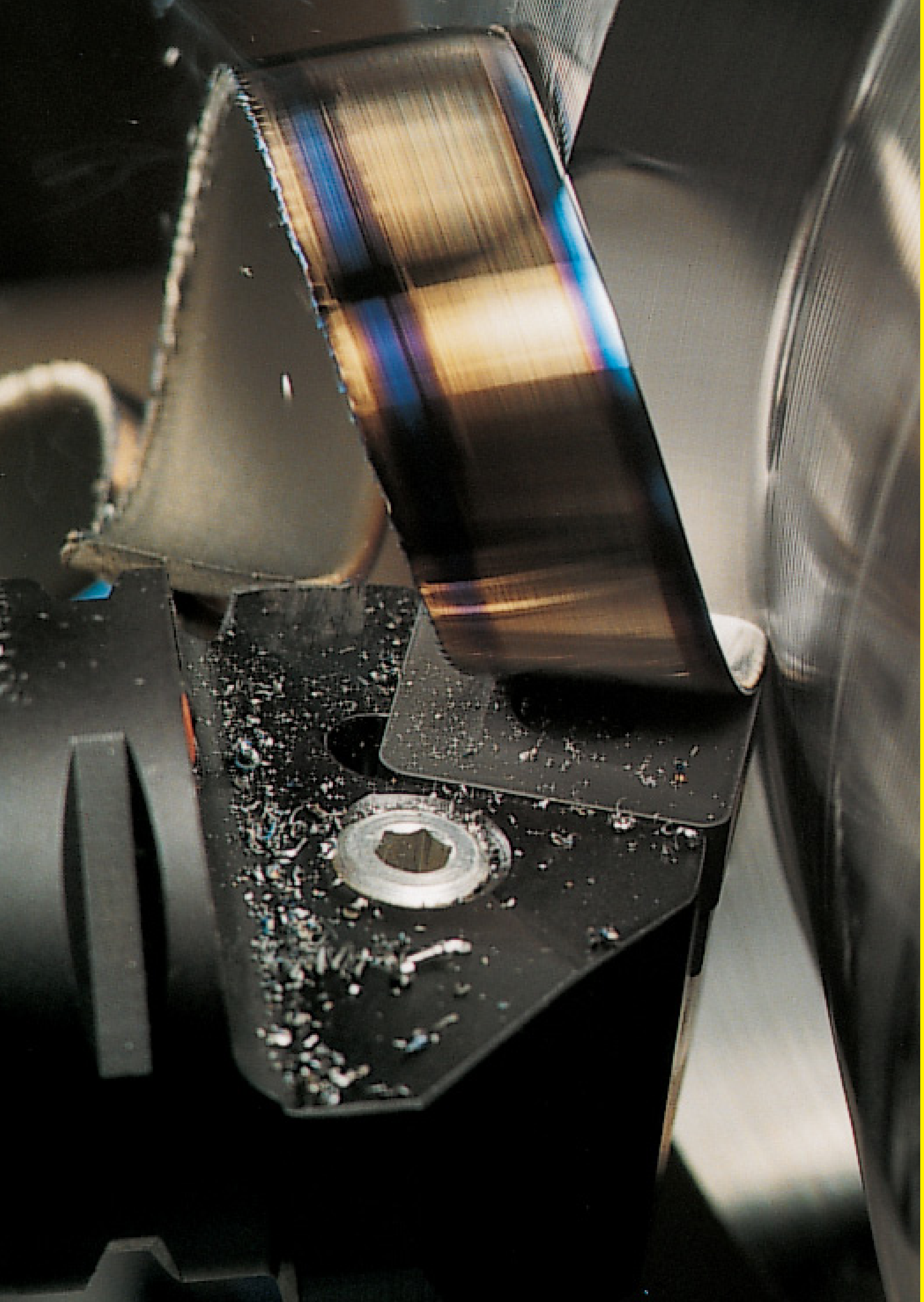
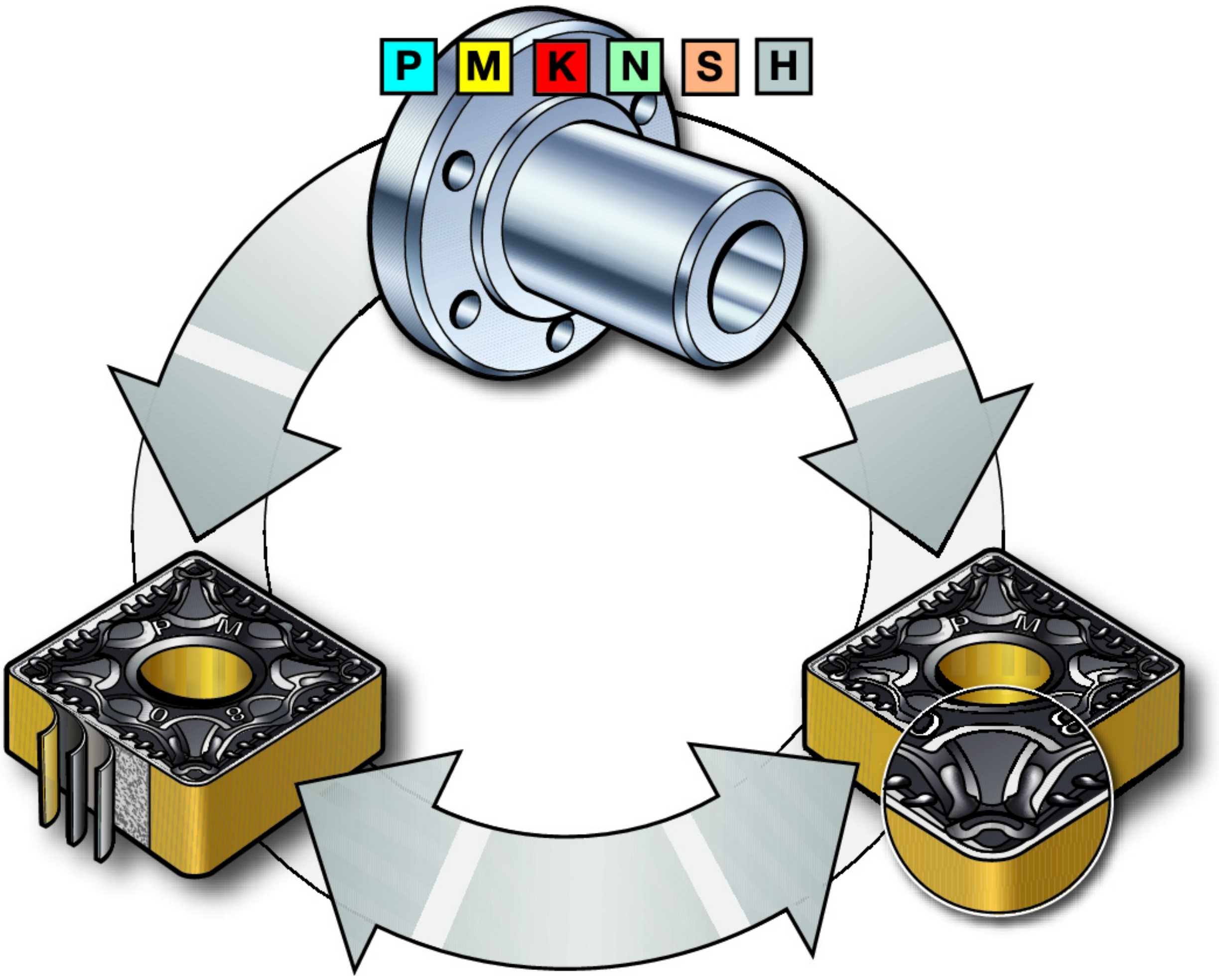


MATERIALS

Cutting tool materials

Workpiece materials



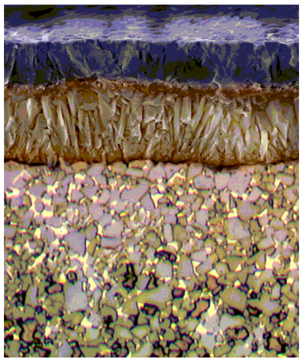
Introduction

Matching the most suited cutting tool material (grade) and insert geometry with the workpiece material to be machined is important for a trouble-free and productive machining process. Other parameters, such as cutting data, tool path, etc. are also vital for a successful result.

This chapter provides basic information about:

- Cutting tool materials, such as cemented carbide, ceramics, CBN, PCD, etc.
- Workpiece materials and classifications from a machinability point of view.

For more information on machining different workpiece materials with different tools, see Getting started in General turning, Chapter A, Parting and grooving, Chapter B, Milling, Chapter D and Drilling, Chapter E.



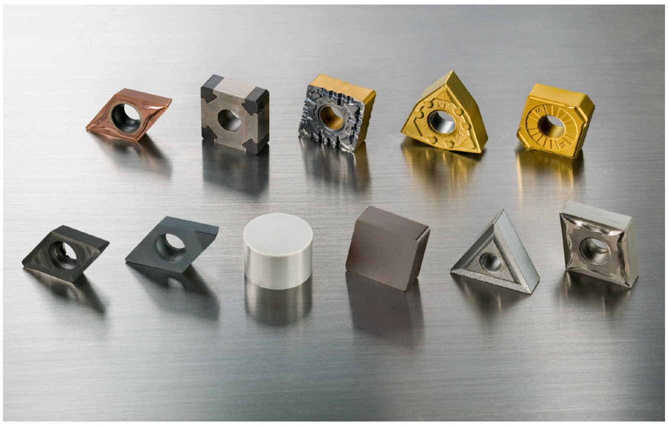
P M K
N S H

Cutting tool materials

The selection of cutting tool material and grade is an important factor to consider when planning a successful metal cutting operation.

A basic knowledge of each cutting tool material and its performance is therefore important so that the correct selection for each application can be made. Considerations include the workpiece material to be machined, the component type and shape, machining conditions and the level of surface quality required for each operation.

The aim of this chapter is to provide additional information on each cutting tool material, its advantages and the recommendations for its best use. An overview of the total Sandvik Coromant grade assortment for each application area will also be provided.



Letter symbols specifying the designation of hard cutting materials:

Hardmetals:

HW Uncoated hardmetal containing primarily tungsten carbide (WC).

HT Uncoated hardmetal, also called cermet, containing primarily titanium carbides (TIC) or titanium nitrides (TIN) or both.

HC Hardmetals as above, but coated.

Ceramics:

CA Oxide ceramics containing primarily aluminium oxide (Al_2O_3).

CM Mixed ceramics containing primarily aluminium oxide (Al_2O_3) but containing components other than oxides.

CN Nitride ceramics containing primarily silicon nitride (Si_3N_4).

CC Ceramics as above, but coated.

Diamond:

DP Polycrystalline diamond [1)]

Boron nitride:

BN Cubic boron nitride [1)]

[1)] Polycrystalline diamond and cubic boron nitride are also called superhard cutting materials.

Cutting tool materials have different combinations of hardness, toughness and wear resistance, and are divided into numerous grades with specific properties. Generally, a cutting tool material that is successful in its application should be:

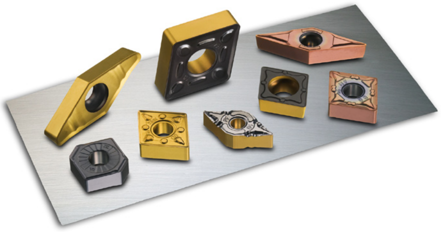
- Hard, to resist flank wear and deformation
- Tough, to resist bulk breakage
- Non-reactive with the workpiece material
- Chemically stable, to resist oxidation and diffusion
- Resistant to sudden thermal changes.

For more infromation about different types of wear, see page H10.

Coated cemented carbide (HC)

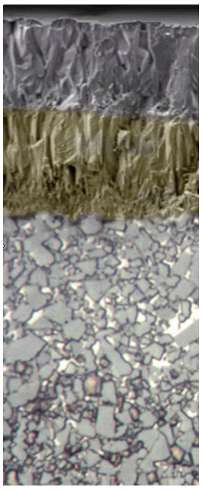
Coated cemented carbide currently represents 80-90% of all cutting tool inserts. Its success as a tool material is due to its unique combination of wear resistance and toughness, and its ability to be formed in complex shapes.

Coated cemented carbide combines cemented carbide with a coating. Together they form a grade which is customized for its application.



Coated cemented carbide grades are the first choice for a wide variety of tools and applications.

Coating – CVD



Definition and properties

CVD stands for Chemical Vapor Deposition. The CVD coating is generated by chemical reactions at temperatures of 700-1050°C.

CVD coatings have high wear resistance and excellent adhesion to cemented carbide.

The first CVD coated cemented carbide was the single layer titanium carbide coating (TiC). Alumina coatings (Al_2O_3) and titanium nitride (TiN) coatings were introduced later. More recently, the modern titanium carbonitride coatings (MT-Ti(C,N) or MT-TiCN, also called MT-CVD) were developed to improve grade properties through their ability to keep the cemented carbide interface intact.

Modern CVD coatings combine MT-Ti(C,N), Al_2O_3 and TiN. The coating properties have been continuously improved for adhesion, toughness and wear properties through microstructural optimizations and post-treatments.

MT-Ti(C,N) - Its hardness provides abrasive wear resistance, resulting in reduced flank wear.

CVD-Al_2O_3 – Chemically inert with low thermal conductivity, making it resistant to crater wear. It also acts as a thermal barrier to improve plastic deformation resistance.

CVD-TiN - Improves wear resistance and is used for wear detection.

Post-treatments - Improve edge toughness in interrupted cuts and reduce smearing tendencies.

Applications

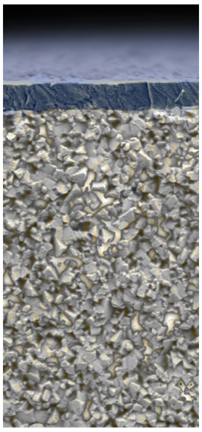
CVD coated grades are the first choice in a wide range of applications where wear resistance is important. Such applications are found in general turning and boring of steel, with crater wear resistance offered by the thick CVD coatings; general turning of stainless steels and for milling grades in ISO P, ISO M, ISO K. For drilling, CVD grades are usually used in the peripheral insert.

Coating – PVD

Definition and properties

Physical Vapor Deposition (PVD) coatings are formed at relatively low temperatures (400-600°C). The process involves the evaporation of a metal which reacts with, for example, nitrogen to form a hard nitride coating on the cutting tool surface.

PVD coatings add wear resistance to a grade due to their hardness. Their compressive stresses also add edge toughness and comb crack resistance.



The main PVD-coating constituents are described below. Modern coatings are combinations of these constituents in sequenced layers and/or lamellar coatings. Lamellar coatings have numerous thin layers, in the nanometer range, which make the coating even harder.

PVD-TiN - Titanium nitride was the first PVD coating. It has all-round properties and a golden color.

PVD-Ti(C,N) - Titanium carbonitride is harder than TiN and adds flank wear resistance.

PVD-(Ti,Al)N - Titanium aluminium nitride has high hardness in combination with oxidation resistance, which improves overall wear resistance.

PVD-oxide - Is used for its chemical inertness and enhanced crater wear resistance.

Applications

PVD coated grades are recommended for tough, yet sharp, cutting edges, as well as in smearing materials. Such applications are widespread and include all solid end mills and drills, and a majority of grades for grooving, threading and milling. PVD-coated grades are also extensively used for finishing applications and as the central insert grade in drilling.

Cemented carbide

Definition and properties

Cemented carbide is a powdery metallurgical material; a composite of tungsten carbide (WC) particles and a binder rich in metallic cobalt (Co). Cemented carbides for metal cutting applications consist of more than 80% of hard phase WC. Additional cubic carbonitrides are other important components, especially in gradient sintered grades.

The cemented carbide body is formed, either through powder pressing or injection moulding techniques, into a body, which is then sintered to full density.

WC grain size is one of the most important parameters for adjusting the hardness/toughness relationship of a grade; the finer grain size means higher hardness at a given binder phase content.

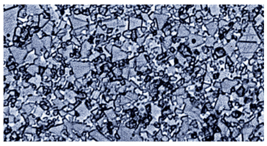
The amount and composition of the **Co-rich binder** controls the grade's toughness and resistance to plastic deformation. At equal WC grain size, an increased amount of binder will result in a tougher grade, which is more prone to plastic deformation wear. A binder content that is too low may result in a brittle material.

Cubic carbonitrides, also referred to as γ-phase, are generally added to increase hot hardness and to form gradients.

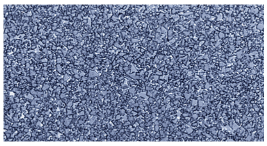
Gradients are used to combine improved plastic deformation resistance with edge toughness. Cubic carbonitrides concentrated in the cutting edge improve the hot hardness where it is needed. Beyond the cutting edge, a binder rich in tungsten carbide structure inhibits cracks and chip hammering fractures.

Applications

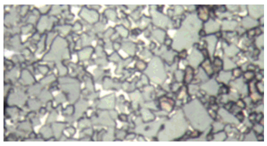
Medium to coarse WC grain size
Medium to coarse WC grain sizes provide the cemented carbides with a superior combination of high hot hardness and toughness. These are used in combination with CVD or PVD coatings in grades for all areas.



Fine or submicron WC grain size
Fine or submicron WC grain sizes are used for sharp cutting edges with a PVD coating to further improve the strength of the sharp edge. They also benefit from a superior resistance to thermal and mechanical cyclic loads. Typical applications are solid carbide drills, solid carbide end mills, parting off and grooving inserts, milling and grades for finishing.



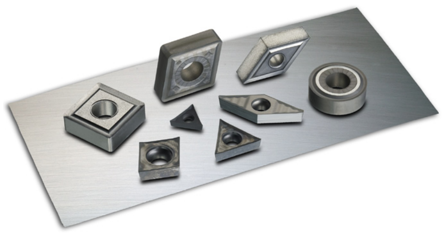
Cemented carbide with gradient
The beneficial dual property of gradients is successfully applied in combination with CVD coatings in many first choice grades for turning, and parting and grooving in steels and stainless steels.



