Case-hardening steel Carbodur

Deutsche Edelstahlwerke

Member of Swiss Steel Group

Carbodur case-hardening steel

For how long a component meets the requirements and how reliably it withstands sudden peak loads, depends on the material that the part is made of. In the end, the performance of a small part determines the cost-effectiveness of large equipment or machines. The more meticulously a material is tailored to the functions of the individual components, the better the performance of the entire system. Deutsche Edelstahlwerke specialises in manufacturing speciality steels with specifically defined qualities. The heavy-duty materials of the “Carbodur” brand underline once again why Deutsche Edelstahlwerke is an international leader in the sector of special steel long products.

Hardness and toughness of the base material are determined by its chemical composition and heat treatment. The desired properties of the steel are already taken into consideration at the melting stage.

The technical facilities at Deutsche Edelstahlwerke allow for exact and reproducible chemical compositions within very narrow analytical ranges.

The high level of control during secondary metallurgical treatments or in the remelting process* means that steel can be produced with an extremely high degree of purity. Non-metallic inclusions are practically excluded.
The high level of macroscopic and microscopic cleanliness, the homogeneous structure and the fine particle stability of the Carbodur steel set standards.

** Information on function and details on the remelting process can be found in our brochure "Remelting for highest standards" on our homepage www.dew-stahl.com*

