FORMVAR

ASSAB

ASSAB	UDDEHOLM	REFERENCE STANDARD		
		AISI	WNr.	JIS
ASSAB DF-2	ARNE	O1	(1.2510)	(SKS 3)
ASSAB DF-3		O1	(1.2510)	(SKS 3)
ASSAB XW-5	SVERKER 3	D6 (D3)	(1.2436)	(SKD 2)
ASSAB XW-10	RIGOR	A2	1.2363	SKD 12
ASSAB XW-41	SVERKER 21	D2	1.2379	SKD 11
ASSAB XW-42		D2	1.2379	SKD 11
CARMO	CARMO		1.2358	
CALMAX	CALMAX		1.2358	
CALDIE	CALDIE			
ASSAB 88	SLEIPNER			
ASSAB PM 23 SUPERCLEAN	VANADIS 23 SUPERCLEAN	(M3:2)	1.3395	SKH 53
ASSAB PM 30 SUPERCLEAN	VANADIS 30 SUPERCLEAN	(M3:2 + Co)	1.3294	SKH 40
ASSAB PM 60 SUPERCLEAN	VANADIS 60 SUPERCLEAN		(1.3292)	
VANADIS 4 EXTRA SUPERCLEAN	VANADIS 4 EXTRA SUPERCLEAN			
VANADIS 6 SUPERCLEAN	VANADIS 6 SUPERCLEAN			
VANADIS 10 SUPERCLEAN	VANADIS 10 SUPERCLEAN			
VANCRON 40 SUPERCLEAN	VANCRON 40 SUPERCLEAN			
ELMAX SUPERCLEAN	ELMAX SUPERCLEAN			
ASSAB 518		P20	1.2311	
ASSAB 618		P20 Mod.	1.2738	
ASSAB 618 HH		P20 Mod.	1.2738	
ASSAB 618 T		P20 Mod.	1.2738 Mod.	
ASSAB 718 SUPREME	IMPAX SUPREME	P20 Mod.	1.2738	
ASSAB 718 HH	IMPAX HH	P20 Mod.	1.2738	
NIMAX	NIMAX			
MIRRAX 40	MIRRAX 40	420 Mod.		
VIDAR 1 ESR	VIDAR 1 ESR	H11	1.2343	SKD 6
UNIMAX	UNIMAX			
CORRAX	CORRAX			
ASSAB 2083		420	1.2083	SUS 420J2
STAVAX ESR	STAVAX ESR	420 Mod.	1.2083 ESR	SUS 420J2
MIRRAX ESR	MIRRAX ESR	420 Mod.		
POLMAX	POLMAX			
RAMAX HH	RAMAX HH	420 F Mod.		
ROYALLOY	ROYALLOY			
PRODAX				
ASSAB MM40				
ALVAR 14	ALVAR 14		1.2714	SKT 4
ASSAB 2714			1.2714	SKT 4
ASSAB 8407 2M	ORVAR 2M	H13	1.2344	SKD 61
ASSAB 8407 SUPREME	ORVAR SUPREME	H13 Premium	1.2344 ESR	SKD 61
DIEVAR	DIEVAR			
QRO 90 SUPREME	QRO 90 SUPREME			
FORMVAR	FORMVAR			
ASSAB 705		4340	1.6582	SNCM8
ASSAB 709		4140	1.7225	SCM4
ASSAB 760		1050	1.1730	S50C

Edition 141223

General

Formvar is a high-performance hot-work tool steel which offers a very good resistance to hot wear and plastic deformation. Formvar is characterised by:

- Good temper resistance
- Good high-temperature strength
- Excellent hardenability
- Good dimensional stability throughout heat treatment and coating operations

Typical analysis %	C 0.35	Si 0.2	Mn 0.5	Cr 5.0	Mo 2.3	V 0.6
Standard specification	None					
Delivery condition	Soft annealed to max. 230 HB					
Colour code	Violet / Yellow-green					

Applications

EXTRUSION

Part	Copper alloys	Aluminium / Magnesium alloys
Dies	-	46 - 52 HRC
Liners, dummy blocks, stems	46 - 52 HRC	44 - 52 HRC

HOT FORGING

Part	Steel / Aluminium
Inserts	46 - 52 HRC

Properties

PHYSICAL PROPERTIES

Hardened and tempered to 44 - 46 HRC.

