MACHINABILITY & WORKPIECE MATERIAL PROPERTIES

YOUR MAIN CHALLENGES

LINK WORKPIECE MATERIAL PROPERTIES TO MACHINABILITY

1. WORKPIECE MATERIAL PROPERTIES

Main workpiece material property	Most important with materials	Biggest machinability issue	ISO MAT. GROUP
Average material properties	ISO-P	Achieve conditions for free cutting (energy efficient machining)	
High hardness	ISO-H	High mechanical and thermal loads on the cutting edges	
High abrasiveness	ISO-K / ISO-S	High scratching effects on the cutting surfaces	
High adhesion tendency and ductility	ISO-M / ISO-S / ISO-N	Bad chip formation and formation of built-up edge on the cutting edge	
High strain hardening factor	ISO-M / ISO-S	Local high loads on cutting edges	
Low thermal conductivity	ISO-M / ISO-S	High temperatures in the cutting zone	

2. WORKPIECE MATERIAL CLASSIFICATION

Steels, ferritic and martensitic stainless steels

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
P1	Free-cutting steels	$360 < R_m < 880$	11 SMn30 $R_m = 385$ N/mm²	1500	0,14
P2	Low-alloy ferritic steels, C < 0.25%wt Low-alloy weldable general structural steels	$320 < R_m < 600$	S235JRG2 $R_m = 420$ N/mm²	1600	0,23
P3	Ferritic & ferritic/pearlitic steels, C < 0.25%wt Weldable general structural steels Case-hardening steels	$430 < R_m < 610$	16 MnCr 5 $R_m = 550$ N/mm²	1800	0,14
P4	Low-alloy general structural steels, 0.25% < C < 0.67%wt Low-alloy Quench & Temper steels	$520 < R_m < 1200$	C 45E $R_m = 660$ N/mm²	2000	0,15
P5	Structural steels, 0.25% < C < 0.67%wt Quench & Temper steels	$550 < R_m < 1200$	42 CrMo 4 $R_m = 700$ N/mm²	2020	0,18
P6	Low-alloy through-hardening steels, C > 0.67%wt Low-alloy spring and bearing steels	$520 < R_m < 1200$	C 100S $R_m = 600$ N/mm²	2100	0,17
P7	Through-hardening steels, C > 0.67%wt Spring and bearing steels	$600 < R_m < 1200$	100 Cr 6 $R_m = 650$ N/mm²	2160	0,17
P8	Tool steels High Speed Steels (HSS)	$600 < R_m < 1200$	X 40 CrMoV 5 1 $R_m = 700$ N/mm²	2400	0,20
P11	Ferritic & martensitic stainless steels	$415 < R_m < 1200$	X 20 Cr 13 $R_m = 675$ N/mm²	2000	0,15
P12	Maraging and precipitation-hardening stainless steels	$500 < R_m < 1200$	X 5 CrNiCuNb 16 4 $R_m = 1100$ N/mm²	2100	0,17

Free-cutting, austenitic and duplex stainless steels

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
M1	Free-cutting austenitic stainless steels		X 10 CrNiS 18 9	1700	0,14
M2	Low-alloy austenitic stainless steels		X 5 CrNi 18 10	1920	0,18
M3	Medium-alloy austenitic stainless steels		X 2 CrNiMo 18 14 3	2070	0,17
M4	High-alloy austenitic and duplex stainless steels		X 2 CrNiMoN 22 5 3	2230	0,16
M5	Difficult high-alloy austenitic and duplex stainless steels		X 2 CrNiMoN 25 7 4	2510	0,13

Cast irons

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
K1	Grey cast irons (GCI)		EN-GJL-250	930	0,32
K2	Compacted graphite irons (CGI)		EN-GJV-400	1000	0,35
K3	Malleable cast irons (MCI)		EN-GJMB-550-4	1050	0,37
K4	Nodular cast irons (SGI)		EN-GJS-500-7	1160	0,37
K5	Austempered ductile irons (ADI)		EN-GJS-1000-5		
K6	Austenitic lamellar cast irons		EN-GJLA-XNiCuCr15-6-2		
K7	Austenitic nodular cast irons		EN-GJSA-XNiMn23-4		

