WORKSHOP REFERENCE · 01

Tapping Drill Sizes

Tap drill and internal thread minor diameters for metric, unified, pipe and Whitworth threads. Drill sizes follow DIN 336 for cutting taps.

ISO metric coarse

ISO 261 · DIN 13 · 6H

Size	Pitch mm	Tap drill mm	Minor Ø min	Minor Ø max
M1	0.25	**0.75**	0.729	0.785
M1.2	0.25	**0.95**	0.929	0.985
M1.4	0.30	**1.10**	1.075	1.142
M1.6	0.35	**1.25**	1.221	1.321
M1.8	0.35	**1.45**	1.421	1.521
M2	0.40	**1.60**	1.567	1.679
M2.2	0.45	**1.75**	1.713	1.838
M2.5	0.45	**2.05**	2.013	2.138
M3	0.50	**2.50**	2.459	2.599
M3.5	0.60	**2.90**	2.850	3.010
M4	0.70	**3.30**	3.242	3.422
M4.5	0.75	**3.70**	3.688	3.878
M5	0.80	**4.20**	4.134	4.334
M6	1.00	**5.00**	4.917	5.153
M7	1.00	**6.00**	5.917	6.153
M8	1.25	**6.80**	6.647	6.912
M9	1.25	**7.80**	7.647	7.912
M10	1.50	**8.50**	8.376	8.676
M11	1.50	**9.50**	9.376	9.676
M12	1.75	**10.20**	10.106	10.441
M14	2.00	**12.00**	11.835	12.210
M16	2.00	**14.00**	13.835	14.210
M18	2.50	**15.50**	15.294	15.744
M20	2.50	**17.50**	17.294	17.744
M22	2.50	**19.50**	19.294	19.744
M24	3.00	**21.00**	20.752	21.252
M27	3.00	**24.00**	23.752	24.252
M30	3.50	**26.50**	26.211	26.771
M33	3.50	**29.50**	29.211	29.771
M36	4.00	**32.00**	31.670	32.270
M39	4.00	**35.00**	34.670	35.270
M42	4.50	**37.50**	37.129	37.799
M45	4.50	**40.50**	40.129	40.799
M48	5.00	**43.00**	42.587	43.297
M52	5.00	**47.00**	46.587	47.297
M56	5.50	**50.50**	50.046	50.796

M1.1–M1.4 minor diameter to 5H.

BSW (Whitworth)

BS 84

Size	TPI	Tap drill mm	Minor Ø min	Minor Ø max
1/8	40	**2.50**	2.362	2.591
3/16	24	**3.60**	3.407	3.745
1/4	20	**5.10**	4.724	5.156
5/16	18	**6.50**	6.130	6.590
3/8	16	**7.90**	7.492	7.987
7/16	14	**9.20**	8.789	9.330
1/2	12	**10.50**	9.989	10.591
9/16	12	**12.00**	11.577	12.179
5/8	11	**13.50**	12.918	13.558
3/4	10	**16.25**	15.797	16.483
7/8	9	**19.25**	18.611	19.353
1	8	**22.00**	21.334	22.147
1 1/8	7	**24.50**	23.928	24.832
1 1/4	7	**27.75**	27.103	28.007
1 1/2	6	**33.50**	32.679	33.703
1 3/4	5	**39.00**	37.944	39.138
2	4.5	**44.50**	43.571	44.877

ISO metric fine

ISO 261 · DIN 13 · 6H

Size	Pitch mm	Tap drill mm	Minor Ø min	Minor Ø max
M2.5×0.35	0.35	**2.15**	2.121	2.221
M3×0.35	0.35	**2.65**	2.621	2.721
M3.5×0.35	0.35	**3.15**	3.121	3.221
M4×0.5	0.50	**3.50**	3.459	3.599
M4.5×0.5	0.50	**4.00**	3.959	4.099
M5×0.5	0.50	**4.50**	4.459	4.599
M5.5×0.5	0.50	**5.00**	4.959	5.099
M6×0.75	0.75	**5.20**	5.188	5.378
M7×0.75	0.75	**6.20**	6.188	6.378
M8×0.5	0.50	**7.50**	7.459	7.599
M8×0.75	0.75	**7.20**	7.188	7.378
M8×1	1.00	**7.00**	6.917	7.153
M9×0.75	0.75	**8.20**	8.188	8.378
M9×1	1.00	**8.00**	7.917	8.153
M10×0.75	0.75	**9.20**	9.188	9.378
M10×1	1.00	**9.00**	8.917	9.153
M10×1.25	1.25	**8.80**	8.647	8.912
M11×0.75	0.75	**10.20**	10.188	10.378
M11×1	1.00	**10.00**	9.917	10.153
M12×1	1.00	**11.00**	10.917	11.153
M12×1.25	1.25	**10.80**	10.647	10.912
M12×1.5	1.50	**10.50**	10.376	10.676
M14×1	1.00	**13.00**	12.917	13.153
M14×1.25	1.25	**12.80**	12.647	12.912
M14×1.5	1.50	**12.50**	12.376	12.676
M15×1	1.00	**14.00**	13.917	14.153
M15×1.5	1.50	**13.50**	13.376	13.676
M16×1	1.00	**15.00**	14.917	15.153
M16×1.25	1.25	**14.80**	14.647	14.912
M16×1.5	1.50	**14.50**	14.376	14.676
M17×1	1.00	**16.00**	15.917	16.153
M17×1.5	1.50	**15.50**	15.376	15.676
M18×1	1.00	**17.00**	16.917	17.153
M18×1.5	1.50	**16.50**	16.376	16.676
M20×1	1.00	**19.00**	18.917	19.153
M20×1.5	1.50	**18.50**	18.376	18.676
M20×2	2.00	**18.00**	17.835	18.210
M22×1	1.00	**21.00**	20.917	21.153
M22×1.5	1.50	**20.50**	20.376	20.676
M22×2	2.00	**20.00**	19.835	20.210
M24×1	1.00	**23.00**	22.917	23.153
M24×1.5	1.50	**22.50**	22.376	22.676
M24×2	2.00	**22.00**	21.835	22.210
M25×1.5	1.50	**23.50**	23.376	23.676
M25×2	2.00	**23.00**	22.835	23.210
M27×1.5	1.50	**25.50**	25.376	25.676
M27×2	2.00	**25.00**	24.835	25.210
M28×1.5	1.50	**26.50**	26.376	26.676
M28×2	2.00	**26.00**	25.835	26.210
M30×1.5	1.50	**28.50**	28.376	28.676
M30×2	2.00	**28.00**	27.835	28.210
M30×3	3.00	**27.00**	26.752	27.252
M32×1.5	1.50	**30.50**	30.376	30.676
M32×2	2.00	**30.00**	29.835	30.210
M33×1.5	1.50	**31.50**	31.376	31.676
M33×2	2.00	**31.00**	30.835	31.210
M35×1.5	1.50	**33.50**	33.376	33.676
M36×1.5	1.50	**34.50**	34.376	34.676
M36×2	2.00	**34.00**	33.835	34.210
M36×3	3.00	**33.00**	32.752	33.252

UNC

ASME B1.1 · 2B

Size	TPI	Tap drill mm	Inch drill	Minor Ø min	Minor Ø max
No. 1	64	**1.55**	#53	1.425	1.580
No. 2	56	**1.85**	#50	1.694	1.872
No. 3	48	**2.10**	#47	1.941	2.146
No. 4	40	**2.35**	#43	2.157	2.385
No. 5	40	**2.65**	#38	2.487	2.698
No. 6	32	**2.85**	#36	2.642	2.896
No. 8	32	**3.50**	#29	3.302	3.531
No. 10	24	**3.90**	#25	3.683	3.937
No. 12	24	**4.50**	#16	4.343	4.597
1/4	20	**5.10**	#7	4.978	5.258
5/16	18	**6.60**	F	6.401	6.731
3/8	16	**8.00**	5/16	7.798	8.153
7/16	14	**9.40**	U	9.144	9.550
1/2	13	**10.80**	27/64	10.592	11.024
9/16	12	**12.20**	31/64	11.989	12.446
5/8	11	**13.50**	17/32	13.386	13.868
3/4	10	**16.50**	21/32	16.307	16.840
7/8	9	**19.50**	49/64	19.177	19.761
1	8	**22.25**	7/8	21.971	22.606
1 1/8	7	**25.00**	63/64	24.638	25.349
1 1/4	7	**28.00**	1 7/64	27.813	28.524
1 3/8	6	**30.75**	1 7/32	30.353	31.115
1 1/2	6	**34.00**	1 11/32	33.528	34.290
1 3/4	5	**39.50**	1 9/16	38.938	39.802
2	4.5	**45.00**	1 25/32	44.679	45.593

UNF

ASME B1.1 · 2B

Size	TPI	Tap drill mm	Inch drill	Minor Ø min	Minor Ø max
No. 1	72	**1.55**	#53	1.473	1.610
No. 2	64	**1.85**	#50	1.755	1.910
No. 3	56	**2.15**	#45	2.024	2.197
No. 4	48	**2.40**	#42	2.271	2.459
No. 5	44	**2.70**	#37	2.550	2.741
No. 6	40	**2.95**	#33	2.819	3.023
No. 8	36	**3.50**	#29	3.404	3.607
No. 10	32	**4.10**	#21	3.962	4.166
No. 12	28	**4.60**	#14	4.496	4.724
1/4	28	**5.50**	#3	5.359	5.588
5/16	24	**6.90**	I	6.782	7.036
3/8	24	**8.50**	Q	8.382	8.636
7/16	20	**9.90**	25/64	9.728	10.033
1/2	20	**11.50**	29/64	11.328	11.608
9/16	18	**12.90**	33/64	12.751	13.081
5/8	18	**14.50**	37/64	14.351	14.681
3/4	16	**17.50**	11/16	17.323	17.678
7/8	14	**20.40**	13/16	20.269	20.650
1	12	**23.25**	59/64	23.114	23.571
1 1/8	12	**26.50**	1 3/64	26.289	26.746
1 1/4	12	**29.50**	1 11/64	29.464	29.921
1 3/8	12	**32.75**	1 19/64	32.639	33.096
1 1/2	12	**36.00**	1 27/64	35.814	36.271

