Steel

Deep-drawing steels DD, DC and DX

Product information

thyssenkrupp

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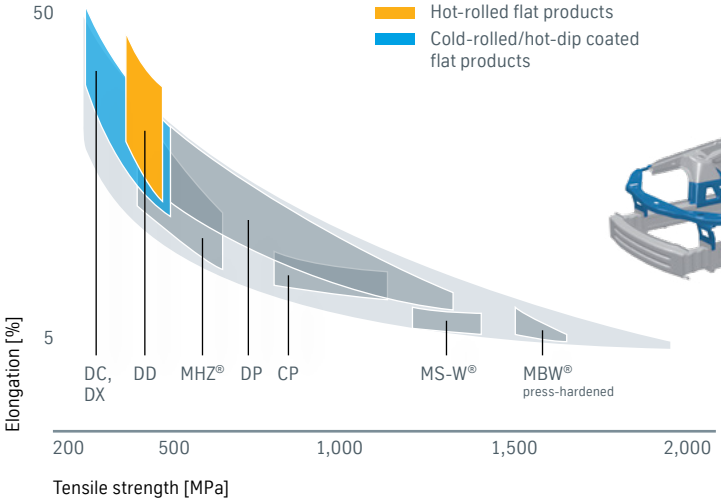
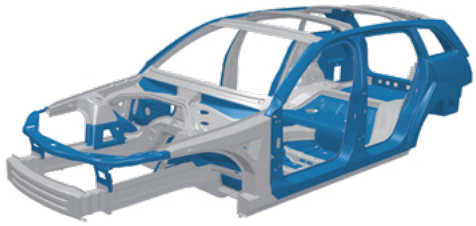
Overview of steel grades



Recommended applications



Content

Areas of application

Deep-drawing steels by thyssenkrupp offer excellent formability and good aging resistance. The mechanical properties of the individual deep-drawing steel grades are characterized by the yield point and tensile strength, as well as by a guaranteed minimum elongation at break. For premium grades the forming properties are additionally described by agreed minimum values for perpendicular anisotropy (r-value) and the tensile strain-hardening exponent (n-value).

Examples of applications for hot-rolled deep-drawing steels are body and structural parts, chassis parts and wheel rims. Due to their specifically designed surface structure and excellent formability cold-rolled steel grades are well-suited to the production of complex, formed body exterior and interior parts such as fenders, side panels, floor panels, spare wheel wells, and door outer and inner panels.

thyssenkrupp offers a wide range of hot-rolled and cold-rolled deep-drawing steels. They are available either uncoated or with a high-quality surface finish. The requirements for which deep-drawing steels are suitable, either as hot-rolled or cold-rolled flat products, must be considered in a project-specific context; they depend on the desired thickness, the surface condition, the surface finish type, and the desired dimensional tolerances.

Steel grade designations and surface refinements

	DIN EN 10130, 10152, 10111, 10346	Surface refinements					
		UC	EG	GI	GA	ZM	AS
To DIN EN							
Steel grade							
● DC01	DC01	●	●				
● DC03	DC03	●	●				
● DC04	DC04	◉	▣				
● DC05	DC05	◉	▣				
● DC06	DC06	◉	▣				
● DC07	DC07	◉	▣				
● DD11	DD11	●					
● DD12	DD12	●					
● DD13	DD13	●					
● DD14	DD14	●					
● DX51D	DX51D			◉	◉	◉	●
● DX52D	DX52D			◉	◉	◉	●
● DX53D	DX53D			◉	◉	◉	●
● DX54D	DX54D			▣	◉	▣	●
● DX56D	DX56D			▣	◉	▣	●
● DX57D	DX57D			▣	●	▣	
● DX58D	Special mill grade			●			

Steel grade designations and surface refinements

	VDA 239-100	Surface refinements					
		UC	EG	GI	GA	ZM	AS
To VDA							
Steel grade							
● CR1	CR1	●	●	●	●	●	●
● CR2	CR2	●	●	●	●	●	●
● CR3	CR3	◉	◉	▣	◉	▣	●
● CR4	CR4	◉	◉	▣	◉	▣	●
● CR5	CR5	◉	◉	▣	●	▣	
● HR2	HR2	●					

- ● Hot-rolled flat products
- ● Cold-rolled/hot-dip coated flat products
- ● Serial production for unexposed applications
- ◉ Serial production for unexposed and exposed applications
- ▣ Serial production for unexposed and exposed applications as well as exposed applications in primetex® finish

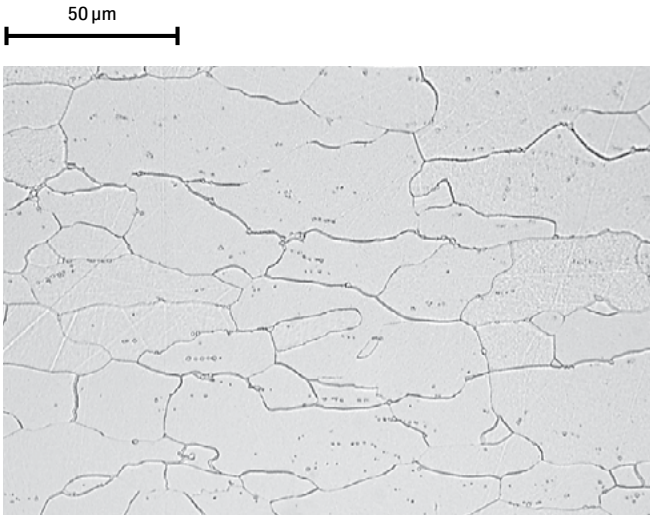
UC	Uncoated	GA	Galvannealed
EG	Electrogalvanized zinc coating	ZM	ZM Ecoprotect®
GI	Hot-dip zinc coating	AS	Aluminum-silicon coating

Material characteristics

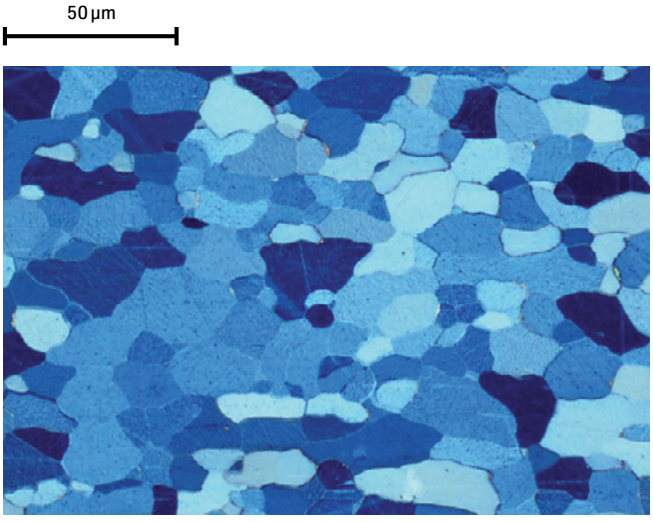
To be able to produce low-carbon steel grades such as premium grade, deep-drawing steels, thyssenkrupp has developed and implemented a number of secondary metallurgical custom steps in the liquid phase in addition to state-of-the-art steel melting methods. For example, the lowest possible carbon content and admixing of special alloys are achieved through modern vacuum systems. In addition, new rolling concepts were developed for unalloyed hot-rolled grades to meet the demand for lowest possible yield limits, good cold formability and resistance to aging. Our cold-rolled steel products are high quality, low-carbon decarburized, Ti and/or TiNb alloyed IF steels.