Temperature	20°C	400°C	600°C
Density kg/m³	7800	7700	7600
Modulus of elasticity MPa	210 000	180 000	145 000
Coefficient of thermal expansion per °C from 20°C	-	12.7 x 10^{-6}	13.3 x 10^{-6}
Thermal conductivity W/m °C	-	31	32

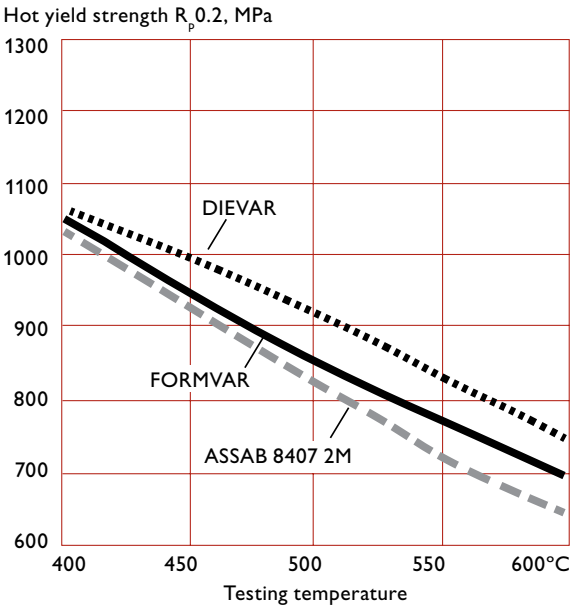
MECHANICAL PROPERTIES

Tensile properties at room temperature, short transverse direction.

Hardness	44 HRC	48 HRC	52 HRC
Tensile strength R_m	1480 MPa	1640 MPa	1900 MPa
Yield strength $R_p0.2$	1210 MPa	1380 MPa	1560 MPa

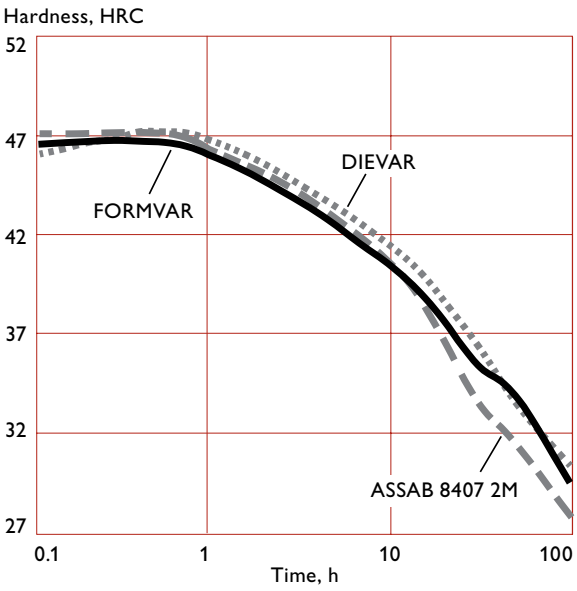
Hot yield strength

Austenitising : 1020°C / 30 min.
Tempering : 616°C / 2 x 2h.



Tempering resistance at 600°C

Austenitising : 1020°C / 30 min.
Tempering : 616°C / 2 x 2h.



Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 850°C. Then cool in furnace at 10°C per hour to 600°C, then freely in air.

STRESS RELIEVING

After rough machining, the tool should be heated through to 650°C, holding time 2 hours. Cool slowly to 500°C, then freely in air.