Uncoated Cemented Carbide (HW)

Definition and properties

Uncoated cemented carbide grades represent a very small proportion of the total assortment. These grades are either straight WC/Co or have a high volume of cubic carbonitrides.



Applications

Typical applications are machining of HRSA (heat resistant super alloys) or titanium alloys and turning hardened materials at low speed.

The wear rate of uncoated cemented carbide grades is rapid yet controlled, with a self-sharpening action.

A General turning
B Parting and grooving
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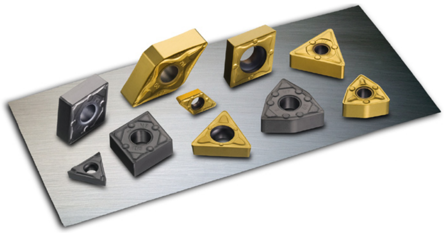
Cermet (CT)



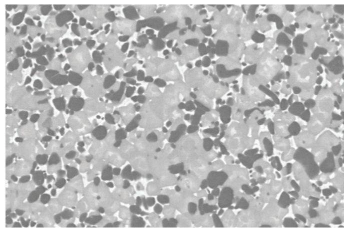
Definition and properties

A cermet is a cemented carbide with titanium based hard particles. The name cermet combines the words ceramic and metal. Originally, cermets were composites of TiC and nickel. Modern cermets are nickel-free and have a designed structure of titanium carbonitride Ti(C,N) core particles, a second hard phase of (Ti,Nb,W)(C,N) and a W-rich cobalt binder.

Ti(C,N) adds wear resistance to the grade, the second hard phase increases the plastic deformation resistance, and the amount of cobalt controls the toughness.

In comparison to cemented carbide, cermet has improved wear resistance and reduced smearing tendencies. On the other hand, it also has lower compressive strength and inferior thermal shock resistance. Cermets can also be PVD coated for improved wear resistance.

Applications



Cermet grades are used in smearing applications where built-up edge is a problem. Its self-sharpening wear pattern keeps cutting forces low even after long periods in cut. In finishing operations, this enables a long tool life and close tolerances, and results in shiny surfaces.

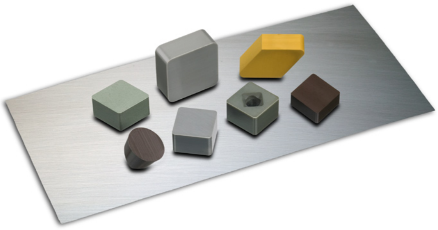
Typical applications are finishing in stainless steels, nodular cast irons, low carbon steels and ferritic steels. Cermets can also be applied for trouble shooting in all ferrous materials.

Hints:

- Use low feed and depth of cut.
- Change the insert edge when flank wear reaches 0.3 mm.
- Avoid thermal cracks and fractures by machining without coolant.

GC1525	Tough coated cermet grade for interrupted cuts, turning.
CT5015	Wear resistant cermet grade for continuous cuts, turning.
CT530	Milling grade for shiny surfaces.
CT525	Parting and grooving grade for finishing.

Ceramic (CA, CM, CN, CC)



Definition and properties

All ceramic cutting tools have excellent wear resistance at high cutting speeds. There are a range of ceramic grades available for a variety of applications.

Oxide ceramics are aluminium oxide based (Al_2O_3), with added zirconia (ZrO_2) for crack inhibition. This generates a material that is chemically very stable, but which lacks thermal shock resistance.

(1) Mixed ceramics are particle reinforced through the addition of cubic carbides or carbonitrides (TiC, Ti(C,N)). This improves toughness and thermal conductivity.

(2) Whisker-reinforced ceramics use silicon carbide whiskers (SiC_w) to dramatically increase toughness and enable the use of coolant. Whisker-reinforced ceramics are ideal for machining Ni-based alloys.

(3) Silicon nitride ceramics (Si_3N_4) represent another group of ceramic materials. Their elongated crystals form a self-reinforced material with high toughness. Silicon nitride grades are successful in grey cast iron, but a lack of chemical stability limits their use in other workpiece materials.

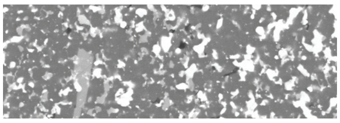
Sialon (SiAlON) grades combine the strength of a self-reinforced silicon nitride network with enhanced chemical stability. Sialon grades are ideal for machining heat resistant super alloys (HRSA).

Applications

Ceramic grades can be applied in a broad range of applications and materials; most often in high speed turning operations but also in grooving and milling operations. The specific properties of each ceramic grade enable high productivity, when applied correctly. Knowledge of when and how to use ceramic grades is important for success.

General limitations of ceramics include their thermal shock resistance and fracture toughness.

(1)



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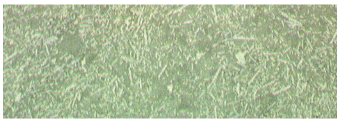

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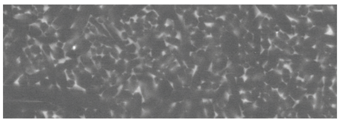


CC620	Oxide ceramic for high speed finishing of grey cast iron in stable and dry conditions.
CC6050	Mixed ceramic for light, continuous finishing in hardened materials.
CC650	Mixed ceramic for high speed finishing of grey cast irons and hardened materials, and for semi-finishing operations in HRSA with low toughness demands.
CC670	Whisker ceramic with excellent toughness for turning, grooving and milling of Ni-based alloys. Can also be used for hard part turning in unfavorable conditions.
CC6190 **CC6090**	Silicon nitride grade for rough to finish turning and high speed dry milling of cast iron, perlitic nodular cast irons and hardened cast irons.
GC1690	Coated silicon nitride grade for light roughing to finish turning of cast iron.
CC6060	Sialon grade for optimized performance when turning pre-machined HRSA in stable conditions. Predictable wear due to good notch wear resistance.
CC6065	Particle reinforced Sialon for turning operations in HRSA that demand tough inserts.

SANDVIK Coromant

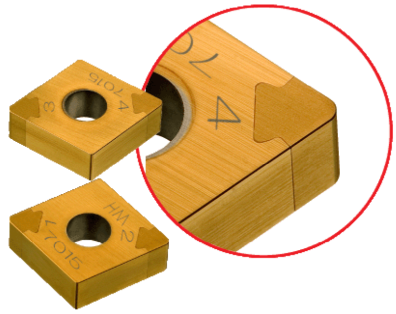
Polycrystalline cubic boron nitride, CBN (BN)

Definition and properties

Polycrystalline cubic boron nitride, CBN, is a material with excellent hot hardness that can be used at very high cutting speeds. It also exhibits good toughness and thermal shock resistance.

Modern CBN grades are ceramic composites with a CBN content of 40-65%. The ceramic binder adds wear resistance to the CBN, which is otherwise prone to chemical wear. Another group of grades are the high content CBN grades, with 85% to almost 100% CBN. These grades may have a metallic binder to improve their toughness.

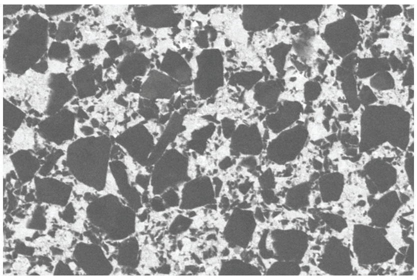
CBN is brazed onto a cemented carbide carrier to form an insert. The Safe-Lok™ technology further enhances the bondage of CBN cutting tips on negative inserts.



Applications

CBN grades are largely used for finish turning of hardened steels, with a hardness over 45 HRc. Above 55 HRc, CBN is the only cutting tool which can replace traditionally used grinding methods. Softer steels, below 45 HRc, contain a higher amount of ferrite, which has a negative effect on the wear resistance of CBN.

CBN can also be used for high speed roughing of grey cast irons in both turning and milling operations.

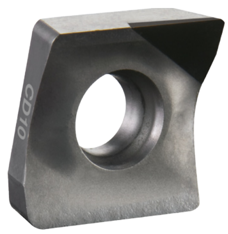


CB7015	PVD coated CBN grade with ceramic binder for continuous turning, and light interrupted cuts in hardened steels.
CB7025	CBN grade with ceramic binder for interrupted cuts and high toughness demands when turning hardened steels.
CB7050	High content CBN grade with metallic binder for heavy interrupted cuts in hardened steels and for finishing grey cast iron. PVD coated.

Polycrystalline diamond, PCD (DP)

Definition and properties

PCD is a composite of diamond particles sintered together with a metallic binder. Diamond is the hardest, and therefore the most abrasion resistant, of all materials. As a cutting tool, it has good wear resistance but it lacks chemical stability at high temperatures and dissolves easily in iron.



Applications

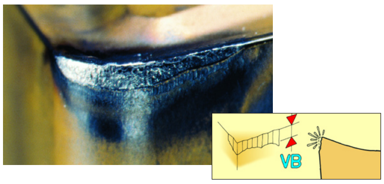
PCD tools are limited to non-ferrous materials, such as high-silicon aluminium, metal matrix composites (MMC) and carbon fibre reinforced plastics (CFRP). PCD with flood coolant can also be used in titanium super-finishing applications.

CD10	PCD grade for finishing and semi-finishing of non-ferrous and non-metallic materials in turning and milling.

Wear on cutting edges

To understand the advantages and limitations of each material, it is important to have some knowledge of the different wear mechanisms to which cutting tools are subjected.

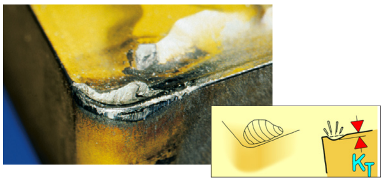
Abrasive



Flank wear

The most common type of wear and the preferred wear type, as it offers predictable and stable tool life. Flank wear occurs due to abrasion, caused by hard constituents in the workpiece material.

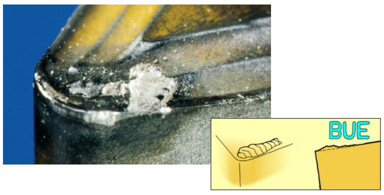
Chemical



Crater wear

Crater wear is localized to the rake side of the insert. It is due to a chemical reaction between the workpiece material and the cutting tool and is amplified by cutting speed. Excessive crater wear weakens the cutting edge and may lead to fracture.

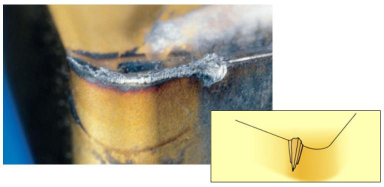
Adhesive



Built-up edge (BUE)

This wear type is caused by pressure welding of the chip to the insert. It is most common when machining sticky materials, such as low carbon steel, stainless steel and aluminium. Low cutting speed increases the formation of built-up edge.

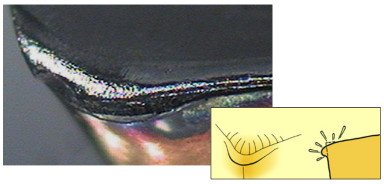
Adhesive



Notch wear

Insert wear characterized by excessive localized damage on both the rake face and flank of the insert at the depth of cut line. Caused by adhesion (pressure welding of chips) and a deformation hardened surface. A common wear type when machining stainless steels and HRSA.

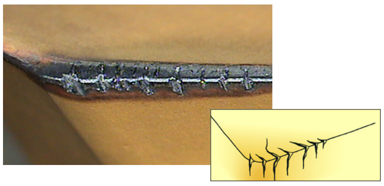
Thermal



Plastic deformation

Plastic deformation takes place when the tool material is softened. This occurs when the cutting temperature is too high for a certain grade. In general, harder grades and thicker coatings improve resistance to plastic deformation wear.

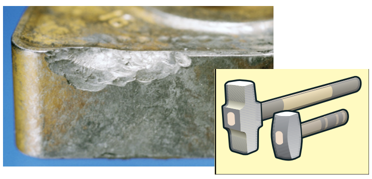
Thermal



Thermal cracks

When the temperature at the cutting edge changes rapidly from hot to cold, multiple cracks may appear perpendicular to the cutting edge. Thermal cracks are related to interrupted cuts, common in milling operations, and are aggravated by the use of coolant.

Mechanic



Edge chipping/breakage

Chipping or breakage is the result of an overload of mechanical tensile stresses. These stresses can be due to a number of reasons, such as chip hammering, a depth of cut or feed that is too high, sand inclusions in the workpiece material, built-up edge, vibrations or excessive wear on the insert.

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Sandvik Coromant grades

The tables on the following pages provide an overview of the Sandvik Coromant grade assortment. They provide information on application areas together with facts about the cutting tool material, which are designed to facilitate the grade selection process. Application areas are shown in bold type for first choice grades and in normal type to indicate a grade that can be used as a complementary choice in the ISO area.

Letter symbols specifying the designation of hard cutting materials:

Hardmetals:

HW Uncoated hardmetal containing primarily tungsten carbide (WC).

HT Uncoated hardmetal, also called cermet, containing primarily titanium carbides (TIC) or titanium nitrides (TIN) or both.

HC Hardmetals as above, but coated.

Ceramics:

CA Oxide ceramics containing primarily aluminium oxide (Al_2O_3).

CM Mixed ceramics containing primarily aluminium oxide (Al_2O_3) but containing components other than oxides.

CN Nitride ceramics containing primarily silicon nitride (Si_3N_4).

CC Ceramics as above, but coated.

Diamond:

DP Polycrystalline diamond [1)]

Boron nitride:

BN Cubic boron nitride [1)]

[1)] Polycrystalline diamond and cubic boron nitride are also called superhard cutting materials.

Symbols:

ISO area applications

- P **ISO P** = Steel
- M **ISO M** = Stainless steel
- K **ISO K** = Cast iron
- N **ISO N** = Non-ferrous material
- S **ISO S** = Heat resistant super alloys
- H **ISO H** = Hardened materials

Cemented carbide type

- Submicron (very fine) WC grain size
- Fine WC grain size
- Medium/coarse grain size
- Gradient grade

Coating thickness

- Thin
- Medium
- Thick

Turning and boring grades

Grade	ISO area applications						Cutting material	Cemented carbide type	Coating procedure and composition		Coating thickness	Color
	P	M	K	N	S	H						
GC1005		M15		N10	**S15**		HC		PVD	(Ti,Al)N+TiN		
GC1025	P25	**M15**			**S15**		HC		PVD	(Ti,Al)N+TiN		
GC1105		M15			**S15**		HC		PVD	(Ti,Al)N		
GC1115		**M15**		N15	S20		HC		PVD	Oxide		
GC1125	P25	**M25**		N25	S25		HC		PVD	Oxide		
GC1515	**P25**	M20	K25				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC2015	P25	**M15**					HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC2025	P35	**M25**					HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC2035		**M35**					HC		PVD	(Ti,Al)N+TiN		
GC235	P45	**M40**					HC		CVD	Ti(C,N)+TiN		
GC3005	**P10**		**K10**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC3205			**K05**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC3210			**K05**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC3215			**K05**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4205	**P05**		K10			H15	HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4215	**P15**		K15			H15	HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4225	**P25**	M15					HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4235	**P35**	M25					HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
S05F					**S05**		HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
H10				**N15**			HW					
H10A					S10		HW					
H10F					S15		HW					
H13A			K20	N15	S15	H20	HW					
GC1525	**P15**	M10					CT		PVD	Ti(C,N)		
CT5015	**P10**		K05				HT					
CC620			K01				CA					
CC650			**K01**		S05	**H05**	CM					
CC6050			K01			**H05**	CM		PVD	TiN		
CC670					**S15**	H10	CM					
CC6090			**K10**				CN					
CC6190			**K10**				CN					
CC6060					**S10**		CN					
CC6065					**S15**		CN					
GC1690			**K10**				CC		CVD	Al_2O_3+TiN		
CB7015						**H15**	BN		PVD	TiN		
CB7025						**H20**	BN					
CB7050/CB50			**K05**			**H05**	BN		PVD	TiN		
CB20						**H01**	BN					
CD10				**N05**			DP					
GC1810				**N10**			HC		CVD	Diamond		

Parting, grooving & threading grades

Grade	ISO area applications P	M	K	N	S	H	Cutting material	Cemented carbide type	Coating procedure and composition		Coating thickness	Color
Parting and grooving (CoroCut:)												
GC1005		M10		**N10**	**S15**		HC		PVD	(Ti,Al)N+TiN		
GC1025	P25	**M25**	K30	**N25**	**S25**		HC		PVD	(Ti,Al)N+TiN		
GC1105		**M15**			S15		HC		PVD	(Ti,Al)N		
GC1125	**P30**	**M25**	**K30**	**N25**	**S25**		HC		PVD	(Ti,Al)N		
GC1145	**P45**	**M40**			**S40**		HC		PVD	Oxide		
GC2135	**P35**	**M30**			S30		HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC2145	P45	**M40**			S40		HC		PVD	(Ti,Al)N		
GC235	P45	M35			S30		HC		CVD	Ti(C,N)+TiN		
GC3020	**P15**		K15				HC		CVD	MT-Ti(C,N)-Al_2O_3		
GC3115	**P15**		**K15**				HC		CVD	MT-Ti(C,N)-Al_2O_3		
GC4125	**P30**	**M25**	**K30**		**S25**		HC		PVD	(Ti,Al)N		
GC4225	**P20**		**K25**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
S05F					**S10**		HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
CT525	P10	M10					HT					
H13A		M15	K20	**N20**	**S15**		HW					
H10				**N10**	S30		HW					
CB7015						**H15**	BN		PVD	TiN		
CB20						**H01**	BN					
CC670					**S10**	**H10**	CM					
CD10				**N01**			DP					
CD1810				**N10**			HC		CVD	Diamond		
Threading:												
GC1020	**P20**	**M20**	**K15**	**N25**	**S20**	**H20**	HC		PVD	TiN		
GC1125	**P20**	**M20**	**K15**		**S20**	**H20**	HC		PVD	(Ti,Al)N		
GC4125	**P20**	**M20**	**K15**		**S20**	**H20**	HC		PVD	(Ti,Al)N		
H13A		**M25**	**K20**	**N25**	**S25**		HW					
CB20						**H10**	BN					

