GENERAL INFORMATION

GENERAL INFORMATION MILLING

Speed, feed and depth of cut are the most important factors to consider for best results in milling. Improper feeds and speeds often cause low production, poor work quality and unnecessary damage to the cutter.
This section covers the basic principles of speed and feed selection for milling cutters and end mills. It will serve as a guide in setting-up new milling jobs.

Speeds
In milling, SPEED is measured in peripheral metres per minute.(rpm x cutter circumference in metres). This is frequently referred to as "peripheral speed" "cutting speed" or "surface speed".

Use lower speed ranges for	Use higher speed ranges for
Hard materials Tough materials Abrasive materials Heavy cuts Minimum tool wear Maximum cutter life	Softer materials Better finishes Smaller diameter cutters Light cuts Unstable workpiece set-ups Hand feed operations Maximum production rates Non-metallic materials

Feeds
Feed is usually measured in milimeters per minute. It is the product of feed per tooth times revolution per minute times the number of teeth in the cutter. Due to variations in cutter sizes, numbers of teeth and revolutions per minute, all feed rates should be calculated from feed per tooth. Feed per tooth is the basis of all feed rates per minute, whether the cutters are large or small, fine or coarse tooth, and are run at high or low peripheral speed. Because feed per tooth affects chip thickness. It is a very important factor in cutter life.
Highest possible feed per tooth will usually give longer cutter life between grinds and greater production per grind. Excessive feeds may over load the cutter teeth and cause breakage or chipping of the cutting edges. The following factors should be kept in mind when using the recommended starting feed per tooth.

Use lower feeds for	Use higher feeds for
Light and finishing cuts Unstable set-ups Hard to machine materials Small diameter cutters Deep slots High tensile strength materials Fine tooth cutters	Heavy, roughing cuts Rigid set-ups Easy to machine materials Rugged cutters Low tensile strength materials Coarse tooth cutters Abrasive materials

Basic formulae

v_c - cutting speed (m/min)
n - RPM (rev/min)
f_n - feed rate (mm/rev)
ø - tool diameter (mm)

To calculate RPM from cutting speed: $n = \frac{v_c * 1000}{\pi * ø}$

To calculate cutting speed from RPM: $v_c = \frac{n * \pi * ø}{1000}$

All recommendations are based on ideal machining conditions. Adjustments may need to be made according to your set-up. The recommendations for speeds, feeds and other parameters presented in this chart are nominal recommendations and should be considered only as good starting points.

TROUBLESHOOTING MILLING

Problem	Instance of problem	Solution options
Tool breaks	At start or end of cut	Reduce overhang Use shorter tool Use lower feed rate
	During cutting	Check tool for wear and replace sooner Check toolholder for wear and replace Reduce overhang Use shorter tool Use lower feed rate Check coolant flow
	Changing direction	Check tool for wear and replace sooner Check toolholder for wear and replace Use lower feed rate when changing direction Use circular interpolation if possible
Cutting edge breaks	Corner chipping	Reduce overhang Use shorter tool Use climb milling
	Break at depth of cut	Use climb milling Use lower cutting speed
	Centre chipping	Use larger tool if possible Use higher cutting speed If noisy during cutting, use higher feed rate Check coolant flow Check toolholder for wear and replace
	Break of cutting edge	Use larger tool if possible Use lower feed rate Use lower cutting speed Check toolholder for wear and replace Check coolant flow
Heavy tool wear		Use lower cutting speed Use conventional milling Use higher feed rate Check coolant flow
Poor surface finish	Good finish but rough	Use lower feed rate Check coolant flow
	Chip welding	Use higher cutting speed Use higher feed rate Use conventional milling Check coolant flow
	Scoring	Use climb milling Check coolant flow
	Excessive cut marks	Use smaller radial depth of cut for finishing Use higher cutting speed Use lower feed rate
Poor accuracy	Undersize	Use conventional milling Use smaller radial depth of cut for finishing Check toolholder for wear and replace Reduce overhang Use higher cutting speed
	Not perpendicular	Use smaller radial depth of cut for finishing Check toolholder for wear and replace Reduce overhang Use higher cutting speed Use lower feed rate Check tool for wear and replace sooner
Chattering		Use higher or lower cutting speed Use higher feed rate Check toolholder for wear and replace Reduce overhang Use climb milling

GENERAL INFORMATION DRILLING & REAMING

Drilling guide.
Recommendations for use.

Ensure workpiece is firmly and securely fastened.
Avoid excess lateral loads.
Ensure collets and drill chucks are in good condition and will not allow drill slippage. Both drill and component damage can occur.
When using taper shank drills ensure all taper sleeves are clean and in good condition. Never allow the drill to drive off the tang. This is an indication that either the drill, the sleeve, or both are damaged. Use only soft faced hammers to drive the taper shank into the sleeve. Use a proper drift key to remove the shank from the sleeve.
Ensure drill is kept sharp, and sharpen before point of failure. If allowed to become blunt extra grinding will be needed to bring the drill back to optimum performance.
Keep the flutes free from swarf. Clogged flutes will hamper drill performance.
Use adequate coolant, particularly at the drill point.
Avoid excessive speed and feed rates. Use the charts in this catalogue. If unsure of the correct speed or feed rate to use, it is generally better to start at low speeds and feeds, and build up as appropriate.
When resharpening it is important that all wear is removed, and the correct point geometry is maintained. Do not overheat or burn the drill when grinding.
Ensure correct drill is chosen for application and material type, particularly with deeper holes to avoid pecking where possible.

Reaming guide.
Recommendations for use.