Deep-drawing steels exhibit a purely ferritic structure, or consist of a ferritic matrix, in which isolated pockets of grain carbide can be embedded. Nital etching reveals the grain boundaries and fine carbides. The carbides are shown in black. Color etching according to Klemm contrasts the grain surfaces and coarse carbides. The grain surfaces appear in brown or blue hues, while the carbides remain white.

Micrograph of deep-drawing steels



Microstructure of deep-drawing steels. Structural contrasting through nital etching.



Microstructural contrasting with color etching according to Klemm.

Technical features

Chemical composition

Mass fractions in ladle analysis	C [%] max.	Si [%] max.	Mn [%] max.	P [%] max.	S [%] max.	Ti [%] max.
To DIN EN						
Steel grade						
● DC01	0.12	–	0.60	0.045	0.045	–
● DC03	0.10	–	0.45	0.035	0.035	–
● DC04	0.08	–	0.40	0.030	0.030	–
● DC05	0.06	–	0.35	0.025	0.025	–
● DC06	0.02	–	0.25	0.020	0.020	0.3
● DC07	0.01	–	0.20	0.020	0.020	0.2
● DD11	0.12	–	0.60	0.045	0.045	–
● DD12	0.10	–	0.45	0.035	0.035	–
● DD13	0.08	–	0.40	0.030	0.030	–
● DD14	0.08	–	0.35	0.025	0.025	–
● DX51D	0.18	0.50	1.20	0.12	0.045	0.30
● DX52D – DX58D [1)]	0.12	0.50	0.60	0.10	0.045	0.30

[1)] Special mill grade DX58D.

Chemical composition

Mass fractions in ladle analysis	C [%] max.	Si [%] max.	Mn [%] max.	P [%] max.	S [%] max.	Al [%] min.	Ti [%] max.
To VDA							
Steel grade							
● CR1	0.12	0.50	0.60	0.065	0.045	0.010	–
● CR2	0.10	0.50	0.50	0.065	0.045	0.010	–
● CR3	0.08	0.50	0.50	0.030	0.030	0.010	0.30
● CR4	0.06	0.50	0.40	0.025	0.025	0.010	0.30
● CR5	0.02	0.50	0.30	0.020	0.020	0.010	0.30
● HR2	0.10	0.50	0.50	0.030	0.030	0.015	–

● Hot-rolled flat products
● Cold-rolled/hot-dip coated flat products

Mechanical properties

Test direction transverse to rolling direction	Surface refinements	Valid for thicknesses [mm]	Yield strength R_e [MPa]	Tensile strength R_m [MPa]	Elongation A [%] min.	Elongation A_{80} [%] min.	Vertical anisotropy r_{90} min.	Strain-hardening exponent n_{90} min.
To DIN EN								
Steel grade								
● DC01	UC/EG	0.7 – 1.5	– / 280[1]	270 – 410	–	28	–	–
● DC03	UC/EG	0.7 – 1.5	– / 240[1]	270 – 370	–	34	1.3	–
● DC04	UC	0.7 – 1.5	– / 210[1]	270 – 350	–	38	1.6	0.180
	EG	0.7 – 1.5	– / 220[1]	270 – 350	–	37	1.6	0.170
● DC05	UC	0.7 – 1.5	– / 180[1]	270 – 330	–	40	1.9	0.200
	EG	0.7 – 1.5	– / 200[1]	270 – 330	–	39	1.9	0.190
● DC06	UC	0.7 – 1.5	– / 170[1]	270 – 350	–	41	2.1	0.220
	EG	0.7 – 1.5	– / 180[1]	270 – 350	–	41	2.1	0.210
● DC07	UC	0.7 – 1.5	– / 150[1]	250 – 310	–	44	2.5	0.230
	EG	0.7 – 1.5	– / 160[1]	250 – 310	–	43	2.5	0.220
● DD11	UC	2.0 – 11.0	170 – 340[2]	≤ 440	28	24[3]	–	–
● DD12	UC	2.0 – 11.0	170 – 320[2]	≤ 420	30	26[3]	–	–
● DD13	UC	2.0 – 11.0	170 – 310[2]	≤ 400	33	29[3]	–	–
● DD14	UC	2.0 – 11.0	170 – 290[2]	≤ 380	36	32[3]	–	–
● DX51D	GI	0.7 – 2.0	–	270 – 500	–	22	–	–
● DX52D	GI	0.7 – 2.0	140 – 300[4]	270 – 420	–	26	–	–
● DX53D	GI	0.7 – 2.0	140 – 260	270 – 380	–	30	–	–
● DX54D	GI	0.7 – 2.0	120 – 220	260 – 350	–	36	1.6[5]	0.18
● DX56D	GI	0.7 – 2.0	120 – 180	260 – 350	–	39	1.9[5]	0.21
● DX57D	GI	0.7 – 2.0	120 – 170	260 – 350	–	41	2.1[5]	0.22
● DX58D[6]	GI	0.7 – 2.0	120 – 160	260 – 330	–	43	2.3	0.22

Refer to the applicable standards for supplements and deductions for deviating thicknesses.
Limitations of the technological properties are possible subject to surcharge and consultation.
The technological properties may deviate depending on the type of surface refinement.

[1] For design purposes, the lower limit of R_e may be assumed to be 140 MPa for grades DC01, DC03, DC04 and DC05, 130 MPa for DC06 and 110 MPa for DC07.
[2] For thicknesses from 1.0 to 2.0 mm, a max. yield strength of 360 MPa applies to DD11, 340 MPa to DD12, 330 MPa to DD13 and 310 MPa to DD14.
[3] Elongation value for plate thicknesses from 2.0 to 3.0 mm.
[4] For surface class A, the maximum value of the yield strengh is R_e = 360 MPa.
[5] For 1.5 mm < t < 2 mm, the r_{90}-minimum value decreases by 0.2. For t ≥ 2 mm, the r_{90}-minimum value decreases by 0.4.
[6] Special mill grade.

● Hot-rolled flat products
● Cold-rolled/hot-dip coated flat products
UC Uncoated
EG Electrogalvanized zinc coating
GI Hot-dip zinc coating
AS Aluminum-silicon coating
R_e Where there is no distinct yield point, the values for 0.2% proof stress $R_{p0.2}$ apply; with a distinct yield point those for the lower yield point ReL apply
A Percentage elongation after fracture using a proportional specimen with $L_0 = 5.65 \sqrt{S_0}$ for sheet thicknesses ≥ 3.0 mm
A_{80} Percentage elongation after fracture using a specimen with gauge length L_0 = 80 mm for sheet thicknesses < 3.0 mm
r_{90}, n_{90} Anisotropy r_{90} and strain-hardening exponent n_{90} determined in the region of the homogeneous plastic deformation for elongations from 10% to 20%

Mechanical properties

Test direction transverse to rolling direction	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation A [%] min.	Elongation A_{50} [%] min.	Elongation A_{80} [%] min.	Vertical anisotropy $r_{90/20}$ min.	Strain-hardening exponent $n_{10\text{-}20/Ag}$ min.
To VDA							
Steel grade							
● CR1	140–300	270–410	–	30	28	–	–
● CR2	140–240	270–370	–	34	34	1.3	0.16
● CR3	140–210	270–350	–	38	38	1.8	0.18
● CR4	140–180	270–330	–	40	39	1.9	0.20
● CR5	110–170	270–330	–	42	41	2.1	0.22
● HR2	180–290	270–400	34	32	30	–	0.16

Restrictions as per VDA 239-100 Section 7.2. The average vertical anisotropy $r_{m/20}$ can be agreed for initial approval.

