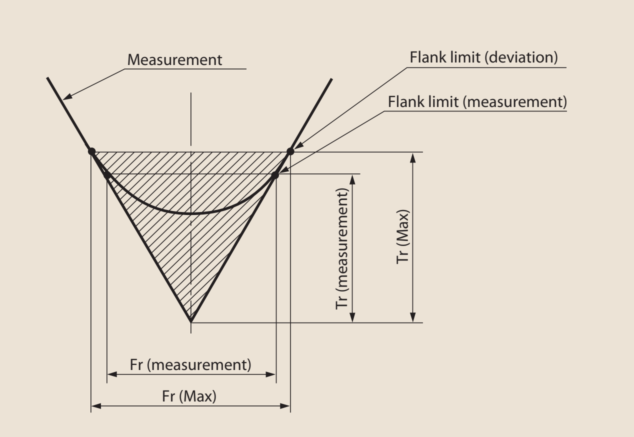


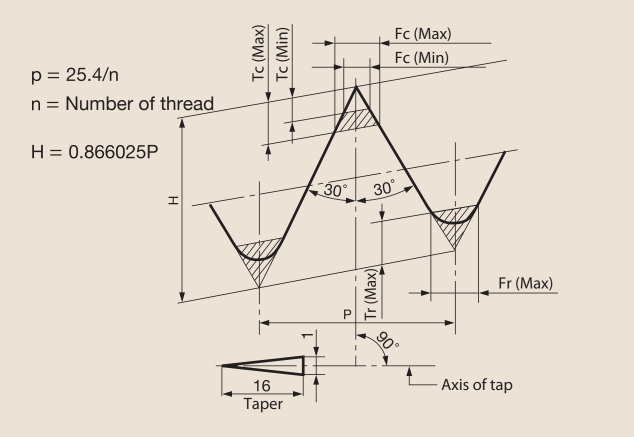
Unit : mm

Nominal Size	Major diameter			Pitch diameter			Minor diameter※		
	Max : Major Dia.	Min : Major Dia.	Tolerance	Max : Pitch Dia.	Min : Pitch Dia.	Tolerance	Max : Major Dia.	Fr (Max)	Tr (Max)
NPSF 1/16 - 27	7.665	7.641	0.024	7.053	7.041	0.012	M−0.638	0.101	0.086
NPSF 1/8 - 27	10.012	9.988	0.024	9.400	9.388	0.012	M−0.638	0.101	0.086
NPSF 1/4 - 18	13.332	13.308	0.024	12.354	12.342	0.012	M−1.004	0.127	0.109
NPSF 3/8 - 18	16.771	16.747	0.024	15.793	15.781	0.012	M−1.004	0.127	0.109
NPSF 1/2 - 14	20.929	20.905	0.024	19.601	19.589	0.012	M−1.354	0.127	0.109
NPSF 3/4 - 14	26.276	26.251	0.025	24.947	24.936	0.011	M−1.354	0.127	0.109

※ : Above dimensions change depending on actually measured.

○Taper pipe thread taps (NPTF) G Class



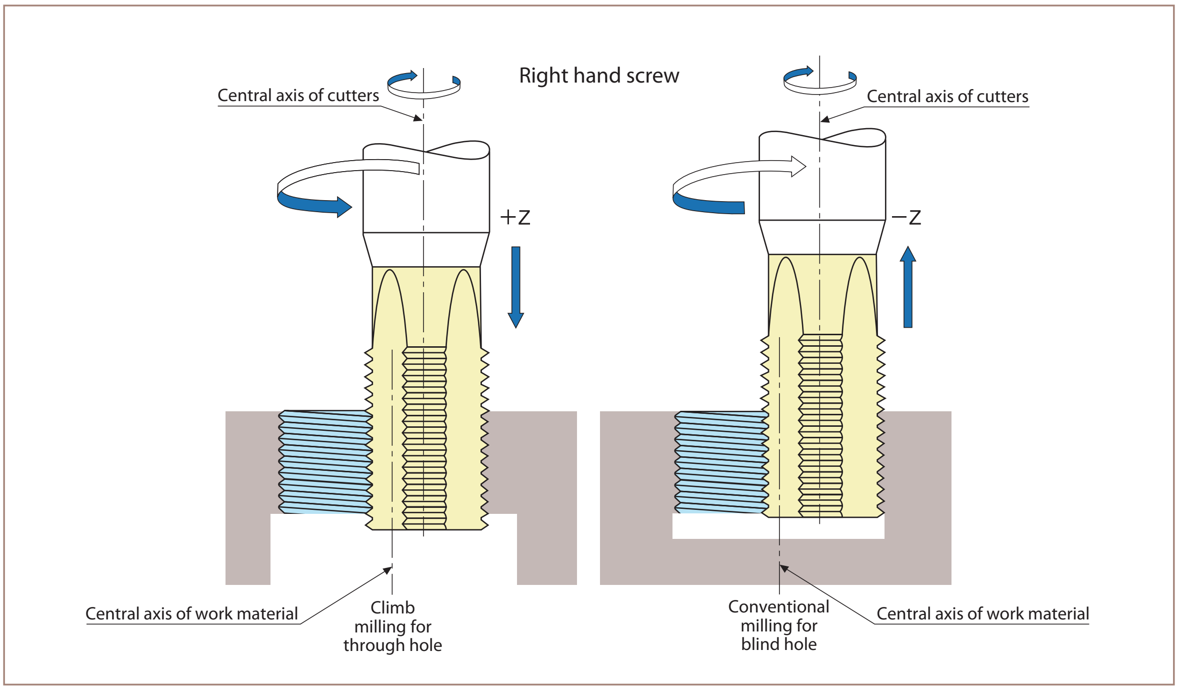


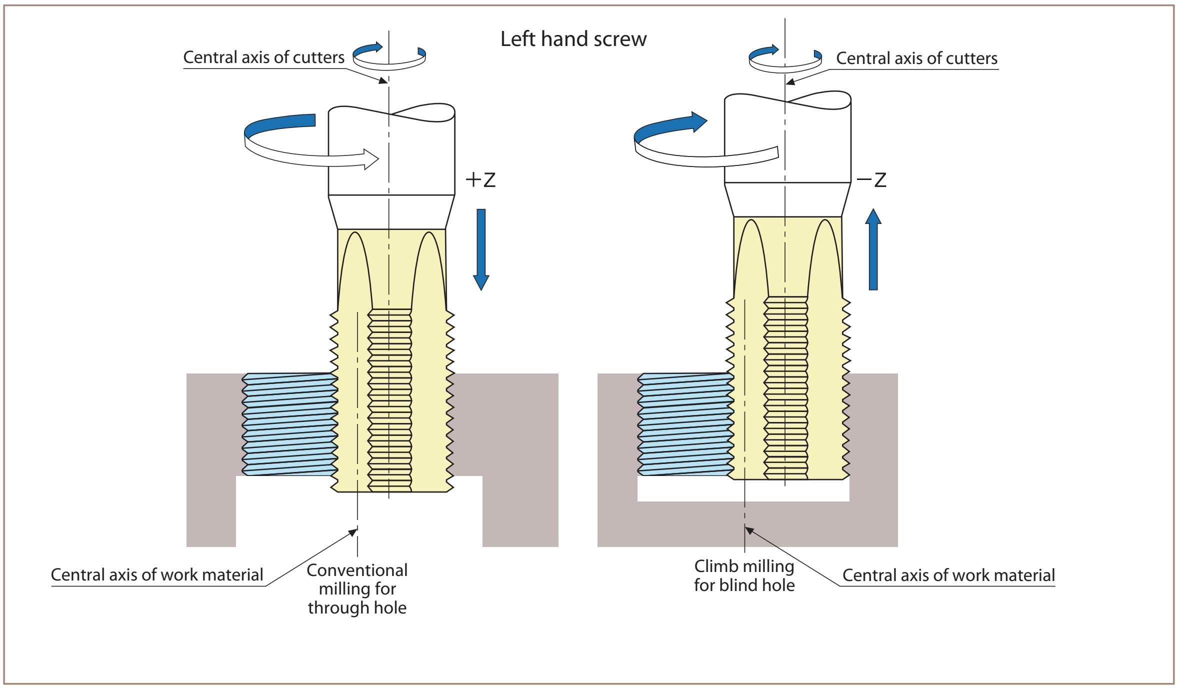
Unit : μm

Nominal Size	Crest				Root	
	Tc		Fc		Tr	Fr
	Max	Min	Max	Min	Max	Min
NPTF 1/16 - 27	110	89	127	103	86	101
NPTF 1/8 - 27	110	89	127	103	86	101
NPTF 1/4 - 18	132	110	152	127	109	125
NPTF 3/8 - 18	132	110	152	127	109	125
NPTF 1/2 - 14	131	109	151	126	108	124
NPTF 3/4 - 14	131	109	151	126	108	124
NPTF 1 - 11 1/2	176	133	203	154	132	152
NPTF 1 1/4-11 1/2	176	133	203	154	132	152
NPTF 1 1/2-11 1/2	176	133	203	154	132	152
NPTF 2 - 11 1/2	176	133	203	154	132	152

19. Features of MC-Helical Thread Mills

- ○Various nominal diameter internal threads of the same pitch can be produced with the same thread mills.
- ○The same mill can be used for both right-hand and left-hand internal threads.
- ○Chips become very minute, and troubles caused by chips are rarely expected.
- ○Internal threads of large diameter are obtainable even with low power machines.
- ○Size control (undersize or oversize) is easy on programming process. Thus, internal threads with voluntary thread limits can be obtained.
- ○When using MC-Helical threads mills for producing taper pipe threads, the threads are produced in a perfect cutting circle, and no stop marks which are inevitable in taper pipe threads tapping and high quality pressure-tight joint can be made.



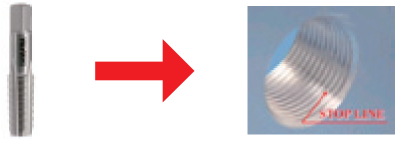


Note : Basically, conventional milling is recommended due to excellent chip ejection. However, climb milling is recommended in the case of poor horse power and poor rigidity of the machine.

■Comparison of internal threads cut by helical cuttter and by PT tap

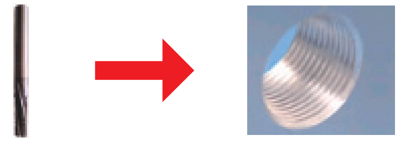
■By tap

When PT tap cuts internal threads, the tap cuts the threads with all cutting edges and the tap reverses from the position where each cutting edge on lands sticks into the material wall of internal threads. This results in the stop line due to a step caused by this sticking.



■By helical cutter

Due to the thread cutting of 3 axis movement without reversing, the internal thread has no stop line.



■Selection of tool diameter against the size of the internal screw

When cutting internal screws with MC-HLC, please choose the tool which diameter is smaller than 70% of internal threads diameter. The cutter of using larger outside diameter is preferable due to its high rigidity. But thread milling cutters do not have screw lead. Please select thread milling cutters by referring to the shape & size table.

■Cutting Condition

○Carbide helical cutter

Material	Cutting Speed (m/min)	Feed per tooth (mm/t)
Stractual Steel	50~250	0.02~0.1
Carbon Steel	50~200	0.02~0.1
Alloy Steel	30~180	0.02~0.1
Tool Steel	30~150	0.02~0.1
Stainless Steel	30~200	0.03~0.1
Cast Iron	50~150	0.03~0.15
Aluminum, Aluminum Alloy	50~300	0.03~0.15
Copper, Copper Alloy	50~180	0.03~0.15

○HSS helical cutter

Material	Cutting Speed (m/min)	Feed per tooth (mm/t)
Stractual Steel	25~45	0.02~0.05
Carbon Steel	20~40	0.02~0.05
Alloy Steel	15~30	0.02~0.05
Tool Steel	10~15	0.02~0.04
Stainless Steel	10~15	0.03~0.05
Cast Iron	30~50	0.03~0.08
Aluminum, Aluminum Alloy	50~90	0.03~0.05
Copper, Copper Alloy	40~80	0.03~0.05

■Feeding speed

Feeding speed is decided by the characteristic of work materials. Feeding speed is an important factor because machining time, thread finish and tool durability are getting influenced by the feeding speed.

In the material of low tensile strength, feed per tooth can be set up rather large. However, if you set up feed per one tooth too large, thread milling cutters can cause deflection and may badly cause thread limit.

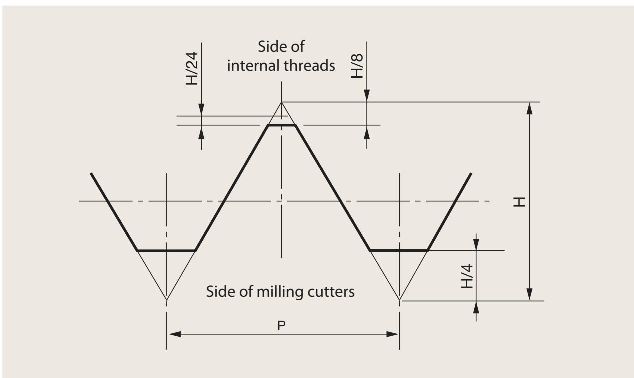
Feed speed of fool

$$F = fz \cdot Z \cdot n \cdot (Dc-d)/Dc \ (mm/min)$$

fz : Feed per tooth
z : Number of tooth
n : Spindles RPM
d : Diameter of tool
Dc : Nominal size of internal thread

■Incision of cutters

Generally, incision of cutter is decided by the machine programming in which the machine enables the cutter to cut the thread height in one revolution. MC helical cutters is so designed that its minor diameter does not cut and the same bored hole size as that for cutting tap is adopted.



—Metric thread

[Minor diam basis]

Tool incision

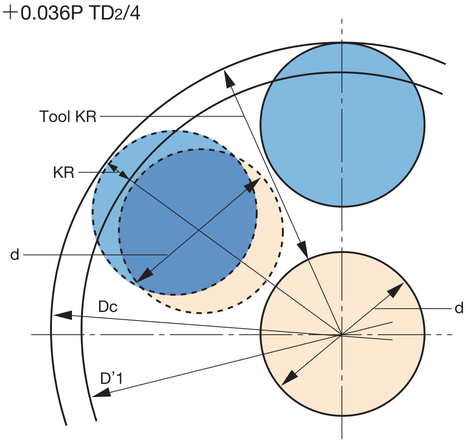
$KR = H - (H/8 + H/4) + H/24 + TD_2/4 - (D'_1 - D_1)/2$
$= (D_1 - D'_1)/2 + 2H/3 + TD_2/4$
$= (D_1 - D_1)/2 + 0.577P + TD_2/4$

—Metric thread

[Tool basis]

Tool transverse

$Tool\ KR = Dc/2 - d/2 + H/24 + TD_2/4$
$= (Dc - d)/2 + H/24 + TD_2/4$
$= (Dc - d)/2 + 0.036P\ TD_2/4$



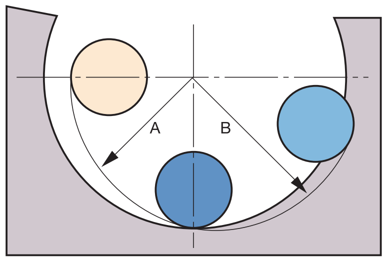
where,

Dc : Nominal size of internal threads
D_1 : Basic minor diameter of internal threads
D'_1 : Minor diameter before cutting
d : Outside diameter of tool
H : 0.866025P
P : Pitch
TD_2 : Tolerance of pitch diameter for producing internal thread
$TD_2/4$: Shrinkage after cutting
(Set up in the middle of pitch diameter tolerance)

H/24 : Difference between of basic thread profile and O.D. of the cutters.

■Approaching and leaving to and from work material

On approaching and leaving to and from work material, the cutter must always be traversed in helical interpolating movement so that the cutter enables smooth cutting in and out. And it is necessary to cut the material gradually by the lead of screw thread. Otherwise, threads can be thinned.



Initial cutting A<B

20. Selecting different tap holder combinations by machine feed system

The function of machine feed systems

Fully synchronous feed (Rigid) tapping system

Spindle revolution and machine feed are synchronized, a perfect thread lead and feed per revolution are realized.

Feed by lead screws

A better-feed condition is realized because the tap is fed by a master lead screw shaft that has the same thread lead as this tap.

Feed by gear

The tap is fed at the same thread lead by a combinations of gears. This creates a better-feed to thread lead condition.

Asynchronous feed system

Best used when the spindle rotation and the machine feed are set independently, especially, if the machine feed value cannot be accurately predicted to be that of the tap thread lead.

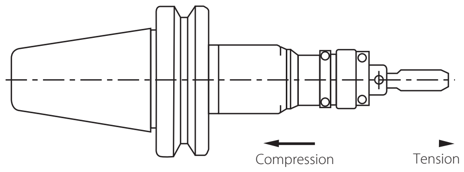
Hydraulic or Pneumatic pressure feed system

Feed is controlled by a pressure regulation system which normally results in an inaccurate feed per revolution compared to the tap thread lead.

Manual feed

Feed is controlled by operator which is difficult to keep a stable amount of feed per revolution.

