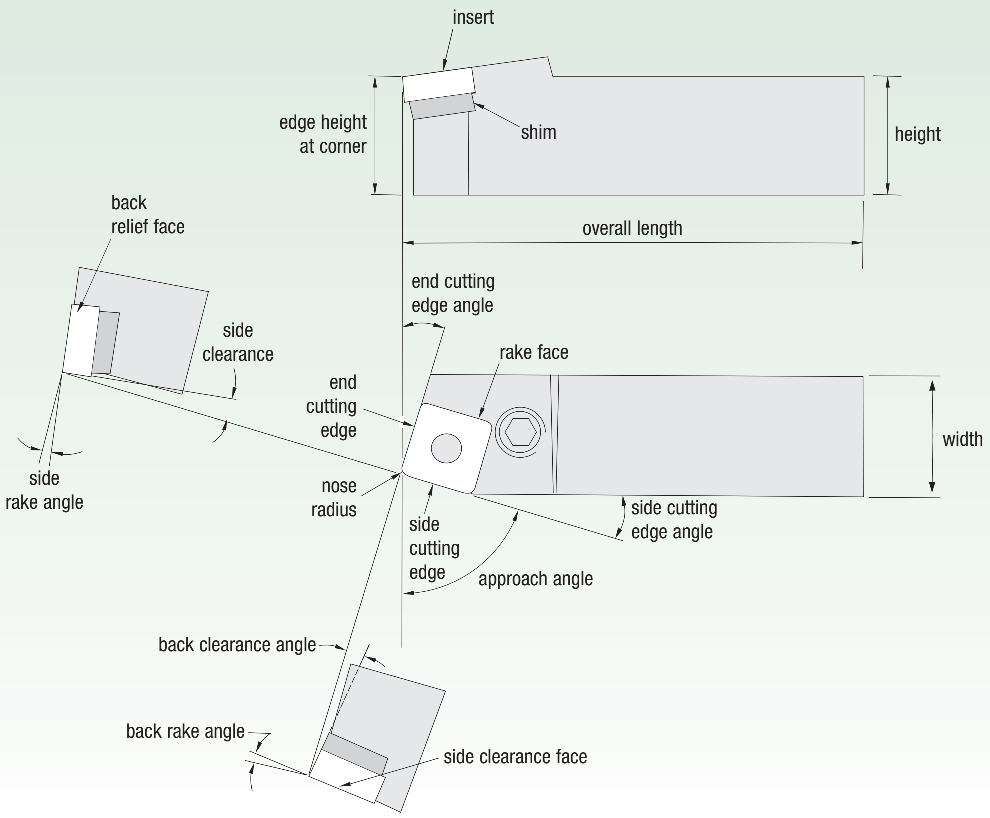
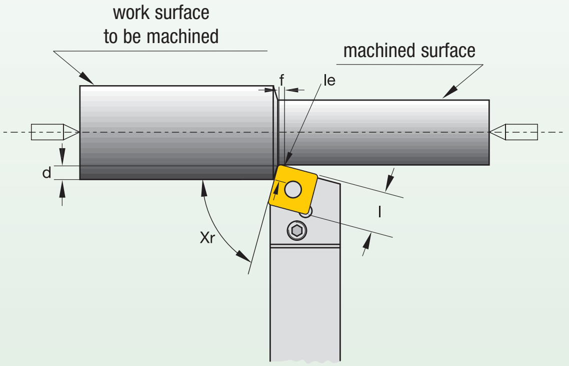
WIDIA

Technical Information

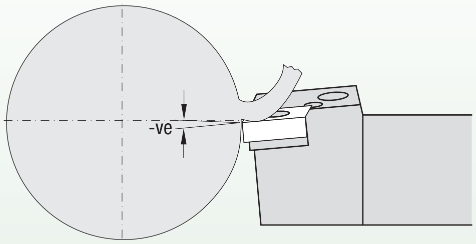


Nomenclature with Respect to Workpiece

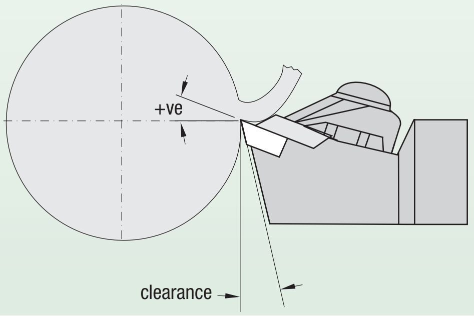


Insert Orientation with Respect to Workpiece

Negative Rake

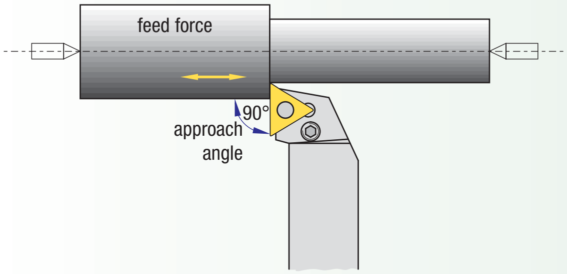


Positive Rake

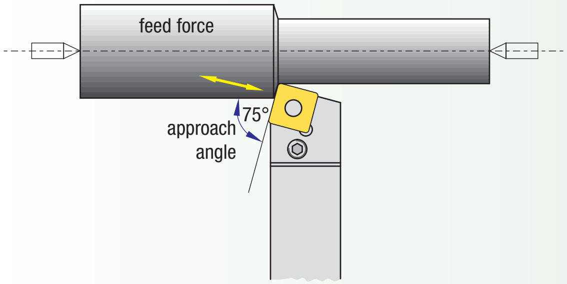


d = Depth of Cut
le = Diameter

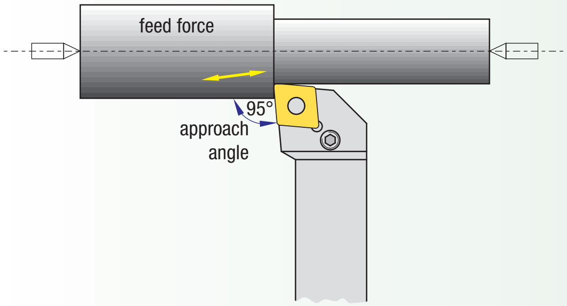
Xr= Approach Angle
f = Feed
l = Insert Cutting Edge Length



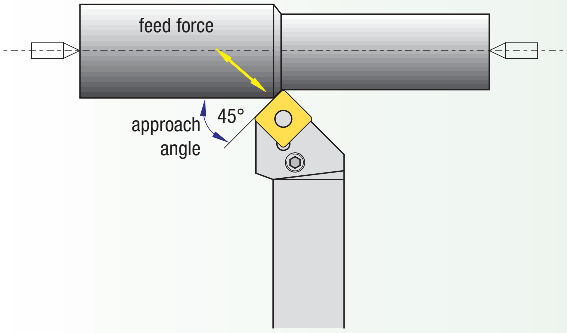
90° approach angle toolholders are generally preferred for machining slender jobs and for workpieces held between centers.



75° approach angle toolholders are preferred for machining barrel-type components and operations with slight interruptions.

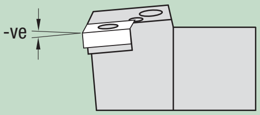
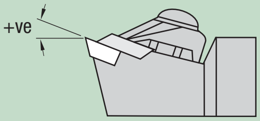
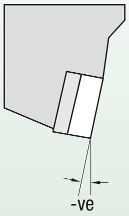
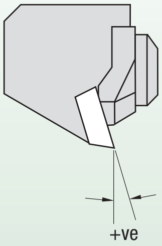


95° approach angle toolholders are preferred for versatile operations like OD turning and facing.



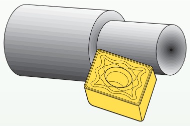
45° approach angle toolholders are preferred for rough machining and for chamfering operations with heavy interruptions.

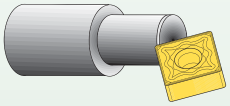
Selection of Toolholder

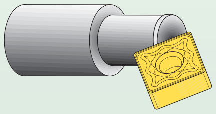
feature	negative rake	positive rake
back rake	• Moves chips towards the machined surface.  	• Moves chips away from the machined surface. 
side rake	• Moves chips towards the job shoulder.  	• Moves chips away from the job shoulder. 
advantages	• Cutting edge is stronger. • Can sustain higher cutting forces. • Ideal for machining interrupted cuts. • Has higher number of cutting edges.	• Free cutting action. • Generates less heat. • Consumes less horsepower. • Directs chips away from the job.
disadvantages	• Compresses the metal. • Consumes more horsepower. • Directs chips towards the job. • Generates more heat while cutting.	• Has fewer cutting edges. • Cutting edge is not strong.

80° Diamond Insert Versatility

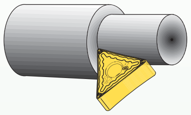
SNMG

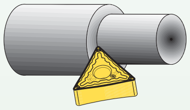

75° turning

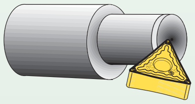

75° facing

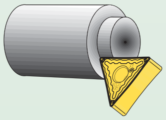

45° chamfering

TNMG

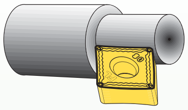

90° turning

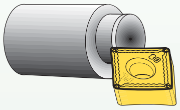

93° turning

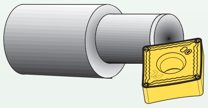

60° chamfering

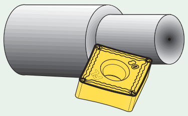

90° facing

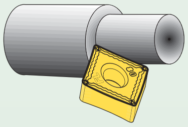
CNMG

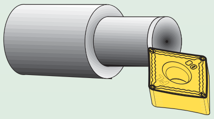

95° turning


95° facing


75° facing


75° turning


90° turning


90° facing

Advantages of the 80° Diamond:

- CNMG has greater strength for maximum material removal.
- CNMG is available in all types of geometries.
- One insert covers a wide variety of jobs.
- CNMG is versatile in application.

Insert selection is mainly based on the characteristics of the insert and the requirements of the application. Performance aspects and cost considerations should be taken into account in the selection process together with the cutting material grade.

Insert Shape

In general, inserts with larger corner angles should be preferred to those with smaller angles in the following order:
S (90°) – C and W (80°) – T (60°) – D (55°) – V (35°).

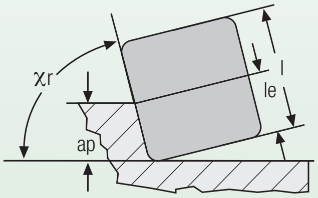
Where applicable, the trigon shape W (80°) should be preferred to the C insert, as more cutting edges are available. Round inserts of shape R are an alternative to S inserts, and may also be suitable for use in form turning.

Negative-rake inserts, which are usable on both sides, are more cost effective than one-sided negative-rake inserts. Positive-rake inserts offer advantages in ID turning operations and for thin-walled parts and soft work materials.

Cutting Edge Length

The size of an indexable insert is governed by maximum depth of cut (ap), the cutting edge angle χr, and by insert shape and geometry.