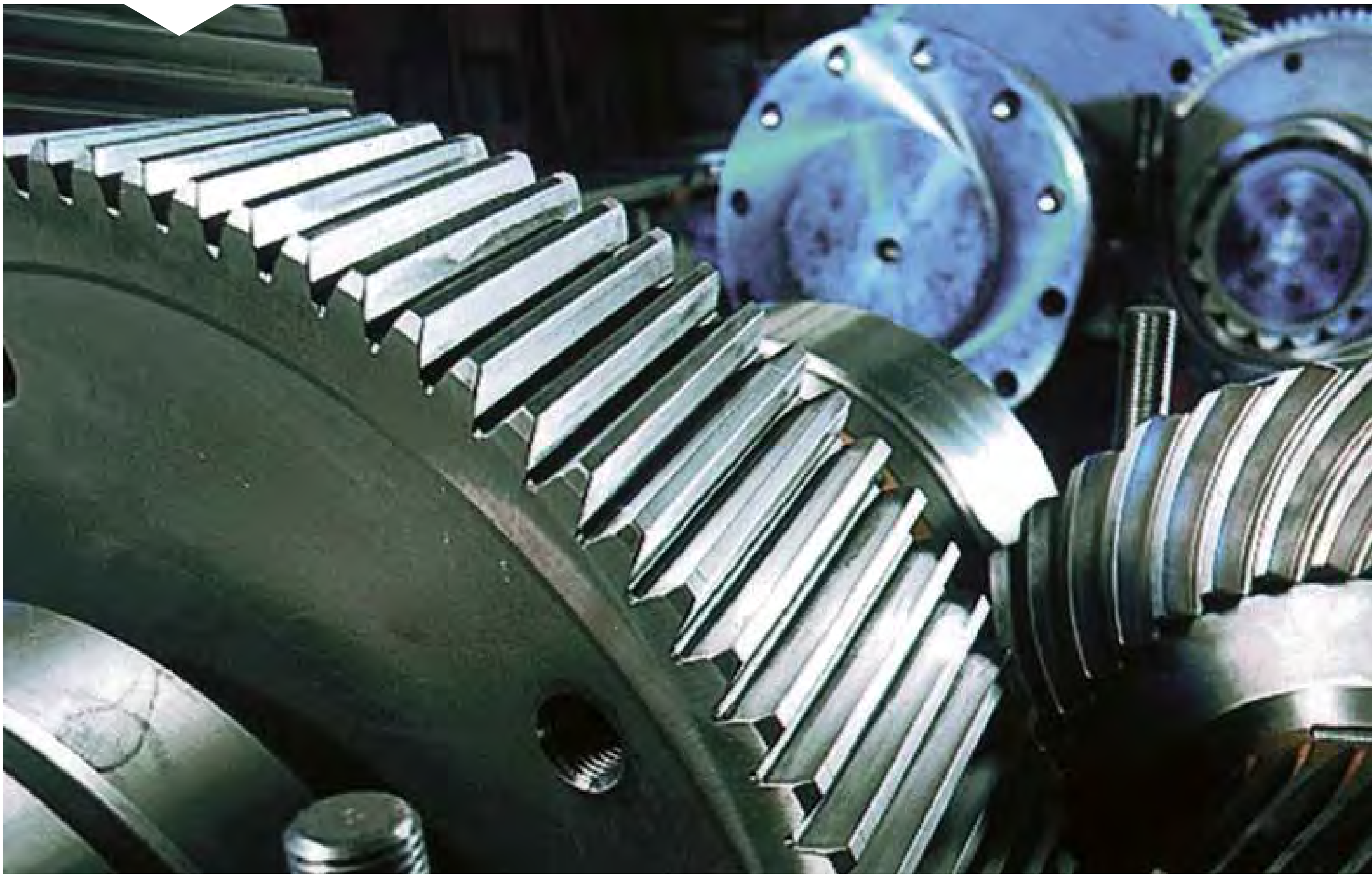
The world of Carbodur steel

… is geared up to meet your needs. Anywhere where force is transmitted, its strengths are in demand. The individual components of the powerful gears used in hydro-electric power plants, wind power plants, and in the marine and offshore industry not only have to withstand enormous pressures per unit of area, they also have to be able to run continuously. Wear resistance and fatigue strength are therefore essential. Carbodur precision gear wheels, for example used in propeller drives on oil rigs and turbo transmissions in power plants are able to reliably withstand these stresses, while their wear resistance ensures that the components remain dimensionally stable. In mining, safety is the top priority.

The underground mining equipment operates continuously. Operational disruptions resulting from the failure of gear components are not only costly to production but also represent an increased safety risk. So in this field, it is not resistance to impacts or shocks that matters most, but hardness and core strength. Our chromium-nickel-alloyed or chromium-nickel-molybdenum-alloyed steel has the best prerequisites for fulfilling these demands.

Our Carbodur steel is as versatile as the requirements for components of the individual moving parts are. For each component, a suitable material is chosen based on factors such as safety, cost-effectiveness, durability as well as extreme short-term stresses, if necessary. The differential of a Formula 1 racing car, for example, must be able to perform for a relatively short period of time (the duration of one race). In this short period of time, however, the stresses resulting from the enormous torque transmission are extremely high. Carbodur steel can be designed specifically for this task.

The gear wheels of a truck used on construction sites, must be tough all the time and able to withstand sudden shock loading and impact without any cogs breaking. The case-hardened parts must be highly wear resistant, exhibit high fatigue strength around the edges and impact resistance in the core.




Mobil 1
aigo
vodafone
Henkel

In passenger transportation, safety is the top priority. In automotive engineering, engines and gears, the specific properties of Carbodur steel are therefore particularly beneficial, for example for piston pins, gear wheels, motor shafts, counter shafts, synchroniser bodies, ring gears, differential bevel gears, bevel pinions and differential side gears. High precision on the one hand and maximum robustness on the other – two different requirements, but Carbodur can meet them both.

The precision required for a printing machine is essentially comparable to that of clockwork mechanisms: screen widths of up to 0.01 mm are required to achieve the finest print results. The many gear wheels of the individual printing mechanisms must be manufactured to extremely narrow tolerances. Wear would lead to clearances in the wheel work and could thus negatively affect the print result. This means that the gear wheels and individual components of premium printing machines must be manufactured from a steel with a chemical composition specifically geared towards requirements such as good hardenability. The steel, and therefore the individual components, must exhibit considerable core strength and wear-resistance around the edges. It must retain these qualities over years, despite very high operational speeds.

The same steel would not be a good choice for heavy-duty gears, for example in mining or for an excavator, purely due to the larger dimensions of the gear wheels and other components. The drive systems of mining and construction machines need to cope with immense stresses. Failure as a result of breakage – for instance, of a gear wheel – causes expensive production downtime.

Deutsche Edelstahlwerke does not only supply the optimum steel for the smallest to the largest cross-sections of 2.8 mm – 1200 mm, but as an extension of the customer's workshop, it also provides, for example, rough-machined parts such as breaker plates, hollow shafts and short pieces > 12 mm in length.

Please ask one of our experts about these options.

