

## 16CrMnNiMo9-5-2\* All

### General Information

Ovako 277 is an air hardenable steel that is suitable for case hardening, nitriding or quench and tempering. By using air-hardening or gas quenching it is possible to reduce the amount of quenching distortion. Additionally the use of quenching medias such as oil and salt can be avoided, which improves both safety and environment. It is produced in two quality classes.

277L - Variant with regulated sulphur content for optimized machinability.

277Q - IQ Isotropic Quality for improved properties transverse to the rolling direction and better fatigue strength due to higher cleanliness level with a finer size distribution of non-metallic inclusions. The steel grade is made according to new process that modifies the the inclusion morphology, i.e. a lower number of elongated sulfides and reduced size distribution of oxides, both in average and in the spread. By using air hardening or gas quenching it is feasible to reduce the amount of quenching distortion.

Ovako 277 steels has very good welding properties. The steels high hardenability and good toughness properties provide a heat-affected zone that meets the high stated demands for the bulk material. Ovako 277Q will be classified as a Group 3 steel according to the standard Welding - Guidelines for a metallic materials grouping system (ISO/TR 15608:2005). Depending on heat treatment execution (yield strength) Ovako 277Q may be classified into subgroup 3.1 or 3.2. Maximum hardness that may be obtained in the HAZ of Ovako 277Q will be 450 HV10kg.

### **IQ-Steel®**

(Isotropic Quality) is an isotropic quality ultra clean steel. IQ-Steel is optimized for fatigue strength by a strict control of steel cleanliness. IQ-Steel, a further development of BQ-Steel, is an isotropic and ultra clean steel with properties that match re-melted steels. Based on thousands of examinations by Ovako into the effects of defects on fatigue performance, the metallurgy of IQ-Steel is purer and far more consistent than conventional grades, and designed specifically to perform well in multi axial loading. This enables the manufacturing of lighter, slimmed down components like gears, bearings and other critical parts. The steels are helping our customers to achieve new design solutions and implement higher standards of finished product performance. Key to these practical advantages are Ovako's own unique, clean and consistent modern steelmaking processes that remove harmful inclusions and impurities from within the steel. IQ-Steels contain smaller and more fragmented inclusions and can handle much higher mechanical forces in all directions than conventional steels. IQ-Steels are newer, but already now well established in high pressure automotive applications. Modern diesel engines, with high and cyclic injection pressures, have proven to be an ideal application. Transmission components are another emerging area of strong interest.

*\* Designation followed by "" is not an official EN standard grade but named according to the rules in EN 10027.*

### Similar designations

16CrMoV8-5, 16CrMoV8-5\*

## Chemical composition

Variant	Cast	Weldability		C %	Si %	Mn %	P %	S %	Cr %	Ni %	Mo %	V %
277L	IC	CEV 1.08 <sub>max</sub>	Mn	0.14	0.05	1.20	-	0.015	2.10	0.45	0.45	0.150
		Pcm 0.45 <sub>max</sub>	Max	0.17	0.15	1.40	0.020	0.023	2.30	0.55	0.55	0.250
277Q	IC	CEV 1.08 <sub>max</sub>	Mn	0.14	0.15	1.20	-	-	2.10	0.45	0.45	0.150
		Pcm 0.45 <sub>max</sub>	Max	0.17	0.30	1.40	0.020	0.002	2.30	0.55	0.55	0.250

## Mechanical Properties

Variant	Condition	Format	Dimension [mm]	Yield strength min [MPa]	Tensile strength [MPa]	Elongation A <sub>5</sub> [%]	Reduction of area Z <sub>min</sub> [%]	Hardness	Impact (ISO-V) strength <sub>min</sub>
277L	+AR	All formats	-	860*	1200 typical	10	60	350 HB typical	-
	+QT	All formats	-	600*	< 800	15	75	220 HB typical	-20 °C 70 J (long)
		All formats	-	650*	< 800	15	75	240 HB typical	-20 °C 70 J (long)
		All formats	-	700*	< 800	15	75	260 HB typical	-20 °C 27 J (long)
	+Q	All formats	-	-	-	-	-	430 HB typical	-
+SA	All formats	-	-	-	-	-	170 HB typical	-	
277Q	+QT	All formats	-	600*	< 800	15	75	220 HB typical	-20 °C 70 J (long) -20 °C 40 J (transv)
		Tube,wall	< 25	650*	720-800	15	75	240 HB typical	-20 °C 70 J (long) -20 °C 40 J (transv)
		All formats	-	700*	< 800	15	75	260 HB typical	-20 °C 27 J (long) -20 °C 27 J (transv)
		Round bar	24 < 75	650	720-800	15	-	240 HB typical	-40 °C 27 J (long)
		Tube,wall	< 25	700	750-800	15	-	260 HB typical	-40 °C 27 J (long) -40 °C 27 J (transv)
		Round bar	24 < 75	700	750-800	15	-	260 HB typical	-40 °C 27 J (long) -40 °C 27 J (transv)
		Tube,wall	26 < 40	600	660-800	15	-	220 HB typical	-40 °C 70 J (long) -40 °C 40 J (transv)
		Round bar	24 < 160	600	660-800	15	-	220 HB typical	-40 °C 70 J (long) -40 °C 40 J (transv)