● Hot-rolled flat products
● Cold-rolled/hot-dip coated flat products
$R_{p0.2}$ Proof strength at 0.2% plastic elongation
R_m Tensile strength
A Percentage elongation after fracture using a proportional specimen with $L_0 = 5.65\sqrt{S_0}$ for sheet thicknesses ≥ 3.0 mm
A_{50} Percentage elongation after fracture using a specimen with gauge length $L_0 = 50$ mm
A_{80} Percentage elongation after fracture using a specimen with gauge length $L_0 = 80$ mm for sheet thicknesses < 3.0 mm
$n_{10\text{-}20/Ag}$ Strain-hardening exponent determined between 10% and 20% plastic strain e.g. uniform elongation limit if $A_g < 20\%$
$r_{90/20}$ Vertical anisotropy in transverse direction at 20% plastic strain

Surfaces

Surface refinements, electrogalvanized zinc coating

Designation	Specification	Nominal coating on each side of single spot sample: Mass [g/m²]	Nominal coating on each side of single spot sample: Thickness [µm]	Coating on each side of single spot sample: Mass [g/m²]	Coating on each side of single spot sample: Thickness [µm]
Electrogalvanized zinc coating					
EG25/25	DIN EN	18	2.5	≥ 12	≥ 1.7
EG18	VDA 239-100	–	–	18–38	2.5–5.4
EG50/50	DIN EN	36	5.0	≥ 29	≥ 4.1
EG29	VDA 239-100	–	–	29–49	4.1–6.9
EG75/75	DIN EN	54	7.5	≥ 47	≥ 6.6
EG53	VDA 239-100	–	–	53–73	7.5–10
EG100/100	DIN EN	72	10	≥ 65	≥ 9.1
EG70	VDA 239-100	–	–	70–90	9.9–13

Also available with single-side zinc coating, or double-sided with different zinc coatings.

Surface refinements, hot-dip zinc coating

	Specification	Minimum coating two-sided [g/m²]		Coating on each side of single spot sample		Informative
		Triple spot sample	Single spot sample	Mass [g/m²]	Thickness [µm]	Typical thickness [µm]
Hot-dip zinc coating						
Designation						
GI100	DIN EN	100	85	–	5 – 12	7
GI40	VDA 239-100	–	–	40 – 60	5.6 – 8.5	–
GI140	DIN EN	140	120	–	7 – 15	10
GI60	VDA 239-100	–	–	60 – 90	8.5 – 13	–
GI200	DIN EN	200	170	–	10 – 20	14
GI85	VDA 239-100	–	–	85 – 115	12 – 16	–
Galvannealed						
GA100	DIN EN	100	85	–	5 – 12	7
GA40	VDA 239-100	–	–	40 – 60	5.6 – 8.5	–
GA120	DIN EN	120	100	–	6 – 13	8
GA50	VDA 239-100	–	–	50 – 80	7 – 10	–
Aluminum-silicon coating						
AS060	DIN EN	60	45	–	7 – 15	10
AS080	DIN EN	80	60	–	10 – 20	14
AS30	VDA 239-100	–	–	30 – 65	10 – 20	–
AS100	DIN EN	100	75	–	12 – 23	17
AS120	DIN EN	120	90	–	15 – 27	20
AS45	VDA 239-100	–	–	45 – 85	15 – 28	–
AS150	DIN EN	150	115	–	19 – 33	25
ZM Ecoprotect®						
ZM070	SEW022	70	60	–		–
ZM30	VDA 239-100	–	–	30 – 55	4.5 – 7.7	–
ZM100	SEW022	100	85	–		–
ZM40	VDA 239-100	–	–	40 – 65	6.2 – 9.2	–
ZM120	SEW022	120	100	–		–
ZM50	VDA 239-100	–	–	50 – 80	7.7 – 12	–

A coating weight of 100 g/m² is recommended. For interior parts that are particularly exposed to corrosion, thicker coatings or our innovative ZM Ecoprotect® zinc-magnesium coating can be supplied on request.

Surface finishes and surface qualities

	Finish type	Quality
Products		
Cold-rolled flat products	Uncoated	A Normal surface
		U Unexposed (interior parts)
		B Best surface
		E Exposed (exterior parts)
Electrolytically zinc coated flat products	Electrogalvanized zinc coating	A Normal surface
		U Unexposed (interior parts)
		B Best surface
		E Exposed (exterior parts)
		primetex®
Hot-dip coated flat products	Hot-dip zinc coating	B Improved surface
		U Unexposed (interior parts)
		C Best surface
		E Exposed (exterior parts)
		primetex®
	Galvannealed	B Improved surface
		U Unexposed (interior parts)
		C Best surface
		E Exposed (exterior parts)
	Aluminum-silicon coating	B Improved surface
		U Unexposed (interior parts)
	ZM Ecoprotect®	B Improved surface
		U Unexposed (interior parts)
		C Best surface
		E Exposed (exterior parts)
		primetex®

A / B / C as per DIN EN
U / E as per VDA 239-100

Surface treatments

Type of surface treatment		UC	EG	GI	GA	ZM	AS
O	Oiled	●	●	●	●	●	●
P	Phosphated		●		●		
µPhos	Micro-phosphated		●				
JAZ®	JFE Advanced Zinc				●		
PO	Phosphated and oiled		●		●		
µPhosO	Micro-phosphated and oiled		●				

● Serial production
UC Uncoated
EG Electrogalvanized zinc coating
GI Hot-dip zinc coating
GA Galvannealed
ZM ZM Ecoprotect®
AS Aluminum-silicon coating

Notes on applications and processing

Forming

Deep-drawing steels are versatile in terms of forming applications. Combined with very high elongation values, they offer a broad yield limit spectrum of between 140 and 340 MPa. For particularly complex deep-drawing and stretch-formed parts such as side panels, oil pans and floor panels, grades such as DC06 or DC07 are particularly suitable due to their excellent deformation behavior. The choice of the right steel grade must also be made with a special focus on the actual anticipated forming stresses. This allows optimum leveraging of specific benefits so that the steels can also be used for difficult drawn parts. In contrast to this, grades with a high r-value behave more favorably in deep-drawing in terms of the limiting drawing ratio. A high r-value indicates that, in a tensile test, the material flows out of the sample width rather than the sheet thickness. High r-values under deep-drawing load thus improve both the resilience to local constriction in the frame and the flow of material under the blank holder. In a combination of stretching and deep-drawing load, steels with equally high r- and n-values offer advantages; this is very much the case with higher-strength IF steels.

