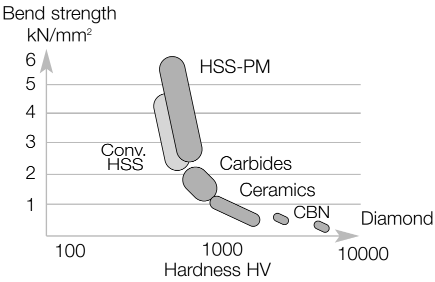
SUMMARY

METALLURGY

COATINGS

TOOL MAKER'S TIP

Excellent strength



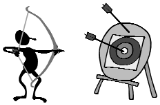
High speed steels offer higher bend strength than any other cutting materials.

High bend strength allows :

- better cutting resistance to edge chipping
- extended cutting depth, i.e. fewer cuts
- increased feed per tooth

TOOL MAKER'S TIP

A super sharp edge



Thanks to the unique strength of high speed steels, tool manufacturers can produce super sharp edges. A sharp cutting edge has many advantages:

• Difficult-to-machine alloys

Easier machining of titanium alloys. Less work hardening of austenitic stainless steels and nickel alloys

• Better quality

Better surface quality and tolerances of machined parts, because the metal is cut and not torn. Lower cutting forces – important when machining thin walls

• Longer tool life

Lower edge temperature thanks to lower cutting forces

• And economy !

Less power consumption from machine tools

TOOL MAKER'S TIP

Safe and reliable tools

Thanks to the unique strength of high speed steels, HSS cutting tools break less often and last longer. HSS cutting tools:

- **Resist vibrations,** whatever the type of machine tool, even if rigidity has been lost over time and regardless of workpiece clamping conditions
- **Resist mechanical** shocks at tooth level in milling or in gear cutting operations
- **Are suitable for special and difficult machining conditions** such as non-homogeneous material, holes, welding joints, stacked plates, inclined plan, etc.
- **Resist thermal shocks,** and are adaptable to all lubrication conditions

Cr	W	Mo	V	Co
Chromium	**Tungsten**	**Molybdenum**	**Vanadium**	**Cobalt**
Quantity • approx. 4%	Quantity • up to 20%	Quantity • up to 10%	Quantity • 1 to 5%, max. 10%	Quantity: 0 to 16%
Role • improves hardenability • prevents scaling	Role • cutting efficiency • resistance to tempering	Role • cutting efficiency • resistance to tempering • improves hardenability	Role • forms very hard carbides for good abrasive wear resistance	Role: • improves heat resistance • improves hot hardness • slightly improves heat conductivity
Origin • various countries	Origin • mainly China	Origin • by-product of copper and tungsten production	Origin • present in many minerals	Origin: • mainly Canada, Morocco, and Zaire

Note: 1w% Mo = 2w% W

	Cr	W	Mo	V	Co
Hardness	↗	↗	↗	↗	↗
Impact resistance	→	→	↗	→	↘
Heat resistance	→	↗	↗	↗	↗
Hardness	↗	↗	↗	↗	↗

HSS

ISO (AISI) standards	C	Cr	W	Mo	V
HS 6-5-2 (M2)	0.9	4	6	5	2
HS 1-8-1 (M1)	0.8	4	1.5	8.75	1
HS 2-8-2 (M7)	1	4	1.75	8.75	2
HS 18-0-1 (T1)	0.75	4	18	0	1

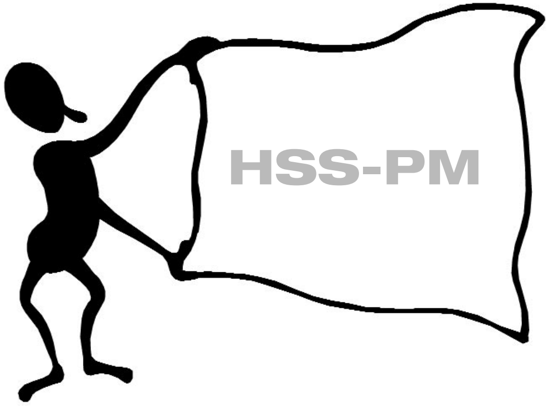
HSS-E
5% cobalt

ISO (AISI) standards	C	Cr	W	Mo	V	Co
HS 6-5-2-5 (M35)	0.9	4.2	6.4	5	1.9	4.8
(T15)	1.5	4	12	0	5	5

