TYRAX ESR & AM TYRAX

UDDEHOLM TYRAX ESR

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TYRAX & AM TYRAX- 20261104-5

TYRAX ESR

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.

GENERAL

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

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

Typical analysis %	C 0.4	Si 0.2	Mn 0.5	Cr 12.0	Mo 2.3	V 0.5	N +
Delivery condition	Soft annealed to approx. 190 HB.						

APPLICATIONS

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

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

PROPERTIES

Physical properties

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

Temperature	20 °C	200 °C	400 °C
Density, kg/m^3	7 750	-	-
Modulus of elasticity MPa	209 000	204 000	187 000
Coefficient of thermal expansion /°C from 20°C	-	11.3 x 10^{-6}	12.0 x 10^{-6}
Thermal conductivity* W/m °C	22.3	24.1	25.
Specific heat capacity J/kg°C	460	-	-

* 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, gas quenched in a vacuum furnace and tempered twice at 530°C for two hours to the given hardness. All specimens have been taken from a bar with the dimension 254x102 mm.

Hardness	56 HRC	58 HRC
Tensile strength, Rm MPa	2 060	2 260
Yield point $Rp_{0.2}$ MPa	1 460	1 610

Compressive strength

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

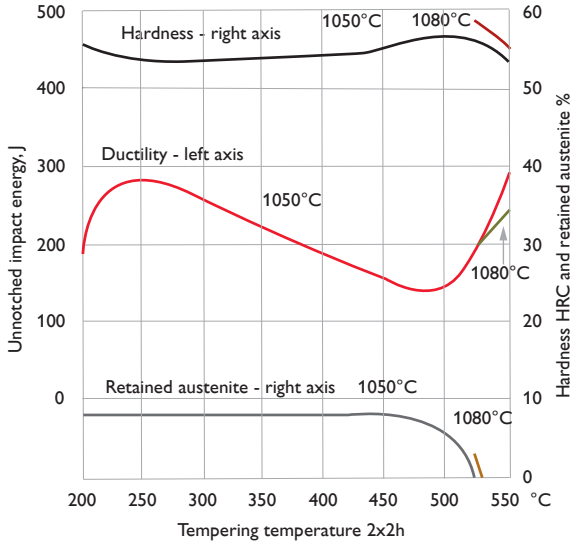
Hardness, HRC	Compressive yield strength, $Rc_{0.2}$, MPa
56	1820

Impact toughness

Tyrax ESR has much higher toughness/ductility compared to other stainless tool steel of W.-Nr. 1.2083 as well as AISI 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 is shown in the graph.
Original bar dimension: 250x80 mm
Specimen size: 7 x 10 x 55 mm unnotched.
Hardened at 1050°C and 1080°C 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

Tyrax ESR shows the best corrosion resistance when tempered at a low temperature and polished to a mirror finish. 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 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. Then cool in furnace at 10 °C per hour to 650 °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 – 850°C. Recommended austenitising temperature is 1050–1080°C, holding time 30 minutes.

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 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 then cool in air blast.
- For complex geometries, an interrupted quench at 400–450°C is recommended to lower the level of distortion and lower the risk of crack formation.
- high speed gas/circulating atmosphere

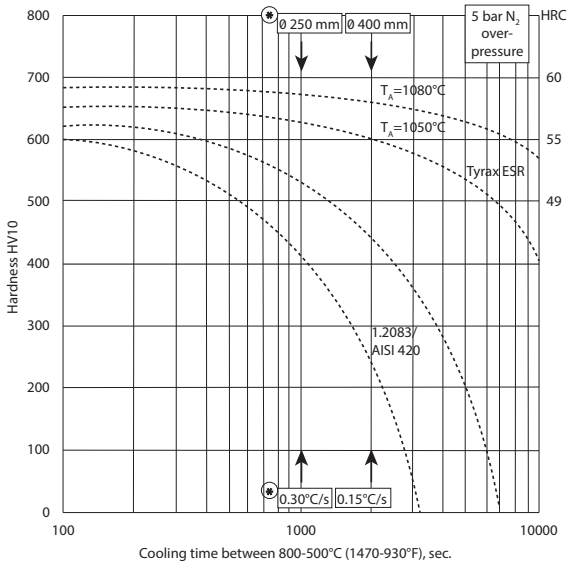
Temper immediately when the tool reaches room temperature. Tyrax ESR has a much better hardenability

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 and 1080°C.



