aperam

Martensitic stainless steel offer

MA MA2 - MA3 - MA3M - MA4 - MA5

Chemical composition

Grades	C	Si	Mn	Cr	Mo	N
MA2	0.22	0.35	0.35	13.3	-	0.03
MA3	0.32	0.35	0.35	13.7	-	0.03
MA3M	0.38	0.35	0.35	14.0	0.8	0.09
MA4	0.46	0.35	0.35	13.8	-	0.03
MA5	0.35	0.35	0.35	16.0	-	0.15

Indicative values (weight%)

MA2	MA3	MA3M	MA4	MA5
European designation (1)				
1.4021	1.4028	1.4419 *	1.4034	-
American designation (2)				
AISI 420	AISI 420	-	-	-

(1) According to EN 10088 - (2) According to ASTM A 176 - * Assimilated

These grades comply with:

- Aperam Stainless Europe - Safety Information Sheet for Stainless Steel
- European Directive 2000/53/EC on end-of-life vehicles and later modifications
- Standard NFA 36 711 « Stainless steel intended for use in contact with foodstuffs, products and beverages for human and animal consumption » (non-packaging steel)
- Standard NSF/ANSI 51 for « Food Equipment Materials » and of the F.D.A. (United States Food and Drug Administration) regarding materials used in contact with food
- French Decree No.92-631 dated 8 July 1992 and Regulation No. 1 935/2004 of the European Parliament and of the Council dated 27 October 2004 on materials and articles intended to come into contact with food
- French Ministerial Order dated 13 January 1976 relating to materials and articles made of stainless steel in contact with foodstuffs
- The EDQM (European Directorate for the Quality of Medicines & HealthCare) recommendation; the publication « Metals and alloys used in food contacting materials and articles - A practical guide for manufacturers and regulators - 1st edition 2013 »

Main Features

The characteristic feature of these Martensitic grades is their ability to be hardened by heat treatment. Thus, when hardened and tempered they attain high levels of resistance enabling the achievement of a cutting edge. Combined with their good corrosion resistance, this aptitude meets the requirements of many applications.

Applications

- Blades for knives and various utensils for food preparation
- Blades for industrial equipment
- Cutting tools
- Mechanical parts and other tools

For kitchen knife blades and utensils used in food preparation, MA3M grade containing molybdenum and MA5 grade with a high chromium content are recommended because of their improved corrosion resistance and the possibility of obtaining high levels of hardness in the hardened and tempered condition.

Product range

Sheet, Coils

	Annealed	Cold worked
Thickness (mm)	0.40 up to 6	
Width (mm)	up to 1,000	
Finish	Cold rolled / Hot rolled (depending on the thickness)	
Class	—	C700: TS = 700 to 850 MPa C850: TS = 850 to 1,000 MPa

Strip

	Annealed	Cold worked
Thickness (mm)	0.075 up to 2.50	0.060 up to 2.50
Width (mm)	up to 700	up to 700
Finish	Cold rolled (2B, 2D, 2R, 2F)	Cold rolled (2H, 2F)
Class	—	C700: TS = 700 to 850 MPa C850: TS = 850 to 1,000 MPa C1,000: TS = 1,000 to 1,150 MPa

TS = Tensile Strength (MPa)

Physical properties

				Cold rolled sheet
Density	d		4°C	7.7
Melting temperature	Tf	°C		1,400 to 1,420
Specific heat capacity	c	J/kg.K	20°C	460
Thermal conductivity	k	W/m.K	20°C 200°C	30 31
Average expansion coefficient	α	10^{-6}/K	20-200°C 20-400°C	11 12
Electrical resistivity	ρ	Ω.m	20°C	$6\cdot 2\cdot 10^{-7}$
Relative permeability	μ	at H=800 A/m	20°C	700
Young's modulus	E	GPa	20°C	215

Mechanical properties

After annealing (as-delivered state)

In accordance with ISO 6892-1, Part 1

Specimen perpendicular to the rolling direction.