HSS-E
8% cobalt

ISO (AISI) standards	C	Cr	W	Mo	V	Co
HS 2-9-1-8 (M42)	1.1	4	1,5	9,5	1.2	8

STANDARD COMPOSITIONS OF HSS IN %

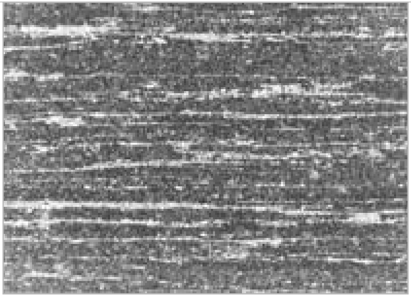

HSS-PM

- HSS produced by powder metallurgy offers a higher content of alloy elements and a **combination of unique properties**:

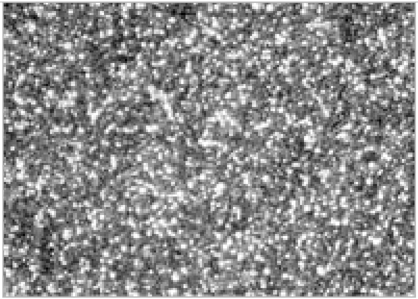
  - higher toughness
  - higher wear resistance
  - higher hardness
  - higher hot hardness

- Using HSS-PM **prolongs tool life**, makes tool life more predictable, improves performance (feed and speed) and offers a solution to chipping problems. HSS-PM is an excellent substrate for making the best possible use of coatings.

- HSS-PM has many advantages in **high performance applications** such as rough milling, gear cutting tools, and broaching, and also in cases of difficult tapping, drilling and reaming operations. HSS-PM is used too in bandsaws, knives, cold work tooling, rolls, etc.

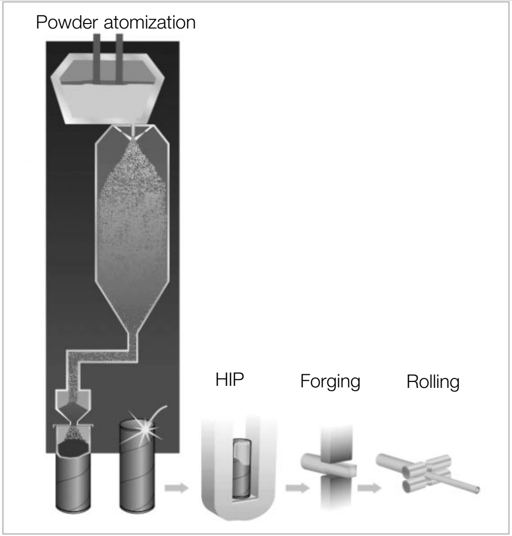


HSS



HSS-PM

The uniform microstructure and the purity of HSS-PM are also very important for tool reliability.


Powder atomization
HIP
Forging
Rolling

TOOL MAKER'S TIP

Steel makers are constantly developing new PM steel grades to achieve even higher cutting performance

HSS-PM

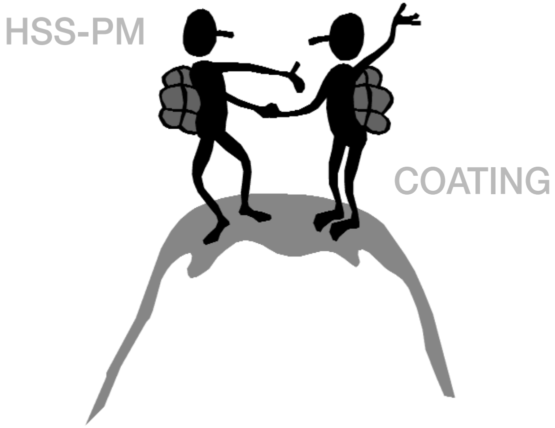
ISO (AISI) standards	C	Cr	W	Mo	V
HS 6-5-3 (M3:2)	1.3	1.4	6.4	5	3
HS 6-5-4 (M4)	1.45	4.1	6.4	5	4

HSS-E-PM

ISO (AISI) standards	C	Cr	W	Mo	V	Co
HS 12-0-5-5 (T15)	1.5	4	12	0	5	5
HS 6-5-3-8	1.3	4.2	6.4	5	3.1	8.5
HS 6-7-6-10	2.3	4.2	6.5	7	6.5	10.5

TOOL MAKER'S TIP

To achieve higher performance, combine the efficiency of coatings with the advantages of HSS-PM