BSP parallel (G / BSPP)

ISO 228-1

Size	TPI	Tap drill mm	Minor Ø min	Minor Ø max
G 1/16	28	**6.80**	6.561	6.843
G 1/8	28	**8.80**	8.566	8.848
G 1/4	19	**11.80**	11.445	11.890
G 3/8	19	**15.25**	14.950	15.395
G 1/2	14	**19.00**	18.631	19.172
G 5/8	14	**21.00**	20.587	21.128
G 3/4	14	**24.50**	24.117	24.658
G 7/8	14	**28.25**	27.877	28.418
G 1	11	**30.75**	30.291	30.931
G 1 1/8	11	**35.50**	34.939	35.579
G 1 1/4	11	**39.50**	38.952	39.592
G 1 1/2	11	**45.25**	44.845	45.485
G 1 3/4	11	**51.00**	50.788	51.428
G 2	11	**57.00**	56.656	57.296

BSP taper (Rc / BSPT)

ISO 7-1 · 1:16

Size	TPI	Tap drill mm
Rc 1/8	28	**8.40**
Rc 1/4	19	**11.20**
Rc 3/8	19	**14.75**
Rc 1/2	14	**18.25**
Rc 3/4	14	**23.75**
Rc 1	11	**30.00**
Rc 1 1/4	11	**38.50**
Rc 1 1/2	11	**44.50**
Rc 2	11	**56.00**

Drill size for use with a taper pipe reamer or a taper tap with long chamfer.

NPT

ASME B1.20.1 · 1:16

Size	TPI	Tap drill mm	Inch drill
1/16	27	**6.39**	D
1/8	27	**8.74**	R
1/4	18	**11.36**	7/16
3/8	18	**14.80**	37/64
1/2	14	**18.32**	23/32
3/4	14	**23.67**	59/64
1	11.5	**29.69**	1 5/32
1 1/4	11.5	**38.45**	1 1/2
1 1/2	11.5	**44.52**	1 47/64
2	11.5	**56.56**	2 7/32

Drill sizes for tapping without a taper reamer.

Quick rules

Cut tap drill ≈ D − P
Form tap drill ≈ D − 0.45 × P
Inch: drill ≈ D − 1 ÷ TPI

D is the nominal diameter and P the pitch, both in mm. Form (roll) taps need a larger hole than cutting taps; check the tap maker's table.

Which tap?

Through hole: spiral point (gun) tap pushes chips ahead.
Blind hole: spiral flute tap lifts chips out.
Tough, short-chip or cast material: straight flute tap.
Ductile material, no chips: form tap, with a larger hole.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up.

A guide only. Always check against the tool maker's data and your machine and set-up, and talk to your Teravin sales engineer before relying on it. Terms: teravin.tools/terms

WORKSHOP REFERENCE · 02

Drill Sizes & Decimal Equivalents

Fractional, number and letter drills in size order with inch and millimetre equivalents, plus everyday workshop conversions.

Under 1/8 inch

0.343 – 3.048 mm

Size	Type	Inch	mm
#80	Number	0.0135	0.343
#79	Number	0.0145	0.368
1/64	Fraction	0.0156	0.397
#78	Number	0.0160	0.406
#77	Number	0.0180	0.457
#76	Number	0.0200	0.508
#75	Number	0.0210	0.533
#74	Number	0.0225	0.571
#73	Number	0.0240	0.610
#72	Number	0.0250	0.635
#71	Number	0.0260	0.660
#70	Number	0.0280	0.711
#69	Number	0.0292	0.742
#68	Number	0.0310	0.787
1/32	Fraction	0.0312	0.794
#67	Number	0.0320	0.813
#66	Number	0.0330	0.838
#65	Number	0.0350	0.889
#64	Number	0.0360	0.914
#63	Number	0.0370	0.940
#62	Number	0.0380	0.965
#61	Number	0.0390	0.991
#60	Number	0.0400	1.016
#59	Number	0.0410	1.041
#58	Number	0.0420	1.067
#57	Number	0.0430	1.092
#56	Number	0.0465	1.181
3/64	Fraction	0.0469	1.191
#55	Number	0.0520	1.321
#54	Number	0.0550	1.397
#53	Number	0.0595	1.511
1/16	Fraction	0.0625	1.587
#52	Number	0.0635	1.613
#51	Number	0.0670	1.702
#50	Number	0.0700	1.778
#49	Number	0.0730	1.854
#48	Number	0.0760	1.930
5/64	Fraction	0.0781	1.984
#47	Number	0.0785	1.994
#46	Number	0.0810	2.057
#45	Number	0.0820	2.083
#44	Number	0.0860	2.184
#43	Number	0.0890	2.261
#42	Number	0.0935	2.375
3/32	Fraction	0.0938	2.381
#41	Number	0.0960	2.438
#40	Number	0.0980	2.489
#39	Number	0.0995	2.527
#38	Number	0.1015	2.578
#37	Number	0.1040	2.642
#36	Number	0.1065	2.705
7/64	Fraction	0.1094	2.778
#35	Number	0.1100	2.794
#34	Number	0.1110	2.819
#33	Number	0.1130	2.870
#32	Number	0.1160	2.946
#31	Number	0.1200	3.048

1/8 to 5/16 inch

3.175 – 7.938 mm

Size	Type	Inch	mm
1/8	Fraction	0.1250	3.175
#30	Number	0.1285	3.264
#29	Number	0.1360	3.454
#28	Number	0.1405	3.569
9/64	Fraction	0.1406	3.572
#27	Number	0.1440	3.658
#26	Number	0.1470	3.734
#25	Number	0.1495	3.797
#24	Number	0.1520	3.861
#23	Number	0.1540	3.912
5/32	Fraction	0.1562	3.969
#22	Number	0.1570	3.988
#21	Number	0.1590	4.039
#20	Number	0.1610	4.089
#19	Number	0.1660	4.216
#18	Number	0.1695	4.305
11/64	Fraction	0.1719	4.366
#17	Number	0.1730	4.394
#16	Number	0.1770	4.496
#15	Number	0.1800	4.572
#14	Number	0.1820	4.623
#13	Number	0.1850	4.699
3/16	Fraction	0.1875	4.762
#12	Number	0.1890	4.801
#11	Number	0.1910	4.851
#10	Number	0.1935	4.915
#9	Number	0.1960	4.978
#8	Number	0.1990	5.055
#7	Number	0.2010	5.105
13/64	Fraction	0.2031	5.159
#6	Number	0.2040	5.182
#5	Number	0.2055	5.220
#4	Number	0.2090	5.309
#3	Number	0.2130	5.410
7/32	Fraction	0.2188	5.556
#2	Number	0.2210	5.613
#1	Number	0.2280	5.791
A	Letter	0.2340	5.944
15/64	Fraction	0.2344	5.953
B	Letter	0.2380	6.045
C	Letter	0.2420	6.147
D	Letter	0.2460	6.248
1/4	Fraction	0.2500	6.350
E	Letter	0.2500	6.350
F	Letter	0.2570	6.528
G	Letter	0.2610	6.629
17/64	Fraction	0.2656	6.747
H	Letter	0.2660	6.756
I	Letter	0.2720	6.909
J	Letter	0.2770	7.036
K	Letter	0.2810	7.137
9/32	Fraction	0.2812	7.144
L	Letter	0.2900	7.366
M	Letter	0.2950	7.493
19/64	Fraction	0.2969	7.541
N	Letter	0.3020	7.671
5/16	Fraction	0.3125	7.938

Over 5/16 to 1 inch

8.026 – 25.400 mm

Size	Type	Inch	mm
O	Letter	0.3160	8.026
P	Letter	0.3230	8.204
21/64	Fraction	0.3281	8.334
Q	Letter	0.3320	8.433
R	Letter	0.3390	8.611
11/32	Fraction	0.3438	8.731
S	Letter	0.3480	8.839
T	Letter	0.3580	9.093
23/64	Fraction	0.3594	9.128
U	Letter	0.3680	9.347
3/8	Fraction	0.3750	9.525
V	Letter	0.3770	9.576
W	Letter	0.3860	9.804
25/64	Fraction	0.3906	9.922
X	Letter	0.3970	10.084
Y	Letter	0.4040	10.262
13/32	Fraction	0.4062	10.319
Z	Letter	0.4130	10.490
27/64	Fraction	0.4219	10.716
7/16	Fraction	0.4375	11.112
29/64	Fraction	0.4531	11.509
15/32	Fraction	0.4688	11.906
31/64	Fraction	0.4844	12.303
1/2	Fraction	0.5000	12.700
33/64	Fraction	0.5156	13.097
17/32	Fraction	0.5312	13.494
35/64	Fraction	0.5469	13.891
9/16	Fraction	0.5625	14.287
37/64	Fraction	0.5781	14.684
19/32	Fraction	0.5938	15.081
39/64	Fraction	0.6094	15.478
5/8	Fraction	0.6250	15.875
41/64	Fraction	0.6406	16.272
21/32	Fraction	0.6562	16.669
43/64	Fraction	0.6719	17.066
11/16	Fraction	0.6875	17.462
45/64	Fraction	0.7031	17.859
23/32	Fraction	0.7188	18.256
47/64	Fraction	0.7344	18.653
3/4	Fraction	0.7500	19.050
49/64	Fraction	0.7656	19.447
25/32	Fraction	0.7812	19.844
51/64	Fraction	0.7969	20.241
13/16	Fraction	0.8125	20.637
53/64	Fraction	0.8281	21.034
27/32	Fraction	0.8438	21.431
55/64	Fraction	0.8594	21.828
7/8	Fraction	0.8750	22.225
57/64	Fraction	0.8906	22.622
29/32	Fraction	0.9062	23.019
59/64	Fraction	0.9219	23.416
15/16	Fraction	0.9375	23.812
61/64	Fraction	0.9531	24.209
31/32	Fraction	0.9688	24.606
63/64	Fraction	0.9844	25.003
1	Fraction	1.0000	25.400