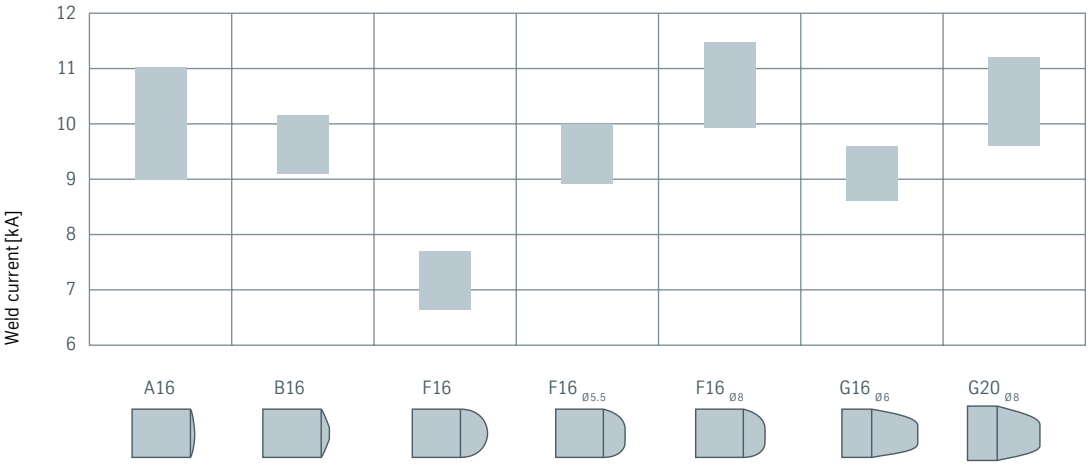
Processing instructions for joining

Resistance spot welding and arc welding are the most commonly used joining methods in the processing of deep-drawing steels. Spot, projection and seam welding have asserted themselves as the dominant joining methods in vehicle construction. They offer the benefits of good automation, low component distortion and the ability to do without welding fillers. Besides this, mechanical joining techniques such as adhesive bonding and laser beam welding are increasingly used. Hybrid joining techniques such as weld bonding and mechanical adhesion bonding can improve the rigidity and crash behavior of a structure while preventing crevice corrosion; this has led to these techniques rapidly gaining importance in state-of-the-art car body manufacturing.

Resistance spot welding

Through the customized selection of parameters for resistance spot welding, deep-drawing steels can be joined reliably in same grade joints or in joints with higher- and high-strength steels. Compared to higher-strength steel grades of the same thickness, the required electrode forces are smaller, which means lower rigidity requirements for the weld heads. In contrast, because of their higher electrical conductivity compared to higher-strength steels, deep-drawing steels need higher welding currents. For resistance spot welding of coated sheets, the process parameters need to be adapted to reflect the finish. For zinc and zinc alloy coatings, the electrode forces, welding currents and welding times must be increased compared to the unmodified base material, to compensate for a contraction of the welding zone due to the coating. In addition to the sheet grade, surface and thickness combination, factors such as the type of current (AC 50 Hz / DC 1,000 Hz) and electrode geometry play an important role in determining the optimum joining parameters. The figure below shows an example of a hot-dip zinc coated, deep-drawing steel to illustrate the relationship between the electrode geometry and the weld area. The welding zone can be significantly increased through careful selection of the tip geometry.

Informative – Influence of the electrode tip geometry on the welding zone of DX56D+Z