Holders aspects



Spring direction

Completely rigid holder type

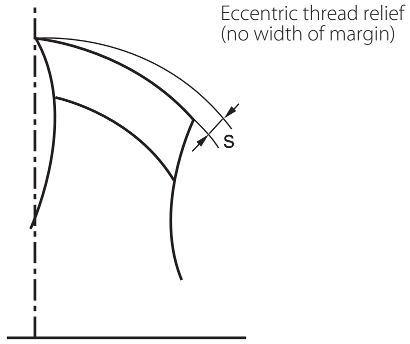
The tap is held with no axial or radial adjustment in the collet and holder.

Adjustable spring floating holder (Tension & Compression)

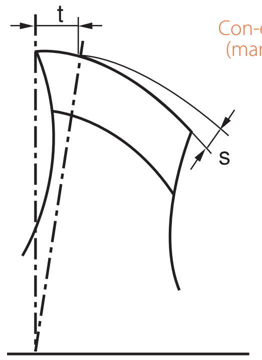
Machine feed and tap's thread lead errors are corrected by two types of spring system in the holder, the axial tension direction of the tap and the axial compression direction of the tap.

Characteristics of tap self-guiding behavior

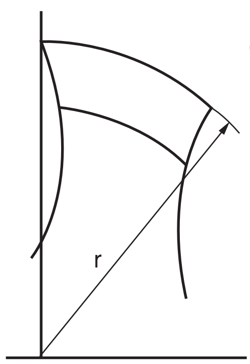
r=tap's radius, s=thread relief, t=margin width



Tap characteristics ; high cutting performance and machining performance, with little to no self-guiding features. Operation ; A fully synchronous machining system with fixed rigid holder is needed.
Example : "High speed tapping" and "fully synchronous tapping."



Tap ; High level of self-guidance due to suitable tap diameter margin and thread relief. The combination of nice portion of margin and chamfer relief helps to make appropriate tap guidance.

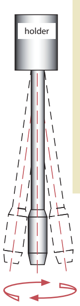


Tap ; A full thread land stays in contact with the thread major diameter at all times. Tap has no thread relief on major diameter, creating a high level of self-guidance even with unbalanced feeding conditions.

21. The common mechanics for a tap to cut oversize on an internal thread

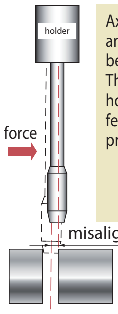
1. Run out, misalignment and tap cutting non perpendicular to holes → Over-cutting at radial direction

Tool run out during tapping



Holder needs to be adjusted. Tapping with run out can be observed and checked when idle running. Chuck needs to be adjusted-Tapping with run out could be observed and checked by idle running.

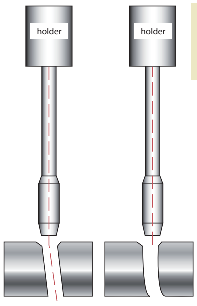
Misalignment during tapping



Axis of tapping process and bored hole should be lined up correctly. The use of adjustable holder with floating features will reduce this problem.

Solutions

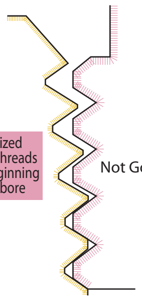
Tapping a non-parallel or non-perpendicular thread to the axis of the hole.



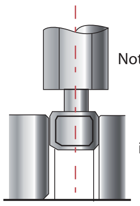
Verification of prepared hole condition.

The tap normally follows the bored hole except when the tap cuts too large at the beginning of the hole from tap run out, misallignment of the tap is to the bore diameter or the bore is out of parallelism to the thread axis. These conditions cause the tap to cut over size at the beginning of the thread and cut smaller as the thread continues.

Excessive-cutting in the radial direction



Normal internal threads



2. Using a tap not suitable for the operation or a tap with a dull cutting edge may cause galling which results in over-cutting. → Over-cutting caused by galling and excess cutting

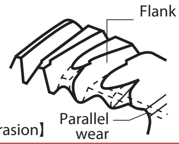
Using an incorrect tap for a specific workpiece material can cause problems

Select the correct Tap
- Straight fluted tap
- Spiral fluted tap
- Spiral pointed tap
- Roll tap

Selection of correct taps by material being tapped is strongly recommended.

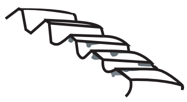
Tapping process with dull edge

Abrasion



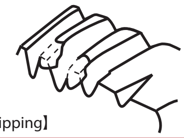
【Abrasion】

Welding



【Welding】

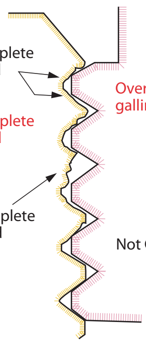
Chipping



【Chipping】

Proper use of cutting oil, confirmed value to establish tool life constant

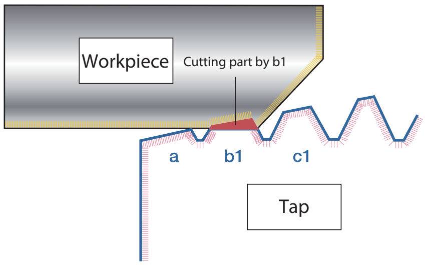
A torn thread is observed on all surfaces of internal thread, the flank angles, the major diameter and the minor diameter. When this situation is continued, an over-cutting of the internal thread occurs, there are deformed threads, there are interrupted threads, and finally it leads to over size cutting of internal thread.



3. Tapping with an improper feed condition ——→ over-cutting at axial direction

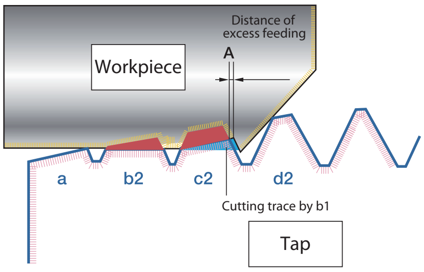
The main reasons for producing an incorrect thread

① At cutting edge b1, cutting chamfer of the tap



② Position of thread after the tap rotates 1 turn.

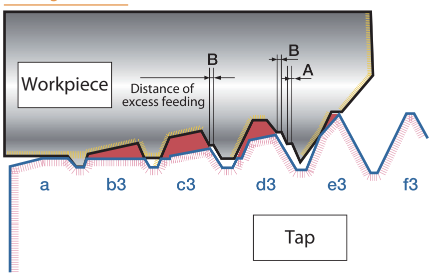
Tap Cutting advancement (b1) and thread advancement of cutting face (c2) are misaligned creating the distance of excessive feeding A.



③ Thread position after the tap rotates 2 turns.

Tap cutting chamfer (c3) is misaligned and the distance of excess feeding B and cutting chamfer (d3) is misaligned to create the distance of over feeding A+B.

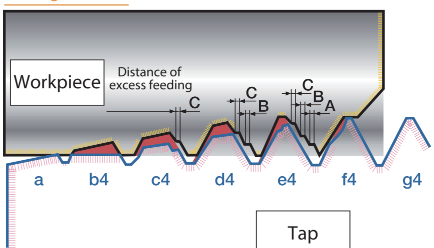
Cutting situation



④ The position of thread after 3 rotations of tap.

The thread continues to misalign until the distance of the thread lead is in error from excessive feeding C.

Cutting situation



Solutions

Feed adjustment is strongly recommended.

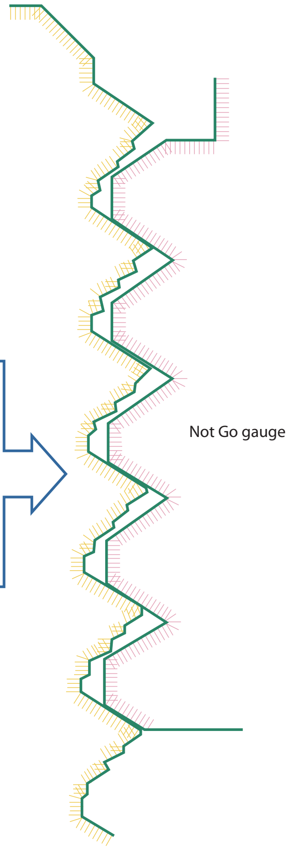
* (Use of fully synchronous feed system and fixing holder)

When using machine that do not have the functions ahown, such as drilling machine.

* The correct balance of main spindle adjustment is strongly recommended.
* Use an axial/radial floating holder for its adjustment.

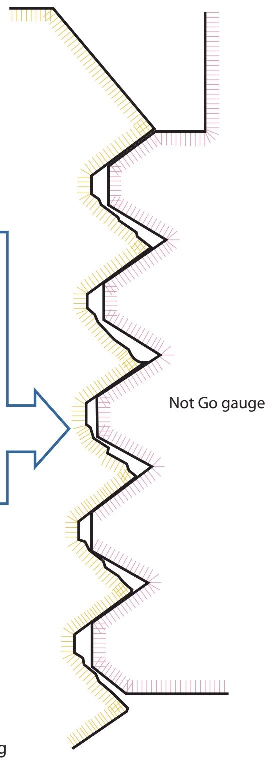
「Excessive-cutting of the thread with excessive feeding」

A clearance gap is created at the back frank of thread. More material is cut at front frank than at the back flank creating an incorrect threads



「over-cutting thread by too slow feeding」

This condition creates just the opposite of excess feeding or over-cutting internal thread. A clearance gap is created at the front frank and extra material is cut at back frank.



Reasons for over-cutting during tapping process (overview)

① The tap mounting condition in the holder.
② The condition of bored hole.
③ The cutting oil selection.
④ Incorrect adjustment of feed balance.
⑤ Selecting the correct tap by material being cut from the tap selection section.

22. Trouble Shooting

<table>
<tr><td colspan="2" rowspan="2">Troubles
Check point
Segments</td><td colspan="3">Breakage</td><td colspan="2">Excessive wear</td></tr>
<tr><td>Prevent excessive cutting torque</td><td>Prevent clogging of chips</td><td>Tap</td><td>Workpiece</td><td>Tap</td></tr>
<tr><td rowspan="4">Workpiece</td><td>Hardness</td><td>●Use workpiece which has even structure and hardness.</td><td></td><td></td><td>○Use workpiece which has even structure and hardness.</td><td></td></tr>
<tr><td>Shape</td><td colspan="2">●Pay attention for tapping position and material thickness.</td><td></td><td>●Pay attention for tapping position and material thickness.</td><td></td></tr>
<tr><td rowspan="2">Bored hole</td><td>◎Provide bigger bored holes.
●Prevent work hardening.</td><td></td><td></td><td>○Provide bigger bored holes.
●Provide countersinking on hole entrance.
○Prevent work hardening.</td><td></td></tr>
<tr><td colspan="2">◎Provide deeper tapping hole.
●Prevent slanting of hole.</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Machine</td><td>●Avoid inconsistent feed.
●Adjust feed stroke.</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Jigs, Holders</td><td>●Use tap holder of floating type.
◎Use tap holder with torque limiter.</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Cutting condition</td><td colspan="2">○Reduce cutting speed.</td><td></td><td>○Reduce cutting speed.</td><td></td></tr>
<tr><td colspan="2">Lubricant</td><td>●Use the other cutting oil which prevents cold welding.
●Use non soluble type cutting oil.</td><td></td><td></td><td colspan="2">●Provide proper timing for changing or filling-up of cutting oil.
●Prevent mixing of other oil into cutting oil.
●Use other cutting oil which prevents cold welding.
●Use cutting oil of non soluble type.
●Adjust flow of cutting oil and method of lubrication.</td></tr>
<tr><td colspan="2">On process</td><td></td><td>●Remove unnecessary chips during tapping.
●Provide bigger space for chips disposal.</td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="4">Tap</td><td>Selection</td><td></td><td></td><td>●Use PO tap(through hole).
●Use SP tap(blind hole).
●Use Roll tap.</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Design</td><td></td><td>●Provide bigger chiproom.</td><td>●Change material of taps.
●Provide proper hardness on taps.</td><td></td><td>●Use set tap.
●Change material of taps.
●Provide proper hardness on taps.</td></tr>
<tr><td colspan="3">●Reconsider length of cutting chamfer.
●Use set tap.</td><td colspan="2">●Reconsider length of cutting chamfer.
●Provide nitride on taps.</td></tr>
<tr><td>Re-grind</td><td colspan="3">●Be careful about burning during re-sharpening.
●Provide proper land.</td><td colspan="2">●Be careful about burning during re-sharpening.
●Increase re-sharpening frequency.</td></tr>
</table>

◎ : Most suitable solution　　○ : Second most suitable solution

Undersize cutting of internal thread			Bad surface, surface damaged		
Improve cutting performance	Selection and design of tap	Work material	Improve cutting performance	Prevent welding	Check cutting condition
		●Check workmaterial.			●Provide proper hardness on workpiece material.
		●Pay attention for tapping position and material thickness.			●Pay attention for tapping position and material thickness.
●Adopt bigger tapping hole. ●Prevent work hardening of material.					
			●Prevent work hardening.	●Provide bigger bored holes.	○Prevent slanting of hole.
					○Feed according to pitch.
					●Use the tap holder of floating type. ●Prevent vibrating of axis of tap ●Prevent centering-off with work piece.
			●Reduce cutting speed.		
			●Provide proper timing for changing or filling-up of cutting oil. ●Prevent mixing of other oil into cutting oil. ●Use other cutting oil which prevents cold welding. ●Use cutting oil of non soluble type. ●Adjust flow of cutting oil and method of lubrication.		
				●Remove unnecessary chips	
●Provide Nitride on taps.	◎Use oversiza taps.		●Use spiral pointed taps (for through hole).	◎Provide oxide coating on taps.	◎Use oil hole taps.
○Provide larger cutting angle.	●Adjust relief angle on cutting chamfer. ○Provide thread relief.		◎Provide larger cutting angle. ●Adjust relief angle on cutting chamfer. ○Provide more narrow margin.	●Change of no. of flutes on taps.	●Reconsider length of cutting chamfer.
●Increase re-sharpening frequency.			●Increase re-sharpening frequency.	●Provide better surface finishing on flutes.	
			●Provide precise re-sharpening. ●Be careful about burning during re-sharpening.		

Description of products

Technical Information

22. Trouble Shooting

Troubles / Check point / Segments		Prevent uneven in feed of tap	Prevent over cutting on thread	Prevent welding	Check cutting condition	Prevent unbalance on entering
		Over-cutting of internal thread				
Workpiece	Hardness	●Use workpiece which has even structure and hardness.				
Workpiece	Shape					
Workpiece	Bored hole			●Provide bigger hole.	●Prevent slanting of hole.	●Provide countersinking on the hole entrance.
Workpiece	Bored hole					
Machine		●Adjust a feed. ◎Feed according to pitch.				
Jigs, Holders					○Use tap holder of floating type.	◎Prevent vibrating of axis of tap. ○Prevent centering-off with work piece. ●Use tap holder of floating type.
Cutting condition				●Reduce cutting speed.		
Lubricant				●Use other cutting lubricant which prevents cold welding. ●Check the viscosity.		
On process						
Tap	Selection			◎Provide oxide surface treatment. ○Use tap with oil hole.		
Tap	Design		○Provide small cutting angle. ●Adjust chamfer relief angle. ◎Check the width of thread margin.	●Provide short thread length.	●Reconsider number of flules of tap.	●Reconsider number of flules
Tap	Re-grind		●Remove burrs on teeth after re-grinding. ●Provide proper land.		●Provide precise re-sharpening.	◎Care for vibration.

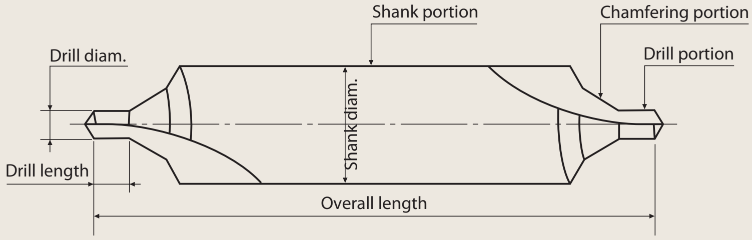
◎ : Most suitable solution ○ : Second most suitable solution

Chipping				Tapping operation	
Prevent clogging of chips	Prevent excessive cutting torque	Improve tapping method	Tap	Prevent clogging of chips	Tap
	●Use workpiece material which has even structure and hardness.				
		○Pay attention for tapping position and material thickness.		●If possible, use finer pitch tap or shorter tapping length.	
Provide deeper tapping hole (Blind hole).	◎Provide bigger tapping hole. ●Prevent work hardnening.	●Prevent slanting of holes.		○Reduce cutting speed. ◎Provide deeper tapping hole (Blind hole).	
●Provide countersinking on hole the entrance.					
	●Avoid inconsistent feed.				
	○Use tapping holder with torque limiter.	●Prevent centering-off with workpiece. ●Prevent vibration of axis of tap. ●Use the tap holder of floating type.			●Use the tap holder of floating type. ●Prevent vibration of axis of tap. ●Prevent centering-off with workpiece.
●Reduce cutting speed.				●Reduce cutting speed.	
	●Use the other cutting oil which prevent cold welding.			●Check the viscosity.	
●Remove unnecessary chips during tapping. ●Provide bigger space for chip disposal.				●Remove unnecessary chips during tapping. ●Provide bigger space for chip disposal.	
			●Use PO taps (Through hole). ●Use SP taps (Blind hole). ●Use Roll tap.		●Use PO taps (Through hole). ●Use SP taps (Blind hole). ●Use Roll tap.
●Provide bigger chip room.			●Change material of tap. ●Provide smaller cutting angle. ●Provide proper hardness.	●Provide bigger chip room. ●Reconsider length of cutting chamfer. ◎Use oil hole tap. ●Provide shorter thread length to tap.	
●Reconsider length of cutting chamfer. ●Reduce cutting speed. ●Adjust relief angle on cutting chamfer.					
●Be careful about burning during re-sharpening.					