Hardenability

Effects of alloying elements on hardenability

Depending on the alloy composition, Carbodur is distinguished by:

» non-alloyed case-hardening steel,
» chromium-alloyed case-hardening steel,
» manganese-chromium and molybdenum-chromium-alloyed case-hardening steel,
» nickel-chromium-alloyed case-hardening steel,
» nickel-chromium-molybdenum-alloyed case-hardening steel and
» chromium-nickel-molybdenum-alloyed case-hardening steel.

The alloy and trace elements affect the hardenability of the base material and of the carburised surface layer. The hardenability of the base material is characterised by the face quenching test according to DIN EN ISO 642 and is an important parameter in assessing hardness in the core. Case-hardened components are tempered at low temperatures of up to 180 °C in order to retain a high degree of surface hardness.

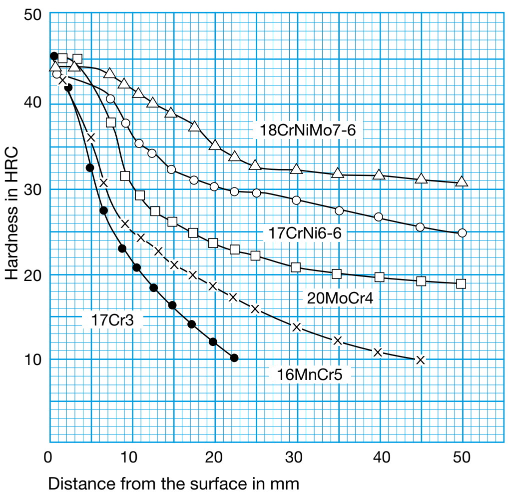
The following diagram shows the effect of alloying elements on the hardenability of case-hardened steels according to the DIN EN 10084 end quenching test. At a distance of 1.5 mm between abutting faces, the hardness is primarily determined from carbon content.

The further progression of the face quenching curve is also affected by the levels of elements that increase hardenability, such as molybdenum, manganese, chromium and nickel. For smaller cross-sections, full hardening is possible with chromium or manganese-chromium steel, whereas larger cross-sections require additional alloying elements such as molybdenum or nickel to fully harden.

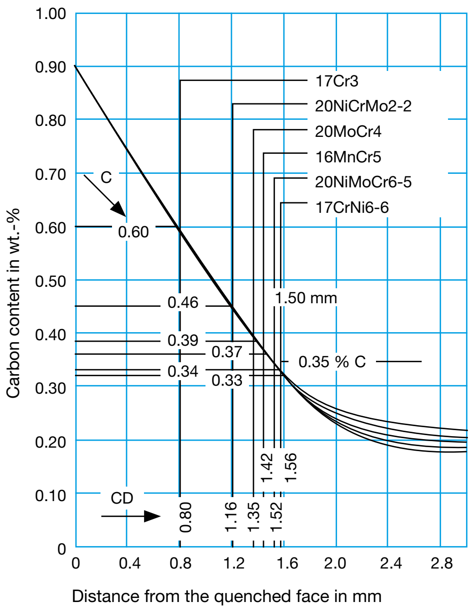
For the sake of retaining toughness, the carbon content is limited to approx. 0.25 %. In special cases, boron may be added to increase hardenability or to increase impact resistance in chromium-manganese steel.

The properties of case-hardened parts are affected by hardness in the core just as much as by the hardness in the carburised layer. A surface hardness of 57 - 63 HRC has proved favourable for optimal wear resistance. This hardness is usually achieved at a surface carbon content of approx. 0.7 % carbon and is largely independent of the steel composition. Higher carbon contents in the surface layer increase hardness only slightly. Over-carburisation in the edge zone may lead to decreased toughness as a result of secondary cementite precipitating. The hardness may also decrease with increasing residual austenite levels.

The case-hardening depth (CD) signifies the distance from the surface of a case-hardened workpiece to the point, where the Vickers hardness is generally 550 HV1 (see DIN EN ISO 642). It is defined by the depth of hardening, the heating and cooling conditions during hardening and by the hardenability in the carburised surface layer.



The effect of alloying elements on the hardenability of case-hardening



The interdependencies that apply to the base material cannot be transferred to the hardenability of the surface layer because the influence of the alloying elements on hardenability also depends on the carbon content. Up to a carbon content of approximately 0.5 %, molybdenum, chromium and manganese increase the hardenability. At higher carbon levels, however, the hardness begins to drop again.

