

# COLD FORMING MANUAL



**ERASTEEL**

[www.erasteel.com](http://www.erasteel.com)



# A LARGE OFFER OF ASP® AND HSS FOR COLD FORMING APPLICATIONS

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# COMPANY PROFILE

Erasteel is a major player in the HSS market with high-end conventional and powder metallurgy High Speed Steels.

With its ASP®\* range, Erasteel is the world leading producer of PM HSS for high performance tooling and components.

Erasteel also produces powder steels and alloys. PM Nickel and Cobalt based alloys, PM stainless steels, PM tool steels and High Speed Steels are standard grades produced and commercialized by Erasteel under the brandname Pearl®\*.

## Erasteel - A member of ERAMET

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Erasteel is a member of ERAMET, a rapidly growing French mining and metallurgical group.

To ensure its profitable and sustainable growth, ERAMET develops its strategy along three lines: innovation policy, customer focus and efficient organization.

The Group employs around 14,000 people in 20 countries on five continents, and holds front rank global positions in each of its activities.

The Group is built around three divisions—ERAMET Nickel, ERAMET Manganese and ERAMET Alloys.

Together, Erasteel and Aubert & Duval make up the ERAMET Alloys division. While Erasteel is a top producer of High Speed Steels, Aubert & Duval is one of the largest producers in the world of high performance special steels and superalloys as well as closed-die forgings for the aerospace and energy industries.

\* ASP® and Pearl® are registered trademarks of Erasteel.

# Products

Erasteel products are available in a wide range of shapes and chemical compositions, perfectly adapted to a wide variety of tooling and other applications. The different geometries and product forms are available in various finishes: hot-rolled, drawn, peeled, ground, etc.



Round bars



Flat bars



Square bars



Sheets (hot rolled)



Profiled bars



LINEA™ prehardened  
HSS blanks



Profiled edges



Strips (cold rolled)



Powders

# COMPANY PROFILE

## Markets

The grades and products of Erasteel are used in a wide range of applications.



Cutting Tools



Cold Work & Hot Work



Plastics



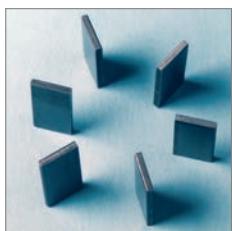
Saws



Conversion Services



Knives



Components



Powders

## Innovation & Expertise

Erasteel has achieved a high standard of quality and experience in the processing of Powder Metallurgy Steels and High Speed Steels. A policy of continuous investments has enabled Erasteel to use the latest technologies to improve both quality and productivity and develop new products in line with customers' needs.

### Customer-oriented research and development

- A solution-oriented spirit to meet and support customers' needs and developments
- A long experience of technical service and examinations of powder metallurgy components and tools in ASP®
- Customer partnerships in product development analysis and improvement of parts

### 40 years of expertise in Powder Metallurgy

- A unique knowledge in gas-atomized metal powders
- A focus on powder cleanliness, processing, consolidation and properties
- A dedicated research laboratory in Söderfors, Sweden, with highly skilled teams, cooperating with a network of universities, laboratories and industry organizations

### A wide range of competences and resources

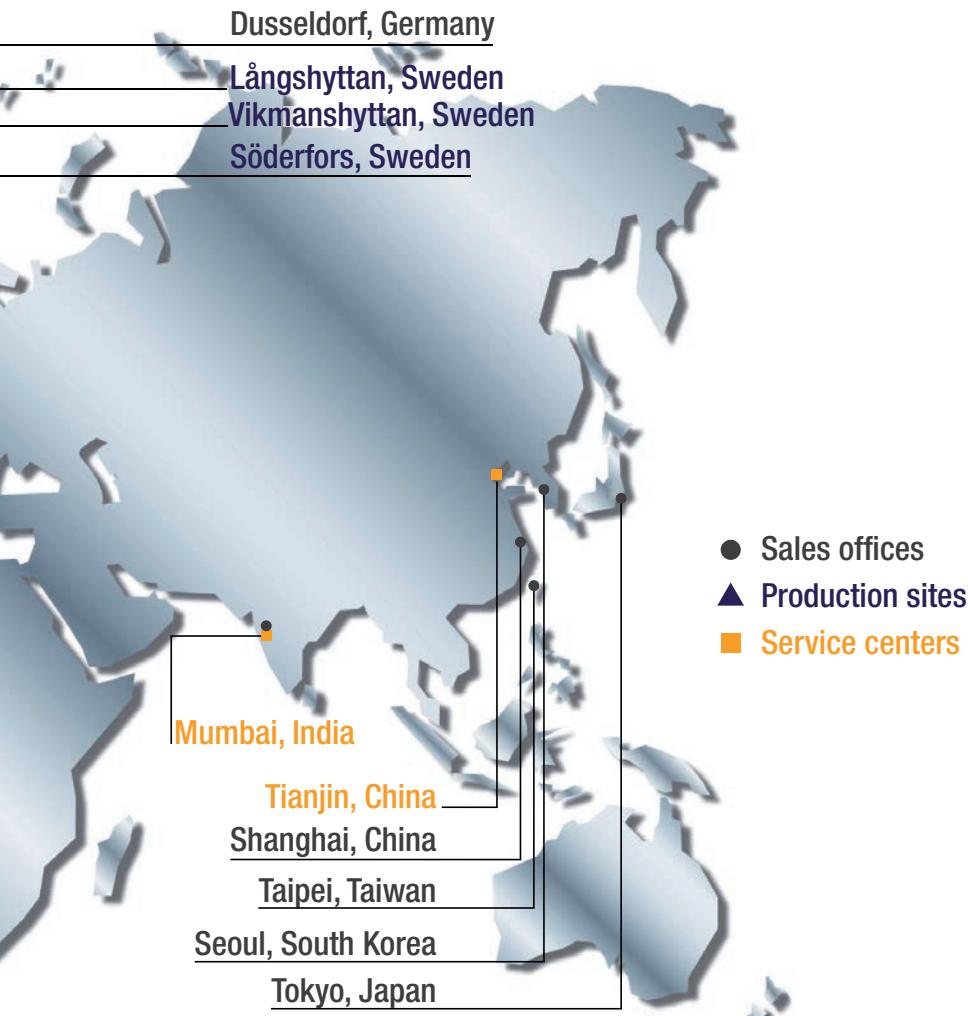
- Alloy development in ASP® as well as Ni-, Co- and Fe- base alloys
- Powder characterization: size, morphology, tap density, flowability, FEG-SEM micrography and chemical analysis
- Evaluation of physical, mechanical (such as impact toughness and fatigue testing) and corrosion properties, as well as cleanliness (e.g. high frequency ultrasonic)

# COMPANY PROFILE

## Worldwide presence

Erasteel has 7 production sites, as well as 6 service centers and 14 sales offices on all continents.





# TECHNOLOGY PROCESS

## **High Speed Steel Conventional Metallurgy**

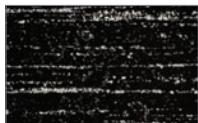
Erasteel is a renowned producer of High Speed Steels and has a unique knowledge in this area.

**We are at the forefront of technology regarding:**

- **Process:** metallurgy, forging, rolling, drawing, heat treatment, etc.
- **Steel grades:** mechanical and physical properties, applications, etc.



Bottom pouring



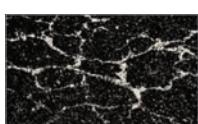
Ø 30 mm / 1,181 inch



Ø 50 mm / 1,969 inch



Ø 125 mm / 4,921 inch

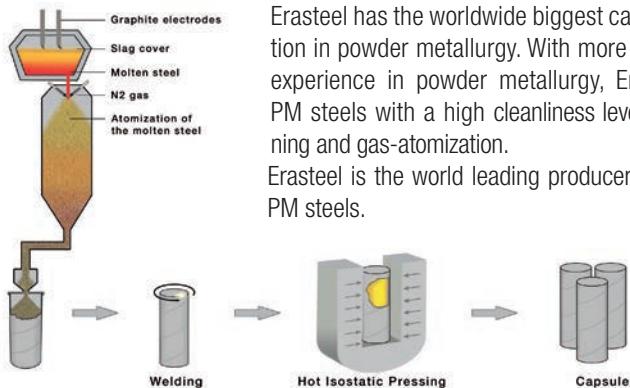


Ingot

Carbide network

High Speed Steel is a high alloyed material. During the solidifying, a brittle carbide rich network is formed. To improve the strength the material must be forged or rolled.

# Powder Metallurgy



Erasteel has the worldwide biggest capacity of production in powder metallurgy. With more than 40 years of experience in powder metallurgy, Erasteel produces PM steels with a high cleanliness level by tundish refining and gas-atomization. Erasteel is the world leading producer of gas-atomized PM steels.

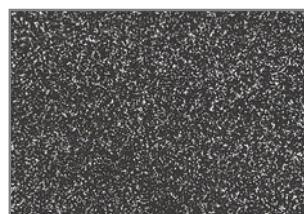
The ASP®-process is a powder metallurgy technology. The molten steel is refined in a heated tundish to remove inclusions and homogenize the composition.

During gas atomization the molten steel is disintegrated by powerful jets of nitrogen gas into small droplets, which solidify at a very high speed. The powder is collected in a steel capsule which is then evacuated and welded. The Hot Isostatic Pressing of the ASP® powder subsequently densifies the powder.

Bars, wire rods, strips and sheets are obtained from forging, hot and cold rolling and wire drawing of the HIP'd capsule.

## Key benefits of Erasteel PM Steels:

- Isotropic properties: a homogenous and fine microstructure with an even distribution of carbide particles in the matrix phase, in contrast to ingot cast material where carbide stringers are formed during manufacturing.
- Higher hardness and wear resistance, due to higher content of carbide-forming elements.
- Higher toughness: the material is free from carbide segregation.
- High cleanliness of the material.



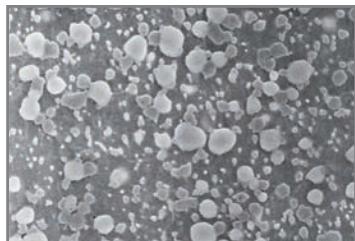
PM steel has small, evenly distributed carbides



Thanks to these properties, Erasteel ASP® grades are widely used in many high performance applications such as tooling for metal, plastics, wood and paper processing as well as mechanical components.

# HEAT TREATMENT

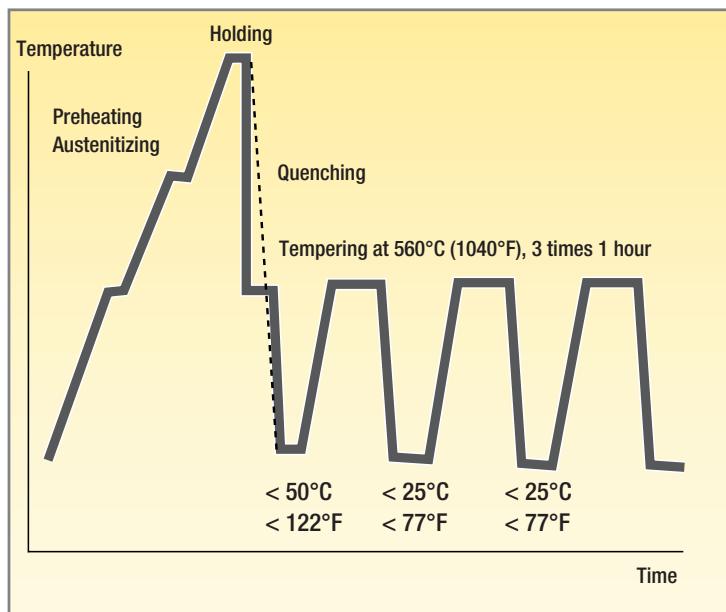
The material from Erasteel is supplied in a soft-annealed condition. The structure consists of a ferritic matrix containing primary carbides and also smaller carbides which are formed during soft-annealing.



Soft-annealed structure

## The three stages

Heat treatment is carried out in three stages – austenitizing, cooling and tempering – giving the ASP® range the required properties for cold forming.



Heat treatment cycle

# Austenitizing

In the austenitizing process, the steel is heated up to the temperature recommended by Erasteel, appropriate for the ultimate hardness required. The ferritic matrix is transformed into austenite and carbides dissolve in the austenite. An *equilibrium condition* will be reached between the carbides and the matrix.

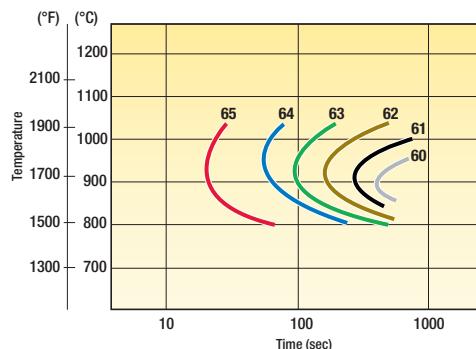
HRC	Austenitizing temperature (°C)						Tempering 3 x 560°C							
	2004	2005	2009	2011	2012	2015	ASP®	2023	2030	2042	2052	2053	2055	2060
50			1060											
52			1100		975									
54			1150	1000										
55			1180	1020	1025									
56				1050										
57				1060										
58		1030		1080	1075	1000	1000	960			990			
59	1040	1040		1100		1040	1030	980		950	1020			
60	1060	1060		1120		1060	1050	1000		1020	1040			
61	1080	1080		1150		1100	1080	1020		1040	1070			
62	1100	1110		1180		1120	1100	1050		1070	1100		950	
63	1120	1140				1150	1120	1075		1100	1130		980	
64	1150	1180				1180	1140	1100		1140	1150	1050	1000	
65	1170					1220	1160	1130	1000	1170	1180	1100	1030	
66	1200					1240	1180	1150	1050	1200		1150	1070	
67						1260		1180	1100	1240		1180	1100	
68									1150				1150	
69									1180				1180	

HRC	Austenitizing temperature (°F)						Tempering 3 x 1040°F							
	2004	2005	2009	2011	2012	2015	ASP®	2023	2030	2042	2052	2053	2055	2060
50			1050											
52			2010		1780									
54			2100	1830										
55			2155	1870	1880									
56				1920										
57				1940										
58		1890		1980	1970	1830	1830	1760			1810			
59	1910	1910		2010		1910	1890	1800		1800	1870			
60	1940	1940		2050		1940	1920	1830		1870	1910			
61	1980	1980		2100		2010	1980	1870		1910	1960			
62	2010	2030		2160		2050	2010	1920		1960	2010		1740	
63	2050	2090				2100	2050	1970		2010	2070		1800	
64	2100	2160				2160	2090	2010		2090	2100	1920	1830	
65	2140					2230	2120	2070	1830	2140	2160	2010	1890	
66	2190					2270	2160	2100	1920	2190		2100	1960	
67								2160	2010	2270		2160	2010	
68										2100			2100	
69										2160			2160	

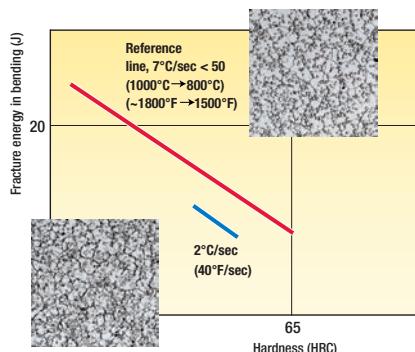
# HEAT TREATMENT

## Quenching

The cooling rate is a very important factor in the heat treatment process. If the cooling rate is too low, due to low pressure or an overloaded furnace, a phenomenon called Pro-Eutectoid Carbide Precipitation – PEC – will take place in the material matrix. The influence of PEC is reduced hardness and reduced toughness. A minimum cooling rate between 1000°C and 800°C of 7°C/sec (~1800 - 1500°F of 45°F/sec) is necessary to avoid loss of hardness.



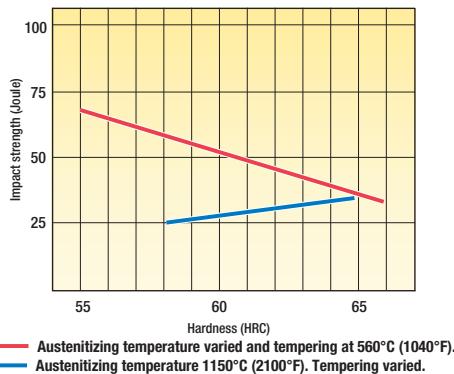
Hardness as function of temperature and quenching time.  
Austenitizing temperature:  
1180°C (2160°F).  
Tempering:  
3 x 1h at 560°C (1040°F).