Ensure workpiece is firmly and securely fastened. Bending and moving may break reamer.
When using taper shank reamers ensure all taper sleeves are clean and in good condition.
Reamers must be kept sharp. As reamers only cut on the bevel lead, only the bevel, and the taper lead in the case of hand reamers, require regrinding. A blunt reamer wears on the outer corners on the bevel lead, resulting in a poor finish, undersized holes and increased torque.
When reaming, ensure that swarf is not allowed to build up in the flutes.
Adequate lubricant must be directed to the cutting area. When reaming high tensile materials, an improved finish can be acheived by using chlorinated or sulphurised oils.
The correct amount of stock must be left in the hole after drilling or coring to obtain the required hole size and finish, and eliminate excessive reamer wear. If too little stock is left for removal by reaming the reamer will rub in the hole giving rise to premature wear and loss of size. The table below shows approximate amounts of stock to be removed by reaming. This is **for guidance only**, as the amount of stock to be left depends greatly on the type of material being reamed and the type of reamer used.
When hand reaming, leave approximately two thirds of machine reaming allowance.

Stock removal.
Amount of material to be left in prior to reaming.

Operation	Finish Reamed Size					
	<ø1.5	ø1.5 -3.0	ø3.0 -6.0	ø6.0 -16.0	ø16.0 -25.0	ø25.0 -50.0
Pre Drilled	0.20	0.20	0.20	0.30	0.30	0.40
Pre Core Drilled or Bored	0.10	0.10	0.10	0.20	0.20	0.30

All recommendations are for guidance only. Adjustments may need to be made according to your set-up.

TROUBLESHOOTING DRILLING & REAMING

Troubleshooting - Drilling

Problem	Probable causes	Suggested actions
Drill will not enter work	Drill is dull	Regrind lip relief
	Lip relief too small	Regrind web thinning
	Web too thick	Select drill with narrow web
Cutting lip breaks	Lip relief too large	Regrind lip relief
	Feed too high	Choose correct data from cutting charts
Tang breaks	Bad fit in taper shank socket	Ensure socket is clean
	Burred or badly worn socket	Replace socket
Drill centre chipped	Lip relief too large	Regrind lip relief
	Feed too high	Choose correct data from cutting charts
Oversize hole	Unequal cutting edge length or angle	Resharpen drill point
	Tool not held tight	Tighten collet or chuck
Outer edges chipped	Cutting speed too high	Choose correct data from cutting charts
	Flutes clogged	Choose correct drill from application guide
	Drill worn	Replace or regrind drill
	Hard spots in work material	Choose correct drill from application guide
Poor surface finish	Incorrect grinding of drill point	Replace or regrind drill
	Insufficient coolant supply	Ensure coolant is targetted correctly
	Feed too high	Choose correct data from cutting charts
	Workpiece not held securely	Replace or tighten fixture or vice

Troubleshooting - Reaming

Problem	Probable causes	Suggested actions
Chattering	Workpiece not held securely	Replace or tighten fixture or vice
	Incorrect speed or feed	Choose correct data from cutting charts
	Incorrect reamer	Select reduced vibration carbide reamer
Rapid wear	Incorrect size of pre-drilled hole	Choose correct data from reaming guide
	Incorrect speed or feed	Choose correct data from cutting charts
Tapering or Bell mouthing	Machine spindle/bearings worn	Replace/repair equipment
	Reamer and hole mis-aligned	Check set-up and re-align
Rubbing	Incorrect size of pre-drilled hole	Choose correct data from reaming guide
	Incorrect bevel lead on reamer	Replace or regrind reamer
Oversize hole	Excessive run-out in collet/chuck	Replace collet/chuck
	Incorrect size of pre-drilled hole	Choose correct data from reaming guide
Poor surface finish	Incorrect speed or feed	Choose correct data from cutting charts
	Reamer worn or damaged	Replace or regrind reamer
	Insufficient coolant supply	Ensure coolant is targetted correctly

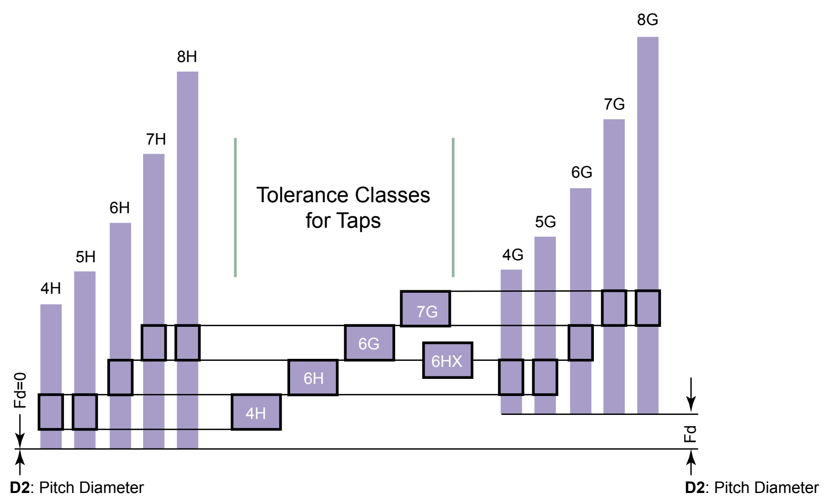
Tapping guide.

TAP SELECTION
The type of tap used depends on the type of material to be machined. Generally, any materials with an elongation of at least 10% can be cold formed, but any other materials need to be cut. Please refer to tap selection guide for most suitable tap.

CORE HOLES
Core holes should be clean and swarf free. In materials that have a tendency to close down after drilling, a slightly larger tapping drill size should be used. Each tap size in this catalogue has a recommended tapping drill size shown in its dimension table.

CUTTING SPEEDS
The correct cutting speed is necessary to control chip flow and establish the best tool life for the tap. Guide values are given in the cutting data charts on pages 86-89. Material hardness and rigidity of workpiece can have a detrimental effect on the tap, so it is worth experimenting with the guide data to establish the best speeds for your particular application.