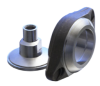
Milling grades

Grade	ISO area applications P	M	K	N	S	H	Cutting material	Cemented carbide type	Coating procedure and composition		Coating thickness	Color
Indexable inserts												
GC1010	P10		K10			**H10**	HC		PVD	(Ti,Al)N		
GC1020			**K20**				HC		PVD	(Ti,Al)N		
GC1025	**P10**	**M15**		N15	**S15**	H15	HC		PVD	Ti(C,N)+TiN		
GC1030	**P30**	**M15**		N15	**S15**	**H10**	HC		PVD	(Ti,Al)N+TiN		
GC2030	P25	**M25**			**S25**		HC		PVD	(Ti,Al)N+TiN		
GC2040	P40	**M30**			**S30**		HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC3040	P20		**K30**			H25	HC		CVD	MT-Ti(C,N)+Al_2O_3		
GC3220			**K20**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4220	**P15**		K25			**H25**	HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4230	**P25**	M15	K30				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
GC4240	**P40**	M40	K35				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
K15W			**K15**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
K20D			K20				HC		CVD	MT-Ti(C,N)+Al_2O_3		
K20W			**K25**				HC		CVD	MT-Ti(C,N)+Al_2O_3+TiN		
H13A			K25	**N15**	S20		HW					
H10				**N10**			HW					
H10F				N20	**S30**		HW					
CT530	**P20**	M20		N15		H15	HT					
CB50			**K05**			**H05**	BN					
CC6190			**K10**				CN					
CD10				**N05**			DP					
Solid end mill												
GC1610						**H**	HC		PVD	(Ti,Al)N		
GC1620	**P**	**M**	**K**		**S**	**H**	HC		PVD	(Ti,Al)N		
GC1630	**P**	**M**	**K**		**S**		HC		PVD	(Ti,Al)N		
GC1640	**P**	**M**	**K**		**S**		HC		PVD	(Ti,Al)N		
H10F				**N**			HW					

Drilling grades

Grade	ISO area applications P	M	K	N	S	H	Cutting material	Cemented carbide type	Coating procedure and composition		Coating thickness	Color
Solid carbide/tipped drills												
GC1020	P20		K20	N20	S20	H20	HC	▲	PVD	Ti(C,N)+TiN	—	
GC1210	P10		**K10**				HC	▲	PVD	AlCrN	—	
GC1220	**P20**	**M20**	**K20**	N20	**S30**	**H20**	HC	▲	PVD	(Ti,Al)N	—	
K20		M30	**K20**	N15		K15	HC	▲	PVD	TiN	—	
N20D				**N20**			HC	▲	PVD	(Ti,Al)N	—	
P20	**P20**						HC	▲	PVD	TiN	—	
H10F	P25		K25	N20	S25		HW	▲				
Drills with indexable inserts												
GC1020	**P40**	**M35**	**K20**	N20	**S35**	**H20**	HC	▲	PVD	TiN	—	
GC1044	**P40**	M35	**K25**	N20	**S35**	**H20**	HC	▲	PVD	(Ti,Al)N	—	
GC1120	**P40**	**M35**	**K20**	**N20**	**S35**	**H20**	HC	▲	PVD	Ti(C,N)	—	
GC235	P40	M35					HC	▲	CVD	Ti(C,N)+TiN	—	
GC1144		**M35**			S35		HC	▲	PVD	Oxide	—	
GC2044		**M35**			S35		HC	▲	PVD	Oxide	—	
GC3040	**P20**	M20	**K20**			H15	HC	▲	CVD	MT-Ti(C,N)+Al_2O_3	—	
GC4014	**P15**		**K15**				HC	■	CVD	MT-Ti(C,N)+Al_2O_3	—	
GC4024	**P25**	M20	**K20**			H15	HC	▲	CVD	MT-Ti(C,N)+Al_2O_3	—	
GC4034	**P30**	M30	**K20**				HC	▲	CVD	MT-Ti(C,N)+Al_2O_3+TiN	—	
GC4044	**P40**	M35	**K20**	N20	**S35**	**H20**	HC	▲	PVD	(Ti,Al)N	—	
H13A		M20	K20	**N20**	S20		HW	▲				

Workpiece materials

P	M	K	N	S	H
					
Steel	Stainless steel	Cast iron	Aluminium	Heat resistant alloys	Hardened steel

Workpiece material groups

The metal cutting industry produces an extremely wide variety of components machined from many different materials. Each material has its own unique characteristics that are influenced by the alloying elements, heat treatment, hardness, etc. These combine to strongly influence the choice of cutting tool geometry, grade and cutting data.

Therefore, workpiece materials have been divided into six major groups, in accordance with the ISO-standard, and each group has unique properties regarding machinability:

- **ISO P** – Steel is the largest material group in the metal cutting area, ranging from unalloyed to high-alloyed material, including steel castings and ferritic and martensitic stainless steels. The machinability is normally good, but differs a lot depending on material hardness, carbon content, etc.
- **ISO M** – Stainless steels are materials alloyed with a minimum of 12% chromium; other alloys may include nickel and molybdenum. Different conditions, such as ferritic, martensitic, austenitic and austenitic-ferritic (duplex), create a large family. A commonality among all these types is that the cutting edges are exposed to a great deal of heat, notch wear and built-up edge.
- **ISO K –** Cast iron is, contrary to steel, a short-chipping type of material. Grey cast irons (GCI) and malleable cast irons (MCI) are quite easy to machine, while nodular cast irons (NCI), compact cast irons (CGI) and austempered cast irons (ADI) are more difficult. All cast irons contain SiC, which is very abrasive to the cutting edge.
- **ISO N** – Non-ferrous metals are softer metals, such as aluminium, copper, brass etc. Auminium with a Si-content of 13% is very abrasive. Generally high cutting speeds and long tool life can be expected for inserts with sharp edges.
- **ISO S** – Heat-Resistant Super Alloys include a great number of high-alloyed iron, nickel, cobalt and titanium based materials. They are sticky, create built-up edge, harden during working (work hardening), and generate heat. They are very similar to the ISO M area but are much more difficult to cut, and reduce the tool life of the insert edges.
- **ISO H** – This group includes steels with a hardness between 45-65 HRc, and also chilled cast iron around 400-600 HB. The hardness makes them all difficult to machine. The materials generate heat during cutting and are very abrasive for the cutting edge.

New material classification – MC codes

Dividing the materials into 6 groups does not provide enough information to select the correct of cutting tool geometry, grade and cutting data. The material groups have to be broken down further into sub-groups, etc. Sandvik Coromant has used the so called CMC-code system (Coromant Material Classification) for many years to identify and describe materials from a variety of suppliers, standards and markets. With the CMC-system, materials are classified according to machinability , and Sandvik Coromant also provides suitable tooling and machining data recommendations.

Now, in order to be even more specific in our recommendations to assist the user in improving productivity, we have generated a new material classification. It has a more detailed structure, includes more sub-groups, and has separate information on type, carbon content, manufacturing process, heat treatment, hardness, etc.

MC code structure

The structure is set up so that the MC code can represent a variety of workpiece material properties and characteristics using a combination of letters and numbers.

Example 1:

The code **P1.2.Z.AN**

- **P** is the ISO-code for steel
- **1** is the material group unalloyed steel
- **2** is the material sub-group for carbon content >0.25% ≤0.55 % C
- **Z** is the manufacturing process: forged/rolled/cold drawn
- **AN** is the heat treatment, annealed, supplied with hardness values

Example 2

N1.3.C.AG

- **N** is the ISO-code for non-ferrous metals
- **1** is the material group aluminium
- **3** is the sub-group aluminium with Si content 1-13%
- **C** is the manufacturing process: casting
- **AG** for the heat treatment: ageing

By describing not only the material composition, but also the manufacturing process and heat treatment, which doubtless influences the mechanical properties, a more exact description is available, which can be used to generate improved cutting data recommendations.

The specific cutting force

For power, torque and cutting force calculations, the specific cutting force, or k_{c1}, is used. It can be explained as the force, F_c, in the cutting direction (see picture), needed to cut a chip area of 1 mm² that has a thickness of 1 mm. The k_{c1} value is different for the six material groups, and also varies within each group.

The k_{c1} value is valid for a neutral insert with a rake angle, γ_0, = 0°; other values must be considered to compensate for this. For example, if the rake angle is more positive than 0 degrees, the actual k_c value will decrease, which is calculated with this formula:

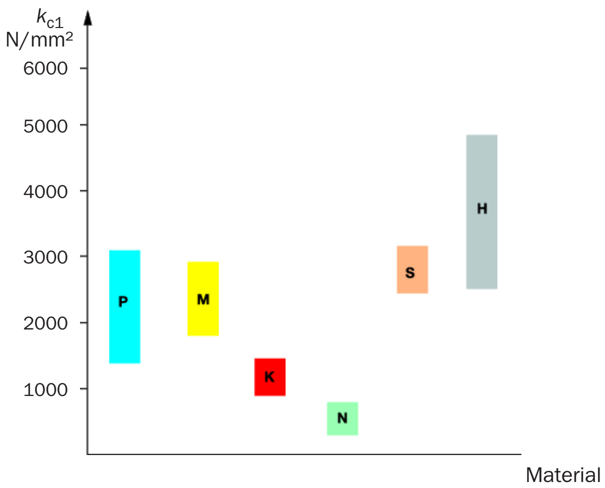
Specific cutting force (k_c)
(N/mm²)

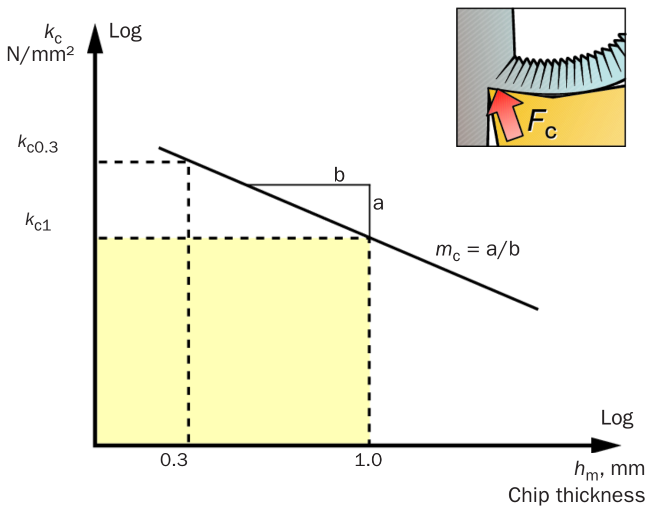
$$k_c = k_{c1} \times h_m^{-m_c} \times \left(1 - \frac{\gamma_0}{100}\right)$$

If the actual chip thickness, h_m, is, for example, 0.3 mm, the k_c value will be higher, see diagram. When the actual k_c value is defined, the power requirement can be calculated accordingly:

Net power requirement (P_c)
(kW)

$$P_c = \frac{a_p \times a_e \times v_f \times k_c}{60 \times 10^6}$$

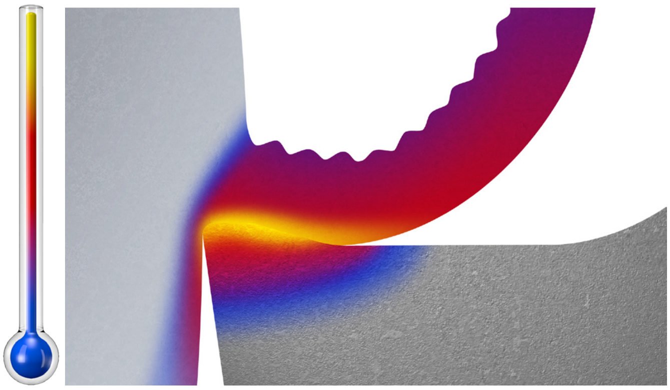


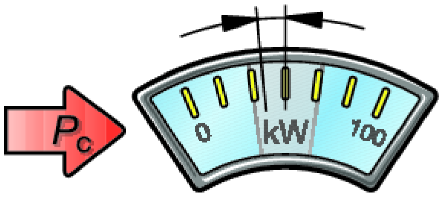


P Steel

Definition

- Steel is the largest workpiece material group in the metal cutting area.
- Steels can be non-hardened, or hardened and tempered with a common hardness up to 400 HB. Steel with a hardness above approx. 48 HRC and up to 62-65 HRC belong to ISO H.
- Steel is an alloy with iron as the major component (Fe-based).
- Unalloyed steels have a carbon content lower than 0.8%, and are composed solely of iron (F_e), with no other alloying elements.
- Alloyed steels have a carbon content that is lower than 1.7 % and alloying elements such as Ni, Cr, Mo, V and W.
- Low alloyed steels have alloying elements less that 5%.
- High alloyed steels have more than 5% alloying elements.





Machinability in general

- The machinability of steel differs, depending on alloying elements, heat treatment and manufacturing process (forged, rolled, cast, etc.).
- In general, chip control is relatively easy and smooth.
- Low carbon steels produce longer chips that are sticky and require sharp cutting edges.
- Specific cutting force kc_1: 1400-3100 N/mm².
- Cutting forces, and thus the power required to machine them, remain within a limited range.

For more information on machining of ISO P materials, see General turning page A 22, Milling page D 32 and Drilling page E 16.

Alloying elements
C influences hardness (higher content increases abrasive wear). Low carbon content <0.2%, increases the adhesive wear, which will lead to built-up edge and bad chip breaking.
Cr, Mo, W, V, Ti, Nb (carbide formers) – increase abrasive wear.
O has a large influence on machinability: it forms non-metallic, oxidic and abrasive inclusions.
Al, Ti, V, Nb are used as fine-grained-treatment of steel ; they make the steel tougher and more difficult to machine.
P, C, N in the ferrite, lowers the ductility, which increases adhesive wear.

Positive effect
Pb in free machining steel (with low melting point) reduces friction between chip and insert, lowers wear and improves chip breaking.
Ca, Mn (**+S**) form soft lubricating sulphides. High S-content improves machinability and chip breaking.
Sulphur (**S**) has a beneficial effect on machinability. Small differences, such as those between 0.001% and 0.003% can have substantial effects on machinability. This effect is used in free machining steels. Sulphur content of around 0.25% is typical. Sulphur forms soft manganese sulfide (MnS) inclusions that will form a lubricating layer between the chip and the cutting edge. MnS will also improve the chip breakage. Lead (Pb) has a similar effect and is often used in combination with S in free machining steels at levels of around 0.25%.

MC codes for steels

Steels are, from a machinability point of view, classified into unalloyed, low alloyed, high alloyed and sintered steels.

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom	Specific cutting force, k_{c1} (N/mm²)	m_c
P1.1.Z.AN	1	unalloyed Mn<1.65	1	≤0.25% C	Z	forged/rolled/cold drawn	AN	annealed	125 HB	1500	0.25
P1.1.Z.HT	1		1		Z		HT	hardened+tempered	190 HB	1770	0.25
P1.2.Z.AN	1		2	>0.25... ≤0.55% C	Z	forged/rolled/cold drawn	AN	annealed	190 HB	1700	0.25
P1.2.Z.HT	1		2		Z		HT	hardened+tempered	210 HB	1820	0.25
P1.3.Z.AN	1		3	high carbon, >0.55% C	Z	forged/rolled/cold drawn	AN	annealed	190 HB	1750	0.25
P1.3.Z.HT	1		3		Z		HT	hardened+tempered	300 HB	2000	0.25
P1.4.Z.AN	1		4	free cutting steel	Z	forged/rolled/cold drawn	AN	annealed	220 HB	1180	0.21
P1.5.C.HT	1		5	all carbon contents (cast)	C	cast	HT	untreated	150 HB	1400	0.25
P1.5.C.AN	1		5		C		AN	hardened+tempered	300 HB	2880	0.25
P2.1.Z.AN	2	low alloyed (alloying elements ≤5%)	1	≤0.25% C	Z	forged/rolled/cold drawn	AN	annealed	175 HB	1700	0.25
P2.2.Z.AN	2		2	>0.25... ≤0.55% C	Z		AN		240 HB	1950	0.25
P2.3.Z.AN	2		3	high carbon, >0.55% C	Z		AN		260 HB	2020	0.25
P2.4.Z.AN	2		4	free cutting steel	Z		AN		225 HB		
P2.5.Z.HT	2		5	all carbon contents (hardened and tempered)	Z	forged/rolled/cold drawn	HT	hardened+tempered	330 HB	2000	0.25
P2.6.C.UT	2		6	all carbon contents (cast)	C	cast	UT	untreated	200 HB	1600	0.25
P2.6.C.HT	2		6		C		HT	hardened+tempered	380 HB	3200	0.25
P3.0.Z.AN	3	high alloyed (alloying elements >5%)	0	main group	Z	forged/rolled/cold drawn	AN	annealed	200 HB	1950	0.25
P3.0.Z.HT	3		0		Z		HT	hardened+tempered	380 HB	3100	0.25
P3.0.C.UT	3		0		C	cast	UT	untreated	200 HB	1950	0.25
P3.0.C.HT	3		0		C		HT	hardened+tempered	340 HB	3040	0.25
P3.1.Z.AN	3		1	HSS	Z	forged/rolled/cold drawn	AN	annealed	250 HB	2360	0.25
P3.2.C.AQ	3		2	Manganese Steel	C	cast	AQ	annealed/quenched or annealed	300 HB	3000	0.25
P4.0.S.NS	4	sintered steels	0	main group	S	sintered	NS	not specified	150 HB		

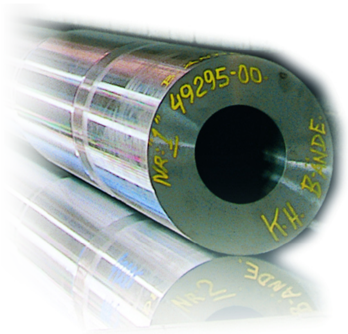
Both positive and negative
Si, Al, Ca form oxide inclusions that increase wear. Inclusions in the steel have an important influence on the machinability, even though they represent very small percentages of the total composition. This influence can be both negative and positive. For example, aluminium (Al) is used to deoxidize the iron melt. However, aluminium forms hard abrasive alumina (Al2O3), which has a detrimental effect on machinability (compare the alumina-coating on an insert). This negative effect can, however, be counteracted by adding Calcium (Ca), which will form a soft shell around the abrasive particles.