With cutting edge angles from 75–105°, the effective cutting edge length is roughly equal to the maximum depth of cut. In outward facing, particularly form turning (copying), the effective cutting edge angle is reduced. Because of the lower thickness of cut, it is possible to use greater cutting edge lengths than stated.



$$le = \frac{ap}{\sin \chi r}$$

ap = Depth of cut

le = Effective cutting edge length (width of cut)

l = Insert cutting edge length

χr = Cutting edge angle

Maximum Effective Lengths le of Cutting Edges:

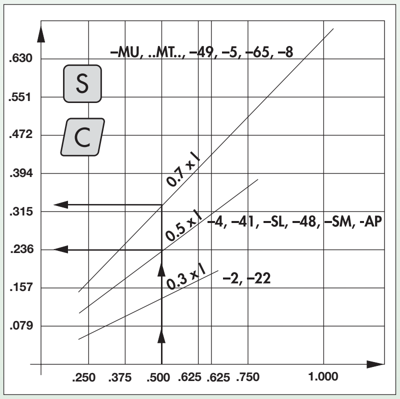
geometry	S	C	T	D	V	W	R
-2, -22	.012 l	.012 l	.008 l	.008 l	—	—	—
-4, -41, -48, -AP	.020 l	.020 l	.012 l	.012 l	—	.016 l	—
-MT..., -49, -5, -65, -8	.028 l	.028 l	.020 l	.020 l	.008 l	.020 l	.016 d

Cutting edge length/effective length

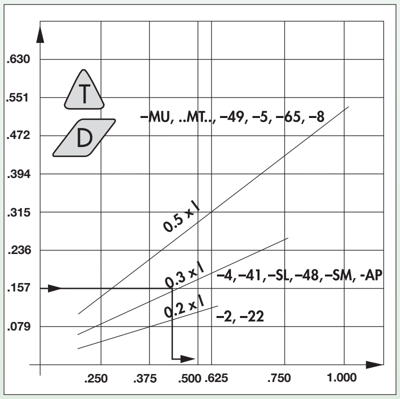
Corner radius
The insert corner determines the strength of the cutting point, the maximum admissible feed, and the surface finish of the workpiece. Select the largest possible corner radius.

Roughing
The following minimum radii, depending on feed, are recommended for rough turning.

Radius r ≥ .063 x feed f for insert shapes C and S
Radius r ≥ .098 x feed f for insert shapes D and T



Cutting edge length l (inch)



Cutting edge length l (inch)

Recommended Maximum Feeds

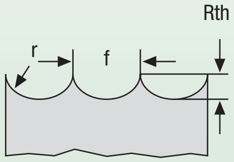
The recommended maximum feeds are based on cutting edge angles 75–105°. Higher feed values are possible under favorable conditions. Under non-rigid conditions, lower values should be applied or smaller radii selected, especially if vibration occurs. Larger radii are generally recommended for cast iron, cast steel, and interrupted cuts.

Finishing

In finishing, exacting demands are placed on surface finish and part accuracy. To determine approximately the surface finish to be expected in turning with feeds > .0039", the following formula for theoretical roughness height Rth can be used.

If the theoretical roughness height Rth is assumed to be roughly equal to Rz, the roughness average Ra can be inferred, which does not show a fixed relationship to Rz. A conversion ratio of Rz:Ra = 4:1 is generally appropriate.

$$\underset{[\mu in]}{Rth} = \frac{125000 \times f^2}{r}$$



Maximum Feed for Radius r

insert shape	.015" (0,4)	.032" (0,8)	.047" (1,2)	.062" (1,6)	.094" (2,4)
C S	.010" (0,25)	.020" (0,5)	.031" (0,8)	.039" (1,0)	.063" (1,6)
D T	.006" (0,16)	.013" (0,32)	.020" (0,5)	.025" (0,63)	.039" (1,0)

Theoretical Roughness Height Rth [µin] for Feed f

radius ANSI (ISO)	.004" (0,10)	.005" (0,12)	.006" (0,16)	.008" (0,20)	.010" (0,25)	.012" (0,32)
.015" (0,4)	.125" (3,2)	.200" (4,5)	.300" (8,0)	.500" (12,5)	.800" (20,0)	—
.032" (0,8)	.063" (1,6)	.100" (2,2)	.150" (4,0)	.250" (6,3)	.400" (10,0)	.700" (16,0)
.047" (1,2)	—	.063" (1,5)	.100" (2,8)	.175" (4,2)	.250" (6,3)	.450" (10,7)
.062" (1,6)	—	—	.075" (2,0)	.125" (3,2)	.200" (5,0)	.350" (8,0)

Approximate Reference Values for the Ratio Rz to Ra

Rz [µin]	.063" (1,6)	.098" (2,5)	.157" (4,0)	.248" (6,3)	.394" (10,0)	.630" (16,0)	.984" (16,0)
Ra [µin]	.016" (0,4)	.024" (0,6)	.039" (1,0)	.063" (1,6)	.098" (2,5)	.157" (4,0)	.248" (6,3)

Good surfaces are achieved with:

- Higher cutting speeds.
- Inserts with sharp cutting edges.
- Positive rake angles and positive chipbreaker geometries.
- Use of cermets.
- Rigid machining setups.
- Use of easily machinable work materials.
- Use of cutting fluid.

Surface characteristics:

AA ≙ arithmetic average Ra

CLA ≙ centerline average Ra

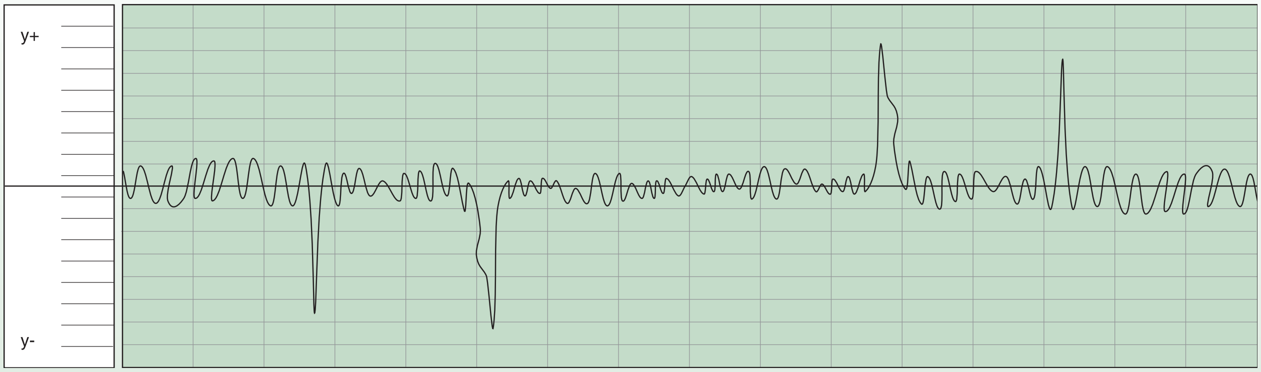
RMS ≙ root mean square 1.1 x AA

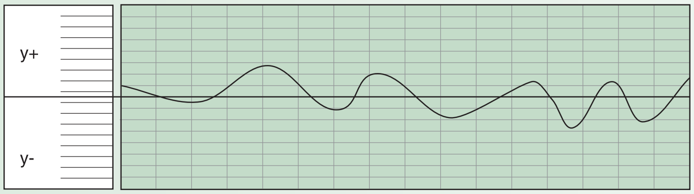
1 µin = 0,025mm

1 mm = 40 µin

Irregularities that form surface relief and that are conventionally defined within the area where deviations of form and waviness are eliminated. The irregularities in the surface roughness, such as traverse feed marks and irregularities within them, result from the inherent action of the production process.

Primary Texture (Roughness)



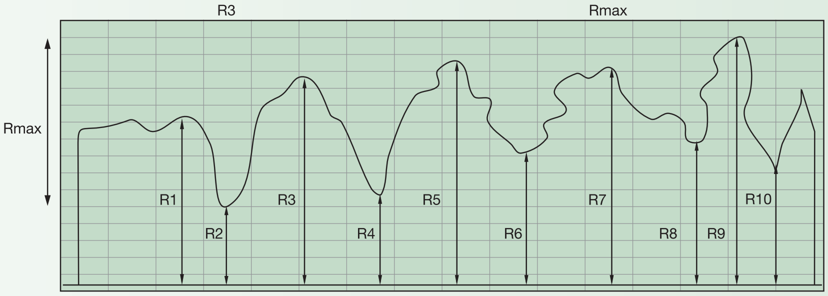


Secondary Texture (Waviness)

The component of surface roughness upon which roughness is superimposed. Waviness may result from such factors as machine or work deflections, vibrations, chatter, or heat treatment of warping strains.

Rmax = Distance between two lines parallel to the mean line and touching the profile at the highest and lowest points within the sampling length.

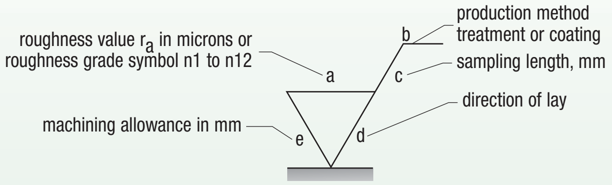
Rz = Average difference between the 5 highest peaks and 5 deepest valleys within the sampling length measured from a line parallel to the mean line and not crossing the profile.

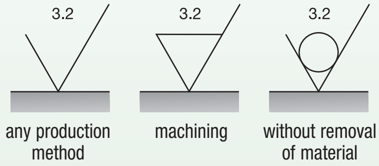


Rz = (R1 + R3 + R5 + R7 + R9) – (R2 + R4 + R6 + R8 + R10) / 5

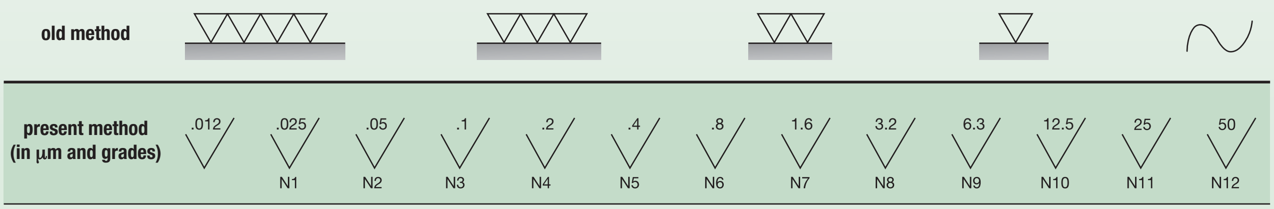
Technical Information

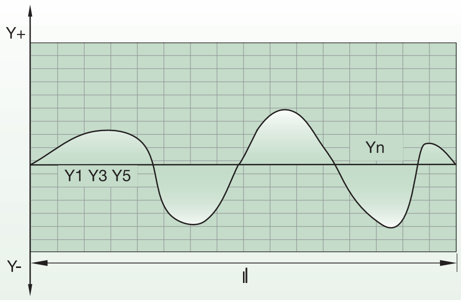
Machining Symbol





Symbols to Denote Surface Roughness





Ra = Average value of ordinates (Y1, Y2…Yn) from their mean line.

$$Ra = 1/l \int_0^l |y|\,dx$$

$$Ra = \frac{\sum_{i}^{n} |yi|}{n}$$

Table gives approximate values only.