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

Sub-zero treatment

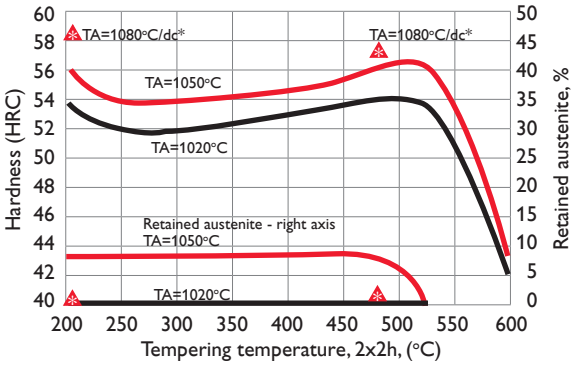
Cryo-treatment in liquid nitrogen (-120°C to -196°C) may be carried out for tools with high demands on dimensional stability after heat treatment. This treatment should be performed before tempering. Intricate shapes should however be avoided because of the risk of cracking.

Cryo-treatment 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 compared to tempering at temperatures 525°C or higher.

Hardening 1080°C / 30min / cryo-treatment at -196°C	Tempering 200°C/2x2h
Hardness	58 – 59 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 2 hour.



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

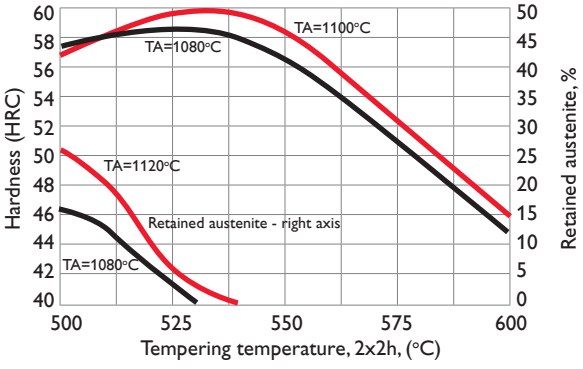
The tempering curve is obtained after heat treatment of samples with a size of 15 x 15 x 40 mm, cooling in a vacuum furnace.

Note: Tempering at 200–250°C 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) to reduce residual stresses and retained austenite to a minimum.