Metric drills in inches

1 in = 25.4 mm

mm	Inch	mm	Inch
0.5	0.0197	11	0.4331
1	0.0394	11.5	0.4528
1.5	0.0591	12	0.4724
2	0.0787	12.5	0.4921
2.5	0.0984	13	0.5118
3	0.1181	14	0.5512
3.5	0.1378	15	0.5906
4	0.1575	16	0.6299
4.5	0.1772	17	0.6693
5	0.1969	18	0.7087
5.5	0.2165	19	0.7480
6	0.2362	20	0.7874
6.5	0.2559	21	0.8268
7	0.2756	22	0.8661
7.5	0.2953	23	0.9055
8	0.3150	24	0.9449
8.5	0.3346	25	0.9843
9	0.3543	26	1.0236
9.5	0.3740	28	1.1024
10	0.3937	30	1.1811
10.5	0.4134	32	1.2598

Workshop conversions

exact or to 4 significant figures

From	Equals
1 inch	25.4 mm
1 mm	0.03937 in
1 thou (0.001 in)	0.0254 mm
1 ft	304.8 mm
1 ft·lbf	1.3558 N·m
1 N·m	0.7376 ft·lbf
1 in·lbf	0.1130 N·m
1 SFM (ft/min)	0.3048 m/min
1 m/min	3.281 SFM
1 in/rev (IPR)	25.4 mm/rev
1 psi	0.06895 bar
1 bar	14.504 psi
1 MPa	145.04 psi
1 lb	0.4536 kg
1 kgf	9.807 N
1 hp	0.7457 kW
°C	(°F − 32) × 5 ÷ 9
°F	°C × 9 ÷ 5 + 32

Number and letter drill sizes per ASME B94.11M. Millimetre values are exact conversions (1 in = 25.4 mm), rounded to 0.001 mm.

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A guide only. Always check against the tool maker's data and your machine and set-up, and talk to your Teravin sales engineer before relying on it. Terms: teravin.tools/terms

WORKSHOP REFERENCE · 03

Drilling Speeds & Feeds

Starting cutting speeds by ISO material group and a ready-reckoner for spindle speed, so the drill is cutting before the first chip lands.

Cutting speed by material

Vc in m/min · starting values

ISO	Material	Hardness	HSS / HSS-Co	Solid carbide, coated
P	Low-carbon & free-cutting steel	< 180 HB	25–35	100–150
P	Medium-carbon & alloy steel, annealed	180–280 HB	18–25	80–120
P	Alloy & tool steel, hardened & tempered	280–350 HB	10–15	60–90
M	Austenitic stainless (304, 316)	< 200 HB	8–12	40–70
M	Duplex & super-duplex stainless	< 300 HB	6–10	30–50
K	Grey cast iron	< 250 HB	20–30	80–130
K	Ductile (SG) cast iron	< 300 HB	15–25	70–110
N	Wrought aluminium	< 120 HB	60–100	150–300
N	Cast aluminium, high silicon	< 120 HB	40–60	100–200
N	Brass, bronze & copper	< 200 HB	30–60	80–150
S	Titanium alloys	< 350 HB	6–10	25–45
S	Nickel superalloys (Inconel, Hastelloy)	< 350 HB	3–6	15–30
H	Hardened steel	45–55 HRC	—	30–50

Start in the middle of the range. Go lower for long-series drills, poor coolant or unstable set-ups. Through-coolant carbide drills can run at the top of the range.

Feed per revolution in steel

f in mm/rev

Drill Ø mm	HSS	Solid carbide
3	0.04–0.06	0.08–0.12
5	0.07–0.10	0.10–0.15
8	0.10–0.15	0.15–0.22
10	0.12–0.18	0.18–0.25
12	0.15–0.20	0.20–0.28
16	0.18–0.25	0.25–0.32
20	0.22–0.30	0.28–0.36

Stainless and titanium: about 70% of these feeds. Aluminium and brass: up to 130%. Peck when depth exceeds 3 × D with HSS.

Formulas

Spindle speed $n = Vc \times 1000 \div (\pi \times D)$
Cutting speed $Vc = \pi \times D \times n \div 1000$
Feed rate $vf = f \times n$ (mm/min)
Milling feed $vf = fz \times z \times n$

n spindle speed (RPM)
Vc cutting speed (m/min)
D tool diameter (mm)
f feed per revolution (mm/rev)
fz feed per tooth (mm) · z number of teeth

Spindle speed (RPM) by drill diameter and cutting speed

n = Vc × 1000 ÷ (π × D)

Drill Ø mm	5	10	15	20	25	30	40	50	60	80	100	120	150	200	250	300
	Cutting speed Vc (m/min) →															
1	1,590	3,200	4,750	6,350	7,950	9,550	12,700	15,900	19,100	25,500	31,800	38,200	47,700	63,700	79,600	95,500
1.5	1,060	2,100	3,200	4,250	5,300	6,350	8,500	10,600	12,700	17,000	21,200	25,500	31,800	42,400	53,100	63,700
2	800	1,590	2,400	3,200	4,000	4,750	6,350	7,950	9,550	12,700	15,900	19,100	23,900	31,800	39,800	47,700
2.5	640	1,270	1,910	2,550	3,200	3,800	5,100	6,350	7,650	10,200	12,700	15,300	19,100	25,500	31,800	38,200
3	530	1,060	1,590	2,100	2,650	3,200	4,250	5,300	6,350	8,500	10,600	12,700	15,900	21,200	26,500	31,800
3.3	480	960	1,450	1,930	2,400	2,900	3,850	4,800	5,800	7,700	9,650	11,600	14,500	19,300	24,100	28,900
4	400	800	1,190	1,590	1,990	2,400	3,200	4,000	4,750	6,350	7,950	9,550	11,900	15,900	19,900	23,900
4.2	380	760	1,140	1,520	1,890	2,250	3,050	3,800	4,550	6,050	7,600	9,100	11,400	15,200	18,900	22,700
5	320	640	950	1,270	1,590	1,910	2,550	3,200	3,800	5,100	6,350	7,650	9,550	12,700	15,900	19,100
6	270	530	800	1,060	1,330	1,590	2,100	2,650	3,200	4,250	5,300	6,350	7,950	10,600	13,300	15,900
6.8	230	470	700	940	1,170	1,400	1,870	2,350	2,800	3,750	4,700	5,600	7,000	9,350	11,700	14,000
8	200	400	600	800	990	1,190	1,590	1,990	2,400	3,200	4,000	4,750	5,950	7,950	9,950	11,900
8.5	190	370	560	750	940	1,120	1,500	1,870	2,250	3,000	3,750	4,500	5,600	7,500	9,350	11,200
10	160	320	480	640	800	950	1,270	1,590	1,910	2,550	3,200	3,800	4,750	6,350	7,950	9,550
10.2	160	310	470	620	780	940	1,250	1,560	1,870	2,500	3,100	3,750	4,700	6,250	7,800	9,350
12	130	270	400	530	660	800	1,060	1,330	1,590	2,100	2,650	3,200	4,000	5,300	6,650	7,950
14	110	230	340	450	570	680	910	1,140	1,360	1,820	2,250	2,750	3,400	4,550	5,700	6,800
16	100	200	300	400	500	600	800	990	1,190	1,590	1,990	2,400	3,000	4,000	4,950	5,950
17.5	90	180	270	360	450	550	730	910	1,090	1,460	1,820	2,200	2,750	3,650	4,550	5,450
20	80	160	240	320	400	480	640	800	950	1,270	1,590	1,910	2,400	3,200	4,000	4,750
22	70	140	220	290	360	430	580	720	870	1,160	1,450	1,740	2,150	2,900	3,600	4,350
25	60	130	190	250	320	380	510	640	760	1,020	1,270	1,530	1,910	2,550	3,200	3,800
28	60	110	170	230	280	340	450	570	680	910	1,140	1,360	1,710	2,250	2,850	3,400
32	50	100	150	200	250	300	400	500	600	800	990	1,190	1,490	1,990	2,500	3,000

Rounded to the nearest 10 RPM (50 above 2,000 and 100 above 10,000). Speeds above 20,000 RPM are greyed out. The same table works for end mills and reamers.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up.

WORKSHOP REFERENCE · 04

Material Cross-Reference

Common workshop materials by ISO machining group, with German Werkstoff numbers, European names and their American equivalents.

ISO material groups

ISO 513 colour code

P — Steel
Unalloyed, low-alloy and high-alloy steel, tool steel, cast steel, ferritic and martensitic stainless.
Long chips. Generally predictable and the easiest group to machine.