$1\mu m = 0{,}001mm = 39\mu^2$
$1\mu^2 = .00001"$

Surface FOMOSJ grade (OS 3073)

Surface Roughness

Rt/max µm	CLA µm	CLA μ^2	RMS µm	RMS μ^2	UDSSR class	CCCP µm Rt
.06	.02	.75	.02	.08	14	.06–.12
.10	.03	1.20	.04	1.3	13	.06–.12
.20	.06	2.50	.08	2.8	12	.12–.25
.30	.09	3.70	.10	4.2	11	.25–.50
.40	.13	5.00	.14	5.6	—	—
.50	.16	6.70	.18	6.9	—	—
.60	.19	7.50	.21	8.3	10	.50–.80
.70	.2	8.70	.25	9.7	—	—
.80	.25	10.00	.28	11.1	—	—
.90	.28	11.20	.32	12.5	—	—
1.00	.31	12.50	.35	14.0	—	—
1.20	.38	15.80	.42	16.7	9	.80–1.60
1.50	.47	18.80	.53	20.9	—	—
1.80	.57	22.60	.64	25.5	—	—
2.00	.64	25.10	.78	27.9	8	1.60–3.20
2.40	.73	30.10	.85	33.4	—	—
2.80	.89	35.20	.99	39.0	—	—
3.00	.95	37.60	1.06	41.9	—	—
3.50	1.11	43.90	1.24	48.8	—	—
4.00	1.27	50.20	1.41	55.8	7	3.20–6.30
5.00	1.59	62.70	1.77	69.7	—	—
6.00	1.91	75.50	2.12	83.6	—	—
7.00	2.22	87.50	2.48	92.6	—	—
8.00	2.54	100.00	2.83	111.7	6	6.30–10.00
10.00	3.16	125.50	3.54	140.0	—	—
20.00	6.40	251.00	7.60	279.0	5	10.00–20.00
40.00	12.70	205.00	14.10	558.0	4	20.00–40.00
60.00	19.10	755.00	21.20	836.0	3	40.00–63.00
125.00	39.50	1560.00	43.50	750.0	2	63.00–125.00
200.00	64.00	2510.00	78.00	2790.0	1	125.00–200.00

Surface Roughness

Roughness Expected from Manufacturing Process

Sl. no.	manufacturing process	values in Ra and μm .012 .025 .050 .10 .20 .40 .80 1.6 3.2 6.3 12.5 25 50 100 200
1	sand casting	5–50
2	permanent mold casting	.80–6.3
3	die casting	.80–3.2
4	high-pressure casting	.32–2
5	hot rolling	2.5–50
6	forging	1.6–25
7	extrusion	.16–5
8	flame cutting, sawing, and chipping	6.3–100
9	radial cut-off sawing	1–6.3
10	hand grinding	6.3–25
11	disc grinding	1.6–25
12	filing	.25–25
13	planing	1.6–50
14	shaping	1.6–25
15	drilling	1.6–20
16	turning and milling	.32–25
17	boring	.40–6.3
18	reaming	.40–3.2
19	broaching	.40–3.2
20	hobbing	.40–3.2
21	surface grinding	.063–5
22	cylindrical grinding	.063–5
23	honing	.025–.40
24	lapping	.012–.16
25	polishing	.040–.16
26	burnishing	.040–.80
27	superfinishing	.016–.32


WIDIA HANITA
WIDIA MANCHESTER
WIDIA CIRCLE
WIDIA CLAPPDICO
WIDIA™
WIDIA GTD
WIDIA RÜBIG

External Turning, Internal Turning

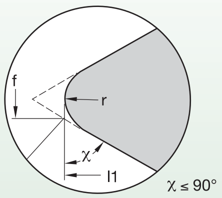
In shape, dimensions, and designations, WIDIA™ toolholders for indexable inserts conform with international standards. The dimensions f and l1 relate to the cutting points of gage inserts of inscribed circle d and corner radius r.

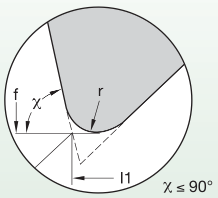
When inserts with smaller or larger corner radii are selected, the dimensions determined by the corner radius will change. For correction values for external turning, see DIN 4984, Part 1; for internal turning, DIN 8025, Part 1.

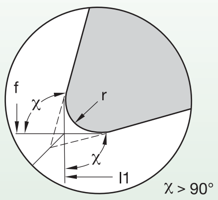
inscribed circle	.188"–.313" (4,76–7,94)	.375"–.500" (9,52–12,7)	.625"–.750" (15,88–19,05)	1.00" (25,4)
circle radius r	.015" (0,4)	.032" (0,8)	.047" (1,2)	.094" (2,4)

Standard Tolerances, External Turning

Cutting edge height h = js 13
Shank height h = h 13
Shank width b = h 13
Holder length l1 = k 16
Dimension f = + 0.20"
(± .010" for symmetrical holders)
Approach angle χ = ± 1°
for χ = 90° + 2°

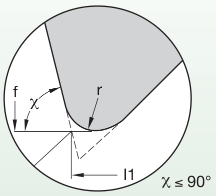


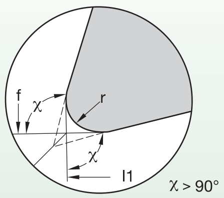




Standard Tolerances, Internal Turning

Shank diameter d1 = g 7
Holder length l1 = k 16
Dimension f = -.010"
Approach angle χ = ± 1°
for χ = 90° + 2°





Mounting Dimensions for Cartridges DIN 4985 and ISO 5611

Fastening Screw and Spring Washer

cartridge size	h1	D min	d	e	l1	g	s	t min	Z max	fastening screw	spring washer
06	.236	.787	.669	.472	.906	M 3,5 x 0,60	.138	.394	.012	MS2173	CSW 035 040
08	.315	.984	.866	.669	1.181	M 4,0 x 0,70	.177	.394	.012	MS2175	CSW 040 050
10	.394	1.575	1.457	.787	1.850	M 6,0 x 1,00	.197	.551	.016	191.405	CSW 060 050
12	.472	1.969	1.850	.787	2.047	M 6,0 x 1,00	.236	.551	.016	191.406	CSW 060 050
16	.630	2.362	2.244	.984	2.323	M 8,0 x 1,25	—	.591	.024	191.407	CSW 060 080
20	.787	2.756	2.638	1.181	2.598	M 8,0 x 1,25	—	.591	.024	191.407	CSW 060 080

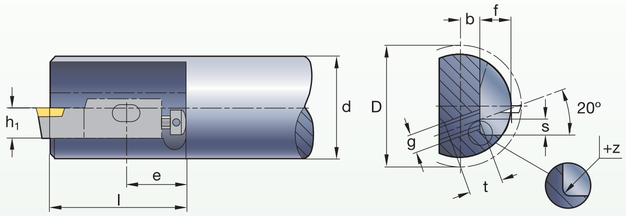
[1] for holder shape K, S, and W I.

Holder Sizes

06,08 CA
Adjustment range
± 0,8mm

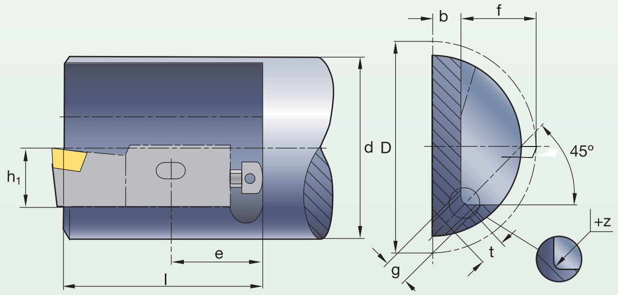
10,12 CA
Adjustment range
± 1,0mm

$$b = \frac{D}{2} - f$$



16,20 CA
Adjustment range
± 1,0mm

$$b = \frac{D}{2} - f$$



Introduction

Troubleshooting should be performed in a sequential method to identify and solve your machining problems. These problems can be recognized as premature insert edge failure, part appearance, machine noise or vibration, and tool appearance. Successful troubleshooting requires that we correctly identify the problem, then take the necessary corrective action one step at a time.

The four key areas of concern are:

1. cutting tool material (grade)
2. machine
3. workpiece
4. set-up

This section discusses possible causes and recommends corrective actions for each of the four areas listed. Remember, if more than one step is taken concurrently, the real cause of the problem may never be discovered. Always perform one corrective measure at a time.

1. Chipping: Appears like normal flank wear to the untrained eye. Actually, normal flank wear lands have a fine, smooth wear pattern, while a land formed by chipping has a saw-toothed, uneven surface. If chipping is not detected soon enough, it may be perceived as depth-of-cut notching.

cause	solution
grade	Use a tougher grade.
edge prep	Use larger hone or T-land possible.
built-up edge	Increase speed.
chatter	Check system rigidity for proper part clamping. Correct worn gibs/bearings. Check for improper tool mounting.
feed	Reduce feed.
recutting chips	Use air blast or coolant to remove chips.

2. Depth-of-cut notching: Appears when chipping or localized wear at the depth-of-cut line on the rake face and flank of the insert occurs. Notching is primarily caused by the condition of the workpiece material. Material conditions prone to depth-of-cut notch include an abrasive workpiece skin of scale, abrasive properties of high-temperature alloys like INCONEL®, a work-hardened outer layer resulting from a previous machining operation, or heat-treated material above 55 HRC.

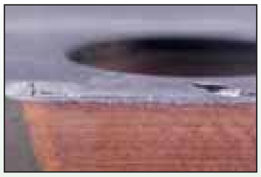
cause	solution
grade	Use a more wear-resistant grade of carbide.
feed	Reduce feed.
speed	Reduce speed.
edge-prep	Use honed or T-land inserts.
programming	Vary depth of cut on very abrasive materials.

3. Thermal cracks: These cracks run perpendicular to the insert's cutting edge and are caused by the extreme temperature variations.

These temperature variations create heat stresses in the insert, which can result in thermal cracks. To the untrained eye, advanced thermal cracking could appear as chipping.

cause	solution
speed and feed	Reduce speed and possibly the feed.
coolant	Shut off coolant.
grade	Use coated grade.

4. Built-up edge: This condition involves the adhesion of layers of workpiece material to the top surface of the insert. Hardened pieces of the adhered material periodically break free, leaving an irregularly shaped depression along the cutting edge. This causes damage to the part and insert. Cutting forces also will be increased due to built-up edge.



cause	solution
speed	Increase cutting speed.
feed	Increase feed.
coolant	Use mist or flood coolant to avoid chips sticking to the insert when machining stainless steel and aluminum alloys.
edge-prep	Use sharper edge, positive rake PVD inserts; use polished inserts for non-ferrous materials.

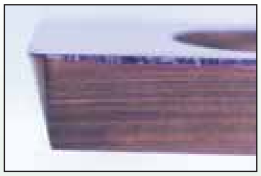
5. Crater wear: A relatively smooth, regular depression is produced on the insert's rake face. Crater wear occurs in two ways:

1. Material adhering to the insert's top surface is dislodged, carrying away minute fragments of the top surface of the insert.
2. Frictional heat builds up from the flow of chips over the top surface of the insert. Eventually, this heat buildup softens the insert behind the cutting edge and removes minute particles of the insert until a crater forms.

cause	solution
grade	Use a more wear-resistant grade.
speed	Reduce cutting speed.
edge-prep	Use smaller T-land or increase feed to proper range for T-land.

6. Flank wear: Uniform flank wear is the preferred method of insert failure because it can be predicted. Excessive flank wear increases cutting forces and contributes to poor surface finish.

NOTE: Inserts should be indexed when roughing (.015"–.020" flank wear is reached) and finishing (.008"–.012" flank wear or sooner).



cause	solution
speed	Speed should be reduced without changing feed.
feed	Increase feed.
grade	Use more wear-resistant grade. Change to a coated grade if you are now using an uncoated grade.
insert geometry	Inspect insert to determine if proper style is being used.

7. Multiple factors: When wear, chipping, thermal cracking, and breakage occur at once, the machine operator must look beyond the normal feed, speed, and depth-of-cut adjustments to find the root cause of the problem.

cause	solution
feed	Reduce feed rate to relieve cutting forces.
insert/grade	If possible, use a larger nose radius. Use T-land insert. Use a tougher grade of carbide.