The upper diagram demonstrates the case-hardening depth of case-hardening steel at equal carbon curves in the surface layer. According to the diagram, the different alloy contents lead to a case-hardening depth that is twice as high in the 17Cr3 steel (CD 0.80 mm) compared with the 17CrNi6-6 steel (CD 1.56 mm) despite the otherwise identical conditions.

Case treatment, a surface hardening procedure

There are many ways to make the surface of a steel harder. Inductive hardening of the surface is possible for steel with a sufficiently high carbon content. Steels with lower carbon contents may be nitrided, borided or carburised. As the chart below shows, there are different carburising methods. The carburising procedure initially used was carburisation in the solid state by means of charcoal powder. Then carburisation in salt baths was developed. Today, carburisation in plasma or in an appropriate gas are standard methods. Standard carburisation today generally entails several steps:

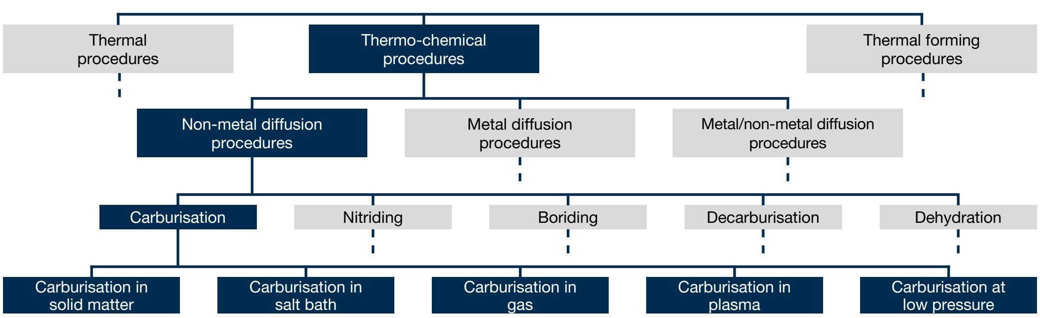
» carburisation of the surface layer by carbon diffusion at high temperatures,
» subsequent hardening and
» stress relief.

Carburisation
The level of carbon in the surface layer primarily depends on the carburising effect of the medium, while the depth of hardening is dependent on the temperature and duration of the treatment. As the diffusion rate increases with rising temperatures, the desired depth of hardening is generally achieved faster at greater temperatures. At the same time, the carbon content gradient flattens from the surface to the core. Representative of their different carbon levels, the surface and core of a workpiece exhibit different Ac_3 and M_S temperatures as well as differing transformation curves. If carburisation occurs at too high temperatures or for too long, it may result in unwanted grain growth (mixed grain) and possibly in distortion.

Hardening
Hardening is a type of heat treatment, which entails austenitisation and quenching under such conditions that the hardness increases as the result of the more or less full transformation of austenite into martensite and possibly bainite. Quenching from hardening temperature is performed in oil, polymer or, if the materials and workpieces are not too sensitive, in water. In order to transform larger amounts of residual austenite into martensite after hardening, subsequent sub-zero cooling may be performed for chromium, nickel and chromium-nickel-molybdenum steels.

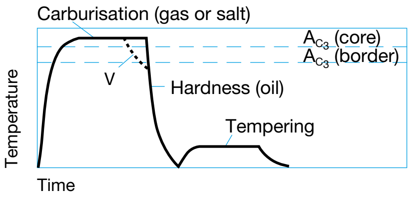
Tempering/stress reliefing
This method entails heating a hardened workpiece once or several times to temperatures of between 150 °C to 200 °C depending on the steel grade. Tempering martensite in this way reduces the risk of tension cracking and increases ductility.

BASIC HEAT TREATING METHOD



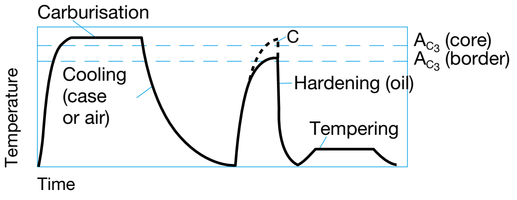
Phases of case treatment

Direct hardening



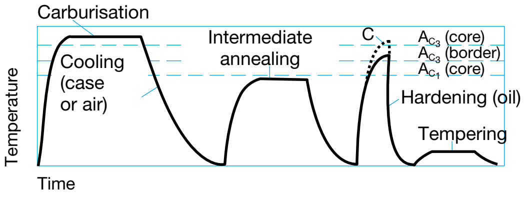
In direct hardening, the temperature is lowered slightly to the hardening temperature after carburisation. The workpiece is then hardened in oil until it reaches room temperature. Finally, it is tempered.