- **Cast steel** has a rough surface structure, which can include sand and slag, and places a high demand on the toughness on the cutting edge.
- **Rolled steel** exhibits a fairly large grain size, which makes the structure uneven, causing variations in the cutting forces.
- **Forged steel** has a smaller grain size and is more uniform in structure, which generates fewer problems when cut.

Unalloyed steel – P 1.1-1.5

Definition

In unalloyed steels, the carbon content is usually only 0.8%, while alloyed steels have additional alloying elements. The hardness varies from 90 up to 350HB. A higher carbon content (>0.2%) enables hardening of the material.



Common components

Predominant uses include: constructional steel, structural steel, deep drawn and stamped products, pressure vessel steel, and a variety of cast steels. General uses include: axles, shafts, tubes, forgings and welded constructions (C<0.25%).

Machinability

Difficulties in chip breaking and smearing tendencies (built-up edge) require special attention in low carbon steels (< 0.25%). High cutting speeds and sharp edges and/or geometries, with a positive rake face and thin coated grades, will decrease the smearing tendencies. In turning, it is recommended that the depth of cut remains close to or bigger than the nose radius to improve chip breaking. In general, the machinability is very good for hardened steels, however, they tend to generate relatively large flank wear on the cutting edges.

Low alloyed steel – P 2.1-2.6

Definition

Low alloyed steels are the most common materials currently available in metal cutting. The group includes both soft and hardened materials (up to 50 HRc).

Common components

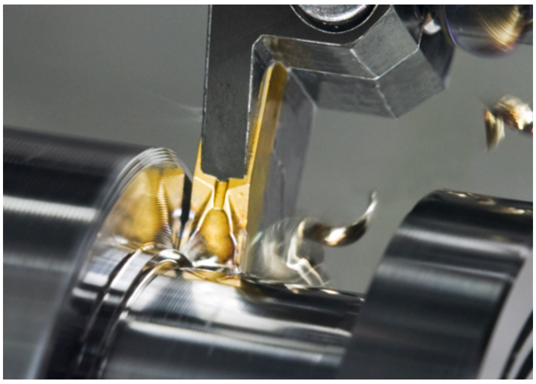
Mo- and Cr-alloyed pressure vessel steels are used for higher temperatures. General uses include: axles, shafts, structural steels, tubes and forgings. Examples of components for the automotive industry are: con rods, cam shafts, cv-joints, wheel hubs, steering pinions.

➤ Low alloyed steel – P 2.1-2.6 – continued

Machinability

Machinability for low alloyed steels depends on the alloy content and heat treatment (hardness). For all materials in the group, the most common wear mechanisms are crater and flank wear.

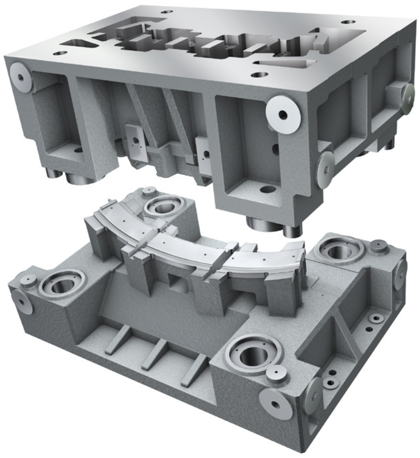
Hardened materials give higher heat in the cutting zone and can result in plastic deformation of the cutting edge.



High alloyed steel – P 3.0-3.2

Definition

High alloyed steels include carbon steels with a total alloy content over 5%. The group includes both soft and hardened materials (up to 50 HRc).

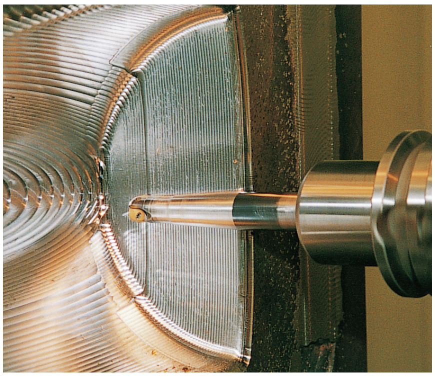


Common components

Typical uses of these steels include: machine tool parts, dies, hydraulic components, cylinders and cutting tools (HSS).

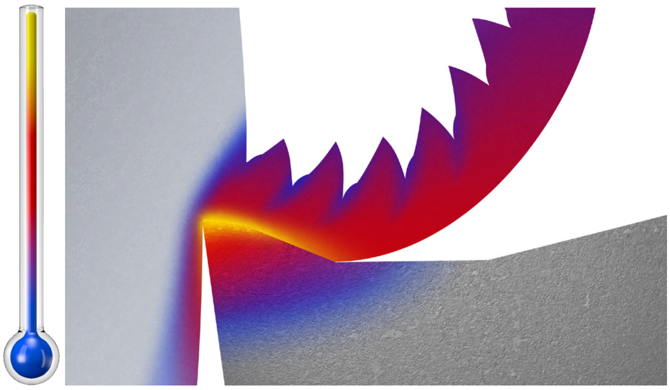
Machinability

In general, machinability decreases at higher alloy contents and hardness. For example, at 12-15% alloying elements and hardness up to 450 HB, the cutting edge needs good heat-resistance to withstand plastic deformation.



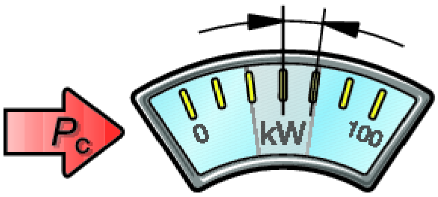
M Stainless steel

Definition



- An alloy with the element iron (Fe) as the major constituent.
- Has a chrome content which is higher than 12%
- Has a generally low carbon content (C ≤ 0.05 %).
- Various additions of Nickel (Ni), Chromium (Cr), Molybdenum (Mo), Niobium (Nb) and Titanium (Ti), supply different characteristics, such as resistance towards corrosion and strength at high temperatures.
- Chrome combines with oxygen (O) to create a passivating layer of Cr_2O_3 on the surface of the steel, which provides a non-corrosive property to the material.

Machinability in general

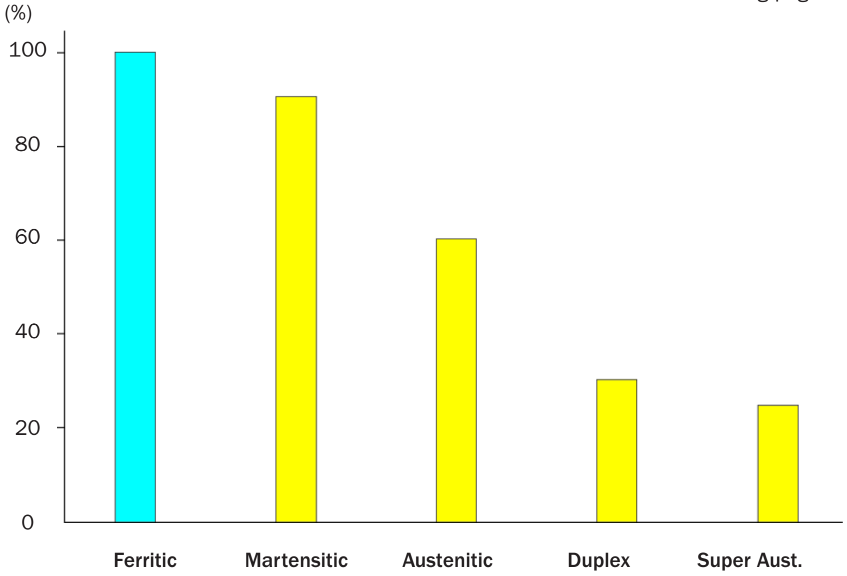


The machinability of stainless steels differs depending on alloying elements, heat treatment and manufacturing processes (forged, cast, etc.) In general, machinability decreases with a higher alloy content, but free-machining or machinability improved materials are available in all groups of stainless steels.

- Long-chipping material.
- Chip control is fair in ferritic/martensitic materials, becoming more complex in the austenitic and duplex types.
- Specific cutting force: 1800-2850 N/mm².
- Machining creates high cuttting forces, built-up edge, heat and work-hardened surfaces.
- Higher nitrogen (N) content austenitic structure, it increases strength and provides some resistance against corrosion, but lowers machinability, while the deformation hardening increases.
- Additions of Sulphur (S) are used to improve machinability.
- High C-content (>0.2%) provides relatively large flank wear.
- Mo and N decrease machinability, however, they provide resistance to acid attacks and contribute to high temperature strength.
- SANMAC (Sandvik trade name) is a material in which machinability is improved by optimizing the volume share of sulphides and oxides without sacryficing corrosion resistance.

Fore more information on machining of ISO M materials, see General turning page A 25, Milling page D 34 and Drilling page E 16.

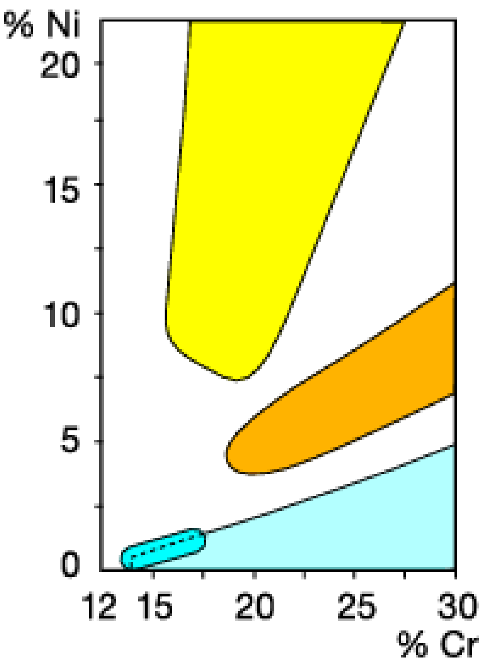
Relative machinability



MC codes for stainless steel

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom	Specific cutting force, k_{c1} (N/mm²)	m_c
P5.0.Z.AN	5	stainless steel ferritic/martensitic	0	main group	Z	forged/rolled/cold/drawn	AN	annealed	200 HB	1800	0.21
P5.0.Z.HT	5		0		Z		HT	hardened+tempered	330 HB	2300	0.21
P5.0.Z.PH	5		0		Z		PH	precipitation hardened	330 HB	2800	0.21
P5.0.C.UT	5		0		C	cast	UT	untreated	250 HB	1900	0.25
P5.0.C.HT	5		0		C		HT	hardened+tempered	330 HB	2100	0.25
P5.1.Z.AN	5		1	free cutting steel	Z	forged/rolled/cold	AN	annealed	200 HB	1650	0.21
M1.0.Z.AQ	1	austenitic	0	main group	Z	forged/rolled/cold drawn	AQ	annealed/quenched or annealed	200 HB	2000	0.21
M1.0.Z.PH	1		0		Z		PH	precipitation hardened	300 HB	2400	0.21
M1.0.C.UT	1		0		C	cast	UT	untreated	200 HB	1800	0.25
M1.1.Z.AQ	1		1	machinability improved (as SANMAC)	Z	forged/rolled/cold drawn	AQ	annealed/quenched or annealed	200 HB	2000	0.21
M1.1.Z.AQ	1		2	free cutting steel	Z		AQ		200 HB	1800	0.21
M1.3.Z.AQ	1		3	Ti-stabilized	Z		AQ		200 HB	1800	0.21
M1.3.C.AQ	1		3		C	cast	AQ		200 HB	1800	0.25
M2.0.Z.AQ	2	super-austenitic, Ni≥20%	0	main group	Z	forged/rolled/cold drawn	AQ		200 HB	2300	0.21
M2.0.C.AQ	2		0		C	cast	AQ		200 HB	2150	0.25
M3.1.Z.AQ	3	duplex (austenitic/ferritic)	1	>60% ferrite (rule of thumb N<0.10%)	Z	forged/rolled/cold drawn	AQ	annealed/quenched or annealed	230 HB	2000	0.21
M3.1.C.AQ	3		1		C	cast	AQ		230 HB	1800	0.25
M3.2.Z.AQ	3		2	<60% ferrite (rule of thumb N≥0.10%)	Z	forged/rolled/cold drawn	AQ		260 HB	2400	0.21
M3.2.C.AQ	3		2		C	cast	AQ		260 HB	2200	0.25

Identification of material group



The microstructure that a stainless steel attains depends primarily on its chemical composition, in which the main alloy components Chromium (Cr), and Nickel (Ni) are most important, see diagram. In reality, the variation can be wide, due to the influence of other alloy components that strive to stabilize either the austenite or the ferrite. The structure can also be modified by heat treatment or, in some cases, by cold working. Precipitation hardening ferritic or austenitic stainless steel have an increased tensile strength.

Austenitic steels

Austenitic-ferritic (duplex) steels

Ferritic chromium steels

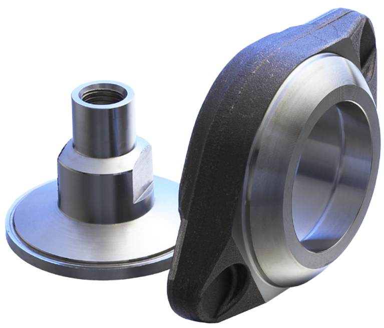
Martensitic chromium steels

Ferritic and martensitic stainless steel – P5.0-5.1

Definition

From a machinability point of view, ferritic and martensitic stainless steels are classified as ISO P. Normal Cr-content is 12-18%. Only small additions of other alloying elements are present.

Martensitic stainless steels have relatively high carbon content, which make them hardenable. Ferritic steels have magnetic properties. Weldability is low for both ferritic and martensitic and medium to low resistance against corrosion, which increases with a larger Cr-content.



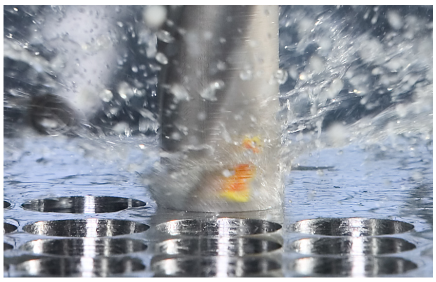
Common components

Often used in applications that place a limited demand on corrosion resistance. The ferritic material is relatively low cost due to the limited Ni-content. Examples of applications are: shafts for pumps, turbines steam and water turbines, nuts, bolts, hot water heaters, pulp and food processing industries due to lower requirements on corrosion resistance.

Martensitic steels can be hardened and are used for the edges in cutlery steel, razor blades, surgical instruments, etc.

Machinability

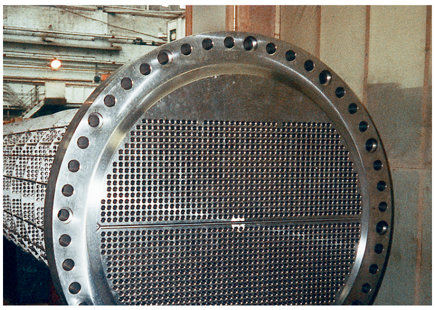
In general, the machinability is good and very similar to low alloyed steels, therefore it is classified as an ISO P material. High carbon content (>0.2%) enables hardening of the material. Machining will create flank and crater wear with some built-up edge. ISO P grades and geometries work well.



Austenitic and super-austenitic stainless steel – M1.0-2.0

Definition

Austenitic steels are the primary group of stainless steels; the most common composition is 18% Cr and 8% Ni (e.g.18/8-steels, type 304). A steel with better resistance to corrosion is created by adding 2-3% molybdenum, which is often called “acid-proof steel”: (type 316). The MC group also includes super-austenitic stainless steels with a Ni-content over 20%. The austenitic precipitation hardening steels (PH) -steels have an austenitic structure in the solution heat treated condition and a Cr-content of >16% and a Ni-content of >7%, with approx. 1% Aluminium (Al). A typical precipitation hardened steel is 17/7 PH steel.



Common components

Used in components where good resistance against corrosion is required. Very good weldability and good properties at high temperatures. Applications include: the chemical, pulp and food processing industries, exhaust manifolds for airplanes. Good mechanical properties are improved by cold working.

➤ Austenitic and super-austenitic stainless steel – M1.0-2.0 – continued

Machinability

Work hardening produces hard surfaces and hard chips , which in turn lead to notch wear. It also creates adhesion and produces built-up edge (BUE). It has a relative machinability of 60%. The hardening condition can tear coating and substrate material from the edge, resulting in chipping and bad surface finish. Austenite produces tough, long, continuous chips, which are difficult to break. Adding S improves machinability, but results in lowered resistance to corrosion.

Use sharp edges with a positive geometry. Cut under the work hardened layer. Keep cutting depth constant. Generates a lot of heat when machined.

Duplex stainless steel – M 3.41-3.42

Definition

By adding Ni to a ferritic stainless Cr-based steel, a mixed base structure/matrix will be formed, containing both ferrite and austenite. This is called a duplex stainless steel. Duplex materials have a high tensile strength and maintain a very high corrosion resistance. Designations, such as super-duplex and hyper-duplex indicates higher content of alloying elements and even better corrosion resistance. A Cr-content between 18 and 28%, and a Ni-content between 4 and 7% are common in the duplex steels and will produce an ferritic share of 25-80%. The ferrite and austenite phase are usually present at room temperature at 50-50% respectively. Typical SANDVIK brand names are SAF 2205, SAF 2507.

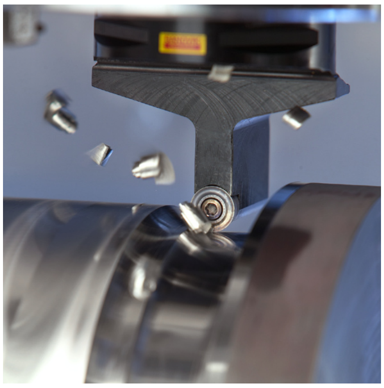
Common components

Used in machines for the chemical, food, construction, medical, cellulose and papermaking industries and in processes that include acids or chlorine. Often used for equipment related to off-shore oil and gas industry.