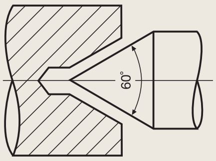
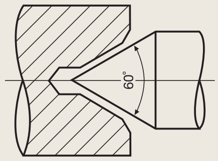
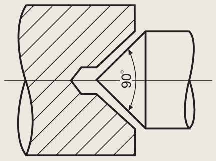
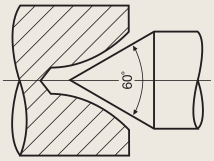
23. Center Drills

Center Drills are the tool for making center hole. Center Drills are also used for positioning before drilling, and for chamfering of the hole.

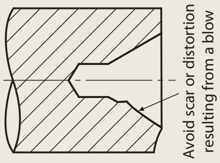
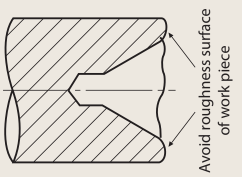
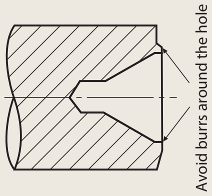
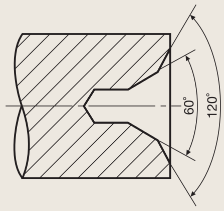
■Names of each part



■Shape of center hole and center

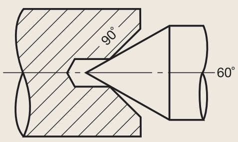
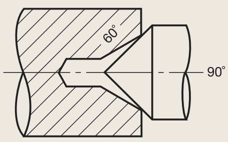
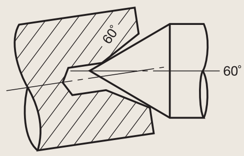
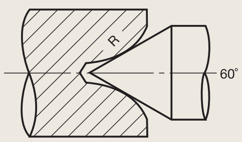
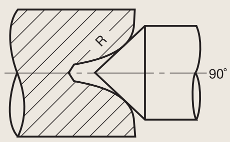
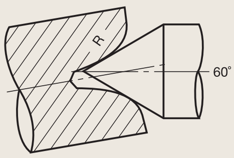
Type A (60°) Center hole & 60°center	Type B (60°) Center hole & 60°center	Type A (90°) Center hole & 90°center	Type R Center hole & 60°center
			

■Advantage of Type B Center holes

Note : Advantage of Type B center holes : B type center drill protect the 60° conical bearing surface from scar or distortion resulting from a blow, roughness of workpiece surface or burrs around the hole.

■Advantage of Type R Center holes

	Angle of center hole is higher than that of center.	Angle of center hole is lower than that of center.	Center hole and center are misaligned.
A type			
R type			

Note : R type center hole stably holds the center. It also some of advantage of B type center hole.

24. Table of recommend centering condition

■Tabie of recommend centering condition.

HSS (PE-Q PE-90°)

Work material	Soft structural steels SS400		Carbon steels S50C		Alloy steels SCM440		Stainless steels SUS304		Aluminum alloy casting AC4B	
Cutting speed (m/min)	30~40		22~30		20~25		10~15		70~100	
Diameter (mm)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)
3	3700	0.04~0.08	2750	0.04~0.08	2400	0.04~0.08	1350	0.04~0.08	9000	0.10~0.22
4	2800	0.05~0.10	2050	0.05~0.10	1800	0.05~0.10	1000	0.05~0.10	6750	0.12~0.26
6	1850	0.06~0.12	1400	0.06~0.12	1200	0.06~0.12	850	0.06~0.12	4500	0.15~0.30
8	1400	0.08~0.15	1050	0.08~0.15	900	0.08~0.15	500	0.08~0.15	3400	0.18~0.35
10	1100	0.10~0.18	850	0.10~0.18	700	0.10~0.18	400	0.10~0.18	2700	0.21~0.40
12	950	0.12~0.22	700	0.12~0.22	600	0.12~0.22	350	0.12~0.22	2250	0.25~0.45
16	700	0.16~0.26	500	0.16~0.26	450	0.16~0.26	250	0.16~0.26	1700	0.32~0.50
20	550	0.20~0.35	400	0.20~0.35	350	0.20~0.35	200	0.20~0.35	1350	0.40~0.60

HSS+TiCN (PE-Q-V PE-90°)

Work material	Soft structural steels SS400		Carbon steels S50C		Alloy steels SCM440		Thermal refined steels SCM440 (30~35HRC)		Stainless steels SUS304		Aluminum alloy casting AC4B	
Cutting speed (m/min)	38~48		28~38		26~33		13~17		13~20		84~120	
Diameter (mm)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)
3	4550	0.04~0.08	3500	0.04~0.08	3150	0.04~0.08	1800	0.03~0.06	1750	0.04~0.08	10800	0.10~0.22
4	3400	0.05~0.10	2650	0.05~0.10	2350	0.05~0.10	1200	0.04~0.08	1300	0.05~0.10	8100	0.12~0.26
6	2300	0.06~0.12	1750	0.06~0.12	1550	0.06~0.12	800	0.05~0.10	900	0.06~0.12	5400	0.15~0.30
8	1700	0.08~0.15	1300	0.08~0.15	1150	0.08~0.15	600	0.06~0.12	650	0.08~0.15	4050	0.18~0.35
10	1350	0.10~0.18	1050	0.10~0.18	950	0.10~0.18	500	0.08~0.15	500	0.10~0.18	3250	0.21~0.40
12	1150	0.12~0.22	900	0.12~0.22	800	0.12~0.22	400	0.10~0.18	450	0.12~0.22	2700	0.25~0.45
16	850	0.16~0.26	650	0.16~0.26	600	0.16~0.26	300	0.12~0.22	350	0.16~0.26	2050	0.32~0.50
20	700	0.20~0.35	500	0.20~0.35	450	0.20~0.35	250	0.16~0.26	250	0.20~0.35	1600	0.40~0.60

Carbide+TiAIN (C-PE-Q-V PE-90°)

Work material	Soft structural steels SS400		Carbon steels S50C		Alloy steels SCM440		Thermal refined steels SCM440 (30~35HRC)		Stainless steels SUS304		Aluminum alloy casting AC4B	
Cutting speed (m/min)	87~102		65~78		60~70		32~40		35~45		120~160	
Diameter (mm)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)	Revolution (min⁻¹)	Feed per revolution (mm/rev)
3	10050	0.04~0.08	7600	0.04~0.08	6900	0.04~0.08	3800	0.04~0.08	4250	0.04~0.08	14850	0.10~0.22
4	7500	0.05~0.10	5700	0.05~0.10	5150	0.05~0.10	2850	0.05~0.10	3200	0.05~0.10	11150	0.12~0.26
6	5000	0.06~0.12	3800	0.06~0.12	3450	0.06~0.12	1900	0.06~0.12	2100	0.06~0.12	7450	0.15~0.30
8	3750	0.08~0.15	2850	0.08~0.15	2600	0.08~0.15	1450	0.08~0.14	1800	0.08~0.15	5550	0.18~0.35
10	3000	0.10~0.18	2300	0.10~0.18	2050	0.10~0.18	1150	0.10~0.16	1250	0.10~0.18	4450	0.21~0.40
12	2500	0.12~0.22	1900	0.12~0.22	1700	0.12~0.22	950	0.10~0.18	1050	0.12~0.22	3700	0.25~0.45
16	1900	0.16~0.26	1400	0.16~0.26	1300	0.16~0.26	700	0.12~0.22	800	0.16~0.26	2800	0.32~0.50

1. Above Condition done by Water Soluble oil.
2. 20% lower feed is recommended when centering prosess to inclined plane.
3. 20% lower feed is recommended in the case of long shank point drills.

24. Tabie of recommend centering condition

■Reference of drilling condition for Center drills (HSS)

Reference table of cutting speed and feed per revolution (when substrate is HSS)

・Drilling speed (Cone diameter at the larger end)

Workpiece materials	Drilling speed
Low carbon steels	15~30
Carbon steels	15~30
Alloy steels	10~25
Stainless steels	5~12
Cast iron	8~15

Drill diameter	Feed per revolution
1~ 3	0.02~0.07
3~ 4	0.04~0.12
4~ 6	0.06~0.17
6~ 8	0.10~0.20
8~10	0.14~0.23
10~12	0.18~0.26

■Reference of drilling condition for Center drills (Carbide)

Reference table of cutting speed and feed per revolution (when substrate is Carbide)

・Drilling speed (Cone diameter at the larger end)

Workpiece materials	Drilling speed
Low carbon steels	30~50
Carbon steels	30~50
Alloy steels	20~40
Stainless steels	15~25
Cast iron	30~50

Drill diameter	Feed per revolution
1	0.01 ~0.03
2	0.01 ~0.035
3	0.015~0.05
4	0.02 ~0.06
5	0.03 ~0.07
6	0.04 ~0.07

■Reference of drilling condition for NC-SD-V

Reference table of drilling speed, feed per revolution

・Drilling speed (Tool diameter)

Workpiece materials	Drilling speed
Low carbon steels	25~40
Carbon steels	25~32
Alloy steels	15~25
Alloy tool steels	7~12
Stainless steels	7~12
Cast iron	20~35
Aluminum	60~90

Tool diameter	Feed per revolution
3	0.03~0.06
4	0.05~0.10
6	0.08~0.15
8	0.10~0.18
10	0.15~0.20
12	0.15~0.25
16	0.15~0.30
20	0.20~0.30
25	0.20~0.30

■Reference of chamfering condition for Countersinks

Reference table of drilling speed, feed per revolution

・Drilling speed (Tool diameter)

Workpiece materials	Drilling speed	
	Single edge	Multiple edges
Low carbon steels	18~25	20~27
Carbon steels	18~25	20~25
Alloy steels	8~16	8~15
Alloy tool steels	8~16	8~15
Stainless steels	8~13	5~10
Cast iron	20~30	15~25
Aluminum	20~70	20~80

Tool diameter	Feed per revolution	
	Single edge	Multiple edges
4	0.02~0.04	0.03~0.10
6	0.03~0.05	0.05~0.12
8	0.05~0.07	0.07~0.15
10	0.06~0.09	0.10~0.16
12	0.07~0.10	0.10~0.20
16	0.08~0.13	0.10~0.20
20	0.09~0.15	0.10~0.25
25	0.10~0.16	0.15~0.30

25. Thread Series

Metric Threads

Unit : mm

Nominal Dia.			Pitch※												
Column 1	Column 2	Column 3	Coarse	Fine											
1			0.25												0.2
	1.1		0.25												0.2
1.2			0.25												0.2
	1.4		0.3												0.2
1.6			0.35												0.2
	1.8		0.35												0.2
2			0.4											0.25	
	2.2		0.45											0.25	
2.5			0.45										0.35		
3			0.5										0.35		
	3.5		0.6										0.35		
4			0.7									0.5			
	4.5		0.75									0.5			
5			0.8									0.5			
		5.5										0.5			
6			1								0.75				
	7		1								0.75				
8			1.25							1	0.75				
		9	1.25							1	0.75				
10			1.5						1.25	1	0.75				
		11	1.5							1	0.75				
12			1.75					1.5	1.25	1					
	14		2					1.5	1.25	1					
		15						1.5		1					
16			2					1.5		1					
		17						1.5		1					
	18		2.5				2	1.5		1					
20			2.5				2	1.5		1					
	22		2.5				2	1.5		1					
24			3				2	1.5		1					
		25					2	1.5		1					
		26						1.5							
	27		3				2	1.5		1					
		28					2	1.5		1					
30			3.5			3	2	1.5		1					
		32					2	1.5							
	33		3.5			3	2	1.5							
		35						1.5							
36			4			3	2	1.5							
		38						1.5							
	39		4			3	2	1.5							
		40				3	2	1.5							
42			4.5		4	3	2	1.5							
	45		4.5		4	3	2	1.5							
48			5		4	3	2	1.5							
		50				3	2	1.5							
	52		5		4	3	2	1.5							
		55			4	3	2	1.5							
56			5.5		4	3	2	1.5							
		58			4	3	2	1.5							
	60		5.5		4	3	2	1.5							
		62			4	3	2	1.5							
64			6		4	3	2	1.5							
		65			4	3	2	1.5							
	68		6		4	3	2	1.5							
		70		6	4	3	2	1.5							
72				6	4	3	2	1.5							
		75			4	3	2	1.5							
	76			6	4	3	2	1.5							
		78					2								
80				6	4	3	2	1.5							
		82					2								
	85			6	4	3	2								
90				6	4	3	2								
	95			6	4	3	2								
100				6	4	3	2								
	105			6	4	3	2								
110				6	4	3	2								
	115			6	4	3	2								
	120			6	4	3	2								
125				6	4	3	2								
	130			6	4	3	2								
		135		6	4	3	2								
140				6	4	3	2								
		145		6	4	3	2								
	150			6	4	3	2								

※ : Please select the first column by priority. And select second column and third column if necessary.

■Unifined Threads

Size		Nominal Dia.		Threads per inch										
Column 1	Column 2	inch	mm	Coarse UNC	Fine UNF	Extra Fine UNEF	Constant pitch series 4UN	6UN	8UN	12UN	16UN	20UN	28UN	32UN
No. 0		0.0600	1.524		80									
	No. 1	0.0730	1.854	64	72									
No. 2		0.0860	2.184	56	64									
	No. 3	0.0990	2.515	48	56									
No. 4		0.1120	2.845	40	48									
No. 5		0.1250	3.175	40	44									
No. 6		0.1380	3.505	32	40									UNC
No. 8		0.1640	4.166	32	36									UNC
No.10		0.1900	4.826	24	32									UNF
	No.12	0.2160	5.486	24	28	32							UNF	UNEF
¼		0.2500	6.350	20	28	32						UNC	UNF	UNEF
5/16		0.3125	7.938	18	24	32						20	28	UNEF
⅜		0.3750	9.525	16	24	32					UNC	20	28	UNEF
7/16		0.4375	11.112	14	20	28					16	UNF	UNEF	32
½		0.5000	12.700	13	20	28					16	UNF	UNEF	32
9/16		0.5625	14.288	12	18	24				UNC	16	20	28	32
⅝		0.6250	15.875	11	18	24				12	16	20	28	32
	11/16	0.6875	17.462			24				12	16	20	28	32
¾		0.7500	19.050	10	16	20				12	UNF	UNEF	28	32
	13/16	0.8125	20.638			20				12	16	UNEF	28	32
⅞		0.8750	22.225	9	14	20				12	16	UNEF	28	32
	15/16	0.9375	23.812			20				12	16	UNEF	28	32
1		1.0000	25.400	8	12	20			UNC	UNF	16	UNEF	28	32
	1 1/16	1.0625	26.988			18			8	12	16	20	28	
1⅛		1.1250	28.575	7	12	18			8	UNF	16	20	28	
	1 3/16	1.1875	30.162			18			8	12	16	20	28	
1¼		1.2500	31.750	7	12	18			8	UNF	16	20	28	
	1 5/16	1.3125	33.338			18			8	12	16	20	28	
1⅜		1.3750	34.925	6	12	18		UNC	8	UNF	16	20	28	
	1 7/16	1.4375	36.512			18		6	8	12	16	20	28	
1½		1.5000	38.100	6	12	18		UNC	8	UNF	16	20	28	
	1 9/16	1.5625	39.688			18		6	8	12	16	20		
1⅝		1.6250	41.275			18		6	8	12	16	20		
	1 11/16	1.6875	42.862			18		6	8	12	16	20		
1¾		1.7500	44.450	5				6	8	12	16	20		
	1 13/16	1.8125	46.038					6	8	12	16	20		
1⅞		1.8750	47.625					6	8	12	16	20		
	1 15/16	1.9375	49.212					6	8	12	16	20		
2		2.0000	50.800	4 1/2				6	8	12	16	20		
	2⅛	2.1250	53.975					6	8	12	16	20		
2¼		2.2500	57.150	4 1/2				6	8	12	16	20		
	2⅜	2.3750	60.325					6	8	12	16	20		
2½		2.5000	63.500	4			UNC	6	8	12	16	20		
	2⅝	2.6250	66.675				4	6	8	12	16	20		
2¾		2.7500	69.850	4			UNC	6	8	12	16	20		
	2⅞	2.8750	73.025				4	6	8	12	16	20		
3		3.0000	76.200	4			UNC	6	8	12	16	20		
	3⅛	3.1250	79.375				4	6	8	12	16			
3¼		3.2500	82.550	4			UNC	6	8	12	16			
	3⅜	3.3750	85.725				4	6	8	12	16			
3½		3.5000	88.900	4			UNC	6	8	12	16			
	3⅝	3.6250	92.075				4	6	8	12	16			
3¾		3.7500	95.250	4			UNC	6	8	12	16			
	3⅞	3.8750	98.425				4	6	8	12	16			
4		4.0000	101.600	4			UNC	6	8	12	16			
	4⅛	4.1250	104.775				4	6	8	12	16			
4¼		4.2500	107.950				4	6	8	12	16			
	4⅜	4.3750	111.125				4	6	8	12	16			
4½		4.5000	114.300				4	6	8	12	16			
	4⅝	4.6250	117.475				4	6	8	12	16			
4¾		4.7500	120.650				4	6	8	12	16			
	4⅞	4.8750	123.825				4	6	8	12	16			
5		5.0000	127.000				4	6	8	12	16			
	5⅛	5.1250	130.175				4	6	8	12	16			
5¼		5.2500	133.350				4	6	8	12	16			
	5⅜	5.3750	136.525				4	6	8	12	16			
5½		5.5000	139.700				4	6	8	12	16			
	5⅝	5.6250	142.875				4	6	8	12	16			
5¾		5.7500	146.050				4	6	8	12	16			
	5⅞	5.8750	149.225				4	6	8	12	16			
6		6.0000	152.400				4	6	8	12	16			

※ : Please select the first column by priority. And select second column and third column if necessary.