K — Cast iron
Grey, ductile (SG), malleable and compacted graphite (CGI) iron.
Short, broken chips. Abrasive, so edge wear is the limit.

S — Superalloys & titanium
Nickel, cobalt and iron-based heat-resistant alloys; titanium and its alloys.
Heat stays in the edge. Low speed, notch wear and work hardening.

M — Stainless steel
Austenitic, duplex and super-duplex stainless steel.
Work-hardens, builds up on the edge and holds heat. Keep the feed up and the edge sharp.

N — Non-ferrous
Aluminium and its alloys, copper, brass, bronze, plastics and composites.
Soft and gummy. Sharp, positive, polished edges at high speed.

H — Hardened materials
Hardened steel 45–68 HRC, chilled and white cast iron, hardfacing.
CBN, ceramic or fine-grain coated carbide. Rigid set-ups only.

P Steel

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
1.0301	C10	Ck10	1010	Case-hardening, low carbon
1.0402	C22	C22	1020	Mild steel, general
1.0503	C45	C45	1045	Medium carbon, shafts
1.0601	C60	C60	1060	High carbon, springs
1.0570	S355J2	St52-3	≈ A572 Gr.50	Structural
1.0715	11SMn30	9SMn28	1215	Free-cutting
1.0718	11SMnPb30	9SMnPb28	12L14	Free-cutting, leaded
1.7131	16MnCr5	16MnCr5	5115	Case-hardening
1.6523	20NiCrMo2-2	21NiCrMo2	8620	Case-hardening, gears
1.7218	25CrMo4	25CrMo4	4130	Chromoly, tube
1.7225	42CrMo4	42CrMo4	4140	Shafting, high tensile
1.6582	34CrNiMo6	34CrNiMo6	≈ 4340	High-strength shafting
1.8159	51CrV4	50CrV4	6150	Spring steel
1.3505	100Cr6	100Cr6	52100	Bearing steel
1.2510	100MnCrW4	100MnCrW4	O1	Tool steel, oil hardening
1.2363	X100CrMoV5	X100CrMoV5-1	A2	Tool steel, air hardening
1.2379	X153CrMoV12	X155CrVMo12-1	D2	Cold-work die steel
1.2344	X40CrMoV5-1	X40CrMoV5-1	H13	Hot-work die steel
1.2311	40CrMnMo7	40CrMnMo7	P20	Plastic mould steel
1.3343	HS6-5-2C	S6-5-2	M2	High-speed steel

K Cast iron

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
0.6020	EN-GJL-200	GG20	A48 Class 30B	Grey iron
0.6025	EN-GJL-250	GG25	A48 Class 40B	Grey iron
0.6030	EN-GJL-300	GG30	A48 Class 45B	Grey iron
0.7040	EN-GJS-400-15	GGG40	A536 60-40-18	Ductile, ferritic
0.7050	EN-GJS-500-7	GGG50	A536 80-55-06	Ductile, ferritic-pearlitic
0.7070	EN-GJS-700-2	GGG70	A536 100-70-03	Ductile, pearlitic
—	EN-GJV-450	GJV-450	—	Compacted graphite (CGI)
5.3400	EN-GJS-800-10	ADI 800	—	Austempered ductile (ADI)

M Stainless steel

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
1.4301	X5CrNi18-10	V2A	304 · S30400	Austenitic, general
1.4307	X2CrNi18-9	—	304L · S30403	Austenitic, low carbon
1.4305	X8CrNiS18-9	—	303 · S30300	Free-machining stainless
1.4401	X5CrNiMo17-12-2	V4A	316 · S31600	Marine, chemical
1.4404	X2CrNiMo17-12-2	—	316L · S31603	Marine, welded
1.4571	X6CrNiMoTi17-12-2	—	316Ti · S31635	Ti-stabilised
1.4541	X6CrNiTi18-10	—	321 · S32100	Ti-stabilised, heat
1.4462	X2CrNiMoN22-5-3	—	2205 · S32205	Duplex
1.4410	X2CrNiMoN25-7-4	—	2507 · S32750	Super-duplex
1.4542	X5CrNiCuNb16-4	—	17-4PH · S17400	Precipitation hardening
1.4016	X6Cr17	—	430 · S43000	Ferritic *
1.4006	X12Cr13	—	410 · S41000	Martensitic *
1.4021	X20Cr13	—	420 · S42000	Martensitic, cutlery *
1.4057	X17CrNi16-2	—	431 · S43100	Martensitic, shafts *

* Ferritic and martensitic stainless are often machined with P-grade inserts.

N Aluminium & copper alloys

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
3.0255	EN AW-1050A	Al99.5	1050	Pure aluminium
3.1325	EN AW-2017A	AlCuMg1	2017	Free-machining, high strength
3.3547	EN AW-5083	AlMg4.5Mn	5083	Marine plate
3.3206	EN AW-6060	AlMgSi0.5	6060	Extrusions
3.3211	EN AW-6061	AlMg1SiCu	6061	General purpose
3.2315	EN AW-6082	AlMgSi1	6082	Structural
3.4365	EN AW-7075	AlZnMgCu1.5	7075	Aerospace, high strength
3.2371	EN AC-42100	G-AlSi7Mg	A356	Cast aluminium
2.0065	CW004A Cu-ETP	E-Cu58	C11000	Electrolytic copper
2.0401	CW614N CuZn39Pb3	Ms58	C38500	Free-cutting brass
2.0321	CW508L CuZn37	Ms63	C27200	Brass, cold forming
2.0966	CW307G CuAl10Ni5Fe4	—	C63000	Aluminium bronze

S Superalloys & titanium

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
2.4360	NiCu30Fe	Monel 400	N04400	Nickel-copper
2.4856	NiCr22Mo9Nb	Inconel 625	N06625	Nickel superalloy
2.4668	NiCr19NbMo	Inconel 718	N07718	Nickel superalloy, aged
2.4819	NiMo16Cr15W	Hastelloy C-276	N10276	Corrosion resistant
2.4654	NiCr19Co14Mo4Ti	Waspaloy	N07001	Turbine alloy
1.4876	X10NiCrAlTi32-21	Incoloy 800	N08800	Iron-nickel, heat resistant
3.7025	Ti Grade 1	Ti1	R50250	Commercially pure titanium
3.7035	Ti Grade 2	Ti2	R50400	Commercially pure titanium
3.7165	TiAl6V4	Ti Grade 5	R56400	Alpha-beta titanium

H Hardened materials

W.Nr.	EN designation	Old DIN / trade	AISI / SAE / UNS	Typical use
1.7225	42CrMo4, hardened	—	4140	45–55 HRC
1.3505	100Cr6, hardened	—	52100	58–64 HRC
1.2379	X153CrMoV12, hardened	—	D2	58–62 HRC
1.3343	HS6-5-2C, hardened	—	M2	62–65 HRC
0.9630	GX300CrNiSi9-5-2	Ni-Hard 4	A532 I-D	Chilled / white iron
1.3401	X120Mn12	Hadfield	A128	Manganese steel, work-hardening

Equivalents marked ≈ are close but not identical in chemistry; check the mill certificate where it matters. Inconel, Monel, Incoloy, Hastelloy and Waspaloy are trademarks of their owners.

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TERAVIN TOOLS

WORKSHOP REFERENCE · 05

Turning Insert & Holder Codes

How to read an ISO insert and toolholder code, position by position. Match the holder to the insert and the job.

Turning insert designation

ISO 1832

C	N	M	G	12	04	08	PM
1 Shape	2 Clearance	3 Tolerance	4 Type	5 Edge length	6 Thickness	7 Nose radius	8 Chipbreaker (maker)

1 · INSERT SHAPE

C Rhombic 80°	D Rhombic 55°	E Rhombic 75°	M Rhombic 86°
V Rhombic 35°	S Square 90°	T Triangle 60°	W Trigon 80°
R Round	H Hexagon 120°	O Octagon 135°	P Pentagon 108°
K Parallelogram 55°	A Parallelogram 85°	B Parallelogram 82°	L Rectangle 90°

2 · Clearance angle

Code	Angle
N	0°
A	3°
B	5°
C	7°
P	11°
D	15°
E	20°
F	25°
G	30°
O	Other

3 · Tolerance class

± mm

Code	IC (d)	Corner (m)	Thick (s)
A	0.025	0.005	0.025
F	0.013	0.005	0.025
C	0.025	0.013	0.025
H	0.013	0.013	0.025
E	0.025	0.025	0.025
G	0.025	0.025	0.13
J	0.05–0.15	0.005	0.025
K	0.05–0.15	0.013	0.025
L	0.05–0.15	0.025	0.025
M	0.05–0.15	0.08–0.20	0.13
N	0.05–0.15	0.08–0.20	0.025
U	0.08–0.25	0.13–0.38	0.13

J to U: IC tolerance grows with insert size. G is ground; M is the common pressed tolerance.