Hardness Cross Reference

Brinell		Vickers	Rockwell			Shore	tensile strength
steel ball	hard metal ball		60 kg	100 kg	150 kg		
HB	HB	HV	HRA	HRB	HRC	Sh	N/mm^2
—	—	940	85,6	—	68,0	97	—
—	—	920	85,3	—	67,5	96	—
—	—	900	85,0	—	67,0	95	—
—	(767)	880	84,7	—	66,4	93	—
—	(757)	860	84,4	—	65,9	92	—
—	(745)	840	84,1	—	65,3	91	—
—	(733)	820	83,8	—	64,7	90	—
—	(722)	800	83,4	—	64,0	88	—
—	(712)	—	—	—	—	—	—
—	(710)	780	83,0	—	63,3	87	—
—	(698)	760	82,6	—	62,5	86	—
—	(684)	740	82,2	—	61,8	—	—
—	(682)	737	82,2	—	61,7	84	—
—	(670)	720	81,8	—	61,0	83	—
—	(656)	700	81,3	—	60,1	—	—
—	(653)	697	81,2	—	60,0	81	—
—	(647)	690	81,1	—	59,7	—	—
—	(638)	680	80,8	—	59,2	80	—
—	630	670	80,6	—	58,8	—	—
—	627	667	80,5	—	58,7	79	—
—	—	677	80,7	—	59,1	—	—
—	601	640	79,8	—	57,3	77	—
—	—	640	79,8	—	57,3	—	—
—	578	615	79,1	—	56	75	—
—	—	607	78,8	—	55,6	—	—
—	555	591	78,4	—	54,7	73	2095
—	—	579	78	—	54	—	2010
—	534	569	77,8	—	53,5	71	1981
—	—	553	77,1	—	52,5	—	1912
—	514	547	76,9	—	52,1	70	1893
(495)	—	539	76,7	—	51,6	—	1854
—	—	530	76,4	—	51,1	—	1824
—	495	528	76,3	—	51,0	68	1824
(477)	—	516	75,9	—	50,3	—	1775
—	—	508	75,6	—	49,6	—	1736
—	477	508	75,6	—	49,6	66	1736
(461)	—	495	75,1	—	48,8	—	1687
—	—	491	74,9	—	48,5	—	1667
—	461	491	74,9	—	48,5	65	1667
444	—	474	74,3	—	47,2	—	1589
—	—	472	74,2	—	47,1	—	1589
—	444	472	74,2	—	47,1	63	1589
429	429	455	73,4	—	45,7	61	1510
415	415	440	72,8	—	44,5	59	1461
401	401	425	72,0	—	43,1	58	1392
388	388	410	71,4	—	41,8	56	1334
375	375	396	70,6	—	40,4	54	1265
363	363	383	70,0	—	39,1	52	1216
352	352	372	69,3	(110,0)	37,9	51	1177
341	341	360	68,7	(109,0)	36,6	50	1128
331	331	350	68,1	(108,5)	35,5	48	1098
321	321	339	67,5	(108,0)	34,3	47	1059
311	311	328	66,9	(107,5)	33,1	46	1030
302	302	319	66,3	(107,0)	32,1	45	1010
293	293	309	65,7	(106,0)	30,9	43	971
285	285	301	65,3	(105,5)	29,9	—	951
277	277	292	64,6	(104,5)	28,8	41	922
269	269	284	64,1	(104,0)	27,6	40	892
262	262	276	63,6	(103,0)	26,6	39	873
255	255	269	63,0	(102,0)	25,4	38	843
248	248	261	62,5	(101,0)	24,2	37	824
241	241	253	61,8	100,0	22,8	36	804

NOTE: Values in ( ) are not common

(continued)

Hardness Cross Reference *(continued)*

Brinell		Vickers	Rockwell			Shore	tensile strength
steel ball	hard metal ball		60 kg	100 kg	150 kg		
HB	HB	HV	HRA	HRB	HRC	Sh	N/mm^2
235	235	247	61,4	99,0	21,7	35	785
229	229	241	60,8	98,2	20,5	34	765
223	223	234	—	97,3	(18,8)	—	—
217	217	228	—	96,4	(17,5)	33	726
212	212	222	—	95,5	(16,0)	—	706
207	207	218	—	94,6	(15,2)	32	686
201	201	212	—	93,8	(13,8)	31	677
197	197	207	—	92,8	(12,7)	30	657
192	192	202	—	91,9	(11,5)	29	637
187	187	196	—	90,7	(10,0)	—	618
183	183	192	—	90,0	(9,0)	28	618
179	179	188	—	89,0	(8,0)	27	598
174	174	182	—	87,8	(6,4)	—	588
170	170	178	—	86,8	(5,4)	26	569
167	167	175	—	86,0	(4,4)	—	559
163	163	171	—	85,0	3,3	25	549
156	156	163	—	82,9	(0,9)	—	520
149	149	156	—	80,8	—	23	500
143	143	150	—	78,7	—	22	490
137	137	143	—	76,4	—	21	461
131	131	137	—	74	—	—	451
126	126	132	—	72	—	20	431
121	121	127	—	69,8	—	19	412
116	116	122	—	67,6	—	18	402
111	111	117	—	65,7	—	15	382

NOTE: Values in ( ) are not common

Dimensions and Tolerances

problem	cause	possible solution
surface roughness	It is affected by the configuration and condition of the cutting point, the cutting conditions, and the rigidity of the machining setup.	• Increase cutting speed. • Reduce feed. • Increase radius. • Use cermets where possible when cutting steel. • Avoid vibrations. • Use cutting fluid.
chatter	Chatter marks or surface damage due to unfavorable chip flow call for special measures.	• Vary feed slightly. • Change approach angle. • Select different chipbreaker geometry. • Check rigidity of tool and holding system.
deformation	Shape and dimensional accuracy are affected by the conditon of the overall machine-part-tool setup.	• Select grade with adequate wear resistance. • Check cutting parameters, including machining allowance. • Check rigidity of tool and work holding. • Keep cutting forces low. • Avoid unbalance.
vibrations, instability	Vibrations in the workpiece usually occur with thin-walled parts and non-rigid setups. Unbalance and excessive cutting forces also cause problems.	• Select larger approach angle for the tool. • Use positive geometries. • Use smaller radii. • Change turning frequency (RPM). • Reduce chip section.
burring	Burring cannot always be avoided when cutting steel workpieces. Chamfering operations should therefore be planned where possible.	• Select inserts with positive geometry. • Use sharpest possible cutting edges (e.g., cermets). • Reduce approach angle. • Check sequence of operations.

Equations

symbol	unit	equations	remarks	validity
n	1/min	n = (vc x 1000) / (D x π)		D, F, B1
vc	m/min	vc = (D x π x n) / 1000	cylindrical turning	D, B
		vc = (d1 x π x n) / 1000		F
tc	min	tc = π x (Da^2 - Di^2) / (4 x f x vc x 1000)	face turning vc = constant	D
		tc = (Da - Di) / (f x n)	face turning	D
		tc = lc / vf		D, F, B
		tc = lc / (f x n)	cylindrical turning	D, B
		tc = lc / (fZ x Z x n)		F
vf	mm/min	vf = f x n		D, B
		vf = fZ x Z x n		F
Q	cm^3/min	Q = ap x f x vc		D
		Q = (ap x ae x vf) / 1000 = (ap x ae x fZ x Z x n) / 1000		F
		Q = (D x f x vc) / 4		B
P	kW	P = X1 x X2 x (ap x f x vc x kc) / (6 x 10^4 x η)		D
		P = X1 x X2 x (ap x ae x vf x kc) / (6 x 10^7 x η) = X1 x X2 x (Q x kc) / (6 x 10^4 x η)		F
		P = X1 x X2 x (D x f x vc x kc) / (24 x 10^4 x η)		B
Mc	Nm	Mc = X1 x X2 x (D x ap x f x kc) / 2000		D
		Mc = X2 x (D2 x f x kc) / 8000		B
Fc	N	Fc = X1 x X2 x ap x f x kc = X1 x X2 x b x h^{1-mc} x kc1.1		D
		Fc = X1 x X2 x ap x fZ x kc x ZiE = X1 x X2 x b x hm^{1-mc} x kc1.1 x ZiE		F
Ff	N	Ff = X1 x X2 x 0,35 x D x f x kc = X1 x X2 x 0,35 x D x f^{1-mc} x kc1.1		B
ZiE		ZiE = (ϕC x Z) / 360		F
ϕC	grade	γC = ϕ1 + ϕ2 = ϕA - ϕE		F
ϕ1	grade	sin ϕ1 = (2 x ae1) / d1		F
ϕ2	grade	sin ϕ2 = (2 x ae2) / d1		F
hm	mm	hm = (sin χe x fZ x ae x 360) / (π x ϕC x d1)		F
		hm $\approx$ sin χe x fZ x $\sqrt{(ae / d1)}$	if ae $\leq$ (d1 / 3)	F
Rth	μm	Rth $\approx$ (f2 x 1000) / (8 x Rε)		D

D = Turning F = Milling B = Drilling

Cross Reference Metric • Inch Units

symbol	unit	
	metric	inch
ae (WOC)	mm = 25,4 x in	in = 0,0394 x mm
ap (DOC)	mm = 25,4 x in	in = 0,0394 x mm
b	mm = 25,4 x in	in = 0,0394 x mm
d, d1 etc	mm = 25,4 x in	in = 0,0394 x mm
f	mm = 25,4 x in	in = (ipr)= 0,0394 x mm
Fc, Ff, Fp	N = 4,448 x lbs	lbs = 0,225 x N
fZ	mm = 25,4 x in	in = (ipt) = 0,0394 x mm
h, hm	mm = 25,4 x in	in = 0,0394 x mm
kc, kc1.1 etc	N/mm^2 = 145 x psi	psi = 0,0069 x N/mm^2
KT	μm = 25,4 x µin	μin = 0,0394 x µm
l, l1 etc	mm = 25,4 x in	in = 0,0394 x mm
P, Pc, Pe	kW = 0,7457 x hp	hp = 1,341 x kW
Ra, Rt, Rz	μm = 25,4 x µin	μin = 0,0394 x µm
Rm	N/mm^2 = 2865 x psi	psi = 0,000349 x N/mm^2
VB	mm = 25,4 x in	in = 0,0394 x mm
vc	m/min = 0,305 x SFM	sfm = 3,281 x m/min
vf	mm/min = 25,4 x IPM	ipm = 0,0394 x mm/min

