Uddeholm

Tyrax® ESR

Also available for Additive Manufacturing

UDDEHOLM
a voestalpine company

Uddeholm Tyrax® ESR

Uddeholm Tyrax ESR is a premium high hardness and corrosion resistant plastic mould steel. It is designed with very high ductility/toughness and is easy and fast to polish to the highest surface finish levels. This grade is suited for moulding of high performance plastics often filled with glass fibre reinforcements and corrosive additives like flame retardants. It is also perfect for lens applications where the surface finish is important.

Classified according to EU Directive 1999/45/EC

For further information see our “Material Safety Data Sheets”.

Edition 5, 09.2024

GENERAL

Uddeholm Tyrax ESR is a premium high hardness and corrosion resistant plastic mould steel with the following properties:

- good corrosion resistance
- excellent polishability
- good wear resistance
- high hardness 55-58 HRC for resistance against indentations
- excellent ductility and toughness
- good dimensional stability at heat treatment and in service
- even microstructure and small grain size
- good hardenability

Uddeholm Tyrax ESR is delivered in soft annealed condition to approximate 190 HB. Uddeholm Tyrax ESR is produced using the Electro-Slag-Remelting (ESR) technique, resulting in very low inclusion content.

Typical analysis %	C 0.40	Si 0.2	Mn 0.5	Cr 12.0	Mo 2.3	V 0.5	N +
Delivery condition	Soft annealed to approx.190 HB						
Colour code	Black/purple						

APPLICATIONS

Uddeholm Tyrax ESR is suitable for long run production moulds, moulds for reinforced plastics and for compression moulding. Engineering applications like plasticizing screws are also an option. Uddeholm Tyrax ESR can be used in corrosive conditions as moulds subjected to humid working/storage conditions or for production of corrosive plastics. The high toughness/ductility makes it suitable for complex moulds. Uddehom Tyrax ESR is also suitable when high gloss surface finish is required.

- High performance plastics filled with glass fibers and corrosive additives
- Corrosive plastics like PVC
- High surface finish, i.e. for production of optical parts

PROPERTIES

Physical data

Hardened and tempered to 56 HRC. Data at room and elevated temperatures.

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density, kg/m³ lbs/in³	7 750	–	–
Modulus of elasticity MPa psi	209 000 30.3x10⁶	204 000 29.6x10⁶	187 000 27.1x10⁶
Coefficient of thermal expansion / °C from 20°C / °F rom 68°F	– –	11.3x10⁻⁶ 6.3x10⁻⁶	12.0x10⁻⁶ 6.7x10⁻⁶
Thermal conductivity* W/m °C Btu in/(ft2h°F)	22,3 154	24,1 167,2	25,1 174,1
Specific heat capacity J/kg °C Btu/lb °F	460 0,11	– –	– –

** Thermal conductivity is very difficult to measure. The scatter can be as high as +-15%.*

Tensile strength at room temperature

The tensile strength values are to be considered as approximate. The test samples have been hardened at 1050-1080°C (1920-1975°F), gas quenched in a vacuum furnace and tempered twice at 530°C (985°F) for two hours to the given hardness. All specimens have been taken from a bar with the dimension 254x102 mm (10” x 4”).

Hardness	56 HRC	58 HRC
Tensile strength Rm MPa p.s.i	2060 299 000	2260 328 000
Yield strength Rp0.2 MPa p.s.i	1460 212 000	1610 234 000

Compressive strength

Approximately compressive strength is shown in the table below. The test samples have been hardened at 1050°C (1920°F), gas quenched in a vacuum furnace and tempered twice at 525°C (980°F) for two hours to the given hardness.

Hardness HRC	Compressive yield strength, Rc0,2 (MPa)
56	1820

Impact toughness

Uddeholm Tyrax ESR has much higher toughness/ductility compared to other stainless tool steel of W.-Nr. 1.2083/AISI as well as 440 type.

Approximate room temperature impact strength as measured by samples removed from the centre of a forged block, tested in the short transverse direction and shown in the graph.

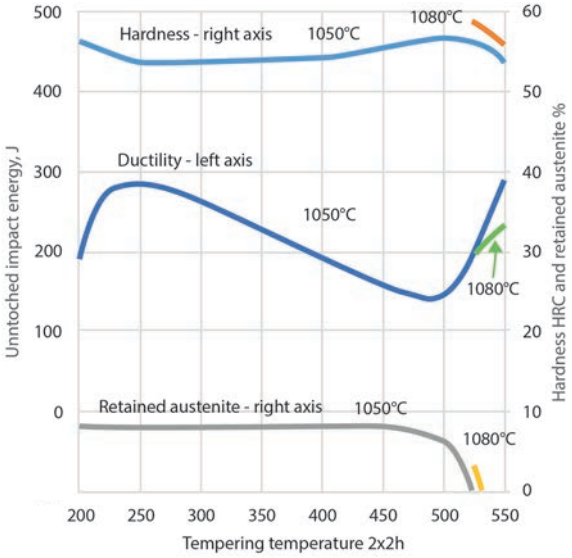
Original bar dimension: 250x80 mm (10” x 3”)

Specimen size: 7 x 10 x 55 mm (0.27” x 0.4” x 2.2”) unnotched.