4 · Insert type

fixing hole and chipbreaker

Code	Fixing	Chipbreaker
N	No hole	None
R	No hole	One side
F	No hole	Both sides
A	Cylindrical hole	None
M	Cylindrical hole	One side
G	Cylindrical hole	Both sides
W	Hole, 40–60° countersink one side	None
T	Hole, 40–60° countersink one side	One side
Q	Hole, 40–60° countersink both sides	None
U	Hole, 40–60° countersink both sides	Both sides
B	Hole, 70–90° countersink one side	None
H	Hole, 70–90° countersink one side	One side
C	Hole, 70–90° countersink both sides	None
J	Hole, 70–90° countersink both sides	Both sides
X	Special	—

6 · Thickness

Code	mm
01	1.59
T1	1.98
02	2.38
T2	2.78
03	3.18
T3	3.97
04	4.76
05	5.56
06	6.35
07	7.94
09	9.52

7 · Nose radius

Code	mm
00	Sharp
01	0.1
02	0.2
04	0.4
08	0.8
12	1.2
16	1.6
24	2.4
32	3.2
M0	Round, metric

8–9 · Optional

Code	Meaning
F	Sharp edge
E	Honed (rounded)
T	Chamfered (T-land)
S	Chamfered & honed
R	Right hand
L	Left hand
N	Neutral

External toolholder designation

ISO 5608

P	C	L	N	R	25	25	M	12
1 Clamping	2 Insert shape	3 Holder style	4 Clearance	5 Hand	6 Shank height	7 Shank width	8 Length	9 Edge length

1 · Clamping system

Code	Method
C	Top clamp, no hole
M	Top clamp and pin through hole
P	Lever lock through hole
S	Screw through hole
D	Rigid clamp (wedge or double)

3 · Holder style

entering angle κr

Code	κr	Code	κr
A	90°	K	75°
B	75°	L	95°
D	45°	N	63°
E	60°	Q	107.5°
F	90°	S	45°
G	90°	T	60°
H	107.5°	U	93°
J	93°	V	72.5°

Holder style sets the entering angle and whether the tool cuts on the side, the end, or both.

5 · Cutting edge length

code by shape and IC (mm)

IC mm	C	D	S	T	V	W	R
6.35	06	07	06	11	11	04	06
9.525	09	11	09	16	16	06	09
12.7	12	15	12	22	22	08	12
15.875	16	—	15	27	—	—	15
19.05	19	—	19	33	—	—	19
25.4	25	—	25	44	—	—	25

Rhombic, square and triangle codes give the edge length in whole mm, ignoring decimals. Round inserts give the diameter.

8 · Tool length

mm

Code	mm	Code	mm
A	32	M	150
B	40	N	160
C	50	P	170
D	60	Q	180
E	70	R	200
F	80	S	250
G	90	T	300
H	100	U	350
J	110	V	400
K	125	W	450
L	140	Y	500

Reading a holder

Positions 2 and 4 must match the insert. A **PCLNR 2525 M12** takes a C-shape, 0° clearance insert with a 12 mm edge (CNMG 12…), right hand, 25 × 25 mm shank, 150 mm long, 95° entering angle.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up.

WORKSHOP REFERENCE · 06

Fasteners, Spanners & Torque

Spanner and hex key sizes, clearance holes and tightening torques for metric and inch fasteners.

Metric spanner, hex key & hole sizes

ISO coarse thread

Size	Pitch	Hex AF ISO	Hex AF DIN	Socket head key	Button head key	Csk head key	Grub screw key	Clear. fine	Clear. medium	Clear. coarse	C'bore Ø
M3	0.5	**5.5**	5.5	2.5	2	2	1.5	3.2	3.4	3.6	6.5
M4	0.7	**7**	7	3	2.5	2.5	2	4.3	4.5	4.8	8
M5	0.8	**8**	8	4	3	3	2.5	5.3	5.5	5.8	10
M6	1	**10**	10	5	4	4	3	6.4	6.6	7	11
M8	1.25	**13**	13	6	5	5	4	8.4	9	10	15
M10	1.5	**16**	17	8	6	6	5	10.5	11	12	18
M12	1.75	**18**	19	10	8	8	6	13	13.5	14.5	20
M14	2	**21**	22	12	—	10	—	15	15.5	16.5	24
M16	2	**24**	24	14	10	10	8	17	17.5	18.5	26
M20	2.5	**30**	30	17	—	12	10	21	22	24	33
M24	3	**36**	36	19	—	14	12	25	26	28	40
M30	3.5	**46**	46	22	—	—	—	31	33	35	48
M36	4	**55**	55	27	—	—	—	37	39	42	57

Hex AF: ISO 4014/4017/4032 and the older DIN 931/933/934 differ at M10, M12, M14 and M22 (M22: ISO 34, DIN 32). Hex keys: socket head ISO 4762, button head ISO 7380, countersunk ISO 10642, grub screw ISO 4026–4029. Clearance holes ISO 273. Counterbore diameter for socket head cap screws (DIN 974-1).

Tightening torque & preload

VDI 2230 · μ = 0.12 · 90% yield

Size	Tightening torque (N·m)			Preload (kN)		
	8.8	10.9	12.9	8.8	10.9	12.9
M4	**3**	**4.6**	**5.1**	4.4	6.5	7.6
M5	**5.9**	**8.6**	**10**	7.2	10.6	12.4
M6	**10.1**	**14.9**	**17.4**	10.2	14.9	17.5
M8	**24.6**	**36.1**	**42.2**	18.6	27.3	32
M10	**48**	**71**	**83**	29.6	43.4	50.8
M12	**84**	**123**	**144**	43	63.2	74
M14	**133**	**195**	**229**	59.1	86.7	101.5
M16	**206**	**302**	**354**	80.9	118.8	139
M20	**415**	**592**	**692**	130	186	217
M24	**714**	**1017**	**1190**	188	267	313
M30	**1428**	**2033**	**2380**	300	427	499
M36	**2482**	**3535**	**4136**	438	623	729

Metric coarse thread, hex head (ISO 4014–4018) or socket head (ISO 4762) screws, lightly oiled, $\mu_G = \mu_K = 0.12$. Values per VDI 2230 as published in the Würth technical handbook. Dry or plated threads, lubricants and washers all change friction, so adjust accordingly.

SAE inch bolt grades

SAE J429

Grade	Head marks	Tensile MPa
Grade 2	None	**510 (74 ksi)**
Grade 5	3 radial lines	**827 (120 ksi)**
Grade 8	6 radial lines	**1034 (150 ksi)**

Grade 5 tensile shown for ¼–1 in. Larger sizes are rated lower.

Inch (UNC) spanner & hex key sizes

ASME B18

Size	TPI	Hex AF	Socket head key	Button head key
No. 4	40	—	3/32	1/16
No. 6	32	—	7/64	5/64
No. 8	32	—	9/64	3/32
No. 10	24	—	5/32	1/8
1/4	20	**7/16**	3/16	5/32
5/16	18	**1/2**	1/4	3/16
3/8	16	**9/16**	5/16	7/32
7/16	14	**5/8**	3/8	—
1/2	13	**3/4**	3/8	5/16
5/8	11	**15/16**	1/2	3/8
3/4	10	**1 1/8**	5/8	—
7/8	9	**1 5/16**	3/4	—
1	8	**1 1/2**	3/4	—

Hex AF for finished hex bolts and cap screws. Socket head ASME B18.3, button head ASME B18.3.

Metric property classes

8.8 800 MPa tensile · 640 MPa yield
10.9 1000 MPa tensile · 900 MPa yield
12.9 1200 MPa tensile · 1080 MPa yield

First number × 100 = tensile strength in MPa. Second number × 10 = yield as a percentage of tensile. Nominal values shown; ISO 898-1 minimums are slightly higher above M16 for 8.8.

Torque values are a starting point for steel-on-steel joints. Critical joints should be calculated for the actual parts.

A guide only. Always check against the tool maker's data and your machine and set-up, and talk to your Teravin sales engineer before relying on it. Terms: teravin.tools/terms

WORKSHOP REFERENCE · 07

ISO Fits & Tolerances

Limit deviations for the most used hole and shaft tolerances, standard IT grades, and how to choose a fit.

Hole tolerances

upper / lower deviation in µm · ISO 286-2

Size mm over – incl.	H6	H7	H8	H9	H11	F7	G7	K7	M7	N7	P7
– 3	+6 0	+10 0	+14 0	+25 0	+60 0	+16 +6	+12 +2	0 −10	−2 −12	−4 −14	−6 −16
3 – 6	+8 0	+12 0	+18 0	+30 0	+75 0	+22 +10	+16 +4	+3 −9	0 −12	−4 −16	−8 −20
6 – 10	+9 0	+15 0	+22 0	+36 0	+90 0	+28 +13	+20 +5	+5 −10	0 −15	−4 −19	−9 −24
10 – 18	+11 0	+18 0	+27 0	+43 0	+110 0	+34 +16	+24 +6	+6 −12	0 −18	−5 −23	−11 −29
18 – 30	+13 0	+21 0	+33 0	+52 0	+130 0	+41 +20	+28 +7	+6 −15	0 −21	−7 −28	−14 −35
30 – 50	+16 0	+25 0	+39 0	+62 0	+160 0	+50 +25	+34 +9	+7 −18	0 −25	−8 −33	−17 −42
50 – 80	+19 0	+30 0	+46 0	+74 0	+190 0	+60 +30	+40 +10	+9 −21	0 −30	−9 −39	−21 −51
80 – 120	+22 0	+35 0	+54 0	+87 0	+220 0	+71 +36	+47 +12	+10 −25	0 −35	−10 −45	−24 −59
120 – 180	+25 0	+40 0	+63 0	+100 0	+250 0	+83 +43	+54 +14	+12 −28	0 −40	−12 −52	−28 −68
180 – 250	+29 0	+46 0	+72 0	+115 0	+290 0	+96 +50	+61 +15	+13 −33	0 −46	−14 −60	−33 −79
250 – 315	+32 0	+52 0	+81 0	+130 0	+320 0	+108 +56	+69 +17	+16 −36	0 −52	−14 −66	−36 −88
315 – 400	+36 0	+57 0	+89 0	+140 0	+360 0	+119 +62	+75 +18	+17 −40	0 −57	−16 −73	−41 −98
400 – 500	+40 0	+63 0	+97 0	+155 0	+400 0	+131 +68	+83 +20	+18 −45	0 −63	−17 −80	−45 −108