Decimal Equivalent Chart

size	decimal inches	size	decimal inches	size	decimal inches	size	decimal inches	size	decimal inches
107	.0019	57	.0430	9/64	.1406	6,60mm	.2598	7/16	.4375
106	.0023	1,10mm	.0433	3,60mm	.1417	G	.2610	11,20mm	.4409
105	.0027	1,15mm	.0453	27	.1440	6,70mm	.2638	11,50mm	.4528
104	.0031	56	.0465	3,70mm	.1457	17/64	.2656	29/64	.4531
103	.0035	3/64	.0469	26	.1470	6,75mm	.2657	11,80mm	.4646
102	.0039	1,20mm	.0472	3,75mm	.1476	H	.2660	15/32	.4688
101	.0043	1,25mm	.0492	25	.1495	6,80mm	.2677	12,00mm	.4724
100	.0047	1,30mm	.0512	3,80mm	.1496	6,90mm	.2717	12,20mm	.4803
99	.0051	55	.0520	24	.1520	I	.2720	31/64	.4844
98	.0055	1,35mm	.0531	3,90mm	.1535	7,00mm	.2756	12,50mm	.4921
97	.0059	54	.0550	23	.1540	J	.2770	1/2	.5000
96	.0063	1,40mm	.0551	5/32	.1562	7,10mm	.2795	12,80mm	.5039
95	.0067	1,45mm	.0571	22	.1570	K	.2810	13,00mm	.5118
94	.0071	1,50mm	.0591	4,00mm	.1575	9/32	.2812	33/64	.5156
93	.0075	53	.0595	21	.1590	7,20mm	.2835	13,20mm	.5197
92	.0079	1,55mm	.0610	20	.1610	7,25mm	.2854	17/32	.5312
0,20mm	.0079	1/16	.0625	4,10mm	.1614	7,30mm	.2874	13,50mm	.5315
91	.0083	1,60mm	.0630	4,20mm	.1654	L	.2900	13,80mm	.5433
90	.0087	52	.0635	19	.1660	7,40mm	.2913	35/64	.5469
0,22mm	.0087	1,65mm	.0650	4,25mm	.1673	M	.2950	14,00mm	.5512
89	.0091	1,70mm	.0669	4,30mm	.1693	7,50mm	.2953	14,25mm	.5610
88	.0095	51	.0670	18	.1695	19/64	.2969	9/16	.5625
0,25mm	.0098	1,75mm	.0689	11/64	.1719	7,60mm	.2992	14,50mm	.5709
87	.0100	50	.0700	17	.1730	N	.3020	37/64	.5781
86	.0105	1,80mm	.0709	4,40mm	.1732	7,70mm	.3031	14,75mm	.5807
85	.0110	1,85mm	.0728	16	.1770	7,75mm	.3051	15,00mm	.5906
0,28mm	.0110	49	.0730	4,50mm	.1772	7,80mm	.3071	19/32	.5938
84	.0115	1,90mm	.0748	15	.1800	7,90mm	.3110	15,25mm	.6004
0,30mm	.0118	48	.0760	4,60mm	.1811	5/16	.3125	39/64	.6094
83	.0120	1,95mm	.0768	14	.1820	8,00mm	.3150	15,50mm	.6102
82	.0125	5/64	.0781	13	.1850	O	.3160	15,75mm	.6201
0,32mm	.0126	47	.0785	4,70mm	.1850	8,10mm	.3189	5/8	.6250
81	.0130	2,00mm	.0787	4,75mm	.1870	8,20mm	.3228	16,00mm	.6299
80	.0135	2,05mm	.0807	3/16	.1875	P	.3230	16,25mm	.6398
0,35mm	.0138	46	.0810	4,80mm	.1890	8,25mm	.3248	41/64	.6406
79	.0145	45	.0820	12	.1890	8,30mm	.3268	16,50mm	.6496
0,38mm	.0150	2,10mm	.0827	11	.1910	21/64	.3281	21/32	.6562
1 /64	.0156	2,15mm	.0846	4,90mm	.1929	8,40mm	.3307	16,75mm	.6594
0,40mm	.0157	44	.0860	10	.1935	Q	.3320	17,00mm	.6693
78	.0160	2,20mm	.0866	9	.1960	8,50mm	.3346	43/64	.6719
0,42mm	.0165	2,25mm	.0886	5,00mm	.1969	8,60mm	.3386	17,25mm	.6791
0,45mm	.0177	43	.0890	8	.1990	R	.3390	11/16	.6875
77	.0180	2,30mm	.0906	5,10mm	.2008	8,70mm	.3425	17,50mm	.6890
0,48mm	.0189	2,35mm	.0925	7	.2010	11/32	.3438	45/64	.7031
0,50mm	.0197	42	.0935	13/64	.2031	8,75mm	.3445	18,00mm	.7087
76	.0200	3/32	.0938	6	.2040	8,80mm	.3465	23/32	.7188
75	.0210	2,40mm	.0945	5,20mm	.2047	S	.3480	18,50mm	.7283
0,55mm	.0217	41	.0960	5	.2055	8,90mm	.3504	47/64	.7344
74	.0225	2,45mm	.0965	5,25mm	.2067	9,00mm	.3543	19,00mm	.7480
0,60mm	.0236	40	.0980	5,30mm	.2087	T	.3580	3/4	.7500
73	.0240	2,50mm	.0984	4	.2090	9,10mm	.3583	49/ 64	.7656
0,62mm	.0244	39	.0995	5,40mm	.2126	23/64	.3594	19,50mm	.7677
72	.0250	38	.1015	3	.2130	9,20mm	.3622	25/32	.7812
0,65mm	.0256	2,60mm	.1024	5,50mm	.2165	9,25mm	.3642	20,00mm	.7874
71	.0260	37	.1040	7/32	.2188	9,30mm	.3661	51/64	.7969
0,70mm	.0276	2,70mm	.1063	5,60mm	.2205	U	.3680	20,50mm	.8071
70	.0280	36	.1065	2	.2211	9,40mm	.3701	13/16	.8125
69	.0292	2,75mm	.1083	5,70mm	.2244	9,50mm	.3740	21,00mm	.8268
0,75mm	.0295	7/64	.1094	5,75mm	.2264	3/8	.3750	53/64	.8281
68	.0310	35	.1100	1	.2280	V	.3770	27/32	.8438
1/32	.0312	2,80mm	.1102	5,80mm	.2283	9,60mm	.3780	21,50mm	.8465
0,80mm	.0315	34	.1110	5,90mm	.2323	9,70mm	.3819	55/64	.8594
67	.0320	33	.1130	A	.2340	9,75mm	.3839	22,00mm	.8661
66	.0330	2,90mm	.1142	15/64	.2344	9,80mm	.3858	7/8	.8750
0,85mm	.0335	32	.1160	6,00mm	.2362	W	.3860	22,50mm	.8858
65	.0350	3,00mm	.1181	B	.2380	9,90mm	.3898	57/64	.8906
0,90mm	.0354	31	.1200	6,10mm	.2402	25/64	.3906	23,00mm	.9055
64	.0360	3,10mm	.1220	C	.2420	10,00mm	.3937	29/32	.9062
63	.0370	1/8	.1250	6,20mm	.2441	X	.3970	59/64	.9219
0,95mm	.0374	3,20mm	.1260	D	.2460	10,20mm	.4016	23,50mm	.9252
62	.0380	3,25mm	.1280	6,25mm	.2461	Y	.4040	15/16	.9375
61	.0390	30	.1285	6,30mm	.2480	13/32	.4062	24,00mm	.9449
1,00mm	.0394	3,30mm	.1299	E	.2500	Z	.4130	61/64	.9531
60	.0400	3,40mm	.1339	1/4	.2500	10,50mm	.4134	24,50mm	.9646
59	.0410	29	.1360	6,40mm	.2520	27/64	.4219	31/32	.9688
0,05mm	.0413	3,50mm	.1378	6,50mm	.2559	10,80mm	.4252	25,00mm	.9843
58	.0420	28	.1405	F	.2570	11,00mm	.4331	63/64	.9844
—	—	—	—	—	—	—	—	1"	1.0000

Technical Information

material number	DIN EN - D	AFNOR - F	BS - UK	JIS
0.6010	GG10	—	Grade 100	FC 100
0.6015	GG15	FGL 150	Grade 150	FC 150
0.6020	GG20	FGL 200	Grade 220	FC 200
0.6025	GG25	FGL 250	Grade 250, 260	FC 250
0.6030	GG30	FGL 300	Grade 300	FC 300
0.6035	GG35	FGL 350	Grade 350	FC 350
0.6655	—	L-NUC 15 6 2	F1	—
0.6656	—	L-NUC 15 6 3	F1	—
0.6660	—	L-NC 20 2	F2	—
0.6661	—	L-NC 20 3	F2	—
0.6676	—	L-NC 30 3	F3	—
0.7040	GGG40	FGS 400-15	Grade 420/12	FCD 400
0.7043	GGG40.3	FGS 370-17	Grade 370/12	FCD 370
0.7050	GGG50	FGS 500-7	Grade 500/7	FCD 500
0.7060	GGG60	FGS 600-3	Grade 600/3	FCD 600
0.7070	GGG70	FGS 700-2	Grade 700/2	FCD 700
0.7080	GGG80	FGS 800-2	Grade 800/2	FCD 800
0.7652	—	S-NM 13 7	S 6	—
0.7660	—	S-NC 20 2	S 2	—
0.7661	—	S-NC 20 3	S 2	—
0.7670	—	S-N 22	S 2 C	—
0.7673	—	S-NM 23 4	S 2 M	—
0.7676	—	S-NC 30 3	S 3	—
0.7677	—	S-NC 30 1	S 3	—
0.8035	GTW35	MB 35-7	W 35-04	FCMW 330
0.8038	—	MB 380-12	—	—
0.8040	GTW40	MB 400-5	W 40-05	FCMW 370
0.8045	GTW45	MB 450-7	W 45-07	FCMWP 440
0.8135	GTS35	MN 350-10	B 35-12	FCMB 340
0.8145	GTS45	MP 50-5	P 45-06	—
0.8155	GTS55	MP 60-3	P 55-04	—
0.8165	GTS65	—	P 65-02	FCMP 540
0.8170	GTS70	MP 70-2	P 70-02	FCMP 690
0.9620	G-X 260 NiCr 4-2	—	Grade 2 A	—
0.9625	G-X 330 NiCr 4-2	—	Grade 2 B	—
0.9630	G-X 300 CrNiSi 9-5-2	—	Grade 2 C, D, E	—
0.9635	G-X 300 CrMo 15-3	—	Grade 3 A, B	—
0.9640	G-X 300 CrMoNi 15-2-1	—	Grade 3 A, B	—
0.9645	G-X 260 CrMoNi 20-2-1	—	Grade 3 C	—
0.9650	G-X 260 Cr 27	—	Grade 3 D	—
0.9655	G-X 300 CrMo 27-1	—	Grade 3 E	—
0.xxx	GGV - 30	—	—	FCV 300
0.xxx	GGV - 40	—	—	FCV 400
1.0301	C 10	XC 10	045 M 10040 A 10	S 10 C
1.0401	C 15	XC 12, XC 18	080 M 15	S 15 C
1.0402	C 22	1 C 22, XC 18, XC 25	1 C 22, 070 M 20	S 20 C, S 2 C
1.0406	C 25	1 C 25	070 M 26	S 25 C
1.0501	C 35	XC 38, 1 C 35	080 M 36, 1 C 35	S 35 C
1.0503	C 45	1 C 45, XC 48 H 1	1 C 45, 080 M 46	S 45 C
1.0511	C 40	1 C 40, XC 42 H 1	080 M 40, 1 C 40	S 40 C
1.0528	C 30	—	1 C 30, XC 32	S 30 C
1.0535	C 55	1 C 55, XC 55 H 1	1 C 55, 070 M 55	S 55 C
1.0540	C 50	1 C 50	1 C 50, 080 M50	S 50 C
1.0570	S355J2G3	E 36-3, E 36-4	Fe 510 D1 FF, 50/35	SM 490 _, SM 520 B
1.0601	C 60	1 C 60, AF 70 C 55	1 C 60, 080 A 67	S 58 C
1.0715	9 SMn 28	S 250	080 M 15, 230 M 07	SUM 22
1.0718	9 SMnPb 28	S 250 Pb	—	SUM 22 L, SUM 23 L
1.0721	10 S 20	13 MF 4, 10 F 1	210 M 15	—
1.0722	10 SPb 20	CC 10 Pb, 10 PbF 2	—	SUM 12
1.0726	35 S 20	35 MF 6	212 M 36	SUM 41
1.0727	45 S 20	45 MF 61, 45 MF 4	212 M 36	SUM 42
1.0728	60 S 20	—	—	—
1.0736	9 SMn 36	S 300	240 M 07	SUM 25
1.0737	9 SMnPb 36	S 300 Pb	—	SUM 24 L
1.1121	Ck 10 (C 10 E)	XC 10	045 M 10, 040 A 10	S 9 CK, S 10 C
1.1141	Ck 15 (C 15 E)	XC 12, XC 15	080 M 15, 040 A 15	S 15, S 15 Ck
1.1151	C 22 E	2 C 22, XC 18/25	055 M 15	S 20 C, S 20 CK, S 22 C
1.1157	40 Mn 4	35 M 5, 40 M 5	150 M 36	—
1.1158	C 25 E	2 C 25, XC 25	070 M 26	S 25 C, S 28 C

UNI - I	UNE - E	AISI - US	condition	material group
G 10	FG 10	Class 20 B	U	15
G 15	FG 15	Class 25 B	U	15
G 20	FG 20	Class 30 B	U	16
G 25	FG 25	Class 40 B	U	16
G 30	FG 30	Class 45 B	U	16
G 35	FG 35	Class 50 B	U	16
—	—	—	GG/AU	17
—	—	—	GG/AU	17
—	—	—	GG/AU	17
—	—	—	GG/AU	18
—	—	—	GG/AU	31
GS 400-12	—	Grade 60-40-18	U	17
—	—	—	U	17
GS 500-7	—	Grade 65-45-12	U	17
GS 600-3	—	Grade 80-55-06	U	18
GS 700-2	—	Grade 100-70-03	U	18
GS 800-2	—	Grade120-90-02	U	18
—	—	—	GGG/AU	17
—	—	—	GGG/AU	17
—	—	—	GGG/AU	18
—	—	—	GGG/AU	17
—	—	—	GGG/AU	17
—	—	—	GGG/AU	31
—	—	—	GGG/AU	31
—	—	—	G	20
W 38-12	—	—	G	19
W 40-05	—	—	G	19
W 45-07	—	—	G	19
B 35-10	Type A	Grade 22010, 32510	G	19
P 45-06	Type E	—	G	19
P 55-04	Type C	—	G	20
P 65-02	—	—	G	20
P 70-02	—	—	G	20
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	40
—	—	—	GO	17
—	—	—	GO	18
C 10	F. 1511	1010	—	1
C 15, C 16	F. 111	1015	—	1
1 C 22, C 20, C 21	1 C 22, F. 112	1020, 1023	—	1
C 25, 1 C 25	—	1025	var[1]	2–3
C 35, 1 C 35	1 C 35, F. 113	1035	var[1]	2–3
C 45, 1 C 45	1 C 45, F. 114	1045	var[1]	2–3
1 C 40	1 C 40, F. 114.A	1040	var[1]	2–3
1 C 30	1 C 30	1030	var[1]	2–3
C 55, 1 C 55	1 C 55	1055	var[1]	4–5
1 C 50	1 C 50	1050	var[1]	2–3
Fe 510 C FN	AE 355 D, Fe 510 D1 FF	—	—	2
C 60, 1 C 60	1 C 60	1060	var[1]	4–5
CF 9 SMn 28, CF 9 M 07	F. 2111	1213	1	—
CF 9 SMnPb 28	F. 2112	12 L 14, 12 L 13	—	1
CF 10 S 20	F. 2121	1102, 1108, 1109	—	1
CF 10 SPb 20	F. 2122	1108, 11 L 08	—	1
CF 35 SMn 10	F. 2131, F. 210.G	1141, 1140	var[1]	2–3
CF 44 SMn 28	F. 2133	1146	var[1]	2–3
—	—	1151	var[1]	4–5
CF 9 SMn 36	F. 2113	1215	—	1
CF 9 SMnPb 36	F. 2114	12 L 14	—	1
C10, 2 C 10	F. 1510, C 10 k	1010	—	1
C 15, C 16	F. 1110, F. 1511	1015	—	1
C 20, C 25	F. 1120	1020, 1023	—	1
—	—	1035, 1041	var[1]	2–3
C 25	F. 1120	1025	var[1]	2–3