Hardened at 1050°C (1920°F) and 1080°C (1980°F) for 30 minutes. Quenched in a vacuum furnace. Tempered 2 x 2h.

Influence of tempering temperature on unnotched impact toughness

All tests has been carried out at room temperature.



Corrosion resistance

Uddeholm Tyrax ESR shows the best corrosion resistance when tempered at a low temperature and polished to a mirror finish. Uddeholm Tyrax ESR is resistant to corrosive attack by water, water vapour, weak organic acids, dilute solutions of nitrates, carbonates and other salts.

A tool made from Uddeholm Tyrax ESR will have good resistance to rusting and staining due to humid working and storage conditions and when moulding corrosive plastics under normal production conditions.

HEAT TREATMENT

Soft annealing

Protect the steel and heat through to 860°C (1580°F). Then cool in the furnace at 10°C/h to 650°C (1200°F), then freely in air.

Stress relieving

After rough machining the tool should be heated through to 650°C (1200°F) and held for 2h. Cool slowly to 500°C (930°F), then freely in air.

Hardening

Preheating temperature: 600-850°C (1110-1560°F).
Austenitizing temperature: 1050-1080°C (1920-1975°F).
Holding time: 30 minutes.

Protect the material against decarburization and oxidation during austenitizing.

Quenching media
As a general rule, quench rates should be as rapid as possible. Accelerated quench rates are required to optimize tool properties specifically with regards to corrosion resistance, toughness and resistance to gross cracking. However, risk of excessive distortion and cracking must be considered.

The quenching media should be capable of creating a fully hardened microstructure. Different quench rates for Uddeholm Tyrax ESR are defined by the CCT graph.

Recommended quenching media

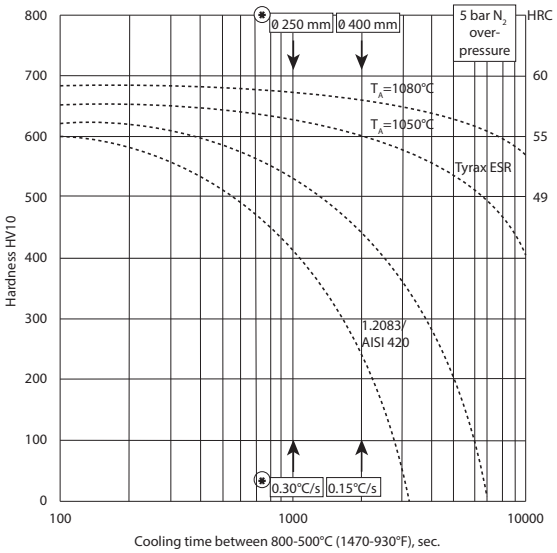
- Vacuum furnace (high speed gas with sufficient overpressure).
- salt bath at 250-550°C(480-1020°F) then cool in air blast.
- For complex geometries, an interrupted quench at 400-450°C (750-840°F) is recommended to lower the level of distortion and lower the risk of crack formation.
- high speed gas/circulating atmosphere

Temper immediately when the tool reaches room temperature. Uddeholm Tyrax ESR has a much better hardenability than the W.-Nr. 1.2083/AISI 420 type of material so the high hardness will be retained even in the centre of large dimensions.

The very good hardenability will also have a decisive effect on other properties such as toughness and corrosion resistance.

Hardness as a function of cooling rate

During hardening at 1050°C (1920°F) and 1080°C (1975°F).



** Cooling rate in the centre of two dimensions is indicated.*

Sub-Zero treatment

Cryo-treatment in liquid nitrogen (-120°C to -196°C (-185°F to -320°F)) may be carried out for tools with high demands on dimensional stability after heat treatment. This treatment should be performed before tempering. Intricate shapes should however be avoided because of the risk of cracking.

Cryotreatment is especially interesting before low temperature tempering as the content of retained austenite will be eliminated/very low resulting in increased hardness and wear resistance. Corrosion resistance is improved using low temperature tempering at 200°C to 300°C (390°F-572°F) compared to tempering at temperatures 525°C (980°F) or higher.

Hardening 1080°C/30min/cryo-treatment at -196°C	Tempering 200°C/2x2h
Hardness	58.5 HRC
Retained austenite	<2 %

Tempering

Tempering temperature should be selected depending on aimed hardness according to the graphs shown below. Temper twice with intermediate cooling to room temperature. Lowest tempering temperature is 200 °C. Holding time at tempering is 2h.

