Think HSS
INTRODUCTION

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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
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
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
<table>
<thead>
<tr>
<th>Element</th>
<th>Quantity</th>
<th>Role</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>approx. 4%</td>
<td>improves hardenability, prevents scaling</td>
<td>various countries</td>
</tr>
<tr>
<td>Tungsten</td>
<td>up to 20%</td>
<td>cutting efficiency, resistance to tempering</td>
<td>mainly China</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>up to 10%</td>
<td>cutting efficiency, resistance to tempering, improves hardenability</td>
<td>by-product of copper and tungsten production</td>
</tr>
<tr>
<td>Vanadium</td>
<td>1 to 5%, max. 10%</td>
<td>forms very hard carbides for good abrasive wear resistance</td>
<td>present in many minerals</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0 to 16%</td>
<td>improves heat resistance, improves hot hardness, slightly improves heat conductivity</td>
<td>mainly Canada, Morocco, and Zaire</td>
</tr>
</tbody>
</table>

Note: 1w% Mo = 2w% W
<table>
<thead>
<tr>
<th></th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact resistance</td>
<td></td>
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<td></td>
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<tr>
<td>Heat resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Standard Compositions of HSS in %

## HSS

<table>
<thead>
<tr>
<th>ISO (AISI) standards</th>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 6-5-2 (M2)</td>
<td>0.9</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>HS 1-8-1 (M1)</td>
<td>0.8</td>
<td>4</td>
<td>1.5</td>
<td>8.75</td>
<td>1</td>
</tr>
<tr>
<td>HS 2-8-2 (M7)</td>
<td>1</td>
<td>4</td>
<td>1.75</td>
<td>8.75</td>
<td>2</td>
</tr>
<tr>
<td>HS 18-0-1 (T1)</td>
<td>0.75</td>
<td>4</td>
<td>18</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

## HSS-E 5% cobalt

<table>
<thead>
<tr>
<th>ISO (AISI) standards</th>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 6-5-2-5 (M35)</td>
<td>0.9</td>
<td>4.2</td>
<td>6.4</td>
<td>5</td>
<td>1.9</td>
<td>4.8</td>
</tr>
<tr>
<td>(T15)</td>
<td>1.5</td>
<td>4</td>
<td>12</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

## HSS-E 8% cobalt

<table>
<thead>
<tr>
<th>ISO (AISI) standards</th>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 2-9-1-8 (M42)</td>
<td>1.1</td>
<td>4</td>
<td>1.5</td>
<td>9.5</td>
<td>1.2</td>
<td>8</td>
</tr>
</tbody>
</table>
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.
The uniform microstructure and the purity of HSS-PM are also very important for tool reliability.
THE POWDER METALLURGY PROCESS

1. Powder atomization
2. HIP
3. Forging
4. Rolling
Steel makers are constantly developing new PM steel grades to achieve even higher cutting performance.

### HSS-PM

<table>
<thead>
<tr>
<th>ISO (AISI) standards</th>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 6-5-3 (M3:2)</td>
<td>1.3</td>
<td>1.4</td>
<td>6.4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>HS 6-5-4 (M4)</td>
<td>1.45</td>
<td>4.1</td>
<td>6.4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

### HSS-E-PM

<table>
<thead>
<tr>
<th>ISO (AISI) standards</th>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Mo</th>
<th>V</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS 12-0-5-5 (T15)</td>
<td>1.5</td>
<td>4</td>
<td>12</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HS 6-5-3-8</td>
<td>1.3</td>
<td>4.2</td>
<td>6.4</td>
<td>5</td>
<td>3.1</td>
<td>8.5</td>
</tr>
<tr>
<td>HS 6-7-6-10</td>
<td>2.3</td>
<td>4.2</td>
<td>6.5</td>
<td>7</td>
<td>6.5</td>
<td>10.5</td>
</tr>
</tbody>
</table>
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
ADVANTAGES OF COATED HSS TOOLS

- Build-up edge
- Cutting speed
- Edge deformation
- Feed rate
- Chemical wear
- Safe zone

Coated HSS

- Ceramic material e.g. coating
- Safe zone
<table>
<thead>
<tr>
<th>Coating Type</th>
<th>Hardness HV(0.05)</th>
<th>Coeff. of friction</th>
<th>Thermal Stability</th>
<th>Additional Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TiN</strong> (Gold)</td>
<td>2300</td>
<td>0.3</td>
<td>600 °C</td>
<td>General purpose coating, For better tool sliding, Improved abrasion resistance</td>
</tr>
<tr>
<td><strong>TiCN</strong> (Grey-violet)</td>
<td>3000</td>
<td>0.4</td>
<td>750 °C</td>
<td>Multi-purpose coating, High performance in construction steels, Higher wear resistance than TiN coatings, Available both in mono and multilayer</td>
</tr>
<tr>
<td><strong>TiAlN or TiAlCN</strong> (Black-violet)</td>
<td>3000-3500</td>
<td>0.45</td>
<td>800° - 900° C</td>
<td>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</td>
</tr>
<tr>
<td><strong>WC-C or MoS₂</strong> (Grey-black)</td>
<td>1000-3000</td>
<td>0.1</td>
<td>300 °C</td>
<td>For copper, brass, bronze etc.</td>
</tr>
</tbody>
</table>

- For copper, brass, bronze etc.
TYPES OF MODERN COATINGS

- TiN
- TiC
- TiCN
- TiAIN
- WC/C

Substrates:
- Monolayer
- Gradient layer
- Multi-layers
- Mano-layers
- Hard/soft layers
- 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.
Coating with high thermal conductivity

- Cutting speed
  \[ V_{c1} = V_{c2} \]
- Heat flow, chip
  \[ Q_{s2} > Q_{s1} \]
- Heat flow, tool
  \[ Q_{w2} > Q_{w1} \]
- Cutting force
  \[ F_{c1} > F_{c2} \]
- Length of contact zone
  \[ l_{k1} > l_{k2} \]

Coating with low thermal conductivity
- 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 °C
- Plasma-assisted