material number	DIN EN - D	AFNOR - F	BS - UK	JIS
1.1170	28 Mn 6	28 Mn 6, 35 M 5	28 Mn 6, 150 M 19	SMn 433
1.1178	C 30 E	—	2 C 30, XC 32	S 30 C
1.1181	C 35 E	2 C 35, XC 38 H 1	080 M 36	S 35 C
1.1183	Cf 35	XC 42 TS	080 A 35	S 35 C
1.1186	C 40 E	2 C 40, XC42 H 1	2 C 40, 080 M 40	S 40 C
1.1191	C 45 E	XC 48 H 1, 2 C 45	2 C 45, 080 M 46	S 45 C
1.1193	Cf 45	XC 42 TS	060 A 47	S 45 C
1.1203	C 55 E	2 C 55, XC 55 H 1	2 C 55, 070 M 55	S 55 C
1.1206	C 50 E	2 C 50	2 C 50, 080 M 50	S 50 C
1.1213	Cf 53	42 M 4 TS	060 A 57	S 50 C
1.1221	C 60 E	2 C 60	2 C 60, 060 A 62	S 58 C
1.2241	51 CrV 4	50 CV 4	735 A 51	SUP 10
1.2369	81 MoCrV 42-16	—	—	—
1.3505	100 Cr 6	100 C 6	535 A 99	SUJ 2
1.3520	100 CrMn 6	—	535 A 99	SUJ 3
1.3533	17 NiCrMo 14	16 NCD 13	—	—
1.3536	100 CrMo 7-3	—	—	—
1.3537	100 CrMo 7	100 CD 7	—	SUJ 4
1.3541	X 45 Cr 13	—	—	—
1.3543	X 102 CrMo 17	Z 100 CD 17	—	SUS440 C
1.3551	80 MoCrV 42-16	80 DCV 40	—	—
1.3553	X 82 WMoCrV 6-5-4	Z 85 WDCV 6	BM 2	SKH 51
1.3558	X 75 WCrV 18-4-1	—	BT 1	SKH 2
1.4000	X 6 Cr 13	Z 6 C 13	403 S 17	SUS 410 S
1.4002	X 6 CrAl 13	Z6 CA 13	405 S 17	SUS 405
1.4005	X 12 CrS 13	Z12 CF 13	416 S 21	SUS 416
1.4006	X 12 Cr 13 (X 10 Cr 13)	Z 10 C 13, Z 12 C 13	410 S 21	SUS 410
1.4007	X 35 Cr 14	—	—	SUS 420
1.4016	X 6 Cr 17	Z 8 C 17	430 S 17	SUS 430
1.4021	X 20 Cr 13	Z 20 C 13	420 S 37	SUS 420
1.4024	X 15 Cr 13	—	403 S 17	—
1.4028	X 30 Cr 13	Z 30 C 13, Z 33 C 13	420 S 45	SUS 420
1.4034	X 46 Cr 13	Z 40 C 14	420 S 45	SUS 420
1.4057	X 20 CrNi 17-2	Z 15 CN 16-02	431 S 29	SUS 431
1.4104	X 12 CrMoS 17	Z 10 CF 17	441 S 29	SUS 430 F
1.411	X 90 CrMoV 1	—	—	SUS 440 B
1.4113	X 6 CrMo 17-1	Z 8 CD 17-01	434 S 17	SUS 434
1.4125	X 105 CrMo 17	Z100 CD 17	—	SUS 440 C
1.4301	X 5 CrNi 18-10 (X 4 CrNi 18-10)	Z 6 CN 18-09	304 S 16	SUS 304
1.4303	X 5 CrNi 18-12 (X 4 CrNi 18-12)	Z 8 CN 18-12	305 S 19	—
1.4305	X 10 CrNiS 18-9	Z 10 CNF 18-09	303 S 21	SUS 303
1.4306	X 2 CrNi 19-11	Z 2 CN 18-10	304 S 11	SUS 304 L
1.4307	X 2 CrNi 18-9	Z 3 CN 18-10	304S11	SUS 304 L
1.4310	X 12 CrNi 17-7	Z 11 CN 18-08	301 S 21	SUS 301
1.4311	X 2 CrNiN 18-10	Z 3 CN 18-10 Az	304 S 61	SUS 304 LN
1.4362	X 2 CrNiN 23-4	Z 3 CN 23-04 Az	—	—
1.4372	X 12 CrMnNiN 17-7-5	Z 12 CMN 17-07 Az	—	—
1.4401	X 5 CrNiMo 17-12-2 (X 4 CrNiMo 17-12-2)	Z 6 CND 17-11	316 S 31	SUS 316
1.4404	X 2 CrNiMo 17-13-2 (X 2 CrNiMo 17-12-2)	Z 2 CND 17-12	316 S 11	SUS 316 L
1.4406	X 2 CrNiMoN 17-11-2 (X 2 CrNiMoN 17-11-2)	Z 2 CND 17-11 Az	316 S 62	SUS 316 LN
1.4410	X 2 CrNiMoN 25-7-4	Z 3 CND 25-06 Az	—	—
1.4418	X 4 CrNiMo 16-5	Z 6 CND 16 05 1	—	—
1.4429	X 2 CrNiMoN 17-13-3	Z 2 CND 17-13 Az	—	SUS 316 LN
1.4432	X 2 CrNiMo 17-12-3	Z 3 CND 17-12-03	316 S 13	SUS 316 L
1.4434	X 2 CrNiMoN 17-12-3	Z 3 CND 19-14 Az	—	SUS 317 LN
1.4435	X 2 CrNiMo 18-14-3	Z 2 CND 17-13	316 S 13	SUS 316 L
1.4436	X 5 CrNiMo 17-13-3 (X 4 CrNiMo 17-13-3)	Z 6 CND 17-12	316 S 33	SUS 316
1.4438	X 2 CrNiMo 18-16-4 (X 2 CrNiMo 18-15-4)	Z 2 CND 19-15	317 S 12	SUS 317 L
1.4439	X 2 CrNiMoN 17-13-5	Z 3 CND 18-14-05 Az	—	—
1.4441	X 2 CrNiMo 18-15-3	Z 3 CND 18-14-13	316 S 13	—
1.4460	X 4 CrNiMoN 27-5-2 (X 3 CrNiMoN 27-5-2)	25 CND 27-05 A2	—	SUS 329
1.4462	X 2 CrNiMoN 22-5-3	Z2 CND 22-05 Az	—	—
1.4466	X 1 CrNiMoN 25-22-2 (X 2 CrNiMoN 25-22-2)	—	—	—
1.4504	[X 8 CrNiAl 17-7]	Z 8 CNA 17-07	316 S 111	17-7 PH
1.4510	X 6 CrTi 17 (X 3 CrTi 17)	Z 8 CT 17	—	—
1.4512	X 6 CrTi 12 (X 2 CrTi 12)	Z 3 CT 12	409 S 19	SUH 409
1.4532	X 7 CrNiMoAl 15-7 (X 8 CrNiMoAl 15-7-2)	Z 8 CNDA 15-7	—	—
1.4540	X 4 CrNiCuNb 16-4	Z 6 CNU 17-04	—	SUS 630
1.4541	X 6 CrNiTi 18-10	Z 6 CNT 18-10	321 S 12	SUS 321

UNI - I	UNE - E	AISI - US	condition	material group
28 Mn 6	28 Mn 6, 36 Mn 6	1330	var[1]	2–3
2 C 30, 080 M 30	2 C 30	—	var[1]	2–3
2 C 35, C 35	2 C 35, C 35 k	—	var[1]	2–3
C 36	C 38 k	1035	var[1]	2–3
2 C 40, C40	2 C 40, C 42 k	1040	var[1]	2–3
2 C 45, C 45	2 C 45, C 45 k	—	var[1]	2–3
C 43	C 42 k	1045	var[1]	2–3
2 C 55, C 55	2 C 55, C 55 k	—	var[1]	4–5
2 C 50, C 50	2 C 50, C 55 k	1050	var[1]	2–3
C 48	C 48 k	1050	var[1]	2–3
2 C 60, C 60	2 C 60	—	var[1]	4–5
50 CrV 4	F.1430	6150	var[1]	6–9
—	—	613	var[1]	10–11
100 Cr 6	—	52100	var[1]	6–9
100 CrMo 7	—	A 485/2	var[1]	6–9
—	—	E-3310	var[1]	6–9
—	—	5120	var[1]	6–9
100 CrMo 7	—	A 485/3	var[1]	6–9
X 45 Cr 13	—	—	var[1]	10–11
X 105 CrMo 17	—	440 C	var[1]	10–11
X 80 MoCrV 44	—	—	var[1]	10–11
X 82 WMoV 6 5	—	M2 regular C	var[1]	10–11
X 75 WCrV 18	—	T 1	var[1]	10–11
X5 Cr 13	—	410 S	FE	12
X 6 CrA 13	—	405	FE	12
X 12 CrS 13	—	416	FE	12
X 12 Cr 13	—	410	MA	12
—	—	420	MA	12
X 8 Cr 17	—	430	FE	12
X 20 Cr 13	—	420	MA	12
—	—	403	MA	12
—	—	420	MA	13.1
—	—	420	MA	13.1
X 15 CrNi 16	—	431	MA	13.1
X 10 CrS 17	—	430 F	MA	13.1
—	—	440 B	MA	13.1
X 8 CrMo 17	—	434	MA	13.1
—	—	440 C	MA	13.1
X 5 CrNi 18 10	—	304	AU	14.1
X 8 CrNi 18 12	—	305	AU	14.1
X 10 CrNiS 18 09	—	303	AU	14.1
X 2 CrNi 18 11	—	304 L	AU	14.1
—	—	304 L	AU	14.1
X 12 CrNi 17 07	—	301	AU	14.1
—	—	304 LN	AU	14.1
—	—	—	DU	14.2
—	—	201	DU	14.2
X 5 CrNiMo 17 12	—	316	AU	14.1
X 2 CrNiMo 17 12	—	316 L	AU	14.1
X 2 CrNiMoN	—	316 LN	AU	14.1
—	—	—	DU	14.2
—	—	—	MA	13.1
X 2 CrNiMoN 17 13	—	316 LN	AU	14.1
—	—	316 L	AU	14.1
—	—	317 LN	AU	14.1
X 2 CrNiMo 17 13	—	316 L	AU	14.1
X 5 CrNiMo 17 13	—	316	AU	14.1
X 2 CrNiMo 18 16	—	317 L	AU	14.1
—	—	—	AU	14.1
—	—	316 LVM	AU	14.1
—	—	329	DU	14.2
—	—	2205	DU	14.2
—	—	310 mod	S-AU	14.3
X 2 CrNiMo 17.12	—	17-7 PH	AU-PH	14.4
—	—	439, 430 Ti	FE	12
—	—	409	FE	12
—	—	632	AU	14.1
—	—	630	AU	14.1
X 6 CrNiTi 18 11	—	321	AU	14.1

