



This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as a warranty of specific properties of the products described or a warranty for fitness for a particular purpose.

Classified according to EU Directive 1999/45/EC  
For further information see our "Material Safety Data Sheets".

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SS-EN ISO 9001  
SS-EN ISO 14001

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## UDDEHOLM VANADIS 60

Uddeholm Vanadis 60 is a high alloyed powder metallurgical high speed steel suitable for very demanding cold work applications and for cutting tools. The high carbon and alloying content, Co, Mo, W and V, gives an extremely high compressive strength, 69 HRC, combined with a very good abrasive wear resistance.

For cutting tool applications Uddeholm Vanadis 60 offers a unique combination of high wear resistance, hot hardness and good toughness compared to all other HSS.

The P/M process ensures a good machinability and grindability together with a good dimensional stability during heat treatment.

## Applications

Uddeholm Vanadis 60 is a high alloyed high performance PM high speed steel with an addition of cobalt.

Uddeholm Vanadis 60 is particularly suitable for cold work tooling where highest wear resistance and highest compressive strength are required at the same time.

## General

Uddeholm Vanadis 60 is a W-Mo-V-Co alloyed PM high speed steel characterized by:

- Highest wear resistance
- Maximum compressive strength
- Good through hardening properties
- Good toughness
- Good dimensional stability on heat treatment
- Very good temper resistance.

Typical analysis %	C 2,3	Cr 4,2	Mo 7,0	W 6,5	V 6,5	Co 10,5
Standard specification	W.-Nr. 1.3292					
Delivery condition	Soft annealed, max. 340 HB					
Colour code	Gold					

Uddeholm Vanadis 60 is a super highly alloyed PM high speed steel with a high cobalt and vanadium content.

## Properties

### Special properties

Uddeholm Vanadis 60 could be hardened to a very high hardness and compressive strength. Uddeholm Vanadis 60 has further the same good dimensional stability during heat treatment as the other Uddeholm Vanadis grades. The toughness is despite the very high alloying content very good. The machinability is lower compared to lower alloyed HSS. The grindability of Uddeholm Vanadis 60 is equal or better than other high alloyed HSS, but somewhat lower than for Uddeholm Vanadis 30. Uddeholm Vanadis 60 has a very high hot hardness.

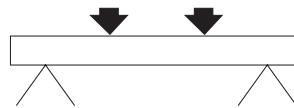
## Physical data

Temperature		20°C (68°F)	400°C (750°F)	600°C (1112°F)
Density				
kg/m <sup>3</sup>	(1)	7960	7860	7810
lbs/in <sup>3</sup>	(1)	0,286	0,283	0,281
Modulus of elasticity				
MPa	(2)	250 000	222 000	200 000
ksi	(2)	36 × 10 <sup>3</sup>	32 × 10 <sup>3</sup>	20 × 10 <sup>3</sup>
Coefficient of thermal expansion per				
°C from 20°C	(2)	–	10,6 × 10 <sup>-6</sup>	11,1 × 10 <sup>-6</sup>
°F from 68°F	(2)	–	5,9 × 10 <sup>-6</sup>	6,1 × 10 <sup>-6</sup>
Thermal conductivity				
W/m·°C	(2)	21	25	24
Btu in/(ft <sup>2</sup> h°F)	(2)	145	173	166
Specific heat				
J/kg °C	(2)	420	510	600
Btu/lb °F	(2)	0,10	0,12	0,14

(1) = for the soft annealed condition.

(2) = for the hardened and tempered condition.

## Bend strength



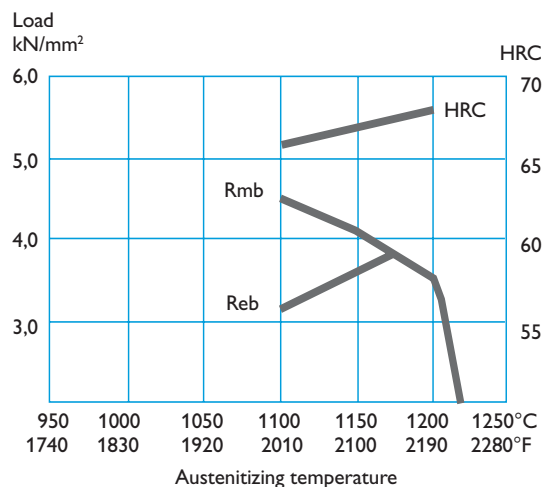
Four-point bend testing.