■Conversion Table

Threads per inch (25.4mm)	Pitch (mm)
100	0.2540
80	0.3175
72	0.3528
64	0.3969
60	0.4233
56	0.4536
48	0.5292
44	0.5773
40	0.6350
36	0.7056
32	0.7938
28	0.9071
27	0.9407
24	1.0583
20	1.2700
19	1.3368
18	1.4111
16	1.5875
14	1.8143
13	1.9538
12	2.1167
11 1/2	2.2087
11	2.3091
10	2.5400
9	2.8222
8	3.1750
7	3.6286
6	4.2333
5	5.0800
4 1/2	5.6444
4	6.3500

General size list of metric trapezoidal threads

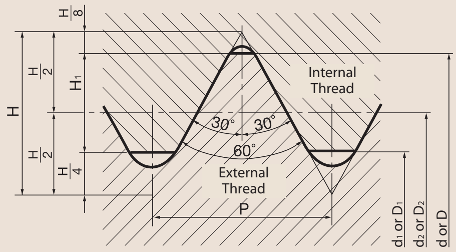
Unit : mm

	1.5	2	3	4	5	6	7	8	10	12
Tr 8	1.5									
Tr 9	1.5	2								
Tr 10	1.5	2								
Tr 11		2	3							
Tr 12		2	3							
Tr 14		2	3							
Tr 16		2		4						
Tr 18		2		4						
Tr 20		2		4						
Tr 22			3		5			8		
Tr 24			3		5			8		
Tr 26			3		5			8		
Tr 28			3		5			8		
Tr 30			3			6			10	
Tr 32			3			6			10	
Tr 34			3			6			10	
Tr 36			3			6			10	
Tr 38			3				7		10	
Tr 40			3				7		10	
Tr 42			3				7		10	
Tr 44			3				7			12
Tr 46			3					8		12
Tr 48			3					8		12

When the tap for the trapezoidal threads not listed in the catalogue is required, please contance Yamawa sales.

26. Basic profile of threads

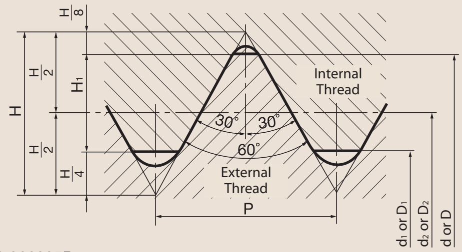
■Metric Screw Threads



$H = 0.866025P$
$H_1 = 0.541266P$
$d_2 = d - 0.649519P$
$d_1 = d - 1.082532P$

$D = d$
$D_2 = d_2$
$D_1 = d_1$

■Unified Screw Threads

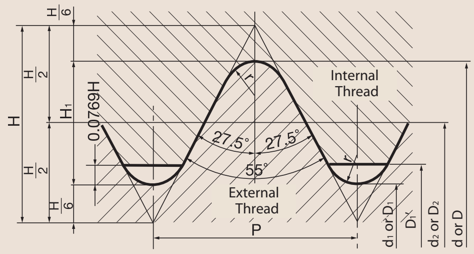


$H = 0.866025P$
$H_1 = 0.541266P$
$d_2 = d - 0.649519P$
$d_1 = d - 1.082532P$

$D = d$
$D_2 = d_2$
$D_1 = d_1$

$P = 25.4/n$
n = Threads per inch

■Whitworth Screw Threads

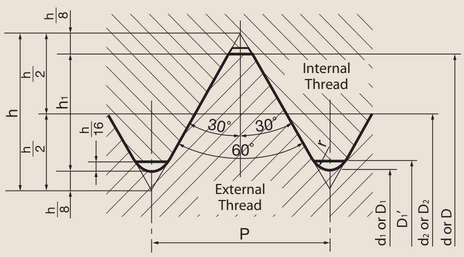


$H = 0.9605P$
$H_1 = 0.6403P$
$d_2 = d - H_1$
$d_1 = d - 2H_1$

$D = d$
$D_2 = d_2$
$D_1 = d_1$
$D_1' = d_1 + 2 \times 0.0769H$

$r = 0.1373P$
$P = 25.4/n$
n = Threads per inch

■Screw Threads for Sewing Machine

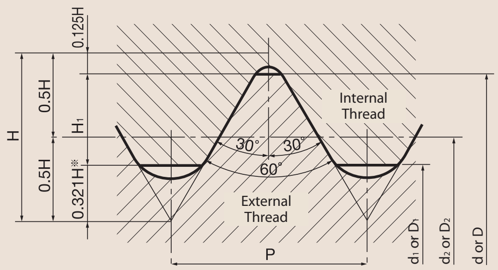


$H = 0.8660P$
$H_1 = 0.6495P$
$d_2 = d - h_1$
$d_1 = d - 2h_1$

$D = d$
$D_2 = d_2$
$D_1 = d_1$
$D_1' = d_1 + 2 \times h/16$

$r = 0.1083P$
$P = 25.4/n$
n = Threads per inch

■Miniature Screw Threads

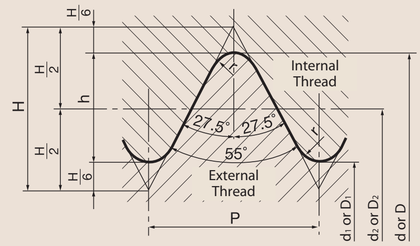


$H = 0.866025P$
$H_1 = 0.48P$
$d_2 = d - 0.649519P$
$d_1 = d - 0.96P$

$D = d$
$D_2 = d_2$
$D_1 = d_1$

Note : This figure rounds off 0.320744H.

■Parallel Pipe Threads

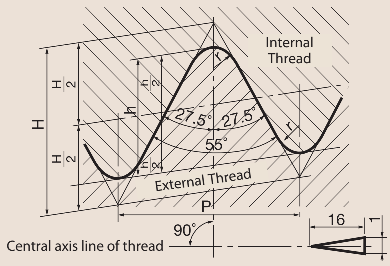


$H = 0.960491P$
$h = 0.640327P$
$d_2 = d - h$
$d_1 = d - 2h$

$D = d$
$D_2 = d_2$
$D_1 = d_1$
$r = 0.137329P$

$P = 25.4/n$
n = Threads per inch

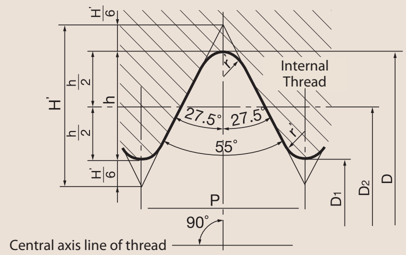
■Taper Pipe Threads



$H = 0.960237P$
$h = 0.640327P$
$r = 0.137278P$

$P = 25.4/n$
n = Threads per inch

■Taper Pipe Threads (Parallel)

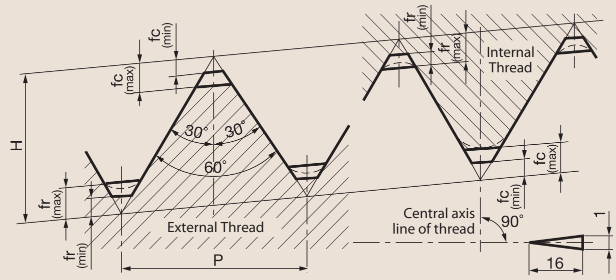


$H' = 0.960491P$
$h = 0.640327P$
$r' = 0.137329P$

$P = 25.4/n$
n = Threads per inch

26. Basic profile of threads

■American Standard Taper Pipe Threads

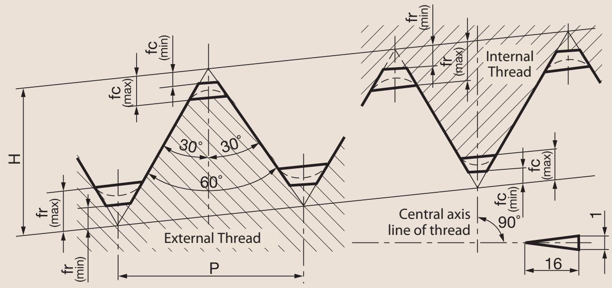


H =0.866025P
P =25.4/n
n =Threads per inch

Truncation — Unit : mm

Threads per inch	Section	fc=fr
27	Max.	0.096P
	Min.	0.033P
18	Max.	0.088P
	Min.	0.033P
14	Max.	0.078P
	Min.	0.033P
11.5	Max.	0.073P
	Min.	0.033P
8	Max.	0.062P
	Min.	0.033P

■Dryseal American Standard Taper Pipe Threads

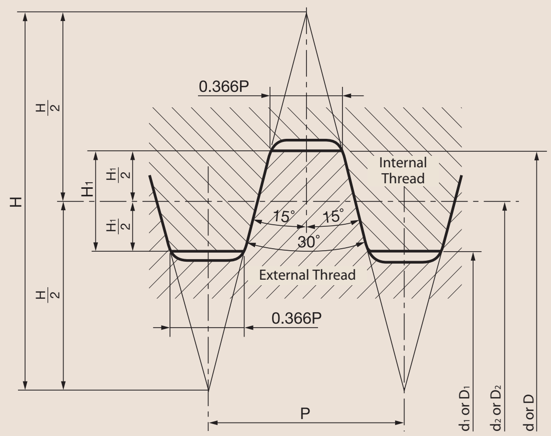


H =0.866025P
P =25.4/n
n =Threads per inch

Truncation — Unit : mm

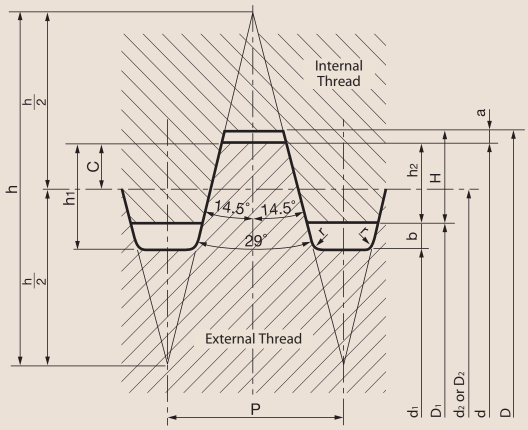
Threads per inch	Section	fc	fr
27	Max.	0.094P	0.140P
	Min.	0.047P	0.094P
18	Max.	0.078P	0.109P
	Min.	0.047P	0.078P
14	Max.	0.060P	0.085P
	Min.	0.036P	0.060P
11.5	Max.	0.060P	0.090P
	Min.	0.040P	0.060P
8	Max.	0.055P	0.076P
	Min.	0.042P	0.055P

■Metric Trapezoidal Screw Threads



$H = 1.866P$
$H_1 = 0.5P$
$d_2 = d - 0.5P$
$d_1 = d - P$
$D = d$
$D_2 = d_2$
$D_1 = d_1$

■29° Trapezoidal Screw Threads



$h = 1.9335P$
$h_1 = 2c + a$
$h_2 = 2c + a - b$
$H = 2c + 2a - b$
$c \fallingdotseq 0.25P$
$d_2 = d - 2c$
$d_1 = d - 2h1$
$P = 25.4/n$
$D = d + 2a$
$D_2 = d_2$
$D_1 = d_1 + 2b$
n =Threads per inch

27. Symbols for Standard Threads

■Japan

Thread symbols	Kinds of threads	Related Standards
M	Metric screw threads	JIS B 0205-1～0205-4
S	Miniature screw threads	JIS B 0201
UNC	Unified threads, Coarse series	JIS B 0206
UNF	Unified threads, Fine series	JIS B 0208
Tr	Metric Trapezoidal screw threads	JIS B 0216
R	Taper external pipe threads	JIS B 0203 (JIS main book)
Rc	Taper internal pipe threads	JIS B 0203 (JIS main book)
Rp	Parallel internal pipe threads	JIS B 0203 (JIS main book)
G	Parallel pipe threads	JIS B 0202 (JIS main book)
PF	Parallel pipe threads	JIS B 0202 (JIS Appendix)
PT	Taper pipe threads	JIS B 0203 (JIS Appendix)
PS	Taper pipe threads (Parallel)	JIS B 0203 (JIS Appendix)
CTC	Screw threads for rigid metal thin-walled conduit and fitting	JIS C 8305
CTG	Screw threads for rigid metal thick-walled conduit and fitting	JIS C 8305
BC	Cycle threads	JIS B 0225
SM	Screw threads for sewing machine	JIS B 0226 (2001.2.20repeal)
E	Electric socket and lamp-base threads	JIS C 7709
V	Tire valve threads of automobile	JIS D 4207
CTV	Tire valve threads of cycle	JIS D 9422

■ISO

Thread symbols	Kinds of threads	Related Standards
M	ISO Metric threads	ISO 261
S	ISO Miniature screw threads	ISO R 1501
Tr	ISO Metric trapezoidal screw threads	ISO 2902
UNC	ISO Unified threads, coarse series	ISO 263
UNF	ISO Unified threads, fine series	ISO 263
UNEF	ISO Unified threads, extra fine series	ISO 263
UN	ISO Unified threads, constant pitch series	ISO 263
UNJC	Unified threads (MIL Standard) coarse	ISO 3161
UNJF	Unified threads (MIL Standard) fine	ISO 3161
UNJEF	Unified threads (MIL Standard) extra fine	ISO 3161
UNJ	Unified threads (MIL Standard) constant pitch series	ISO 3161
MJ	Metric threads, MIL Standard	ISO 5855
R	Taper external pipe threads	ISO 7/1
Rc	Taper internal pipe threads	ISO 7/1
Rp	Parallel internal pipe threads	ISO 7/1
G	Parallel pipe threads	ISO 228/1
GL	Glass container threads	ISO R 1115
V	Tire valve threads	ISO 4570/1～3

27. Symbols for Standard Threads

■America

Thread symbols	Kinds of threads	Related Standards
UN	Unified inch screw threads	ANSI B 1.1
UNC/UNRC	Unified coarse thread series	ANSI B 1.1
UNF/UNRF	Unified fine thread series	ANSI B 1.1
UNEF/UNREF	Unified extra-fine thread series	ANSI B 1.1
4UN/4UNR	Unified constant-pitch series with 4-threads	ANSI B 1.1
6UN/6UNR	Unified constant-pitch series with 6-threads	ANSI B 1.1
8UN/8UNR	Unified constant-pitch series with 8-threads	ANSI B 1.1
12UN/12UNR	Unified constant-pitch series with 12-threads	ANSI B 1.1
16UN/16UNR	Unified constant-pitch series with 16-threads	ANSI B 1.1
20UN/20UNR	Unified constant-pitch series with 20-threads	ANSI B 1.1
28UN/28UNR	Unified constant-pitch series with 28-threads	ANSI B 1.1
32UN/32UNR	Unified constant-pitch series with 32-threads	ANSI B 1.1
UNS/UNRS	Unified threads of special diameters, pitches and lengths of engagement	ANSI B 1.1
NR	American National thread with a 0.108p to 0.144p controlled root radius	MIL-B-7838
Acme	Acme screw threads	ANSI B 1.5
Stub-Acme	Stub Acme screw threads	ANSI B 1.8
Butt	Buttress inch screw threads	ANSI B 1.9
UNM	Unified miniature thread series	ANSI B 1.10
NC5	Class 5 interference-fit thread	ANSI B 1.12
NPT	American Standard taper pipe threads for general use	ANSI/ASME B 1.20.1
NPTR	American Standard taper pipe threads for railing joints	ANSI/ASME B 1.20.1
NPSC	American Standard straight pipe thread in pipe couplings	ANSI/ASME B 1.20.1
NPSL	American standard straight pipe threads for loose-fitting mechanical joints with locknuts	ANSI/ASME B 1.20.1
NPSM	American Standard straight pipe threads for free-fitting mechanical joints for fixture	ANSI/ASME B 1.20.1
NPSH	American Standard straight pipe threads for loose-fitting mechanical joints for hose couplings	ANSI/ASME B 1.20.1
NPTF	Dryseal American Standard taper pipe threads	ANSI B 1.20.3, 1.20.4
F-PTF	Dryseal fine taper pipe thread series	ANSI B 1.20.3, 1.20.4
PTF-SAE SHORT	Dryseal SAE short taper pipe threads	ANSI B 1.20.3, 1.20.4
PTF-SPL SHORT	Dryseal special short taper pipe threads	ANSI B 1.20.3, 1.20.4
PTF-SPL EXTRA SHORT	Dryseal special extra short taper pipe threads	ANSI B 1.20.3, 1.20.4
SPL-PTF	Dryseal special taper pipe threads	ANSI B 1.20.3, 1.20.4
NPSI	Dryseal American Standard intermediate internal straight pipe threads	ANSI B 1.20.3, 1.20.4
NPSF	Dryseal American Standard fuel internal straight pipe threads	ANSI B 1.20.3, 1.20.4
ANPT	Aeronautical National Form taper pipe threads	MIL-P-7150
NGO	National gas outlet threads	ANSI B 57.1
NGS	National gas straight threads	ANSI B 57.1
NGT	National gas taper threads	ANSI B 57.1
SGT	Special gas taper threads	ANSI B 57.1
NH	Hose coupling and firehose coupling threads	USAS B 2.4
NHR	Hose coupling and firehose coupling threads	USAS B 2.4
NPSH	Hose coupling and firehose coupling threads	USAS B 2.4
AMO	American standard microscope objective threads	ANSI B 1.11

■British※

Thread symbols	Kinds of threads	Related Standards
UNS	Unified special series	BS 1580
B.S.W.	British Standard Whitworth coarse threads	BS 84
B.S.F.	British Standard fine threads	BS 84
BSP	British Standard pipe thread (corresponding to R, Rc, Rp of ISO)	BS 21,2779
B.A.	B.A.-Screw threads	BS 93
Acme	General purpose, Acme screw threads	BS 1104
Buttress	Buttress threads	BS 1657
BSC	Cycle threads	BS 811
BSMO	Microscope objective threads	BS 3569
E	Edison screw threads	BS 5042

※ : We left out the symbols after ISO standard was adopted.