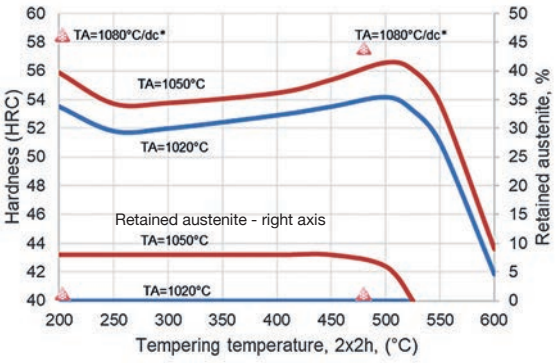
The tempering curves are obtained after heat treatment of samples with a size of 15 x 15 x 40 mm, cooling in a vacuum furnace.

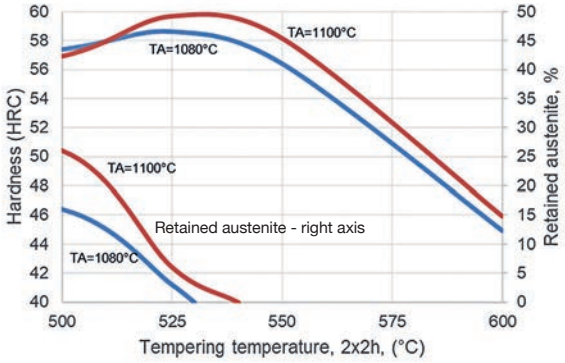
Note: Tempering at 200-250°C (390-480°F) results in the best combination of toughness, hardness and corrosion resistance. However for complicated design it is recommended to use a high temperature tempering (lowest 525°C (980°F)) to reduce residual stresses and retained austenite to a minimum.

Hardening at 1080°C (1975°F) will give a hardness up to 58 HRC when tempering at 530°C (985°F), still with good ductility.

In special cases a hardening temperature of 1100°C (2010°F) may be used. Hardness is increased up to 60 HRC when tempering at 525-530°C (980-985°F). 1100°C (2010°F) is only recommended when toughness is of secondary importance.

Uddeholm Tyrax ESR may also be used at a normal AISI 420 hardness of 52 HRC using 1020°C (1870°F) as hardening temperature and tempering twice at 250°C (480°F) for two hours, giving <2% retained austenite.

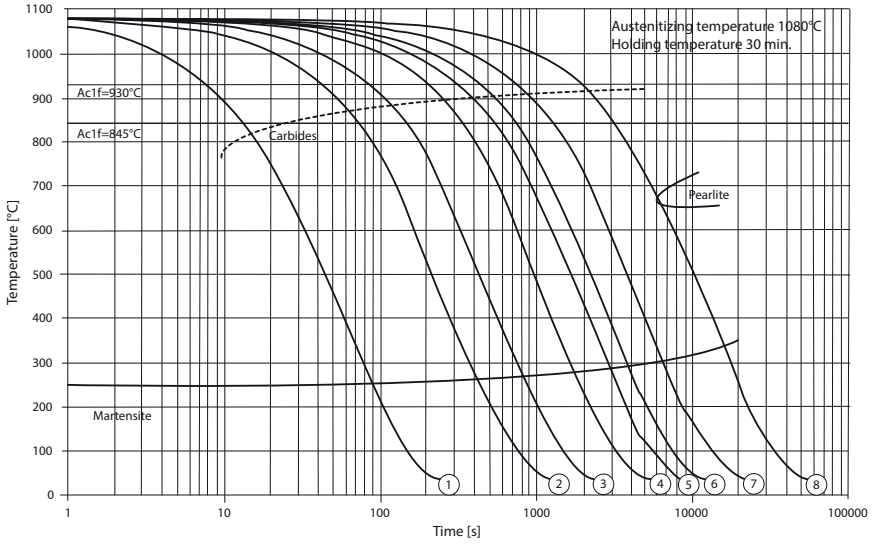




*dc= deep cooled - Cryo-treatment in liquid nitrogen (-170 to -196°C)

CCT-diagram

Austenitizing temperature 1080°C (1975°F). Holding time 30 minutes.