Specimen size: 5 mm (0,2") Ø

Loading rate: 5 mm/min. (0,2"/min.)

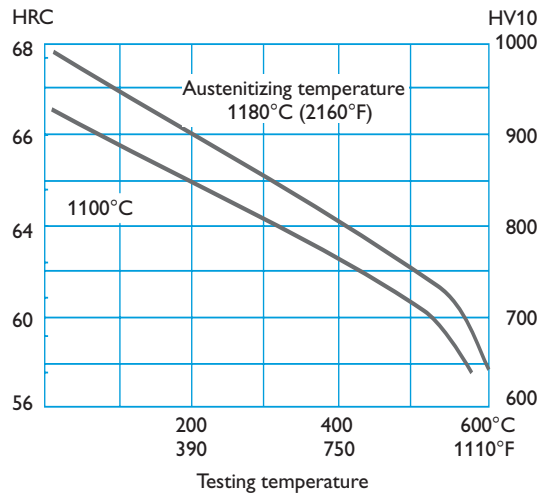
Austenitizing temperature: 1100–1210°C (2010–2210°F)

Tempering: 3 × 1 h at 560°C (1040°F), air cooling to room temperature.



## High temperature properties

Uddeholm Vanadis 60 hot hardness.



Hardness for different austenitizing temperatures after tempering 3 times for one hour at 560°C (±1 HRC).

HRC	°C	°F
62	960	1760
64	1000	1832
66	1070	1960
68	1150	2102
69	1180	2156

## Heat treatment

### Soft annealing

Protect the steel and heat through to 850–900°C (1560–1650°F). Then cool in the furnace at 10°C/h (20°F/h) to 700°C (1290°F), then freely in air.

### Stress relieving

After rough machining the tool should be heated through to 600–700°C (1110–1290°F), holding time 2 hours. Cool slowly to 500°C (930°F), then freely in air.

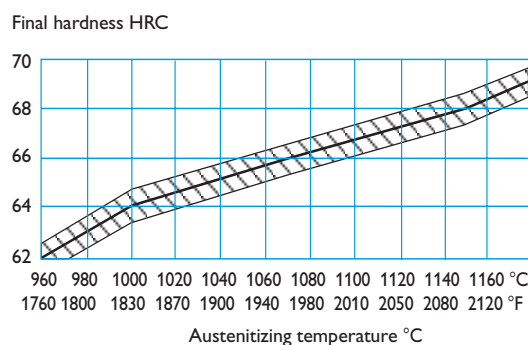
### Tempering

Pre-heating temperature: 450–500°C (840–930°F) and 850–900°C (1560–1650°F).

Austenitizing temperature: 1100–1180°C, according to the desired final hardness, see diagram below.

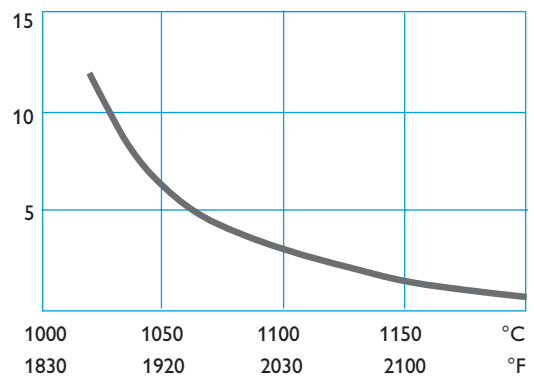
The tool should be protected against decarburization and oxidation during hardening.

HARDNESS AFTER TEMPERING 3 TIMES FOR ONE HOUR AT 560°C (1040°F).