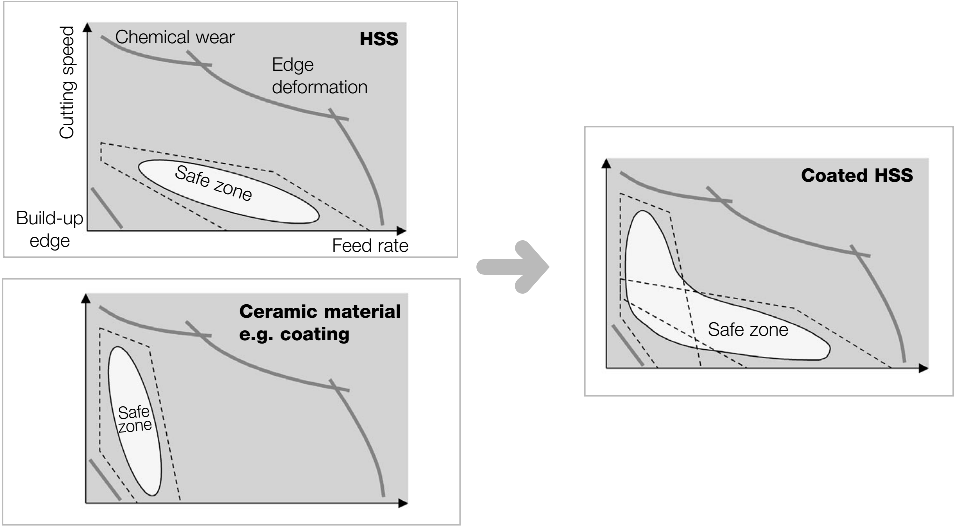


- HSS and HSS-PM are excellent substrates for all coatings such as TiN, TiAlN, TiCN, solid lubricant coatings and multilayer coatings.

- Coatings considerably **improve tool life** and **boost the performance** of HSS tools in high productivity, high speed and high feed cutting or in dry machining, and machining of difficult-to-machine materials.

- Coatings provide:

  - **Increased surface hardness**, for **higher wear resistance** (abrasive and adhesive wear, flank or crater wear)
  - **Reduced friction coefficients** for better chip sliding, to reduce cutting forces, to prevent built-up edges, to reduce heat generation etc.
  - **Reduced heating of the tool**
  - Corrosion and oxidation resistance thanks to the **chemical barrier**
  - Crater wear resistance
  - **Improved surface quality** of finished parts


Cutting speed
Chemical wear
HSS
Edge
deformation
Safe zone
Build-up
edge
Feed rate
Ceramic material
e.g. coating
Safe
zone
Coated HSS
Safe zone

TiN
Gold

Hardness HV(0.05) 2300

Coeff. of friction: 0.3

Thermal stability 600 °C

- General purpose coating
- For better tool sliding
- Improved abrasion resistance

TiCN
Grey-violet

Hardness HV(0.05) 3000

Coeff. of friction: 0.4

Thermal stability 750 °C

- Multi-purpose coating
- High performance in construction steels
- Higher wear resistance than TiN coatings
- Available both in mono and multilayer

TiAlN or TiAlCN
Black-violet

Hardness HV(0.05) 3000-3500

Coeff. of friction: 0.45

Thermal stability 800° - 900° C

- High performance coating for increased cutting parameters and higher tool life. Also suitable for dry machining
- Reduces heating of the tool
- Multilayered, nanostructured or alloyed versions offer even better performance