Cooling curve no.	Hardness HV10	t800-500 (sec)
1	685	28
2	664	140
3	681	280
4	680	630
5	677	1030
6	688	1390
7	654	2400
8	609	6240

Dimensional changes

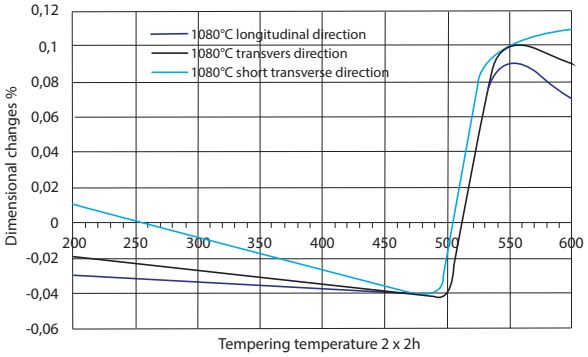
Dimensional changes have been measured after hardening and tempering.

Austenitizing: 1080°C/30 min. (1975°F/30 min.) cooling in vacuum furnace at 0,64°C/sec. (1,15°F/sec) between 800°C (1470°F) and 500°C (930°F).

Tempering: 2 x 2 h at various temperatures

Sample size: 100 x 40 x 20 mm (4” x 1,6” x 0,8”).

A machining allowance of 0,15 % is recommended for Uddeholm Tyrax ESR.

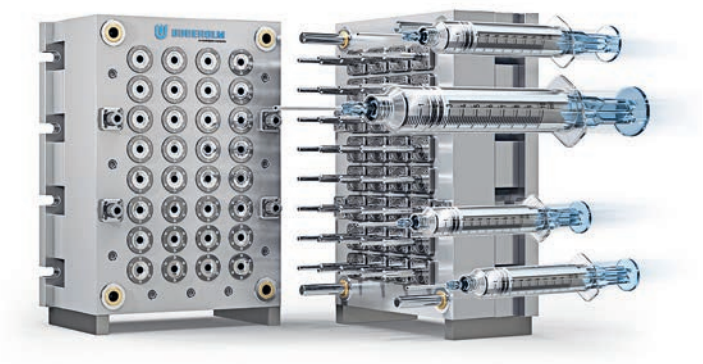


MACHINING RECOMMENDATIONS

The cutting data below are to be considered as guiding values which must be adapted to existing local conditions.

The recommendations in following tables are valid for Uddeholm Tyrax ESR in soft annealed condition, ~190HB

Indexable milling inserts: Select ISO P designation also compatible to M and S area.



Turning

Cutting data parameters	Turning with carbide: Rough turning	Turning with carbide: Fine turning	Turning with HSS: Fine turning
Cutting speed (v_c) m/min. f.p.m.	140–190 460–620	190–240 620–790	15–20 50–65
Feed (f) mm/r i.p.r.	0.2–0.4 0.008–0.016	0.05–0.2 0.002–0.008	0.05–0.3 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	P20-P30 C6-C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

Drilling

High speed steel twist drill

Drill diameter mm	inch	Cutting speed (v_c) m/mm	f.p.m.	Feed (f) mm/r	i.p.r.
–5	–3–16	12–16*	40–52*	0.05–0.15	0.002–0.006
5–10	3/16–3/8	12–16*	40–52*	0.15–0.20	0.006–0.008
10–15	3/8–5/8	12–16*	40–52*	0.20–0.25	0.008–0.010
15–20	5/8–3/4	12–16*	40–52*	0.25–0.35	0.010–0.014

** For coated HSS drill v_c ~22-24 m/min (72-79 f.p.m)*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Solid carbide	Carbide tip[1]
Cutting speed (v_c) m/min. f.p.m.	160–200 525–650	80–100 260–330	60–90 195–295
Feed (f) mm/r i.p.r.	0.03–0.1[2] 0.001–0.004[2]	0.10–0.25[3] 0.004–0.01[3]	0.15–0.25[4] 0.006–0.01[4]

[1] Drills with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 20-40 mm (0.8”-1.6”)
[3] Feed rate for drill diameter 5-20 mm (0.2”-0.8”)
[4] Feed rate for drill diameter 10-20 mm (0.4”0.8”)

The recommendations in the following tables are valid for Uddeholm Tyrax ESR in hardened and tempered condition, 54-58 HRC.

Indexable milling inserts: Select ISO P designation also compatible to M, S and H area.

Turning

Cutting data parameters	Turning with carbide	
	Rough turning	Fine turning
Cutting speed (v_c) m/min. f.p.m.	40–60 130–200	60–80 200–265
Feed (f) mm/r i.p.r.	0.1–0.2 0.004–0.008	0.05–0.1 0.002–0.004
Depth of cut(a_p) mm inch	0.5–2.0 0.02–0.08	0.2–0.5 0.008–0.02
Carbide designation ISO	K10–K20 P10–P20 Coated carbide, CBN	K10, P05–P15 C7 Coated carbide, cermet, CBN

- Cutting fluid is recommended
- Avoid CBN at interrupt cutting conditions
- If using ceramic insert increase cutting speed during interrupt cut
- Use high temp resistant coating