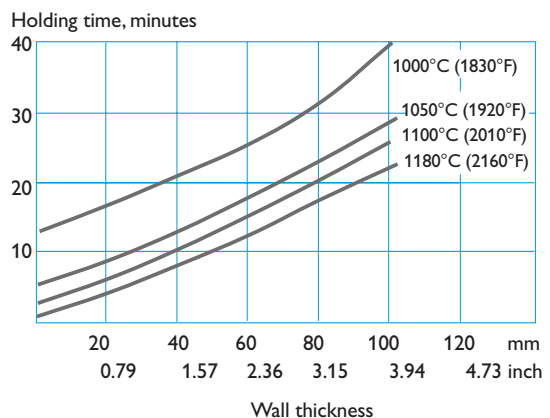
## RECOMMENDED HOLDING TIME

Holding time\* minutes



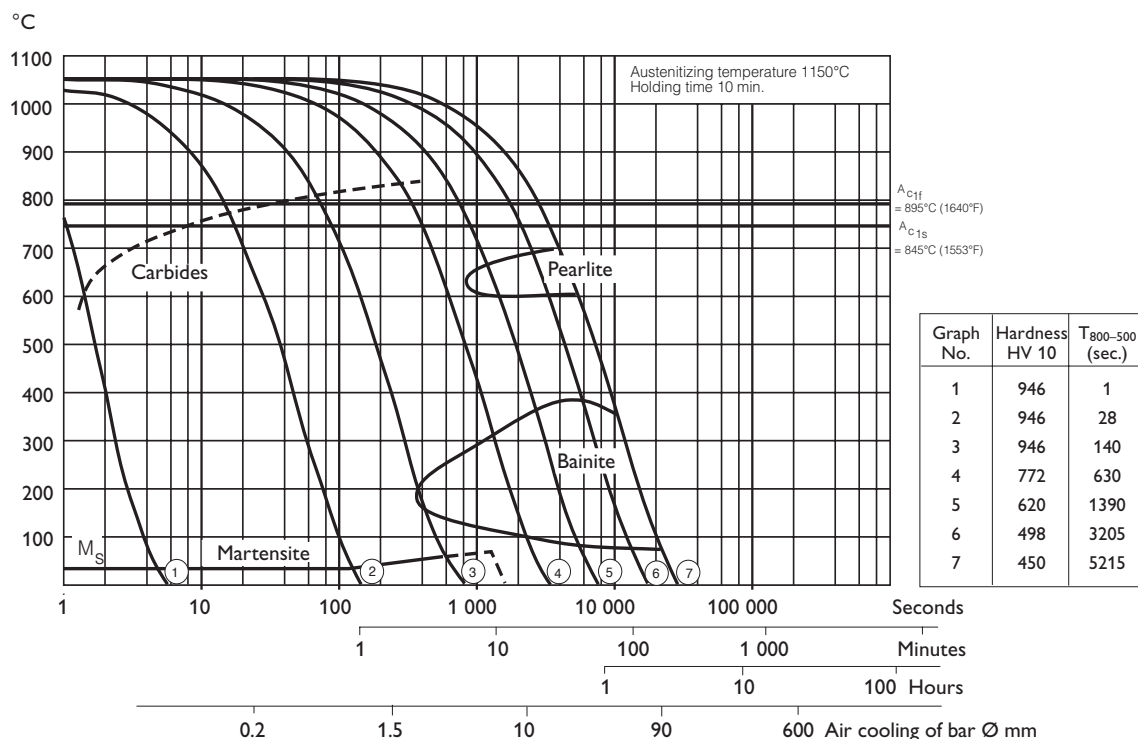
\* Holding time = time at austenitizing temperature after the tool is fully heated through.

TOTAL SOAKING TIME IN A SALT BATH AFTER PRE-HEATING IN TWO STAGES AT 450°C (840°F) AND 850°C (1560°F).



## CCT-GRAPH (CONTINUOUS COOLING)

Austenitizing temperature 1150°C (1920°F). Holding time 10 minutes.



### Quenching media

- Martempering bath at approx. 540°C (1004°F)
- Vacuum furnace with high speed gas at sufficient overpressure

*Note. 1:* Quenching should be continued until the temperature of the tool reaches approx. 25°C (77°F). The tool should then be tempered immediately.

*Note. 2:* In order to obtain a high toughness, the cooling speed in the core should be at least 10°C/sec. (20°F/sec.). This is valid for cooling from the austenitizing temperature down to approx. 540°C (1004°F). After temperature equalization between the surface and core, the cooling rate of approx. 5°C/sec. (10°F/sec.) can be used. The above cooling cycle results in less distortion and residual stresses.

### Tempering

For cold work applications tempering should always be carried out at 560°C (1040°F) irrespective of the austenitizing temperature. Temper three times for one hour at full temperature. The tool should be cooled to room temperature between the tempers. The retained austenite content will be less than 1% after this tempering cycle.

### Dimensional changes

Dimensional changes after hardening and tempering.

*Heat treatment:* austenitizing between 1050–1130°C (1920–2070°F) and tempering 3 x 1 h at 560°C (1040°F).