Machinability

Relative machinability is generally poor, 30%, due to high yield point and high tensile strength. Higher content of ferrite, above 60%, improves machinability. Machining produces strong chips, which can cause chip hammering, and create high cutting forces. Generates a lot of heat during cutting, which can cause plastic deformation and severe crater wear.

Small entering angles are preferable to avoid notch wear and burr formation. Stabilty in tool clamping and workpiece fixing is essential.

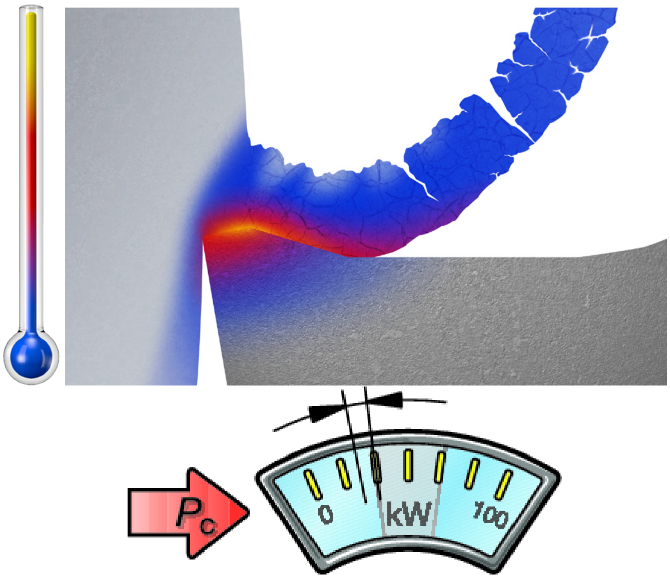


K Cast iron

Definition

There are 5 main types of cast iron:
- Grey Cast Iron (GCI),
- Malleable Cast Iron (MCI),
- Nodular Cast Iron (NCI),
- Compacted Graphite Iron (CGI)
- Austempered Ductile Iron (ADI).

Cast iron is a Fe-C composition with a relatively high percentage of Si (1-3%). Carbon content is over 2%, which is the maximum solubility of C in the austenitic phase. Cr (Chromium), Mo (Molybdenum) and V (Vanadium) form carbides, which increase strength and hardness, but lower machinability.



Machinability in general

- Short-chipping material with good chip control in most conditions. Specific cutting force: 790 – 1350 N/mm².
- Machining at higher speeds, especially in cast irons with sand inclusions, creates abrasive wear.
- NCI, CGI and ADI require extra attention due to the different mechanical properties and the presence of graphite in the matrix, compared to normal GCI.
- Cast irons are often machined with negative type of inserts, as these provide strong edges and safe applications.
- The carbide substrates should be hard and the coatings should be of thick aluminium oxide types for good abrasive wear resistance.
- Cast irons are traditionally machined dry, but can also be used in wet conditions, mainly to keep the contamination of dust from carbon and iron to a minimum. There are also grades available that suit applications with coolant supply.

Fore more information on machining of ISO K materials, see General turning page A 28, Milling page D 36 and Drilling page E 16.

Influence of hardness

- The influence of hardness related to machinability for cast irons follows the same rules as for any other material.
- E.g, ADI (austempered ductile iron) and CGI (compacted graphite iron) as well as NCI (nodular cast iron) have hardnesses up to 300-400 HB. MCI and GCI average 200-250 HB.
- White cast iron can achieve a hardness over 500 HB at rapid cooling rates where the carbon reacts with the iron to form a carbide Fe3C (cementite), instead of being present as free carbon. White cast irons are very abrasive and difficult to machine.

A General turning
B Parting and grooving
C Threading
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H Materials
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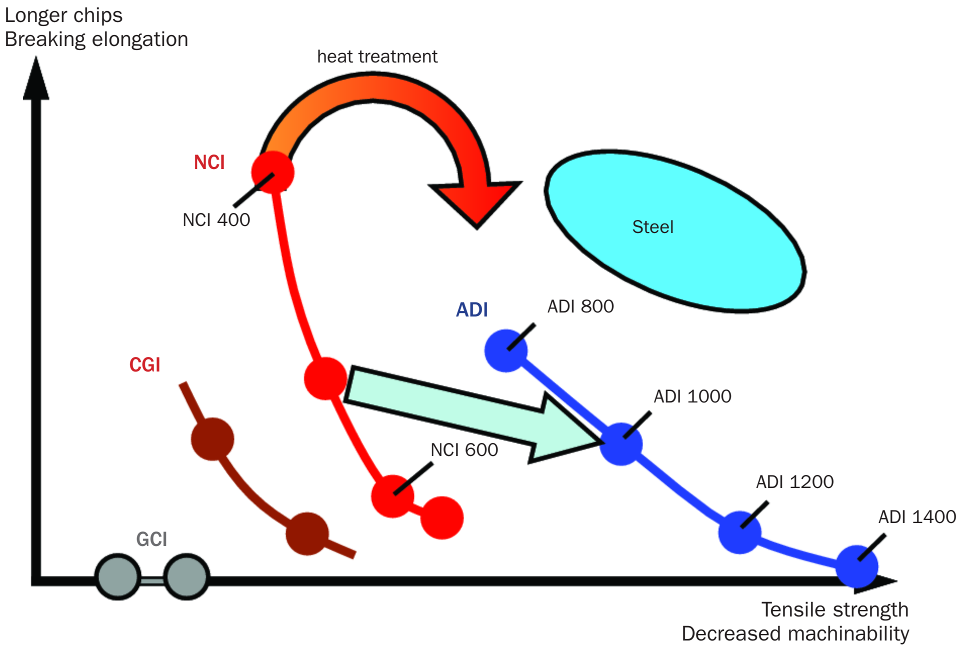
MC codes for cast iron

From a machinability point of view, cast irons are classified into malleable, grey, nodular, compacted graphite iron (CGI) and austempered ductile iron (ADI) types. Some of the higher hardnesses can be found in nodular cast irons and the ADI's.

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom	Specific cutting force, k_{c1} (N/mm²)	m_c
K1.1.C.NS	1	malleable	1	low tensile	C	cast	NS	not specified	200 HB	780	0.28
K1.2.C.NS	1		2	high tensile	C		NS		260 HB	1020	0.28
K2.1.C.UT	2	grey	1	low tensile	C	cast	UT	untreated	180 HB	900	0.28
K2.2.C.UT	2		2	high tensile	C		UT		245 HB	1100	0.28
K2.3.C.UT	2		3	austenitic	C		UT		175 HB	1300	0.28
K3.1.C.UT	3	nodular	1	ferritic	C	cast	UT	untreated	155 HB	870	0.28
K3.2.C.UT	3		2	ferritic/perlitic	C		UT		215 HB	1200	0.28
K3.3.C.UT	3		3	perlitic	C		UT		265 HB	1440	0.28
K3.4.C.UT	3		4	martensitic	C		UT		330 HB	1650	0.28
K3.5.C.UT	3		5	austenitic	C		UT		190 HB		
K4.1.C.UT	4	CGI	1	low tensile (perlite <90%)	C	cast	UT	untreated	160 HB	680	0.43
K4.2.C.UT	4		2	high tensile (perlite ≥90%)	C		UT		230 HB	750	0.41
K5.1.C.NS	5	ADI	1	low tensile	C	cast	NS	not specified	300 HB		
K5.2.C.NS	5		2	high tensile	C		NS		400 HB		
K5.3.C.NS	5		3	extra high tensile	C		NS		460 HB		



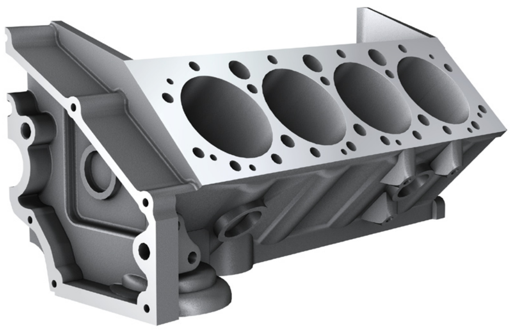
The austempering heat treatment converts ductile iron, (NCI), into austempered ductile iron (ADI).

Malleable Cast Iron (MCI) K 1.1-1.2 and Grey Cast Iron (GCI) K 2.1-2.3

Definition

Malleable cast iron is produced from a close to white iron matrix, which is then heat treated in two steps, producing a ferrite+perlite+tempered carbon structure, leading to irregular graphite grains, when compared to the more fracture-inducing lamellar structure in the grey cast iron. This means that the malleable material is less sensitive to cracking, and its values for rupture strength and elongation are higher.

Grey cast iron has the graphite in typical flake form, and the main characteristics are: low impact strength (brittle behavior); good thermal conductivity, less heat when engine operates and low heat in cutting process; good dampening properties, absorbs the vibrations in the engine.



Common components

Components manufactured from MCI material include: axle bearings, track wheels, pipe fittings and high strength gears.

Components manufactured form GCI material include: frying pans, engine blocks, cylinders for compressors, gears and gear box cases.

Machinability

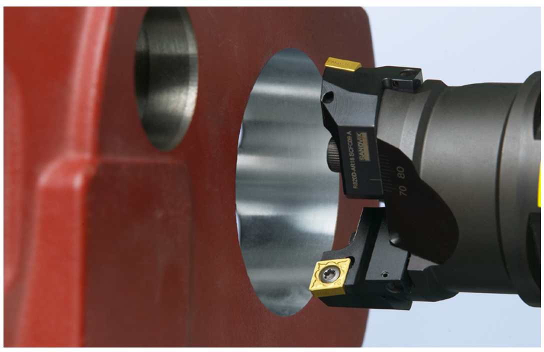
Malleable cast iron has a higher tensile strength compared to GCI, and resembles NCI in its machinability, but both have generally excellent machining properties. In general cast iron with a perlitic struture increases the abrasive wear, while ferritic structures increase the adhesive wear.

Grey cast iron has low impact strength, generates low cutting forces and the machinability is very good. Wear is created in the cutting process only by abrasion; there is no chemical wear. Grey cast iron is often alloyed with Cr in order to improve the mechanical properties. The higher strength will then result in decreased machinability.

Nodular Cast Iron (NCI) K 3.1-3.5

Definition

Nodular cast iron has spherically shaped graphite, and the main characteristics are good stiffness (Young’s module); good impact strength = tough material, not brittle; good tensile strength; bad damping properties, does not absorb the vibrations in the engine; bad thermal conductivity, higher heat in cutting process. In comparison GCI, the graphite in NCI appears in the form of nodules, which contributes to higher tensile properties and toughness, when compared to GCI.



Nodular Cast Iron (NCI) K 3.1-3.5 – continued

Common components

Hubs, tubing, rollers, exhaust manifolds, crankshafts, differential housings, bearing caps, exhaust manifolds, bedplates, turbo charger housings, clutch plates and fly wheels.

Turbo-charger housings and exhaust manifolds are often made of SiMo alloyed cast iron, which is more resistant to heat.

Machinability

Nodular cast iron has a strong tendency to form built-up edge. This tendency is stronger for the softer NCI materials with higher ferritic contents. When machining components with high ferritic contents and with interrupted cuts, adhesion wear is often the dominating wear mechanism. This can cause problems with flaking of the coating.

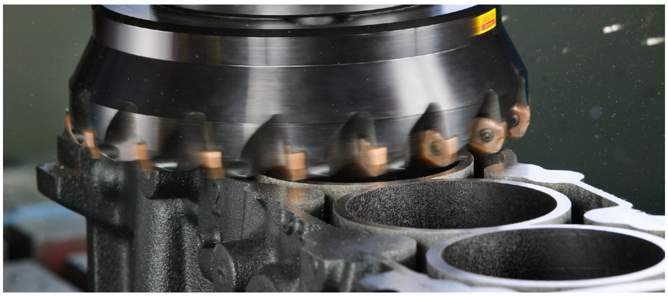
The adhesion problem is less pronounced with harder NCI-materials that have a higher perlitic content. Here abrasive wear and/or plastic deformation are more likely to occur.

Compacted Graphite Iron (CGI) K 4.1-4.2

Definition

CGI is a material that can meet both the increasing demands for strength and weight reduction and still retain reasonable machinability. The thermal and damping characteristics of CGI are between NCI and GCI. The resistant to metal fatigue is twice that of grey iron. The graphite particles in CGI are elongated and randomly oriented, as in grey cast iron, but they are shorter, thicker and have rounded edges. The coral-like morphology in CGI, together with the rounded edges and irregular bumpy surfaces of the graphite particles, provides strong adhesion between the graphite and the iron matrix. This is why the mechanical properties are so improved in CGI, relative to grey cast iron. CGI with a perlitic content below 90% is most common.

➤ Compacted Graphite Iron (CGI) K 4.1-4.2 – continued



Common components

CGI is well suited for engine manufacturing, where lighter and stronger materials are needed which can absorb more power. The engine block weight alone can be reduced by approx. 20 percent compared with one made from GCI. Other examples are cylinder heads and disc brakes.

Machinability

From a machinability point of view compacted graphite iron is between grey and nodular cast iron. With two to three times the tensile strength of grey cast iron and lower thermal conductivity machining of CGI generates higher cutting forces and more heat in the cutting zone. An increased content of titanium in the CGI-material influences tool life negatively.

The most common machining operations are face milling and cylinderboring. Instead of cylinderboring a change of method to circular milling can improve both the tool life and the productivity.

Austempered Ductile Iron (ADI) K 5.1- 5.3

Definition

Austempered ductile iron forms a family of heat-treated cast irons. The austempering heat treatment converts ductile iron to austempered ductile iron (ADI), whose characteristics include excellent strength, toughness, and fatigue characteristics. ADI is stronger per unit weight than aluminium and as wear resistant as steel. Tensile and yield strength values are twice those of standard ductile iron. Fatigue strength is 50% higher, and it can be enhanced by shot peening or fillet rolling.

Common components

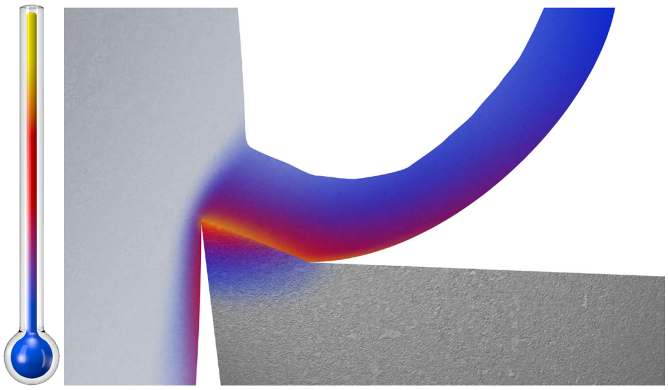
ADI castings are increasingly displacing steel forgings and castings, welded fabrications, carburised steel, and aluminium, due to its superior performance. Its dominant uses are in the automotive industry, where it is used for suspension and transmission parts, etc. It is also used in the power/energy and the mining and construction sectors.

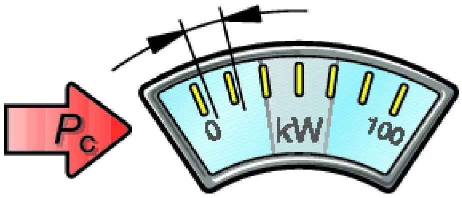
Machinability

A 40-50% reduction in tool-life compared to NCI can be expected. Tensile strength and ductility of ADI are near to steel, but the chip formation process classifies ADI as a ductile iron (segmented chip formation).
The micro hardness of ADI is higher, when compared to steels of comparable hardness. Higher ADI grades contain hard particles in the micro-structure. High thermal and mechanical loads, due to high strength and ductility, will concentrate wear near the cutting edge, due to the segmented chip formation process, and wear on the top rake. Hardening during chip formation results in high dynamic cutting forces. The cutting edge temperature is a strong factor for determining wear.

N Non-ferrous materials

Definition:
- This group contains non-ferrous, soft metals with hardnesses under 130 HB, except for high strength bronzes (>225HB)
- Aluminium (Al) alloys comprising less than 12-13% silicon (Si) represent the largest part
- MMC: Metal Matrix Composite: Al + SiC (20-30%)
- Magnesium based alloys
- Copper, electrolytic copper with 99.95% Cu
- Bronze: Copper with Tin (Sn) (10-14%) and/or aluminium (3-10%)
- Brass: Copper (60-85%) with Zinc (Zn) (40-15%)





Machinability of aluminium
- Long-chipping material
- Relatively easy chip control, if alloyed
- Pure Al is sticky and requires sharp cutting edges and high v_c
- Specific cutting force: 350–700 N/mm²
- Cutting forces, and thus the power required to machine them, are low.
- The material can be machined with fine-grained, uncoated carbide grades when the Si-content is below 7-8%, and with PCD-tipped grades for Aluminium with higher Si-content.
- Over eutectic Al with higher Si-content > 12% is very abrasive.

Common components

Engine block, cylinder head, transmission housings, casings, aerospace frame components.

Fore more information on machining of ISO N materials, see General turning page A 39, Parting and grooving page B 9, Milling page D 38 and Drilling page E 17.