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

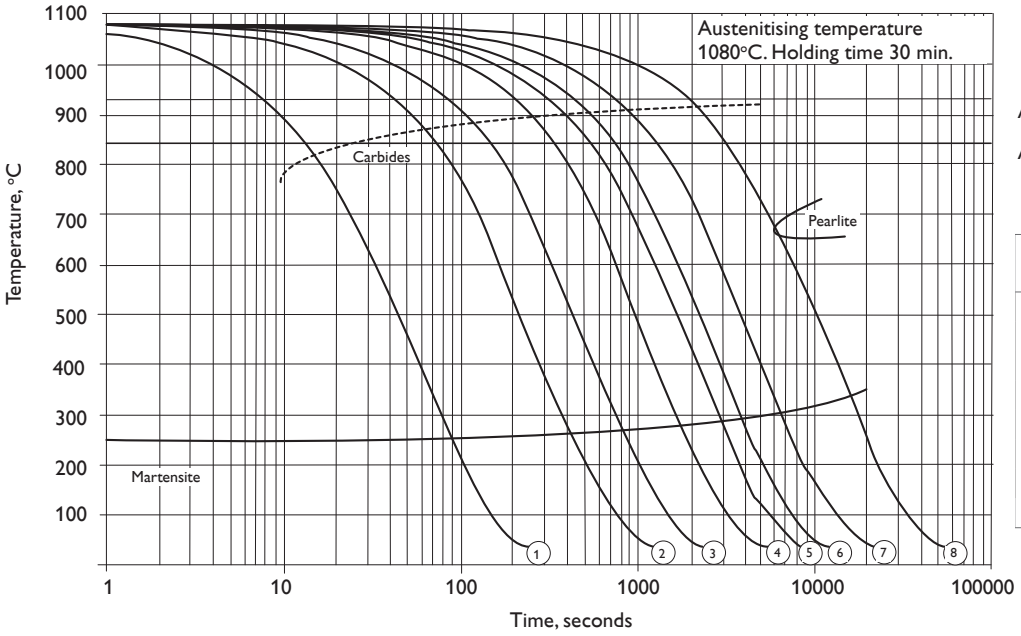
In special cases a hardening temperature of 1100°C may be used. Hardness is increased up to 60 HRC when tempering at 525–530°C. 1100°C is only recommended when toughness is of secondary importance.

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



CCT-GRAPH

Austenitising temperature 1080 °C. Holding time 30 minutes.



A_{C1f} = 930 °C

A_{C1f} = 845 °C

Cooling Curve No.	Hardness HV 10	$T_{800-500}$ sec
1	685	28
2	664	140
3	681	280
4	680	630
5	677	1 030
6	688	1 390
7	654	2 400
8	609	6 240

Dimensional changes

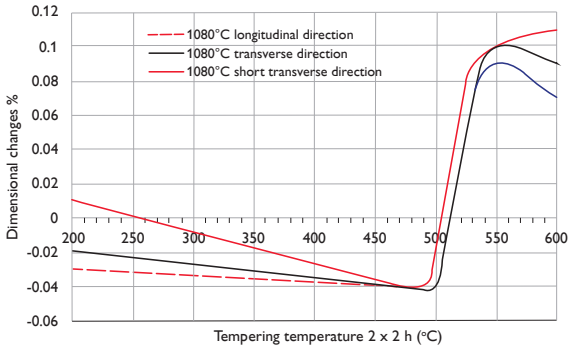
Dimensional changes have been measured after hardening and tempering.

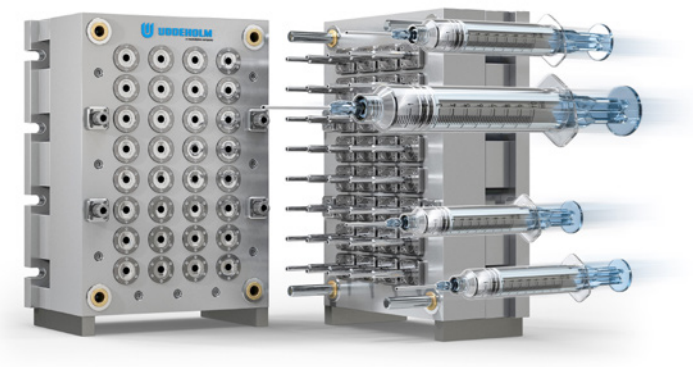
Austenitising: 1080°C/30 min. cooling in vacuum furnace at 0.64°C/sec. between 800°C and 500°C.

Tempering: 2 x 2 h at various temperatures

Sample size: 100 x 40 x 20 mm.

A machining allowance of 0.15 % is recommended for Tyrax ESR.





MACHINING RECOMMENDATIONS

The cutting data below should be considered as guidelines only. These guidelines must be adapted to local machining conditions.