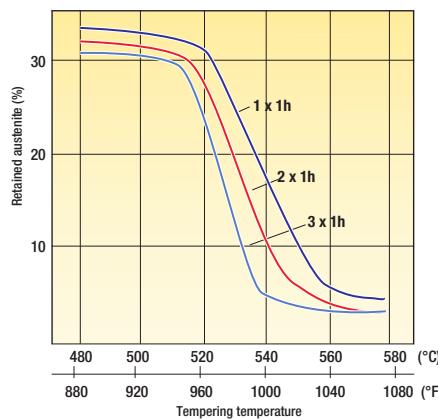
The effect of PEC on the toughness.  
ASP® 2023 tempered 560°C (1040°F),  
3 x 1h. (Structures after hardening,  
before tempering).

# Tempering

Tempering is made in order to transform the retained austenite into martensite and fully temper all the martensite. *For high alloyed ASP®, three temperings at 560°C (1040°F) 1 h are recommended to achieve the best combination of hardness and toughness.* The best properties are obtained when the austenitization temperature is varied and the tempering is carried out at 560°C (1040°F).



Unnotched impact toughness  
for ASP® 2023.



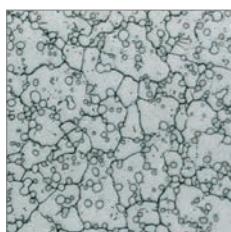
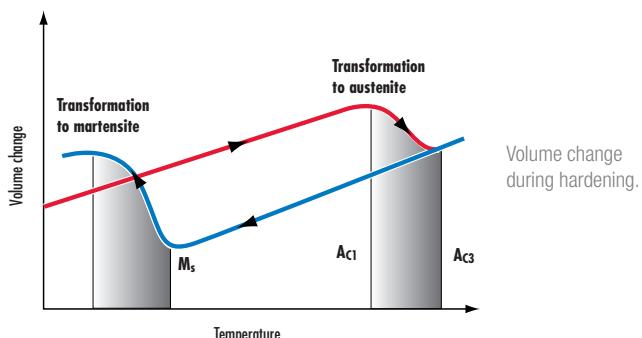
Retained austenite content in ASP® 2023.  
Austenitized at 1180°C (2160°F) as a  
function of the tempering temperature  
and the number of temps.

# HEAT TREATMENT

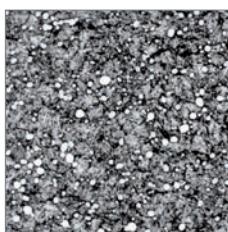
## Phase transformation and volume change

When ferrite transforms into austenite during heat treatment, the volume decreases due to a denser lattice. When the austenite transforms into martensite during the quenching, the volume increases again to a level above the ferrite volume. At the following tempering, the volume again decreases, but not fully to ferrite level, leaving the final hardened and tempered material with a slightly increased volume.

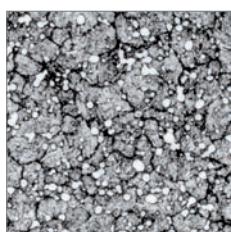
Temperature gradients are impossible to avoid, there is always a difference between surface and core. However, the general rule is to keep the gradient as symmetrical as possible.



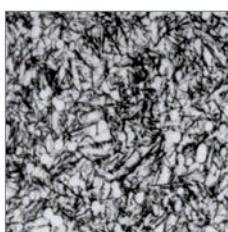
Structure only austenitized.



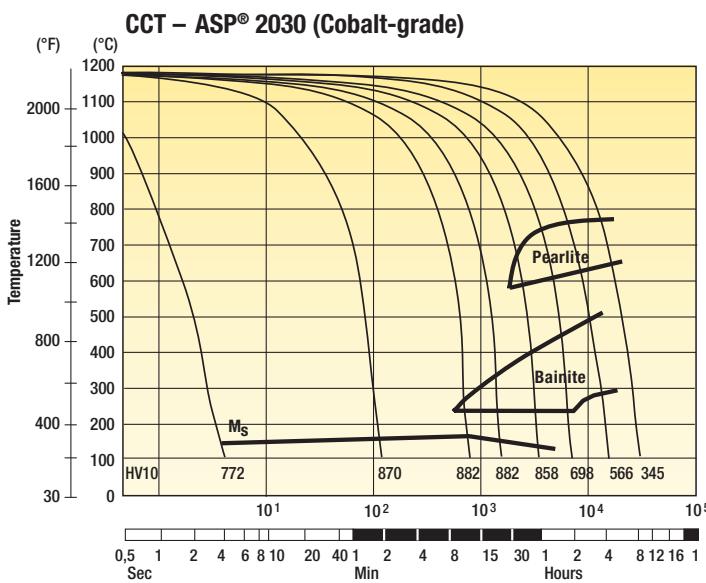
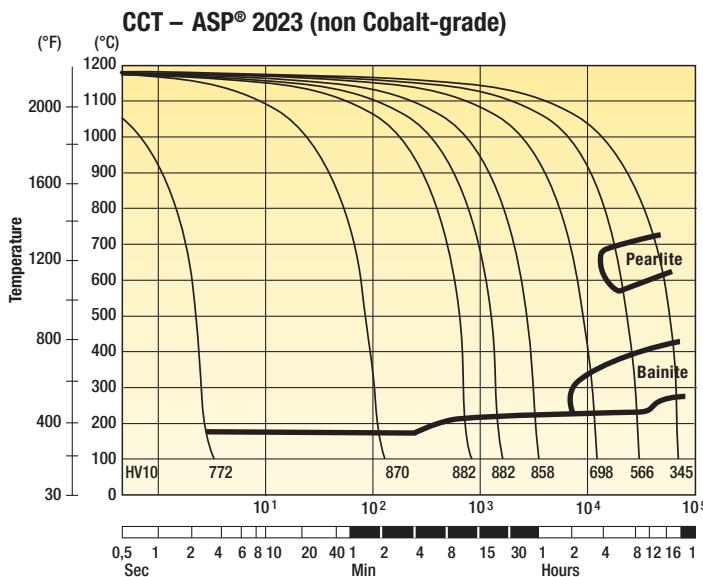
Structure after proper tempering.



Structure after overtempering.



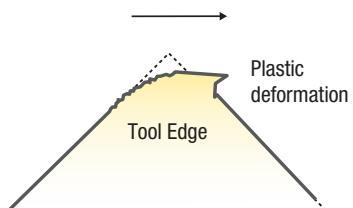
Structure after insufficient tempering.



# DEFINITION OF WEAR MECHANISMS

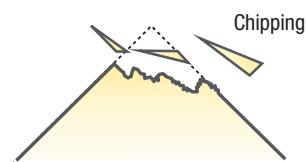
## Plastic deformation

During contact between a tool and its corresponding work material, the tool is affected by high stresses and temperature along the contact surface. High load and temperature at a tool edge can easily cause plastic deformation.



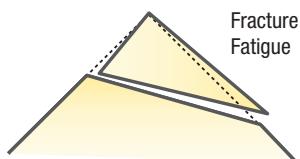
## Chipping and fracture

The stresses in tools are mainly compressive but tensile stress components are also present. In most cases, the stresses are cyclic and can eventually cause also fatigue fracture. Wear mechanisms are chipping or fracture.



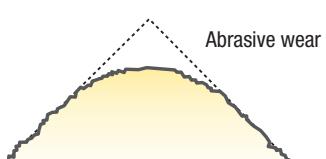
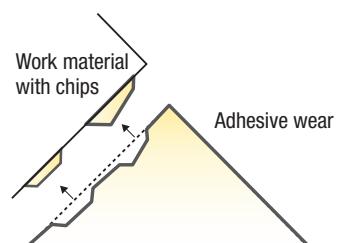
## Adhesive wear

In situations where stressed tool surfaces are neither plastic deformed nor fractured, adhesion or abrasion are dominating wear mechanisms. Continuous forming and breaking of adhesive welds at areas of contact is a normal occurrence. A certain small fracture of these breaking points will occur not along the original contact surface but inside the tool material resulting in adhesive wear.

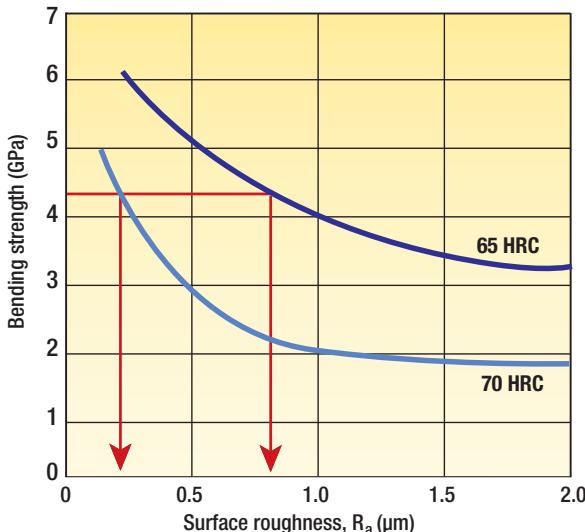


## Abrasive wear

Abrasive wear is often a slow, but unavoidable wear mechanism caused by hard non-metallic inclusions or other hard particles in contact with the tool surface. For the naked eye, a worn surface may look smooth, but the abrasive particles will probably have formed microscopic furrows in the tool material.



# INCREASED TOOL PERFORMANCES WITH AN IMPROVED SURFACE FINISH



Bending strength vs. surface roughness for standard (65 HRC)  
and high performance (70 HRC) material.

High hardness inevitably implies a lower fracture toughness. However, the same high level of strength is achievable for both types of materials, provided that the surface of the high performance material is prepared with a sufficiently high surface finish.



# EDM AND WIRE CUTTING

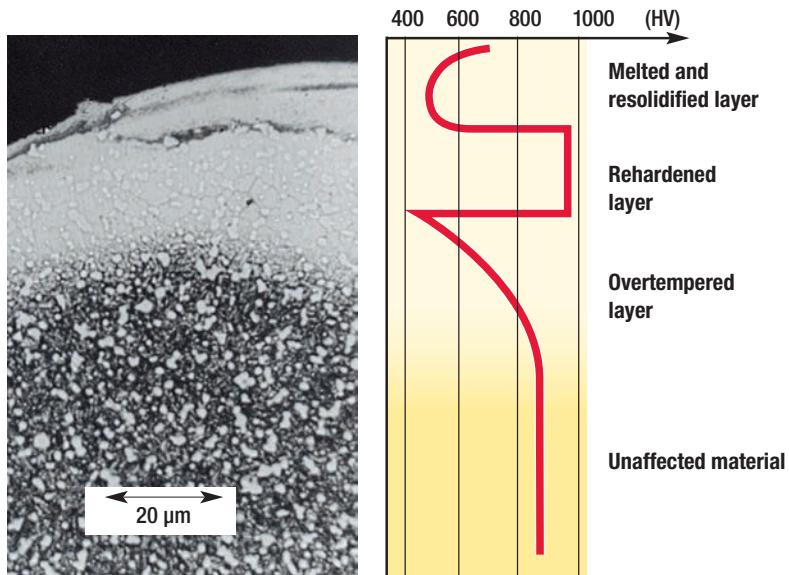
In Electric Discharge Machining (EDM), the temperature at the surface layer can be very high.

In this example, the temperature has been high enough to melt the outermost area of the surface, further down in the material to form a rehardening zone and finally cause an overtempered zone.

This heat affected zone, which in total stretches some hundred  $\mu\text{m}$  down in the material, has a severe influence on the mechanical properties. Indeed, the resolidification cracks in the melted zone provides excellent fracture initiation points, the rehardening zone contains very brittle untempered martensite and the overtempered zone gives a softening of the tool.

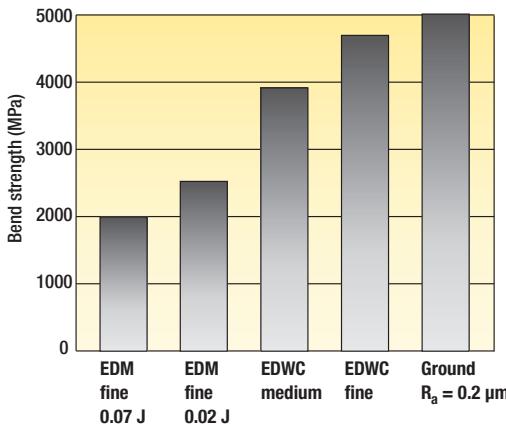
Clearly, it is very important to remove the entire heat affected zone before the tool can be used.

It is recommended to do a stress relieving process after EDM.

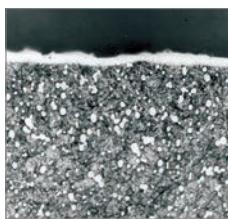


Depending on the type of EDM machining and strength of the discharge energy, the final surface quality and hence the final mechanical properties of the ASP® steel will vary.

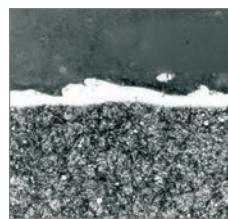
From the figure below, we may conclude that die sinker EDM has more severe influence on surface quality than wire cutting EDM (EDWC) and that increased discharge energy decreases the surface quality and hence the bend strength.



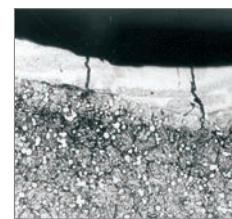
An uppermost melted and resolidified layer, often referred to as the “white layer”, is always found after EDM-machining. The thickness of the layer can vary owing to, for instance, the discharge energy. For HSS, this uppermost layer should be removed as it contains very brittle non-tempered martensite which will lower the properties and the performance of the tool.



EDM 4  $\mu\text{m}$



EDM 9  $\mu\text{m}$



EDM 18  $\mu\text{m}$

# COATINGS - PVD / CVD



**TiN**

Gold

- Conventional, general purpose coating.
- Reduces friction.
- Good abrasion-wear resistance.
- Injection moulding of plastic material.



**TiCN**

Grey-violet

- Multi-purpose coating, especially for roughing end mills and forming tools.
- High abrasion-wear resistance.
- Available as mono or multilayer.
- Recommended for construction steels ( $R_m < 1000$  MPa).



**TiAlN or  
TiAlCN**

Black-violet

- High performance coating for a wide range of cutting parameters.
- 2x to 6x longer tool life than with conventional coatings.
- Reduced heating of the tool.
- Multilayered, nanostructured or alloyed versions offer even better performance.
- Suitable for dry machining.

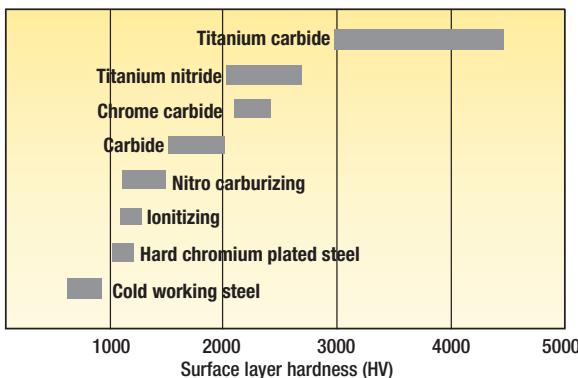


**MoS<sub>2</sub> or**

**WC-C**

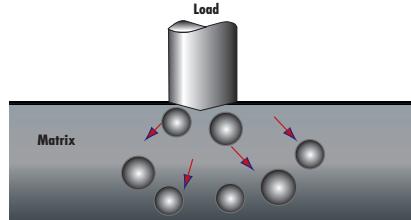
Grey-black

- Reduced friction.
- Limited temperature resistance.
- Recommended for aluminium alloys, copper and non-metallic materials.



# HARDNESS

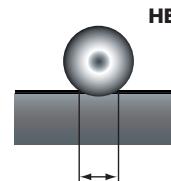
Hardness is the power needed to deform the matrix and to push the carbides away, but also a measure of how difficult it is to achieve a permanent deformation of the material.



Increased Co-content increases the matrix hardness, and increased Mo-, W- and V-content increases the amount of carbide that has to be pushed away.

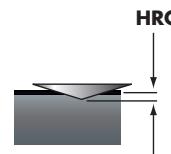
## Brinell

A hard steel, or carbide ball is pressed into the material at a given load. The diameter of the impression is measured and the hardness is obtained from a table. The hardness of soft annealed High Speed Steel is measured in Brinell.



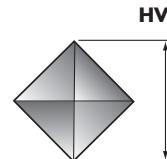
## Rockwell

A diamond cone with a top angle of  $120^\circ$  is pressed into the material at a given load. The impression depth gives the Rockwell hardness. The material surface must have a good finish, be clean and parallel with the bottom surface of the sample. The hardness of heat treated High Speed Steel is measured in Rockwell.



## Vickers

The Vickers hardness test uses a squarebase diamond pyramid. The angle between opposite faces of the pyramid is  $136^\circ$ . The diagonals of the square impression are measured under a microscope and the hardness can be obtained from a table. Vickers is commonly used today, because measurements done at different indentation loads can be compared directly. Hardness of a coating can be compared directly to a bulk hardness. The hardness of soft annealed or heat treated High Speed Steel is measured in Vickers.