Non-ferrous metals

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
N1	Aluminium alloys, Si < 9%		AW-7075		
N2	Aluminium alloys, 9% < Si < 16%		AC-44200 Si = 12%		
N3	Aluminium alloys, Si >16%		AlSi17Cu5		
N11	Copper alloys		CW614N	740	0,26

Superalloys and titanium

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
S1	Iron-based superalloys		Discalloy		
S2	Cobalt-based superalloys		Stellite 21		
S3	Nickel-based superalloys		Inconel 718	2530	0,21
S11	Titanium, low alloyed, (α)		Ti		
S12	Titanium, medium alloyed, (α+β)		TiAl6V4	1500	0,24
S13	Titanium, high alloyed, (near β and β)		Ti10V2Fe3Al		

Hard materials

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
H3	Case-hardened steels	58 < HRC < 62	16 MnCr 5 60 HRC	2070	0,14
H5	Quenched & Tempered steels	38 < HRC < 56	42 CrMo 4 50 HRC	2320	0,18
H7	Quenched & Tempered steels Bearing steels	56 < HRC < 64	100 Cr 6 60 HRC	2480	0,17
H8	Tool steels High Speed Steels (HSS)	38 < HRC < 64	X 40 CrMoV 5 1 50 HRC	2750	0,20
H11	Martensitic stainless steels	38 < HRC < 50	X 20 Cr 13 45 HRC	2300	0,15
H12	Maraged and precipitation-hardened stainless steels	$1200 < R_m < 1650$	X 5 CrNiCuNb 16 4 $R_m = 1450$ N/mm²	2410	0,17
H21	Manganese steels	23 < HRC < 64	X 120 Mn 12 50 HRC		
H31	White cast irons	50 < HRC < 64	EN-GJN-HV600(XCr11) 55 HRC		

Other difficult materials

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
PM1	Low-alloy PM-materials		F-0008 Fe-0.7C		
PM2	Medium-alloy PM-materials		FLC-4608 Fe2Cu1.8Ni 0.5Mo0.2Mn0.8C		
PM3	High-alloy PM-materials Exhaust valve seat materials, etc.				
HF1	Hardfacing alloys Welded or plasma-deposited iron-based alloys				
HF2	Hardfacing alloys Welded or plasma-deposited cobalt- and nickel-based alloys				
CC1	Sintered tungsten carbide		G50		