Single hardening after cooling from the case



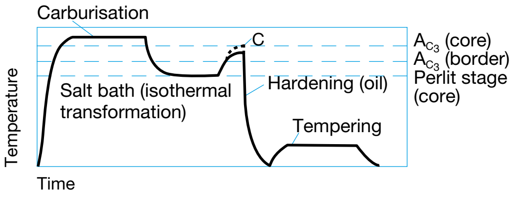
In this procedure, the component is cooled down to room temperature after carburisation and then heated up to hardening temperature again with subsequent steps. This method is time-consuming and can lead to cracking.

Single hardening after intermediate annealing



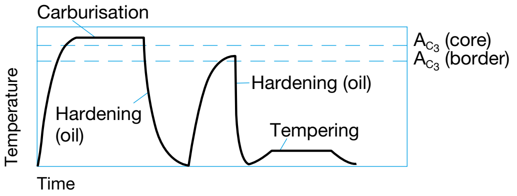
The diagram shows additional intermediate annealing after cooling from the case, so that the carburised product becomes more resistant to cracking. However, manufacturing is tedious.

Single hardening after isothermal transformation



After carburisation, the product is placed in a salt bath for isothermal transformation. It is then heated up to hardening temperature again, hardened in oil and then tempered. This is a very time-consuming procedure that is barely used today.

Double hardening



After carburisation, the product is hardened in oil from the carburisation temperature. Afterwards it is then heated to hardening temperature once again. Following this, the material is hardened in oil and then tempered. Double hardening is only performed if tough surface layers and cores are required in large cross-sections with high hardening depths. Double hardening generally entails hardening from slightly above the Ac_3 temperature of the core and then from slightly above the Ac_3 temperature of the surface layer. The high risk of deformation is a disadvantage of double hardening. The case-hardening methods and media may therefore vary, and are greatly and generally dependent on the material and geometry.

For economic reasons, however, the direct hardening procedure is most widely used.

Processing guidelines

Cost reduction potential
Case-hardening is a rather tedious process that consumes large amounts of energy. Since the diffusion process in carburisation is dependent upon temperature, the process time can be cut in half if the temperature is increased significantly, up to 1,050 °C. So as to maintain fine grain stability despite the higher temperature, we provide suitable modified steel. The fine grain stability of this steel at high temperatures and its suitability for operation are proven. This steel is also suitable for components with large cross-sections that require enormous hardening depths, making carburising treatments of up to 80 h necessary.

Heat treatment before case hardening
The preceding heat treatment, for example for soft machining, is essential for a good result after case hardening (also determined by the grain size of the material). The different types of heat treatment have a significant impact on the fine grain stability (see figure). It is therefore important to choose the preheating treatment that is appropriate for the material before the process steps are determined so that the final product fulfils all of its requirements.

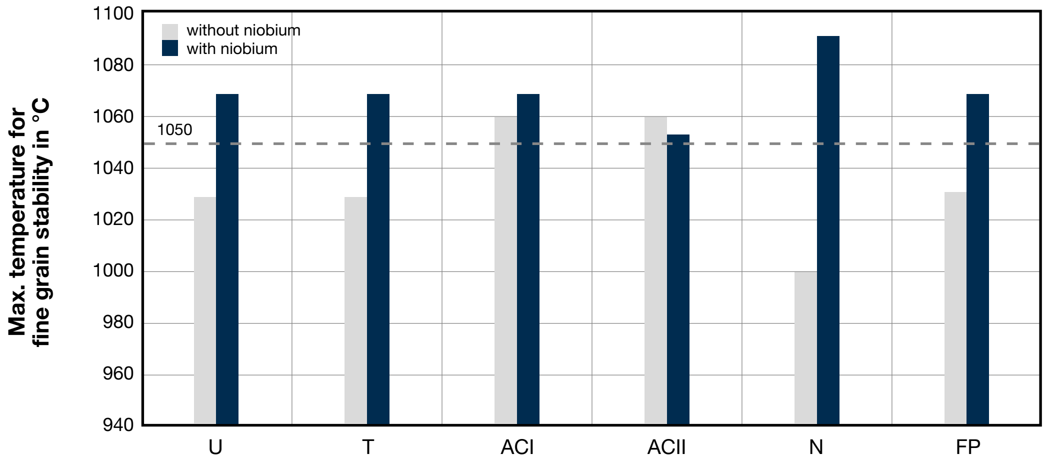
Machinability of the case-hardening steel in the soft state
Machinability depends on the chosen material and its state of heat treatment. In isolated cases, modified analyses may be helpful and, to a lesser extent, adding a small amount of certain alloying elements that promote machinability. It is important for the machinability to conserve the materials and be low in residual stress, otherwise distortion may occur in the case-hardened state.