Lo: 80 mm (thickness < 3 mm), 5.65 √ So (thickness ≥ 3 mm)

Grades	Rm [1] (MPa)	$Rp_{0.2}$ [2] (MPa)	A [3] %	HRB
MA2	580	340	25	81
MA3	610	330	24	85
MA3M	680	400	21	89
MA4	670	390	21	89
MA5	680	390	21	89

Typical values - [1] Tensile strength (Rm) - [2] Yield Strength ($Rp_{0.2}$) - [3] Elongation (A)

After austenitising, quenching and tempering

Grades	According to EN 10088 [4]		Typical values [5-6]	
	HRC	HV	HRC	HV
MA2	44 to 50	440 to 530	52	546
MA3	45 to 51	450 to 550	54	585
MA3M	-	-	57	636
MA4	49 to 55	510 to 610	56	609
MA5	-	-	58	653

[4] Austenitisation at 950-1050°C for MA2 and MA3, at 1,000-1,100°C for MA4 + tempering at 200-350°C.

[5] Austenitisation for 10 minutes at 1025°C - Forced air cooling to 20°C -Tempering for 1 hour at 180°C.

[6] Values not guaranteed as obtained after heat treatment in the laboratory by taking into consideration the temperature of the metal and not that of the furnace.

Heat treatment

The delivery state is an annealed structure consisting of ferrite and carbides.

Martensitic stainless steels have high mechanical strength after full heat treatment comprising austenitisation, fast cooling and tempering.

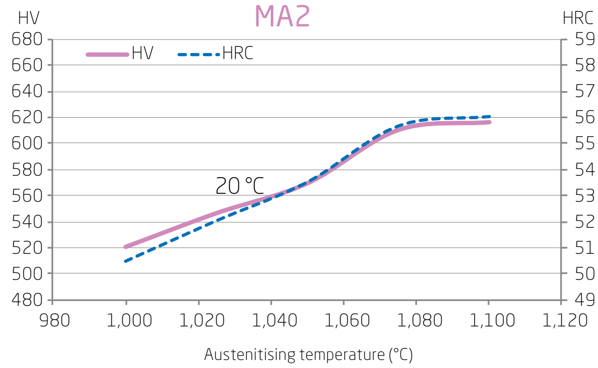
The recommended treatment is austenitisation with 10 minutes holding at 1,025°C - 1,050°C followed by cooling in less than 1 minute to 20°C in a nitrogen and hydrogen reducing atmosphere and then tempering for 1 hour at 180°C. They are thermal conditions on the part. A charge with excessive overlap between parts must be avoided because it will make compliance with these conditions more difficult and as a result may degrade corrosion resistance and hardness of the parts.

An austenitising temperature below 1,025°C is possible but it will result in a lower hardness. Conversely, an austenitising temperature higher than 1,050°C, without exceeding 1,100°C, will allow to increase the hardness of martensitic grades but for the MA5 grade sub-zero cooling treatment will be imperative in order to lower the retained austenite rate.

The tempering temperature can be increased slightly to 225°C to improve impact resistance but at the expense of the hardness. On the other hand it is not recommended to drop it below 180°C in order to prevent embrittlement of the part.

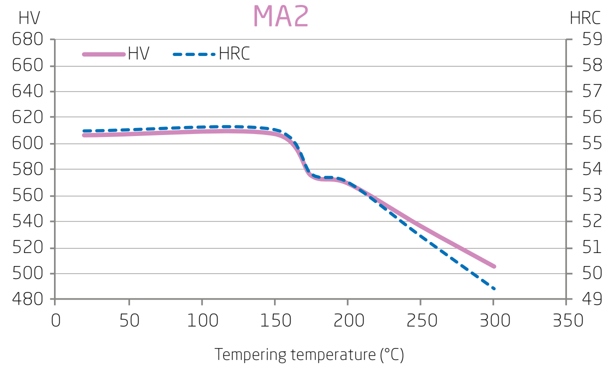
Influence of the austenitising temperature on hardness