Tap tolerances.
Tolerance classes of taps and tolerance positions for screw threads as per Metric ISO standard



Tap tolerance ISO	Tap tolerance DIN	Correct class to obtain nut thread with tolerance				
ISO 1	4H	4H	5H			
ISO 2	6H	4G	5G	6H		
ISO 3	6G			6G	7H	8H
	7G				7G	8G

Standard fit for a thread corresponds to tolerance class ISO 2/6H. For more precise fits, without allowance on thread flank, tolerance class ISO 1/4H must be chosen. ISO 3/6G is used in case of loose fits, with large allowance, which is often required for subsequent coatings.

Between classes 6H and 6G taps are produced with tolerance 6HX. These taps are used for tapping abrasive materials, such as cast iron or Al-Si alloys, in order to increase their tool life. Another important application is on cold forming taps, which create the thread by plastic deformation and not by cutting. In this case, due to the elastic return of the material, in order to obtain a thread 6H tolerance, a 6HX tap must be used.

The tolerances described above are collected in the ISO standard ISO 68-1.

Problem	Probable causes	Suggested actions
Tapped hole oversize	Incorrect tap in use (cutting geometry unsuitable for application)	Use tap selected from the relevant material group
	Faulty alignment	Ensure that the tap is correctly aligned with the core hole axis
	Cold welding	Improve lubrication and direction of coolant Adjust cutting speed
	Re-ground tap (lead-in is not concentric)	Regrind tap lead correctly on a suitable tap grinding machine
Stripped threads	Incorrect tap in use (cutting geometry incorrect for application	Use a tap from the relevant material group.
	Spindle speed and feed rate not synchronized	Check feed rate programming and / or pitch of leading spindle Use a tapping spindle with axial float
	Insufficient start pressure exerted on tap with peel-cut	Increase start pressure
Bell mouthed tapped hole	Incorrect start pressure applied to tap	Use a tapping spindle with axial float
Unsatisfactory thread surface finish	Incorrect tap in use (Cutting geometry unsuitable for application)	Select tap from the relevant material group
	The tap is blunt	Replace or re-grind tap
	Tap badly re-ground	Re-grind tap again. Check that cutting geometry is suitable for material
	Coolant lacking in lubricating qualities and / or quantity	Ensure the use of a suitable coolant and an ample supply
Partial chipping of tap	Swarf jamming	Check cutting speed Use alternative tap type
	Tap has jammed against bottom of core hole	Check hole and thread depths Drill core hole deeper
	Tap incorrectly re-ground (lead-in diameter too small therefore too few cutting teeth)	Ensure that original values are maintained when regrinding
	Irregular workpiece material structure	Adjust cutting speed Improve lubricating quality of coolant
Excessive tap wear	Incorrect cutting speed	Adjust cutting speed to suit workpiece material
	Coolant lacking in lubricating qualities and / or quantity	Ensure the use of a suitable coolant and an ample supply Check that coolant is reaching the cutting zone
	Surface of the core hole is compacted	Check core hole drilling conditions (drill carefully to reduce risk of surface compacting) Check drill cutting edges
Tap breakage	Incorrect tap in use (cutting geometry unsuitable for application)	Use tap from the relevant material group
	Centering error	Ensure that axes of tap and core hole are aligned
	Blunt tap	Re-grind tap Ensure that taps are stored carefully
	Tap has reached bottom of core hole	Use tapping spindle with axial float and slipping clutch
	Core hole too small	Ensure tapping drill is correct size.

Tapping drill sizes for Metric threads.

Metric-ISO threads coarse pitch			
M	Pitch mm.	Maximun core dia. mm.	Drill size mm.
1	0.25	0.785	0.75
1.1	0.25	0.885	0.85
1.2	0.25	0.985	0.95
1.4	0.3	1.16	1.1
1.6	0.35	1.321	1.25
1.7	0.35	1.346	1.3
1.8	0.35	1.521	1.45
2	0.4	1.679	1.6
2.2	0.45	1.838	1.75
2.3	0.4	1.92	1.9
2.5	0.45	2.138	2.05
2.6	0.45	2.176	2.1
3	0.5	2.599	2.5
3.5	0.6	3.01	2.9
4	0.7	3.422	3.3
4.5	0.75	3.878	3.7
5	0.8	4.334	4.2
6	1.0	5.153	5.0
7	1.0	6.153	6.0
8	1.25	6.912	6.8
9	1.25	7.912	7.8
10	1.5	8.676	8.5
11	1.5	9.676	9.5
12	1.75	10.441	10.2
14	2.0	12.21	12.0
16	2.0	14.21	14.0
18	2.5	15.744	15.5
20	2.5	17.744	17.5
22	2.5	19.744	19.5
24	3.0	21.252	21.0
27	3.0	24.252	24.0
30	3.5	26.771	26.5
33	3.5	29.771	29.5
36	4.0	32.27	32.0
39	4.0	35.27	35.0
42	4.5	37.799	37.5
45	4.5	40.799	40.5
48	5.0	43.297	43.0
52	5.0	47.297	47.0
56	5.5	50.796	50.5
60	5.5	54.796	54.5
64	6.0	58.305	58.0
68	6.0	62.305	62.0

Metric-ISO threads fine pitch			
MF	Pitch mm.	Maximun core dia. mm.	Drill size mm.
2.5	0.35	2.221	2.15
3	0.35	2.271	2.65
3.5	0.35	3.221	3.15
4	0.5	3.599	3.5
4.5	0.5	4.099	4.0
5	0.5	4.599	4.5
5.5	0.5	5.099	5.0
6	0.75	5.378	5.2
7	0.75	6.378	6.2
8	0.75	7.378	7.2
8	1.0	7.153	7.0
9	0.75	8.378	8.2
9	1.0	8.153	8.0
10	0.75	9.378	9.2
10	1.0	9.153	9.0
10	1.25	8.912	8.8
11	0.75	10.378	10.2
11	1.0	10.153	10.0
12	1.0	11.153	11.0
12	1.25	10.912	10.8
12	1.5	10.676	10.5
14	1.0	13.153	13.0
14	1.25	12.912	12.8
14	1.5	12.676	12.5
15	1.0	14.153	14.0
15	1.5	13.676	13.5
16	1.0	15.153	15.0
16	1.5	14.676	14.5
17	1.0	16.153	16.0
17	1.5	15.676	15.5
18	1.0	17.153	17.0
18	1.5	16.676	16.5
18	2.0	16.21	16.0
20	1.0	19.153	19.0
20	1.5	18.676	18.5
20	2.0	18.21	18.0
22	1.0	21.153	21.0
22	1.5	20.676	20.5
22	2.0	20.21	20.0
24	1.0	23.153	23.0
24	1.5	22.676	22.5
24	2.0	22.21	22.0
25	1.0	24.153	24.0
25	1.5	23.676	23.5