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

Turning

Cutting data parameters	Turning with carbide		Turning with High speed steel
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c), m/min	140 – 190	190 – 240	15 – 20
Feed (f) mm/rev	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 – 3
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/rev
≤ 5	12 – 16 *	0.05 – 0.15
5 – 10	12 – 16 *	0.15 – 0.20
10 – 15	12 – 16 *	0.20 – 0.25
15 – 20	12 – 16 *	0.25 – 0.35

* For coated HSS drill v_c = 22 - 24 m/min.

CARBIDE DRILL

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Carbide tip [1]
Cutting speed (v_c), m/min	160 – 200	80 – 100	60 – 90
Feed (f) mm/rev	0.03 – 0.10 [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

The recommendations in the following tables are valid for 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	40 – 60	60 – 80
Feed (f) mm/rev	0.1 – 0.2	0.05 – 0.1
Depth of cut (a_p) mm	0.5 – 2.0	0.2 – 0.5
Carbide designation ISO	K10 – K20 Coated carbide, CBN	K10, P05 – P15 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	30 – 40	40 – 50
Feed (f) mm/rev	0.05 – 0.20 [2]	0.10 – 0.20 [3]

[1] Drill with replaceable or brazed carbide tip
[2] Feed rate for drill diameter 5 – 20 mm
[3] 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	30 – 50	50 – 70
Feed (f_z) mm/tooth	0.05 – 0.2	0.05 – 0.1
Depth of cut (a_p) mm	0.5 – 2.0	0.1 – 0.5
Carbide designation ISO	P10 – P30 H20 – H30 Coated carbide*	P10 – P20 H10 – H20 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	60 – 80	40 – 80
Feed (f_z) mm/tooth	0.01 – 0.10 [1]	0.05 – 0.15 [1]
Carbide designation ISO	Semi-Finishing Select range suitable for 55-60 HRC [2]	P10 – P30 [2] H20 – H30 [2]

[1] Depending on radial depth of cut and cutter diameter
[2] Use high temperature resistant coating

Grinding

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

Type of grinding	Soft annealed	Hardened
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

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
Preheating temperature*	250 °C ± 25 °C
Welding consumables	TYRAX TIG Weld STAVAX TIG Weld MIRRAX TIG Weld
Maximum interpass temperature	150 °C above preheating temperature
Post welding cooling rate	20 – 40 °C/h for the first 2 hours and then freely in air.
Hardness after welding	48 – 58 HRC
Heat treatment after welding	
Hardened condition	Temper 25°C below the original tempering temperature.
Soft annealed condition	Soft-anneal the material at 860 °C in protected atmosphere. The subsequent cooling should be carried out in the furnace at 10°C/h to 650 °C then freely in air.

POLISHING

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, please refer to “Polishing of Tool Steel”.

FURTHER INFORMATION

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



ADDITIVE MANUFACTURING

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

GENERAL

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

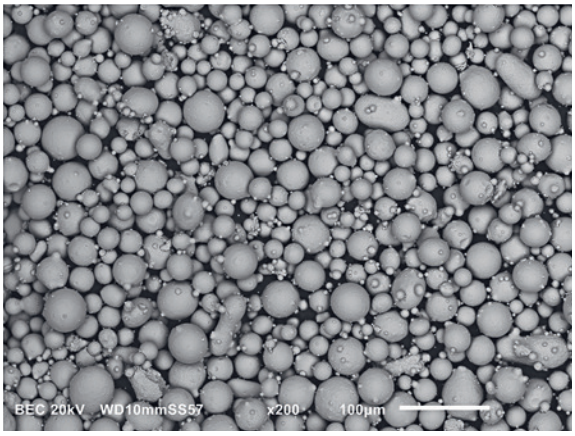
- High hardness up to 58–60 HRC
- Direct tempering can be used
- Good dimensional stability since it is possible to reach a content of retained austenite <2% after heat treatment
- Excellent polishability i.e very high density 99.997% combined with very high glossiness
- Isotropic and superior toughness 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/cm³	4.0
Tap density g/cm³	4.8
True density g/cm³	7.8