■German※

Thread symbols	Kinds of threads	Related Standards
GL	Glass containers thread	DIN 168
S	Buttress thread	DIN 513,2781,20401
Rd	Knuckle thread	DIN 262,3182,7273,15403,20400
W	Whitworth-gewinde	DIN 168,477,6630,49301
KS,KT	Screw siles for packages made of Plastics	DIN 6063
E	Edison screw thread	DIN 40400
Pg	Steel conduit thread	DIN 40430
Vg	Automobil tire valve thread	DIN 7756
Gf	Thread for freezing pipes	DIN 4930
Gg	Threads for drill pipe	DIN 4941,20314
HA	Thread for bone screws and nuts	DIN 58810
FG	Bicycle threads	DIN 79012

※ : We left out the symbols after ISO standard was adopted.

28. Cross chart of thread cutting tool standard

Tap and Die names	JIS	JSCTA	ISO	ANSI	BS	DIN
General specification		4051				
Measuring method		4053				
Technical requirement			8830			2197
Thread limit (Metric)		4052	2857			
Thread limit (Pipe)			5969			
Hand taps (Metric coarse)	B4430	4105	529	B94.9	949	352
Hand taps (Metric fine)	B4430	4106	529	B94.9	949	2181
Hand taps (Unified coarse)	B4432	4107	529	B94.9	949	
Hand taps (Unified fine)	B4438		529	B94.9	949	
Hand taps (Parallel pipe thread)	B4445		2284	B94.9	949	
Hand taps (Taper pipe thread)	B4446		2284	B94.9	949	
Hand taps (American parallel pipe thread)		4113		B94.9		
Hand taps (American taper pipe thread)		4114		B94.9		
Hand taps (American dryseal parallel pipe thread)		4115		B94.9		
Hand taps (American dryseal taper pipe thread)		4116		B94.9		
Nut taps (Metric coarse)	B4433	4109			357	
Nut taps (Metric fine)		4110				
Nut taps (Unified coarse)		4111		B94.9		
Nut taps (Unified fine)		4112				
Machine taps (Metric coarse)						371,376
Machine taps (Metric fine)						374
Bent shank taps (Metric coarse)		4101				
Bent shank taps (Metric fine)		4102				
Bent shank taps (Unified coarse)		4103				
Bent shank taps (Unified fine)		4104				
Long shank machine taps (Metric thread)		4153	2283			
Long shank machine taps (Inch thread)		4153	2283			
Spiral pointed taps		4155		B94.9		
Spiral fluted taps		4154		B94.9		
Shell taps (Metric thread)		4117				
Pulley taps				B94.9		
Thread Forming taps				B94.9		
Blanks for carbide taps				B94.1		
Thread cutting round dies (Metric coarse, Adjustable)	B4451					223
Thread cutting round dies (Metric fine, Adjustable)	B4451					223
Thread cutting round dies (Metric, Solid)	B4451		2568		1127	223
Thread cutting round dies (Unified coarse adjustable)	B4451					
Thread cutting round dies (Unified fine adjustable)	B4451					
Thread cutting round dies (Unified thread)	B4451		2568		1127	
Thread cutting round dies (Parallel pipe thread)	B4455		4231		1127	5158
Thread cutting round dies (Taper pipe thread)	B4456		4230			5159
Hexagon dies			7226		1127	382

Symbols : Organization names

ISO : International Organization for Standardization

JIS : Japanese Industrial Standards Committee

JSCTA : The Japan Solid Cutting Tools' Association

ANSI : American National Standards Institute

BS : British Standards Institution, UK

DIN : Deutsches Institiut fur Normung

29. Hardness conversion table

■Conversion table from Rockwell C hardness of steel. (Approximate)

Rockwell C Scale Hardness	Vickers Hardness	Brinell Hardness		Rockwell Hardness※2			Rockwell Superficial Hardness			Shore Hardness	Tensile Strength MPa※1	Rockwell C Scale Hardness※2
		Standard ball	Tungsten Carbide ball	A scale	B scale	D scale	15-N scale	30-N scale	45-N scale			
HRC	HV	HB		HRA	HRB	HRD	HS15N	HS30N	HS45N	HS	–	HRC
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	66.7	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	55
54	577	–	543	78.0	–	66.1	87.4	72.0	59.8	72	2015	54
53	560	–	525	77.4	–	65.4	86.9	71.2	58.6	71	1950	53
52	544	(500)	512	76.8	–	64.6	86.4	70.2	57.4	69	1880	52
51	528	(487)	496	76.3	–	63.8	85.9	69.4	56.1	68	1820	51
50	513	(475)	481	75.9	–	63.1	85.5	68.5	55.0	67	1760	50
49	498	(464)	469	75.2	–	62.1	85.0	67.6	53.8	66	1695	49
48	484	451	455	74.7	–	61.4	84.5	66.7	52.5	64	1635	48
47	471	442	443	74.1	–	60.8	83.9	65.8	51.4	63	1580	47
46	458	432	432	73.6	–	60.0	83.5	64.8	50.3	62	1530	46
45	446	421	421	73.1	–	59.2	83.0	64.0	49.0	60	1480	45
44	434	409	409	72.5	–	58.5	82.5	63.1	47.8	58	1435	44
43	423	400	400	72.0	–	57.7	82.0	62.2	46.7	57	1385	43
42	412	390	390	71.5	–	56.9	81.5	61.3	45.5	56	1340	42
41	402	381	381	70.9	–	56.2	80.9	60.4	44.3	55	1295	41
40	392	371	371	70.4	–	55.4	80.4	59.5	43.1	54	1250	40
39	382	362	362	69.9	–	54.6	79.9	58.6	41.9	52	1215	39
38	372	353	353	69.4	–	53.8	79.4	57.7	40.8	51	1180	38
37	363	344	344	68.9	–	53.1	78.8	56.8	39.6	50	1160	37
36	354	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	1115	36
35	345	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	1080	35
34	336	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	1055	34
33	327	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	1025	33
32	318	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	1000	32
31	310	294	294	65.8	(106.0)	48.4	75.6	51.3	32.5	43	980	31
30	302	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	950	30
29	294	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	930	29
28	286	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	910	28
27	279	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	880	27
26	272	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	860	26
25	266	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	840	25
24	260	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	825	24
23	254	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	805	23
22	248	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	785	22
21	243	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	770	21
20	238	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	760	20
(18)	230	219	219	–	96.7	–	–	–	–	33	730	(18)
(16)	222	212	212	–	95.5	–	–	–	–	32	705	(16)
(14)	213	203	203	–	93.9	–	–	–	–	31	675	(14)
(12)	204	194	194	–	92.3	–	–	–	–	29	650	(12)
(10)	196	187	187	–	90.7	–	–	–	–	28	620	(10)
(8)	188	179	179	–	89.5	–	–	–	–	27	600	(8)
(6)	180	171	171	–	87.1	–	–	–	–	26	580	(6)
(4)	173	165	165	–	85.5	–	–	–	–	25	550	(4)
(2)	166	158	158	–	83.5	–	–	–	–	24	530	(2)
(0)	160	152	152	–	81.7	–	–	–	–	24	515	(0)

※1 : 1Mpa=1N/mm^2
※2 : In above table, numbers in parenthesis are only for reference.
This table is abstracted from SAE J 417.

Technical Information

Think threads with YAMAWA

30. Conversion table from inch to millimeter

■Conversion table from inch to millimeter

Designation		0"	1"	2"	3"	4"	5"	6"	7"	8"	9"
Fractional	Decimal										
0"	0"	–	25.400	50.800	76.200	101.600	127.000	152.400	177.800	203.200	228.600
1/64"	0.015625"	0.397	25.797	51.197	76.597	101.997	127.397	152.797	178.197	203.597	228.997
1/32"	0.03125"	0.794	26.194	51.594	76.994	102.394	127.794	153.194	178.594	203.994	229.394
3/64"	0.046875"	1.191	26.591	51.991	77.391	102.791	128.191	153.591	178.991	204.391	229.791
1/16"	0.0625"	1.588	26.988	52.388	77.788	103.188	128.588	153.988	179.388	204.788	230.188
5/64"	0.078125"	1.984	27.384	52.784	78.184	103.584	128.984	154.384	179.784	205.184	230.584
3/32"	0.09375"	2.381	27.781	53.181	78.581	103.981	129.381	154.781	180.181	205.581	230.981
7/64"	0.109375"	2.778	28.178	53.578	78.978	104.378	129.778	155.178	180.578	205.978	231.378
1/8"	0.125"	3.175	28.575	53.975	79.375	104.775	130.175	155.575	180.975	206.375	231.775
9/64"	0.140625"	3.572	28.972	54.372	79.772	105.172	130.572	155.972	181.372	206.772	232.172
5/32"	0.15625"	3.969	29.369	54.769	80.169	105.569	130.969	156.369	181.769	207.169	232.569
11/64"	0.171875"	4.366	29.766	55.166	80.566	105.966	131.366	156.766	182.166	207.566	232.966
3/16"	0.1875"	4.762	30.162	55.562	80.962	106.362	131.762	157.162	182.562	207.962	233.362
13/64"	0.203125"	5.159	30.559	55.959	81.359	106.759	132.159	157.559	182.959	208.359	233.759
7/32"	0.21875"	5.556	30.956	56.356	81.756	107.156	132.556	157.956	183.356	208.756	234.156
15/64"	0.234375"	5.953	31.353	56.753	82.153	107.553	132.953	158.353	183.753	209.153	234.553
1/4"	0.25"	6.350	31.750	57.150	82.550	107.950	133.350	158.750	184.150	209.550	234.950
17/64"	0.265625"	6.747	32.147	57.547	82.947	108.347	133.747	159.147	184.547	209.947	235.347
9/32"	0.28125"	7.144	32.544	57.944	83.344	108.744	134.144	159.544	184.944	210.344	235.744
19/64"	0.296875"	7.541	32.941	58.341	83.741	109.141	134.541	159.941	185.341	210.741	236.141
5/16"	0.3125"	7.938	33.338	58.738	84.138	109.538	134.938	160.338	185.738	211.138	236.538
21/64"	0.328125"	8.334	33.734	59.134	84.534	109.934	135.334	160.734	186.134	211.534	236.934
11/32"	0.34375"	8.731	34.131	59.531	84.931	110.331	135.731	161.131	186.531	211.931	237.331
23/64"	0.359375"	9.128	34.528	59.928	85.328	110.728	136.128	161.528	186.928	212.328	237.728
3/8"	0.375"	9.525	34.925	60.325	85.725	111.125	136.525	161.925	187.325	212.725	238.125
25/64"	0.390625"	9.922	35.322	60.722	86.122	111.522	136.922	162.322	187.722	213.122	238.522
13/32"	0.40625"	10.319	35.719	61.119	86.519	111.919	137.319	162.719	188.119	213.519	238.919
27/64"	0.421875"	10.716	36.116	61.516	86.916	112.316	137.716	163.116	188.516	213.916	239.316
7/16"	0.4375"	11.112	36.512	61.912	87.312	112.712	138.112	163.512	188.912	214.312	239.712
29/64"	0.453125"	11.509	36.909	62.309	87.709	113.109	138.509	163.909	189.309	214.709	240.109
15/32"	0.46875"	11.906	37.306	62.706	88.106	113.506	138.906	164.306	189.706	215.106	240.506
31/64"	0.484375"	12.303	37.703	63.103	88.503	113.903	139.303	164.703	190.103	215.503	240.903
1/2"	0.5"	12.700	38.100	63.500	88.900	114.300	139.700	165.100	190.500	215.900	241.300
33/64"	0.515625"	13.097	38.497	63.897	89.297	114.697	140.097	165.497	190.897	216.297	241.697
17/32"	0.53125"	13.494	38.894	64.294	89.694	115.094	140.494	165.894	191.294	216.694	242.094
35/64"	0.546875"	13.891	39.291	64.691	90.091	115.491	140.891	166.291	191.691	217.091	242.491
9/16"	0.5625"	14.288	39.688	65.088	90.488	115.888	141.288	166.688	192.088	217.488	242.888
37/64"	0.578125"	14.684	40.084	65.484	90.884	116.284	141.684	167.084	192.484	217.884	243.284
19/32"	0.59375"	15.081	40.481	65.881	91.281	116.681	142.081	167.481	192.881	218.281	243.681
39/64"	0.609375"	15.478	40.878	66.278	91.678	117.078	142.478	167.878	193.278	218.678	244.078
5/8"	0.625"	15.875	41.275	66.675	92.075	117.475	142.875	168.275	193.675	219.075	244.475
41/64"	0.640625"	16.272	41.672	67.072	92.472	117.872	143.272	168.672	194.072	219.472	244.872
21/32"	0.65625"	16.669	42.069	67.469	92.869	118.269	143.669	169.069	194.469	219.869	245.269
43/64"	0.671875"	17.066	42.466	67.866	93.266	118.666	144.066	169.466	194.866	220.266	245.666
11/16"	0.6875"	17.462	42.862	68.262	93.662	119.062	144.462	169.862	195.262	220.662	246.062
45/64"	0.703125"	17.859	43.259	68.659	94.059	119.459	144.859	170.259	195.659	221.059	246.459
23/32"	0.71875"	18.256	43.656	69.056	94.456	119.856	145.256	170.656	196.056	221.456	246.856
47/64"	0.734375"	18.653	44.053	69.453	94.853	120.253	145.653	171.053	196.453	221.853	247.253
3/4"	0.75"	19.050	44.450	69.850	95.250	120.650	146.050	171.450	196.850	222.250	247.650
49/64"	0.765625"	19.447	44.847	70.247	95.647	121.047	146.447	171.847	197.247	222.647	248.047
25/32"	0.78125"	19.844	45.244	70.644	96.044	121.444	146.844	172.244	197.644	223.044	248.444
51/64"	0.796875"	20.241	45.641	71.041	96.441	121.841	147.241	172.641	198.041	223.441	248.841
13/16"	0.8125"	20.638	46.038	71.438	96.838	122.238	147.638	173.038	198.438	223.838	249.238
53/64"	0.828125"	21.034	46.434	71.834	97.234	122.634	148.034	173.434	198.834	224.234	249.634
27/32"	0.84375"	21.431	46.831	72.231	97.631	123.031	148.431	173.831	199.231	224.631	250.031
55/64"	0.859375"	21.828	47.228	72.628	98.028	123.428	148.828	174.228	199.628	225.028	250.428
7/8"	0.875"	22.225	47.625	73.025	98.425	123.825	149.225	174.625	200.025	225.425	250.825
57/64"	0.890625"	22.622	48.022	73.422	98.822	124.222	149.622	175.022	200.422	225.822	251.222
29/32"	0.90625"	23.019	48.419	73.819	99.219	124.619	150.019	175.419	200.819	226.219	251.619
59/64"	0.921875"	23.416	48.816	74.216	99.616	125.016	150.416	175.816	201.216	226.616	252.016
15/16"	0.9375"	23.812	49.212	74.612	100.012	125.412	150.812	176.212	201.612	227.012	252.412
61/64"	0.953125"	24.209	49.609	75.009	100.409	125.809	151.209	176.609	202.009	227.409	252.809
31/32"	0.96875"	24.606	50.006	75.406	100.806	126.206	151.606	177.006	202.406	227.806	253.206
63/64"	0.984375"	25.003	50.403	75.803	101.203	126.603	152.003	177.403	202.803	228.203	253.603