MC codes for N-materials

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom	Specific cutting force, k_{c1} (N/mm²)	m_c
N1.1.Z.UT	1	aluminium based alloys	1	commercially pure	Z	cast	UT	untreated	30 HB	350	0.25
N1.2.Z.UT	1		2	AlSi alloys, Si ≤1%	Z		UT		60 HB	400	0.25
N1.2.Z.AG	1		2		Z		AG	aged	100 HB	650	0.25
N1.2.S.UT	1		2		S	sintered	UT	untreated	75 HB	410	0.25
N1.2.C.NS	1		2		C	cast	NS	not specified	80 HB	410	0.25
N1.3.C.UT	1		3	AlSi cast alloys, Si ≤1% and <13%	C		UT	untreated	75 HB	600	0.25
N1.3.C.AG	1		3		C		AG	aged	90 HB	700	0.25
N1.4.C.NS	1		4	AlSi cast alloys, Si ≥13%	C		NS	not specified	130 HB	700	0.25
N2.0.C.UT	2	magnesium based alloys	0	main group	C	cast	UT	untreated	70 HB		
N3.1.U.UT	3	copper based alloys	1	non-leaded copper alloys (incl. electrolytic copper)	U	not specified	UT	untreated	100 HB	1350	0.25
N3.2C.UT	3		2	leaded brass & bronzes (Pb ≤1%)	C	cast	UT		90 HB	550	0.25
N3.3.S.UT	3		2		S	sintered	UT		35 HB		
N3.3.U.UT	3		3	free cutting copper based alloys (Pb >1%)	U	not specified	UT		110 HB	550	0.25
N3.4.C.UT	3		4	high strength bronzes (>225HB)	C	cast	UT		300 HB		
N4.0.C.UT	4	zinc based alloys	0	main group	C	cast	UT	untreated	70 HB		

A General turning
B Parting and grooving
C Threading
D Milling
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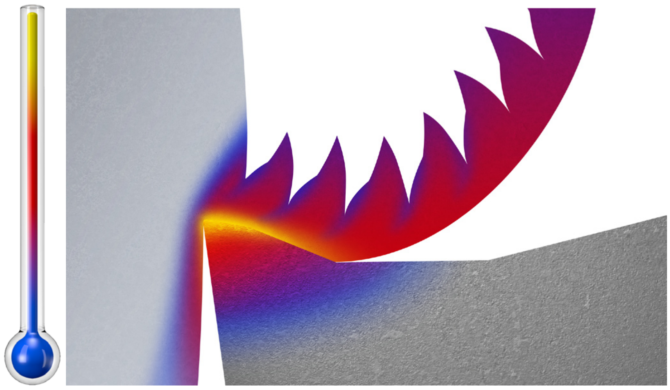
S Heat Resistant Super Alloys (HRSA) and Titanium

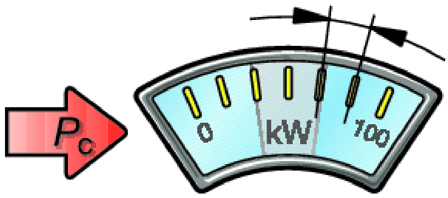
Definition

- The ISO S group can be divided into heat resistant super alloys (HRSA) and titanium.
- HRSA materials can be split into three groups: Nickel-based, iron-based and cobalt-based alloys.
- Condition: Annealed, solution heat treated, aged, rolled, forged, cast
- Properties: Increased alloy content (Co more so than Ni), results in better resistance to heat, increased tensile strength and higher corrosive resistance

Machinability in general

- The physical properties and machining behavior of each varies considerably, due both to the chemical nature of the alloy and the precise metallurgical processing it receives during manufacture.
- Annealing and aging are particularly influential on the subsequent machining properties.
- Difficult chip control (segmented chips)
- Specific cutting force: 2400–3100 N/mm² for HRSA and 1300–1400 N/mm² for titanium
- Cutting forces and power required are quite high



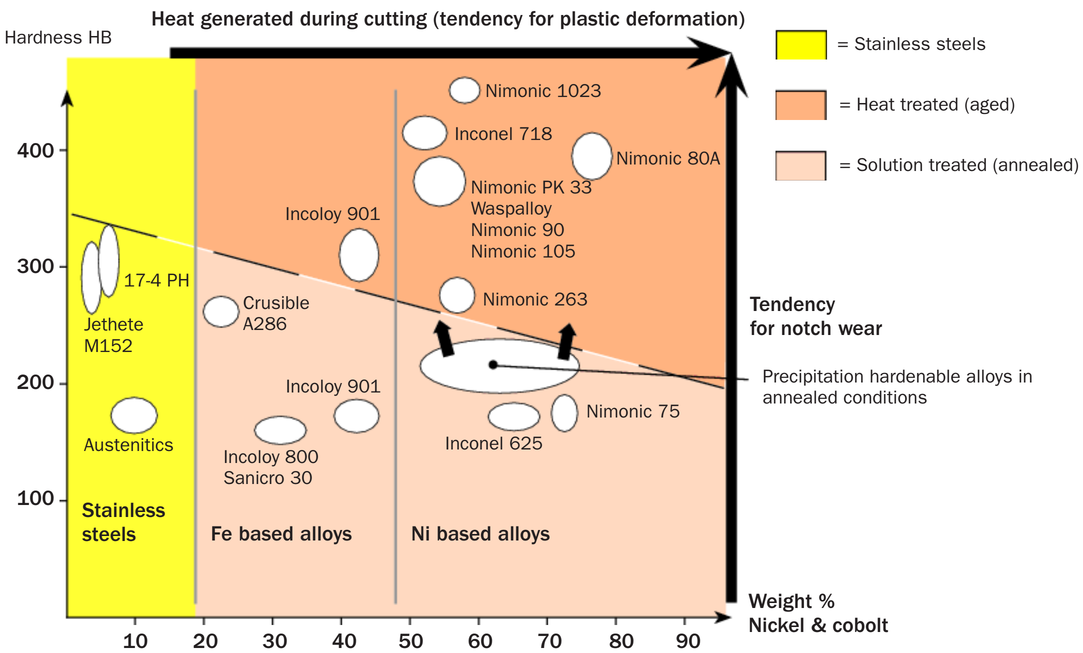


Aging

In order to achieve higher strength, the heat-resistant alloys can be “precipitation hardened”.

By treating the material at elevated temperatures, i.e. aging treatment, small intermetallic particles are precipitated in the alloy. These particles will hinder movement in the crystal structure and, as a results the material will be more difficult to deform.

Fore more information on machining of ISO S materials, see General turning page A 30, Parting and grooving page B 10, Milling page D 39 and Drilling page E 17.



MC codes for S-materials

From a machinability point of view, HRSA steels are classified into iron-, nickel- and cobalt-based materials. Titanium is divided into commercially pure, alpha-alloys and near alpha-alloys, alpha/beta alloys and beta-alloys.

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom		Specific cutting force, k_{c1} (N/mm²)	m_c
S1.0.U.AN	1	iron-based alloys	1	main group	U	not specified	AN	annealed	200	HB	2400	0.25
S1.0.U.AG	1		2		U		AG	aged	280	HB	2500	0.25
S2.0.Z.AN	2	nickel based alloys	0	main group	Z	forged/rolled/cold drawn	AN	annealed	250	HB	2650	0.25
S2.0.Z.AG	2		0		Z		AG	aged	350	HB	2900	0.25
S2.0.Z.UT	2		0		Z		UT	untreated	275	HB	2750	0.25
S2.0.C.NS	2		0		C	cast	NS	not specified	320	HB	3000	0.25
S3.0.Z.AN	3	cobalt based alloys	0	main group	Z	forged/rolled/cold drawn	AN	annealed	200	HB	2700	0.25
S3.0.Z.AG	3		0		Z		AG	aged	300	HB	3000	0.25
S3.0.C.NS	3		0		C	cast	NS	not specified	320	HB	3100	0.25
S4.1.Z.UT	4	titanium based alloys	1	commercially pure (>99.5% Ti)	Z	forged/rolled/cold drawn	UT	untreated	200	HB	1300	0.23
S4.2.Z.AN	4		2	alpha- and near alpha alloys	Z		AN	annealed	320	HB	1400	
S4.3.Z.AN	4		3	alpha/beta alloys	Z		AN		330	HB	1400	
S4.3.Z.AG	4		3		Z		AG	aged	375	HB	1400	
S4.4.Z.AN	4		4	beta alloys	Z		AN	annealed	330	HB	1400	
S4.4.Z.AG	4		4		Z		AG	aged	410	HB	1400	
S5.0.U.NS	3	tungsten based	0	main group	U	not specified	NS	not specified	120	HB		
S6.0.U.NS	3	molybdenum based	0	main group	U	not specified	NS	not specified	200	HB		

HRSA materials – S 1.0-3.0

Definition

High corrosion-resistant materials which retain their hardness and strength at higher temperatures. The material is used at up to 1000°C and is hardened through an aging process.

- **The nickel based** version is the most widely used - over 50% of the weight of an airplane engine. Precipitation hardened materials include: Inconel 718, 706 Waspalloy, Udimet 720. Solution strengthened (not hardenable) include: Inconel 625.
- **Iron based** material evolves from austenitic stainless steels and has the poorest hot strength properties: Inconel 909 Greek Ascolloy and A286.
- **Cobalt based** materials have the best hot temperature performance and corrosion resistance, and are predominantly used in the medical industry: Haynes 25 (Co49Cr20W15Ni10), Stellite 21, 31.
- **Main alloying elements** in HRSA materials.
  Ni: Stabilizes metal structure and material properties at high temperatures.
  Co, Mo, W: Increase strength at elevated temperatures
  Cr, Al, Si: Improve resistance to oxidation and high temperature corrosion
  C: Increases creep strength

Common components

Aerospace engine and power gas turbines in the combustion and turbine sections. Oil and gas marine applications. Medical joint implants. High corrosion resistant applications.

➤ HRSA materials – S 1.0-3.0 – continued

Machinability

Machinability of HRSA-materials increases in difficulty according to the following sequence: iron based materials, nickel based materials and cobalt based materials. All the materials have high strength at high temperatures and produce segmented chips during cutting which create high and dynamic cutting, forces.

Poor heat conductivity and high hardness generate high temperatures during machining. The high strength, work hardening and adhesion hardening properties create notch wear at maximum depth of cut and an extremely abrasive environment for the cutting edge.

Carbide grades should have good edge toughness and good adhesion of the coating to the substrate to provide good resistance to plastic deformation. In general, use inserts with a large entering angle (round inserts) and select a positive insert geometry. In turning and milling, ceramic grades can be used, depending on the application.

Titanium– S 4.1-4.4

Definition

Titanium alloys can be split into four classes, depending on the structures and alloying elements present.

- Untreated, commercially pure titanium.
- Alpha alloys – with additions of Al, O and/or N.
- Beta alloys – additions of Mb, Fe, V, Cr and/or Mn.
- Mixed α+ß alloys, in which a mixture of both classes is present.

The mixed $\alpha+\beta$ alloys, with type Ti-6Al-4V, account for the majority of titanium alloys currently in use, primarily in the aerospace sector, but also in general purpose applications. Titanium has a high strength to weight ratio, with excellent corrosion resistance at 60% the density of steel. This enables the design of thinner walls.

Common components

Titanium can be used under very harsh environments, which could cause considerable corrosion attacks on most other construction materials. This is due to the titanium oxide, TiO_2, which is very resistant and covers the surface in a layer which is approx. 0.01 mm thick. If the oxide layer is damaged and there is oxygen available, the titanium rebuilds the oxide immediately. Suitable for heat exchangers, de-salting equipment, jet engine parts, landing gears, structural parts in aerospace frame.

Machinability

The machinability of titanium alloys is poor, compared to both general steels and stainless steels, which places special demands on the cutting tools. Titanium has poor thermal conductivity; strength is retained at high temperatures, which generates high cutting forces and heat at the cutting edge. Highly-sheared, thin chips, with a tendency for galling create a narrow contact area on the rake face, generating concentrated cutting forces close to the cutting edge. A cutting speed that is too high produces a chemical reaction between the chip and the cutting tool material, which can result in sudden insert chippings/breakages. Cutting tool materials should have good hot hardness, low cobalt content, and not react with the titanium. Fine-grained, uncoated carbide is usually used. Choose a positive/open geometry with good edge toughness.

A General turning
B Parting and grooving
C Threading
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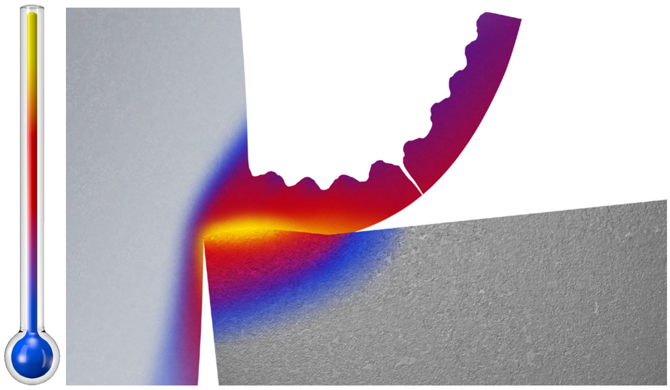
H Hardened steel

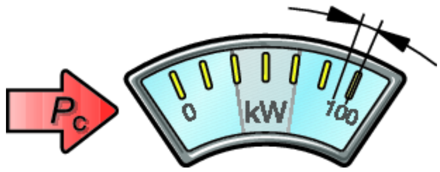
Definition

- This group of materials contains hardened and tempered steels with hardnesses >45 – 68 HRC.
- Common steels include carburizing steel (~60 HRc), ball bearing steel (~60 HRc) and tool steel (~68 HRc). Hard types of cast irons include white cast iron (~50 HRc) and ADI/Kymenite (~40 HRc). Construction steel (40–45 HRc), Mn-steel and different types of hardcoatings, i.e. stellite, P/M steel and cemented carbide also belong to this group.
- Typically hard part turning fall within the range of 55–68 HRC.



Machinability

- Hardened steel is the smallest group from a machining point of view and finishing is the most common machining operation. Specific cutting force: 2550–4870 N/mm². The operation usually produces fair chip control. Cutting forces and power requirements are quite high.
- The cutting tool material needs to have good resistance to plastic deformation (hot hardness), chemical stability (at high temperatures), mechanical strength and resistance to abrasive wear. CBN has these characteristics and allows turning instead of grinding.
- Mixed or whisker reinforced ceramic are also used in turning, when the workpiece has moderate surface finish demands and the hardness is too high for carbide.
- Cemented carbide dominates in milling and drilling applications and is used up to approx. 60 HRc.



Common components

Typical components include: transmission shafts, gear box housings, steering pinions, stamping dies.

Fore more information on machining of ISO H materials, see General turning page A 40, Parting and grooving page B 9, Milling page D 41 and Drilling page E 17.

MC codes for Hardened steel

MC code	Material group		Material sub-group		Manufacturing process		Heat treatment		nom		Specific cutting force, k_{c1} (N/mm²)	m_c
H1.1.Z.HA	1	steels (extra hard)	1	Hardness level 50	Z	forged/rolled/cold drawn	HA	hardened (+tempered)	50	HRc	3090	0.25
H1.2.Z.HA	1		2	Hardness level 55	Z		HA		55	HRc	3690	0.25
H1.3.Z.HA	1		3	Hardness level 60	Z		HA		60	HRc	4330	0.25
H1.4.Z.HA	1		4	Hardness level 63	Z		HA		63	HRc	4750	0.25
H2.0.C.UT	2	chilled cast iron	0	main group	C	cast	UT	untreated	55	HRc	3450	0.28
H3.0.C.UT	3	stellites	0	main group	C	cast	UT	not specified	40	HRc		
H4.0.S.AN	4	Ferro-TiC	0	main group	S	sintered	AN	annealed	67	HRc		

A General turning
B Parting and grooving
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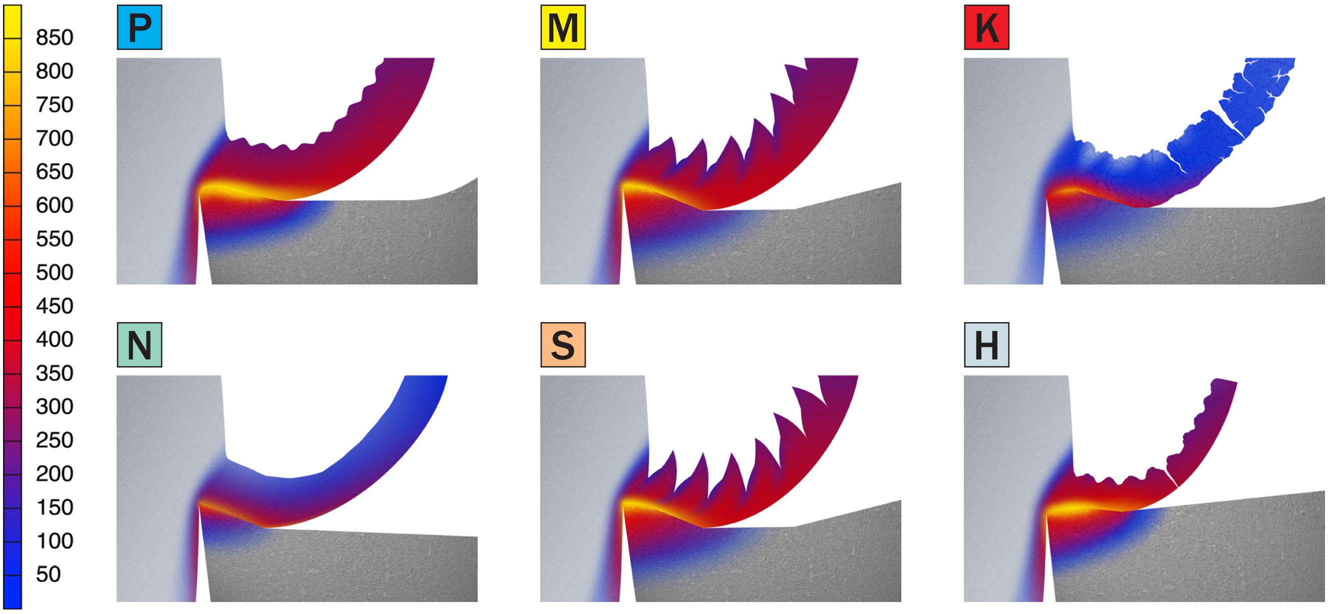
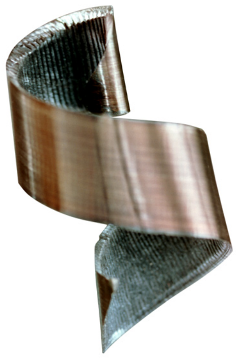
Machinability – definition



Cross section of cemented carbide insert cutting in steel. Temperature in degrees Celsius.