Shaft tolerances

upper / lower deviation in µm · ISO 286-2

Size mm over – incl.	d9	e8	f7	g6	h6	h7	h9	h11	js6	k6	m6	n6	p6
– 3	−20 −45	−14 −28	−6 −16	−2 −8	0 −6	0 −10	0 −25	0 −60	+3 −3	+6 0	+8 +2	+10 +4	+12 +6
3 – 6	−30 −60	−20 −38	−10 −22	−4 −12	0 −8	0 −12	0 −30	0 −75	+4 −4	+9 +1	+12 +4	+16 +8	+20 +12
6 – 10	−40 −76	−25 −47	−13 −28	−5 −14	0 −9	0 −15	0 −36	0 −90	+4.5 −4.5	+10 +1	+15 +6	+19 +10	+24 +15
10 – 18	−50 −93	−32 −59	−16 −34	−6 −17	0 −11	0 −18	0 −43	0 −110	+5.5 −5.5	+12 +1	+18 +7	+23 +12	+29 +18
18 – 30	−65 −117	−40 −73	−20 −41	−7 −20	0 −13	0 −21	0 −52	0 −130	+6.5 −6.5	+15 +2	+21 +8	+28 +15	+35 +22
30 – 50	−80 −142	−50 −89	−25 −50	−9 −25	0 −16	0 −25	0 −62	0 −160	+8 −8	+18 +2	+25 +9	+33 +17	+42 +26
50 – 80	−100 −174	−60 −106	−30 −60	−10 −29	0 −19	0 −30	0 −74	0 −190	+9.5 −9.5	+21 +2	+30 +11	+39 +20	+51 +32
80 – 120	−120 −207	−72 −126	−36 −71	−12 −34	0 −22	0 −35	0 −87	0 −220	+11 −11	+25 +3	+35 +13	+45 +23	+59 +37
120 – 180	−145 −245	−85 −148	−43 −83	−14 −39	0 −25	0 −40	0 −100	0 −250	+12.5 −12.5	+28 +3	+40 +15	+52 +27	+68 +43
180 – 250	−170 −285	−100 −172	−50 −96	−15 −44	0 −29	0 −46	0 −115	0 −290	+14.5 −14.5	+33 +4	+46 +17	+60 +31	+79 +50
250 – 315	−190 −320	−110 −191	−56 −108	−17 −49	0 −32	0 −52	0 −130	0 −320	+16 −16	+36 +4	+52 +20	+66 +34	+88 +56
315 – 400	−210 −350	−125 −214	−62 −119	−18 −54	0 −36	0 −57	0 −140	0 −360	+18 −18	+40 +4	+57 +21	+73 +37	+98 +62
400 – 500	−230 −385	−135 −232	−68 −131	−20 −60	0 −40	0 −63	0 −155	0 −400	+20 −20	+45 +5	+63 +23	+80 +40	+108 +68

Choosing a fit

hole-basis system

Fit	Type and typical use	Clearance at Ø25 µm
H9/d9	**Loose running** Wide clearance for slow, loose bearings, idler pulleys, rough parts.	+65 to +169
H8/f7	**Close running** Running fits on accurate machines at moderate speed: spindle and gearbox bearings.	+20 to +74
H7/g6	**Sliding** Parts that move and turn freely with little play: guides, spigots, slide valves.	+7 to +41
H7/h6	**Locational clearance** Snug fit that still assembles by hand: locating spigots, gears on shafts.	0 to +34
H7/k6	**Transition** Accurate location, light tap to assemble: couplings, bearing inner races.	−15 to +19
H7/n6	**Transition, tight** Firmer location, press or mallet: gears and pulleys with keys.	−28 to +6
H7/p6	**Light press** Interference for parts that must not move: bushes, dowels, bearing housings.	−35 to −1

Positive figures are clearance, negative figures are interference. Ø25 sits in the 18–30 mm range.

Standard tolerance grades

IT grade in µm

Size mm	IT5	IT6	IT7	IT8	IT9	IT10	IT11
– 3	4	6	10	14	25	40	60
3 – 6	5	8	12	18	30	48	75
6 – 10	6	9	15	22	36	58	90
10 – 18	8	11	18	27	43	70	110
18 – 30	9	13	21	33	52	84	130
30 – 50	11	16	25	39	62	100	160
50 – 80	13	19	30	46	74	120	190
80 – 120	15	22	35	54	87	140	220
120 – 180	18	25	40	63	100	160	250
180 – 250	20	29	46	72	115	185	290
250 – 315	23	32	52	81	130	210	320
315 – 400	25	36	57	89	140	230	360
400 – 500	27	40	63	97	155	250	400

Reading the table

Ø25 H7 hole: 25.000 – 25.021
Ø25 g6 shaft: 24.980 – 24.993

Add the deviations to the nominal size. Capital letters are holes, lower case are shafts. The number is the IT grade: smaller means tighter.

Values per ISO 286-1 and ISO 286-2 for nominal sizes up to 500 mm. Deviations in micrometres (µm); 1 µm = 0.001 mm. Clearances are calculated from the tabulated limits.

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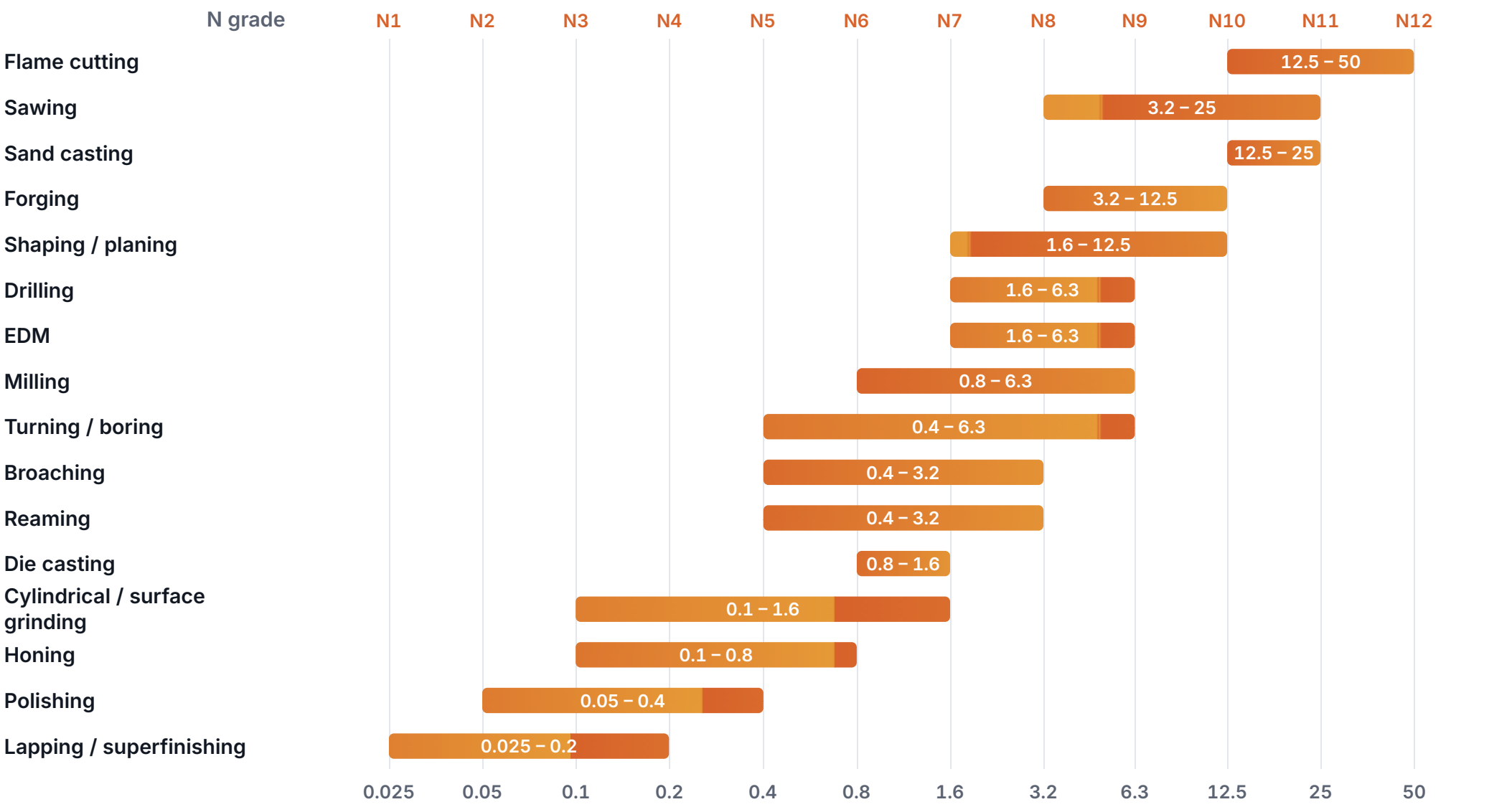
WORKSHOP REFERENCE · 08

Surface Finish

Roughness grades, what each process can achieve, drawing symbols, and the finish to expect from an insert's feed and nose radius.

Finish by process

typical Ra range in µm



Typical production ranges. Finer finishes are possible with extra care and cost; rougher results come from worn tools or unstable set-ups.