material number	DIN EN - D	AFNOR - F	BS - UK	JIS
1.4542	X 5 CrNiCuNb 17-4	Z 6 CNU 17-04, Z 7 CNNb 17-07	—	SUS 630
1.4548	X 5 CrNiCuNb 17-4-4	Z 7 CNNb 17-07	—	SUS 630
1.4550	X 6 CrNiNb 18-10	Z 6 CNNB 18-10	347 S 17	SUS 347
1.4552	GX 5 CrNiNb 19-10 (G-X 5 CrNiNb 18-9)	Z 6 CNNb 18.10 M	347 C 17	SCS 21
1.4567	X 3 CrNiCu 18-9 (X 3 CrNiCu 18-9-4)	Z 3 CNU 18-09 FF	—	—
1.4568	X 7 CrNiAl 17-7	Z 8 CNA 17-7	316 S 111	17-7 PH
1.4571	X 6 CrNiMoTi 17-12-2	Z 6 CNDT 17-12	320 S 31	SUS 316 Ti
1.4573	X 10 CrNiMoTi 18-12	Z 6 CNDT 17-13	320 S 33	—
1.4580	X 6 CrNiMoNb 17-12-2	Z 6 CNDNb 17-12	—	—
1.4581	GX 5 CrNiMoNb 19-11 (G-X 5 CrNiMoNb 18-10)	Z 4 CNDNb 18.12 M	318 C 17	SCS 22
1.4583	X 10 CrNiMoNb 18-12	Z 6 CNDNb 17-13	—	—
1.4713	X 10 CrAl 7	Z 8 CA 7	—	—
1.4718	X 45 CrSi 9-3	Z 45 CS 9	401 S 45	SUH 1
1.4720	X 7 CrTi 12	Z 6 CT 12	—	SUS 409
1.4724	X 10 CrAl 13	Z 10 C 13	403 S 17	SUS 405
1.4731	X 40 CrSiMo 10-2	Z 40 CSD 10	—	SUH 3
1.4742	X 10 CrAl 18	Z 12 CAS 18, Z 10 CAS 18	430 S 17	SUS 430
1.4748	X 85 CrMoV 18-2	Z 85 CDV 18.02	—	—
1.4762	X 10 CrAl 24	Z10 CAS 24	—	SCH446
1.4821	X 20 CrNiSi 25-4	Z 20 CNS 25.04	—	—
1.4828	X 15 CrNiSi 20-12 Z	15 CN 23-13, Z 15 CNS 20-12	309 S 24	SUS 309 S
1.4833	X 7 CrNi 23-14	Z 15 CN 23.13, Z 15 CN 24.13	309 S 16	SUH 309
1.4841	X 15 CrNiSi 25-20	Z 15 CNS 25-20, Z 12 CNS 25-20	310 S 24	SUS310
1.4845	X 12 CrNi 25-21	Z 12 CN 26.21, Z 12 CN 25.20	310 S 31	SUH 310
1.4864	X 12 NiCrSi 36-16	Z 20 NCS 33.16, Z 12 NCS 35.16	—	SUH 330
1.4871	X 53 CrMnNiN 21-9	Z 53 CMN 21.09 Az	349 S 54	SUH 35
1.4873	X 45 CrNiW 18-9	Z 35 CNWS 14.14	331 S 40	SUH 31
1.4875	X 55 CrMnNiN 20-8	Z 55 CMN 20.08 Az	—	—
1.4876	X 10 NiCrAlTi 32-20	Z 8 NC 33.21, Z 8 NC 32.21	—	—
1.487	X 12 CrNiTi 18-9	Z 6 CNT 18.12, Z 6 CNT 18.10	321 S 12, 321 S 51	SUS 321
1.4948	X 6 CrNi 18-11	Z 6 CN 18-09	304 S 51	SUS304
1.5023	38 Si 7	46 S 7	—	—
1.5092	60 SiCr 7	61 SC 7	251 A 61	SUP 7
1.5919	15 CrNi 6	16 NC 6	815 M 17	SNC 15
1.5920	18 CrNi 8	20 NC 6	822 M17	SNCM 616
1.6511	36 CrNiMo 4	36 CrNiMo 4	36 CrNiMo 4, 817 A 37	SNCM 439
1.6580	30 CrNiMo 8	30 CrNiMo 8, 30 CND 8	30 CrNiMo 8	SNCM 630
1.6582	34 CrNiMo 6	34 CrNiMo 6	34 CrNiMo 6, 817 M 40	SNCM 447
1.6587	17 CrNiMo 6	18 NCD 6	820 M 17	SNCM 815
1.7003	38 Cr 2	38 Cr 2	38 Cr 2, 120 M 36	SMn 438
1.7003	46 Cr 2	46 Cr 2, 42 C 2	46 Cr 2, 605 M 36	SMn 443
1.7030	28 Cr 4	30 CD 4	530 A 30	—
1.7033	34 Cr 4	34 Cr 4, 32 C 4	34 Cr 4, 530 A 32	SCr 430
1.7034	37 Cr 4	37 Cr 4, 38 C 4	37 Cr 4, 530 A 36	SCr 435
1.7035	41 Cr 4	41 Cr 4, 42 C 4	41 Cr 4, 530 M 40	41 Cr 4SCr 440
1.7037	34 CrS 4	34 CrS 4, 32 C 4	34 CrS 4, 530 A 32	—
1.7038	37 CrS 4	37 CrS 4, 38 C 4	37 CrS 4, 530 A 36	—
1.7039	41 CrS 4	41 CrS 4, 42 C 4	41 CrS 4, 530 M 40	—
1.7102	54 SiCr 6	51 S 7	251 A 58	SKD12
1.7131	16 MnCr 5	16 MC 5	527 M 17	—
1.7147	20 MnCr 5	20 MC 5	—	SMnC 420
1.7176	55 Cr 3	55 C 3	525 A 60	SUP 9
1.7213	25 CrMoS 4	25 CrMoS 4, 25 CD 4	25 CrMoS 4, 708 A 25	—
1.7218	25 CrMo 4	25 CrMo 4, 25 CD 4	25 CrMo 4, 708 A 25	SCM 430
1.7220	34 CrMo 4	34 CrMo 4, 34 CD 4	34 CrMo 4, 708 A 37	SCM 435
1.7225	42 CrMo 4	42 CrMo 4, 42 CD 4	42 CrMo 4, 708 M 40	SCM440
1.7226	34 CrMoS 4	34 CrMoS 4, 34 CD 4	34 CrMoS 4708 A 37	—
1.7227	42 CrMoS 4	42 CrMoS 4, 42 CD 4	42 CrMoS 4, 708 M 40	—
1.7228	50 CrMo 4	50 CrMo 4	50 CrMo 4, 708 A 47	—
1.7321	20 MoCr 4	—	805 M 20	SNCM 220
1.7325	25 MoCr 4	18 CD 4	—	—
1.7361	32 CrMo 12	30 CD 12	722 M 24	—
1.7701	51 CrMoV 4	51 CDV 4	—	SUP 13
1.8159	51 CrV 4	51 CrV 4, 50 CV 4	51 CrV 4	SUP 10
1.8507	34 CrAlMo 5	—	—	—
1.8509	41 CrAlMo 7	40 CAD 6 12	905 M 39	—
1.8515	31 CrMo 12	30 CD 12	722 M 24	—
1.8523	39 CrMoV 13-9	—	897 M 39	—
1.8550	34 CrAlNi 7	—	—	—

UNI - I	UNE - E	AISI - US	condition	material group
—	—	630	AU-PH	14.4
—	—	630	AU-PH	14.4
X 8 CrNiNb 18 11	—	347	AU	14.1
—	—	—	AU	14.1
—	—	302 HQ	AU	14.1
X 2 CrNiMo 17.12	—	17-07 PH	AU-PH	14.4
X 6 CrNiMoTi 17 12	—	316 Ti	AU	14.1
X 6 CrNiMoTi 17 12	—	(316 Ti)	AU	14.1
X 6 CrNiMoNb 17 12	—	316 Cb	AU	14.1
GX 6 CrNiMoNb 20 11	—	—	AU	14.1
X 6 CrNiMoNb 17 13	—	316 Cb, (318)	AU	14.1
—	—	—	FE	10–11
X 45 CS 8	—	HNV 3	—	31–32
—	—	409	—	31–32
X 10 CrAl 12	X 10 CrAl 13	405	FE	12
—	—	—	—	12
X 8 Cr 17	X 10 CrAl 18	430	—	12
—	—	—	—	31–32
X 16 Cr 26	—	446	—	12
—	X 15 CrNiSi 25 04	—	DU	14.2
—	X 10 CrNiSi 20	309	AU	14.1
X 6 CrNi 23 14	—	309 S	AU	14.1
X 16 CrNiSi 25 20	X 15 CrNiSi 25 20	310	AU	14.1
—	—	310 S	AU	14.1
—	X 12 NiCrSi 36 16	330	—	31–32
—	—	EV 8	—	10
X 45 CrNiW 18 9	—	EV 9	—	31–32
—	—	EV 11	—	31–32
—	X 10 NiCrAlTi 32 20	—	S-AU	31–32
X 6 CrNiTi 18 11	—	321, 321 H	—	31–32
—	—	304H	AU	14.1
—	—	—	var[1]	6–9
60 SiCr 8	F.1442	9260	var[1]	6–9
—	F.1581	4320	var[1]	6–9
16 NiCrMo 12	F.1525	—	var[1]	6–9
36 CrNiMo 4, 39 NiCrMo 3 1	36 CrNiMo 4, 40 NiCrMo 4	—	var[1]	6–9
SNCM 630	30 CrNiMo 8, 32 NiCrMo 16	—	var[1]	6–9
34 CrNiMo 6	34 CrNiMo 6	4340	var[1]	6–9
18 NiCrMo 12	F.1560	—	var[1]	6–9
38 Cr 2	38 Cr 2, 38 Cr 3	—	var[1]	6–9
46 Cr 2	46 Cr 2	—	var[1]	6–9
—	—	—	var[1]	6–9
34 Cr 4	34 Cr 4	5132	var[1]	6–9
37 Cr 4	37 Cr 4, 38 Cr 4	5135	var[1]	6–9
41 Cr 4	41 Cr 4, 42 Cr 4	5140	var[1]	6–9
34 CrS 4	34 CrS 4	—	var[1]	6–9
37 CrS 4	37 Cr 4, 38 Cr 4-1	—	var[1]	6–9
41 CrS 4	41 CrS 4, 42 Cr 4-1	—	var[1]	6–9
48 Si 7	F.1450	9260	var[1]	6–9
16 MnCr 5	F.1516	—	var[1]	6–9
20 MnCr 5	F.1523	—	var[1]	6–9
55 Cr 3	—	5155	var[1]	6–9
25 CrMoS 4, 25 CrMo 4	25 CrMoS 4, 30 CrMo 4-1	—	var[1]	6–9
25 CrMo 4	25 CrMo 4, 30 CrMo 4	4130	var[1]	6–9
34 CrMo 4, 35 CrMo 4	34 CrMo 4, 35 CrMo 4	4137	var[1]	6–9
42 CrMo 4	42 CrMo 4	—	var[1]	6–9
34 CrMoS 4, 35 CrMo 4	34 CrMoS 4, 35 CrMo 4	—	var[1]	6–9
42 CrMoS 4, 42 CrMo 4	42 CrMoS 4, 40 CrMo 4-1	—	var[1]	6–9
50 CrMo 4	50 CrMo 4	4150	var[1]	6–9
16 NiCrMo 2	F.1523	8620	var[1]	6–9
20 NiCrMo 2	—	8625	var[1]	6–9
—	—	—	var[1]	6–9
51 CrMoV 4	—	—	var[1]	6–9
51 CrV 4, 50 CrV 4	51 CrV 4	6150	var[1]	6–9
—	35 CrAlMo 5	A 355/D	var[1]	6–9
41 CrAlMo 7	41 CrAlMo 7	A 355/A	var[1]	6–9
31 CrMo 12	31 CrMo 12	—	var[1]	6–9
36 CrMoV 12	—	—	var[1]	6–9
—	—	A 355/C	var[1]	6–9