Premium quality for premium products
We supply premium quality for your special requirements. Our selected materials are distinguished by the following properties:

» steels may be used as components for anti-friction bearings
» low distortion due to modified hardenability of the steel
» high-grade quality according to DNV approval
» supplied with properties according to ISO 6336-5
» superclean and sulphur free
» case-hardening up to process temperatures of 1,060 °C (for example by adding niobium)

CARBODUR FINE GRAIN STABILITY (WITH OR WITHOUT NIOBIUM)

U: untreated
T: tempered (BF)
ACI: GKZ < Ac_1
ACII: GKZ > Ac_1
N: normalised
FP: treated on ferrite-perlite structure



Grade overview

DEW grade	Designation	SAE similar	Core strength	Tough-ness	Costs	Availa-bility
Carbodur 1140	C15R		- -	- -	+ +	o
Carbodur 5714	16NiCr4		o	+	o	-
Carbodur 5715	16NiCrS4		o	+	o	-
Carbodur 5732	14NiCr10	3415	+	+	-	-
Carbodur 5752	17NiCr13	3310, 3312, 3316	+ +	+ +	-	-
Carbodur 5792	12NiCr3		o	+	o	-
Carbodur 5805	10NiCr5-4		o	+	o	-
Carbodur 5807	15NiCr6-4		o	+	o	-
Carbodur 5810	18NiCr5-4		+	+	-	-
Carbodur 5860	14NiCr18		+ +	+ +	-	o
Carbodur 5918	17CrNi6-6		+	+	o	+
Carbodur 5919	15CrNi6	4320	+	+	o	+
Carbodur 5920	18CrNi8		+	+ +	o	+
Carbodur 6523	21NiCrMo2-2	8615, 8617, 8620, 8717	o	+	o	+
Carbodur 6526	21NiCrMoS2-2		o	o	o	o
Carbodur 6543	21NiCrMo2-2		o	+	o	-
Carbodur 6566	17NiCrMo6-4		o	+	o	-
Carbodur 6569	17NiCrMoS6-4		+	o	o	-
Carbodur 6571	20NiCrMoS6-4		+	o	o	o
Carbodur 6587	18CrNiMo7-6		+ +	+	o	+ +
Carbodur 6657	14NiCrMo13-4	9310	+	+ +	-	o
Carbodur 6723	15NiCrMo16-5		+ +	+ +	- -	-
Carbodur 6757	20NiMoCr6-5		+	+	o	+
Carbodur 7015	15Cr3	5015	-	-	+ +	+
Carbodur 7016	17Cr3		-	-	+ +	+
Carbodur 7121	20CrMnS3-3		-	-	+ +	+
Carbodur 7131	16MnCr5	5115	-	-	+ +	+ +
Carbodur 7139	16MnCrS5		-	-	+ +	+ +
Carbodur 7147	20MnCr5	5120	-	-	+ +	+
Carbodur 7179	20MnCrS5		-	-	+ +	+
Carbodur 7160	16MnCrB5		-	-	+ +	o
Carbodur 7168	18MnCrB5		o	-	+ +	+
Carbodur 7211	23CrMoB4		+	o	+	-
Carbodur 7242	16CrMo4		+	o	+	o
Carbodur 7243	18CrMo4		+	o	+	-
Carbodur 7264	20CrMo5		+	o	+	++
Carbodur 7271	23CrMoB3-3		+	o	o	o
Carbodur 7311	20CrMoS2		+	o	o	-
Carbodur 7321	20MoCr4		+	+	o	o
Carbodur 7323	20MoCrS4		+	o	o	o
Carbodur 7325	25MoCr4		+	+	o	++
Carbodur 7326	25MoCrS4		+	o	o	++
Carbodur 7332	17CrMo3-5		+	o	o	o
Carbodur 7333	22CrMoS3-5		+	o	o	+