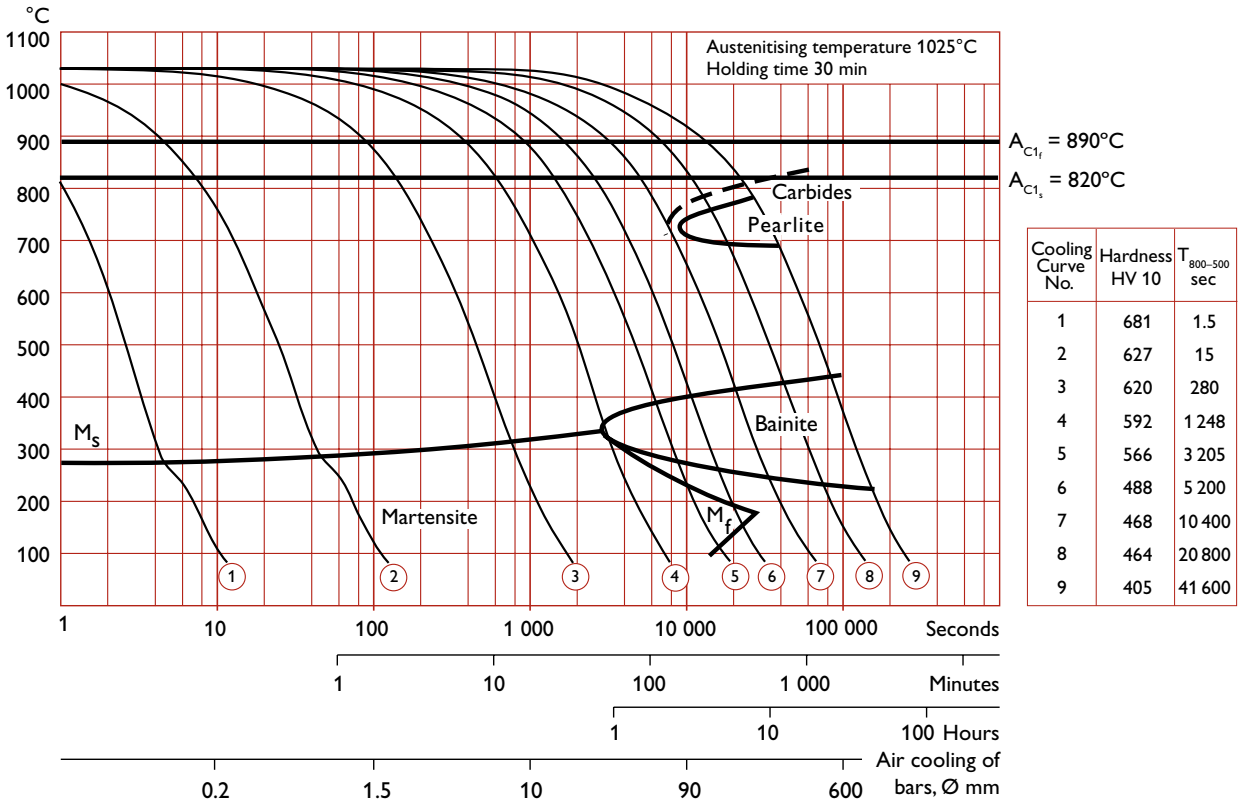
HARDENING

Preheating temperature: 600 - 900°C. Normally a minimum of two preheats, the first in the 600 - 650°C range, and the second in the 820 - 850°C range. When three preheats are used, the second is carried out at 820°C and the third at 900°C.

Austenitising temperature: 1000 - 1030°C.

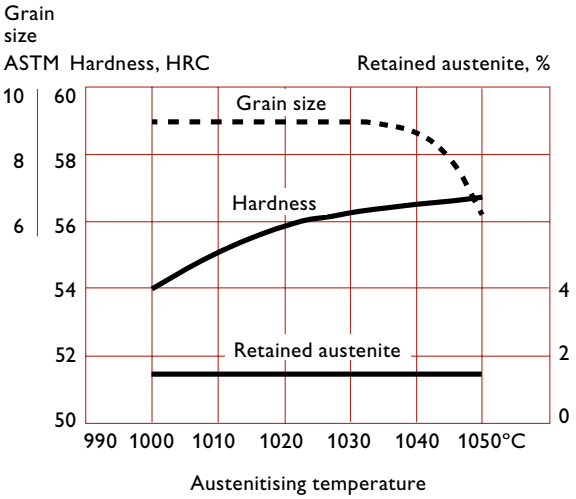
CCT graph

Austenitising temperature 1025°C. Holding time 30 minutes.