Technical Information

Material Overview

AISI

DIN ISO 513	VDI 3323	Material		Condition	Rm N/mm^2	Hardness HB 30	Examples
P	1	Unalloyed steel/cast steel	C < 0,25%	G	420	125	1010, 1015, 1020, 1023, 1102, 1108, 1109, 1213, 1215
	2		0,25 ≤ C < 0,55%	G	650	190	1025, 1030, 1035, 1040, 1041, 1045, 1050, 1140, 1141, 1146, 1330
	3	Free cutting steel		V	850	250	1025, 1030, 1035, 1040, 1041, 1045, 1050, 1140, 1141, 1146, 1330
	4		0,55% ≤ C	G	750	220	1055, 1060,1151
	5			V	1000	300	1055, 1060,1151
	6	Low-alloyed steel/cast steel		G	600	180	4130, 4140, 4150, 4320, 4340, 5120, 5132, 5135, 5140, 5155, 6150, 8620, 8625, 9260, A 355/A, A 355/C, A 355/D, A485/2, A 485/3, E-3310
	7			V	930	275	
	8			V	1000	300	
	9			V	1200	350	
	10	High-alloyed steel/cast steel		G	680	200	440 C, 613, EV 8, M2 regular C, T1
	11	Tool steel		V	1100	325	440 C, 613, EV 8, M2 regular C, T1
	12	Stainless steel/cast steel		FE/MA	680	200	403, 405, 409, 410, 410 S, 416, 420, 430, 430 Ti, 439, 446,
	13.1			MA	820	240	420, 430 F, 431, 434, 440 B, 440 C
	13.2			MA-PH	1060	330	630, 630
M	14.1	Stainless steel/cast steel		AU	600	180	301, 303, 304, 304 L, 304 LN, 305, 309 S, 316, 316 L, 316 LN, 317 L, 317 LN
	14.2			DU	740	230	201, 329, 2205
	14.3			S-AU	680	200	310 mod
	14.4			AU-PH	1060	330	17-7 PH, 630
K	15	Gray iron GG		FE/PE		180	Class 20 B, Class 25 B,
	16			PE		260	Class 30 B, Class 40 B, Class 45 B, Class 50 B
	17	Nodular iron GGG		FE		160	Class 50 B, Grade 60-40-18, Grade 65-45-12
	18			PE		250	Grade 80-55-06, Grade 100-70-03, Grade120-90-02
	19	Malleable iron GTS/GTW		FE		130	Grade 22010, 32510
	20			PE		230	GTW-35-04, GTS-55-04, GTS-65-02
N	21	Wrought aluminum alloys		NAG		60	6061, 2014-T6, 2011-T3, 2024-T4, A2, 7075, 1000, AlMg 1, AlCuMg 1, AlMgSiPb, AlMgSi 1
	22			AG		100	6061, 2014-T6, 2011-T3, 2024-T4, A2, 7075, 1000, AlMg 1, AlCuMg 1, AlMgSiPb, AlMgSi 1
	23	Cast aluminum alloys	Si < 12%	NAG		75	A380-1, A280, A390-1, G-AlSi 10 Mg, G-AlSi12, G-AlCu 5 Si 3, G-AlSi 17, G-AlSi 23
	24			AG		90	A380-1, A280, A390-1, G-AlSi 10 Mg, G-AlSi12, G-AlCu 5 Si 3, G-AlSi 17, G-AlSi 23
	25		Si > 12%			130	A380-1, A280, A390-1, G-AlSi 10 Mg, G-AlSi12, G-AlCu 5 Si 3, G-AlSi 17, G-AlSi 23
	26	Copper/copper alloys	Pb > 1%			110	Free cutting brass, CuNi 18 Zn 19 Pb
	27					90	Brass, red brass, CuZn33, CuZn-/CuSnZn-alloys
	28					100	Bronze, electrolytic copper, CuNi 3 Si, CuSn-alloys
	29	Non-metals					Thermosetting plastics, FVK, Fiber-reinforced plastics, Bakelit
	30						Hard rubber
S	31	High-temperature alloys	Fe-based	G		200	A-286, 321, 321 H, 330, 409, EV 9, EV11, HNV3
	32			AG		280	A-286, 321, 321 H, 330, 409, EV 9, EV11, HNV3
	33		Ni-/Co-based	G		250	INCONEL® 601/617/625/700/706/718, Nimonic 80 A, Hasteloy, Udimet, Haynes 25, Waspaloy, Rene41, Stelite
	34			AG		350	INCONEL 601/617/625/700/706/718, Nimonic 80 A, Hasteloy, Udimet, Haynes 25, Waspaloy, Rene41, Stelite
	35			GO		320	INCONEL 601/617/625/700/706/718, Nimonic 80 A, Hasteloy, Udimet, Haynes 25, Waspaloy, Rene41, Stelite
	36	Titanium/titanium alloys, Alpha-/Beta-alloys			400		Titanium
	37			AG	1050		TiAl 64 V
H	38.1	Steel		H		45 HRC	90 MnV 8, Hardox 400
	38.2			H		55 HRC	Hardox 500
	39.1			H		60 HRC	HSS, 90 MnV 8
	39.2			H		> 62 HRC	HSS, 90 MnV 8
	40.1	Chilled cast iron		GO		400	G-X 260 Cr 27, G-X 260 NiCr 42, G-X 300 CrNiSi 9 5 2, G-X 330 NiCr 42
	40.2			GO		> 440	G-X 260 Cr 27, G-X 260 NiCr 42, G-X 300 CrNiSi 9 5 2, G-X 330 NiCr 42
	41.1	Cast iron		H		55 HRC	G-X 300 NiMo 3 Mg
	41.2			H		> 57 HRC	G-X 300 NiMo 3 Mg

Material Groups and Condition

Many materials — mostly steels — can be available in various microstructures that differ in their machinability significantly.
Those materials are part of several material groups depending on their actual conditions.

AG — Aged
AU — Austenitic, AISI 300
BF — Heat treated to specified strength
BG — Heat treated to specified microstructure
BY — Heat treated to improved machinability
DU — Stainless steel duplex (austenitic-ferritic)
FE — Ferritic

G — Annealed
GG — Gray cast iron
GGG — Nodular cast iron
GO — Cast
H — Hardened
MA — Martensitic
N — Normalized

NAG — Non-aged (non-aging)
PH — Precipitation hardened
S-AU — Superaustenitic
U — Untreated
V — Heat treated
var^1 — Variable

Material Overview

DIN

DIN ISO 513	VDI 3323	Material	Condition	Rm N/mm^2	Hardness HB 30	Examples
P	1	Unalloyed steel/cast steel C < 0,25%	G	420	125	9 SMn 28, St 37.3, C 10, Ck 22, GS-16 Mn 5
	2	0,25 ≤ C < 0,55%	G	650	190	35 S 20, GS-45, GS-52, St 52.3, C 25, C 45, Ck 45, Cf 53
	3	Free cutting steel	V	850	250	35 S 20, GS-45, GS-52, St 52.3, C 25, C 45, Ck 45, Cf 53
	4	0,55% ≤ C	G	750	220	GS-60, 60 S 20, C 60, Ck 67, C 60 W, Ck 75, C 105 W 1, C 110 W
	5		V	1000	300	GS-60, 60 S 20, C 60, Ck 67, C 60 W, Ck 75, C 105 W 1, C 110 W
	6	Low-alloyed steel/cast steel	G	600	180	15 Cr 3, 16 MnCr 5, 17 CrNiMo 6, 25 CrMo 4, 29 CrMoV 9, 30 CrNiMo8
	7		V	930	275	31 CrV 3, 42 CrMo 4, 51 CrV 4, 62 SiMnCr 4, 100 Cr 6, G-105 W 1
	8		V	1000	300	105 WCr 6
	9		V	1200	350	105 WCr 6
	10	High-alloyed steel/cast steel	G	680	200	X 210 Cr 12, X 40 CrMoV 5 1, X 30 WCrV 9 3, X 85 CrMoV 18 2
	11	Tool steel	V	1100	325	X 38 CrMoV 5 3, X 23 CrNi 17, X 155 CrVMo 12 1, S 6-5-2-5
	12	Stainless steel/cast steel	FE/MA	680	200	1.4000, 1.4005, 1.4021, 1.4109, 1.4119, 1.4120, 1.4313, 1.4510, 1.4512, 1.4523
	13.1		MA	820	240	1.4000, 1.4002, 1.4005, 1.4006, 1.4024, 1.4119, 1.4120, 1.4313, 1.4510, 1.4512, 1.4523
	13.2		MA-PH	1060	330	1.4542, 1.4548, 1.4923
M	14.1	Stainless steel/cast steel	AU	600	180	1.4301, 1.4401, 1.4436, 1.4541, 1.4550, 1.4568, 1.4571, 1.4573, 1.4580
	14.2		DU	740	230	1.4362, 1.4417, 1.4410, 1.4460, 1.4462, 1.4575, 1.4582
	14.3		S-AU	680	200	1.4465, 1.4505, 1.4506, 1.4529 (254SMO), 1.4539, 1.4563, 1.4577, 1.4586, 654SMO
	14.4		AU-PH	1060	330	1.4504, 1.4568
K	15	Gray iron GG	FE/PE		180	GG-10, GG-15, GG-170 HB
	16		PE		260	GG20, GG-25, GG-30, GG-25Cr
	17	Nodular iron GGG	FE		160	GGG-35.3, GGG-40, GGG-50, GGV-30
	18		PE		250	≥GGG-60, GGV-40
	19	Malleable iron GTS/GTW	FE		130	GTS-35-10, GTS-45-06, GTW-S-38-12
	20		PE		230	GTW-35-04, GTS-55-04, GTS-65-02
N	21	Wrought aluminum alloys	NAG		60	Al 99,5, AlMg 1
	22		AG		100	AlCuMg 1, AlMgSiPb, AlMgSi 1
	23	Cast aluminum alloys Si < 12%	NAG		75	G-AlSi 10 Mg, G-AlSi12
	24		AG		90	G-AlCu 5 Si 3
	25	Si > 12%			130	G-AlSi 17, G-AlSi 23
	26	Copper/copper alloys Pb > 1%			110	Free cutting brass, CuNi 18 Zn 19 Pb
	27				90	Brass, red brass, CuZn33, CuZn-/CuSnZn-alloys
	28				100	Bronze, electrolytic copper, CuNi 3 Si, CuSn-alloys
	29	Non-metals				Thermosetting plastics, FVK, Fiber-reinforced plastics, Bakelit
	30					Hard rubber
S	31	High-temperature alloys Fe-based	G		200	1.4864, 1.4865, 1.4876
	32		AG		280	1.4864, 1.4865, 1.4876
	33	Ni-/Co-based	G		250	INCONEL® 718, Nimonic 80 A, Hasteloy, Udimet
	34		AG		350	INCONEL 718, Nimonic 80 A, Hasteloy, Udimet
	35		GO		320	INCONEL 718, Nimonic 80 A, Hasteloy, Udimet
	36	Titanium/titanium alloys, Alpha-/Beta-alloys		400		Titanium
	37		AG	1050		TiAl 6 V 4
H	38.1	Steel	H		45 HRC	90 MnV 8, Hardox 400
	38.2		H		55 HRC	Hardox 500
	39.1		H		60 HRC	HSS, 90 MnV 8
	39.2		H		> 62 HRC	HSS, 90 MnV 8
	40.1	Chilled cast iron	GO		400	G-X 260 Cr 27, G-X 260 NiCr 42, G-X 300 CrNiSi 9 5 2, G-X 330 NiCr 42
	40.2		GO		> 440	G-X 260 Cr 27, G-X 260 NiCr 42, G-X 300 CrNiSi 9 5 2, G-X 330 NiCr 42
	41.1	Cast iron	H		55 HRC	G-X 300 NiMo 3 Mg
	41.2		H		> 57 HRC	G-X 300 NiMo 3 Mg

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