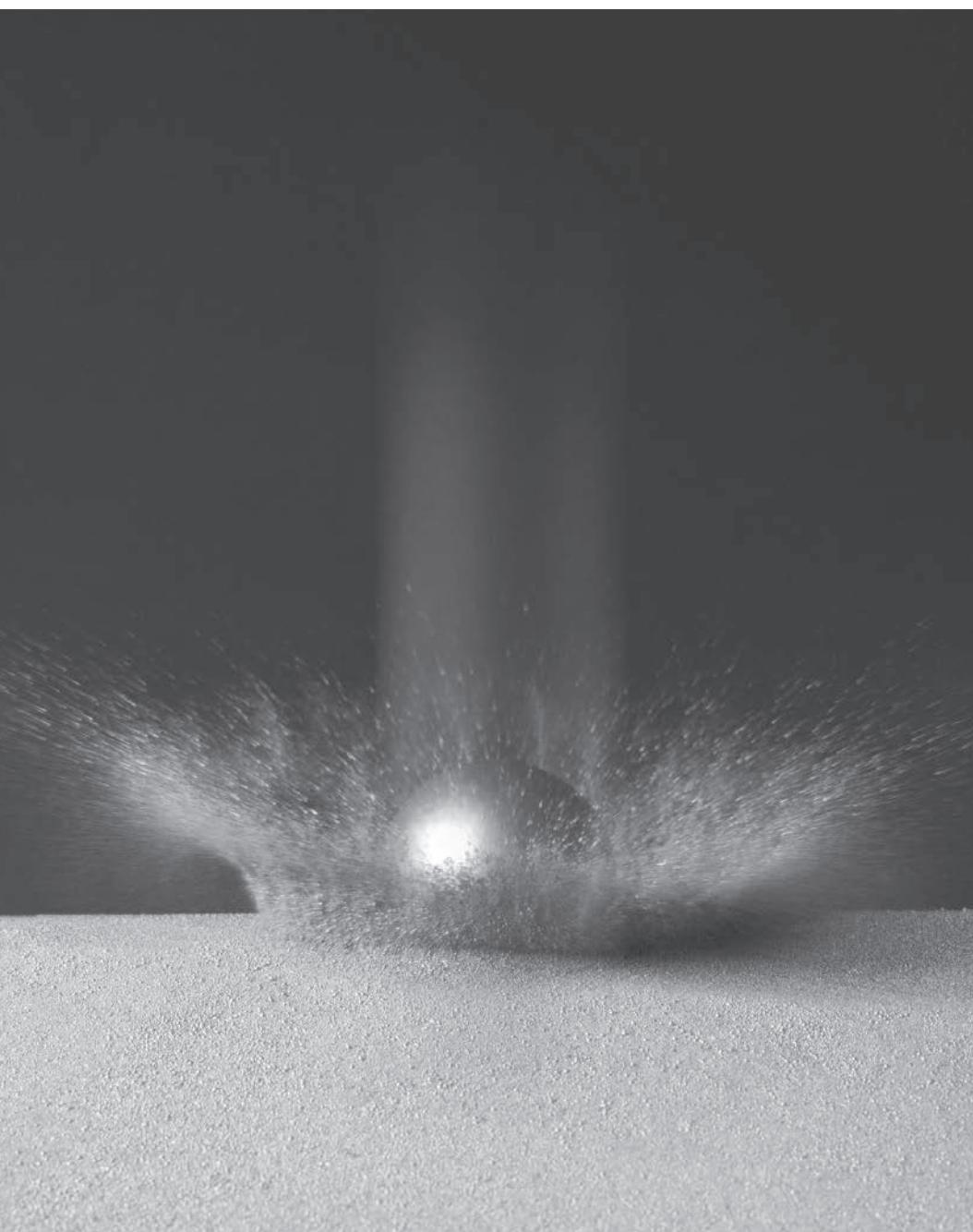
# HARDNESS

## Approximate conversion between hardness HV 10, HRC, HRB and HB

HV 10	HRC	HRB	HB
160	-	83	155
180	-	88	171
200	-	91.5	190
220	-	94.5	209
240	-	98	228
260	-	101	247
280	-	103	264
300	30	105.5	284
320	33	107	303
340	35	108	322
360	37	109	341
380	39	-	360
400	41	-	379
420	42.5	-	397
440	44	-	-
460	45.5	-	-
480	47	-	-
500	48.5	-	-
520	50	-	-
540	51	-	-
560	52.5	-	-
580	53.5	-	-
600	54.5	-	-
620	55.5	-	-
640	56.5	-	-
660	57.5	-	-
680	58	-	-
700	59	-	-
720	60	-	-
740	60.5	-	-
760	61.5	-	-
780	62.5	-	-
800	63	-	-
820	63.5	-	-
840	64.5	-	-
860	65	-	-
880	66	-	-
900	66.5	-	-
920	67	-	-
940	68	-	-
960	68.5	-	-
980	69	-	-
1000	69.5	-	-
1020	70	-	-
1040	70.5	-	-
1060	71	-	-



# PRODUCT OFFER



# ASP® AND HIGH SPEED STEEL GUIDE

ERASTEEL		Equivalent	Analysis, %					
Grades	C		Cr	Mo	W	Co	V	
ASP®, non Cobalt-grades	ASP 2004*	PM M4	1.40	4.2	5.0	5.8	-	4.1
	ASP 2005	-	1.50	4.0	2.5	2.5	-	4.0
	ASP 2009	PM 9% V	1.80	5.25	1.3	-	-	9.10
	ASP 2011	PM A11	2.45	5.25	1.3	-	-	9.75
	ASP 2012**	-	0.60	4.0	2.0	2.1	-	1.5
	ASP 2023	-	1.28	4.1	5.0	6.4	-	3.1
	ASP 2053	-	2.48	4.2	3.1	4.2	-	8.0
	ASP 2062	PM M62	1.30	3.75	10.5	6.25	-	2.0
ASP®, Cobalt-grades	ASP 2015	PM T15	1.55	4.0	-	12.0	5.0	5.0
	ASP 2017	-	0.80	4.0	3.0	3.0	8.0	1.0
	ASP 2030*	-	1.28	4.2	5.0	6.4	8.5	3.1
	ASP 2042	-	1.08	3.8	9.4	1.6	8.0	1.2
	ASP 2048*	PM M48	1.50	3.75	5.25	9.75	8.50	3.10
	ASP 2052	-	1.60	4.8	2.0	10.5	8.0	5.0
	ASP 2055	-	1.69	4.0	4.6	6.3	9.0	3.2
	ASP 2060	-	2.30	4.2	7.0	6.5	10.5	6.5
HSS, non Cobalt-grades	E T1	T1	0.75	4.1	-	18.0	-	1.1
	E M1	M1	0.83	3.8	8.5	1.8	-	1.2
	E M50	M50	0.84	4.0	4.2	-	-	1.1
	E M2	M2	0.90	4.2	5.0	6.4	-	1.8
	ABC III	-	0.99	4.1	2.7	2.8	-	2.4
	E M7	M7	1.02	3.8	8.6	1.8	-	1.9
	E M3:2	M3:2	1.20	4.1	5.0	6.2	-	3.0
	Grindamax™ V3	-	1.20	3.9	5.2	7.0	-	2.7
	E M4	M4	1.30	4.2	4.5	5.6	-	4.0
HSS, Cobalt-grades	E M35	M35	0.93	4.2	5.0	6.4	4.8	1.8
	C8	-	1.05	4.0	6.0	5.0	7.8	1.6
	E MAT II	-	0.72	4.0	5.0	1.0	8.0	1.0
	E M42	M42	1.08	3.8	9.4	1.5	8.0	1.2

\* also available with sulfur, \*\* Si 1.0%; Mn 0.3%

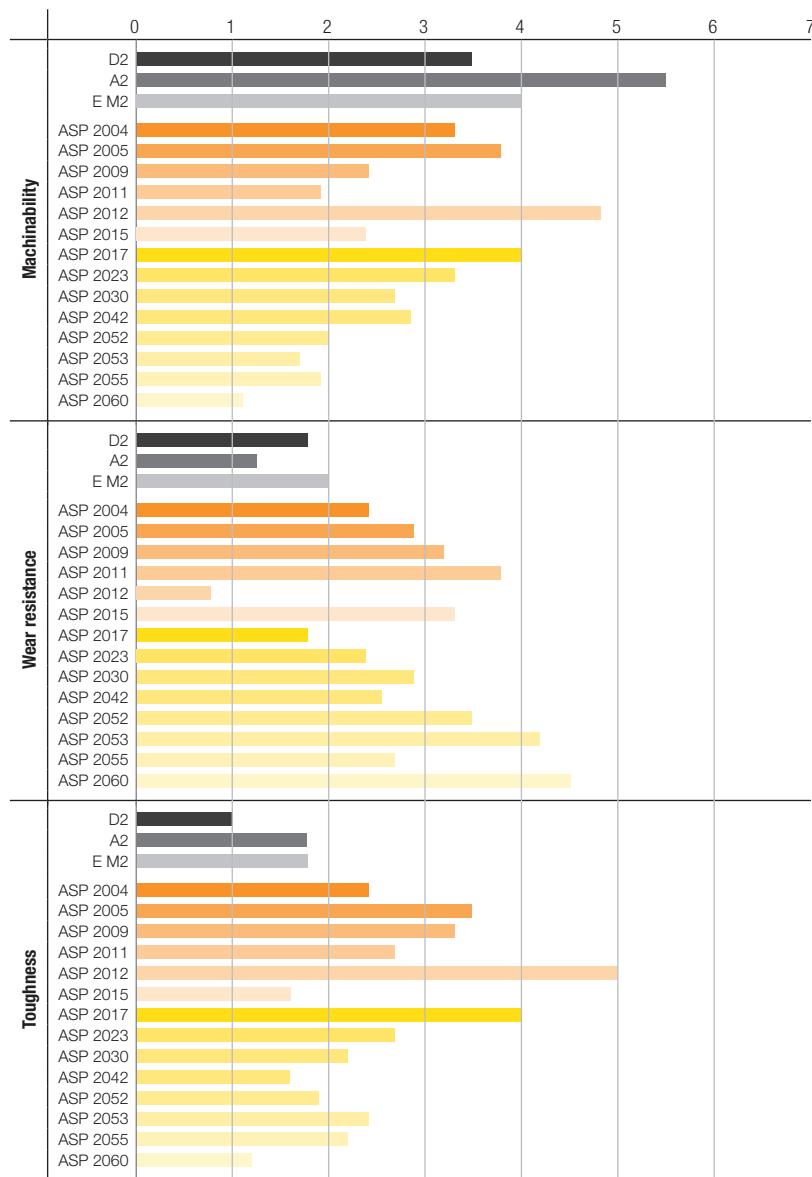
ERASTEEL		Hardness, HB		Analysis, %
	Grades	Annealed	Drawn	Characteristics and Applications
ASP®, non Cobalt-grades	ASP 2004*	260	300	Good wear resistance and hardness
	ASP 2005	260	310	Good wear resistance and toughness
	ASP 2009	270	-	Wear resistance and toughness for plastics extrusion
	ASP 2011	280	320	V-alloyed with high abrasion resistance
	ASP 2012**	230	-	Very high toughness for hot and cold work
	ASP 2023	260	320	Non-Co-grade for cold work and cutting tools Good wear resistance
	ASP 2053	300	340	V-alloyed grade for abrasive wear resistance
	ASP 2062	290	-	High red-hardness, good abrasive wear resistance
ASP®, Cobalt-grades	ASP 2015	280	300	High W-alloyed grade for high performance cutting
	ASP 2017	260	320	1% Nb. High toughness and excellent grindability
	ASP 2030*	300	320	Co-grade for high performance cutting and cold forming
	ASP 2042	280	320	Applications: flat thread rolling die / cross punch
	ASP 2048*	320	-	High alloyed for high performance cutting tools
	ASP 2052	300	320	High W-alloyed grade for high performance cutting Good wear resistance
	ASP 2055	320	340	2.1% Nb. High alloyed Co-grade with good grindability
	ASP 2060	340	-	For both hot hardness and wear resistance
HSS, non Cobalt-grades	E T1	270	320	W-alloyed grade for knives
	E M1	260	310	Mo-grade for taps, twist drills, dies and rolls
	E M50	260	300	Low alloyed grade for "Do-It-Yourself" drills
	E M2	260	310	Grade for general applications
	ABC III	250	320	Grade for metal saws and wear parts
	E M7	260	310	Grade for twist drills, taps, end mills, etc.
	E M3:2	270	320	M2 upgraded for higher wear resistance
	Grindamax™ V3	270	320	Grade with excellent grindability, ideal for taps
HSS, Cobalt-grades	E M4	280	320	Excellent wear resistance, for cold forming and rolls
	E M35	270	320	Grade for taps and general applications
	C8	280	320	8% Co-grade with improved hot hardness for end mills
	E MAT II	270	300	Grade for bimetal saws with good toughness
	E M42	280	320	Co-grade for cutting tools and bimetal bandsaws

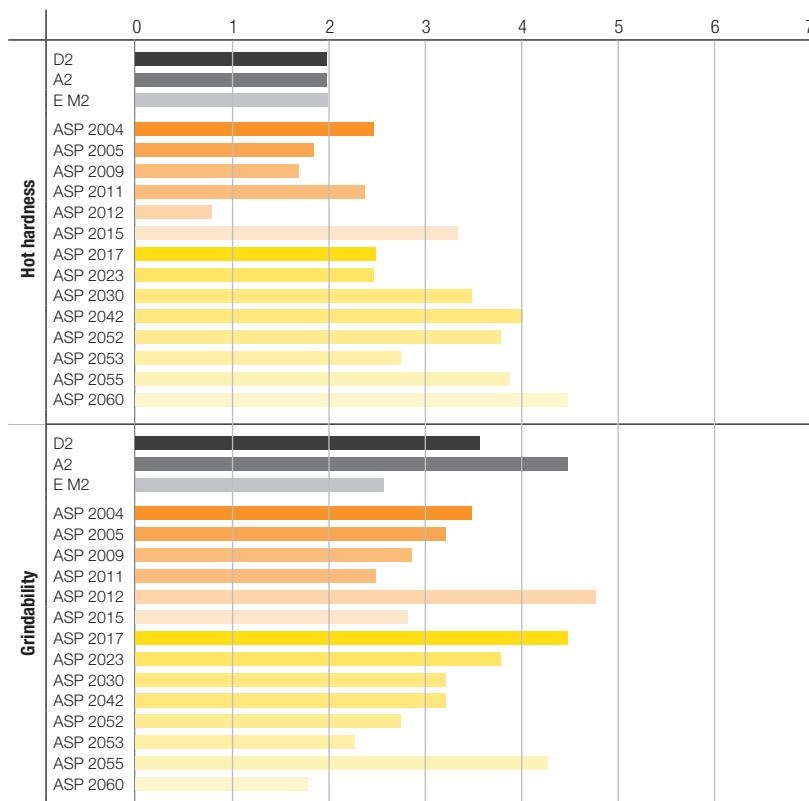
\* also available with sulfur, \*\* Si 1.0%; Mn 0.3%

# ASP® AND HIGH SPEED STEEL GUIDE

## Relative comparative mechanical properties for some tool steels and ASP® grades

The hardness for A2 and D2 are low temperature tempered.





# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2004 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	V
1.40	4.2	5.0	5.8	4.1

### STANDARDS

- Europe: HS 6-5-4
- USA: AISI M4

### DELIVERY HARDNESS

Soft annealed max. 260 HB

Cold drawn max. 300 HB

### DESCRIPTION

ASP® 2004 is a high Vanadium alloyed grade with high wear resistance and toughness suitable for cold work applications.

### FORM SUPPLIED

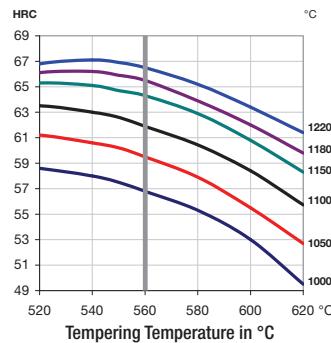
- Flat & square bars
- Round bars
- Forged blanks

Available surface conditions: drawn, ground, hot worked, peeled, rough machined, hot rolled.