There are usually three main factors that must be identified in order to determine a material's machinability, that is, its ability to be machined.

1. Classification of the workpiece material from a metallurgical/mechanical point of view.
2. The cutting edge geometry to be used, on the micro and macro levels.
3. The cutting tool material (grade) with its proper constituents, e.g. coated cemented carbide, ceramic, CBN, or PCD, etc.



The selections above will have the greatest influence on the machinability of the material at hand. Other factors involved include: cutting data, cutting forces, heat treatment of the material, surface skin, metallurgical inclusions, tool holding, and general machining conditions, etc.

Machinability has no direct definition, like grades or numbers. In a broad sense it includes the ability of the workpiece material to be machined, the wear it creates on the cutting edge and the chip formation that can be obtained. In these respects, a low alloyed carbon steel is easier to cut, compared to the more demanding austenitic stainless steels. The low alloyed steel is considered to have a better machinability compared to the stainless steel. The concept "good machinability", usually means undisturbed cutting action and a fair tool life. Most evaluations of the machinability for a certain material are made using practical tests, and the results are determined in relation to another test in another type of material under approximately the same conditions. In these tests, other factors, such as micro-structure, smearing tendency, machine tool, stability, noise, tool-life, etc. will be taken into consideration.

Material cross reference list

ISO	MC	CMC	Country Europe	Germany	Great Britain		Sweden	USA	France	Italy	Spain	Japan
			Standard									
			DIN EN	W.-nr	BS	EN	SS	AISI/SAE/ASTM	AFNOR	UNI	UNE	JIS
P	**Unalloyed steel**											
Steel	P1.1.Z.AN	01.1	S235JR G2	1.0038	4360 40 C		1311	A570.36	E 24-2 Ne			STKM 12A;C
	P1.1.Z.AN	01.1	S235J2 G3	1.0116	4360 40 B		1312	A573-81 65	E 24-U	Fe37-3		
	P1.1.Z.AN	01.1	C15	1.0401	080M15	-	1350	1015	CC12	C15C16	F.111	-
	P1.1.Z.AN	01.1	C22	1.0402	050A20	2C/2D	1450	1020	CC20	C20C21	F.112	-
	P1.1.Z.AN	01.1	C15E	1.1141	080M15	32C	1370	1015	XC12	C16	C15K	S15C
	P1.1.Z.AN	01.1	C25E	1.1158	-	-	–	1025	-	-	-	S25C
	P1.1.Z.AN	01.1	S380N	1.8900	4360 55 E		2145	A572-60	-	FeE390KG		
	P1.1.Z.AN	01.1	17MnV7	1.0870	4360 55 E		2142	A572-60	NFA 35-501 E 36	-	-	
	P1.1.Z.AN	02.1	55Si7	1.0904	250A53	45	2085	9255	55S7	55Si8	56Si7	-
	P1.1.Z.AN	02.2	-	-	-	-	2090	9255	55S7	-	-	-
	P1.2.Z.AN	01.2	C35	1.0501	060A35	-	1550	1035	CC35	C35	F.113	-
	P1.2.Z.AN	01.2	C45	1.0503	080M46	-	1650	1045	CC45	C45	F.114	-
	P1.2.Z.AN	01.2	40Mn4	1.1157	150M36	15	-	1039	35M5	-	-	-
	P1.2.Z.AN	01.2	36MN5	1.1167	–	–	2120	1335	40M5	–	36Mn5	SMn438(H)
	P1.2.Z.AN	01.2	28Mn6	1.1170	150M28	14A	-	1330	20M5	C28Mn	-	SCMn1
	P1.2.Z.AN	01.2	C35G	1.1183	060A35	-	1572	1035	XC38TS	C36	-	S35C
	P1.2.Z.AN	01.2	C45E	1.1191	080M46	-	1672	1045	XC42	C45	C45K	S45C
	P1.2.Z.AN	01.2	C53G	1.1213	060A52	-	1674	1050	XC48TS	C53	-	S50C
	P1.2.Z.AN	01.3	C55	1.0535	070M55	-	1655	1055	-	C55	-	-
	P1.2.Z.AN	01.3	C55E	1.1203	070M55	-	-	1055	XC55	C50	C55K	S55C
	P1.2.Z.AN	02.1	S275J2G3	1.0144	4360 43C		1412	A573-81	E 28-3	-	-	SM 400A;B;C
	P1.2.Z.AN	02.1	S355J2G3+C2	1.0570	4360 50B		2132	-	E36-3	Fe52BFN/Fe52CFN	-	SM490A;B;C;YA;YB
	P1.2.Z.AN	02.1	S355J2G3	1.0841	150 M 19		2172	5120	20 MC 5	Fe52	F-431	
	P1.3.Z.AN	01.3	C60E	1.0601	080A62	43D	-	1060	CC55	C60	-	-
	P1.3.Z.AN	01.3	C60E	1.1221	080A62	43D	1678	1060	XC60	C60	-	S58C
	P1.3.Z.AN	01.4	C101E	1.1274	060 A 96		1870	1095	XC 100	-	F-5117	
	P1.3.Z.AN	01.4	C101u	1.1545	BW 1A		1880	W 1	Y105	C36KU	F-5118	SK 3
	P1.3.Z.AN	01.4	C105W1		BW2	-	2900	W210	Y120	C120KU	F.515	SUP4
	P1.3.Z.AN	02.1	S340 MGC	1.0961	-	-	-	9262	60SC7	60SiCr8	60SiCr8	-
	P1.4.Z.AN	01.1	11SMn30	1.0715	230M07	-	1912	1213	S250	CF9SMn28	11SMn28	SUM22
	P1.4.Z.AN	01.1	11SMnPb30	1.0718	-	-	1914	12L13	S250Pb	CF9SMnPb28	11SMnPb28	SUM22L
	P1.4.Z.AN	01.1	10SPb20	1.0722	-	-	-	-	10PbF2	CF10SPb20	10SPb20	-
	P1.4.Z.AN	01.1	11SMn37	1.0736	240M07	1B	-	1215	S 300	CF9SMn36	12SMn35	-
	P1.4.Z.AN	01.1	11SMnPb37	1.0737	-	-	1926	12L14	S300Pb	CF9SMnPb36	12SMnP35	-
	P1.4.Z.AN	01.2	35S20	1.0726	212M36	8M	1957	1140	35MF4	-	F210G	-
	P1.5.C.UT	01.1	GC16E	1.1142	030A04	1A	1325	1115	-	-	-	-
	Low-alloy steel											
	P2.1.Z.AN	02.1	16Mo3	1.5415	1501-240	-	2912	A204Gr.A	15D3	16Mo3KW	16Mo3	-
	P2.1.Z.AN	02.1	14Ni6	1.5622	-	-	-	A350LF5	16N6	14Ni6	15Ni6	-
	P2.1.Z.AN	02.1	21NiCrMo2	1.6523	805M20	362	2506	8620	20NCD2	20NiCrMo2	20NiCrMo2	SNCM220(H)
	P2.1.Z.AN	02.1	17CrNiMo6	1.6587	820A16	-	-	-	18NCD6	-	14NiCrMo13	-
	P2.1.Z.AN	02.1	15Cr3	1.7015	523M15	-	-	5015	12C3	-	-	SCr415(H)
	P2.1.Z.AN	02.1	55Cr3	1.7176	527A60	48	-	5155	55C3	-	-	SUP9(A)
	P2.1.Z.AN	02.1	15CrMo5	1.7262	-	-	2216	-	12CD4	-	12CrMo4	SCM415(H)
	P2.1.Z.AN	02.1	13CrMo4-5	1.7335	1501-620Gr27	-	-	A182 F11;F12	15CD3.5 15CD4.5	14CrMo4 5	14CrMo45	-
	P2.1.Z.AN	02.1	10CrMo9 10	1.7380	1501-622 Gr.31;45	-	2218	A182 F.22	12CD9, 10	12CrMo9, 10	TU.H	-
	P2.1.Z.AN	02.1	14MoV6 3	1.7715	1503-660-440	-	-	-	-	-	13MoCrV6	-
	P2.1.Z.AN	02.1	50CoMo4	1.7228	823M30	33	2512	-	-	653M31	-	-
	P2.1.Z.AN	02.2	14NiCr10	1.5732	-	-	-	3415	14NC11	16NiCr11	15NiCr11	SNC415(H)
	P2.1.Z.AN	02.2	14NiCr14	1.5752	655M13; A12	36A	-	3415;3310	12NC15	-	-	SNC815(H)
	P2.1.Z.AN	02.1/02.2	16MnCr5	1.7131	(527M20)	-	2511	5115	16MC5	16MnCr5	16MnCr5	-
	P2.1.Z.AN	02.1/02.2	34CrMo4	1.7220	708A37	19B	2234	4137;4135	35CD4	35CrMo4	34CrMo4	SCM432;SCCRM3
	P2.1.Z.AN	02.1/02.2	41CrMo4	1.7223	708M40	19A	2244	4140;4142	42CD4TS	41CrMo4	42CrMo4	SCM 440
	P2.1.Z.AN	02.1/02.2	42CrMo4	1.7225	708M40	19A	2244	4140	42CD4	42CrMo4	42CrMo4	SCM440(H)
	P2.1.Z.AN	03.11	14NiCrMo134	1.6657	832M13	36C	-	-	-	15NiCrMo13	14NiCrMo131	-
	P2.2.Z.AN	02.1	31CrMo12	1.8515	722 M 24		2240	-	30 CD 12	30CrMo12	F-1712	
	P2.2.Z.AN	02.1	39CrMoV13 9	1.8523	897M39	40C	-	-	-	36CrMoV12	-	-
	P2.2.Z.AN	02.1	41CrS4	1.7039	524A14	-	2092	L1	-	105WCR 5	-	-
	P2.2.Z.AN	02.1	50NiCr13	1.2721	-		2550	L6	55NCV6	-	F-528	
	P2.2.Z.AN	03.11	45WCrV7	1.2542	BS1	-	2710	S1	-	45WCrV8KU	45WCrSi8	-
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	36CrNiMo4	1.6511	816M40	110	-	9840	40NCD3	38NiCrMo4(KB)	35NiCrMo4	-
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	34CrNiMo6	1.6582	817M40	24	2541	4340	35NCD6	35NiCrMo6(KB)	-	-
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	34Cr4	1.7033	530A32	18B	-	5132	32C4	34Cr4(KB)	35Cr4	SCr430(H)
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	41Cr4	1.7035	530A40	18	-	5140	42C4	41Cr4	42Cr4	SCr440(H)
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	32CrMo12	1.7361	722M24	40B	2240	-	30CD12	32CrMo12	F.124.A	-
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	51CrV4	1.8159	735A50	47	2230	6150	50CV4	50CrV4	51CrV4	SUP10
	P2.2.Z.AN/P2.5.Z.HT	02.1/02.2	41CrAlMo7	1.8509	905M39	41B	2940	-	40CAD6, 12	41CrAlMo7	41CrAlMo7	-
	P2.3.Z.AN	02.1	100Cr6	1.3505	534A99	31	2258	52100	100C6	100Cr6	F.131	SUJ2
	P2.3.Z.AN/H1.2.Z.HA	02.1/02.2	105WCr6	1.2419	-	-	2140	-	105WC13	10WCr6	105WCr5	SKS31
	P2.3.Z.AN/H1.2.Z.HA									107WCr5KU		SKS2, SKS3
	P2.3.Z.AN/H1.2.Z.HA	02.1/02.2	-	1.2714	-	-	-	L6	55NCDV7	-	F.520.S	SKT4
	P2.3.Z.AN/H1.3.Z.HA	02.1/02.2	100Cr6	1.2067	BL3	-	-	L3	Y100C6	-	100Cr6	-

➤

ISO	MC	CMC	Country: Europe – Standard: DIN EN	Germany: W.-nr	Great Britain: BS	Great Britain: EN	Sweden: SS	USA: AISI/SAE/ASTM	France: AFNOR	Italy: UNI	Spain: UNE	Japan: JIS
P	P2.4.Z.AN	02.1	16MnCr5	1.7139	-	-	2127	-	-	-	-	-
	P2.5.Z.HT	02.1	16Mo5	1.5423	1503-245-420	-	-	4520	-	16Mo5	16Mo5	-
	P2.5.Z.HT	02.1	40NiCrMo8-4	1.6562	311-Type 7	-	-	8740	-	40NiCrMo2(KB)	40NiCrMo2	SNCM240
	P2.5.Z.HT	02.1	42Cr4	1.7045	-	-	2245	5140	-	-	42Cr4	SCr440
	P2.5.Z.HT	02.1	31NiCrMo14	1.5755	830 M 31		2534	-	-	-	F-1270	
	P2.5.Z.HT	02.2	36NiCr6	1.5710	640A35	111A	-	3135	35NC6	-	-	SNC236
	P2.6.C.UT	02.1	22Mo4	1.5419	605A32	-	2108	8620	-	-	F520.S	-
	P2.6.C.UT	02.1/02.2	25CrMo4	1.7218	1717CDS110	-	2225	4130	25CD4	25CrMo4(KB)	AM26CrMo4	SCM420;SCM430
	P2.6.C.UT	06.2	-	-	-	-	2223	-	-			
	High-alloy steel											
	P3.0.Z.AN	03.11	X210Cr12	1.2080	BD3	-	-	D3	Z200C12	X210Cr13KU X250Cr12KU	X210Cr12	SKD1
	P3.0.Z.AN	03.11	X43Cr13	1.2083			2314					
	P3.0.Z.AN	03.11	X40CrMoV5 1	1.2344	BH13	-	2242	H13	Z40CDV5	X35CrMoV05KU X40CrMoV511KU	X40CrMoV5	SKD61
	P3.0.Z.AN	03.11	X100CrMoV5 1	1.2363	BA2	-	2260	A2	Z100CDV5	X100CrMoV51KU	X100CrMoV5	SKD12
	P3.0.Z.AN	03.11	X210CrW12	1.2436	-	-	2312	-	-	X215CrW12 1KU	X210CrW12	SKD2
	P3.0.Z.AN	03.11	X30WCrV9 3	1.2581	BH21	-	-	H21	Z30WCV9	X28W09KU X30WCrV9 3KU	X30WCrV9	SKD5
	P3.0.Z.AN	03.11	X165CrMoV 12	1.2601	-	-	2310	-	-	X165CrMoW12KU	X160CrMoV12	-
	P3.0.Z.AN	03.21	X155CrMoV12-1	1.2379	-	-	2736	HNV3	-	-	-	-
	P3.0.Z.HT	03.11	X8Ni9	1.5662	1501-509;510	-	-	ASTM A353	-	X10Ni9	XBNi09	-
	P3.0.Z.HT	03.11	12Ni19	1.5680	-	-	-	2515	Z18N5	-	-	-
	P3.1.Z.AN	03.11	S6-5-2	1.3343	4959BA2	-	2715	D3	Z40CSD10	15NiCrMo13	-	SUH3
	P3.1.Z.AN	03.13	-	-	BM 2		2722	M 2	Z85WDCV	HS 6-5-2-2	F-5603.	SKH 51
	P3.1.Z.AN	03.13	HS 6-5-2-5	1.3243	BM 35		2723	M 35	6-5-2-5	HS 6-5-2-5	F-5613	SKH 55
	P3.1.Z.AN	03.13	HS 2-9-2	1.3348	-		2782	M 7	-	HS 2-9-2	F-5607	-
	P3.2.C.AQ	06.33	G-X120Mn12	1.3401	Z120M12	-	2183	L3	Z120M12	XG120Mn12	X120Mn12	SCMnH/1
Steel	**Ferritic/martensitic stainless steel**											
	P5.0.Z.AN	05.11/15.11	X10CrAL13	1.4724	403S17	-	-	405	Z10C13	X10CrAl12	F.311	SUS405
	P5.0.Z.AN	05.11/15.11	X10CrAL18	1.4742	430S15	60	-	430	Z10CAS18	X8Cr17	F.3113	SUS430
	P5.0.Z.AN	05.11/15.11	X10CrAL2-4	1.4762	-	-	2322	446	Z10CAS24	X16Cr26	-	SUH446
	P5.0.Z.AN	05.11/15.11	X1CrMoTi18-2	1.4521	-		2326	S44400		-	-	-
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X6Cr13	1.4000	403S17		2301	403	Z6C13	X6Cr13	F.3110	SUS403
	P5.0.Z.AN/P5.0.Z.HT		X7Cr14	1.4001					-	-	F.8401	-
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X10Cr13	1.4006	410S21	56A	2302	410	Z10C14	X12Cr13	F.3401	SUS410
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X6Cr17	1.4016	430S15	960	2320	430	Z8C17	X8Cr17	F3113	SUS430
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X6CrAL13	1.4002	405S17	-	-	405	Z8CA12	X6CrAl13	-	-
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X20Cr13	1.4021	420S37	-	2303	420	Z20C13	X20Cr13	-	-
	P5.0.Z.AN/P5.0.Z.HT	05.11/15.11	X6CrMo17-1	1.4113	434S17	-	2325	434	Z8CD17.01	X8CrMo17	-	SUS434
	P5.0.Z.HT	03.11	X45CrS9-3-1	1.4718	401S45	52	-	HW3	Z45CS9	X45GrSi8	F322	SUH1
	P5.0.Z.HT	05.11/15.11	X85CrMoV18-2	1.4748	443S65	59	-	HNV6	Z80CSN20.02	X80CrSiNi20	F.320B	SUH4
	P5.0.Z.HT	05.11/15.11	X20CrMoV12-1	1.4922	-		2317	-	-	X20CrMoNi 12 01	-	-
	P5.0.Z.PH	05.11/15.11	X12CrS13	1.4005	416 S 21		2380	416	Z11CF13	X12 CrS 13	F-3411	SUS 416
	P5.0.Z.PH	05.11/15.11	X46Cr13	1.4034	420S45	56D	2304	-	Z40CM	X40Cr14	F.3405	SUS420J2
	P5.0.Z.PH	05.11/15.11	X19CrNi17-2	1.4057	431S29	57	2321	431	Z15CNi6.02	X16CrNi16	F.3427	SUS431
	P5.0.Z.PH	05.12/15.12	X5CrNiCuNb16-4	1.4542 1.4548	-		-	630	Z7CNU17-04	-	-	-
	P5.0.Z.PH	15.21	X4 CrNiMo16-5	1.4418	-		2387	-	Z6CND16-04-01			
	P5.1.Z.AN/P5.0.Z.HT	05.11/15.11	X14CrMoS17	1.4104	-	-	2383	430F	Z10CF17	X10CrS17	F.3117	SUS430F

MC	CMC	W.-nr	Trade names
P2.1.Z.AN	02.1		OVAKO 520M (Ovako Steel)
P2.2.Z.AN	02.1	1.0045	FORMAX (Uddeholm Tooling)
P2.2.Z.AN	02.1		IMACRO NIT (Imatra Steel)
P2.5.Z.HT	02.2		INEXA 482 (XM) (Inexa Profil)
P1.2.Z.AN			S355J2G3(XM)
P1.2.Z.AN			C45(XM)
P1.2.Z.AN			16MnCrS5(XM)
P2.5.Z.HT			INEXA280(XM)
P2.5.Z.HT	02.2		070M20(XM)
P2.5.Z.HT	02.2		HARDOX 500 (SSAB – Swedish Steel Corp.)
P2.5.Z.HT			WELDOX 700 (SSAB – Swedish Steel Corp.)