Drilling

Carbide drill

Cutting data parameters	Type of drill	
	Solid carbide	Carbide tip[1]
Cutting speed (v_c) m/min. f.p.m.	30–40 100–130	40–50 130–165
Feed (f) mm/r i.p.r.	0.05–0.20[2] 0.002–0.008[2]	0.10–0.20[3] 0.004–0.008[3]

[1] Drills with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 5–20 mm (0.2”–1.8”)
[3] Feed rate for drill diameter 10–20 mm (0.4”–0.8”)

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.	30–50 100–165	50–70 165–230
Feed (f_z) mm/tooth in/tooth	0.05–0.2 0.002–0.008	0.05–0.1 0.002–0.004
Depth of cut (a_p) mm inch	0.5–2.0 0.02–0.08	0.1–0.5 0.004–0.02
Carbide designation ISO US	P10–P30 H20–H30 C7–C6 coated carbide*	P10–P20 H10–H20 C7–C6 coated carbide*

** Use high temp resistant coating*

End milling

Cutting data parameters	Type of milling	
	Solid carbide	Carbide indexable insert
Cutting speed (v_c) m/min. f.p.m.	60–80 200–260	40–80 130–260
Feed (f) mm/tooth in/tooth	0.01–0.10 [1] 0.0004–0.004 [1]	0.05–0.15 [1] 0.002–0.006 [1]
Carbide designation ISO US	Semi-Finishing Select range suitable for 55–60 HRc [2]	P10–P30 [2] H20–H30 [2] C7–C6

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

[2] Use high temp resistant coating

Grinding

A general grinding wheel recommendation is given below. More information can be found in the Uddeholm publication “Grinding of tool steel”.

Wheel recommendation

Type of grinding	Annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	A 46 HV
Face grinding segments	A 24 GV	A 36 GV
Cylindrical grinding	A 46 LV	A 60 KV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 LV	A 120 KV

POLISHING

Uddeholm Tyrax ESR has excellent polishability in the hardened and tempered condition. It can be polished up to the highest levels of surface finish in very few steps. More detailed information on polishing of Uddeholm Tyrax ESR is given in the brochure “Polishing of Tool Steel”.

WELDING

Good results can be obtained if proper precautions are taken before, during and after the welding operation. Joint preparation, preheating, interpass temperature, post weld heat treatment and handling of consumables are all crucial for the end result.

Use consumables with the same chemical composition as the tool steel for optimal results after polishing or photo etching.

Welding method	TIG
Welding consumables	TYRAX TIG WELD STAVAX TIG WELD MIRRAX TIG WELD
Preheat temperature	250°C ± 25°C (480°F)
Max interpass temperature	150ºC (270°F) Above preheating temperature
Post weld cooling rate	20–40ºC/h (35–70°F/h) for the first 2 hours, then freely in air
Hardness after welding	48–58
Post Weld Heat Treatment	
Hardened condition	Temper 25ºC (50°F) below the original tempering temperature
Soft annealed condition	Soft anneal the material at 860ºC (1580°F) in a protected atmosphere. The subsequent cooling should be carried out in the furnace at 10°C/h (20ºF/h) to 650°C (1200ºF), then freely in air

Further information is given in the Uddeholm broschure ”Welding of Tool Steel”.

FURTHER INFORMATION

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

ADDITIVE MANUFACTURING

Uddeholm Tyrax ESR is also available as powder for Additive Manufacturing Processes as Laser Powder Bed Fusion (LPBF) and Laser Metal Deposition (LMD). This powder is a gas atomized Uddeholm Tyrax ESR product with physical properties within the normal variation for the ESR material.

GENERAL

Uddeholm Tyrax for Additive Manufacturing offers several advantages and a unique combination of properties compared to other AM tool steels:

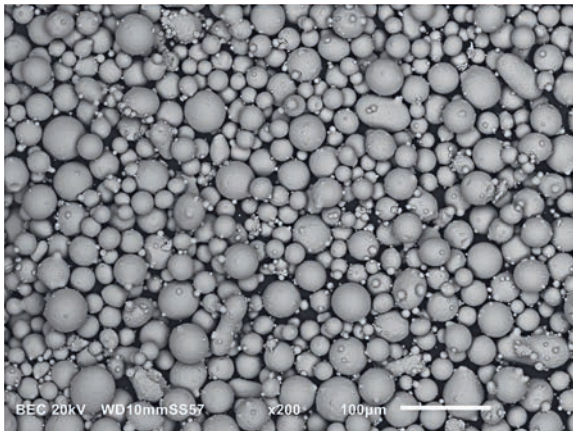
- High hardness up to 58-60 HRC
- Direct tempering can be used
- Good dimensional stability since it is possible to reach a content of retained austenite <2% after heat treatment
- Excellent polishability i.e very high density 99.997% combined with very high glossiness
- Isotropic and superior toughness level in both hardened + tempered condition as well as in direct tempered condition
- Good corrosion resistance
- Very good wear resistance with high hardness after hardening and tempering in combination with hard carbides in the microstructure
- Very high applicability for hybrids especially when Tyrax ESR is used as a base
- Very high temper back resistance especially in the direct tempered condition