*R<sub>p0.2</sub> \* R<sub>eh</sub>, \*\* R<sub>el</sub>*

Condition "Q" is water quenched.

## Transformation temperatures

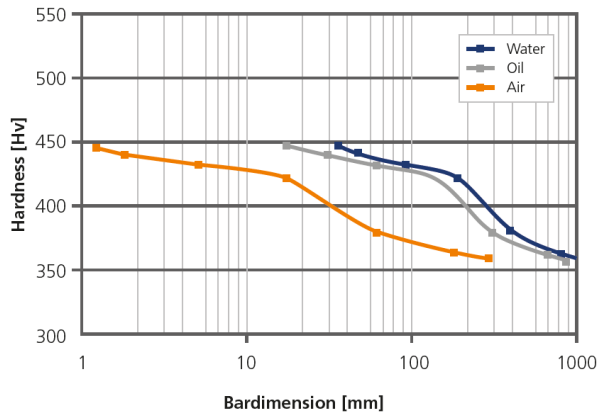
	Temperature °C
MS	399
AC1	741
AC3	852

## Heat treatment recommendations

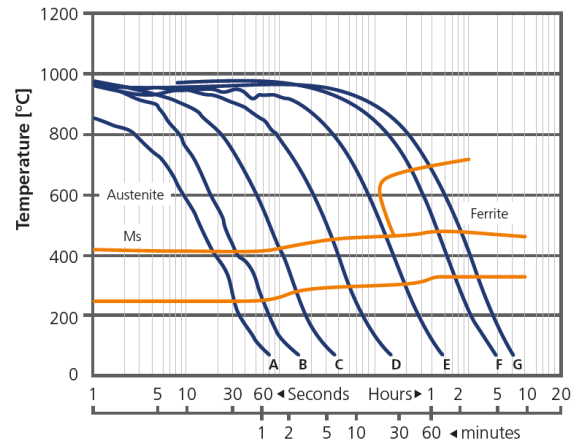
Treatment	Condition	Temperature cycle	Cooling/quenching
Hot forging	+AR	850-1200°C	Air cool
Quenching	+Q	860-1000°C	In air/gas, oil or water
Soft annealing	+SA	Slow cooling from 750°C to 690°C (8h)	In air
Carburizing	+C	850-930°C See Carbon potential in diagram	
Nitriding	+Nt	450-550°C Surface and core hardness, see diagram	
Tempering	+T	160-700°C See tempering diagram	In air

## OVAKO 277

Hardenability for various cooling media



## CCT - Ovako 277



	A	B	C	D	E	F
$t_{0.5}$ [s]	10	15	50	200	800	3000
HV <sub>30</sub>	446	440	432	422	383	366

## Steel cleanliness 277

Micro inclusions - 277L									Macro inclusions - 277L	
Applied standard	ASTME45								Applied standard	ISO 3763 (Blue fracture)
Sampling	ASTMA295								Sampling	Statistical testing on billets.
Maximum average limits	A		B		C		D		Limits	< 5 mm/dm <sup>2</sup>
	Th	He	Th	He	Th	He	Th	He		
	2,0	1,5	1,0	0,5	0	0	0,5	0,5		

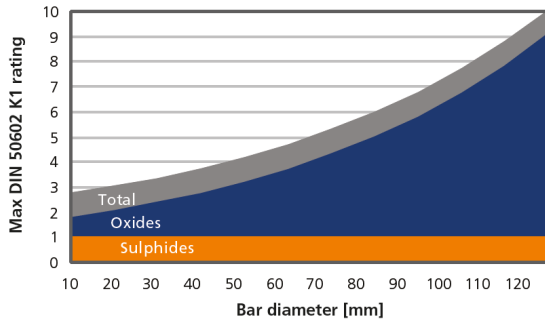
Micro inclusions - 277Q									Macro inclusions - 277Q		
Applied standard	DIN 50602 K1								Applied standard	ISO 3763 (Blue fracture)	10 MHz UST (Ovako internal procedure)
Sampling	Six random samples from final product dimension								Sampling	Statistical testing on billets	
Limits	The limit is dimension dependent. The average rating of six samples should not exceed the limits given in the graph								Limits	< 1 mm/dm <sup>2</sup>	< 10 defects/dm <sup>3</sup> > 0,2 mm FBH