Particle size and distrubution

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

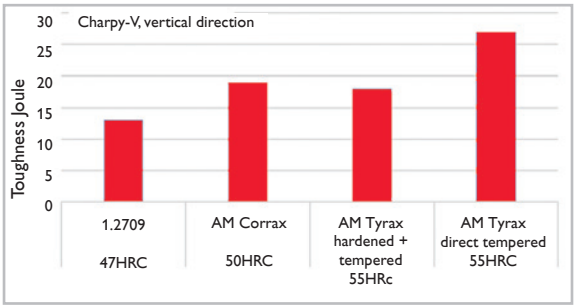
TYPICAL VALUES

D10	D50	D90
22 µm	34 µm	48 µm

PROPERTIES

Impact toughness

AM Tyrax 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).

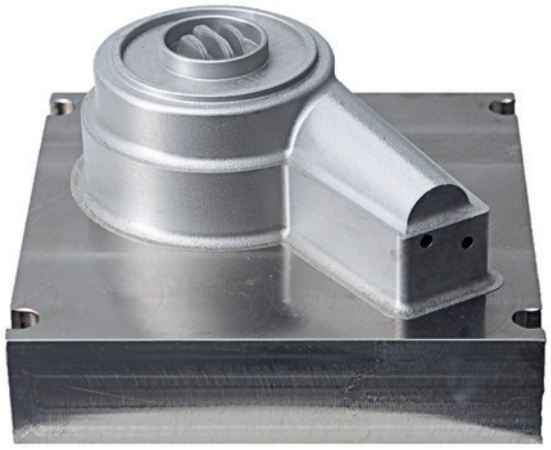
T_{aust} °C	T_{temp} °C	HRC	Toughness J vertical	Toughness J horizontal
1050 / 30 min	540/2x2h	55	17	15
-	570/2x2h	52	33	33

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 $Rp_{0.2}$	1 600	1 520
Tensile strength Rm MPa	2 070	1 830
Elongation A_5%	9	13

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



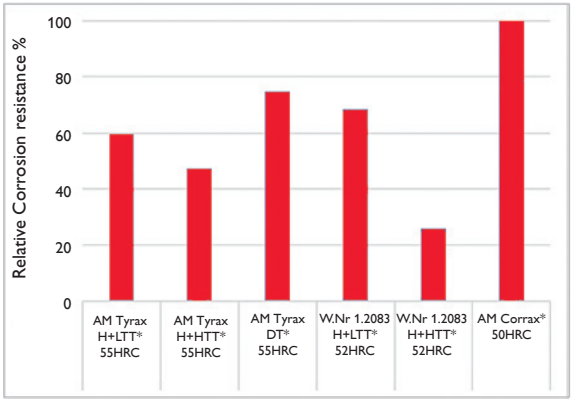
Corrosion resistance

AM Tyrax 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

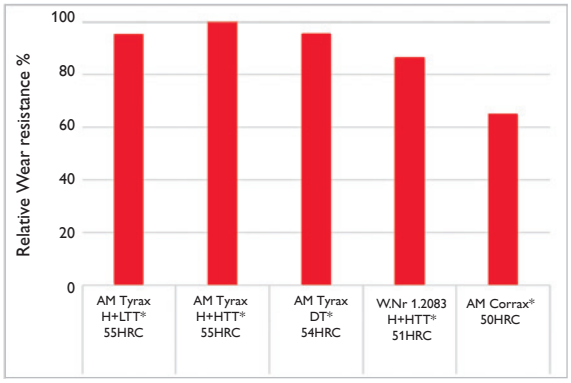
H+LTT = hardened + low temperature tempered,
H+HTT = hardened + high temperature tempered,
DT = Direct Tempered.
Steels marked * forms a passive film in a 0.1M NaCl solution.