Austenitisation, quenching to 20°C or -80°C and tempering for 1 hour at 180°C



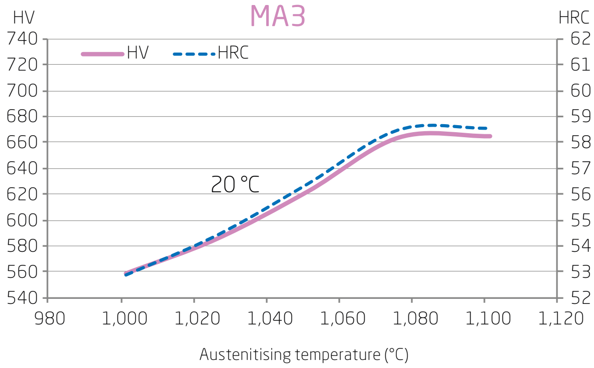
Influence of the tempering temperature on hardness

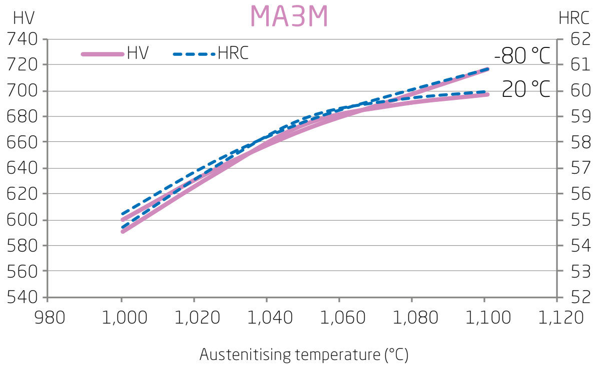
Austenitisation at 1050°C, quenching to 20°C and tempering

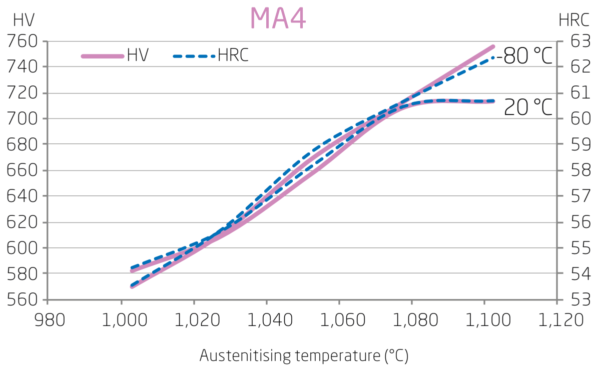


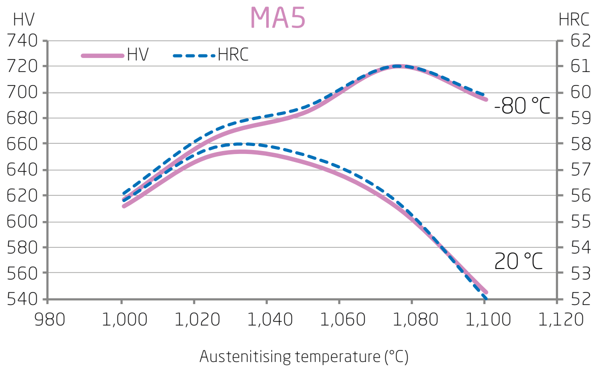
Influence of the austenitising temperature on hardness