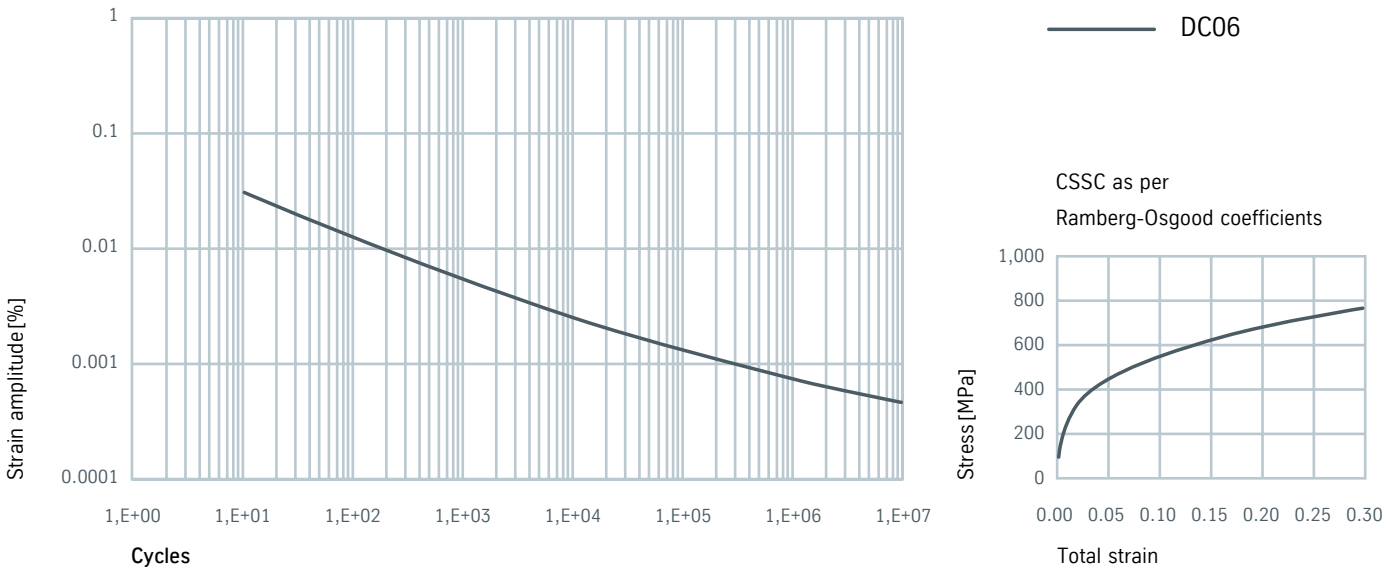
Sheet thickness
t = 1.2 mm

50 Hz welding
Electrode force: 3.2 kN
Current time: 13 periods
Dwell time: 10 periods

Fatigue strength and crash performance

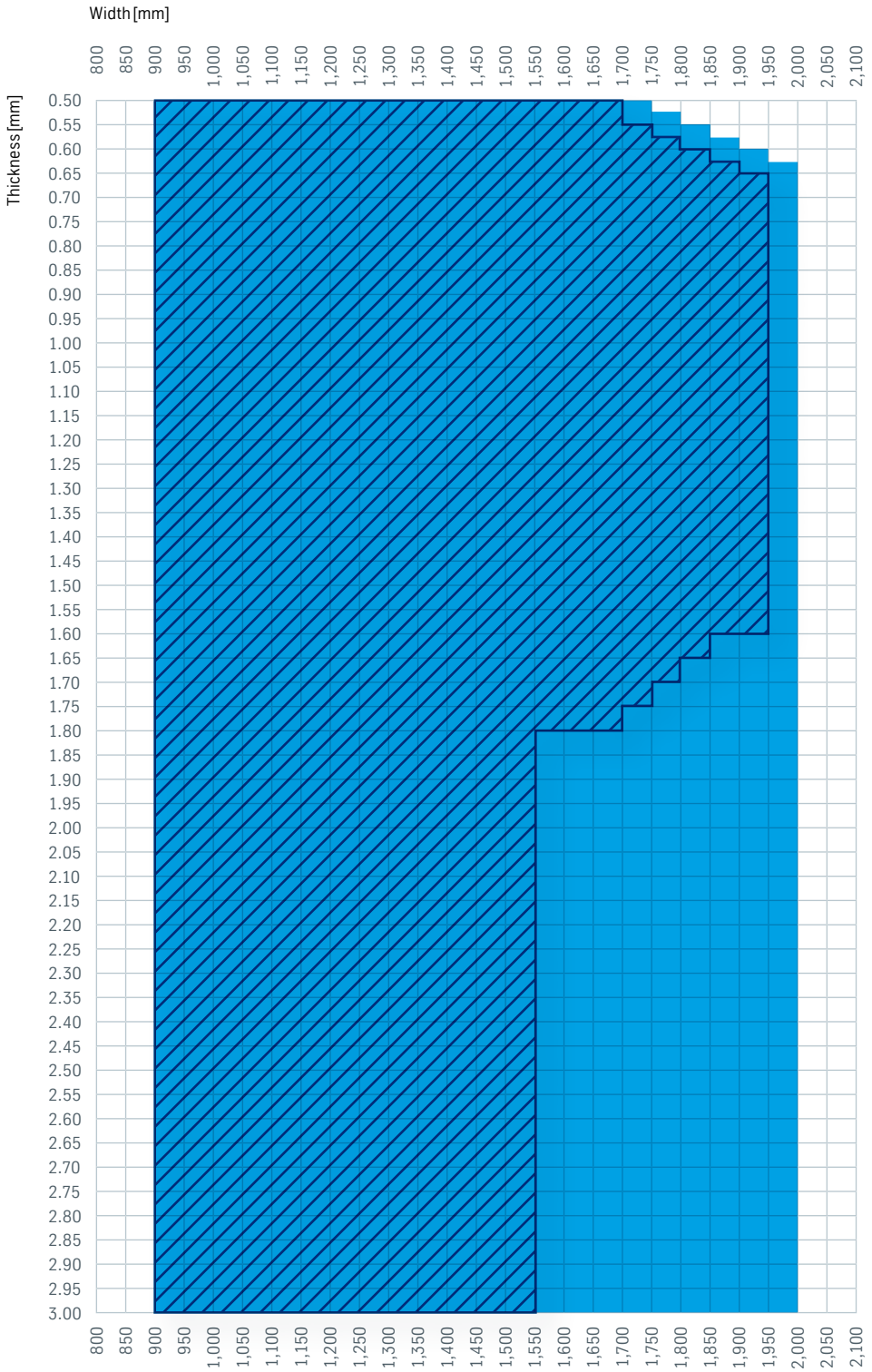
As the classification clearly shows, deep-drawing steels are characterized by particularly good formability. Deep drawing steels have a low fatigue strength. In terms of their stress-strain curve, they are at a low level; however, they are insensitive to excessive elongation, i.e. to misuse load cases. Their energy absorption capacity plays only a minor role, as other thyssenkrupp materials are available for crash-relevant components today.

Stress-strain curve of a deep-drawing steel DC06



Available dimensions

DC01, DC03, CR1, CR2



EG Electrogalvanized zinc coating

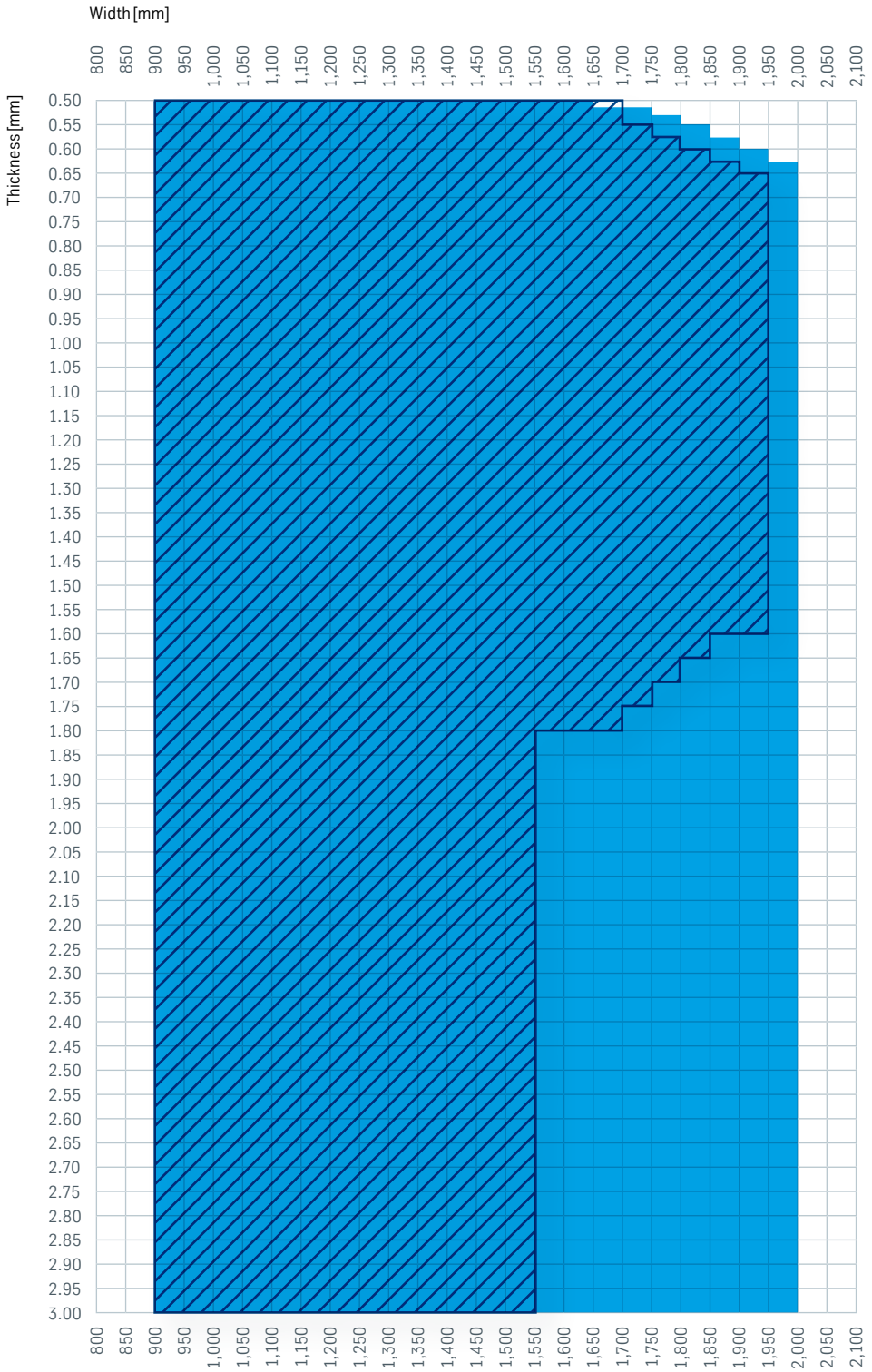
EG trimmed
Uncoated with mill edge

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.20 mm
Width 900 to 1,600 mm

Further dimensions on request.