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

### PROPERTIES

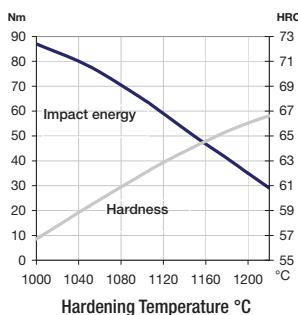
#### PHYSICAL PROPERTIES

	20°C	Temperature 400°C	600°C
Density g/cm³ (1)	8.0	7.9	7.8
Modulus of elasticity kN/mm² (2)	240	214	192
Specific heat J/kg °C (2)	420	510	600

(1) Soft annealed

(2) Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions Ø 14 mm

Tempering 3 x 1 hour at 560°C

	Approximate Conversion													
	°C	20	25	400	450	500	520	540	560	600	620	700	800	850
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP®2005 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.50	4.0	2.5	2.5	-	4.0

## STANDARDS

- Europe: HS 3-3-4

## DELIVERY HARDNESS

Soft annealed	max. 260 HB
Cold drawn	max. 310 HB
Cold rolled	max. 310 HB

## DESCRIPTION

ASP® 2005 is a grade for applications demanding high toughness.

## FORM SUPPLIED

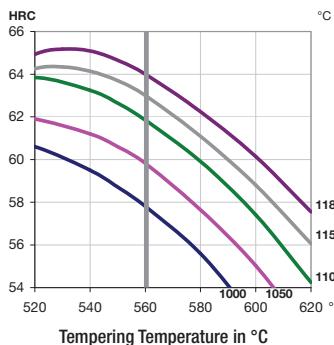
- Round bars
- Flat & square bars

Available surface conditions: drawn, ground, peeled, rough machined, hot rolled.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

## PROPERTIES

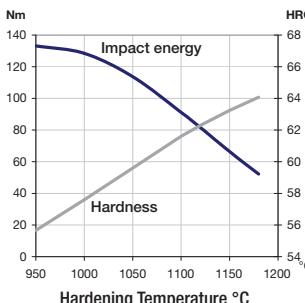
### PHYSICAL PROPERTIES

	Temperature 20°C	400°C	600°C
Density g /cm³ (1)	7.8	7.7	7.6
Modulus of elasticity kN/mm² (2)	220	195	175
Thermal expansion ratio per °C (2)	-	12,1x10⁻⁶	12,7x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1) Soft annealed

(2) Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions Ø 16 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2009 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	V
1.9	5.25	1.3	-	9.1

### DELIVERY HARDNESS

Soft annealed      max. 270 HB

### DESCRIPTION

ASP® 2009 is a high alloyed PM grade for applications where high wear resistance and toughness are needed.

### FORM SUPPLIED

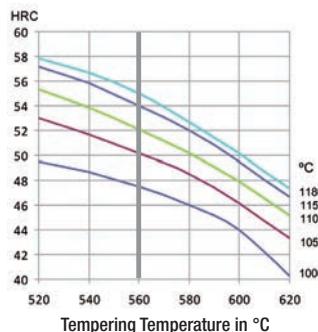
- Round bars
- Flat & square bars
- Forged blanks

Available surface conditions: drawn, ground, hot worked, peeled, rough machined, hot rolled.

### HEAT TREATMENT

- Soft annealing: heat in a protective atmosphere to 850-900°C, hold for 3 hours, slow cool at 10°C/h down to 700°C, then air cooling.
- Stress-relieving: heat to 600-700°C for approximately 2 hours, slow cool down to below 500°C.
- Hardening: use a protective atmosphere. Pre-heat in 2 steps at 450-500°C and 850-900°C. Austenitize at a temperature suitable for chosen working hardness. Quench down to 40-50°C or lower.
- Temper three times at 560°C. Hold at least 1 hour at temperature each time. Cool to room temperature (25°C) between tempers.

### GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

### PROPERTIES

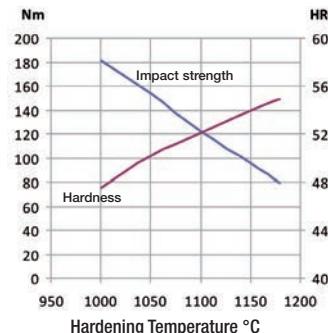
#### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	7.5	7.4	7.3
Modulus of elasticity kN/mm² (2)	221	197	177
Thermal expansion ratio per °C (2)	1.11x10⁻⁵	1.16x10⁻⁵	1.19x10⁻⁵

(1) Soft annealed

(2) Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions 9 x 12 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

	Approximate Conversion													
	°C	20	25	400	450	500	520	540	560	600	620	700	800	850
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP®2011 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
2.45	5.25	1.3	-	-	9.75

## STANDARDS

- USA: AISI A11

## DELIVERY HARDNESS

Soft annealed	max. 300 HB
Cold drawn	max. 320 HB
Cold rolled	max. 320 HB

## DESCRIPTION

ASP® 2011 is a high Vanadium grade for wear applications.

## FORM SUPPLIED

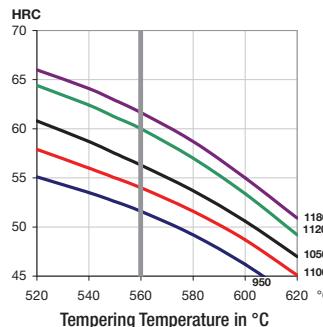
- Round bars
- Flat and square bars
- Sheets
- Discs
- Pieces cut from sheets

Available surface conditions: peeled, rough machined, cold rolled, hot rolled.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

## PROPERTIES

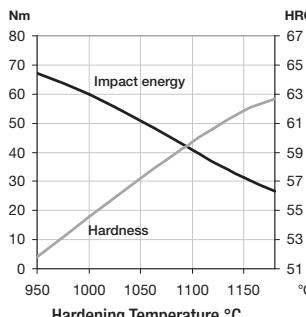
### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	7,4	7,3	7,3
Modulus of elasticity kN/mm² (2)	220	197	177
Thermal expansion ratio per °C (2)	-	11.8x10⁻⁶	12.3x10⁻⁶
Thermal conductivity W/m°C (2)	20	25	26
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions 9 x 12 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2012 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Si	Mn	Cr	Mo	W	V
0.60	1.0	0.3	4.0	2.0	2.1	1.5

### DELIVERY HARDNESS

Soft annealed max. 230 HB

### DESCRIPTION

ASP 2012® is a PM-HSS steel for hot and cold work applications, where high toughness is needed.

### FORM SUPPLIED

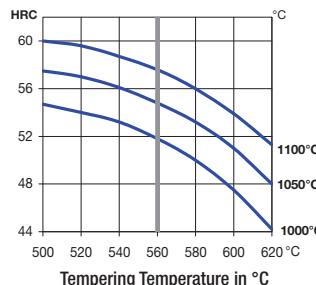
- Round bars
- Flat bars

Available surface conditions: Drawn, peeled, rough machined.

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850–900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600–700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450–500°C and 850–900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40–50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

### PROPERTIES

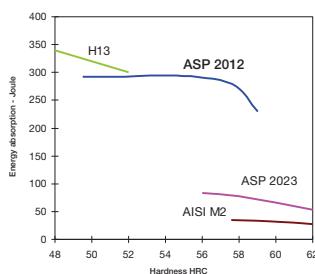
#### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	7.8	7.7	7.6
Modulus of elasticity kN/mm² (2)	220	195	175
Thermal expansion ratio per °C (2)	-	12.1x10⁻⁶	12.7x10⁻⁶

(1) Soft annealed

(2) Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Hardening Temperature °C

Original dimensions Ø 118 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

°C	Approximate Conversion													
	20	25	400	450	500	520	540	560	600	620	700	800	850	900
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP®2015 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.55	4.0	-	12	5.0	5.0

## STANDARDS

- USA: AISI T15
- Europe: HS 12-0-5-5
- Germany: W.Nr.1.3202

## DELIVERY HARDNESS

Soft annealed max. 280 HB  
Cold drawn max. 300 HB

## DESCRIPTION

ASP® 2015 is a high Tungsten alloy grade for high performance cutting tools.

## FORM SUPPLIED

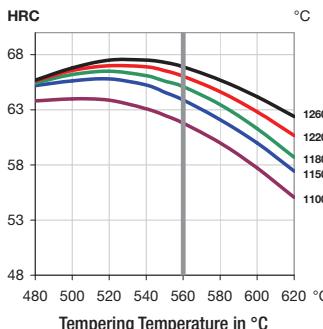
- Round bars
- Flat & square bars
- Forged blanks

Available surface conditions: drawn, centerless-ground, hot-worked, peeled, rough-machined, cold rolled, hot rolled.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.

## GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

## PROPERTIES

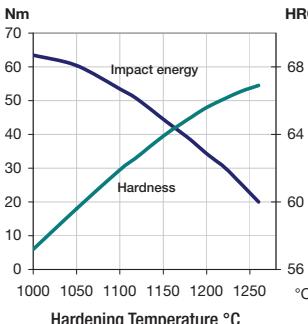
### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	8.2	8.1	8.0
Modulus of elasticity kN/mm² (2)	245	220	195
Thermal expansion ratio per °C (2)	-	11.0x10⁻⁶	11.7x10⁻⁶

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions 9 x 12 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2017 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V	Nb
0.80	4.0	3.0	3.0	8.0	1.0	1.0

### STANDARDS

- Europe: HS 3-3-1-8

### DELIVERY HARDNESS

Soft annealed	max. 260 HB
Cold drawn	max. 320 HB
Cold rolled	max. 320 HB

### DESCRIPTION

ASP® 2017 is a grade with high toughness and excellent grindability.

### FORM SUPPLIED

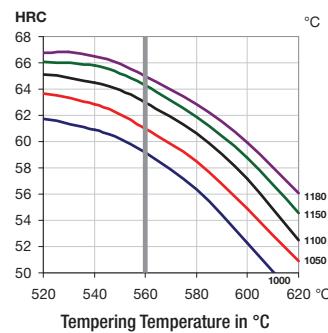
- Coils
- Forged blanks
- Round bars
- Flat & square bars

Available surface conditions: drawn, ground, hot worked, peeled, rough machined, cold rolled, hot rolled.

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850–900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600–700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450–500°C and 850–900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40–50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



Tempering time 3x1 hour at 560°C

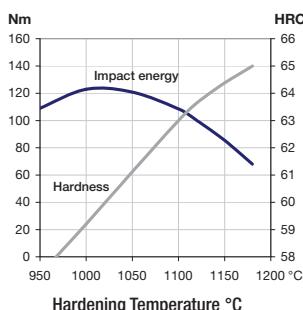
### PROPERTIES

#### PHYSICAL PROPERTIES

	Temperature		
	20°C	400°C	600°C
Density g/cm³ (1)	8.0	7.9	7.8
Modulus of elasticity kN/mm² (2)	235	210	190
Thermal conductivity W/m°C (3)	20	27.5	29
Specific heat J/kg °C (2)	420	510	600

- (1) Soft annealed  
(2) Hardened 1180°C and tempered 560°C, 3x1 hour  
(3) Hardened 1100°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions Ø 14 mm  
Tempering 3 x 1 hour at 560°C

	Approximate Conversion													
	°C	20	25	400	450	500	520	540	560	600	620	700	800	850
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP®2023 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.28	4.0	5.0	6.4	-	3.1

## STANDARDS

- USA: AISI (M3:2)
- Europe: HS 6-5-3
- Germany: W.Nr. 1.3344
- Sweden: SS 2725
- Japan: JIS SKH53

## DELIVERY HARDNESS

Soft annealed	max. 260 HB
Cold drawn	max. 300 HB
Cold rolled	max. 320 HB

## DESCRIPTION

ASP® 2023 is a non Cobalt grade for high performance cutting tools, cold work tools and rolls for cold rolling.

## FORM SUPPLIED

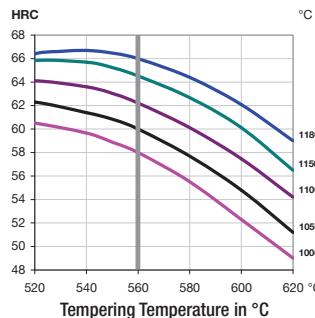
- Round bars
- Flat & square bars
- Strips
- Sheets
- Discs

Available surface conditions: drawn, ground, peeled, rough machined, cold rolled, hot rolled.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

## PROPERTIES

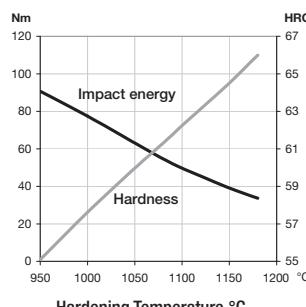
### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	8.0	7.9	7.9
Modulus of elasticity kN/mm² (2)	230	205	184
Thermal expansion ratio per °C (2)	-	12.1x10⁻⁶	12.7x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions 9 x 12 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2030 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.28	4.2	5.0	6.4	8.5	3.1

### STANDARDS

- Europe: HS 6-5-3-8

### DELIVERY HARDNESS

Soft annealed	max. 300 HB
Cold drawn	max. 320 HB
Cold rolled	max. 320 HB

### DESCRIPTION

ASP® 2030 is a Cobalt grade for high performance cutting tools.

### FORM SUPPLIED

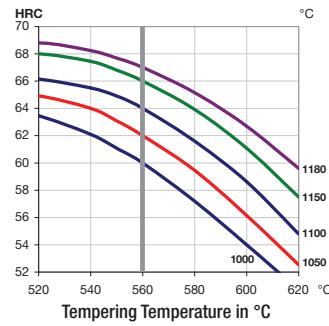
- Round bars
- Flat & square bars
- Sheets
- Forged blanks

Available surface conditions: drawn, ground, hot worked, peeled, rough machined.

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850–900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600–700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450–500°C and 850–900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40–50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



### PROPERTIES

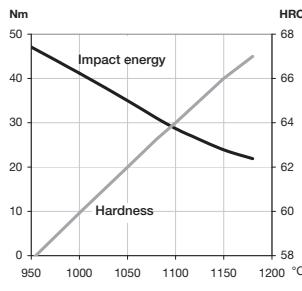
#### PHYSICAL PROPERTIES

	20°C	Temperature 400°C	600°C
Density g /cm³ (1)	8.1	7.9	7.9
Modulus of elasticity kN/mm² (2)	240	214	192
Thermal expansion ratio per °C (2)	-	11.8x10⁻⁶	12.3x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions 9 x 12 mm - Tempering 3 x 1 hour at 560°C - Unnotched test piece 7 x 10 x 55 mm

°C	Approximate Conversion													
	20	25	400	450	500	520	540	560	600	620	700	800	850	900
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP®2042 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.08	3.8	9.4	1.5	8.0	1.2

## STANDARDS

- USA: AISI M42
- Europe: HS 2-9-1-8, ~1.3247
- Japan: JIS SKH59

## DELIVERY HARDNESS

Soft annealed	max. 280 HB
Cold drawn	max. 320 HB
Cold rolled	max. 320 HB

## DESCRIPTION

ASP® 2042 is a PM HSS grade with high hardness and high toughness. It is an upgraded material in particular in applications where standard M42 is traditionally used. This grade offers the highest combination between high hardness and excellent grindability.

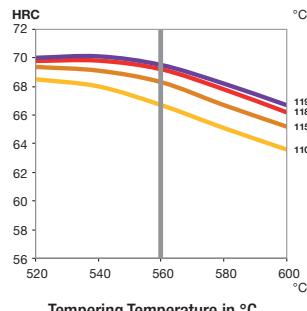
## FORM SUPPLIED

- Bimetal edge wire
- Round bars
- Flat bars

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850–900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600–700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere at a temperature suitable for chosen working hardness. Pre-heating in 2 or 3 steps depending on tool dimension-design and austenitising temperature, last step 50°C below chosen austenitising temperature. Cooling down to 40–50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Hardness after hardening, quenching and tempering 3x1 hour

## PROPERTIES

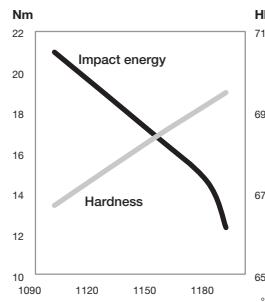
### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g /cm³ (1)	8.0	7.9	7.9
Modulus of elasticity kN/mm² (2)	225 33x10⁶	200 29x10⁶	180 26x10⁶
Thermal expansion ratio per °C (2)	-	11.5x10⁻⁶	11.8x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Hardening Temperature °C

Original dimensions 70 x 15 mm  
Tempering 3 x 1 hour at 560°C  
Unnotched test piece 7 x 10 x 55 mm

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2052 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
1.60	4.8	2.0	10.5	8.0	5.0

### STANDARDS

- Europe: HS 10-2-5-8

### DELIVERY HARDNESS

Soft annealed max. 300 HB  
Cold drawn max. 320 HB

### DESCRIPTION

ASP® 2052 is a high W-alloyed grade for high performance cutting tools.