Metric-ISO threads fine pitch			
MF	Pitch mm.	Maximun core dia. mm.	Drill size mm.
25	2.0	23.21	23.0
26	1.5	24.676	24.5
27	1.0	26.153	26.0
27	1.5	25.676	25.5
27	2.0	25.21	25.0
28	1.0	27.153	27.0
28	1.5	26.676	26.5
28	2.0	26.21	26.0
30	1.0	29.153	29.0
30	1.5	28.676	28.5
30	2.0	28.21	28.0
30	3.0	27.252	27.0
32	1.5	30.675	30.5
32	2.0	30.21	30.0
33	1.5	31.676	31.5
33	2.0	31.21	31.0
33	3.0	30.252	30.0
35	1.5	33.676	33.5
36	1.5	34.676	34.5
36	2.0	34.21	34.0
36	3.0	33.252	33.0
38	1.5	36.676	36.5
39	1.5	37.676	37.5
39	2.0	37.21	37.0
39	3.0	36.252	36.0
40	1.5	38.676	38.5
40	2.0	38.21	38.0
40	3.0	37.252	37.0
42	1.5	40.676	40.5
42	2.0	40.21	40.0
42	3.0	39.252	39.0
45	1.5	43.676	43.5
45	2.0	43.21	43.0
45	3.0	42.252	42.0
48	1.5	46.676	46.5
48	2.0	46.21	46.0
48	3.0	45.252	45.0
50	1.5	48.676	48.5
50	2.0	48.21	48.0
50	3.0	47.252	47.0
52	1.5	50.676	50.5
52	2.0	50.21	50.0
52	3.0	49.252	49.0

Tapping drill sizes for UNC and UNF threads.

Unified Coarse threads			
UNC	TPI	Maximun core dia. mm	Drill size mm.
No.1	64	1.585	1.5
No.2	56	1.872	1.8
No.3	48	2.146	2.1
No.4	40	2.385	2.3
No.5	40	2.697	2.6
No.6	32	2.896	2.85
No.8	32	3.528	3.6
No.10	24	3.95	3.9
No.12	24	4.59	4.5
1/4	20	5.25	5.2
5/16	18	6.68	6.6
3/8	16	8.082	8.0
7/16	14	9.441	9.4
1/2	13	10.881	10.75
9/16	12	12.301	12.25
5/8	11	13.693	13.5
3/4	10	16.624	16.5
7/8	9	19.520	19.5
1	8	22.344	22.25
1.1/8	7	25.082	25.0
1.1/4	7	28.258	28.25
1.3/8	6	30.851	30.75
1.1/2	6	34.026	34.0
1.3/4	5	39.560	39.5
2	4.5	45.367	45.25

Unified Fine threads			
UNF	TPI	Maximun core dia. mm	Drill size mm.
No.0	80	1.306	1.3
No.1	72	1.613	1.6
No.2	64	1.913	1.9
No.3	56	2.197	2.1
No.4	48	2.459	2.4
No.5	44	2.741	2.7
No.6	40	3.012	3.0
No.8	36	3.597	3.5
No.10	32	4.168	4.1
No.12	28	4.717	4.7
1/4	28	5.563	5.5
5/16	24	6.995	6.9
3/8	24	8.565	8.5
7/16	20	9.947	9.9
1/2	20	11.524	11.5
9/16	18	12.969	12.9
5/8	18	14.554	14.5
3/4	16	17.546	17.5
7/8	14	20.493	20.5
1	12	13.363	23.25
1.1/8	12	26.538	26.5
1.1/4	12	29.713	29.5
1.3/8	12	32.888	32.7
1.1/2	12	36.063	36.0

MATERIAL CHARTS

Please note: These charts are not cross-reference charts.
Materials are grouped according to machinability and are not necessarily identical in chemical composition.