Grade overview*

DEW grade	Group	Application/Properties
Carbodur 1140	Non-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with low core strength, predominantly for high wear applications such as levers and shafts
Carbodur 5714	Ni-Cr-alloyed case-hardening steel	for highly stressed, shock-loaded components in mechanical engineering with high toughness requirements at low temperatures
Carbodur 5715		
Carbodur 5732		
Carbodur 5752		
Carbodur 5792		
Carbodur 5805		
Carbodur 5807		
Carbodur 5810		
Carbodur 5860		
Carbodur 5918	Cr-Ni-alloyed case-hardening steel	for highly stressed components in mechanical engineering and vehicle construction
Carbodur 5919		
Carbodur 5920		
Carbodur 6523	Ni-Cr-Mo-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with high core strength, such as gear wheels, universal joint crosses and ball bearing retainers
Carbodur 6526		
Carbodur 6543		
Carbodur 6566		
Carbodur 6569		
Carbodur 6571		
Carbodur 6587	Cr-Ni-Mo-alloyed case-hardening steel	for heavy and highly stressed gear parts in mechanical engineering with high toughness requirements, such as gear wheels, pinions and worm shafts
Carbodur 6657		
Carbodur 6723		
Carbodur 6757	Ni-Mo-Cr-alloyed case-hardening steel	for highly stressed components with an excellent toughness in mechanical engineering and vehicle construction, such as drive bevel gears, pinions, shafts, bolts and counter shafts
Carbodur 7015	Cr-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with low core strength, predominantly for high wear applications such as piston pins and cam shafts
Carbodur 7016		
Carbodur 7121	Cr-Mn-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with high core strength, such as piston pins, cam shafts and gear wheels
Carbodur 7131		
Carbodur 7139		
Carbodur 7147		for components in mechanical engineering and vehicle construction with higher core strength, e.g. gear wheels, ring gears and counter shafts
Carbodur 7179		
Carbodur 7160		
Carbodur 7168		
Carbodur 7211	Cr-Mo-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with high core strength, such as gear wheels and drive bevel gears with high tooth root strength
Carbodur 7242		
Carbodur 7243		
Carbodur 7264		
Carbodur 7271		
Carbodur 7311		
Carbodur 7321	Mo-Cr-alloyed case-hardening steel	for components in mechanical engineering and vehicle construction with high core strength, such as gear wheels, universal joint crosses and ball bearing retainers
Carbodur 7323		
Carbodur 7325		
Carbodur 7326		
Carbodur 7332	Cr-Mo-alloyed Case-hardening steel	for components in mechanical engineering and vehicle construction with high core strength, e.g. piston pins, cam shafts and gear wheels
Carbodur 7333		

**material diagrams and material data sheets of our Carbodur steel can be found on our homepage www.dew-stahl.com/en/services/publications/*

Carbodur – no mass-market steel. Custom-tailored to your needs. Any of the basic grades listed here may be adjusted for optimal processing and/or low distortion during case hardening by means of heat treatment at the factory.

Preparatory work upon request
Deutsche Edelstahlwerke also supplies this steel as bars with large cross-sections and at any processing stage, for example as hollow shafts or steel discs sawed from the bar with or without bores.
We can also manufacture components that are forged to shape. The manufacturing depth includes shiny surfaces with tight tolerances.

Take advantage of our diverse facilities and allow us to be your subcontractor. Our experts will develop a customised solution with you.

General note (liability)
Information about the quality or usability of materials or products is for descriptive purposes only. Confirmations in relation to the existence of certain characteristics or with reference to a certain application always require a special written agreement. Printing errors, omissions and changes are subject to modification.

Swiss Steel Group
www.swisssteel-group.com

Deutsche Edelstahlwerke
Specialty Steel GmbH & Co. KG

Auestr. 4
58452 Witten
GERMANY

Phone: +49 (0)2302 29 - 0
Fax: +49 (0)2302 29 - 4000

info@dew-stahl.com
www.dew-stahl.com

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