Roughness grades

ISO 1302

N grade	Ra µm	Ra µin
N12	50	2000
N11	25	1000
N10	12.5	500
N9	6.3	250
N8	3.2	125
N7	1.6	63
N6	0.8	32
N5	0.4	16
N4	0.2	8
N3	0.1	4
N2	0.05	2
N1	0.025	1

Ra (arithmetic mean roughness) is also called CLA or AA. Rz is typically 4 to 7 times Ra, depending on the process.

Drawing symbols

ISO 1302 · ISO 21920-1



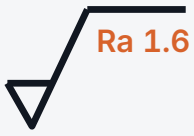
Basic symbol
Any process allowed



Machined
Material removal required



Not machined
Material removal not allowed



With a value
Ra 1.6 µm maximum, machined

Turning finish from feed and nose radius

theoretical Ra in µm

Feed mm/rev	0.2	0.4	0.8	1.2	1.6	2.4
	Insert nose radius rε (mm) →					
0.05	0.40	0.20	0.10	0.07	0.05	0.03
0.08	1.03	0.51	0.26	0.17	0.13	0.09
0.10	1.60	0.80	0.40	0.27	0.20	0.13
0.12	2.31	1.15	0.58	0.38	0.29	0.19
0.15	3.61	1.80	0.90	0.60	0.45	0.30
0.18	5.20	2.60	1.30	0.87	0.65	0.43
0.20	6.42	3.21	1.60	1.07	0.80	0.53
0.25	10.02	5.01	2.51	1.67	1.25	0.84
0.30	14.43	7.22	3.61	2.41	1.80	1.20
0.35	19.65	9.82	4.91	3.27	2.46	1.64
0.40	25.66	12.83	6.42	4.28	3.21	2.14
0.50	40.09	20.05	10.02	6.68	5.01	3.34

Geometric values for a sharp insert. Real finish is usually worse because of wear, built-up edge and vibration. Wiper inserts give roughly half the Ra at the same feed.

Formulas

Peak to valley $Rt = f^2 \div (8 \times r\varepsilon) \times 1000$
Average $Ra \approx f^2 \div (31.2 \times r\varepsilon) \times 1000$
µin to µm $\mu m = \mu in \times 0.0254$

f is the feed in mm/rev, rε the nose radius in mm; results in µm. Double the nose radius and Ra halves; double the feed and Ra goes up four times.

Process ranges are typical values compiled from ISO 1302 and ASME B46.1 guidance. Theoretical turning values are geometric and assume a sharp tool.

A guide only. Always check against the tool maker's data and your machine and set-up, and talk to your Teravin sales engineer before relying on it. Terms: teravin.tools/terms

WORKSHOP REFERENCE · 09

Toolholding Tapers & Collets

Spindle tapers, collet ranges and shank tapers for milling, drilling and turning centres.

ER collets

ISO 15488 (DIN 6499)

Size	Collet OD mm	Clamping range mm	Each collet closes
ER8	8.5	**0.5–5**	0.5 mm
ER11	11.5	**0.5–7**	0.5 mm
ER16	17	**0.5–10**	1.0 mm
ER20	21	**1–13**	1.0 mm
ER25	26	**1–16**	1.0 mm
ER32	33	**2–20**	1.0 mm
ER40	41	**3–26**	1.0 mm
ER50	52	**6–34**	1.0 mm

Each ER collet grips over a short range below its nominal size, so Ø10 covers 9–10 mm. For through-coolant or high-speed work use sealed or precision collets.

Morse taper

ISO 296 · DIN 228

Taper	Gauge Ø D mm	Taper ratio
MT0	**9.045**	1:19.212
MT1	**12.065**	1:20.047
MT2	**17.780**	1:20.020
MT3	**23.825**	1:19.922
MT4	**31.267**	1:19.254
MT5	**44.399**	1:19.002
MT6	**63.348**	1:19.180

D is the diameter at the gauge line (the large end of the socket). All Morse tapers are close to 1:20 (about 1.5° included).

Jacobs tapers

drill chucks

Taper	Large end Ø mm
JT0	**6.350**
JT1	**9.754**
JT2	**14.199**
JT33	**15.850**
JT6	**17.170**
JT3	**20.599**

DIN B tapers

DIN 238

Taper	Large end Ø mm
B10	**10.094**
B12	**12.065**
B16	**15.733**
B18	**17.780**
B22	**21.793**
B24	**23.825**

Steep taper 7:24

ISO 7388 · MAS 403 · ANSI B5.50

Size	Gauge Ø mm	SK / DIN pull stud	BT pull stud	CAT pull stud
30	**31.75**	M12	M12	1/2-13 UNC
40	**44.45**	M16	M16	5/8-11 UNC
45	**57.15**	M20	M20	3/4-10 UNC
50	**69.85**	M24	M24	1-8 UNC

SK (DIN 69871 / ISO 7388-1), BT (MAS 403) and CAT (ANSI) share the 7:24 taper but have different flanges and pull studs, so they are not interchangeable. Pull studs vary by machine maker; check the spindle manual.

HSK hollow taper

ISO 12164 · DIN 69893

Size	Flange Ø mm	Taper Ø mm
HSK-A32	**32**	24
HSK-A40	**40**	30
HSK-A50	**50**	38
HSK-A63	**63**	48
HSK-A80	**80**	60
HSK-A100	**100**	75
HSK-A125	**125**	95

HSK clamps on the taper and the flange face at once, giving high stiffness and repeatability at speed. Form A is the common auto-change version.

Choosing a holder

ER collet chuck: versatile, wide clamping range, good for drills, taps and small cutters.
Side-lock (Weldon): cannot pull out under heavy roughing; needs a flatted shank.
Hydraulic chuck: low runout and good damping for finishing and reaming.
Shrink fit: slim, very rigid, very low runout; needs a heating unit.
Milling chuck: high grip for heavy roughing with plain shanks.

Runout matters

Every 0.01 mm of runout puts more load on one cutting edge and cuts tool life noticeably. Clean the taper and collet before every change, and torque the nut to the maker's value.

Dimensions are nominal values from the cited standards. Tool makers' catalogues give full tolerances, lengths and thread details.

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Insert Wear & Troubleshooting

Read the edge, fix the cause. The common wear patterns on turning and milling inserts and the first changes to make.

Insert wear: what you see and what to do

turning and milling

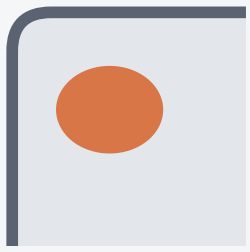


Flank wear

Even wear land on the clearance face. Normal wear; index when the land reaches about 0.3 mm.

Cause: Abrasion; cutting speed too high; grade not wear-resistant enough.

Fix: Lower Vc; choose a more wear-resistant or coated grade.

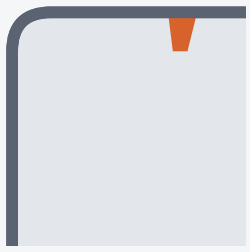


Crater wear

A hollow worn into the rake face behind the edge.

Cause: Heat and diffusion, mostly in steel at high speed.

Fix: Lower Vc and feed; use an alumina-coated grade; more positive geometry.

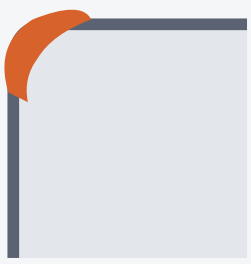


Notch wear

A deep notch at the depth-of-cut line.

Cause: Work-hardened surface, scale or casting skin; common in stainless and superalloys.

Fix: Vary the depth of cut; smaller entering angle or round insert; tougher grade.

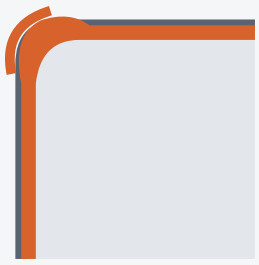


Built-up edge

Workpiece material welded onto the edge, breaking away with bits of edge.

Cause: Speed too low; sticky materials such as stainless, aluminium and low-carbon steel.

Fix: Raise Vc; sharp positive edge; coolant; polished or PVD-coated grade.

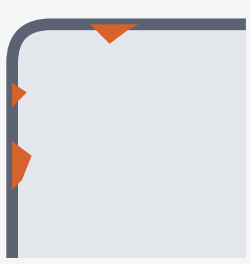


Plastic deformation

The edge sags or bulges from heat and pressure.

Cause: Too much heat and load at the edge.

Fix: Lower Vc and feed; harder grade; larger nose radius; more coolant.

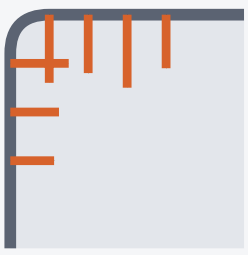


Edge chipping

Small pieces broken out of the edge line.

Cause: Interrupted cuts, vibration, inclusions or a too-brittle grade.

Fix: Tougher grade; honed or chamfered edge; reduce feed on entry; improve rigidity.

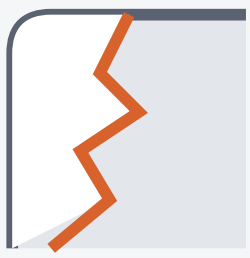


Thermal cracks

Fine cracks across the edge, like a comb.

Cause: Heating and cooling cycles in interrupted cuts or milling.

Fix: Tougher grade; run dry or flood fully, never on-off; reduce Vc.

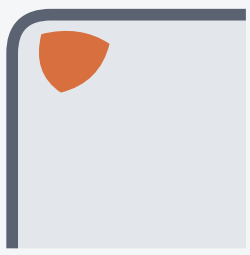


Insert fracture

The corner or a large part of the insert breaks off.

Cause: Overload, late indexing, or a weak set-up.