*Specimen size:* 80 x 80 x 80 mm (2.91 x 2.91 x 2.91 in.) and 100 x 100 x 25 mm (3.94 x 3.94 x 0.99 in.).

*Dimensional changes:* growth in length, width and thickness: +0.03% to +0.13%.

## Cutting data recommendations

The cutting data below are to be considered as guiding values which must be adapted to existing local conditions. More information can be found in the Uddeholm publication “Cutting data recommendations”

### Turning

Cutting data parameters	Turning with carbide		Turning with high speed steel Fine turning
	Rough turning	Fine turning	
Cutting speed ( $v_c$ ) m/min f.p.m.	60–90 200–300	90–110 300–365	6–10 20–33
Feed ( $f$ ) mm/r i.p.r.	0.20–0.40 0.008–0.016	0.05–0.20 0.002–0.008	0.05–0.30 0.002–0.012
Depth of cut ( $a_p$ ) mm inch	2–4 0.08–0.16	0.5–2 0.02–0.08	0.5–3 0.02–0.12
Carbide designation ISO	K20, P20*	K15, P10*	–

\* Preferably a wear resistant CVD coated carbide grade

### Drilling

#### HIGH SPEED STEEL TWIST DRILL

Drill diameter		Cutting speed ( $v_c$ )		Feed ( $f$ )	
mm	inch	m/min	f.p.m.	mm/r	i.p.r.
–5	3/16	6–8*	20–26*	0.05–0.15	0.002–0.006
5–10	3/16–3/8	6–8*	20–26*	0.15–0.20	0.006–0.008
10–15	3/8–5/8	6–8*	20–26*	0.20–0.25	0.008–0.010
15–20	5/8–3/4	6–8*	20–26*	0.25–0.35	0.010–0.012

\* For coated high speed steel drill  $v_c = 12–14$  m/min

#### CARBIDE DRILL

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip <sup>1)</sup>
Cutting speed ( $v_c$ ) m/min f.p.m.	80–100 265–335	40–60 130–200	20–30 65–100
Feed ( $f$ ) mm/r i.p.r.	0.08–0.14 <sup>2)</sup> 0.003–0.006 <sup>2)</sup>	0.10–0.15 <sup>2)</sup> 0.004–0.006 <sup>2)</sup>	0.10–0.20 <sup>2)</sup> 0.004–0.008 <sup>2)</sup>

<sup>1)</sup> Drill with replaceable or brazed carbide tip

<sup>2)</sup> Depending on drill diameter

### Milling

#### FACE AND SQUARE SHOULDER MILLING

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed ( $v_c$ ) m/min f.p.m.	40–60 130–200	60–80 200–265
Feed ( $f_z$ ) mm/tooth inch/tooth	0.20–0.30 0.008–0.012	0.10–0.20 0.004–0.008
Depth of cut ( $a_p$ ) mm inch	2–4 0.08–0.16	1–2 0.04–0.08
Carbide designation ISO	K20, P20*	K15, P10*

\* Preferably a wear resistant CVD coated carbide grade

#### END MILLING

Cutting data parameters	Type of mill		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed ( $v_c$ ) m/min f.p.m.	30–40 100–130	40–60 130–200	10–14 <sup>1)</sup> 30–50 <sup>1)</sup>
Feed ( $f_z$ ) mm/tooth inch/tooth	0.01–0.20 <sup>2)</sup> 0.0004–0.008 <sup>3)</sup>	0.06–0.20 <sup>2)</sup> 0.002–0.008 <sup>2)</sup>	0.01–0.30 <sup>2)</sup> 0.0004–0.012 <sup>2)</sup>
Carbide designation ISO	–	K15, P10–P20 Coated carbide <sup>3)</sup>	–

<sup>1)</sup> A coated high speed steel end mill

<sup>2)</sup> Depending on radial depth of cut and cutter diameter

<sup>3)</sup> Preferably a wear resistant CVD coated carbide grade

### Grinding

General grinding wheel recommendation is given below. More information can be found in the Uddeholm publication “Grinding of Tool Steel”.