Cooling Curve No.	Hardness HV 10	$T_{800-500}$ sec
1	681	1.5
2	627	15
3	620	280
4	592	1 248
5	566	3 205
6	488	5 200
7	468	10 400
8	464	20 800
9	405	41 600

Hardness, grain size and retained austenite as functions of austenitising temperature



QUENCHING MEDIA

- High-speed gas/circulating atmosphere
- High-speed gas with sufficient positive pressure quenching in vacuum furnace. An interrupted quench at 320 - 450°C is recommended where distortion control and quench cracking are a concern.
- Martempering bath, salt bath or fluidised bed at 450 - 550°C
- Martempering bath, salt bath or fluidised bed at 180 - 200°C
- Warm oil, approx. 80°C

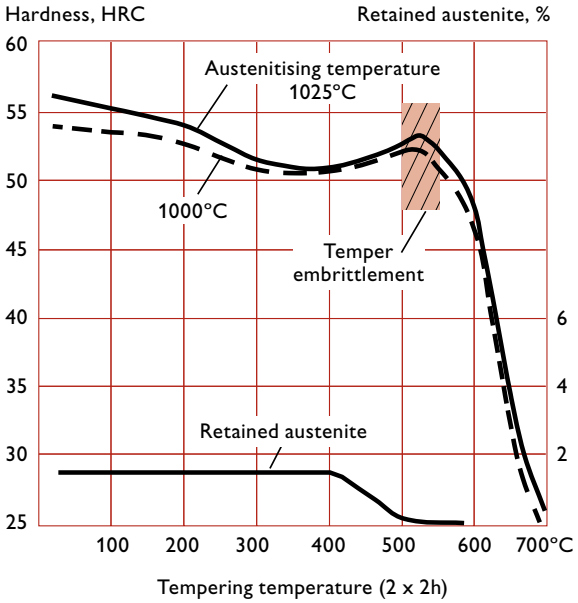
Note 1: Temper the tool as soon as its temperature reaches 50 - 70°C.

TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph. Temper minimum twice for forging and extrusion tools and three times for die-casting dies with intermediate cooling to room temperature. Holding time at temperature is minimum 2 hours.

Tempering in the range of 500 - 550°C for the intended final hardness will result in a lower toughness.

Tempering graph



Above tempering curves are obtained after heat treatment of samples with a size of 15 x 15 x 40 mm, cooling in forced air. Lower hardness can be expected after heat treatment of tools and dies due to factors like actual tool size and heat-treatment parameters.

Forging die (left) for producing hooks (right). Courtesy: Gunnebo Industries, Sweden.

Machining recommendations

The cutting data below are to be considered as guiding values and as starting points for developing your own best practice.

Condition: Soft-annealed condition ~160 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with HSS†
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min	150 - 200	200 - 250	15 - 20
Feed (f) mm/r	0.2 - 0.4	0.05 - 0.2	0.05 - 0.3
Depth of cut (a_p) mm	2 - 4	0.5 - 2	0.5 - 2
Carbide designation ISO	P20 - P30 Coated carbide	P10 Coated carbide or cermet	-

† *High-speed steel*

DRILLING

High-speed steel twist drill

Drill diameter mm	Cutting speed (v_c) m/min	Feed (f) mm/r
≤ 5	15 - 20*	0.05 - 0.15
5 - 10	15 - 20*	0.15 - 0.20
10 - 15	15 - 20*	0.20 - 0.25
15 - 20	15 - 20*	0.25 - 0.35

* *For coated HSS drill, v_c ~ 35 - 40 m/min*

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip[1]
Cutting speed (v_c) m/min	180 - 220	120 - 150	60 - 90
Feed (f) mm/r	0.05 - 0.25[2]	0.10 - 0.25[3]	0.15 - 0.25[4]

[1] *Drill with replaceable or brazed carbide tip*
[2] *Feed rate for drill diameter 20 - 40 mm*
[3] *Feed rate for drill diameter 5 - 20 mm*
[4] *Feed rate for drill diameter 10 - 20 mm*

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min	130 - 180	180 - 220
Feed (f_z) mm/tooth	0.2 - 0.4	0.1 - 0.2
Depth of cut (a_p) mm	2 - 4	- 2
Carbide designation ISO	P20 - P40 Coated carbide	P10 Coated carbide or cermet