DC04, DC05, CR3, CR4



EG Electrogalvanized zinc coating

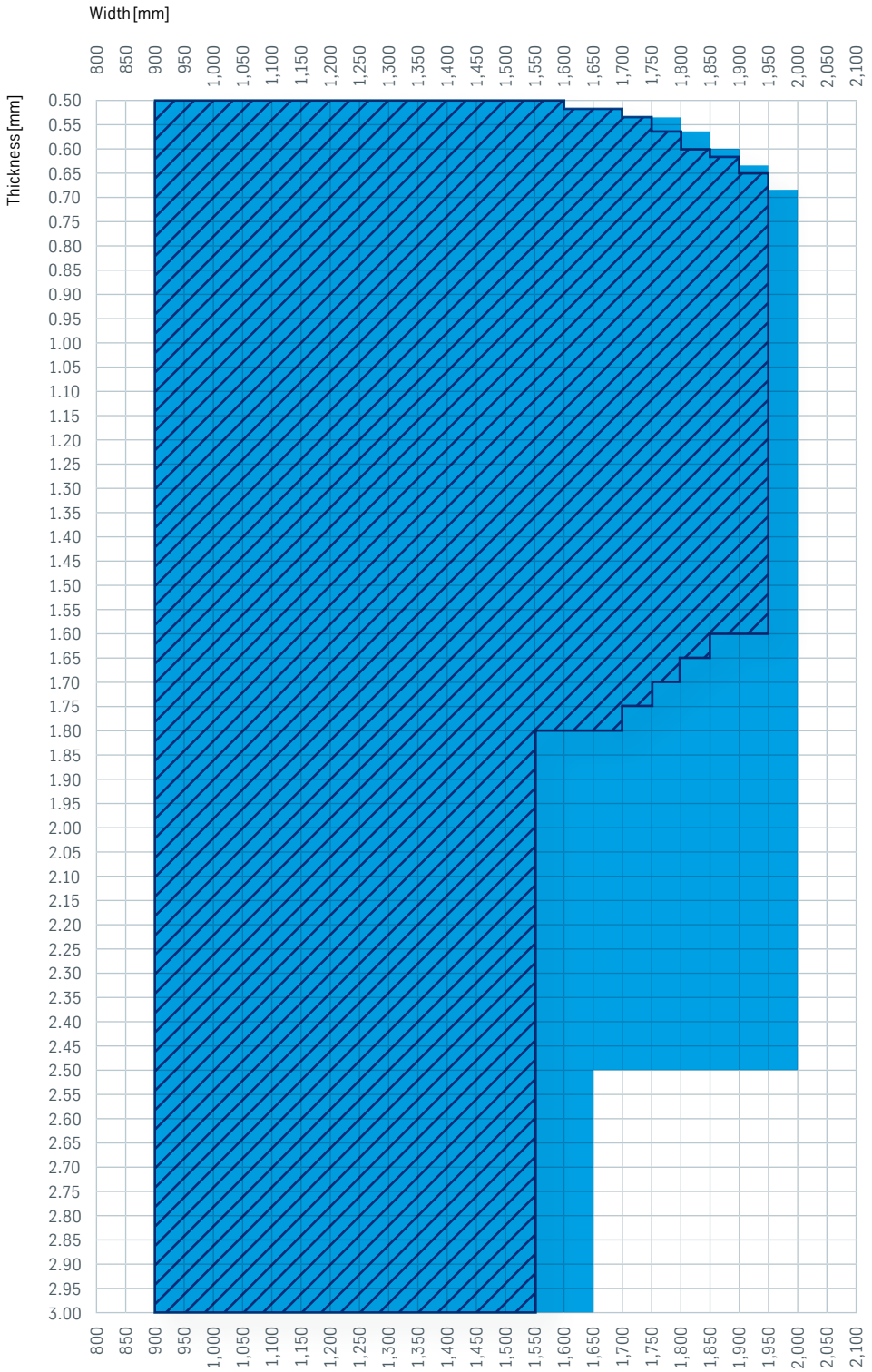
EG trimmed
Uncoated with mill edge

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.20 mm
Width 900 to 1,600 mm

Further dimensions on request.