Type of grinding	Soft annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	B151 R50 B3 <sup>1)</sup> A 46 HV <sup>2)</sup>
Face grinding (segments)	A 36 GV	B151 R50 B3 <sup>1)</sup> A 46 GV <sup>2)</sup>
Cylindrical grinding	A 60 KV	B151 R50 B3 <sup>1)</sup> A 60 KV <sup>2)</sup>
Internal grinding	A 60 JV	B151 R75 B3 <sup>1)</sup> A 60 JV <sup>2)</sup>
Profile grinding	A 100 IV	B126 R100 B6 <sup>1)</sup> A 120 JV <sup>2)</sup>

<sup>1)</sup> If possible use CBN wheels for this application

<sup>2)</sup> Preferably a wheel type containing sintered  $Al_2O_3$  (seeded gel)

# Relative comparison of Uddeholm cold work tool steel

## Material properties and resistance to failure mechanisms

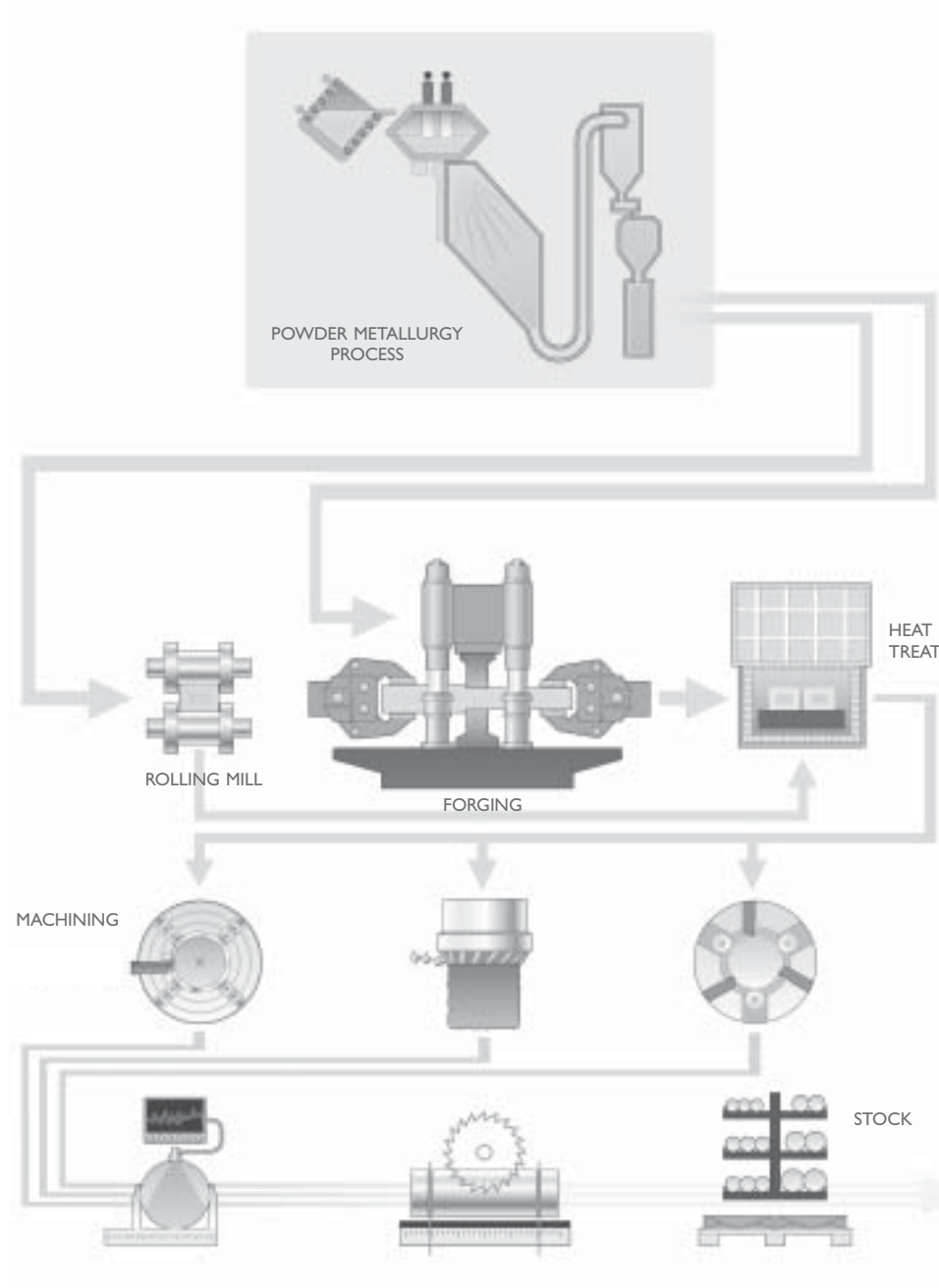
Uddeholm grade	Hardness/ Resistance to plastic deformation	Machinability	Grindability	Dimension stability	Resistance to		Fatigue cracking resistance	
					Abrasive wear	Adhesive wear	Ductility/ Resistance to chipping	Toughness/ Gross cracking
Conventional cold work tool steel								
ARNE	■	■	■	■	■	■	■	■
CALMAX	■	■	■	■	■	■	■	■
CALDIE (ESR)	■	■	■	■	■	■	■	■
RIGOR	■	■	■	■	■	■	■	■
SLEIPNER	■	■	■	■	■	■	■	■
SVERKER 21	■	■	■	■	■	■	■	■
SVERKER 3	■	■	■	■	■	■	■	■
Powder metallurgical tool steel								
VANADIS 4 EXTRA	■	■	■	■	■	■	■	■
VANADIS 6	■	■	■	■	■	■	■	■
VANADIS 10	■	■	■	■	■	■	■	■
VANCRON 40	■	■	■	■	■	■	■	■
Powder metallurgical high speed steel								
VANADIS 23	■	■	■	■	■	■	■	■
VANADIS 30	■	■	■	■	■	■	■	■
VANADIS 60	■	■	■	■	■	■	■	■
Conventional high speed steel								
AISI M2	■	■	■	■	■	■	■	■