### FORM SUPPLIED

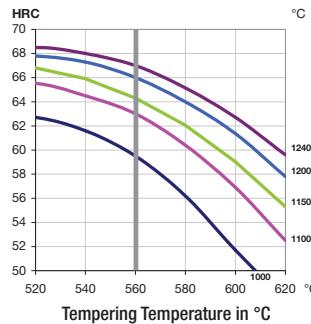
- Round bars

Available surface conditions: drawn, ground, peeled, rough machined, hot rolled.

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



Tempering time 3x1 hour at 560°C

### PROPERTIES

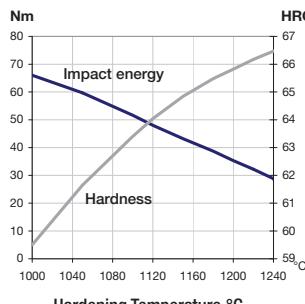
#### PHYSICAL PROPERTIES

	20°C	Temperature 400°C	600°C
Density g /cm³ (1)	8.2	8.1	8.1
Modulus of elasticity kN/mm² (2)	245	218	196
Thermal expansion ratio per °C (2)	-	11.2x10⁻⁶	11.7x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions 70 x 15 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

# ASP®2053 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
2.48	4.2	3.1	4.2	-	8.0

## STANDARDS

- Europe: HS 4-3-8

## DELIVERY HARDNESS

Soft annealed	max. 300 HB
Cold drawn	max. 340 HB
Cold rolled	max. 340 HB

## DESCRIPTION

ASP® 2053 is a high V-alloyed grade with excellent abrasive wear resistance.

## FORM SUPPLIED

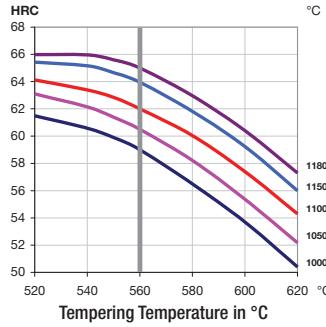
- Coils
- Sheets
- Round bars
- Discs
- Forged blanks
- Flat & square bars

Available surface conditions: drawn, ground, peeled, rough machined, hot rolled.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Tempering time 3x1 hour at 560°C

## PROPERTIES

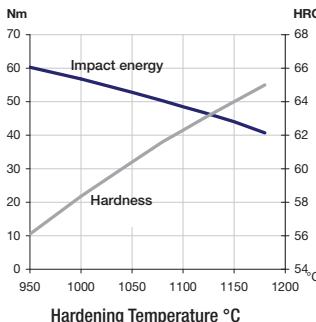
### PHYSICAL PROPERTIES

	Temperature		
	20°C	400°C	600°C
Density g /cm³ (1)	7.7	7.6	7.5
Modulus of elasticity kN/mm² (2)	250	220	200
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions Ø 16 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

	Approximate Conversion													
	°C	20	25	400	450	500	520	540	560	600	620	700	800	850
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# ASP® OFFER FOR COLD WORK APPLICATIONS

## ASP®2055 POWDER METALLURGY HSS

### CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V	Nb
1.69	4.0	4.6	6.3	9.0	3.2	2.1

### STANDARDS

- Not yet standardised

### DELIVERY HARDNESS

Soft annealed	max. 320 HB
Cold drawn	max. 340 HB
Cold rolled	max. 340 HB

### DESCRIPTION

ASP® 2055 is a high alloyed PM-HSS grade with a refined carbide structure for high demanding cutting and cold work applications.

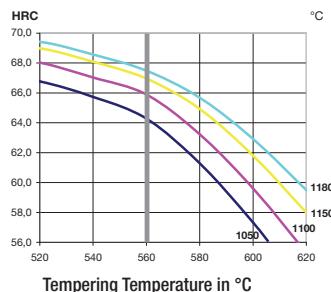
### FORM SUPPLIED

- Peeled bars
- Drawn & Ground bars

### HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

### GUIDELINES FOR HARDENING



Approximate values of hardness after hardening, quenching and tempering 3x1 hour

### PROPERTIES

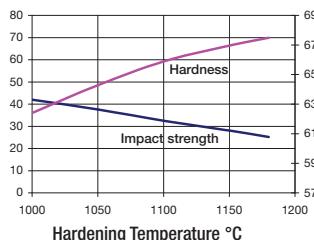
#### PHYSICAL PROPERTIES

	20°C	Temperature 400°C	600°C
Density g /cm³ (1)	8.0	7.9	7.9
Modulus of elasticity kN/mm² (2)	240	214	192
Thermal expansion ratio per °C (2)	-	11.8x10⁻⁶	12.3x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

### IMPACT STRENGTH



Original dimensions 9 x 12 mm  
Tempering 3 x 1 hour at 560° C  
Unnotched test piece 7 x 10 x 55 mm

# ASP®2060 POWDER METALLURGY HSS

## CHEMICAL COMPOSITION

C	Cr	Mo	W	Co	V
°C					
2.30	4.2	7.0	6.5	10.5	6.5

## STANDARDS

- Europe: PMHS 7-7-7-11
- Germany: W.Nr. 1.3292

## DELIVERY HARDNESS

Soft annealed max. 340 HB

## DESCRIPTION

ASP® 2060 is a very high alloyed grade for applications requiring both hot hardness and wear resistance.

## FORM SUPPLIED

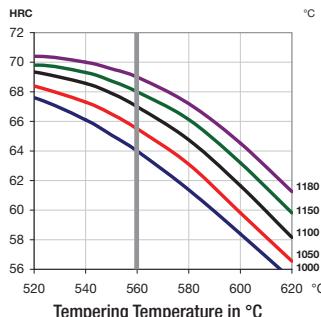
- Round bars
- Forged bars
- Flat & square bars

Available surface conditions: drawn, ground, hot worked, peeled, rough machined.

## HEAT TREATMENT

- Soft annealing in a protective atmosphere at 850-900°C for 3 hours, followed by slow cooling at 10°C/h down to 700°C, then air cooling.
- Stress-relieving at 600-700°C for approximately 2 hours, slow cooling down to 500°C.
- Hardening in a protective atmosphere with pre-heating in 2 steps at 450-500°C and 850-900°C and austenitizing at a temperature suitable for chosen working hardness. Cooling down to 40-50°C.
- Tempering at 560°C three times for at least 1 hour each time. Cooling to room temperature (25°C) between temperings.

## GUIDELINES FOR HARDENING



Tempering time 3x1 hour at 560°C

## PROPERTIES

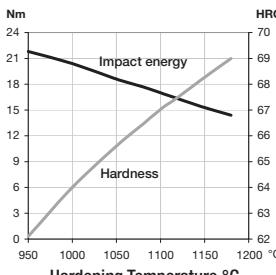
### PHYSICAL PROPERTIES

	20°C	400°C	600°C
Density g/cm³ (1)	7.9	7.9	7.8
Modulus of elasticity kN/mm² (2)	250	222	200
Thermal expansion ratio per °C (2)	-	10.6x10⁻⁶	11.1x10⁻⁶
Thermal conductivity W/m°C (2)	24	28	27
Specific heat J/kg °C (2)	420	510	600

(1)=Soft annealed

(2)=Hardened 1180°C and tempered 560°C, 3x1 hour

## IMPACT STRENGTH



Original dimensions 9 x 12 mm

Tempering 3 x 1 hour at 560°C

Unnotched test piece 7 x 10 x 55 mm

°C	Approximate Conversion													
	20	25	400	450	500	520	540	560	600	620	700	800	850	900
°F	70	80	750	840	930	970	1000	1040	1110	1150	1290	1470	1560	1650

# MACHINING DATA

## ASP® 2005

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		130–170	170–220	18–25
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	18–25 0.015–0.030	18–25 0.03–0.04	18–25 0.04–0.05	18–25 0.05–0.06	18–25 0.07–0.08
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	70–100 0.006–0.01	70–100 0.01–0.02	70–100 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	130–180 0.06–0.10	130–180 0.10–0.12	130–180 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

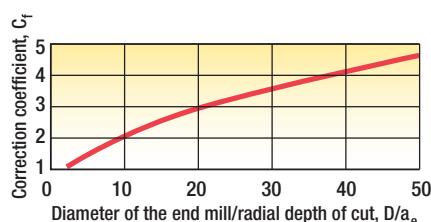
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 160 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	120–150	150–200
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	130–160	120–150	110–140
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3150 or SECO T15M.

DRILLING	DRILL DIAMETER (mm)					
	1–5	5–10	10–20	20–30	30–40	
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	8–14 0.05–0.15	8–14 0.15–0.25	8–14 0.25–0.35	8–14 0.35–0.40	8–14 0.40–0.45
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	25–30 0.05–0.15	25–30 0.15–0.25	25–30 0.25–0.35	25–30 0.35–0.40	25–30 0.40–0.45
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	140–160 0.08–0.12	140–160 0.10–0.14
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	80–110 0.1–0.15	80–110 0.1–0.15	80–110 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45 0.1–0.2	45 0.1–0.2	45 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2005 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2012

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		190–220	220–250	21–26
Feed, $f$ (mm/rev)		0.2–0.5	0.05–0.3	0.05–0.4
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	35–45 0.008–0.02	35–45 0.02–0.04	35–45 0.03–0.05	35–45 0.05–0.07	35–45 0.05–0.09
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	100–120 0.006–0.02	100–120 0.01–0.03	100–120 0.02–0.05	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	170–200 0.06–0.12	170–200 0.10–0.15	170–200 0.15–0.25
Suitable tools	-	coated carbide, K15, P25				

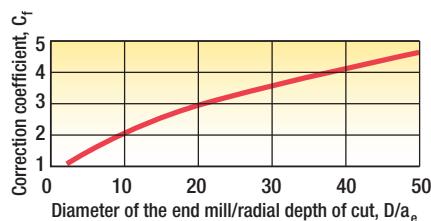
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 180 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	170-200	220-250
Feed, $f_z$ (mm/tooth)	0.2-0.4	0.1-0.4
Cutting depth, $a_p$ (mm)	2-4	1-2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	230-250	210-240	170-220
Feed, $f_z$ (mm/tooth)	0.3	0.2	0.15
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3020 or SECO TP10.

DRILLING	DRILL DIAMETER (mm)				
	1-5	5-10	10-20	20-30	30-40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	12-18 0.05-0.12	12-18 0.15-0.23	12-18 0.25-0.34	12-18 0.35-0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	35-40 0.05-0.12	35-40 0.15-0.3	35-40 0.25-0.4	35-40 0.35-0.5
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	150-170 0.08-0.12
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	60 0.1-0.12	60 0.1-0.12
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	50 0.1-0.3	50 0.1-0.3

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2012 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2015

Recommendations for machining in soft annealed condition, 260–230 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		110–140	130–150	15–20
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	20–25 0.005–0.01	20–25 0.01–0.02	20–25 0.02–0.03	20–25 0.03–0.05	20–25 0.05–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	45–55 0.006–0.01	45–55 0.01–0.02	45–55 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	100–130 0.06–0.10	100–130 0.10–0.12	100–130 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

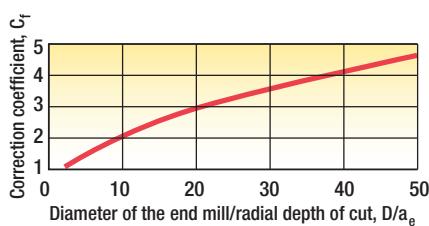
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 120 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	90–120	90–120
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	140–160	110–140	100–130
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3020 or SECO TP10.

DRILLING	DRILL DIAMETER (mm)					
	1–5	5–10	10–20	20–30	30–40	
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	8–14 0.05–0.15	8–14 0.15–0.25	8–14 0.25–0.35	8–14 0.35–0.40	8–14 0.40–0.45
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	25–30 0.05–0.15	25–30 0.15–0.25	25–30 0.25–0.35	25–30 0.35–0.40	25–30 0.40–0.45
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	110–130 0.08–0.12	110–130 0.10–0.14
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	40 0.1–0.15	40 0.1–0.15	40 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	35 0.1–0.2	35 0.1–0.2	35 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2015 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2017

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		170–200	200–230	18–25
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	30–40 0.008–0.015	30–40 0.02–0.03	30–40 0.03–0.04	30–40 0.05–0.06	30–40 0.07–0.08
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	90–110 0.006–0.01	90–110 0.01–0.02	90–110 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	160–190 0.06–0.10	160–190 0.10–0.12	160–190 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

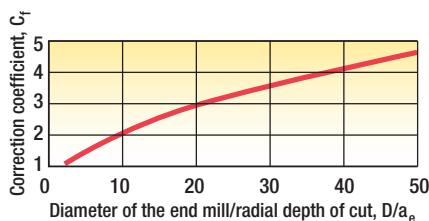
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 170 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	140–170	170–200
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	200–220	180–200	160–190
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3150 or SECO T15M.

DRILLING	DRILL DIAMETER (mm)					
	1–5	5–10	10–20	20–30	30–40	
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	8–14 0.05–0.15	8–14 0.15–0.25	8–14 0.25–0.35	8–14 0.35–0.40	8–14 0.40–0.45
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	30–35 0.05–0.15	30–35 0.15–0.25	30–35 0.25–0.35	30–35 0.35–0.40	30–35 0.40–0.45
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	140–160 0.08–0.12	140–160 0.10–0.14
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	50 0.1–0.15	50 0.1–0.15	50 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45 0.1–0.2	45 0.1–0.2	45 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2017 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2023

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		110–160	160–210	12–20
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	16–18 0.015–0.030	16–18 0.03–0.04	16–18 0.04–0.05	16–18 0.05–0.06	16–18 0.07–0.08
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	40–45 0.006–0.01	40–45 0.01–0.02	40–45 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	90–120 0.06–0.10	90–120 0.10–0.12	90–120 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

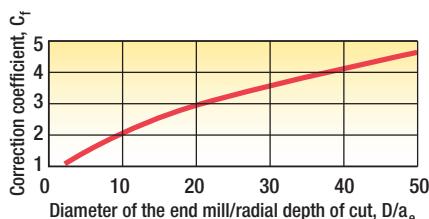
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.20 = 0.56 \text{ mm/tooth}$
- Cutting speed:  $v_c = 100 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	110–120	130–140
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	120–150	110–140	100–130
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3150 or SECO T15M.

DRILLING	DRILL DIAMETER (mm)					
	1–5	5–10	10–20	20–30	30–40	
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	12–14 0.05–0.15	12–14 0.15–0.25	12–14 0.25–0.35	12–14 0.35–0.40	12–14 0.40–0.45
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	18–20 0.05–0.15	18–20 0.15–0.25	18–20 0.25–0.35	18–20 0.35–0.40	18–20 0.40–0.45
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	120–150 0.08–0.10	120–150 0.10–0.14
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45–50 0.1–0.15	45–50 0.1–0.15	45–50 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	35–40 0.1–0.2	35–40 0.1–0.2	35–40 0.2–0.3

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2023 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2030

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		80–110	110–140	10–15
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	14–16 0.015–0.03	14–16 0.03–0.04	14–16 0.04–0.05	14–16 0.05–0.06	14–16 0.06–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	35–40 0.006–0.01	35–40 0.01–0.02	35–40 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	70–90 0.06–0.10	70–90 0.10–0.12	70–90 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

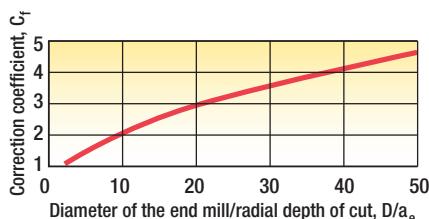
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 80 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	60–80	80–110
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	100–130	90–120	80–100
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3150 or SECO T15M.

DRILLING	DRILL DIAMETER (mm)				
	1–5	5–10	10–20	20–30	30–40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	10–12 0.05–0.15	10–12 0.15–0.25	10–12 0.25–0.35	10–12 0.35–0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	15–20 0.05–0.15	15–20 0.15–0.25	15–20 0.25–0.35	15–20 0.35–0.40
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	120–130 0.08–0.10
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45–50 0.1–0.15	45–50 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	32 0.1–0.2	32 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2030 has been machined in hardened condition up to 66 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2052

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		80–110	110–140	10–15
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	14–16 0.015–0.03	14–16 0.03–0.04	14–16 0.04–0.05	14–16 0.05–0.06	14–16 0.06–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	35–40 0.006–0.03	35–40 0.03–0.02	35–40 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	70–90 0.06–0.10	70–90 0.10–0.12	70–90 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

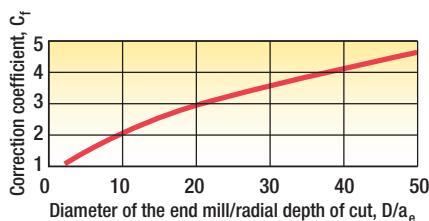
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 80 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	60–80	80–110
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	100–130	90–120	80–110
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3150 or SECO T15M.