WC-C or MoS_2
Grey-black

Hardness HV(0.05) 1000-3000

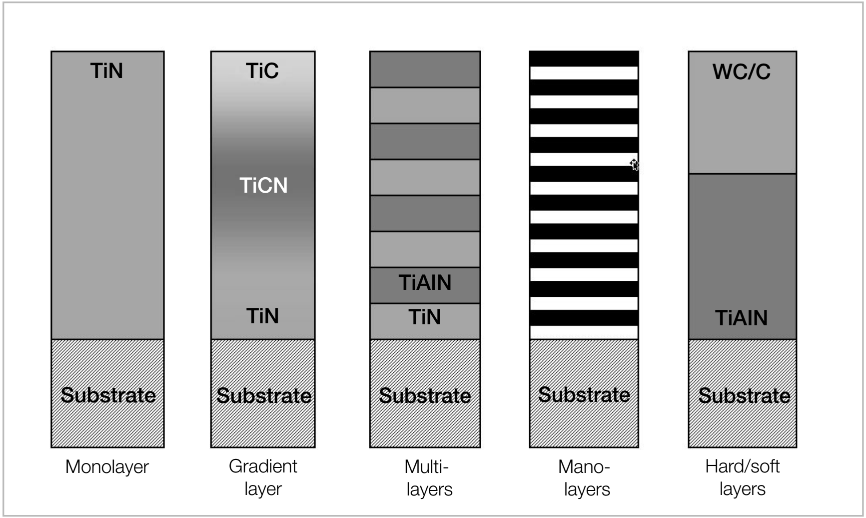
Coeff. of friction: 0.1

Thermal stability 300 °C

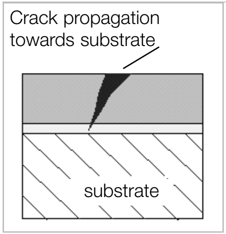
- Improved sliding
- But limited temperature resistance
- For sticky materials such as aluminium alloys, copper and non metallic marterials

CrN
Metal

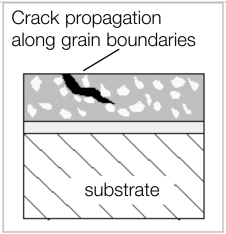
- For copper, brass, bronze etc.



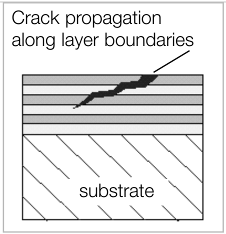
TYPES OF MODERN COATINGS



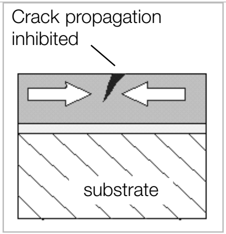
Monolayer with low internal compressive stress



Nano crystalline structure



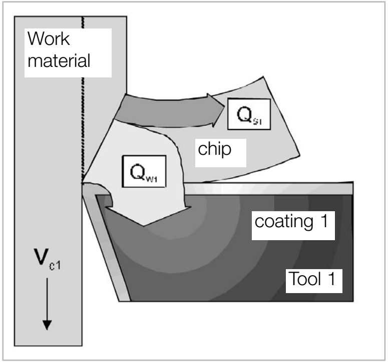
Multilayer



Monolayer with high internal compressive stress

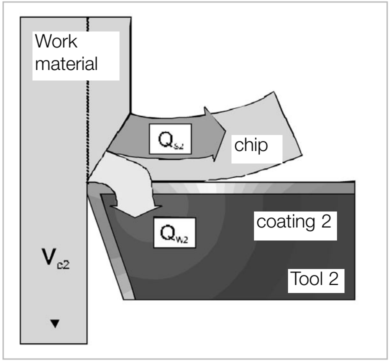
- Coating fracture toughness is as important as coating hardness in crack retardation.
- Balance between high compressive stress (poor adhesion) and low residual stress (no crack retardation) is necessary.

CRACK RETARDATION IN DIFFERENT COATINGS



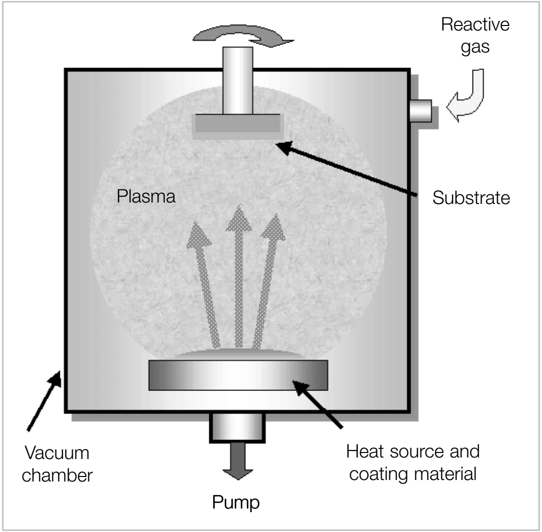
Coating with high thermal conductivity

- Cutting speed
  $Vc_1 = Vc_2$
- Heat flow, chip
  $Qs_2 > Qs_1$
- Heat flow, tool
  $Qw_2 > Qw_1$
- Cutting force
  $Fc_1 > Fc_2$
- Length of
  contact zone
  $lk_1 > lk_2$



Coating with low thermal conductivity

THERMAL CONDUCTIVITY OF COATINGS



- A material is evaporated and then allowed to condense and solidify on the substrate (= the tool)
- Vacuum: 10^{-6}-10^{-4} torr
- Temperature: 200 - 500 ºC
- Plasma-assisted