ISO GROUP	STANDARDS						VDI GROUP
	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
10 STEEL **P**	**11. Magnetic soft steels - Hardness < 120 HB 30 - Tensile strength < 400 N/mm^2**						1, 2
	1.1013	RFe 100		OSOA12	EN2		
	1.1014	RFe 80					
	1.1015	RFe 60		230Mo7	EN1		
	1.0718	9 S MnPb 28					
	12. Structural steels - Hardness < 200 HB 30 - Tensile strength < 700 N/mm^2						3, 4
	12.1 - Structural steels						
	1.0034	RSt 34-2	A34-2 EN	1449 34/20 HR			
	1.0035	St 33	A33	Fe 310-0			
	1.0036	St 37-2		060A35	EN3A,4,5,6,7,8		
	1.0037	RSt 37-2			EN3B		
	1.0044	St 44-2					
	1.0050	St 50-2		4360-50B	EN 207		
	1.0060	St 60-2					
	1.0070	St 70-2					
	1.0116	St 37-3					
	1.0144	St 44-3					
	12.2 - Case carburizing steels						
	1.0301	C 10	AF 34 C 10	040 A 10		M 1010	
	1.0401	C 15	AF 37 C 12	080 A 15		M 1015	
	1.1121	Ck 10	XC 10	040 A 10		1010	
	1.1141	Ck 15	XC 12	040 A 15		1015	
	1.5732	14 Ni Cr 10	14 NC 11			3415	
	1.7015	15 Cr 3	12 C 3	523 M 15		5015	
	1.7131	16 Mn Cr 5	16 MC 4	527 M 17	EN 32	5115	
	1.7147	20 Mn Cr 5	20 MC 5			5120	
	12.3 - Free machining steels						
	1.0710	15 S 10					
	1.0715	9 S Mn 28	S 250	230 M 07		1213	
	1.0718	9 S Mn Pb 28	S 250 Pb			12 L 13	
	1.0721	10 S 20	10 F1	210 M 15		1108 1109	
	1.0722	10 S Pb 20	10 Pb F 2			11 L 08	
	1.0723	15 S 20		210 A 15			
	1.0726	35 S 20	35 MF 6	212 M 36		1140	
	1.0727	45 S 20	45 MF 4			1146	
	1.0736	9 S Mn 36	S 300			1215	
	1.0737	9 S Mn Pb 36	S 300 P			12 L 14	
	12.4 - Cast structural steels						
	1.0416	GS - 38					
	1.0446	GS - 45					
	1.0552	GS - 52					
	1.0553	GS - 60	E 36 - 3				
	1.0554	GS - 70					
	13. Plain carbon steels - tempered						5
	13.1 - Steels, tempered - Hardness < 250 HB 30 - Tensile strength < 850 N/mm^2						
	1.0402	C 22	1 C 22	070 M 20		M 1023	
	1.0501	C 35	1 C 35	080 A 32		1035	
	1.0503	C 45	1 C 45	060 A 47		1045	
	1.0535	C 55	1 C 55	070 M 55		1055	
	1.0601	C 60	1 C 60	060 A 62	EN 43	1060	
	1.1157	40 Mn 4	35 M 5	150 M 36		1035 1041	
	1.1151	Ck 22	2 C 22	055 M 15		1020 1023	
	1.1181	Ck 35	2 C 35	080 A 35		1035 1038	
	1.1191	Ck 45	2 C 45	080 M 46	EN 9, 10	1045	
	1.1203	Ck 55	2 C 55	060 A 57		1055	
	1.1221	Ck 60	2 C 60	060 A 62		1060 1064	

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	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
10 STEEL **P**	**14. Alloy steels - Hardness < 250 HB 30, < 25 HRC - Tensile strength < 850 N/mm^2**						6 - 9
	14.1 - Cold work tool steels						
	1.2056	90 Cr 3					
	1.2067	100 Cr 6	Y 100 C 6	BL 3		L 1 L 3	
	1.2080	X 210 Cr 12	Z 200 C 12	BD 3		D3	
	1.2083	X 42 Cr 13	Z 40 C 14			420	
	1.2363	X 100 CrMoV5 1	Z 100 CDV 5	BA 2		A 2	
	1.2379	X 155 CrVMo 12 1	Z 160 CDV 12	BD 2		D 2	
	1.2510	100 MnCrW 4	90 MWCV 5	BO 1		O1	
	1.2550	60 WCrV 7	55WC 20	BS 1		S1	
	1.2823	70 Si 7					
	1.2826	60 Mn Si Cr 4					
	1.2842	90 MnCrV 8	90 MV 8	BO 2		O 2	
	14.2 - High speed steels						
	1.3202	S 12-4-4-5	Z 130 WKCV 12-05-04-04	BT 15		T 15	
	1.3207	S 10-4-3-10	Z130 WKCDV10-10-04-04-03	BT 42		T 42	
	1.3243	S 6-5-2-5	Z85 WDKCV 06-05-05-04-02	BM 35		M 35	
	1.3247	S 2-10-1-8	Z110 DKCWV 09-08-04-02-01	BM 42		M 42	
	1.3343	S 6-5-2	Z 85 WDCV 06-05-04-02	BM 2		M 2	
	1.3344	S 6-5-3	Z 120 WDCV 06-05-04-03			M 3 / 2	
	1.3348	S 2-9-2	Z 100 DCWV 09-04-02-02			M 7	
	ASP 23	(S 6-5-3)					
	ASP 30						
	ASP 60						
	14.3 - Tempered steels						
	1.0503	C 45	1 C 45	060 A 47		1045	
	1.7220	34 Cr Mo 4	34 Cr Mo 4	708 A 37		4135, 4137	
	1.7225	42 Cr Mo 4	42 CD 4	708 A 42	EN16, 17, 19	4140, 4142	
	1.7228	50 Cr Mo 4	50 Cr Mo 4	708 A 47		4150	
	14.4 - Nitriding steels						
	1.7779	20 Cr Mo V 13.5					
	1.8504	34 Cr Al 6					
	1.8506	34 Cr Al S 5					
	1.8507	34 Cr Al Mo 5	30 CAD 6.12			A 355 Cl.D	
	1.8509	41 Cr Al Mo 7	40 CAD 6.12	905 M 39		A 355 Cl.A	
	1.8515	31 Cr Mo 12	30 CD 12	722 M 24			
10 HARDENED STEEL **H**	**15. Alloy steels / Tempered steels - Hardness 250-350 HB 30, 25-38 HRC Tensile strength 850-1,200 N/mm^2**						10, 11
	15.1 - Alloy steels for tools						
	1.2311	40 Cr Mn Mo 7					
	1.2312	40 Cr Mn Mo S 86					
	1.2436	X 210 Cr W 12	Z 200 CW 12				
	1.2711	54 Ni Cr Mo V 6					
	1.2713	55 Ni Cr Mo V 6	55 NCDV 7	826 M 40	S95, 97, 98	L 6	
	1.2714	56 Ni Cr Mo V 7					
	1.2743	60 Ni Cr Mo V 12 4					
	1.2766	35 Ni Cr Mo 16					
	15.2 - Alloy steels for hot work						
	1.2343	X 38 Cr Mo V 5 1	Z 38 CDV 5	BH 11		H 11	
	1.2344	X 40 Cr Mo V 5 1	Z 40 CDV 5	BH 13		H 13	
	1.2365	X 32 Cr Mo V 3 3	32 DCV 28	BH 10		H 10	
	1.2367	X 40 Cr Mo V 5 3	Z 38 CDV 5.3				
	1.2581	X 30 W Cr V 9 3	Z 30 WCV 9.3	BH 21		H 21	
	1.2622	X 60 W Cr Mo V 9					
	1.2678	X 45 CoCrWV 5 5 5					
	1.2550	60 WCr V 7	55 WC 20	BS 1		S 1	
	1.2567	X 30 W Cr V 5 3	Z 32 WCV 5				