ISO	MC	CMC	Country Europe	Germany	Great Britain		Sweden	USA	France	Italy	Spain	Japan
			Standard									
			DIN EN	W.-nr	BS	EN	SS	AISI/SAE/ASTM	AFNOR	UNI	UNE	JIS
M	**Austenitic stainless steels**											
Stainless steel	M1.0.Z.AQ	05.11/15.11	X3CrNiMo13-4	1.4313	425C11	-	2385	CA6-NM	Z4CND13.4M Z38C13M	(G)X6CrNi304	-	SCS5
	M1.0.Z.AQ	05.11/15.11	X53CrMnNiN21-9	1.4871	349S54		-	EV8	Z52CMN21.09	X53CrMnNiN21 9	-	SUH35, SUH36
	M1.0.Z.AQ	05.21/15.21	X2CrNiN18-10	1.4311	304S62	-	2371	304LN	Z2CN18.10	-	-	SUS304LN
	M1.0.Z.AQ	05.21/15.21	X2CrNiMoN17-13-3	1.4429	-	-	2375	316LN	Z2CND17.13	-	-	SUS316LN
	M1.0.Z.AQ	05.21/15.21	X2CrNiMo17-12-2	1.4404	316S13		2348	316L	Z2CND17-12	X2CrNiMo1712	-	-
	M1.0.Z.AQ	05.21/15.21	X2CrNiMo18-14-3	1.4435	316S13	-	2353	316L	Z2CND17.12	X2CrNiMo17 12	-	SCS16, SUS316L
	M1.0.Z.AQ	05.21/15.21	X3CrNiMo17-3-3	1.4436	316S33	-	2343, 2347	316	Z6CND18-12-03	X8CrNiMo1713	-	-
	M1.0.Z.AQ	05.21/15.21	X2CrNiMo18-15-4	1.4438	317S12	-	2367	317L	Z2CND19.15	X2CrNiMo18 16	-	SUS317L
	M1.0.Z.AQ	05.21/15.21	X6CrNiNb18-10	1.4550	347S17	58F	2338	347	Z6CNNb18.10	X6CrNiNb18 11	F.3552 F.3524	SUS347
	M1.0.Z.AQ	05.21/15.21	X6CrNiMoTi17-12-2	1.4571	320S17	58J	2350	316Ti	Z6NDT17.12	X6CrNiMoTi17 12	F.3535	-
	M1.0.Z.AQ	05.21/15.21	X10CrNiMoNb 18-12	1.4583	-	-	-	318	Z6CNDNb17 13B	X6CrNiMoNb17 13	-	-
	M1.0.Z.AQ	05.21/15.21	X15CrNiSi20-12	1.4828	309S24	-	-	309	Z15CNS20.12	-	-	SUH309
	M1.0.Z.AQ	05.21/15.21	X2CrNiMoN17-11-2	1.4406	301S21	58C	2370	308	Z1NCDU25.20	-	F.8414	SCS17
	M1.0.Z.AQ	05.23/15.23	X1CrNiMoCuN20-18-7	1.4547	-	-	2378	S31254	Z1CNDU20-18-06AZ	-	-	-
	M1.0.Z.PH	05.21/15.21	X9CrNi18-8	1.4310	-	-	2331	301	Z12CN17.07	X12CrNi17 07	F.3517	SUS301
	M1.0.Z.PH	05.22/15.22	X7CrNiAL17-7	1.4568 1.4504	316S111	-	-	17-7PH	Z8CNA17-07	X2CrNiMo1712	-	-
	M1.1.Z.AQ	05.21/15.21	X2CrNi19-11	1.4306	304S11 304S12	-	2352	304L	Z2CN18-10	X2CrNi18 11	-	-
	M1.1.Z.AQ	05.21/15.21			304S31	58E	2332, 2333	304	Z6CN18.09	X5CrNi18 10	F.3504 F.3541	SUS304
	M1.1.Z.AQ	05.21/15.21	X5CrNi18-10	1.4301	304S15	58E	2332	304	Z6CN18.09	X5CrNi18 10	F.3551	SUS304
	M1.1.Z.AQ	05.21/15.21	X5CrNiMo17-2-2	1.4401	316S16	58J	2347	316	Z6CND17.11	X5CrNiMo17 12	F.3543	SUS316
	M1.1.Z.AQ	05.21/15.21	X6CrNiTi18-10	1.4541	321S12	58B	2337	321	Z6CNT18.10	X6CrNiTi18 11	F.3553 F.3523	SUS321
	M1.2.Z.AQ	05.21/15.21	X8CrNiS18-9	1.4305	303S21	58M	2346	303	Z10CNF 18.09	X10CrNiS 18.09	F.3508	SUS303
	Super-austenitic stainless steels (Ni > 20%)											
	M2.0.C.AQ	20.11	G-X40NiCrSi36-18	1.4865	330C11	-	-	-	-	XG50NiCr39 19	-	SCH15
	M2.0.Z.AQ	05.21/15.21	X1NiCrMoCu25-20-5	1.4539	-		2562	UNS V 0890A	Z2 NCDU25-20	-	-	-
	M2.0.Z.AQ	05.21/15.21	X8CrNi25-21	1.4845	310S24	-	2361	310S	Z12CN25 20	X6CrNi25 20	F.331	SUH310
	M2.0.Z.AQ	20.11	X12NiCrSi36 16	1.4864	-	-	-	330	Z12NCS35.16	F-3313	-	SUH330
	M2.0.Z.AQ	05.23/15.23	X1NiCrMoCu31-27-4	1.4563	-	-	2584	N08028	Z1NCDU31-27-03	-	-	-
	Duplex (austenitic/ferritic) stainless steels											
	M3.1.Z.AQ/M3.1.C.AQ	05.51/15.51	X2CrNiN23-4	1.4362	-		2376	S31500	-	-	-	-
	M3.1.Z.AQ/M3.1.C.AQ	05.51/15.51	X8CrNiMo27-5	-	-		2324	S32900	-	-	-	-
	M3.2.Z.AQ/M3.2.C.AQ	05.52/15.52	X2CrNiN23-4	-	-		2327	S32304	Z2CN23-04AZ	-	-	-
	M3.2.Z.AQ/M3.2.C.AQ	05.52/15.52	-	-	-		2328	-	-	-	-	-
	M3.2.Z.AQ/M3.2.C.AQ	05.52/15.52	X2CrNiMoN22-53	-	-		2377	S31803	Z2CND22-05-03	-	-	-
					Trade names							
	M1.1.Z.AQ	05.21/15.21			SANMAC 304 (Sandvik Steel)							
	M1.1.Z.AQ	05.21/15.21			SANMAC 304L (Sandvik Steel)							
	M1.1.Z.AQ	05.21/15.21			SANMAC 316 (Sandvik Steel)							
	M1.1.Z.AQ	05.21/15.21			SANMAC 316L (Sandvik Steel)							
	M1.0.Z.AQ	05.23/15.23			254 SMO							
	M2.0.Z.AQ	05.23/15.23			654 SMO							
	M3.2.Z.AQ	05.52/15.52			SANMAC SAF 2205 (Sandvik Steel)							
	M3.2.Z.AQ	05.52/15.52			SANMAC SAF 2507 (Sandvik Steel)							

ISO	MC	CMC	Country Europe	Germany	Great Britain	Sweden	USA	France	Italy	Spain	Japan
			Standard								
			DIN EN	W.-nr	BS EN	SS	AISI/SAE/ASTM	AFNOR	UNI	UNE	JIS
K	**Malleable cast iron**										
Cast iron	K1.1.C.NS	07.1	-		8 290/6	0814		MN 32-8			FCMB310
	K1.1.C.NS	07.1	EN-GJMB350-10	0.8135	B 340/12	0815	32510	MN 35-10			FCMW330
	K1.1.C.NS	07.2	EN-GJMB450-6	0.8145	P 440/7	0852	40010	Mn 450	GMN 45		FCMW370
	K1.1.C.NS	07.2	EN-GJMB550-4	0.8155	P 510/4	0854	50005	MP 50-5	GMN 55		FCMP490
					P 570/3	0858	70003	MP 60-3			FCMP540
	K1.1.C.NS	07.2	EN-GJMB650-2	0.8165	P570/3	0856	A220-70003	Mn 650-3	GMN 65	-	FCMP590
	K1.1.C.NS	07.3	EN-GJMB700-2	0.8170	P690/2	0862	A220-80002	Mn700-2	GMN 70		FCMP690
	Grey cast iron										
	K2.1.C.UT	08.1				0100					
	K2.1.C.UT	08.1	EN-GJL-100	0.6010		0110	No 20 B	Ft 10 D			FC100
	K2.1.C.UT	08.1	EN-GJL-150	0.6015	Grade 150	0115	No 25 B	Ft 15 D	G 15	FG 15	FC150
	K2.1.C.UT	08.1	EN-GJL-200	0.6020	Grade 220	0120	No 30 B	Ft 20 D	G 20		FC200
	K2.1.C.UT	08.2	EN-GJL-250	0.6025	Grade 260	0125	No 35 B	Ft 25 D	G 25	FG 25	FC250
	K2.1.C.UT	08.2	EN-JLZ	0.6040	Grade 400	0140	No 55 B	Ft 40 D			
	K2.2.C.UT	08.2	EN-GJL-300	0.6030	Grade 300	0130	No 45 B	Ft 30 D	G 30	FG 30	FC300
	K2.2.C.UT	08.2	EN-GJL-350	0.6035	Grade 350	0135	No 50 B	Ft 35 D	G 35	FG 35	FC350
	K2.3.C.UT	08.3	GGL-NiCr20-2	0.6660	L-NiCuCr202	0523	A436 Type 2	L-NC 202	-	-	
	Nodular cast iron										
	K3.1.C.UT	09.1	EN-GJS-400-15	0.7040	SNG 420/12	0717-02	60-40-18	FCS 400-12	GS 370-17	FGE 38-17	FCD400
	K3.1.C.UT	09.1	EN-GJS-400-18-LT	0.7043	SNG 370/17	0717-12	-	FGS 370-17			
	K3.1.C.UT	09.1	EN-GJS-350-22-LT	0.7033	-	0717-15	-	-			
	K3.1.C.UT	09.1	EN-GJS-800-7	0.7050	SNG 500/7	0727	80-55-06	FGS 500-7	GS 500	FGE 50-7	FCD500
	K3.2.C.UT	09.2	EN-GJS-600-3	0.7060	SNG 600/3	0732-03	-	FGS 600-3			FCD600
	K3.3.C.UT	09.2	EN-GJS-700-2	0.7070	SNG 700/2	0737-01	100-70-03	FGS 700-2	GS 700-2	FGS 70-2	FCD700
	K3.5.C.UT	-	EN-GJSA-XNiCr20-2	0.7660	Grade S6	0776	A43D2	S-NC 202	-	-	
	Compacted graphite iron										
	K4.1.C.UT	-	EN-GJV-300								
	K4.1.C.UT	-	EN-GJV-350								
	K4.2.C.UT	-	EN-GJV-400								
	K4.2.C.UT	-	EN-GJV-450								
	K4.2.C.UT	-	EN-GJV-500								
	Austempered ductile iron										
	K5.1.C.NS	-	EN-GJS-800-8				ASTM A897 No. 1				
	K5.1.C.NS	-	EN-GJS-1000-5				ASTM A897 No. 2				
	K5.2.C.NS	-	EN-GJS-1200-2				ASTM A897 No. 3				
	K5.2.C.NS	-	EN-GJS-1400-1				ASTM A897 No. 4				
	K5.3.C.NS						ASTM A897 No. 5				

ISO	MC	CMC	Country Europe	Germany	Great Britain		Sweden	USA	France	Italy	Spain	Japan
			Standard									
			DIN EN	**W.-nr**	**BS**	**EN**	**SS**	**AISI/SAE/ASTM**	**AFNOR**	**UNI**	**UNE**	**JIS**
N Non-ferrous metals	**Aluminium-based alloys**											
	N1.3.C.AG	30.21	G-AlSi9MGWA	3.2373			4251	SC64D	A-S7G			C4BS
	N1.3.C.UT	30.21	G-ALMG5		LM5		4252	GD-AlSi12	A-SU12			AC4A
	N1.3.C.UT/N1.3.C.AG	30.21/30.22			LM25		4244	356.1				A5052
	N1.3.C.UT		GD-AlSi12				4247	A413.0				A6061
	N1.3.C.AG		GD-AlSi8Cu3		LM24		4250	A380.1				A7075
	N1.3.C.UT		G-AlSi12(Cu)		LM20		4260	A413.1				ADC12
	N1.3.C.UT		G-AlSi12		LM6		4261	A413.2				
	N1.3.C.AG		G-AlSi10Mg(Cu)		LM9		4253	A360.2				
S Heat resistance super alloys	**Nickel based alloys**											
	S2.0.C.NS	20.22	S-NiCr13A16MoNb	LW2 4670	mar-46	-	-	5391	NC12AD	-	-	
	S2.0.C.NS	20.24	NiCo15Cr10MoAlTi	LW2 4674	-	-	-	AMS 5397	-	-	-	
	S2.0.Z.AG	20.22	NiFe35Cr14MoTi	LW2.4662	-	-	-	5660	ZSNCDT42	-	-	
	S2.0.Z.AG	20.22	NiCr19Fe19NbMo	LW2.4668	HR8	-	-	5383	NC19eNB	-	-	
	S2.0.Z.AG	20.22	NiCr20TiAk	2.4631	Hr401.601	-	-	-	NC20TA	-	-	
	S2.0.Z.AG	20.22	NiCr19Co11MoTi	2.4973	-	-	-	AMS 5399	NC19KDT	-	-	
	S2.0.Z.AG	20.22	NiCr19Fe19NbMo	LW2.4668	-	-	-	AMS 5544	NC20K14	-	-	
	S2.0.Z.AN	20.21	-	2.4603	-	-	-	5390A	NC22FeD	-	-	
	S2.0.Z.AN	20.21	NiCr22Mo9Nb	2.4856	-	-	-	5666	NC22FeDNB	-	-	
	S2.0.Z.AN	20.21	NiCr20Ti	2.4630	HR5.203-4	-	-	-	NC20T	-	-	
	S2.0.Z.AN	20.22	NiCu30AL3Ti	2.4375	3072-76	-	-	4676	-	-	-	
	Cobalt based alloys											
			CoCr20W15Ni		-	-	-	5537C, AMS	KC20WN	-	-	
	S3.0.Z.AG	20.32	CoCr22W14Ni	LW2.4964				5772	KC22WN			
	Titanium alloys											
	S4.2.Z.AN	23.22	TiAl5Sn2.5	3.7115.1	TA14/17	-	-	UNS R54520	T-A5E	-	-	
									UNS R56400			
	S4.2.Z.AN	23.22	TiAl6V4	3.7165.1	TA10-13/TA28		-	-	UNS R56401	T-A6V	-	-
	S4.3.Z.AN	23.22	TiAl5V5Mo5Cr3									
	S4.2.Z.AN	23.22	TiAl4Mo4Sn4Si0.5	3.7185	-	-	-	-	-	-	-	
			Trade names									
			Iron base									
	S2.0.Z.UT/S2.0.Z.AN	20.11	Incoloy 800									
			Nickel base									
	S2.0.Z.AN	20.2	Haynes 600									
	S2.0.Z.AN	20.2	Nimocast PD16									
	S2.0.Z.AG	20.2	Nimonic PE 13									
	S2.0.Z.AG	20.2	Rene 95									
	S2.0.Z.AN	20.21	Hastelloy C									
	S2.0.Z.AN	20.21	Incoloy 825									
	S2.0.Z.AN	20.21	Inconel 600									
	S2.0.Z.AN	20.21	Monet 400									
	S2.0.Z.AG	20.22	Inconel 700									
	S2.0.Z.AG	20.22	Inconel 718									
	S2.0.Z.AG	20.22	Mar – M 432									
	S2.0.Z.AG	20.22	Nimonic 901									
	S2.0.Z.AG	20.22	Waspaloy									
	S2.0.C.NS	20.24	Jessop G 64									
			Cobalt base									
	S3.0.Z.AG	20.3	Air Resist 213									
	S3.0.Z.AG	20.3	Jetalloy 209									
H Hardened materials	**Hardened materials**											
	H1.2.Z.HA	04.1	X100CrMo13	1.4108	-	-	2258 08	440A	-	-	-	C4BS
	H1.3.Z.HA	04.1	X110CrMoV15	1.4111	-	-	2534 05	610	-	-		AC4A
	H1.2.Z.HA	04.1	X65CrMo14	-	-	-	2541 06	0-2	-	-		AC4A