APPLICATIONS

- Cores and cavities for
  - corrosive reinforced plastics
  - optical parts
  - parts with complex design
  - long serial production
- Engineering parts

POWDER CHARACTERISTICS

The chemical composition is the same as for the ESR material regarding core elements and a maximum Oxygen level of 200 ppm on the powder.



Shape distribution and density

Typical values

Sphericity	0.94
Aspect ratio	0.90
Apparent density g/cm^3	4.0
Tap density g/cm^3	4.8
True density g/cm^3	7.8

Particle size and distrubution

AM Tyrax has a sieved particle size that is between 20-50 µm.

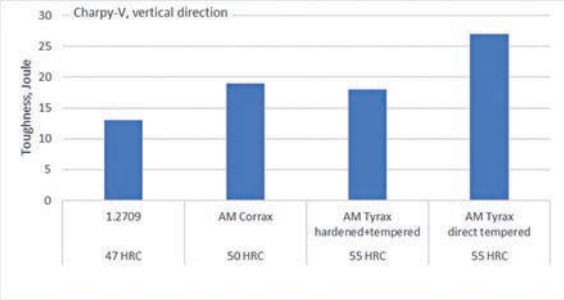
Typical values

D10	D50	D90
22 µm	34 µm	48 µm

PROPERTIES

Impact toughness

Tyrax for additive manufacturing has a high toughness at elevated hardness levels, approximate values can be seen in the graph below.



The toughness has also been measured on cubes with the dimension 77x77x80 mm showing that the toughness is very isotropic in two different directions (vertical and horizontal)

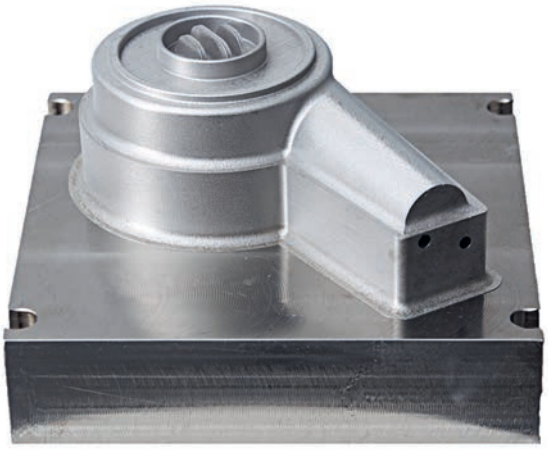
T_{aust} °C	T_{temp} °C	HRC	Toughness J vertical	Toughness J horizontal
1050/30 min	540/2x2 h	55	17	15
–	570/2x2 h	52	33	33

Tensile strength

Tensile strength and elongation have been measured in the vertical direction

	Hardened + tempered to 56 HRC *	Direct tempered to 52 HRC **
Yield strength Rp0,2 MPa	1600	1520
Tensile strength Rm MPa	2070	1830
Elongation A5%	9	13

* 1050°C + 540°C / 2 x 2h
** 570°C / 2 x 2h

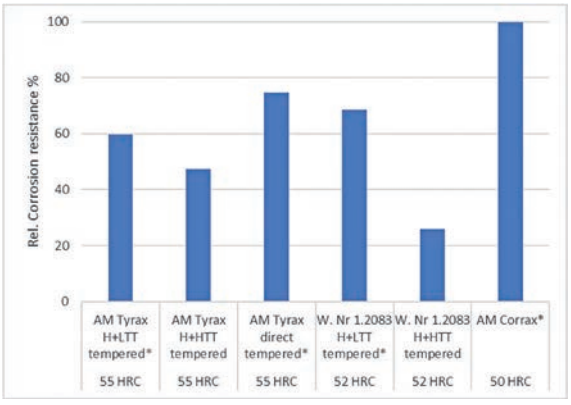


Corrosion resistance

Tyrax for additive manufacturing has a good corrosion resistance, fully comparable with Tyrax ESR.