DRILLING	DRILL DIAMETER (mm)				
	1–5	5–10	10–20	20–30	30–40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	10–12 0.05–0.15	10–12 0.15–0.25	10–12 0.25–0.35	10–12 0.35–0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	15–20 0.05–0.15	15–20 0.15–0.25	15–20 0.25–0.35	15–20 0.35–0.40
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	120–130 0.08–0.12
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45–50 0.1–0.15	45–50 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	32 0.1–0.2	32 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2052 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2053

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		80–110	110–130	10–15
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	15–20 0.005–0.01	15–20 0.01–0.02	15–20 0.02–0.03	15–20 0.03–0.05	15–20 0.05–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	40–45 0.006–0.01	40–45 0.01–0.02	40–45 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	80–110 0.06–0.10	80–110 0.10–0.12	80–110 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

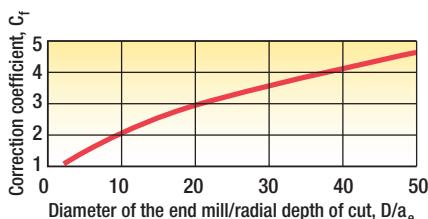
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 50 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	60–90	90–120
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	120–140	100–120	80–110
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3020 or SECO TP10.

DRILLING	DRILL DIAMETER (mm)				
	1–5	5–10	10–20	20–30	30–40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	5–10 0.05–0.15	5–10 0.15–0.25	5–10 0.25–0.35	5–10 0.35–0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	15–20 0.05–0.15	15–20 0.15–0.25	15–20 0.25–0.35	15–20 0.35–0.40
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	90–110 0.08–0.12
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	35 0.1–0.15	35 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	30 0.1–0.2	30 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2053 has been machined in hardened condition up to 65 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2055

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		90–120	110–130	10–15
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	15–17 0.015–0.03	15–17 0.03–0.04	15–17 0.04–0.05	15–17 0.05–0.06	15–17 0.06–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	40–45 0.006–0.01	40–45 0.01–0.03	40–45 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	70–90 0.06–0.10	70–90 0.10–0.12	70–90 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

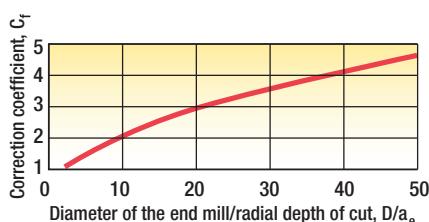
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 90 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	70–90	90–110
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	110–130	100–120	90–110
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3020 or SECO TP10.

DRILLING	DRILL DIAMETER (mm)				
	1–5	5–10	10–20	20–30	30–40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	10–12 0.05–0.15	10–12 0.15–0.25	10–12 0.25–0.35	10–12 0.35–0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	15–20 0.05–0.15	15–20 0.15–0.25	15–20 0.25–0.35	15–20 0.35–0.40
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	120–130 0.08–0.10
Solid	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	45–50 0.1–0.15	45–50 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	32 0.1–0.2	32 0.1–0.2

TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2055 has been machined in hardened condition up to 66 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# MACHINING DATA

## ASP® 2060

Recommendations for machining in soft annealed condition, 260–300 HB.

TURNING		CEMENTED CARBIDE		HSS
		medium turning	finish turning	
Cutting speed, $v_c$ (m/min)		60–90	90–110	8–10
Feed, $f$ (mm/rev)		0.2–0.4	0.05–0.2	0.05–0.3
Cutting depth, $a_p$ (mm)		2–4	0.5–2	0.5–3
Tools according to ISO		coated carbide P10–P20	coated carbide P10	coated

Use a wear resistant coated cemented carbide, e.g. Coromant 4015 or Seco TP 100.

Black ceramics are usually the best tools at finish turning, e.g. Coromant 650 or Feldmühle SH20.

END MILLING, SLOT MILLING		DIAMETER (mm)				
		3–5	5–10	10–20	20–30	30–40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	10–15 0.015–0.030	10–15 0.03–0.04	10–15 0.02–0.03	10–15 0.05–0.05	10–15 0.05–0.07
Coated solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	30–35 0.006–0.01	30–35 0.01–0.02	30–35 0.02–0.04	-	-
Indexable carbide tips	cutting speed, $v_c$ (m/min) feed, $f_z$ (mm/tooth)	-	-	40–60 0.06–0.10	40–60 0.10–0.12	40–60 0.15–0.20
Suitable tools	-	coated carbide, K15, P25				

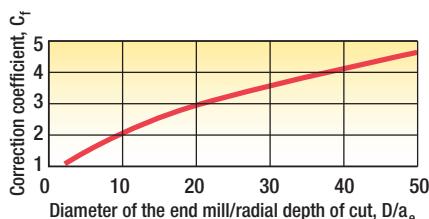
## SIDE MILLING

The same cutting speed can be used in side milling as in slot milling. However, the feed has to be adjusted to produce an adequate chip thickness.

The diameter of the mill ( $D$ ) over the radial depth of cut ( $a_e$ ) is used as a parameter. Read the correction coefficient ( $C_f$ ) from the diagram and multiply by the feed for slot milling from the table above.

### Comments (slot and side milling)

1. Coated tools are always recommended for end milling both with HSS tools and cemented carbide tools. TiCN, TiAlN or multilayer (Futura) is preferred.
2. The cutting speed must be decreased considerably if uncoated tools are used.



### Example

- Tool: End mill with indexable tips
- Diameter of the end mill:  $D = 40 \text{ mm}$
- Radial depth of cut:  $a_e = 2 \text{ mm}$
- $D/a_e$ :  $40/2 = 20$
- Correction coefficient:  $C_f = 2.8$
- Feed:  $f_z = 2.8 \times 0.17 = 0.48 \text{ mm/tooth}$
- Cutting speed:  $v_c = 50 \text{ m/min}$

FACE MILLING	CEMENTED CARBIDE TOOL	
	rough machining	finish machining
Cutting speed, $v_c$ (m/min)	40–60	60–80
Feed, $f_z$ (mm/tooth)	0.2–0.3	0.1–0.2
Cutting depth, $a_p$ (mm)	2–4	1–2
Tools according to ISO	coated cemented carbide K15, P25	

SQUARE SHOULDER MILLING	RADIAL DEPTH OF CUT, $a_e$		
	$a_e = 0.1 \times D$	$a_e = 0.5 \times D$	$a_e = 1 \times D$
Cutting speed, $v_c$ (m/min)	60–80	50–70	40–60
Feed, $f_z$ (mm/tooth)	0.25	0.15	0.10
Tools according to ISO	coated carbide K15, P25		

Use a wear resistant coated cemented carbide, e.g. Coromant 3020 or SECO TP10.

DRILLING	DRILL DIAMETER (mm)				
	1–5	5–10	10–20	20–30	30–40
HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	5–10 0.05–0.15	5–10 0.15–0.25	5–10 0.25–0.35	5–10 0.35–0.40
Coated HSS	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	10–15 0.05–0.15	10–15 0.15–0.25	10–15 0.25–0.35	10–15 0.35–0.40
Short hole drill indexable (cemented carbide)	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	-	80–100 0.08–0.12
Solid cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	30 0.1–0.15	30 0.1–0.15
Brazed cemented carbide	cutting speed, $v_c$ (m/min) feed, $f$ (mm/rev)	-	-	25 0.1–0.2	25 0.1–0.2

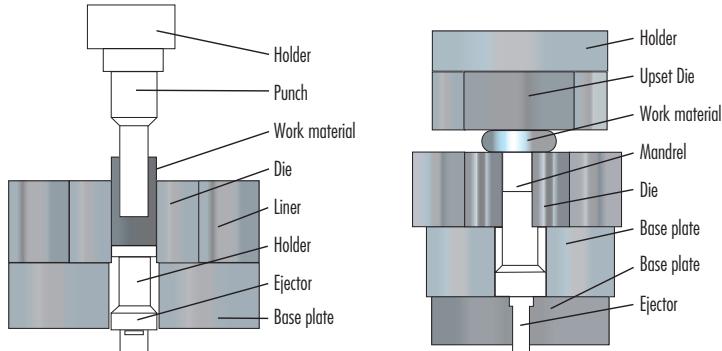
TiCN or TiAlN multi layer are recommended coatings for HSS drilling.

### Machining in hardened condition

ASP® 2060 has been machined in hardened condition up to 67 HRC. CBN tools are recommended. Whisker reinforced ceramics (Coromant 670 or Kennametal 4300) can be used in turning, but the tool life is shorter and more difficult to predict.

# ASP® STEEL RECOMMENDATIONS...

## For cold forging



Element	Steel grade	Hardness (HRC)	N.B.
Base plate	ASP 2005 ASP 2023/ASP 2004	61-64 62-64	
Upper punch	ASP 2030 ASP 2005 ASP 2023/ASP 2004	63-65 62-64 63-64	PDV Coating
Punch	ASP 2030 ASP 2005/ASP 2053 ASP 2023/ASP 2004	63-65 62-64 62-63	
Mandrel	ASP 2030 ASP 2005 ASP 2012	63-65 62-64 56-58	Nitrided/ PVD Coating
Die	ASP 2005 / ASP 2030 ASP 2023 / ASP 2004 ASP 2017	62-64 62-64 62-64	
Base plate	Hot work steels		
Holder	ASP 2005 ASP 2023/ASP 2004	62-64 62-64	
Ejector	ASP 2012 ASP 2005/ASP 2023	57-58 60-62	PVD Coating

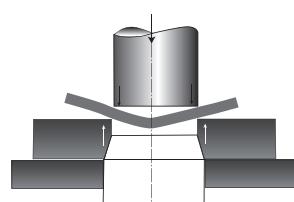
## For blanking and punching

Steel grade	Tool design	Work materials, thickness strength 400-600 N/mm <sup>2</sup> ~ 30-80 ksi					Hard materials	Tough materials non ferrous materials
		0.5-2 mm 0.02-0.08 in	2-3 mm 0.08-0.12 in	3-6 mm 0.12-0.24 in	6-8 mm 0.24-0.31 in	>8 mm >0.31 in		
ASP 2005	●	64	63	62	60	-	62-58	64-60
	■	63	62	61	60	-		
	▲	63	62	61	60	-		
ASP 2012	●	-	-	-	58	58	58	58
	■	-	-	-	58	58		
	▲	-	-	57	58	58		
ASP 2023/ 2030 2004	●	65	63	61	58	-	63-60	65-60
	■	64	62	60	-	-		
	▲	63	61	59	-	-		
ASP 2052/ 2055 2053	●	-	64/65	62	61	-	62-60	66-60
	■	66	63	60	-	-		
	▲	65	63	60	-	-		
EM2	●	64	62	61	59	-	62-59	64-60
	■	63	62	60	-	-		
	▲	62	61	59	-	-		

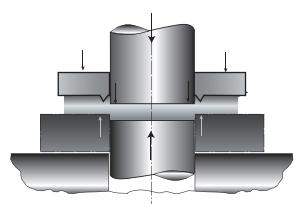
● simple tool design

■ normal tool design

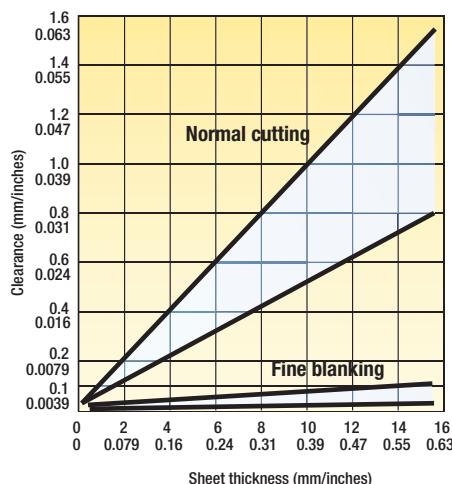
▲ complicated tool design



Principle of normal blanking.

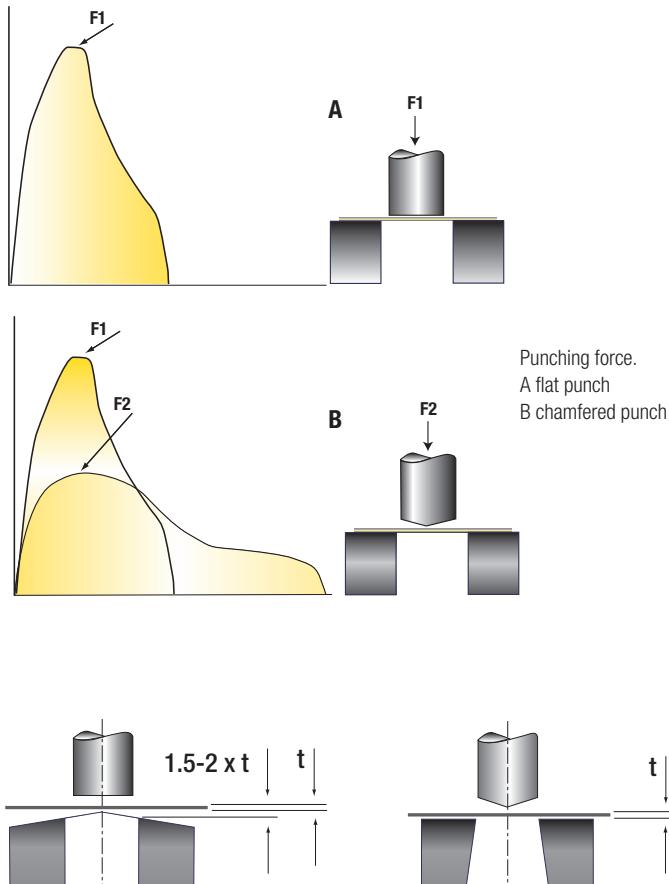


Principle of fine blanking.



## Reducing blanking pressure

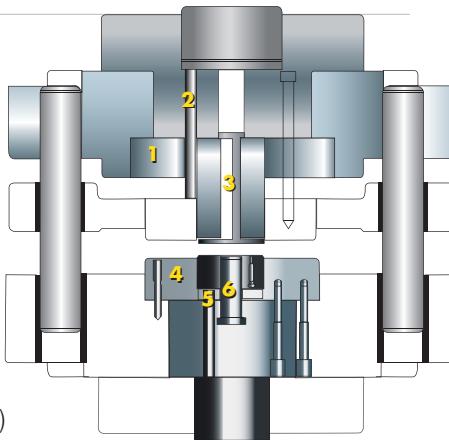
To reduce the blanking pressure, the die or punch is sometimes ground at an angle. This draft angle or shear is applied to the die for blanking and to the punch for piercing. The shear depth is usually 1.5 times to twice the thickness. Application of shear reduces the blanking pressure by about two thirds.



Chamfered tools. Blanking tool to the left and piercing tool to the right.