End milling

Cutting data parameters	Type of end mill		
	Solid carbide	Carbide indexable insert	High-speed steel
Cutting speed (v_c) m/min	130 - 170	120 - 160	25 - 30[1]
Feed (f) mm/tooth	0.03 - 0.20[2]	0.08 - 0.20[2]	0.05 - 0.35[2]
Carbide designation ISO	-	P20 - P30	-

[1] For coated HSS end mill, v_c ~ 45 - 50 m/min
[2] Depending on radial depth of cut and cutter diameter

GRINDING

Wheel recommendation

Type of grinding	Grinding wheel designation
Face grinding straight wheel	A 46 HV
Face grinding segments	A 24 GV
Cylindrical grinding	A 46 LV
Internal grinding	A 46 JV
Profile grinding	A 100 LV

Machining recommendations

The cutting data below are to be considered as guiding values and as starting points for developing your own best practice.

Condition: Hardened and tempered to 45±1 HRC

TURNING

Cutting data parameters	Turning with carbide	
	Rough turning	Fine turning
Cutting speed (v_c) m/min	40 - 60	70 - 90
Feed (f) mm/r	0.2 - 0.4	0.05 - 0.2
Depth of cut (a_p) mm	1 - 2	0.5 - 1
Carbide designation ISO	P20 - P30 Coated carbide	P10 Coated carbide or cermet

DRILLING

High-speed steel twist drill

Drill diameter mm	Cutting speed (v_c) m/min	Feed (f) mm/r
≤ 5	4 - 6	0.05 - 0.10
5 - 10	4 - 6	0.10 - 0.15
10 - 15	4 - 6	0.15 - 0.20
15 - 20	4 - 6	0.20 - 0.30

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip[1]
Cutting speed (v_c) m/min	60 - 80	60 - 80	40 - 50
Feed (f) mm/r	0.05 - 0.25[2]	0.10 - 0.25[3]	0.15 - 0.25[4]

[1] Drill with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 20 - 40 mm
[3] Feed rate for drill diameter 5 - 20 mm
[4] Feed rate for drill diameter 10 - 20 mm

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min	50 - 90	90 - 130
Feed (f_z) mm/tooth	0.2 - 0.4	0.1 - 0.2
Depth of cut (a_p) mm	2 - 4	- 2
Carbide designation ISO	P20 - P40 Coated carbide	P10 Coated carbide or cermet

End milling

Cutting data parameters	Type of end mill		
	Solid carbide	Carbide indexable insert	High-speed steel
Cutting speed (v_c) m/min	60 - 80	70 - 90	5 - 10
Feed (f) mm/tooth	0.03 - 0.20[1]	0.08 - 0.20[1]	0.05 - 0.35[1]
Carbide designation ISO	-	P10 - P20	-

[1] Depending on radial depth of cut and cutter diameter

GRINDING

Wheel recommendation

Type of grinding	Grinding wheel designation
Face grinding straight wheel	A 46 HV
Face grinding segments	A 36 GV
Cylindrical grinding	A 60 KV
Internal grinding	A 60 IV
Profile grinding	A 120 JV

Surface treatment

NITRIDING AND NITROCARBURISING

Nitriding and nitrocarburising result in a hard surface layer which has the potential to improve resistance to wear and soldering, as well as resistance to premature heat checking.

Formvar can be nitrided and nitrocarburised via a plasma, gas, fluidised bed or salt process. Before nitriding, the tool should be hardened and tempered at a temperature at least 25 - 50°C above the nitriding temperature. Otherwise, a permanent loss of core hardness, strength, and/or dimensional tolerances may be experienced.

During nitriding and nitrocarburising, a brittle compound layer, known as the white layer, may be generated. The white layer is very brittle and may result in cracking or spalling when exposed to heavy mechanical or thermal loads. As a general rule, the white layer formation must be avoided.

Nitriding in ammonia gas at 510°C or plasma nitriding at 480°C both result in a surface hardness of approx. 1100 $HV_{0.2}$.

In general, plasma nitriding is the preferred method because of better control over nitrogen potential. However, careful gas nitriding can give same results.

The surface hardness after nitrocarburising in either gas or salt bath at 580°C is approx. 1100 $HV_{0.2}$.