31. Chemical Component table of work materials

The name of work materials and material Symbols			Chemical Composition (%)							
			C	Si	Mn	P	S	Ni	Cr	Mo
Carbon steels for machine structural use	Low carbon steels	S10C	0.08～0.13	0.15～0.35	0.30～0.60	0.030≧	0.035≧	—	—	—
		S15C	0.13～0.18	0.15～0.35	0.30～0.60	0.030≧	0.035≧	—	—	—
		S20C	0.18～0.23	0.15～0.35	0.30～0.60	0.030≧	0.035≧	—	—	—
	Medium carbon steels	S25C	0.22～0.28	0.15～0.35	0.30～0.60	0.030≧	0.035≧	—	—	—
		S35C	0.32～0.38	0.15～0.35	0.60～0.90	0.030≧	0.035≧	—	—	—
		S45C	0.42～0.48	0.15～0.35	0.60～0.90	0.030≧	0.035≧	—	—	—
	High carbon steels	S48C	0.45～0.51	0.15～0.35	0.60～0.90	0.030≧	0.035≧	—	—	—
		S55C	0.52～0.58	0.15～0.35	0.60～0.90	0.030≧	0.035≧	—	—	—
		S58C	0.55～0.61	0.15～0.35	0.60～0.90	0.030≧	0.035≧	—	—	—
Alloy steels for machine structural use	Chromium Molybdenum Steels	SCM415	0.13～0.18	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.25
		SCM418	0.16～0.21	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.25
		SCM420	0.18～0.23	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.25
		SCM430	0.28～0.33	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.30
		SCM435	0.33～0.38	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.30
		SCM440	0.38～0.43	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.30
		SCM445	0.43～0.48	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	0.15～0.30
	Nickel Chromium Steels	SNC236	0.32～0.40	0.15～0.35	0.50～0.90	0.030≧	0.030≧	1.00～1.50	0.50～0.90	—
		SNC415	0.12～0.18	0.15～0.35	0.35～0.65	0.030≧	0.030≧	2.00～2.50	0.20～0.50	—
		SNC631	0.27～0.35	0.15～0.35	0.35～0.65	0.030≧	0.030≧	2.50～3.00	0.60～1.00	—
		SNC815	0.12～0.18	0.15～0.35	0.35～0.65	0.030≧	0.030≧	3.00～3.50	0.60～1.00	—
	Chromium Steels	SCr415	0.13～0.18	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	—
		SCr420	0.18～0.23	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	—
		SCr430	0.28～0.33	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	—
		SCr440	0.38～0.43	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.25≧	0.90～1.20	—
	Nickel Chromium Molybdenum Steels	SNCM220	0.17～0.23	0.15～0.35	0.60～0.90	0.030≧	0.030≧	0.40～0.70	0.40～0.60	0.15～0.25
		SNCM240	0.38～0.43	0.15～0.35	0.70～1.00	0.030≧	0.030≧	0.40～0.70	0.40～0.60	0.15～0.30
		SNCM420	0.17～0.23	0.15～0.35	0.40～0.70	0.030≧	0.030≧	1.60～2.00	0.40～0.60	0.15～0.30
		SNCM439	0.36～0.43	0.15～0.35	0.60～0.90	0.030≧	0.030≧	1.60～2.00	0.60～1.00	0.15～0.30

Chemical Composition (%)					Mechanical Property of Standard test block		
W	V	Pb	Cu	others	Tensile strength (N/mm²)	Hardness	Heat treatment of standard test block
－	－	－	－	－	314≦	109〜156 HB	900〜950℃ normalizing
－	－	－	－	－	373≦	111〜167 HB	880〜930℃ normalizing
－	－	－	－	－	402≦	116〜174 HB	870〜920℃ normalizing
－	－	－	－	－	441≦	123〜183 HB	860〜910℃ normalizing
－	－	－	－	－	510≦	149〜207 HB	840〜890℃ normalizing
					569≦	167〜235 HB	840〜890℃ water hardening・550〜650℃ air hardening
－	－	－	－	－	569≦	167〜229 HB	820〜870℃ normalizing
					686≦	201〜269 HB	820〜870℃ water hardening・550〜650℃ air hardening
－	－	－	－	－	608≦	179〜235 HB	810〜860℃ normalizing
					735≦	212〜277 HB	810〜860℃ water hardening・550〜650℃ air hardening
－	－	－	－	－	647≦	183〜255 HB	800〜850℃ normalizing
					785≦	229〜285 HB	800〜850℃ water hardening・550〜650℃ air hardening
－	－	－	－	－	647≦	183〜255 HB	800〜850℃ normalizing
					785≦	229〜285 HB	800〜850℃ water hardening・550〜650℃ air hardening
－	－	－	－	－	834≦	235〜321 HB	850〜900℃ Oil hardening 800〜850℃ Oil hardening 150〜200℃ tempering
－	－	－	－	－	883≦	248〜331 HB	
－	－	－	－	－	932≦	262〜352 HB	
－	－	－	－	－	834≦	241〜302 HB	830〜880℃ Oil hardening・530〜630℃ air hardening 150〜200℃ tempering
－	－	－	－	－	932≦	269〜331 HB	
－	－	－	－	－	980.7≦	285〜352 HB	
－	－	－	－	－	1030≦	302〜363 HB	
－	－	－	－	－	736≦	217〜277 HB	820〜880℃ Oil hardening・550〜650℃ air hardening 150〜200℃ tempering
－	－	－	－	－	785≦	235〜341 HB	850〜900℃ Oil hardening 740〜790℃ Water hardening 150〜200℃ tempering
－	－	－	－	－	834≦	248〜302 HB	820〜880℃ Oil hardening・550〜650℃ air hardening
－	－	－	－	－	980.7≦	285〜388 HB	830〜880℃ Oil hardening 750〜800℃ Oil hardening 150〜200℃ tempering
－	－	－	－	－	785≦	217〜302 HB	850〜900℃ Oil hardening 800〜850℃ Oil hardening 150〜200℃ tempering
－	－	－	－	－	834≦	235〜321 HB	
－	－	－	－	－	785≦	229〜293 HB	830〜880℃ Oil hardening・520〜620℃ air hardening 150〜200℃ tempering
－	－	－	－	－	932≦	269〜331 HB	
－	－	－	－	－	834≦	248〜341 HB	850〜900℃ Oil hardening 800〜850℃ Oil hardening 150〜200℃ tempering
－	－	－	－	－	883≦	255〜311 HB	820〜870℃ Oil hardening・580〜680℃ air hardening 150〜200℃ tempering
－	－	－	－	－	980.7≦	293〜375 HB	850〜900℃ Oil hardening 770〜820℃ Oil hardening 150〜200℃ tempering
－	－	－	－	－	980.7≦	293〜352 HB	820〜870℃ Oil hardening・580〜680℃ air hardening 150〜200℃ tempering

31. Chemical Component table of work materials

The name of work materials and material Symbols			Chemical Composition (%)							
			C	Si	Mn	P	S	Ni	Cr	Mo
Alloy steels for machine structural use	Nickel Chromium Molybdenum Steels	SNCM625	0.20〜0.30	0.15〜0.35	0.35〜0.60	0.030≧	0.030≧	3.00〜 3.50	1.00〜 1.50	0.15〜0.30
		SNCM630	0.25〜0.35	0.15〜0.35	0.35〜0.60	0.030≧	0.030≧	2.50〜 3.50	2.50〜 3.50	0.50〜0.70
		SNCM815	0.12〜0.18	0.15〜0.35	0.30〜0.60	0.030≧	0.030≧	4.00〜 4.50	0.70〜 1.00	0.15〜0.30
Tool steels	Chromium Tool steels	SK2	1.15〜1.25	0.10〜0.35	0.10〜0.50	0.030≧	0.030≧	—	—	—
		SK4	0.90〜1.00	0.10〜0.35	0.10〜0.50	0.030≧	0.030≧	—	—	—
		SK6	0.70〜0.80	0.10〜0.35	0.10〜0.50	0.030≧	0.030≧	—	—	—
	Alloys Tool steels	SKS11	1.20〜1.30	0.35≧	0.50≧	0.030≧	0.030≧	—	0.20〜 0.50	—
		SKS51	0.75〜0.85	0.35≧	0.50≧	0.030≧	0.030≧	1.30〜 2.00	0.20〜 0.50	—
		SKS4	0.45〜0.55	0.35≧	0.50≧	0.030≧	0.030≧	—	0.50〜 1.00	—
		SKS3	0.90〜1.00	0.35≧	0.90〜1.20	0.030≧	0.030≧	—	0.50〜 1.00	—
		SKS94	0.90〜1.00	0.50≧	0.80〜1.10	0.030≧	0.030≧	—	0.20〜 0.60	—
		SKD11	1.40〜1.60	0.40≧	0.60≧	0.030≧	0.030≧	—	11.00〜13.00	0.80〜1.20
		SKD61	0.35〜0.42	0.80〜1.20	0.25〜0.50	0.030≧	0.020≧	—	4.80〜 5.50	1.00〜1.50
		SKT3	0.50〜0.60	0.35≧	0.60〜1.00	0.030≧	0.020≧	0.25〜 0.60	0.90〜 1.20	0.30〜0.50
		SKT4	0.50〜0.60	0.10〜0.40	0.60〜0.90	0.030≧	0.020≧	1.50〜 1.80	0.80〜 1.20	0.35〜0.55
Stainless steels	Austenite type	SUS301	0.15≧	1.00≧	2.00≧	0.045≧	0.030≧	6.00〜 8.00	16.00〜18.00	—
		SUS303	0.15≧	1.00≧	2.00≧	0.20≧	0.15≦	8.00〜10.00	17.00〜19.00	—
		SUS304	0.08≧	1.00≧	2.00≧	0.045≧	0.030≧	8.00〜10.50	18.00〜20.00	—
		SUS316	0.08≧	1.00≧	2.00≧	0.045≧	0.030≧	10.00〜14.00	16.00〜18.00	2.00〜3.00
	Martensite type	SUS403	0.15≧	0.50≧	1.00≧	0.040≧	0.030≧	—	11.50〜13.00	—
		SUS416	0.15≧	1.00≧	1.25≧	0.060≧	0.15≦	—	12.00〜14.00	—
		SUS420J2	0.26〜0.40	1.00≧	1.00≧	0.040≧	0.030≧	—	12.00〜14.00	—
		SUS440C	0.95〜1.20	1.00≧	1.00≧	0.040≧	0.030≧	—	16.00〜18.00	—
	Ferrite type	SUS430	0.12≧	0.75≧	1.00≧	0.040≧	0.030≧	—	16.00〜18.00	—
	Precipitation hardening	SUS630	0.07≧	1.00≧	1.00≧	0.040≧	0.030≧	3.00〜 5.00	15.00〜17.50	—
Cast steels	Carbon steels Cast steels	SC360	0.20≧	—	—	0.040≧	0.040≧	—	—	—
		SC410	0.30≧	—	—	0.040≧	0.040≧	—	—	—
		SC450	0.35≧	—	—	0.040≧	0.040≧	—	—	—
		SC480	0.40≧	—	—	0.040≧	0.040≧	—	—	—
	Stainless steels casting	SCS13	0.08≧	2.00≧	2.00≧	0.040≧	0.040≧	8.00〜11.00	18.00〜21.00	—
		SCS14	0.08≧	2.00≧	2.00≧	0.040≧	0.040≧	10.00〜14.00	17.00〜20.00	2.00〜3.00
	Steel casting for high temperature and high pressure	SCPH1	0.25≧	0.60≧	0.70≧	0.040≧	0.040≧	—	—	—
		SCPH2	0.30≧	0.60≧	1.00≧	0.040≧	0.040≧	—	—	—
		SCPH21	0.20≧	0.60≧	0.50〜0.80	0.040≧	0.040≧	—	1.00〜 1.50	0.45〜0.65
		SCPH32	0.20≧	0.60≧	0.50〜0.80	0.040≧	0.040≧	—	2.00〜 2.75	0.90〜1.20
	Steel casting for welded structure	SCW480	0.22≧	0.80≧	1.50≧	0.040≧	0.040≧	0.50≧	0.50≧	—

Chemical Composition (%)					Mechanical Property of Standard test block		
W	V	Pb	Cu	others	Tensile strength (N/mm²)	Hardness	Heat treatment of standard test block
–	–	–	–	–	932≦	269～321 HB	820～870℃ oil hardening・570～670℃ air hardening
–	–	–	–	–	1079≦	302～352 HB	850～950℃ normalizing・550～650℃ air hardening
–	–	–	–	–	1079≦	311～375 HB	830～880℃ Oil hardening 750～800℃ Oil hardening 150～200℃ tempering
–	–	–	–	–	–	212 HB≦	750～780℃ annealing
–	–	–	–	–	–	207 HB≦	740～760℃ annealing
–	–	–	–	–	–	201 HB≦	730～760℃ annealing
3.00～4.00	0.10～0.30	–	–	–	–	241 HB≦	780～850℃ annealing
–	–	–	–	–	–	207 HB≦	750～800℃ annealing
0.50～1.00	–	–	–	–	–	201 HB≦	740～780℃ annealing
0.50～1.00	–	–	–	–	–	217 HB≦	750～800℃ annealing
–	–	–	–	–	–	212 HB≦	740～760℃ annealing
–	0.20～0.50	–	–	–	–	255 HB≦	830～880℃ annealing
–	0.80～1.15	–	–	–	–	229 HB≦	820～870℃ annealing
–	–	–	–	–	–	235 HB≦	760～810℃ annealing
–	0.05～0.15	–	–	–	–	241 HB≦	740～800℃ annealing
–	–	–	–	–	520≦	187 HB≦	1010～1150℃ solution treatment
–	–	–	–	–	520≦	187 HB≦	
–	–	–	–	–	520≦	187 HB≦	
–	–	–	–	–	520≦	187 HB≦	
–	–	–	–	–	–	200 HB≦	800～900℃ annealing
–	–	–	–	–	–	200 HB≦	
–	–	–	–	–	–	235 HB≦	
–	–	–	–	–	–	269 HB≦	800～920℃ annealing
–	–	–	–	–	451≦	183 HB≦	780～850℃ normalizing
–	–	–	3.00～5.00	Nb0.15～0.45	–	363 HB≦	1020～1060℃ solution treatment
–	–	–	–	–	363≦	–	annealing, normalizing, or normalizing, tempering
–	–	–	–	–	412≦	–	
–	–	–	–	–	451≦	–	
–	–	–	–	–	481≦	–	
–	–	–	–	–	440≦	183 HB≦	1030～1150℃ solution treatment
–	–	–	–	–	480≦	183 HB≦	
–	–	–	–	–	412≦	–	annealing, normalizing, or normalizing, tempering
–	–	–	–	–	481≦	–	
–	–	–	–	–	481≦	–	
–	–	–	–	–	481≦	–	
–	–	–	–	–	480≦	–	

31. Chemical Component table of work materials

The name of work materials and material Symbols			Chemical Composition (%)							
			C	Si	Mn	P	S	Ni	Cr	Mo
Cast irons	Gray iron castings	FC150	—	—	—	—	—	—	—	—
		FC200	—	—	—	—	—	—	—	—
		FC250	—	—	—	—	—	—	—	—
		FC300	—	—	—	—	—	—	—	—
		FC350	—	—	—	—	—	—	—	—
Tough cast irons Ductile cast irons	Spheroidal graphite Cast irons	FCD400	2.5≧	—	—	—	0.02≧	—	—	—
		FCD450	2.5≧	—	—	—	0.02≧	—	—	—
		FCD500	2.5≧	—	—	—	0.02≧	—	—	—
		FCD600	2.5≧	—	—	—	0.02≧	—	—	—
		FCD700	2.5≧	—	—	—	0.02≧	—	—	—
High carbon chromium bearing steels		SUJ2	0.95〜1.10	0.15〜0.35	0.50≧	0.025≧	0.025≧	—	1.30〜1.60	—
		SUJ3	0.95〜1.10	0.40〜0.70	0.90〜1.15	0.025≧	0.025≧	—	0.90〜1.20	—
		SUJ4	0.95〜1.10	0.15〜0.35	0.50≧	0.025≧	0.025≧	—	1.30〜1.60	0.10〜0.25
		SUJ5	0.95〜1.10	0.40〜0.70	0.90〜1.15	0.025≧	0.025≧	—	0.90〜1.20	0.10〜0.25
Free cutting carbon steels		SUM22	0.13≧	—	0.70〜1.00	0.07〜0.12	0.24〜0.33	—	—	—
		SUM22L	0.13≧	—	0.70〜1.00	0.07〜0.12	0.24〜0.33	—	—	—
		SUM31	0.14〜0.20	—	1.00〜1.30	0.040≧	0.08〜0.13	—	—	—
		SUM31L	0.14〜0.20	—	1.00〜1.30	0.040≧	0.08〜0.13	—	—	—
		SUM42	0.37〜0.45	—	1.35〜1.65	0.040≧	0.08〜0.13	—	—	—
Rolled steels for general structure		SS330	—	—	—	0.050≧	0.050≧	—	—	—
		SS400	—	—	—	0.050≧	0.050≧	—	—	—
		SS490	—	—	—	0.050≧	0.050≧	—	—	—
		SS540	0.30≧	—	1.60≧	0.040≧	0.040≧	—	—	—
Cold-reduced carbon steel sheets		SPCC	0.15≧	—	0.60≧	0.100≧	0.035≧	—	—	—
		SPCD	0.10≧	—	0.50≧	0.040≧	0.035≧	—	—	—
		SPCE	0.08≧	—	0.45≧	0.030≧	0.030≧	—	—	—