Wear resistance

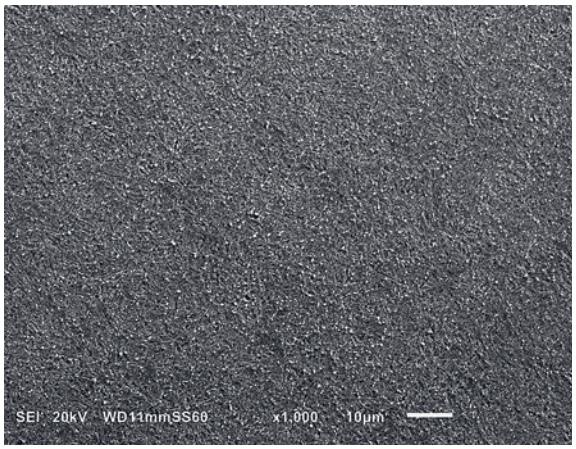
Due to a high hardness together with hard carbides in the microstructure AM Tyrax has an excellent wear resistance towards most abrasive media.

RELATIVE WEAR RESISTANCE



H+LTT = hardened + low temperature tempered,
H+HTT = hardened + high temperature tempered.
DT = Direct Tempered

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



Polishing

AM Tyrax offers extremely high polishability that results in excellent surface finish and a high gloss polished surface. When processed correctly AM Tyrax fully matches 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.

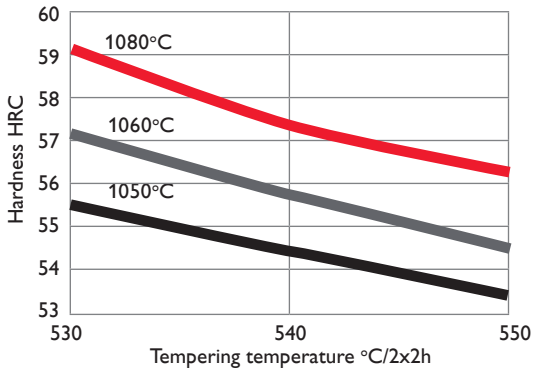
Pre-heating before hardening

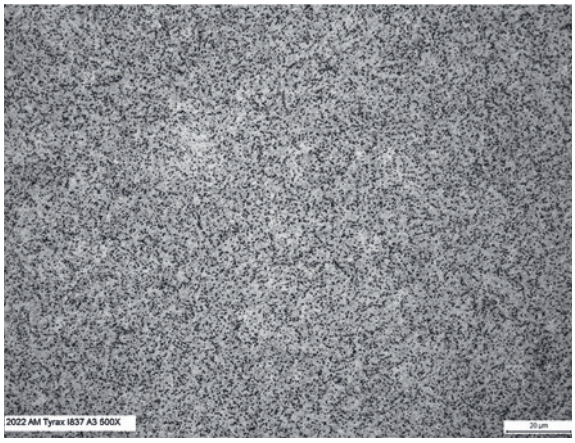
After printing, the built part will contain a various amount of residual stresses. To lower the harmful stresses and avoid extra thermal stresses preheating is recommended before hardening.

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

Hardening and tempering

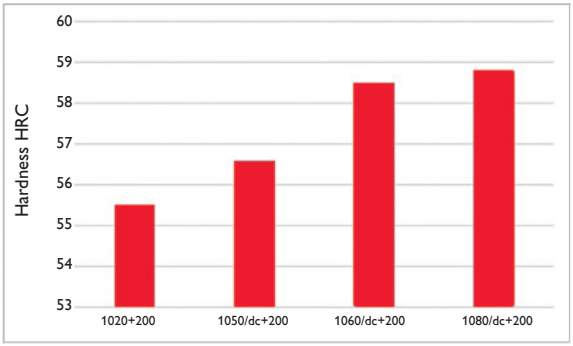
AM Tyrax can be hardened and tempered according to the tempering curves below with retained austenite content < 2 %. Holding time at austenitizing is 30 minutes.