Plastics and Composites

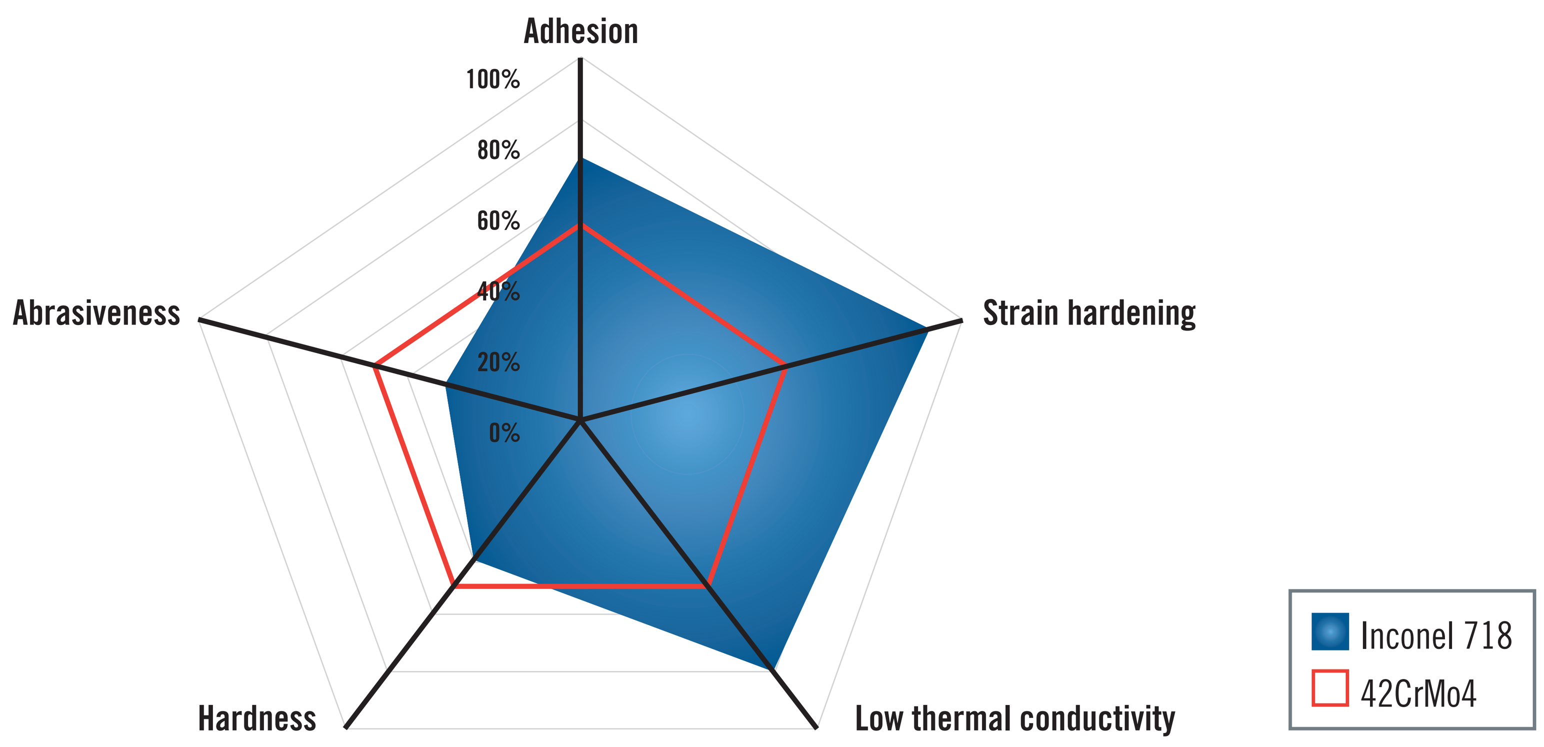
SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
TS1	Thermosetting polymers		Urea formaldehyde (UF)		
TS2T	hermosetting carbon-fibre composites		T300 T700 T800 HTA-S IMA - Epoxy (M21)...		
TS3T	hermosetting glass-fibre composites		Epoxy - HX..(42..)/E glass (7781...)...		
TS4T	hermosetting aramide-fibre composites		Kevlar 49		
TP1	Thermoplastic polymers		Polycarbonate (PC)		
TP2T	hermoplastic carbon-fibre composites		PPS/PEEK - T300..		
TP3T	hermoplastic glass-fibre composites		PPS/PEEK - E glass or A glass...		
TP4T	hermoplastic aramide-fibre composites				

Graphite

SMG	Description	Properties	Reference	$k_{c1.1}$	m_c
GR1	Graphite		R 8500		

3. MACHINABILITY POLAR DIAGRAM

A machinability polar diagram visualizes the influence of five important material properties on the machinability. Below is an example for Inconel 718. In this example can be observed that mainly the high strain hardening and the low thermal conductivity of this material determines the machinability of the material.



1. THIS MATERIAL PROPERTY:

High adhesion / ductility	High strain hardening tendency	Low thermal conductivity	High hardness	High abrasiveness

2. ... CAUSES ...

Bad chip formation	High localised loads	High temperatures in cutting zone	High mechanical and thermal loads	Low tool utilisation

3. ... LEADS TO

Tool wear	Micro chipping (BUE) Flaking, notch wear	Plastic deformation Chipping / notching	Plastic deformation High wear rate	Plastic deformation Chipping / breakage	Flank - crater wear Notching

4. GENERAL RECOMMENDATIONS FOR TOOL SELECTION AND CUTTING CONDITION SELECTION

Cutting material	Toughness Tough coating	Toughness	High compressive strength	Hard or tough (feed dependant)	Abrasion resistance
Cutting conditions	Temperature control	Low cutting speed High feed and DOC	Low cutting speed and feed	Low feed and DOC	Low speed and feed High DOC
Cutting geometry	Sharp edge radius High rake angle	Small nose radius Adapted cutting edge geometry	High rake angle, strong cutting point and edge	Small rake angle	Cutting edge strength

This overview represents a generic approach to link workpiece material properties to general machinability rating.
For more detailed analysis of machinability ratings for specific workpiece materials, please contact your business partner at Seco.

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