Chemical Composition (%)					Mechanical Property of Standard test block		
W	V	Pb	Cu	others	Tensile strength (N/mm²)	Hardness	Heat treatment of standard test block
–	–	–	–	–	127～186	210～241 HB	
–	–	–	–	–	167～235	217～255 HB	
–	–	–	–	–	216～275	229～269 HB	–
–	–	–	–	–	265～304	248～269 HB	
–	–	–	–	–	314～343	269～277 HB	
–	–	–	–	–	392≦	201 HB ≧	
–	–	–	–	–	441≦	143～217 HB	
–	–	–	–	–	490≦	170～241 HB	–
–	–	–	–	–	588≦	192～269 HB	
–	–	–	–	–	686≦	229～302 HB	
–	–	–	–	–	–	201 HB ≧	
–	–	–	–	–	–	207 HB ≧	spheroidizing
–	–	–	–	–	–	201 HB ≧	
–	–	–	–	–	–	207 HB ≧	
–	–	–	–	–			
–	–	0.10～0.35	–	–			
–	–	–	–	–	–	–	–
–	–	0.10～0.35	–	–			
–	–	–	–	–			
–	–	–	–	–	330～430		
–	–	–	–	–	400～510	–	
–	–	–	–	–	490～610		–
–	–	–	–	–	540≦		
–	–	–	–	–			
–	–	–	–	–	270≦	65 HRB ≧	Standerd thermal refining
–	–	–	–	–			

31. Chemical Component table of work materials

The name of work materials and material Symbols			Chemical Composition (%)									
			Cu	Pb	Fe	Sn	Zn	Al	Mn	Ni	P	Si
Copper	Oxygen free high conductivity copper	C1020	99.96≦	—	—	—	—	—	—	—	—	—
	tough pitch copper	C1100	99.90≦	—	—	—	—	—	—	—	—	—
	Phosphor deoxidized copper	C1201	99.90≦	—	—	—	—	—	—	—	0.004～0.015	—
		C1221	99.75≦	—	—	—	—	—	—	—	0.004～0.040	—
Brass	Brass	C2600	68.5～71.5	0.05≧	0.05≧	—	remaining	—	—	—	—	—
		C2720	62.0～64.0	0.05≧	0.05≧	—	remaining	—	—	—	—	—
		C2801	59.0～62.0	0.10≧	0.07≧	—	remaining	—	—	—	—	—
	Free cutting brass	C3560	61.0～64.0	2.0～3.0	0.10≧	—	remaining	—	—	—	—	—
		C3713	58.0～62.0	1.0～2.0	0.10≧	—	remaining	—	—	—	—	—
Bras s casting		CAC201	83.0～88.0	0.5≧	0.2≧	0.1≧	11.0～17.0	0.2≧	—	0.2≧	—	—
		CAC203	58.0～64.0	0.5～3.0	0.8≧	1.0≧	30.0～41.0	0.5≧	—	1.0≧	—	—
Bronze casting		CAC401	79.0～83.0	3.0～7.0	0.35≧	2.0～4.0	8.0～12.0	—	—	1.0≧	—	—
		CAC403	86.5～89.5	1.0≧	0.2≧	9.0～11.0	1.0～3.0	—	—	1.0≧	—	—
		CAC406	83.0～87.0	4.0～6.0	0.3≧	4.0～6.0	4.0～6.0	—	—	1.0≧	—	—
Aluminum alloy	Aluminum rolling material	A1080 / A1080-H16	0.03≧	—	0.15≧	—	0.03≧	99.80≦	0.02≧	—	—	0.15≧
		A2017 / A2017-T3	3.5～4.5	—	0.7≧	—	0.25≧	remaining	0.40～1.0	—	—	0.20～0.8
		A3003 / A3003-H16	0.05～0.20	—	0.7≧	—	0.10≧	remaining	1.0～1.5	—	—	0.6≧
		A5052 / A5052-H16	0.10≧	—	0.4≧	—	0.10≧	remaining	0.10≧	—	—	0.25≧
		A6061 / A6061-T6	0.15～0.40	—	0.7≧	—	0.25≧	remaining	0.15≧	—	—	0.40～0.8
		A7075 / A7075-T6	1.2～2.0	—	0.50≧	—	5.1～6.1	remaining	0.30≧	—	—	0.40≧
	Aluminum alloy casting	AC2A-F / AC2A-T6	3.0～4.5	0.15≧	0.8≧	0.05≧	0.55≧	remaining	0.55≧	0.30≧	—	4.0～6.0
		AC2B-F / AC2B-T6	2.0～4.0	0.20≧	1.0≧	0.10≧	1.0≧	remaining	0.50≧	0.35≧	—	5.0～7.0
		AC4B-F / AC4B-T6	2.0～4.0	0.20≧	1.0≧	0.10≧	1.0≧	remaining	0.50≧	0.35≧	—	7.0～10.0
		AC4C-F / AC4C-T6	0.20≧	0.05≧	0.50≧	0.05≧	0.30≧	remaining	0.60≧	0.05≧	—	6.5～7.5
	Aluminum alloy diecasting	ADC10	2.0～4.0	0.2≧	1.3≧	0.2≧	1.0≧	remaining	0.5≧	0.5≧	—	7.5～9.5
		ADC12	1.5～3.5	0.2≧	1.3≧	0.2≧	1.0≧	remaining	0.5≧	0.5≧	—	9.6～12.0

Chemical Composition (%)							Mechanical Property of Standard test block		
Mg	Cr	Ti	Zr	Zr+Ti,V,Zr	Cd	others	Tensile strength (N/mm²)	Hardness	Heat treatment of standard test block
–	–	–	–	–	–	–	215～275	55～100 HV	C1020P-¼H
–	–	–	–	–	–	–	215～275	55～100 HV	C1100P-¼H
–	–	–	–	–	–	–	215～275	55～100 HV	C1201P-¼H
–	–	–	–	–	–	–	215～275	55～100 HV	C1221P-¼H
–	–	–	–	–	–	–	325～410	75～125 HV	C2600P-¼H
–	–	–	–	–	–	–	325～410	75～125 HV	C2720P-¼H
–	–	–	–	–	–	–	355～440	85～145 HV	C2801P-¼H
–	–	–	–	–	–	–	345～430	–	C3560P-¼H
–	–	–	–	–	–	–	375～460	–	C3713P-¼H
–	–	–	–	–	–	–	147≦	–	–
–	–	–	–	–	–	–	245≦	–	
–	–	–	–	–	–	impurity 2.0≧	167≦	–	–
–	–	–	–	–	–	impurity 1.0≧	245≦	–	
–	–	–	–	–	–	impurity 2.0≧	196≦	–	
0.02≧	–	0.03≧	–	–	–	–	54～94	–	annealing
							98～137	–	thermal refining
0.40～0.8	0.10≧	0.15≧	–	–	–	0.15≧	216≧	–	annealing
							373≦	–	–
–	–	–	–	–	–	0.15≧	94～127	–	annealing
							167～206	–	thermal refining
2.2～2.8	0.15～0.35	–	–	–	–	0.15≧	177～216	–	annealing
							255～304	–	thermal refining
0.8～1.2	0.04～0.35	0.15≧	–	–	–	0.15≧	147≧	–	annealing
							294≦	–	–
2.1～2.9	0.18～0.28	0.20≧	–	–	–	0.15≧	275≧	–	annealing
							530≦	–	–
0.25≧	0.15≧	0.20≧	–	–	–	–	186≦	about 75 HB	casted
							275≦	about 90 HB	–
0.50≧	0.20≧	0.20≧	–	–	–	–	157≦	about 70 HB	casted
							245≦	about 90 HB	–
0.50≧	0.20≧	0.20≧	–	–	–	–	177≦	about 80 HB	casted
							245≦	about 100 HB	–
0.2～0.4	–	0.20≧	–	–	–	–	157≦	about 55 HB	casted
							226≦	about 85 HB	–
0.3≧	–	0.3≧	–	–	–	–	–	–	–
0.3≧	–	0.3≧	–	–	–	–			

31. Chemical Component table of work materials

The name of work materials and material Symbols			Chemical Composition (%)									
			Cu	Pb	Fe	Sn	Zn	Al	Mn	Ni	P	Si
Magnesium alloy Casting	Magnesium alloy	MC1-F	0.10≧	—	—	—	2.5~3.5	5.3~6.7	0.15~0.6	0.01≧	—	0.30≧
		MC1-T6	—	—	—	—	—	—	—	—	—	—
		MC3-F	0.10≧	—	—	—	1.6~2.4	8.3~9.7	0.10~0.5	0.01≧	—	0.30≧
		MC3-T6	—	—	—	—	—	—	—	—	—	—
		MC6-T5	0.10≧	—	—	—	3.6~5.5	—	—	0.01≧	—	—
	Magnesium alloy diecasting	MDC1A	0.10≧	—	—	—	0.35~1.0	8.3~9.7	0.15≦	0.03≧	—	0.50≧
		MDC1B	0.35≧	—	0.03≧	—	0.35~1.0	8.3~9.7	0.13~0.5	0.03≧	—	0.50≧
Zinc alloy	Zinc alloy diecasting	ZDC1	0.75~1.25	0.005≧	0.10≧	0.003≧	emaining	3.5~4.3	—	—	—	—
		ZDC2	0.25≧	0.005≧	0.10≧	0.003≧	emaining	3.5~4.3	—	—	—	—

■Category and brevity code of thermoplastic resin

name	symbol
ASB resin	ASB
Acetal resin	POM
Methacrylic resin	PMMA
Acetyl cellulose	CA
Tetrafluoride ethylene resin	PTFE
Trifluoride ethylene resin	PCTEF
Hexafluoride ethylene resin	PFEP
Fluoride vinyl resin	PVF
Fluoride vinyliden resin	PVDF
Ethylene tetrafluoride ethylene copolymer	ETFE
Ionomer	IO
Methyl Benzene polyme	MPP
Nylon (Polyamide)	PA
Polycarbonate	PC
Polyethylene	PE

name	symbol
Polyethylene tephthalate	PETP
Polyethylene telephthalate	PBTP
Polyimid	PI
Polyphenylene oxide	PPO
Polyphenylene sulfide	PPS
Polyalysulfone	PASF
Polyarlylate	PAR
Polypropylene	PP
Polystyrene	PS
Polysulfone	PSF
Vinyl acetate resin	PVAC
Vinylidene chloride fiber	PVDC
AS resin	SAN
Vinyl chloride resin	PVC

・Thermoplastic resin : As temperature rises, this resin becomes soft → gammy → fluidity liquid. For example, polystyrene (PS) is like glass at normal temperature. From 60℃ and higher its elastic modules decreases, from 110℃ it becomes gammy, and higher than 170℃, it becomes sticky paste.

Chemical Composition (%)							Mechanical Property of Standard test block		
Mg	Cr	Ti	Zr	Zr+Ti,V,Zr	Cd	others	Tensile strength (N/mm²)	Hardness	Heat treatment of standard test block
remaining	–	–	–	–	–	–	177≦	–	Casted
–	–	–	–	–	–	–	235≦		–
remaining	–	–	–	–	–	–	157≦		Casted
–	–	–	–	–	–	–	235≦		–
remaining	–	–	0.50～1.0	–	–	–	235≦		–
remaining	–	–	–	–	–	–	–	–	–
remaining	–	–	–	–	–	–			
0.020～0.06	–	–	–	–	0.004≧	–	–	–	–
0.020～0.06	–	–	–	–	0.004≧	–			

■Kinds of thermosetting plastics and symbols

name	symbol
Alkyd resin	Alk
Allyl resin	DAP
Urea resin	UF
Melamine resin	MF
Epoxy resin	EP

name	symbol
Phenol resin	PF
Unsaturated polyester resin	UP
Silicone resin	SI
Polyurethane	PUR

・Thermosetting resin : Heated at 80 °C, it becomes sticky paste with fluidity. Then it is injected into the mould under pressure. Once hardened, the plastics does not get soft owing to polymer processing.

32. Materials used for Cutting Tools

■Materials

We have been seeking the best materials used for cutting tools since the company establishment because the performance of tools are depending on the selection of materials used. Major materials used in our company are listed below.

(1) Taps	● HSS :	Equivalent to SKH58, SKH51, SKH56 Powder HSS (SKH10, High Vanadium High cobalt material)
	● Carbide :	Cemented Carbide Materials of ultra micro grain
(2) Dies	● HSS :	SKH51, SKH56
	● Alloy Tool Steel :	SKS2, SKS21, SKS3, SKS31
(3) Center Drills and Centering Tools	● HSS :	SKH51, SKH56 Powder HSS (SKH10, High Vanadium High cobalt material)
	● Carbide :	Cemented Carbide Materials of ultra micro grain

※For product's improvement, material may be changed without notice.

■Circumstance of tools' materials

Tensile strength, heat resistance, corrosion resistance and accuracy are the important features required of tool' s materials. These requirements have been changing due to miniaturization and lightening of parts.

And manufacturing methods, as well, have been changing because of necessity of economical efficiency such as saving process/cycle time while parts become hard-to-machine type and their hardness increases.

As a result, the demand of industrial tools by users has become very tough.

For example, higher wear resistance and chipping resistance are required in the area of hardness, and heavy cutting process or high-speed cutting are required in the area of cycle time.

Moreover, product accuracy with its rigidity, laborsaving brought by uniformity, and systematic reliability are highly required.

Therefore, technological improvement of tool steels never stops developing so that they satisfy users needs.

○The major materials used for taps are already listed in the chart, but those materials are ready to develop from conventional alloy tool steels and current high speed steel into next generation materials such as cemented carbide and cermet materials.

New materials are developed even in high-speed tool steel area, such as SKH51 and SKH58 from SKH2, and they are moving into high performance materials, such as high vanadium, cobalt, and powder HSS made of high vanadium and high cobalt contents.

○As the material for round dies, were alloy tool steels mostly used because of the relationship with the use of adjustable round dies. However, for the hard-to-machine material. die material has been shifted into High Speed Steel.

○Major materials for center drills and centering tools are high speed steel materials, but they have been shifting to cobalt type or even cemented carbide from SKH51.

We keep on seeking to develop our technology to meet user's needs and are trying to find the best materials in collaboration with steel manufacturers.

■Chemical composition of the materials specified in JIS

Classification	Symbols	Chemical composition									
		C	Si	Mn	P	S	Cr	Mo	W	V	Co
W type HSS	SKH 2	0.73～0.83	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	—	17.20～18.70	1.00～1.20	—
	SKH 3	0.73～0.83	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	—	17.00～19.00	0.80～1.20	4.50～ 5.50
	SKH 4	0.73～0.83	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	—	17.00～19.00	1.00～1.50	9.00～11.00
	SKH10	1.45～1.60	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	—	11.50～13.50	4.20～5.20	4.20～ 5.20
Mo type HSS	SKH51	0.80～0.88	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	4.70～ 5.20	5.90～ 6.70	1.70～2.10	—
	SKH52	1.00～1.10	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	5.50～ 6.50	5.90～ 6.70	2.30～2.80	—
	SKH53	1.15～1.25	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	4.70～ 5.20	5.90～ 6.70	2.70～3.20	—
	SKH54	1.25～1.40	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	4.20～ 5.00	5.20～ 6.00	3.70～4.20	—
	SKH55	0.87～0.95	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	4.70～ 5.20	5.90～ 6.70	1.70～2.10	4.50～ 5.00
	SKH56	0.85～0.95	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	4.70～ 5.20	5.90～ 6.70	1.70～2.10	7.00～ 9.00
	SKH57	1.20～1.35	≦0.45	≦0.4	≦0.030	≦0.030	3.80～4.50	3.20～ 3.90	9.00～10.00	3.00～3.50	9.50～10.50
	SKH58	0.95～1.05	≦0.7	≦0.4	≦0.030	≦0.030	3.50～4.50	8.20～ 9.20	1.50～ 2.10	1.70～2.20	—
	SKH59	1.05～1.15	≦0.7	≦0.4	≦0.030	≦0.030	3.50～4.50	9.00～10.00	1.20～ 1.90	0.90～1.30	7.50～ 8.50

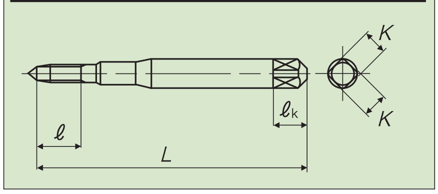
Classification	Symbols	Usage	Cross chart		
			AISI	VDEH	ISO
W type HSS	SKH 2	Tools for general cutting and other kinds of tools.	T 1	S18-0-1	S1（HS18-0-1）
	SKH 3	Tools for high speed heavy cutting and other kinds of tools.	T 4	S18-1-2-5	S7（HS18-1-1-5）
	SKH 4	Tools for cutting hard -to-machine materials and other kinds of tools.	T 5	S18-1-2-10	S6（HS18-0-1-10）
	SKH10	Tools for cutting ultra hard-to-machine materials and other kinds of tools.	T15	—	S9（HS12-1-5-5）
Mo type HSS	SKH51	General cutting tools from which toughness is particularly required, and other kinds of tools.	M 2	S6-5-2	S4（HS6-5-2）
	SKH52	Tools for cutting high hardness material from which comparatively high toughness is required and other kinds of tools.	M 3-1	—	—
	SKH53		M 3-2	S6-5-3	S5（HS6-5-3）
	SKH54	Tools for cutting ultra hard-to-machine materials and other kinds of tools.	M 4	—	—
	SKH55	High speed cutting tools from which comparatively high toughness is required and other kinds of tools.	M35	S6-5-2-5	S8（HS6-5-2-5）
	SKH56		M36	—	—
	SKH57	Tools for cutting ultra hard-to-machine materials and other kinds of tools.	—	S10-4-3-10	S10（HS10-4-3-10）
	SKH58	General cutting tools from which toughness is particularly required, and other kinds of tools.	M 7	S2-9-2	S2（HS2-9-2）
	SKH59	High speed heavy cutting tools from which comparatively high toughness is required, and other kinds of tools.	M42	S2-10-1-8	S11（HS2-9-1-8）

The standard of HSS material is specified in JIS. But there are many HSS materials which standard is not specified in JIS. Recently even the kind of HSS-P is getting wider and various. Besides, SKH10, SKH53, SKH57 and their equivalents, such Hi vanadium/hi cobalt material as contains 4-12% vanadium and 8-11% cobalt is now being manufactured. Material engineering will be developed rapidly in the future. Under such situation, there can be many cases where JIS symbols are not used, and the use of larger classification and their symbols is getting popular.