Austenitisation, quenching to 20°C or -80°C and tempering for 1 hour at 180°C



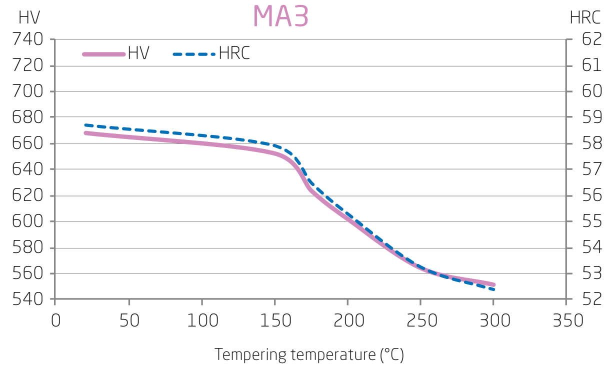


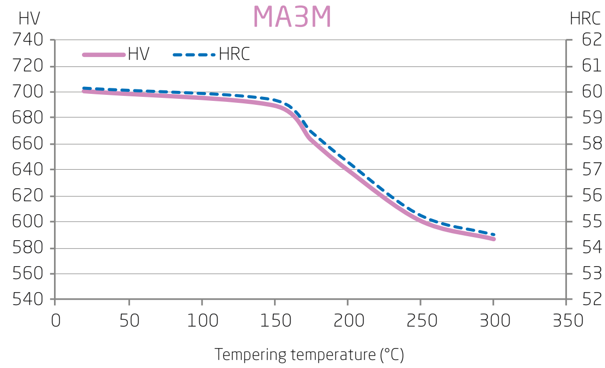


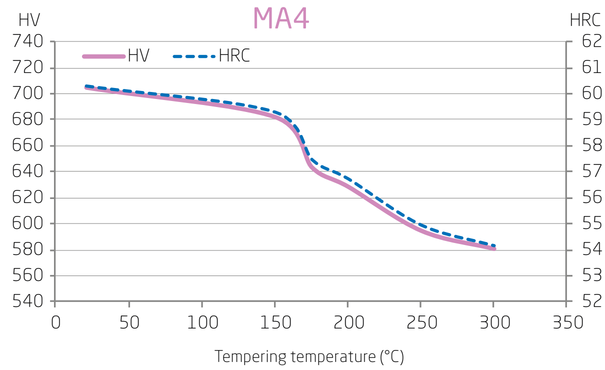


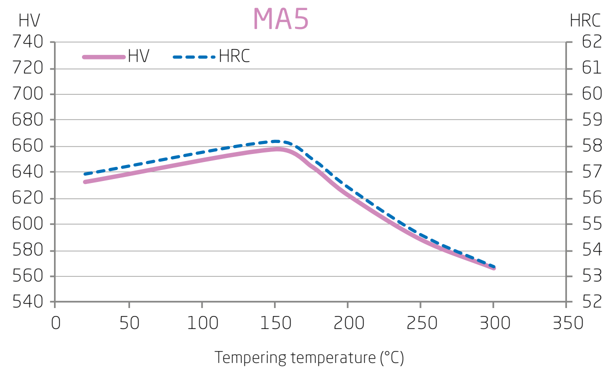
Influence of the tempering temperature on hardness

Austenitisation at 1,050°C, quenching to 20°C and tempering









Corrosion resistance

The corrosion resistance depends on the hardening and tempering conditions used and mainly on the cooling rate after austenitisation.

Below the critical cooling rate, of the order of 10°C/s, a loss of resistance to pitting corrosion is observed, due to the precipitation of chromium carbides and nitrides leading to a depletion in chromium around the precipitates. In practice, this means that simple air cooling is to be banned and that cooling must be done using forced reductive gas or oil quenching. A tempering temperature higher than 300°C should also be banned because it leads to the precipitation of chromium carbides and nitrides.

Furthermore, local heating due to mechanical component finishing operations such as grinding, sharpening, polishing, or grooving must not induce temperatures higher than that recommended for tempering.

Corrosion resistance (continued)

Finally, the surface condition is another factor that can affect corrosion resistance: a polished surface with low roughness is always beneficial.