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



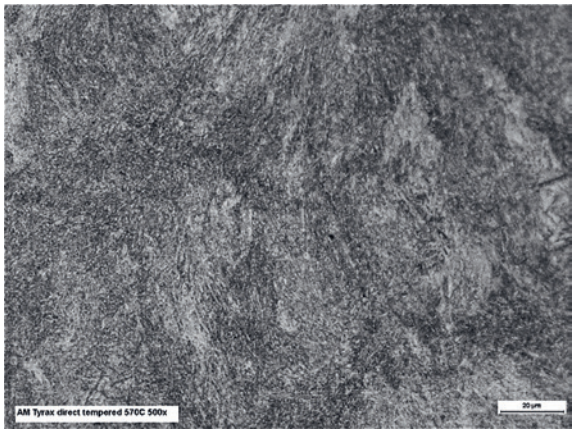
tempering LTT.
Hardness levels reached after hardening + tempering at 200°C/2x2h with or without deep cooling,

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

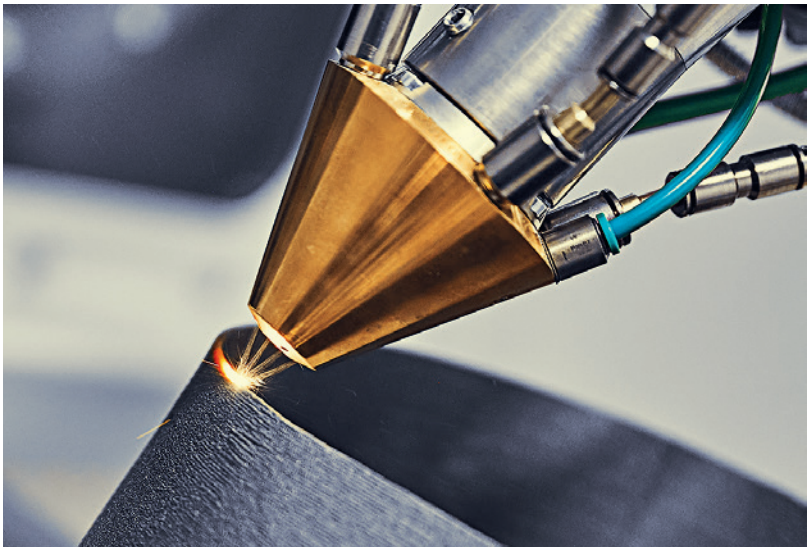


LMD

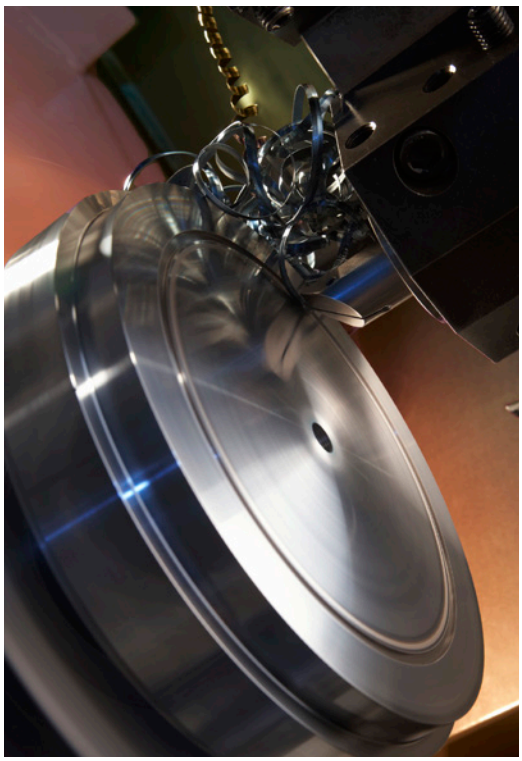
AM Tyrax can be used in the Laser Metal Deposition process and is therefore available in the size fraction 50-125 µm.