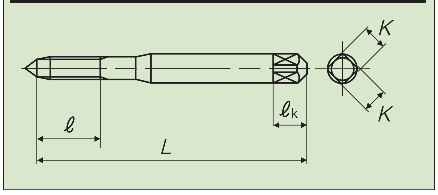
33. Design of taps and dies

∗Design of oil hole : refer to icons shown in product page

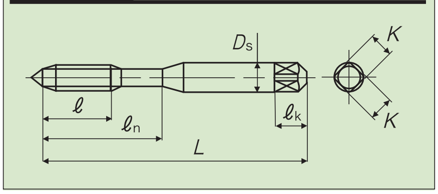
TYPE a



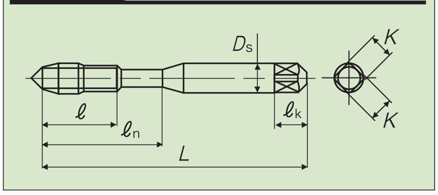
TYPE b



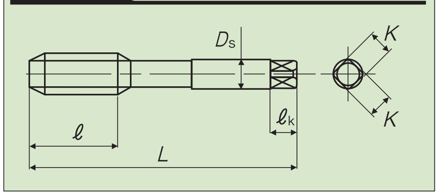
TYPE c



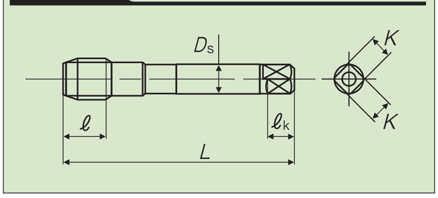
TYPE d



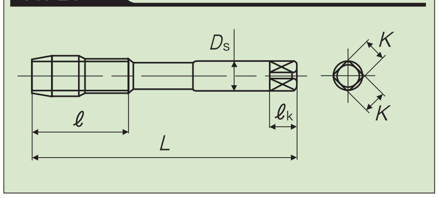
TYPE e



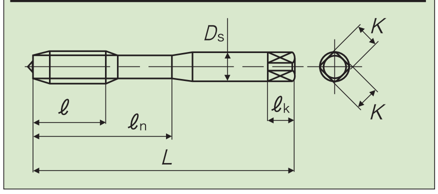
TYPE e-1



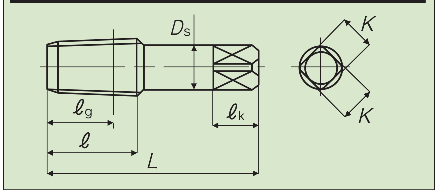
TYPE f



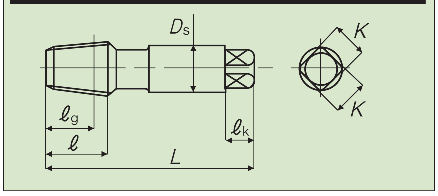
TYPE g



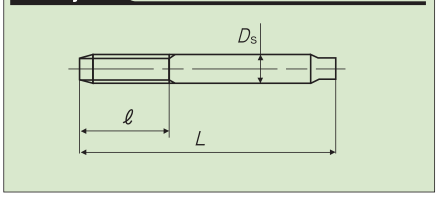
TYPE h



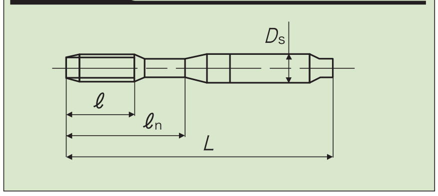
TYPE i



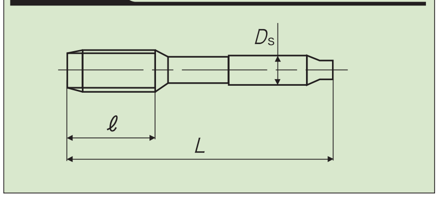
TYPE j



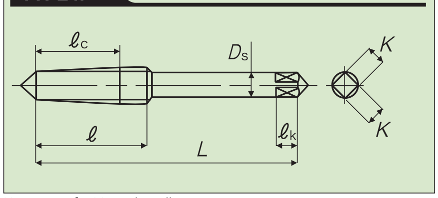
TYPE k



TYPE m

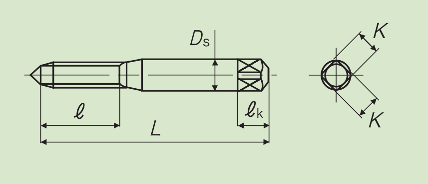


TYPE n

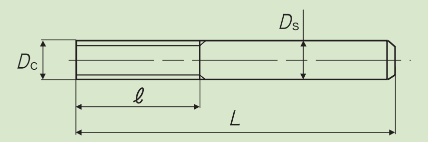


No square : for M4 and smaller,
Internal center on tap end : M8 and larger

TYPE p

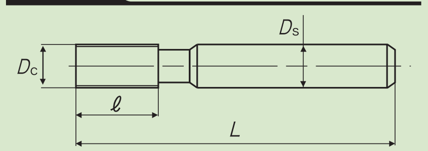


TYPE q



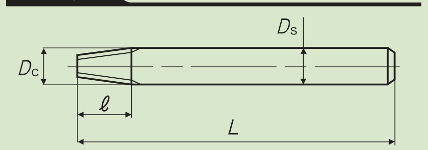
D_c=Major Dia.

TYPE r



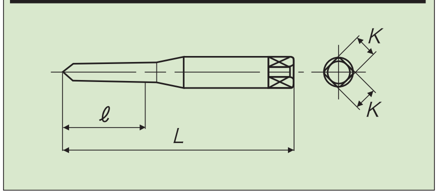
D_c=Major Dia.

TYPE s

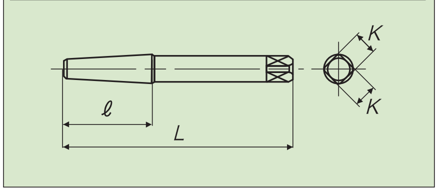


D_c= Major Dia.

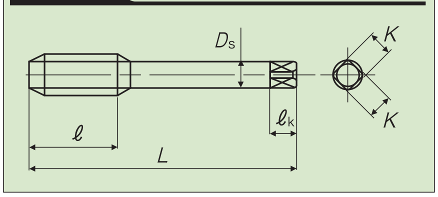
TYPE t



TYPE u



TYPE v



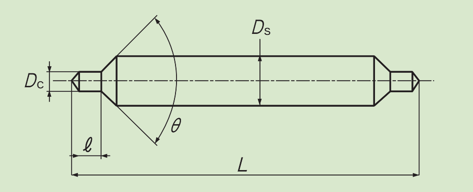
Simbols common in cutting tools and tool dimensions

Symbols were used by each tool manufacturer by refering to his own specification, resulting in confusion. In order to increas convenience at customers, small tool association and carbide tool association in Japan confirmed the common symbols. Yamawa is adopting these common symbols in this catalogue.

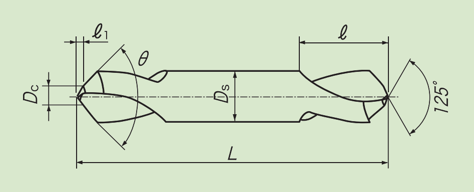
Overall length	Thead length	Chamfer length	Thread+Neck length	Outside dia.	Shank dia.	Length of square	Size of square
L	ℓ	ℓ_c	ℓ_n	D	D_s	ℓ_k	K

34. Design of center drills and centering tools

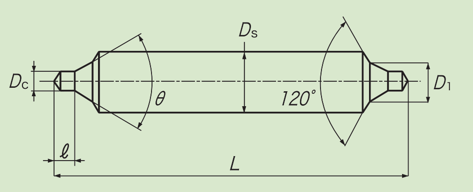
TYPE Ca



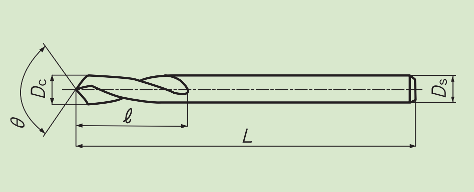
TYPE Ch



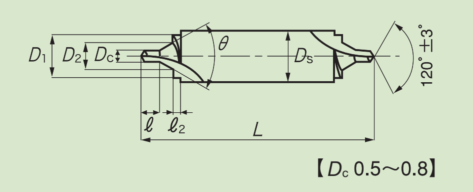
TYPE Cb



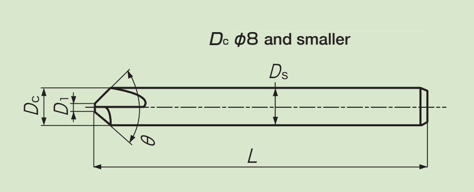
TYPE Ci



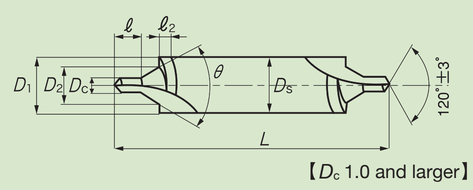
TYPE Cc



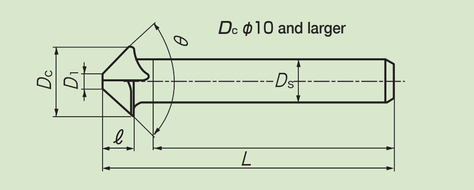
TYPE Cj



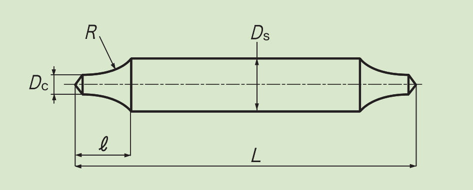
TYPE Cd



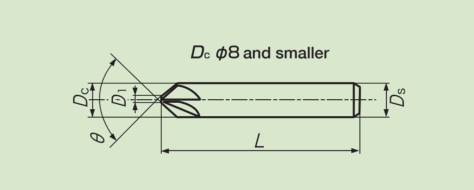
TYPE Ck



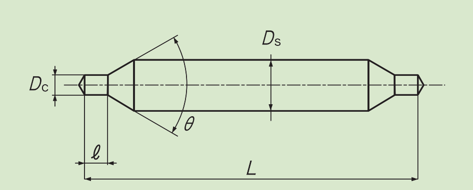
TYPE Ce-1



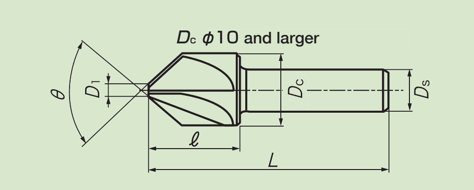
TYPE Cm



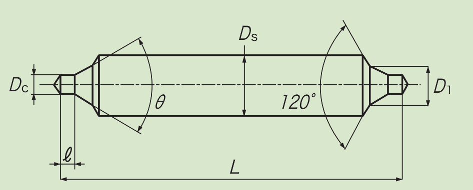
TYPE Cf



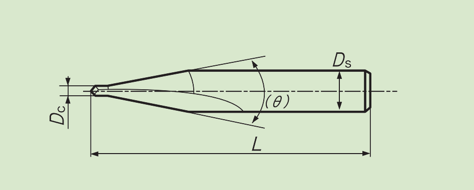
TYPE Cn



TYPE Cg

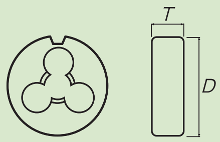


TYPE Cp

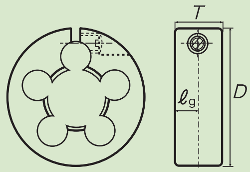


35. Design of dies

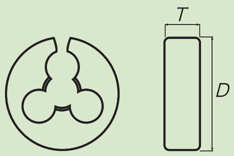
TYPE Da



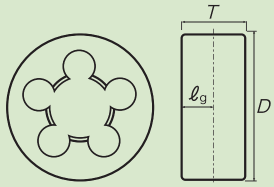
TYPE Dd



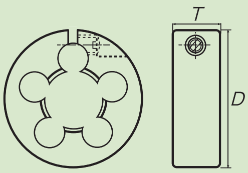
TYPE Db



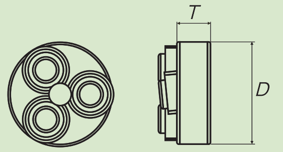
TYPE De



TYPE Dc



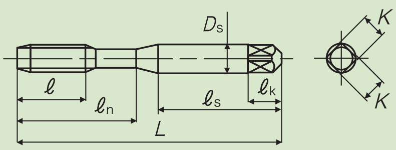
TYPE Df



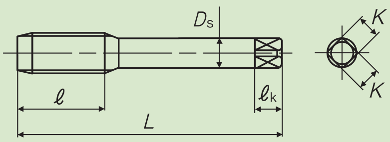
36. Design of taps for USA market and European market

Design of taps for USA market

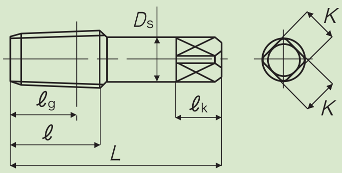
Ua



Ub

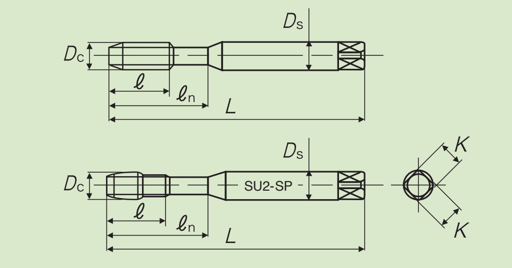


Uc

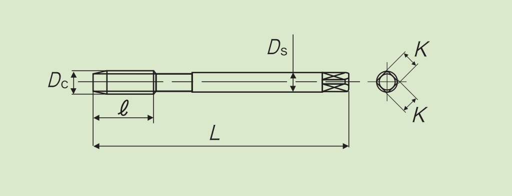


Design of taps for European market

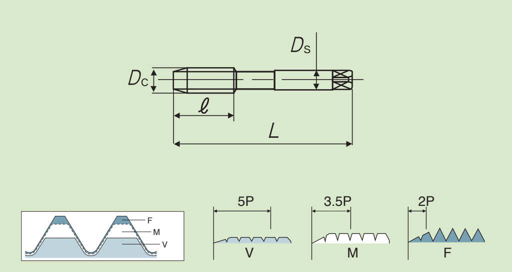
DIN371



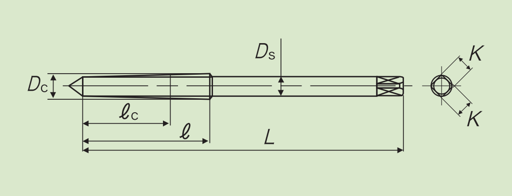
DIN374/376



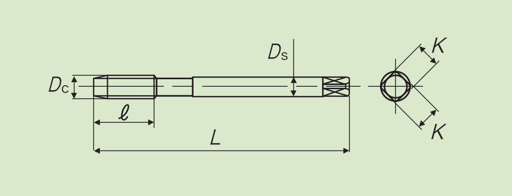
DIN351/352



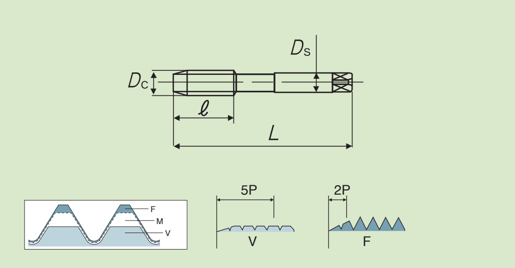
DIN357



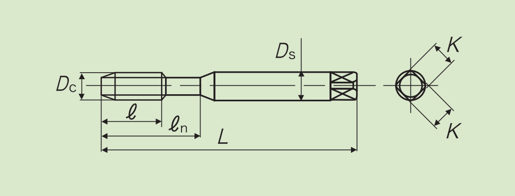
DIN5156



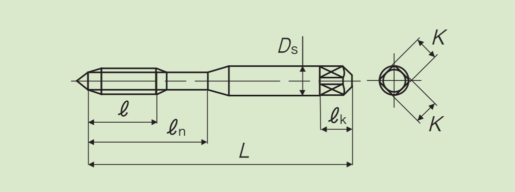
DIN5157/DIN2181



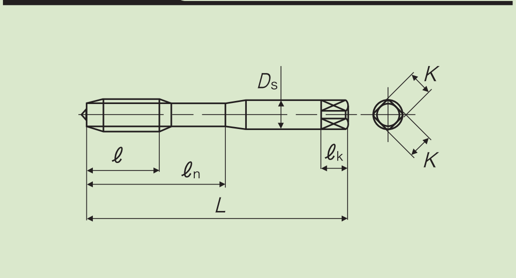
ISO529



Ea



Eb



Ec