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	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
10 HARDENED STEEL **H**	15.3 -Hardened tempered steels - Hardness may differ according to presentation and dimensions of material						**10, 11**
	1.5864	35 Ni Cr 18					
	1.6580	30 Cr Ni Mo 8	30 Cr Ni Mo 8		S99		
	1.7361	32 Cr Mo 12	30 CD 12	722 M 24			
	1.7707	30 Cr Mo V 9					
	1.8161	58 Cr V 4					
	15.4 - Nitriding steels						
	1.8515	31 Cr Mo 12	30 CD 12	722 M 24			
	1.8519	31 Cr Mo V 9		830 M 31			
	1.8523	39 Cr Mo V 13 9		897 M 39			
	1.8550	34 Cr Al Ni 7		826 M 40	EN24T		
	16. Alloy steels / Hardened tempered steels - Hardness > 38 HRC - Tensile strength > 1,200 N/mm^2 To this group belong most of the materials of group 15, but present a higher tensile strength						**38, 39**
	1.2713	100 Mn Cr W 12			Hardox 400	M42	
	1.3247	X 210 Cr 12			Hardox 500		
	1.2080				Hardox 600	8130	
	1.3343				P20		
20 STAINLESS STEEL **M**	**21. Free machining stainless steels - Hardness < 250 HB 30 - Tensile strength < 850 N/mm^2**						**12**
	1.4104	X 12 Cr Mo S 17	Z 13 CF 17	416 S 37	EN 56	430 F	
	1.4305	X 10 Cr Ni S 18 09	Z 8 CNF 18-09	303 S 21	EN 60	303	
	22. Austenitic stainless steels - Hardness < 250 HB 30 - Tensile strength < 850 N/mm^2						**13**
	1.4300	X 12 Cr Ni 18 8		320 S 12	S130		
	1.4301	X 5 Cr Ni 18 10	Z 6 CN 18-09	304 S 15	EN80, EN 58 + C	304	
	1.4311	X 2 CrNiN 18 10	Z 3 CN 18-07 Az	304 S 61		304 LN	
	1.4406	X 2 CrNiMoN 17 12 2	Z 3 CND 17 11 02	316 S 61		316 LN	
	1.4433	X 2 CrNiMo 18 15		316 S			
	1.4435	X 2 CrNiMo 18 14 3	Z3 CND 17-12-03	316 S 11		316 L	
	1.4539	X 1 CrNiMoCu 25 20 5	Z 1 NCDU 25-20	321 S 17		UNS N08904	
	1.4541	X 6 CrNiTi 18 10	Z 6 CNT 18 10	321 S 18	EN 58 J, 316	321	
	1.4571	X 6 CrNiMoTi 17 12 2	Z 6 CNDT 17 12	320 S 18		316 Ti	
	1.4573	X 10 CrNiMoTi 18 12		320 S 33			
	1.4828	X 15 CrNiSi 20 12	Z 15 CNS 20-12	309 S 24		309	
	22.1 - Cast austenitic stainless steels						
	1.4308	G-X 6 CrNi 18 9	Z 6 CN 18.10 M	304 C 15(LT196)		CF-8	
	1.4313	G-X 5 CrNi 13 4	Z 8 CD 17-01	425 C 12		CA 6 -NM	
	1.4408	G-X 6 CrNiMo 18 10		316 C 16(LT196)		CF-8M	
	1.4581	G-X 5 CrNiMoNb 18 10	Z 4 CNDNb 18.12M	318 C 17			
	23. Martensitic stainless steels - Hardness < 320 HB 30 - Tensile strength < 1,100 N/mm^2						**14**
	1.4021	X 20 Cr 13	Z 20 C 13	420 S 37		420	
	1.4034	X 46 Cr 13	Z 44 C 14	(420 S 45)			
	1.4057	X 20 CrNi 17 2	Z 15 CN 16-02	431 S 29		431	
	1.4112	X 90 CrMoV 18					
	1.4116	X 45 CrMoV 15			EN 58, b.e.j.t		
	1.4125	X 105 CrMo 17	Z 100 CD 17		Duplex alloys	440 C	
	1.4718	X 45 CrSi 9 3	Z 45 CS 9	401 S 45		HNV 3	
	1.4747	X 80 CrNiSi 20	Z 80 CSN 20-02	443 S 65		HNV 6	
	1.4086	G-X 120 Cr 29					
	1.4106	G-X 10 CrMo 13					
	1.4138	G-X 120 CrMo 29 2					
	23.1 Ferritic stainless steels - Hardness < 320 HB 30 - Tensile strength < 1,100 N/mm^2						
	1.4002	X 6 Cr Al 13	Z 8 CA 12	405 S 17		405	
	1.4006	X 10 Cr 13	Z 10 C 13	410 C 21	Super Duplex	410	
	1.4016	X 6 Cr 17	Z 8 C 17	430 S 17		430	
	1.4510	X 6 Cr Ti 17	Z 8 CT 17			430 Ti	
	1.4512	X 6 Cr Ti 12	Z 6 CT 12	409 S 19		409	
	23.2 Ferritic-Austenitic stainless steels - Hardness < 320 HB 30 - Tensile strength < 1,100 N/mm^2						
	1.4460	X 8 CrNiMo 27 5	Z 5 CND 27-05 Az			329	
	1.4582	X 4 CrNiMoNb 25 7			15-5PH		
	1.4821	X 20 CrNiSi 25 4			17-4PH		