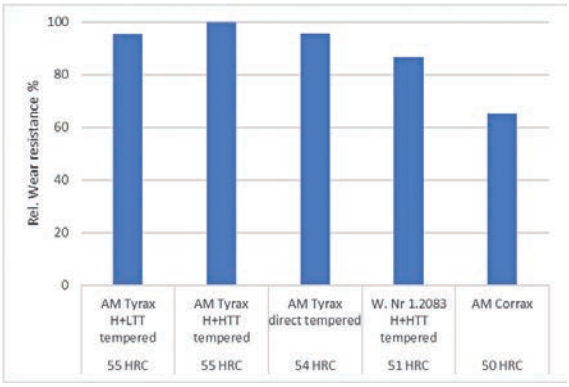
In general, martensitic stainless steels show the best corrosion resistance when tempered at a low temperature and polished to a mirror finish which is also valid for AM Tyrax. However, for AM Tyrax the direct tempered condition shows even better corrosion resistance.

*Relative corrosion resistance. H+LTT = hardened + low temperature tempered, H+HTT = hardened + high temperature tempered. Steels marked * forms a passive film in a 0,1M NaCl solution.*

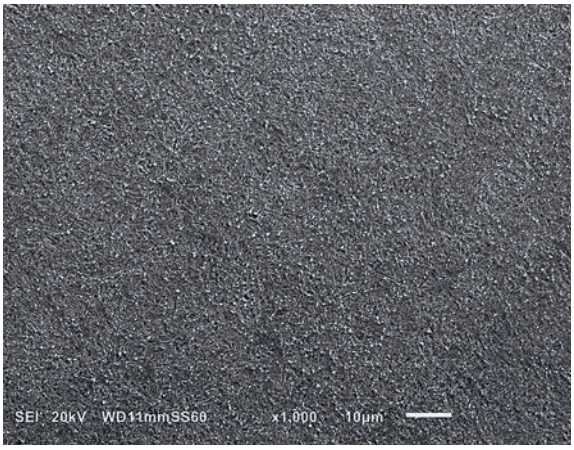


Wear resistance

Due to a high hardness together with hard carbides in the microstructure Uddeholm AM Tyrax has an excellent wear resistance towards most abrasive media.



Relative wear resistance. H+LTT = hardened + low temperature tempered, H+HTT = hardened + high temperature tempered.



Microstructure in hardened and tempered condition. White particles are evenly distributed carbides in a hard martensitic matrix.

Polishing

Uddeholm AM Tyrax offers extremely high polishabilty that results in excellent surface finish and a high gloss polished surface. When processed correctly Uddeholm AM Tyrax fully matches Uddeholm Tyrax ESR with its low amount of porosity and inclusions giving it perfect surfaces for high demanding tooling applications.

AM Tyrax can be polished the same way as Tyrax ESR, which means that fewer steps are needed compared to 420 type of material.

An extremely high density of 99,997 ± 0,003 % can be reached with a glossiness that is outstanding.

AM PROCESSING

Machine	EOS M290
Protective gas	Argon
Layer thickness	60 µm
Laser Power	338 W
Scan speed	1008 mm/s
Hatch distance	0.094 mm
Hatch mode	Stripes, 9.75 mm
Build plate temperature	200 °C

Base plate (≥ 55 mm) and hybrid material of similar thermal properties e.g. Tyrax ESR is recommended.

POST PROCESSING

After printing the hardness is around 60 HRC and contains up to 25% of retained austenite. After recommended heat treatments the amount can be reduced to a minimum. No deep cooling is necessary. However deep cooling can be used if a combination of high corrosion resistance (low temperature tempering) and high hardness is desired.

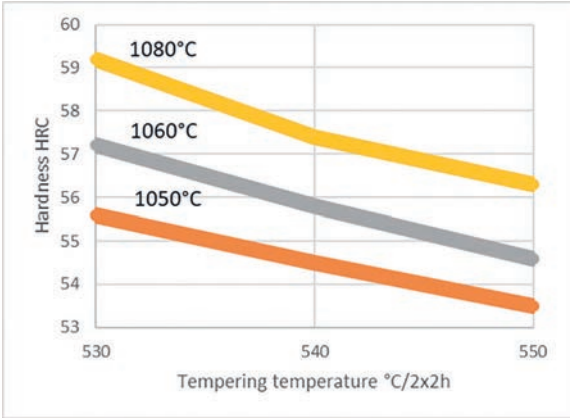
Pre-heating before hardening

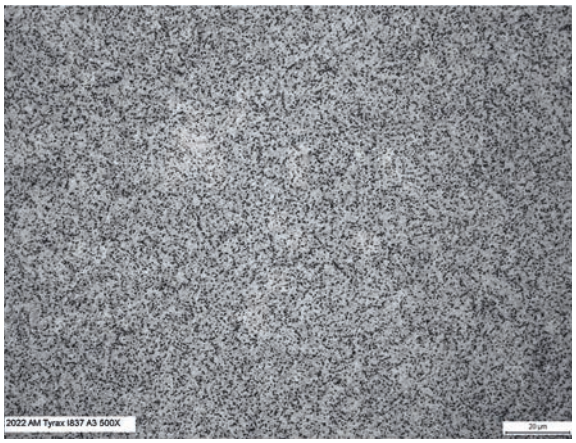
After printing, the built part will contain a various amount of residual stresses. To lower the harmful stresses and avoid extra thermal stresses preheating is recommended before hardening.