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.



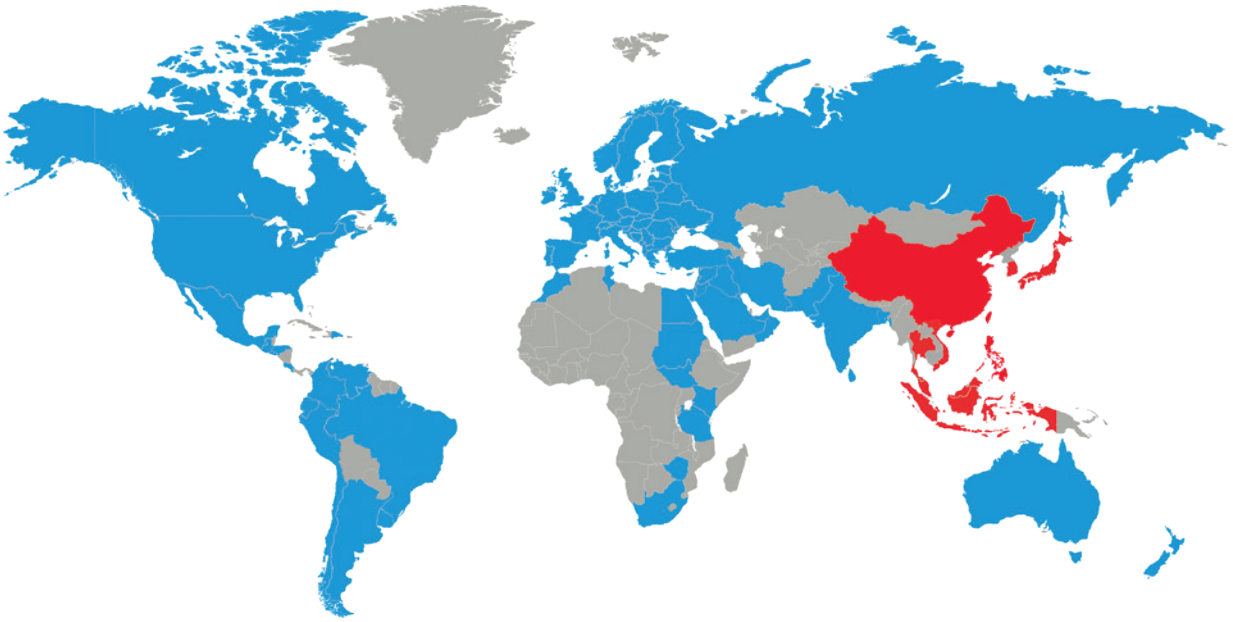
ASSAB
SUPERIOR TOOLING SOLUTIONS
A ONE-STOP SHOP





ASSAB is a one-stop product and service provider that offers superior tooling solutions. In addition to the supply of tool steel and other special steel, our range of comprehensive value-added services, such as machining, heat treatment and coating services, span the entire supply chain to ensure convenience, accountability and optimal usage of steel for customers. We are committed to achieving solutions for our customers, with a constant eye on time-to-market and total tooling economy.





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 most suitable treatment for each application. ASSAB not only supplies steel products of superior quality, but we also offer state-of-the-art machining, heat treatment, surface treatment services and additive manufacturing (3D printing) to enhance your tooling performance while meeting your requirements in the shortest lead time. Using a holistic approach as a one-stop solution provider, we are more than just another tool steel supplier.

In Asia Pacific, ASSAB anchors the distribution network for Uddeholm, a Swedish tool steel manufacturer with more than 350 years of experience in the tool steel industry. Both are integral parts of voestalpine AG, a prominent Austrian-based company listed on the Vienna Stock Exchange since 1995. Together, we establish ourselves as a key player in the steel and technology sector, with a diverse range of products and services.

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