Corrosion resistance depends on the chemical composition of the different grades of Martensitic stainless steel. Beneficial chemical elements are chromium, molybdenum and nitrogen and the detrimental chemical element is carbon due to its ability to consume chromium in the form of chromium carbides not completely dissolved during austenitisation. The following formula correctly expresses the effect of these chemical elements on corrosion resistance:% Cr + 3.3% Mo + 16% N – 5% C.

Susceptibility to pitting corrosion is measured using an electrochemical multi-pitting test for determining the pitting potential. The higher the pitting potential, the more resistant the grade is to pitting corrosion.

This is how MA2, MA3 and MA4 Martensitic steels with moderate corrosion resistance are distinguished from MA3M and MA5 Martensitic steels with good corrosion resistance.

Corrosion resistance	MA4	MA3	MA2	MA3M	MA5
% Cr + 3.3% Mo + 16% N - 5% C	12.0	12.6	12.7	16.2	16.7
Pitting potential $E_{0.1}$ (mV/ECS) - NaCl 0.02M, 23°C, pH 6.6	300 to 350	300 to 350	300 to 350	420	470

Welding

Certain operating precautions are necessary when welding Martensitic stainless steels, since the Martensitic transformation tends to cause cracking (sometimes of a delayed nature) at temperatures below 400°C. It is recommended to preheat parts to about 200°C before welding them.

In welding processes requiring the use of shielding gas (TIG, MIG, plasma), the use of hydrogen and nitrogen is strictly forbidden. Martensitic stainless steels can be assembled by spot welding and seam welding, and also by arc welding.

A post-weld heat treatment is recommended for grades whose carbon content is greater than 0.2%.

When welding is performed without filler metal, the following post-weld heat treatments can be used:

- Softening between 650 and 800°C, but in this case corrosion resistance is degraded
- Austenitising at 1,025°C, followed by tempering at 180°C

When welding is carried out with a filler metal, the choice is between:

- An alloy having the same composition as the base metal (homogeneous welding with AWS 420 electrode or wire), with postoperative heat treatment as above if it is desired to obtain the same hardness of the weld and base metal
- An alloy of different composition from the base metal (heterogeneous welding with electrode or austenite wire of type ER 308L, 309L or 316L in accordance with EN-ISO 14343), but a postoperative heat treatment will always have to be applied to prevent embrittlement of the H.A.Z. (Heat Affected Zone)

Pickling

The welds must be pickled and repassivated to obtain the corrosion resistance of the base metal.

Pickling can be done in a bath or locally using specific pastes designed for stainless steels.

For pickling a mixture of nitric acid and hydrofluoric acid may be used (15% HNO_3 + 1% HF).

For passivation nitric acid at 25% can be used (2 hours at 20°C or 10 min at 50°C) followed by thorough rinsing with cold water (according to EN-ISO 14343).

Welding process	No filler material	With filler metal			Shielding gas
	Typical thicknesses	Thicknesses	Filler material		Hydrogen and nitrogen forbidden in all cases
			Rod	Wire	
Resistance : spot, seam	≤ 2 mm				
TIG	≤ 1.5 mm	> 0.5 mm	ER 309 L (Si) ER 420 (1)	ER 309 L (Si) ER 420 (1)	Ar, Ar + He
PLASMA	≤ 1.5 mm	> 0.5 mm		ER 309 L (Si) ER 420 (1)	Ar
MIG		> 0.8 mm		ER 309 L (Si) ER 420 (1)	Ar + 2% CO_2 or Ar + 2% O_2
S.A.W.		> 2 mm		ER 309 L (Si) ER 420 (1)	
Electrode		Repairs	ER 309 L (Si) ER 420 (1)		
Laser	≤ 5 mm				He

(1) The homogeneous filler metal ER 420 should be used when subsequent quenching and tempering is to be performed in order to obtain the same hardness in the weld and the base metal.

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