Heating rate of 7°C/minutes, pre-heating steps: 650°C/10 minutes and 850°C/10 minutes.

Hardening and tempering

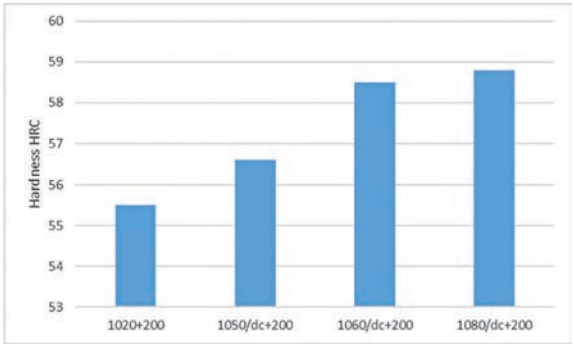
AM Tyrax can be hardened and tempered according to the tempering curves below with retained austenite content < 2 %. Holding time at austenitizing is 30 minutes.





Microstructure in hardened and tempered condition

It is also possible to low temperature temper (LTT) the material to improve the corrosion resistance compared to high temperature tempering (HTT). The heat treatments given in the diagram below gives <2% retained austenite. Note however that HTT will release more stresses compared to low temperature tempering LTT.

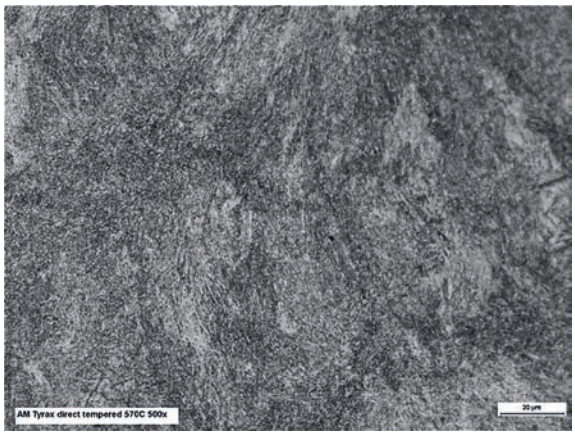


Hardness levels reached after hardening + tempering at 200°C/2x2h with or without deep cooling, dc = deep cooling to -196°C

Direct tempering

After printing AM Tyrax can alternatively be direct tempered according to the table below with a retained austenite content ≤ 2 %.

Tempering temperature / time	Hardness
560 °C/ 2x2 hours	55 ± 1 HRC
565 °C/ 2x2 hours	54 ± 1 HRC
570 °C/ 2x2 hours	53 ± 1 HRC



Microstructure in direct tempered condition

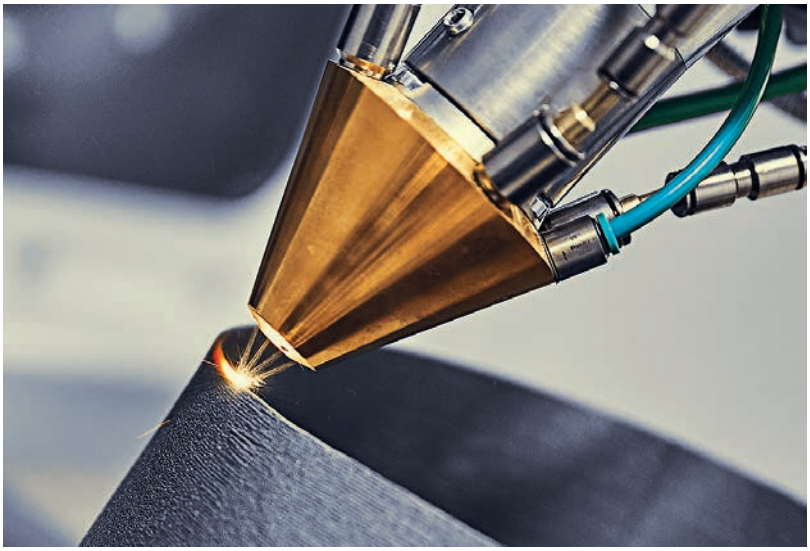
ADDITIVE MANUFACTURING

LMD

AM Tyrax can be used in the Laser Metal Deposition process and is therefore available in the size fraction 50-125 µm.

Recommended post process treatment after cladding is tempering 25 °C below the prior tempering temperature of the base material.

A hardness of 57-59 HRC can been reached when using the following heat treatment after cladding: 550°C for 5 hours.



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