## For fine blanking

1. Upper punch (ASP 2005, ASP 2023, ASP 2004, ASP 2053, ASP 2011, ASP 2052)
2. Pressure pin (ASP 2005)
3. Ejector (ASP 2012, ASP 2005, ASP 2023)
4. Die (ASP 2023, ASP 2004, ASP 2030 ASP 2005, ASP 2053, ASP 2011)
5. Ejector (ASP 2012, ASP 2005, ASP 2023)
6. Lower punch (ASP 2053, ASP 2011, ASP 2023, ASP 2004, ASP 2005, ASP 2052)



Sheet thickness	Carbon steels 200-600 N/mm <sup>2</sup>		Carbon steels 600-1000 N/mm <sup>2</sup>		Tough steels < 200 N/mm <sup>2</sup>	
	Grade	HRC	Grade	HRC	Grade	HRC
< 1 mm < 0.04 in	ASP 2053 ASP 2052/ASP 2055 ASP 2005/ASP 2017	64-65 64-65 62-64	ASP 2053 ASP 2052 ASP 2005/ASP 2017	62-64 62-64 60-62	ASP 2053 ASP 2052 ASP 2005/ASP 2017	64-65 64-65 62-64
1-3 mm 0.04-0.12 in	ASP 2053 ASP 2005/ASP 2017 ASP 2023/ASP 2004	62-63 62-64 62-64	ASP 2053/ASP 2011 ASP 2005/ASP 2017 ASP 2023/ASP 2004	60-62 60-62 60-62	ASP 2053/ASP 2011 ASP 2005/ASP 2017 ASP 2023/ASP 2004	62-64 62-64 63-64
3-6 mm 0.12-0.24 in	ASP 2005/ASP 2017 ASP 2023/ASP 2004	60-62 60-62	ASP 2005/ASP 2017 ASP 2053/ASP 2011	58-60 58-69	ASP 2005/ASP 2017 ASP 2023/ASP 2004	61-63 61-63
6-10 mm 0.24-0.39 in	ASP 2005/ASP 2017 ASP 2023 ASP 2012	58-60 58-60 56-58	ASP 2005 ASP 2023/ASP 2017	57-59 57-59	ASP 2005 ASP 2023/ASP 2017 ASP 2012	59-61 59-61 56-58
> 0.39 in	ASP 2012	56-57	ASP 2012	57-58	ASP 2012	56-58

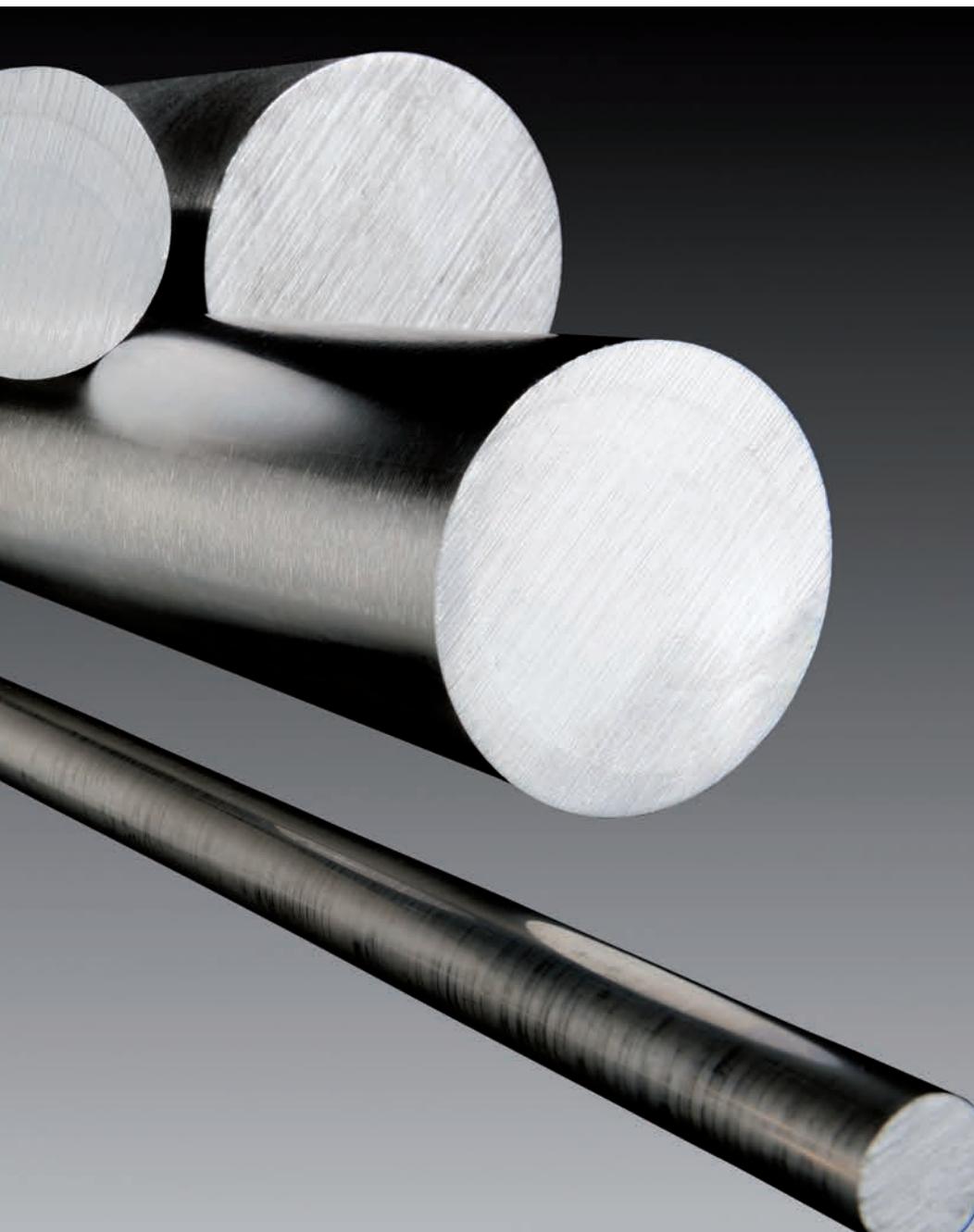
# ASP® STEEL RECOMMENDATIONS...

## For powder compacting tools

Tool	ASP® grade –hardness (HRC)						
	Simple design		Complicated design		Very fragile design		
	Grade	HRC	Grade	HRC	Grade	HRC	
Die		ASP 2053 ASP 2055 ASP 2060	64-66 66-67 66-67	ASP 2017 ASP 2053 ASP 2055 ASP 2060	61-63 64-65 64-65 64-65	ASP 2005 ASP 2017	62-64
Upper punch		ASP 2005 ASP 2017	61-62 61-63	ASP 2005 ASP 2017 ASP 2055	58-60 58-60 64-66	ASP 2012 ASP 2017	56-58 58-60
Lower outer punch		ASP 2005 ASP 2017	62-64	ASP 2005 ASP 2017	58-60	ASP 2005 ASP 2012 ASP 2017	56-58 56-58 58-60
Lower inner punch		ASP 2005 ASP 2017	62-64	ASP 2005 ASP 2017	60-62	ASP 2012 ASP 2017	56-58 58-60
Tube		ASP 2005 ASP 2017	62-64	ASP 2005 ASP 2017	58-60	ASP 2012 ASP 2017	56-58 58-60
Crown		ASP 2005 ASP 2017	62-64 61-63	ASP 2005 ASP 2017	60-62 59-61	ASP 2005 ASP 2012	58-60 56-57
Core		ASP 2030 ASP 2053	63-66 62-65	ASP 2030 ASP 2053	62-64	ASP 2012	56-58
		Ion nitriding		Ion nitriding		Ion nitriding	



# USEFUL INFORMATION



# CONVERSION TABLES

## Temperature scales

Refer to the center column and find the number of degrees to be converted. If °F is to be converted to °C, the required figure is to be found in the left-hand column under C; for converting °C to °F refer to the right hand column.

C	0	F	C	0	F	C	0	F
-17.8	0	32	127	260	500	296	565	1049
-15.0	5	41	132	270	518	299	570	1058
-12.2	10	50	138	280	536	302	575	1067
-9.4	15	59	143	290	554	304	580	1076
-6.7	20	68	149	300	572	307	585	1085
-3.9	25	77	154	310	590	310	590	1094
-1.1	30	86	160	320	608	313	595	1103
1.7	35	95	166	330	626	316	600	1112
4.4	40	104	171	340	644	318	605	1121
7.2	45	113	177	350	662	321	610	1130
10.0	50	122	182	360	680	324	615	1139
12.8	55	131	188	370	698	327	620	1148
15.6	60	140	193	380	716	329	625	1157
18.3	65	149	199	390	734	332	630	1166
21.1	70	158	204	400	752	335	635	1175
23.9	75	167	210	410	770	338	640	1184
26.7	80	176	216	420	788	341	645	1193
29.4	85	185	221	430	806	343	650	1202
32.2	90	194	227	440	824	346	655	1211
35.0	95	203	232	450	842	349	660	1220
37.8	100	212	238	460	860	352	665	1229
43	110	230	243	470	878	354	670	1238
49	120	248	249	480	896	357	675	1247
54	130	266	254	490	914	360	680	1256
60	140	284	260	500	932	363	685	1265
66	150	302	263	505	941	366	690	1274
71	160	320	266	510	950	368	695	1283
77	170	338	268	515	959	371	700	1292
82	180	356	271	520	968	377	710	1310
88	190	374	274	525	977	382	720	1328
93	200	392	277	530	986	388	730	1346
99	210	410	279	535	995	393	740	1364
99	210	410	282	540	1004	399	750	1382
104	220	428	285	545	1013	404	760	1400
110	230	446	288	550	1022	410	770	1418
116	240	464	291	555	1031	416	780	1436
121	250	482	293	560	1040	421	790	1454

$$^{\circ}\text{F} = \frac{{}^{\circ}\text{C} \times 9}{5} + 32$$

$$^{\circ}\text{C} = (\text{F} - 32) \times \frac{5}{9}$$

C	O	F	C	O	F	C	O	F
427	800	1472	671	1240	2264	916	1680	3056
432	810	1490	677	1250	2282	921	1690	3074
438	820	1508	682	1260	2300	927	1700	3092
443	830	1526	688	1270	2318	932	1710	3110
449	840	1544	693	1280	2336	938	1720	3128
454	850	1562	699	1290	2354	943	1730	3146
460	860	1580	704	1300	2372	949	1740	3164
466	870	1598	710	1310	2390	954	1750	3182
471	880	1616	716	1320	2408	960	1760	3200
477	890	1634	721	1330	2426	966	1770	3218
482	900	1652	727	1340	2444	971	1780	3236
488	910	1670	732	1350	2462	977	1790	3254
493	920	1688	738	1360	2480	982	1800	3272
499	930	1706	743	1370	2498	988	1810	3290
504	940	1724	749	1380	2516	993	1820	3308
510	950	1742	754	1390	2534	999	1830	3326
516	960	1760	760	1400	2552	1004	1840	3344
521	970	1778	766	1410	2570	1010	1850	3362
527	980	1796	771	1420	2588	1016	1860	3380
532	990	1814	777	1430	2606	1021	1870	3398
538	1000	1832	782	1440	2624	1027	1880	3416
543	1010	1850	788	1450	2642	1032	1890	3434
549	1020	1868	793	1460	2660	1038	1900	3452
554	1030	1886	799	1470	2678	1043	1910	3470
560	1040	1904	804	1480	2696	1049	1920	3488
566	1050	1922	810	1490	2714	1054	1930	3506
571	1060	1940	816	1500	2732	1060	1940	3524
577	1070	1958	821	1510	2750	1066	1950	3542
582	1080	1976	827	1520	2768	1071	1960	3560
588	1090	1994	832	1530	2786	1077	1970	3578
593	1100	2012	838	1540	2804	1082	1980	3596
599	1110	2030	843	1550	2822	1093	2000	3632
604	1120	2048	849	1560	2840	1121	2050	3722
610	1130	2066	854	1570	2858	1149	2100	3812
616	1140	2084	860	1580	2876	1177	2150	3902
621	1150	2102	866	1590	2894	1204	2200	3992
627	1160	2120	871	1600	2912	1232	2250	4082
632	1170	2138	877	1610	2930	1260	2300	4172
638	1180	2156	882	1620	2948	1288	2350	4262
643	1190	2174	888	1630	2966	1316	2400	4352
649	1200	2192	893	1640	2984	1343	2450	4442
654	1210	2210	899	1650	3002	1371	2500	4532
660	1220	2228	904	1660	3020	-	-	-
666	1230	2246	910	1670	3038	-	-	-

# CONVERSION TABLES

## ISO-tolerances

The tolerance range IT in mm is given according to the international ISO-system.

Diameter (mm)		Tolerance range						
over	up to	IT8	IT9	IT10	IT11	IT12	IT13	IT14
	3	0.014	0.025	0.040	0.060	0.100	0.140	0.250
3	6	0.018	0.030	0.048	0.075	0.120	0.180	0.300
6	10	0.022	0.036	0.058	0.090	0.150	0.220	0.360
10	18	0.027	0.043	0.070	0.110	0.180	0.270	0.430
18	30	0.033	0.052	0.084	0.130	0.210	0.330	0.520
30	50	0.039	0.062	0.100	0.160	0.250	0.390	0.620
50	80	0.046	0.074	0.120	0.190	0.300	0.460	0.740
80	120	0.054	0.087	0.140	0.220	0.350	0.540	0.870
120	180	0.063	0.100	0.160	0.250	0.400	0.630	1.000
180	250	0.072	0.115	0.185	0.290	0.460	0.720	1.150
250	315	0.081	0.130	0.210	0.320	0.520	0.810	1.300
315	400	0.089	0.140	0.230	0.360	0.570	0.890	1.400
400	500	0.097	0.155	0.250	0.400	0.630	0.970	1.550
500	630	0.110	0.175	0.280	0.440	0.700	1.100	1.750
630	800	0.125	0.200	0.320	0.500	0.800	1.250	2.000

Tolerance location for external dimensions:

h = minus only

js = half minus, half plus

k = plus only

## Inches and fractions to millimetres

Inches	0	1/64	1/32	1/16	1/8	3/16	1/4	5/16
	Millimetres							
0		0.40	0.79	1.59	3.18	4.76	6.35	7.94
1	25.40	25.80	26.19	26.99	28.58	30.16	31.75	33.34
2	50.80	51.20	51.59	52.39	53.98	55.56	57.15	58.74
3	76.20	76.60	76.99	77.79	79.38	80.96	82.55	84.14
4	101.60	102.00	102.39	103.19	104.78	106.36	107.95	109.54
5	127.00	127.40	127.79	128.59	130.18	131.76	133.35	134.94
6	152.40	152.80	153.19	153.99	155.58	157.16	158.75	160.34
7	177.80	178.20	178.59	179.39	180.98	182.56	184.15	185.74
8	203.20	203.60	203.99	204.79	206.38	207.96	209.55	211.14
9	228.60	229.00	229.39	230.19	231.78	233.36	234.95	236.54
10	254.00	254.40	254.79	255.59	257.18	258.76	260.35	261.94
11	279.40	254.40	280.19	280.99	282.58	284.16	285.75	287.34
12	304.80	254.40	305.59	306.39	307.98	309.56	311.15	312.74

Inches	3/8	7/16	1/2	9/16	5/8	3/4	7/8
	Millimetres						
0	9.53	11.11	12.70	14.29	15.88	19.05	22.26
1	34.93	36.51	38.10	39.69	41.28	44.45	47.63
2	60.33	61.91	63.50	65.09	66.68	69.85	73.03
3	85.73	87.31	88.90	90.49	92.08	95.25	98.43
4	111.13	112.71	3114.30	115.89	117.48	120.65	123.83
5	136.53	138.11	3139.70	141.29	142.88	146.05	149.23
6	161.93	163.51	3165.10	166.69	168.28	171.45	174.63
7	187.33	188.91	3190.50	192.09	193.68	196.85	200.03
8	212.73	214.31	3215.90	217.49	219.08	222.25	225.43
9	238.13	239.71	3241.30	242.89	244.48	247.65	250.83
10	263.53	265.11	3266.70	268.29	269.88	273.05	276.23
11	288.93	290.51	3292.10	293.69	295.28	298.45	301.63
12	314.33	315.91	3317.50	319.09	320.68	323.85	327.03

# CONVERSION TABLES

## Millimetres to inches

mm	inch	mm	inch	mm	inch	mm	inch
1	0.039	31	1.220	61	2.402	91	3.583
2	0.079	32	1.260	62	2.441	92	3.622
3	0.118	33	1.299	63	2.480	93	3.661
4	0.157	34	1.339	64	2.520	94	3.701
5	0.197	35	1.378	65	2.559	95	3.740
6	0.236	36	1.417	66	2.598	96	3.780
7	0.276	37	1.457	67	2.638	97	3.819
8	0.315	38	1.496	68	2.677	98	3.858
9	0.354	39	1.535	69	2.717	99	3.898
10	0.394	40	1.575	70	2.756	100	3.937
11	0.433	41	1.614	71	2.795	110	4.331
12	0.472	42	1.654	72	2.835	120	4.724
13	0.512	43	1.693	73	2.874	130	5.118
14	0.551	44	1.732	74	2.913	140	5.512
15	0.591	45	1.772	75	2.953	150	5.906
16	0.630	46	1.811	76	2.992	160	6.299
17	0.669	47	1.850	77	3.031	170	6.693
18	0.709	48	1.890	78	3.071	180	7.087
19	0.748	49	1.929	79	3.110	190	7.480
20	0.787	50	1.969	80	3.150	200	7.874
21	0.827	51	2.008	81	3.189	210	8.268
22	0.866	52	2.047	82	3.228	220	8.661
23	0.906	53	2.087	83	3.268	230	9.055
24	0.945	54	2.126	84	3.307	240	9.449
25	0.984	55	2.165	85	3.346	250	9.843
26	1.024	56	2.205	86	3.386	260	10.236
27	1.063	57	2.244	87	3.425	270	10.630
28	1.102	58	2.283	88	3.465	280	11.024
29	1.142	59	2.323	89	3.504	290	11.417
30	1.181	60	2.362	90	3.543	300	11.811