Fix: Index earlier; stronger insert (thicker, larger angle); lower feed and depth; check clamping.



Coating flaking

Coating peels away, often with built-up material.

Cause: Sticking material and edge loading.

Fix: Raise Vc; sharper PVD grade; check coolant concentration.

Troubleshooting

problem and first things to try

Problem	Try this
Poor surface finish	Raise Vc; larger nose radius or wiper insert; lower feed; check for built-up edge or a worn edge.
Chatter and vibration	Shorten overhang; smaller nose radius; more positive insert; lower depth of cut; try a different speed.
Long, stringy chips	Increase feed or depth of cut; choose a chipbreaker for that feed; use high-pressure coolant.
Chips too short, jamming	Reduce feed; use a more open chipbreaker; increase depth of cut.
Burr at the exit	Sharper edge; chamfer before breaking out; reduce feed at exit; change the entering angle.
Size drifting	Edge wear or heat growth. Warm up the machine, index on schedule, check offsets.
Short tool life	Check Vc against the grade; correct coolant concentration; improve stability; match grade to the ISO material group.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up.

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WORKSHOP REFERENCE · 11

Hardness Conversion

Rockwell, Vickers and Brinell equivalents for steel, with approximate tensile strength.

Hardened steel · HRC 68–45

ASTM E140

HRC	HV	HB	Tensile MPa ≈
68	940	—	—
67	900	—	—
66	865	—	—
65	832	739	—
64	800	722	—
63	772	706	—
62	746	688	—
61	720	670	—
60	697	654	—
59	674	634	—
58	653	615	—
57	633	595	—
56	613	577	—
55	595	560	—
54	577	543	—
53	560	525	—
52	544	512	—
51	528	496	—
50	513	481	—
49	498	469	—
48	484	455	1530
47	471	443	1510
46	458	432	1480
45	446	421	1440
44	434	409	1400

Hardened steel · HRC 44–20

ASTM E140

HRC	HV	HB	Tensile MPa ≈
43	423	400	1360
42	412	390	1320
41	402	381	1290
40	392	371	1260
39	382	362	1230
38	372	353	1190
37	363	344	1160
36	354	336	1130
35	345	327	1100
34	336	319	1080
33	327	311	1050
32	318	301	1020
31	310	294	990
30	302	286	970
29	294	279	950
28	286	271	920
27	279	264	900
26	272	258	880
25	266	253	870
24	260	247	850
23	254	243	830
22	248	237	800
21	243	231	780
20	238	226	760

Softer steel · HRB

BS 860 · ASTM E140

HRB	HV	HB	Tensile MPa ≈
100	269	255	873
99	261	248	853
98	253	241	824
97	247	235	794
96	241	229	775
95	228	217	745
94	223	212	716
93	218	207	696
91	208	197	667
89	197	187	637
87	189	179	608
85	179	170	559
83	172	163	539
81	165	156	530
79	157	149	500
77	150	143	481
74	144	137	471
72	138	131	461
69	133	126	451
67	127	121	431
64	122	116	422
61	117	111	402

Which scale?

HRC (Rockwell C, diamond cone, 150 kgf): hardened steel, about 20–70 HRC.
HRB (Rockwell B, ball, 100 kgf): soft steel, brass, aluminium, below 20 HRC.
HB (Brinell, 10 mm ball): castings, forgings and bar stock up to about 650 HB.
HV (Vickers, diamond pyramid): any hardness, thin parts and case depth.

Rules of thumb

Steel tensile ≈ 3.4 × HB MPa
Above 45 HRC use CBN or ceramic
HSS tools reach 62–67 HRC

Conversions between scales are approximate and apply to carbon and alloy steels. They do not apply to austenitic stainless or non-ferrous metals.

HRC table per ASTM E140 Table 1 (non-austenitic steels); HB with tungsten carbide ball. HRB table per BS 860 / ASTM E140 approximations. Tensile strengths are approximate and for guidance only.

A guide only. Always check against the tool maker's data and your machine and set-up, and talk to your Teravin sales engineer before relying on it. Terms: teravin.tools/terms

WORKSHOP REFERENCE · 12

Milling Speeds & Feeds

Starting cutting speeds and feeds per tooth for end mills, chip thinning, and a spindle speed ready-reckoner.

Cutting speed by material

Vc in m/min · starting values

ISO	Material	Hardness	HSS / HSS-Co	Solid carbide, coated
P	Low-carbon & free-cutting steel	< 180 HB	30–40	150–250
P	Medium-carbon & alloy steel, annealed	180–280 HB	20–30	120–180
P	Alloy & tool steel, hardened & tempered	280–350 HB	10–18	80–120
M	Austenitic stainless (304, 316)	< 200 HB	12–20	80–120
M	Duplex & super-duplex stainless	< 300 HB	10–15	60–90
K	Grey cast iron	< 250 HB	20–30	120–200
K	Ductile (SG) cast iron	< 300 HB	15–25	100–150
N	Wrought aluminium	< 120 HB	150–300	300–1000
N	Cast aluminium, high silicon	< 120 HB	100–200	200–500
N	Brass, bronze & copper	< 200 HB	40–80	150–300
S	Titanium alloys	< 350 HB	10–20	40–80
S	Nickel superalloys (Inconel, Hastelloy)	< 350 HB	5–10	20–40
H	Hardened steel	45–55 HRC	—	60–120
H	Hardened steel	55–65 HRC	—	40–80

For side milling with radial engagement up to half the diameter. Full slotting: use about 70% of these speeds. Aluminium figures are usually capped by spindle speed.

Feed per tooth in steel

fz in mm · end mills

Cutter Ø mm	HSS	Solid carbide
3	0.005–0.012	0.010–0.020
6	0.012–0.025	0.020–0.040
8	0.015–0.030	0.030–0.050
10	0.020–0.035	0.040–0.060
12	0.025–0.040	0.050–0.070
16	0.030–0.050	0.060–0.090
20	0.035–0.060	0.070–0.100
25	0.040–0.070	0.080–0.120

Stainless: about 80%. Aluminium: up to 150%. Titanium and nickel alloys: about 60%. Hardened steel: about 50%.

Chip thinning

light radial cuts

ae ÷ D	Raise fz by
50%	× 1.00
40%	× 1.02
30%	× 1.09
25%	× 1.15
20%	× 1.25
15%	× 1.40
10%	× 1.67
5%	× 2.29
2%	× 3.57

With light radial engagement the real chip is thinner than fz. Raise the feed by this factor to keep the chip load right, as in high-efficiency milling.

Formulas

Table feed $vf = fz \times z \times n$ (mm/min)
Metal removal $Q = ap \times ae \times vf \div 1000$ (cm^3/min)
Chip thinning $fz' = fz \times D \div (2\sqrt{(ae \cdot D - ae^2)})$

z number of teeth · ap axial depth · ae radial width (mm)

Spindle speed (RPM) by cutter diameter and cutting speed

n = Vc × 1000 ÷ (π × D)

Cutter Ø mm	10	20	30	40	60	80	100	120	150	200	250	300	400	500
	Cutting speed Vc (m/min) →													
1	3,200	6,350	9,550	12,700	19,100	25,500	31,800	38,200	47,700	63,700	79,600	95,500	127,300	159,200
1.5	2,100	4,250	6,350	8,500	12,700	17,000	21,200	25,500	31,800	42,400	53,100	63,700	84,900	106,100
2	1,590	3,200	4,750	6,350	9,550	12,700	15,900	19,100	23,900	31,800	39,800	47,700	63,700	79,600
3	1,060	2,100	3,200	4,250	6,350	8,500	10,600	12,700	15,900	21,200	26,500	31,800	42,400	53,100
4	800	1,590	2,400	3,200	4,750	6,350	7,950	9,550	11,900	15,900	19,900	23,900	31,800	39,800
5	640	1,270	1,910	2,550	3,800	5,100	6,350	7,650	9,550	12,700	15,900	19,100	25,500	31,800
6	530	1,060	1,590	2,100	3,200	4,250	5,300	6,350	7,950	10,600	13,300	15,900	21,200	26,500
8	400	800	1,190	1,590	2,400	3,200	4,000	4,750	5,950	7,950	9,950	11,900	15,900	19,900
10	320	640	950	1,270	1,910	2,550	3,200	3,800	4,750	6,350	7,950	9,550	12,700	15,900
12	270	530	800	1,060	1,590	2,100	2,650	3,200	4,000	5,300	6,650	7,950	10,600	13,300
14	230	450	680	910	1,360	1,820	2,250	2,750	3,400	4,550	5,700	6,800	9,100	11,400
16	200	400	600	800	1,190	1,590	1,990	2,400	3,000	4,000	4,950	5,950	7,950	9,950
20	160	320	480	640	950	1,270	1,590	1,910	2,400	3,200	4,000	4,750	6,350	7,950
25	130	250	380	510	760	1,020	1,270	1,530	1,910	2,550	3,200	3,800	5,100	6,350
32	100	200	300	400	600	800	990	1,190	1,490	1,990	2,500	3,000	4,000	4,950
40	80	160	240	320	480	640	800	950	1,190	1,590	1,990	2,400	3,200	4,000
50	60	130	190	250	380	510	640	760	950	1,270	1,590	1,910	2,550	3,200
63	50	100	150	200	300	400	510	610	760	1,010	1,260	1,520	2,000	2,550
80	40	80	120	160	240	320	400	480	600	800	990	1,190	1,590	1,990

Rounded to the nearest 10 RPM (50 above 2,000 and 100 above 10,000). Speeds above 30,000 RPM are greyed out.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up. Speeds and feeds are general starting values for end mills.