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	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
30 CAST IRON **K**	**31. Grey graphite cast irons - Hardness < 150 HB 30 - Tensile strength < 500 N/mm^2**						**15**
	0.6010	GG-10	Ft 10 D			A 48-20 B	
	0.6015	GG-15	Ft 20 D	Grade 150	Grey cast iron soft	A 48-25 B	
	0.6020	GG-20	Ft 25 D	Grade 220		A 48-30 B	
	0.6025	GG-25	Ft 30 D	Grade 260		A 48-40 B	
	0.6030	GG-30	Ft 30 D	Grade 300		A 48-45 B	
	0.6035	GG-35	Ft 35 D	Grade 350		A 48-50 B	
	0.6040	GG-40	Ft 40 D	Grade 400		A 48-60 B	
	31.1 - Meehanite - Hardness < 150 HB 30 - Tensile strength < 500 N/mm^2						
		GF - 150					
		GD - 260					
	32. Grey graphite cast irons - Hardness 150 - 300 HB 30 - Tensile strength 500 - 1,000 N/mm^2						**16**
	0.6020	GG - 20	Ft 25 D	Grade 220	Grey cast iron hard	A 48-30 B	
	0.6025	GG - 25	Ft 30 D	Grade 260		A 48-40 B	
	0.6030	GG - 30	Ft 30 D	Grade 300		A 48-45 B	
	0.6035	GG - 35	Ft 35 D	Grade 350		A 48-50 B	
	0.6040	GG - 40	Ft 40 D	Grade 400		A 48-60 B	
	32.1 - Meehanite - Hardness 150-300 HB 30 - Tensile strength 500-1,000 N/mm^2						
		GF - 150					
		GD - 260					
	33. Nodular graphite, malleable cast irons - Hardness < 200 HB 30 - Tensile strength < 700 N/mm^2						**17, 18**
	0.7033	GGG-35.3					
	0.7040	GGG-40	FGS 400-12	420 / 12		60-40-18	
	0.7043	GGG-40.3	FGS 370-17	370 / 17			
	0.7050	GGG-50	FGS 500-7	500 / 7			
	0.7060	GGG-60	FGS 600-3	600 / 3	S.G.iron, Meehanite	65-45-12	
	0.8035	GTW-35		700/2,30g/72	Black & White Heart	80-55-06	
	0.8040	GTW-40					
	0.8045	GTW-45					
	0.8065	GTW-65					
	0.8135	GTS-35					
	0.8145	GTS-45					
	0.8155	GTS-55					
	0.8165	GTS-65					
	33.1 - Meehanite - Hardness < 200 HB 30 -Tensile strength < 700 N/mm^2						
		SF 400					
		SPF 600					
	34. Nodular graphite, tempered malleable cast irons - Hardness 200-300 HB 30 - Tensile strength 700-1,000 N/mm^2 Also materials from Group 33 tempered						**19, 20**
	0.7070	GGG-70	FGS 700-2	700 / 2	S.G.iron,Meehanite	100-70-03	
	0.7080	GGG-80	FGS 800-2	800 / 2	Black & White Heart	120-90-02	
	34.1 - Meehanite - Hardness 200-300 HB 30 - Tensile strength 700-1,000 N/mm^2						
		SH 800		420/12, P 440/7			
		SH 1000					
40 TITANIUM **S**	**41. Titanium, unalloyed - Hardness < 200 HB 30 - Tensile strength < 700 N/mm^2**						**36**
	3.7024.1LN	Ti 99.5					
	3.7034.1LN	Ti 99.7					
	3.7035	Ti 2					
	3.7055	Ti 99.4		TA 1-9	Ti 99,0		
	3.7064.1LN	Ti 99.2					
	3.7065	Ti 4					
	3.7255	Ti 3 Pd					
	42. Titanium alloys - Hardness < 270 HB 30 - Tensile strength < 900 N/mm^2						**37**
		Ti4Al4 Mn					
	3.7144 LN	Ti5Al2Sn					
	3.7124 LN	Ti2Cu		TA 10-14, TA 17	Ti - 2AL		
	3.7164 LN	Ti6Al4V		TA 18			
	3.7174 LN	Ti6Al6V2Sn					
		Ti6Al2Sn4Zr2Mo					
		Ti4Al4Mo2Sn0.5Si					