## EDM

If EDM is performed in the hardened and tempered condition, finish with “finesparking”, i.e. low current, high frequency. For optimal performance the EDM'd surface should then be ground/polished and the tool retempered at approx. 535°C (995°F).

## Further information

Please, contact your local Uddeholm office for further information on the selection, heat treatment, application and availability of Uddeholm tool steels.



## The Powder Metallurgy process

In the powder metallurgy process nitrogen gas is used to atomise the melted steel into small droplets, or grains. Each of these small grains solidifies quickly and there is little time for carbides to grow. These powder grains are then compacted to an ingot in a hot isostatic press (HIP) at high temperature and pressure. The ingot is then rolled or forged to steel bars by conventional methods.

The resulting structure is completely homogeneous steel with randomly distributed small carbides, harmless as sites for crack initiation but still protecting the tool from wear.

Large slag inclusions can take the role as sites for crack initiation instead. Therefore, the powder metallurgical process has been further developed in stages to improve the cleanliness of the steel. Powder steel from Uddeholm Tooling is today of the third generation and is considered the cleanest powder metallurgy tool steel product on the market.

### HEAT TREATMENT

Prior to delivery all of the different bar materials are subjected to a heat treatment operation, either as soft annealing or hardening and tempering. These operations provide the steel with the right balance between hardness and toughness.

### MACHINING

Before the material is finished and put into stock, we also rough machine the bar profiles to required size and exact tolerances. In the lathe machining of large dimensions, the steel bar rotates against a stationary cutting tool. In peeling of smaller dimensions, the cutting tools revolve around the bar.

To safeguard our quality and guarantee the integrity of the tool steel we perform both surface- and ultrasonic inspections on all bars. We then remove the bar ends and any defects found during the inspection.





## Network of excellence

UDDEHOLM is present on every continent. This ensures you high-quality Swedish tool steel and local support wherever you are. ASSAB is our wholly-owned subsidiary and exclusive sales channel, representing Uddeholm in various parts of the world. Together we secure our position as the world's leading supplier of tooling materials.

UDDEHOLM is the world's leading supplier of tooling materials. This is a position we have reached by improving our customers' everyday business. Long tradition combined with research and product development equips Uddeholm to solve any tooling problem that may arise. It is a challenging process, but the goal is clear – to be your number one partner and tool steel provider.

Our presence on every continent guarantees you the same high quality wherever you are. ASSAB is our wholly-owned subsidiary and exclusive sales channel, representing Uddeholm in various parts of the world. Together we secure our position as the world's leading supplier of tooling materials. We act worldwide, so there is always an Uddeholm or ASSAB representative close at hand to give local advice and support. For us it is all a matter of trust – in long-term partnerships as well as in developing new products. Trust is something you earn, every day.

For more information, please visit [www.uddeholm.com](http://www.uddeholm.com), [www.assab.com](http://www.assab.com) or your local website.

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