DC06, CR5



EG Electrogalvanized zinc coating

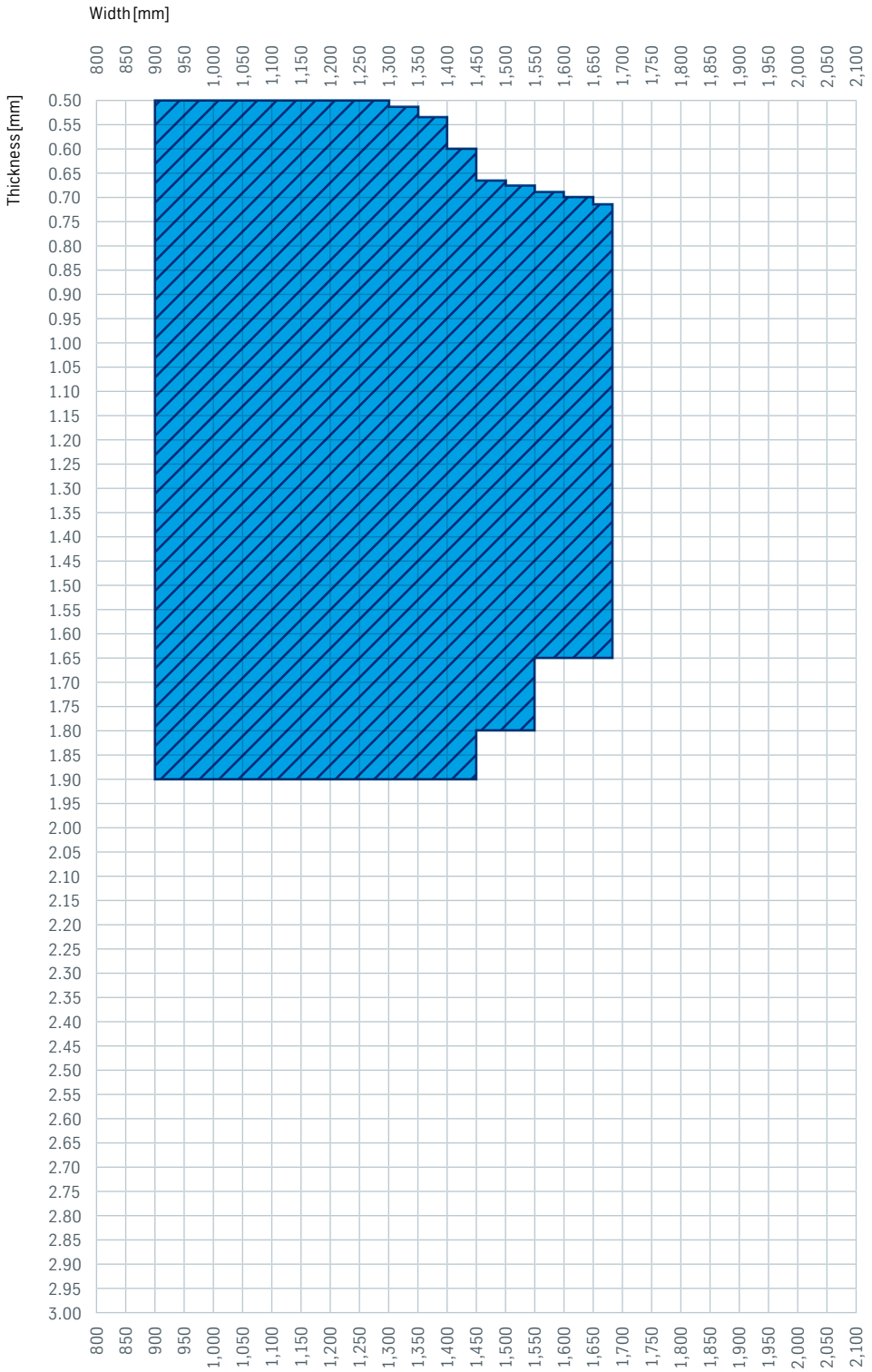
EG trimmed
Uncoated with mill edge

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.20 mm
Width 900 to 1,600 mm

Further dimensions on request.

DC07



EG Electrogalvanized zinc coating

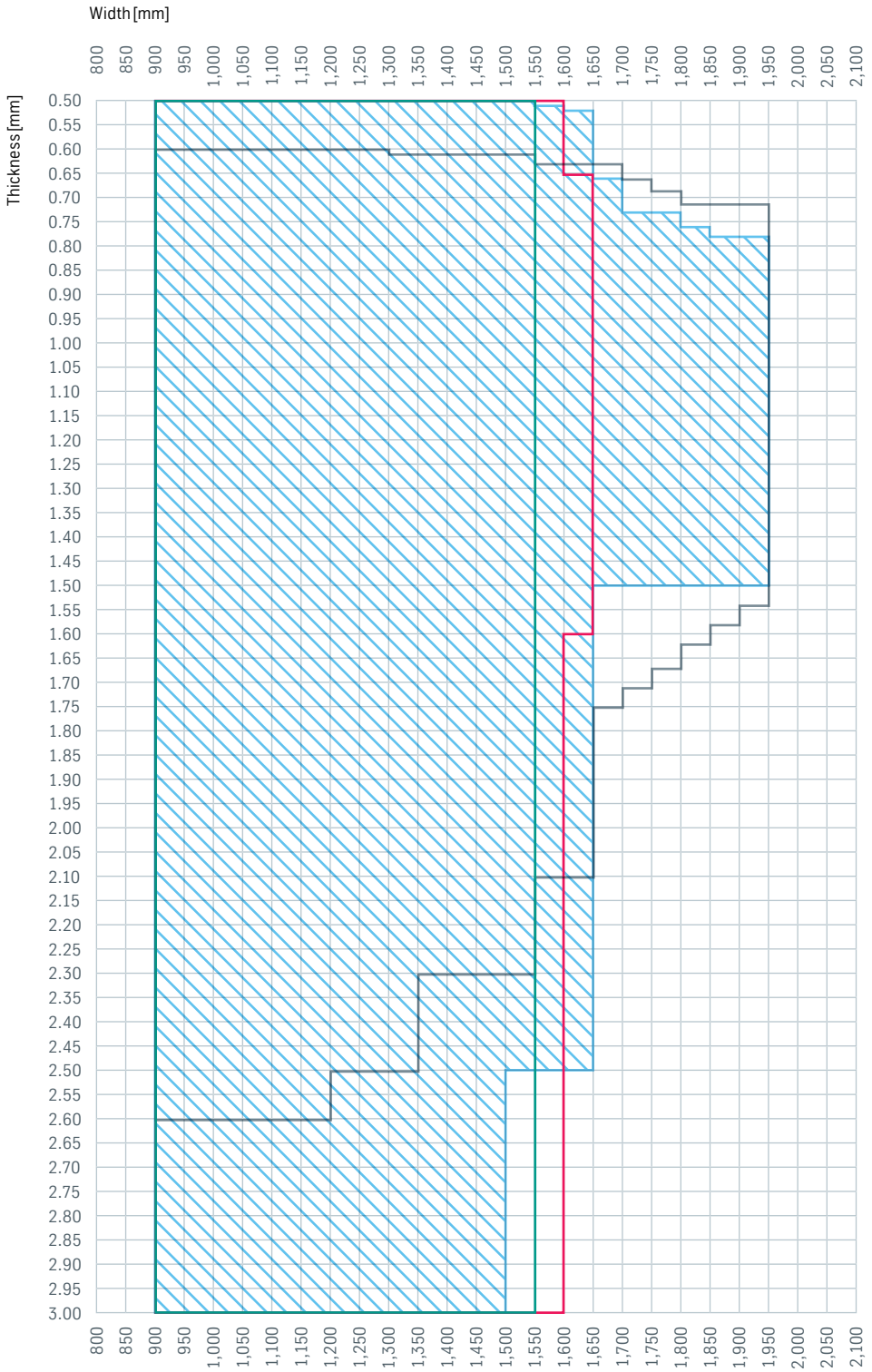
EG trimmed
Uncoated with mill edge

For interior parts
Typical dimensions for automotive customers.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.00 mm
Width 900 to 1,680 mm

Further dimensions on request.

DX51, DX52, DX53, DX54, DX56, CR1, CR2, CR3, CR4



ZM	ZM Ecoprotect®
AS	Aluminum-silicon coating
GA	Galvannealed
GI	Hot-dip zinc coating