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	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
40 TITANIUM **S**	**43. Titanium alloys - Hardness 270-300 HB 30 - Tensile strength 900-1,300 N/mm^2**						**37**
		Ti10Al2Fe3Al					
		Ti5Al5V5Mo3Cr			Ti AL		
		Ti7Al4Mo		TA 10-13, TA 28			
		Ti3Al8V6Cr4Zr4Mo					
		Ti6Al6V6Sn					
		Ti15V3Cr3Sn3Al					
50 NICKEL ALLOYS **S**	**51. Nickel, unalloyed - Hardness < 150 HB 30 - Tensile strength < 500 N/mm^2**						**31, 32**
	2.1504 LN	Ni Al Bz					
	2.4042	Ni 99 CSi		NA 11, NA 12	Nickel 200		
	2.4060	Ni 99.6			Nickel 270		
	2.4062	Ni 99.4 Fe					
	52. Heat resisting nickel alloys - Hardness < 270 HB 30 - Tensile strength < 900 N/mm^2						**33**
	2.4360 LN	Monel 400					
	2.4374 LN	Monel 500					
	2.4617	Hastelloy B 2			Nimonic 75		
	2.4665	Hastelloy X		HR 203			
	2.4812			3027-76			
	2.4816	Inconel 600, 617, 625			Haynes Alloys		
	1.4876	Incoloy 800, 825					
	2.4983	Udimet 500					
	53. Heat resisting nickel alloys - Hardness 270-410 HB 30 - Tensile strength 900-1,400 N/mm^2						**34, 35**
	2.4631	Nimonic 80 A			Nimonic 80		
	2.4632	Nimonic 90					
	2.4634	Nimonic 105			Hastelloy B, C		
	2.4662	Nimonic 901		HR 8			
	2.4668	Inconel 718		HR 401, 601	Rene 41		
	2.4669	Inconel 750-X					
	2.4670 LN	Nimocast 713			Incoloy 925		
	2.4674 LN	Nimocast PK 24					
	2.4856	Inconel 625			Monel K-500		
	2.6554 LN	Waspaloy					
60 COPPER **N**	**61. Copper, unalloyed - Hardness < 100 HB 30 - Tensile strength < 350 N/mm^2**						**26**
	2.0060	E - Cu 57					
	2.0070	SE - Cu			Pure		
	2.0090	SF - Cu		C 101			
	2.1356	Cu Mn 3					
	2.1522	Cu Si 2 Mn					
	62. Short chip copper alloys - Hardness < 200 HB 30 - Tensile strength < 700 N/mm^2						**26**
	62.1 - Brass						
	2.0360	Cu Zn 40(MS 60)					
	2.0380	Cu Zn 39 Pb 2 (MS 58)		CZ120, CZ109			
	2.0410	Cu Zn 44 Pb 2		PB104			
	2.0561	Cu Zn 40 Al 1			2.1030, 2.1080		
	2.0580	Cu Zn 40 Mn 1 Pb					
	2.0771	Cu Ni 7 Zn 39 Mn 5 Pb3					
	62.2 - Bronzes						
	2.1086	G-Cu Sn 10 Zn					
	2.1093	G-Cu Sn 6 Zn Ni					
	2.1096	G-Cu Sn 5 Zn Pb					
	63. Long chip copper alloys - Hardness < 200 HB 30 - Tensile strength < 700 N/mm^2						**27**
	63.1 - Brass						
	2.0250	Cu Zn 20					
	2.0265	Cu Zn 30					
	2.0321	Cu Zn 37		CZ108, CZ106			
	2.0335	Cu Zn 36 (Ms 63)					
	63.2 - Bronzes						
	2.1020	Cu Sn 6					
	2.1030	Cu Sn 8					
	2.1080	Cu Sn 6 Zn 6					

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	GERMANY		FRANCE AFNOR	GREAT BRITAIN B.S.	EN & OTHER CLASSES	U.S.A. AISI	
	W.Nr	DIN					
60 COPPER **N**	63.3 - Copper alloys tempered by forging						
	2.1245	Cu Be 1.7					
	2.1247	Cu Be 2					
	2.1293	Cu Cr Zr					
	64. Cu - Al - Fe alloys Hardness < 440 HB 30 - Tensile strength < 1,500 N/mm^2						**28**
	64.1 - Ampco						
		Ampco 18			Ampco 18		
		Ampco 20		AB 1 type			
		Ampco 25			Ampco 26		
70 ALUMINIUM **N**	**71. Aluminium - Magnesium, unalloyed - Hardness < 100 HB 30 - Tensile strength < 350 N/mm^2**						**21**
	3.0250	Al 99.5 H		LM0, 1B			
	3.0280	Al 99.8 H					
	3.0305	Al 99.9					
	3.3308	Al 99.9 Mg 0.5					
	72. Aluminium alloys, Si < 0.5% - Hardness < 180 HB 30 - Tensile strength < 600 N/mm^2						**22**
	72.1 - Forging aluminium alloys						
	3.0515	Al Mn 1		LM5, 10, 12			
	3.0516	S-Al Mn					
	3.0525	Al Mn 1 Mg 0.5			6061		
	3.0615	Al Mg Si Pb					
	3.1325	Al Cu Mg 1			7075		
	3.1355	Al Cu Mg 2					
	3.3315	Al Mg 1					
	3.3535	Al Mg 3					
	3.4365	Al Zn Mg Cu 1.5					
	72.2 - Cast aluminium alloys						
	3.1841	G - Al Cu 4 Ti					
	3.3241	G - Al Mg 3 Si					
	3.3292	GD - Al Mg 9					
	73. Aluminium alloys, 0.5-10% Si - Hardness < 180 HB 30 - Tensile strength < 600 N/mm^2						**23, 24**
	73.1 - Cast aluminium alloys						
	3.2134	G - AL SI 5 CU 1 MG		LM2, 4	6063		
	3.2152	GD - Al Si 6 Cu 4		LM16, 18, 21	6082		
	3.2162	GD - AL SI 8 CU 3		LM22, 24, 25			
	3.2373	G - AL SI 9 MG		LM26, 27			
	74. Aluminium alloys, Si > 10% - Hardnes < 180 HB 30 - Tensile strength < 600 N/mm^2						**25**
	74.1 - Cast aluminium alloys						
	3.2381	G - AL SI 10 MG		LM6,12,13			
	3.2383	G - AL SI 10 MG (CU)		LM20,28			
	3.2581	G - AL SI 12		LM29, 30			
	3.2583	G - AL SI 12 (CU)					
	3.2982	GD - AL SI 12 (CU)					
	74.2 - Cast aluminium - magnesium alloys						
	3.5106	G - MG AG 3 SE 2 ZR 1					
	3.5662	G - MG AL 6					
	3.5812	G - MG AL 8 ZN 1					
	3.5912	G - MG AL 9 ZN 1					
80 SYNTHETIC MATERIAL **O**	**81. Thermoplastics**						**29**
				Nylon		Nylon	
				PVC Cellulose		PVC	
				Acetate	Acetal		
	82. Thermosetting Plastics						**29**
				Tufnol			
				Bakelite		Bakelite	
	83. Reinforced Plastics						**29**
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	84. Graphite						**30**
				Synthetic graphite			

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