## Other properties (typical values)

Youngs module (GPa)	Poisson's ratio (-)	Shear module (GPa)	Density (kg/m <sup>3</sup> )
210	0.3	80	7800
Average CTE 20-300°C (µm/m°K)	Specific heat capacity 50/100°C (J/kg°K)	Thermal conductivity Ambient temperature (W/m°K)	Electrical resistivity Ambient temperature (µΩm)
12	460 - 480	40 - 45	0.20 - 0.25

Contact us

### Inclusion limits IQ-processed steel



Would you like to know more about our offers? Don't hesitate to contact us:

Via e-mail: [info@ovako.com](mailto:info@ovako.com)

Via telephone: +46 8 622 1300

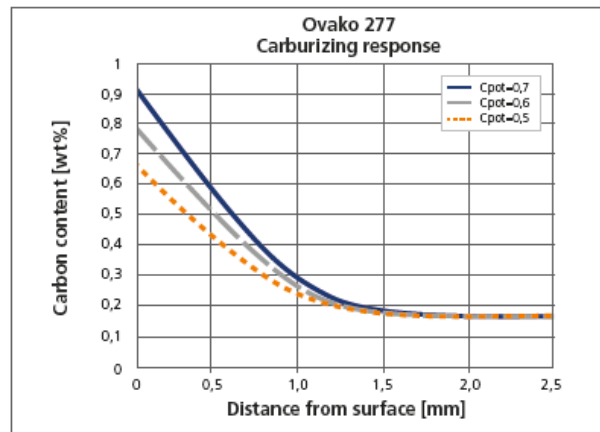
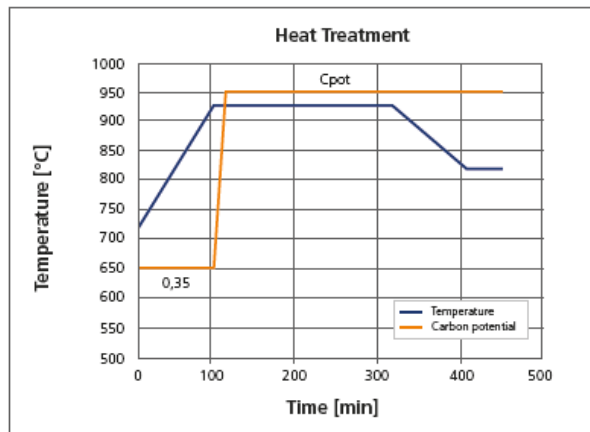
For more detailed information please visit <http://www.ovako.com/en/Contact-Ovako/>

### Disclaimer

### Carburizing

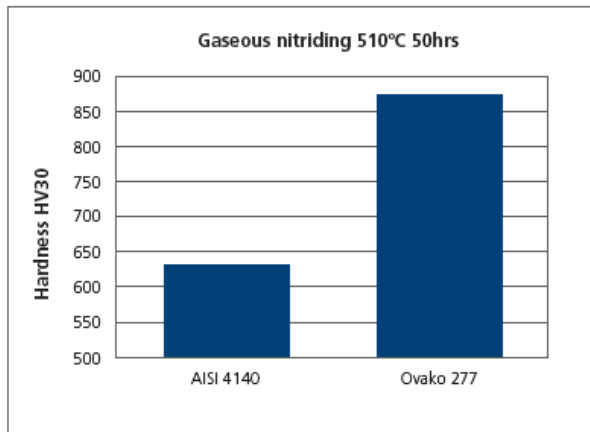
#### Case carburizing response

Maximum carbon potential should be 0,7wtC to avoid carbide precipitation

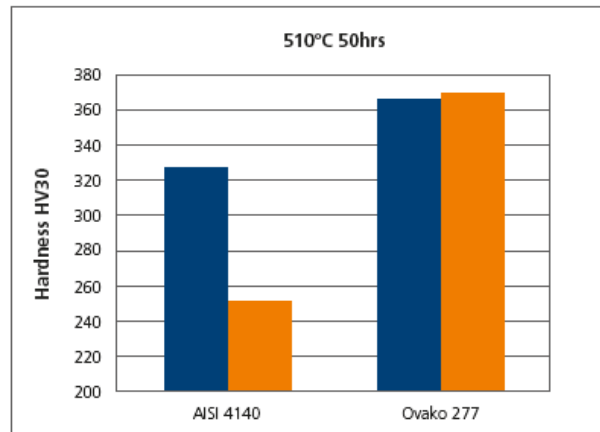


Carburization response for Ovako 277 for the cycles shown in the left figure.