## Length

	<b>m</b>	<b>mm</b>	<b>inch</b>	<b>foot</b>	<b>yard</b>
1 m	1	$10^3$	39.3701	3.2808	1.0936
1 mm	$10^{-3}$	1	$39.37 \times 10^{-3}$	$3.281 \times 10^{-3}$	$1.094 \times 10^{-3}$
1 inch	$25.4 \times 10^{-3}$	25.4	1	$83.33 \times 10^{-3}$	$27.78 \times 10^{-3}$
1 foot	0.3048	304.8	12	1	0.3333
1 yard	0.9144	914.4	36	3	1
1 mile (eng.)	$1.6093 \times 10^3$	$1.6093 \times 10^6$	$63.36 \times 10^3$	$5.28 \times 10^3$	$1.76 \times 10^3$
1 mile (nautic)	$1.852 \times 10^3$	$1.852 \times 10^6$	$72.91 \times 10^3$	$6.076 \times 10^3$	$2.025 \times 10^3$

1 km = 0.6214 mile (eng.) = 0.5396 mile (nautic)

1 A.U. =  $10^{-10}$  m =  $10^{-4}$  μm

## Area

	<b>m<sup>2</sup></b>	<b>mm<sup>2</sup></b>	<b>inch<sup>2</sup></b>	<b>foot<sup>2</sup></b>	<b>yard<sup>2</sup></b>
1 m <sup>2</sup>	1	$10^6$	$1.55 \times 10^3$	10.76	1.196
1 mm <sup>2</sup>	$10^{-6}$	1	$1.55 \times 10^{-3}$	$10.76 \times 10^{-6}$	$1.196 \times 10^{-6}$
1 inch <sup>2</sup>	$0.645 \times 10^{-3}$	645.16	1	$6.944 \times 10^{-3}$	$0.772 \times 10^{-3}$
1 foot <sup>2</sup>	$92.9 \times 10^{-3}$	$92.9 \times 10^3$	144	1	0.1111
1 yard <sup>2</sup>	0.8361	$836.1 \times 10^3$	$1.296 \times 10^3$	9	1
1 acre	$4.047 \times 10^3$	$4.047 \times 10^9$	$6.273 \times 10^6$	$43.56 \times 10^3$	$4.84 \times 10^3$
1 mile <sup>2</sup> (eng.)	$2.5907 \times 10^6$	$2.5907 \times 10^{12}$	$4.014 \times 10^9$	$27.88 \times 10^6$	$3.0976 \times 10^6$

1 km<sup>2</sup> = 247

1 acre = 0.3861 mile<sup>2</sup> (eng)

## Volume

	<b>m<sup>3</sup></b>	<b>l = dm<sup>3</sup></b>	<b>inch<sup>3</sup></b>	<b>foot<sup>3</sup></b>	<b>yard<sup>3</sup></b>
1 m <sup>3</sup>	1	$10^3$	$61.0237 \times 10^3$	35.3147	1.308
1 l = 1 dm <sup>3</sup>	$10^{-3}$	1	61.02	$35.31 \times 10^{-3}$	$1.3 \times 10^{-3}$
1 inch <sup>3</sup>	$16.387 \times 10^{-6}$	$16.387 \times 10^{-3}$	1	$0.579 \times 10^{-3}$	$21.43 \times 10^{-6}$
1 foot <sup>3</sup>	$28.317 \times 10^{-3}$	28.317	$1.728 \times 10^3$	1	$37.04 \times 10^{-3}$
1 yard <sup>3</sup>	0.76455	764.55	$46.656 \times 10^3$	27	1
1 gallon (UK)	$4.546 \times 10^{-3}$	4.5461	277.4	0.1605	$5.946 \times 10^{-3}$
1 gallon (US)	$3.785 \times 10^{-3}$	3.7854	231	0.1337	$4.951 \times 10^{-3}$

1 l = 1 dm<sup>3</sup> = 0.219969 gallon (UK) = 0.264172 gallon (US)

1 cm<sup>3</sup> =  $61 \times 10^{-3}$  in<sup>3</sup>

# CONVERSION TABLES

## Velocity

	m/s	km/h	ft/s	mile/h	kn (knot)
1 m/s	1	3.6	3.2808	2.2369	1.9438
1 km/h	0.2778	1	0.9113	0.6214	0.54
1 ft/s	0.3048	1.0973	1	0.6818	0.5925
1 mile/h	0.447	1.6093	1.4666	1	0.869
1 kn (knot)	0.5144	1.852	1.6878	1.1508	1

1 knot = 1 nautic mile

1 mach = ca.  $1.2 \times 10^3$  km/h

## Mass

	kg	g	lb (pound)	slug	oz (ounce)
1 kg	1	$10^3$	2.2046	$68.52 \times 10^{-3}$	35.274
1 g	$10^{-3}$	1	$2.2 \times 10^{-3}$	$68.52 \times 10^{-6}$	$35.274 \times 10^{-3}$
1 lb (pound)	0.4536	453.59	1	$31.08 \times 10^{-3}$	16
1 slug	14.594	$14.5939 \times 10^3$	32.17	1	514.8
1 oz (ounce)	$28.35 \times 10^{-3}$	28.35	$62.5 \times 10^{-3}$	$1.943 \times 10^{-3}$	1
1 long cwt (UK)	50.8023	$50.8023 \times 10^3$	112	3.481	$1.792 \times 10^3$
1 long ton (UK)	$1.016 \times 10^3$	$1.016 \times 10^6$	$2.24 \times 10^3$	69.62	$35.84 \times 10^3$
2 short cwt (US)	45.3592	$45.3592 \times 10^3$	100	3.108	$1.6 \times 10^3$
1 short ton (US)	907.185	$907.185 \times 10^3$	$2 \times 10^3$	61.16	$32 \times 10^3$

1 long ton (UK) = 20 long cwt (UK)    1 short ton (US) = 20 short cwt (US)

1 kg =  $0.9842 \times 10^{-3}$  long ton (UK) =  $1.1023 \times 10^{-3}$  short ton (US)

1 kg =  $19.684 \times 10^{-3}$  long cwt (UK) =  $22.046 \times 10^{-3}$  short cwt (US)

## Density

	kg/m <sup>3</sup>	g/cm <sup>3</sup>	lb/in <sup>3</sup>	lb/ft <sup>3</sup>
1 kg/m <sup>3</sup>	1	$10^{-3}$	$36.13 \times 10^{-6}$	$62.43 \times 10^{-3}$
1 g/cm <sup>3</sup>	$10^3$	1	$36.13 \times 10^{-3}$	62.428
1 lb/in <sup>3</sup>	$27.6799 \times 10^3$	27.68	1	$1.728 \times 10^3$
1 lb/ft <sup>3</sup>	16.0185	$16.02 \times 10^{-3}$	$0.579 \times 10^{-3}$	1

## Force

	N	dyn	kp	lbf
1 N	1	0,1 x10 <sup>6</sup>	0.10197	0.2248
1 dyn	10 x10 <sup>-6</sup>	1	1.02 x10 <sup>-6</sup>	2.248 x10 <sup>-6</sup>
1 kp	9.80665	980.665 x10 <sup>3</sup>	1	2.2046
1 lbf	4.448	444.8 x10 <sup>3</sup>	0.4536	1

## Power

	W	kpm/s	kcal/h	hk	ft x lbf/s
1 W	1	0.102	0.8598	1.36 x10 <sup>-3</sup>	0.7376
1 kpm/s	9.80665	1	8.432	13.33 x10 <sup>-3</sup>	7.233
1 kcal/h	1.163	0.1186	1	1.581 x10 <sup>-3</sup>	0.8578
1 hk	735.5	75	632.5	1	542.5
1 ft x lbf/s	1.356	0.1383	1.166	1.843 x10 <sup>-3</sup>	1
1 hp (UK, US)	745.7	76.04	641.2	1.014	550
1 Btu/h	0.2931	29.89 x10 <sup>-3</sup>	0.252	398.5 x10 <sup>-6</sup>	0.2162

1 kcal/s = 4.1868 x10<sup>3</sup>W

1 W = 238.8 x10<sup>-6</sup> kcal/s = 1.341 x10<sup>-3</sup> hp

## Pressure, stress

	Pa = N/m <sup>2</sup>	MPa = N/mm <sup>2</sup>	bar	kp/mm <sup>2</sup>	lbf/in <sup>2</sup> (psi)
1 Pa = 1 N/m <sup>2</sup>	1	10 <sup>-6</sup>	10 x10 <sup>-6</sup>	0.102 x10 <sup>-6</sup>	0.145 x10 <sup>-3</sup>
1 MPa = 1 N/mm <sup>2</sup>	10 <sup>6</sup>	1	10	0.102	145
1 bar	100x10 <sup>3</sup>	0.1	1	10.2 x10 <sup>-3</sup>	14.5
1 kp/mm <sup>2</sup>	9.80665 x10 <sup>6</sup>	9.807 x10 <sup>-6</sup>	98.0665	1	1.4223 x10 <sup>3</sup>
1 lbf/in <sup>2</sup> = psi	6.895 x10 <sup>3</sup>	6.895 x10 <sup>-3</sup>	68.95 x10 <sup>-3</sup>	703 x10 <sup>-6</sup>	1

## Energy, work

	J	kWh	kpm	kcal	ft x lb
1 J	1	0.278 x10 <sup>-6</sup>	0.102	0.239 x10 <sup>-3</sup>	0.7376
1 kWh	3.6 x10 <sup>6</sup>	1	367.1 x10 <sup>3</sup>	859.8	2.655 x10 <sup>6</sup>
1 kpm	9.80665	2.724 x10 <sup>-6</sup>	1	2.342 x10 <sup>-3</sup>	7.233
1 kcal	4.1868 x10 <sup>3</sup>	1.163 x10 <sup>-3</sup>	426.9	1	3.088 x10 <sup>3</sup>
1 ft x lbf	1.356	376.6 x10 <sup>-9</sup>	0.1383	323.8 x10 <sup>-3</sup>	1

# MULTILINGUAL GLOSSARY

English	French	German	Spanish	Swedish
Alloy	Alliage	Legierung	Aleación	Legering
Aluminum	Aluminium	Aluminium	Aluminio	Aluminium
Annealing	Recuit	Glühen	Recocido	Glödning
Austenitizing	Austénisation	Austenitisierung	Austenización	Austenitisering
Bar	Barre	Stang	Barra	Stång
Base plate	Plaque de fondation	Grundplatte	Placa base	Grundplatta
Brass	Laiton	Messing	Latón	Mässing
Breakage	Rupture	Bruch	Rotura	Brott
Brittle	Fragile	Spröde	Fragil	Spröd
Bronze	Bronze	Bronze	Bronce	Brons
Burr	Bavure	Grat	Rebabá	Skägg
Carbide	Carbure	Karbid	Carburo	Karbid
Carbon	Carbone	Kohlenstoff	Carbono	Kol
Casting	Fonte	Guss	Fundición	Gjutning
Case hardening	Cémentation	Einsatzhärten	Cementación	Sätthardning
Cemented carbide	Carbure	Hartmetall	Metal duro	Hårdmetall
Chamfer	Chanfrein	Fase	Chafian	Avfasning
Chip	Copeau	Span	Viruta	Spän
Chipping	Écaillage	Spanen	Desconchamiento	Avflagning
Chromium	Chrome	Chrom	Cromo	Krom
Coating	Revêtir	Beschichtung	Recubrimiento	Ytbeläggning
Cobalt	Cobalt	Kobalt	Cobalto	Kobolt
Cold extrusion	Extrusion à froid	Kaltfließpressen	Extrusión en frío	Kallextrusion
Cold work tool	Outil de travail à froid	Kaltarbeitswerkzeug	Hta trabajo en frío	Kallarbetsverktyg
Cooling	Refroidissement	Kühlung	Enfriamiento	Kylning
Copper	Cuivre	Kupfer	Cobre	Koppar
Cut	Découper	Schneiden	Cortar	Kapa
Cutting depth	Profondeur de coupe	Schnitttiefe	Profundidad de corte	Skärdjup
Cutting speed	Vitesse de coupe	Schnittgeschwindigkeit	Velocidad de corte	Skärhastighet
Cutting tool	Outil de coupe	Schneidwerkzeug	Hta de corte	Skärverktyg
Density	Densité	Dichtigkeit	Densidad	Täthet
Die	Matrice	Matrize	Matriz	Dyna
Die casting	Coulée sous pression	Spritzguss	Fundición a presión	Pressgjutning
Drawn wire	Fil tiré	Gezogener Draht	Alambre estirado	Dragen tråd
Drill	Foret	Bohrer	Broca	Borr
Factory/plant	Usine	Werk	Fabrica	Fabrik
Feed	Avance	Vorschub	Avance	Matning
Finishing	Finition	Schlichten	Acabado	Finbearbetning
Flat bar	Barre plate	Flachstahl	Barra rectangular	Plattstång
Ferroalloys	Ferro-alliages	Ferrolegerungen	Ferroaleaciones	Ferrolegeringar
Forge	Forge	Schmiede	Forja	Smedja
Groove	Rainure	Nute	Ranura	Spår
Grinding	Rectification	Schleifen	Rectificado	Slipning
Ground bar	Barre rectifiée	Geschliffener Stabstahl	Barra rectificada	Slipad stång
Hardness	Dureté	Härte	Dureza	Hårdhet
Heat treatment	Traitement thermique	Wärmebehandlung	Tratamiento térmico	Värmebehandling
Helix	Hélice	Spirale	Helice	Spiral

English	French	German	Spanish	Swedish
High speed steel	Acier rapide	Schnellarbeitsstahl	Acero rápido	Snabbstål
Hot hardness	Dureté à chaud	Warmhärte	Dureza en caliente	Varmhärdhet
Impact resistance	Résistance au choc	Schlagfestigkeit	Resistencia al impacto	Slagseghet
Length	Longueur	Länge	Longitud	Längd
Machining	Usinage	Zerspanung	Mecanizado	Bearbetning
Milling	Fraisage	Fräsen	Fresado	Fräsning
Milling cutter	Fraise	Fräser	Fresa	Fräs
Molybdenum	Molybdène	Molybdän	Molibdeno	Molybden
Nickel	Nickel	Nickel	Níquel	Nickel
Ore	Minerai	Erz	Mineral	Malm
Out of roundness	Ovalisation	Undrundheit	Ovalidad	Ovalitet
Pickling	Décapage	Beizen	Decapado	Betning
Polishing	Polissage	Feinschleifen	Pulido	Läppning
Powder	Poudre	Pulver	Polvo	Pulver
Process	Procédé	Verlauf	Proceso	Förlopp
Punch	Poinçon	Stempel	Punzón	Stans
Raw material	Matière brute	Rohstoff	Materia prima	Råmaterial
Reamer	Alésoir	Reibahle	Escarificador	Brotsch
Remove burrs	Ebarber	Entgraten	Desbarbar	Avgrada
Roll	Cylindre de laminoir	Walzen	Rodillo laminacion	Valsar
Roller	Rouleau	Walze	Rodillo	Vals
Rough down	Dégrossir	Grobearbeiten	Deshastar	Grovbearbeta
Roughness	Rugosité	Rauh	Rugosidad	Skrovlig
Round bar	Barre ronde	Rundstahl	Barra redonda	Rundstång
Scrap	Ferraille	Schrott	Chatarra	Skrot
Sheet	Tôle	Tafel	Chapa	Plåt
Soft annealing	Recuit doux	Weichglühen	Recocido blando	Mjуглödning
Square bar	Barre carrée	Vierkantstäbe	Barra cuadrada	Fyrkantstång
Stamping	Empreinte	Prägearbeit	Estampación	Prägling
Stainless steel	Acier inoxydable	Rostfreier Stahl	Acero inoxidable	Rostfritt stål
Steel	Acier	Stahl	Acero	Stål
Strip	Feuillard	Streifen	Fleje	Band
Tap	Taraud	Gewindebohrer	Macho de roscar	Gängtapp
Tempering	Revenu	Anlassen	Revenido	Anlöpning
Tension	Tension	Spannung	Tensiones	Spänning
Thickness	Épaisseur	Dicke	Espesor	Tjocklek
Thread	Filet	Gewinde	Rosca	Gänga
Tool	Outil	Werkzeug	Herramienta	Verktyg
Tool steel	Acier à outil	Werkzeugstahl	Acero herramientas	Verktygstål
Toughness	Ténacité	Zähigkeit	Tenacidad	Seghet
Tungsten	Tungstène	Wolfram	Tungsteno	Wolfram
Turning	Tournage	Drehen	Torneado	Svarvning
Wear	Usure	Verschleiß	Desgaste	Nötring
Wear resistance	Résistance à l'usure	Verschleißbeständigkeit	Resistencia al desgaste	Nötringsbeständighet
Weld	Soudure	Schweißung	Soldadura	Svets
Width	Largeur	Breite	Ancho	Bredd
Wire	Fil	Draht	Alambre	Tråd
Zinc	Zinc	Zink	Zinc	Zink

A large, vertical, abstract graphic composed of numerous thin, yellowish-orange lines that form a continuous, flowing spiral pattern, resembling a twisted ribbon or a complex helix.

# ERASTEEL

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