Depth of nitriding

Process	Time h	Depth* mm	Hardness $HV_{0.2}$
Gas nitriding at 510°C	10 30	0.16 0.22	1100 1100
Plasma nitriding at 480°C	10	0.15	1100
Nitrocarburising – in gas at 580°C – in salt bath at 580°C	 2 1	 0.13 0.08	 1100 1100

* Depth of case = distance from surface where hardness is 50 $HV_{0.2}$ over base hardness

Forged crankshafts.

Relative comparison of ASSAB hot-work die steels

QUALITATIVE COMPARISON OF RESISTANCE TO DIFFERENT DIE FAILURES

ASSAB grade	Hot wear	Plastic deformation	Premature cracking	Heat checking
QRO 90 SUPREME				
UNIMAX				
DIEVAR				
ASSAB 8407 SUPREME				
ASSAB 8407 2M				
ALVAR 14				
FORMVAR				

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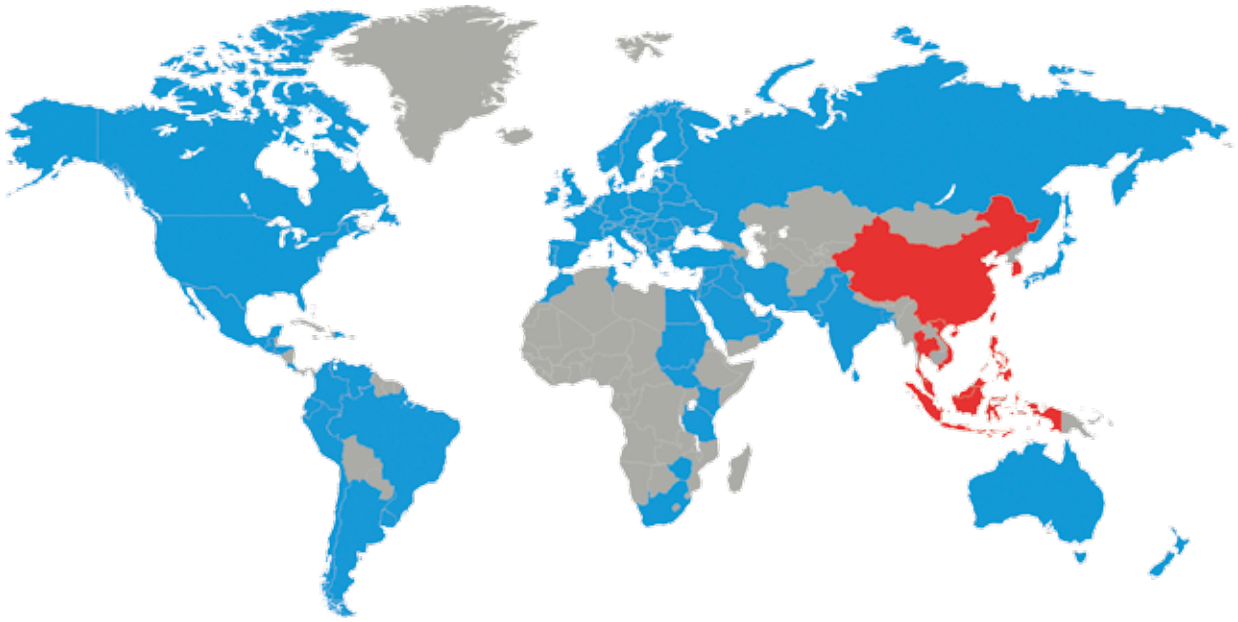

Choosing the right steel is of vital importance. ASSAB engineers and metallurgists are always ready to assist you in your choice of the optimum steel grade and the best treatment for each application. ASSAB not only supplies steel products with superior quality, we offer state-of-the-art machining, heat treatment and surface treatment services to enhance steel properties to meet your requirement in the shortest lead time. Using a holistic approach as a one-stop solution provider, we are more than just another tool steel supplier.

ASSAB and Uddeholm are present on every continent. This ensures you that high-quality tool steels and local support are available wherever you are. Together we secure our position as the world's leading supplier of tooling materials.

For more information, please visit www.assab.com

UDDEHOLM

ASSAB