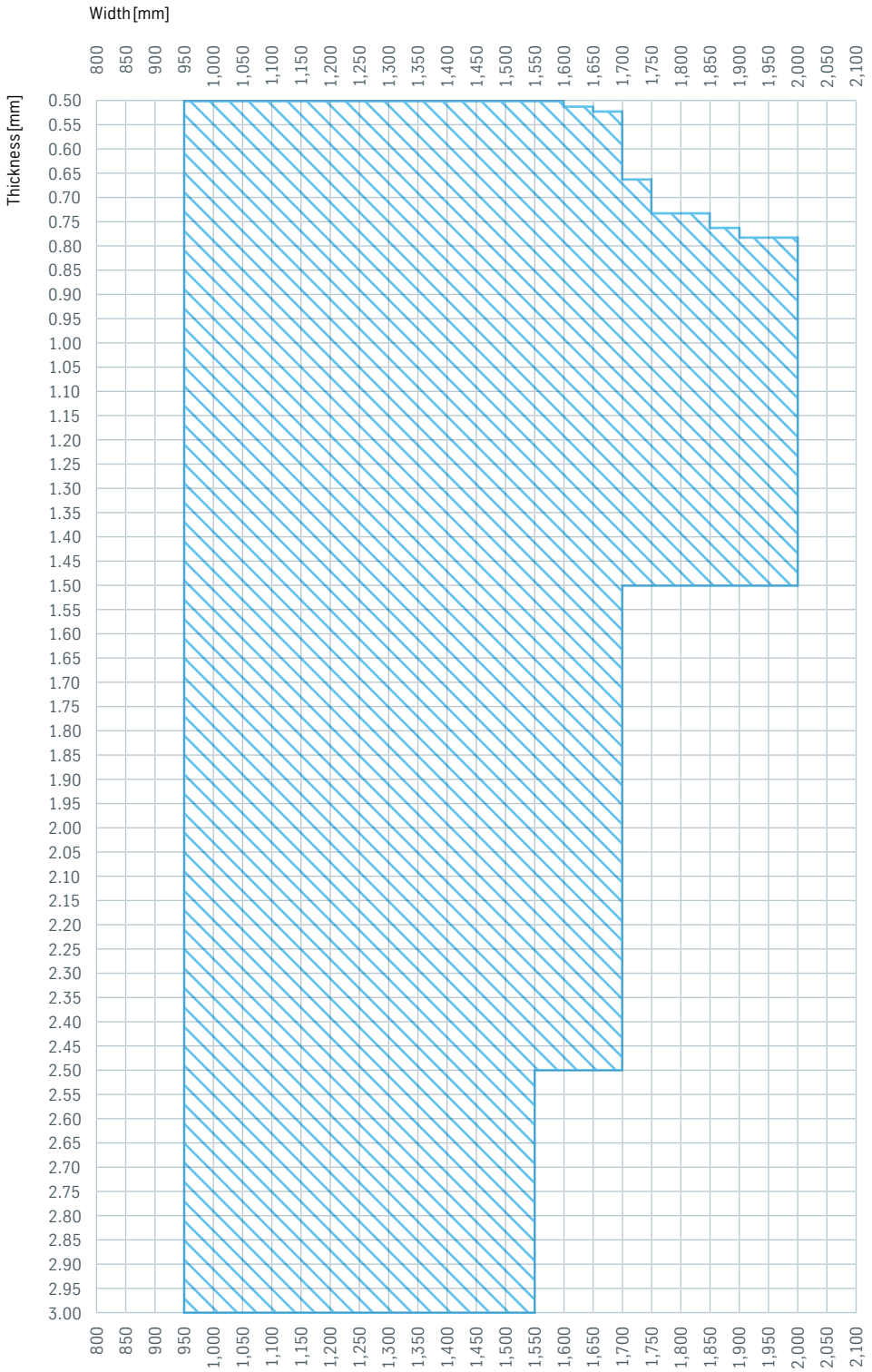
ZM trimmed
AS trimmed
GA trimmed
GI trimmed

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.20 mm
Width 900 to 1,600 mm

Further dimensions on request.

DX57, CR5



GI Hot-dip zinc coating

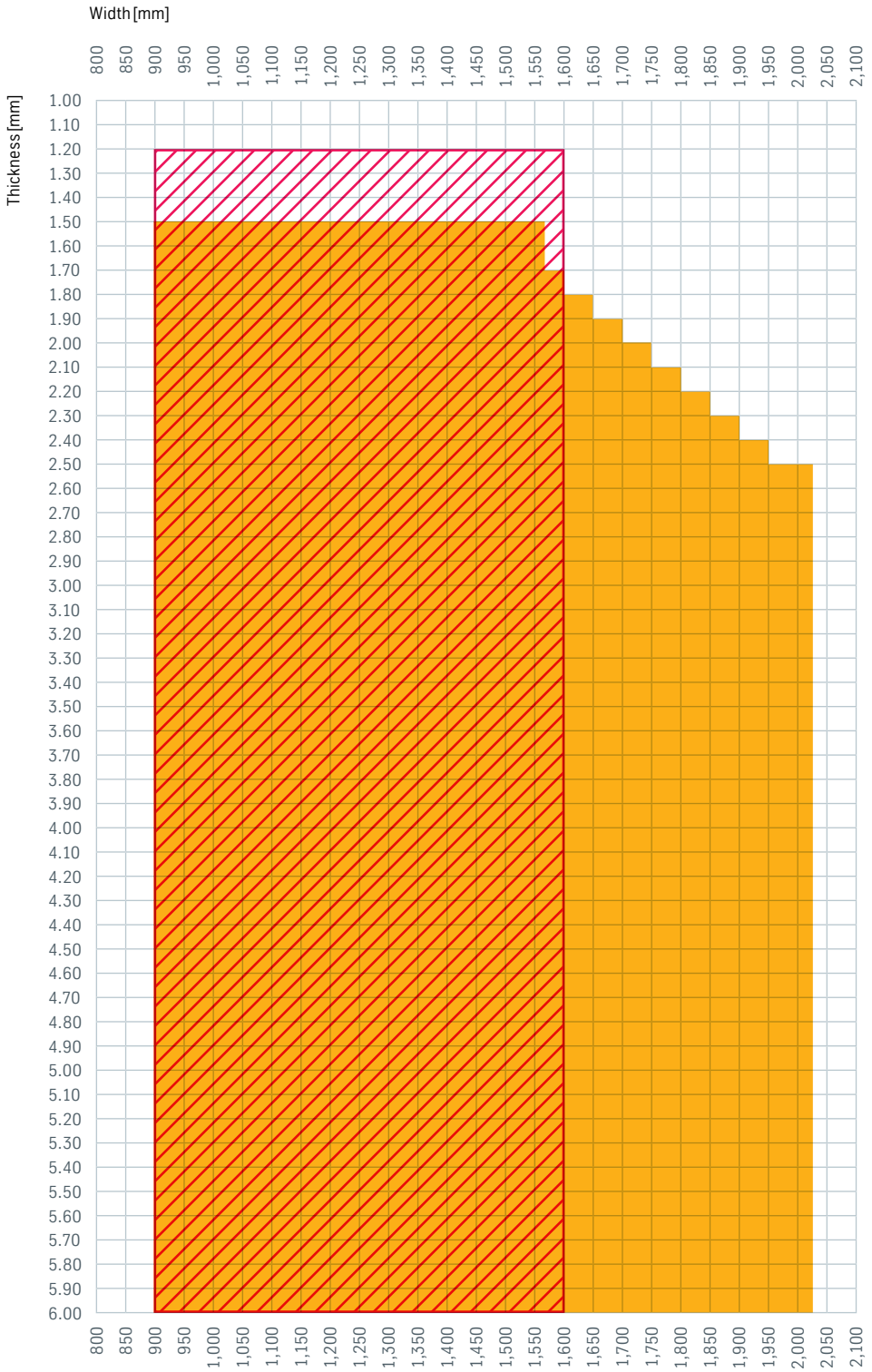
GI trimmed

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

For exterior parts
Similar to figure in the ranges:
Thickness 0.50 to 1.20 mm
Width 900 to 1,600 mm

Further dimensions on request.

DD11, DD12, DD13, DD14, HR2



Uncoated with mill edge
Product version scalur®

scalur® is a pickled hot-rolled strip from thyssenkrupp with very close thickness tolerances. For more information please refer to the product information on scalur®.

For interior parts
Typical dimensions for automotive customers. Restrictions may apply to steel grades as per VDA 239-100.

Further dimensions on request.

Special mill grades are supplied subject to the special conditions of thyssenkrupp. Other delivery conditions not specified here will be based on the applicable specifications. The specifications used will be those valid on the date of issue of this product information brochure.

General note

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