### Nitriding response



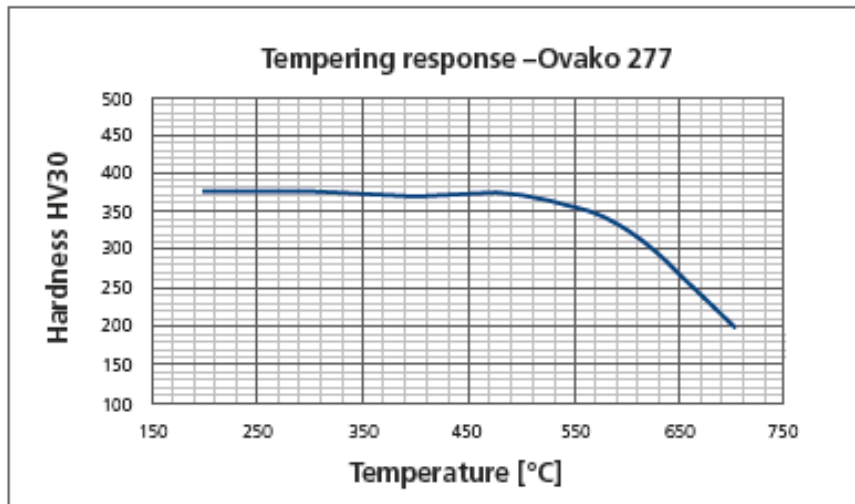
Expected surface hardness after nitriding of Ovako 277 compared with AISI 4140.



Expected core hardness after nitriding of low temperature tempered Ovako 277 compared with AISI 4140.

*The information in this document is for illustrative purposes only. The data and examples are only general recommendations and not a warranty or a guarantee. The suitability of a product for a specific application can be confirmed only by Ovako once given the actual conditions. The purchaser of an Ovako product has the responsibility to ascertain and control the applicability of the products before using them. Continuous development may necessitate changes in technical data without notice. This document is only valid for Ovako material. Other material, covering the same international specifications, does not necessarily comply with the properties presented in this document.*

## Tempering



Tempering response after austenitization and air-hardening. Tempering time 1h.

## Welding properties

Ovako 277 steels have very good welding properties. The steels high hardenability and good toughness properties provide a heat-affected zone that meets the high stated demands for the bulk material. Ovako 277Q will be classified as a Group 3 steel according to the standard Welding - Guidelines for a metallic materials grouping system (ISO/TR 15608:2005). Depending on heat treatment execution (yield strength) Ovako 277Q may be classified into subgroup 3.1 or 3.2. Maximum hardness that may be obtained in the HAZ of Ovako 277Q will be 450 HV<sub>10kg</sub>.

- For the best results welding should be continuous, and slowly cooled in ambient air conditions.
- Preheat before welding. If the welding is performed in a damp environment or if the temperature is below 5°C the preheating temperature should be increased by 25°C.
- Consumables should be selected on the basis of strength and toughness requirements of the weld joint. A consumable with low strength, that still fulfils the strength requirements, minimizes the residual stresses over the weld. The consumable should also be selected with a as similar as possible chemical composition as the base material.
- Hydrogen content should not exceed 5ml/100g weld metal.
- Post heat treatment is a good alternative to preheating. It should be performed at 200°C, directly after welding, holding for 5min/mm material thickness, for at least one hour.
- If stress relieve annealing is necessary it should be performed between 500°C and 680°C with 1h holding time.

### Recommended pre-heating temperatures for welding with ferritic consumables

Combined wall thickness [mm]						
10	20	30	40	50	60	70
100°C	125°C	150°C	175°C			

The recommended preheating temperatures are based upon a heat input around 1.7KJ/mm and that the hydrogen content does not exceed 5ml/100g weld metal.

## Machining

Ovako 277 has good machining properties. ISO 3685 test show tool life for various cutting speeds in Q&T 277Q. Because of the very high cleanliness the variant 277Q may have a reduced chip breaking propensity. The controlled sulphur content of Ovako 277L will enhance chip breaking.

### Tool wear test

Test material:	Ovako 277Q Q&T
Test procedure:	ISO 3685
Insert:	SNMA 120408 P15
Tool holder:	CSRNL
Feed rate:	0.4 mm/r
Cutting depth:	2.5 mm
Wear criteria:	$vB_{\text{mean}}$ 0.3mm

	Cutting speed					$\alpha$
	$V_5$	$V_{10}$	$V_{15}$	$V_{30}$	$V_{60}$	
221Hv	405	357	332	293	259	0,18
230Hv	374	325	300	261	227	0,20
280Hv	264	242	221	189	162	0,23

