Steel

RA-K®

Product information for retained-austenite steels

thyssenkrupp

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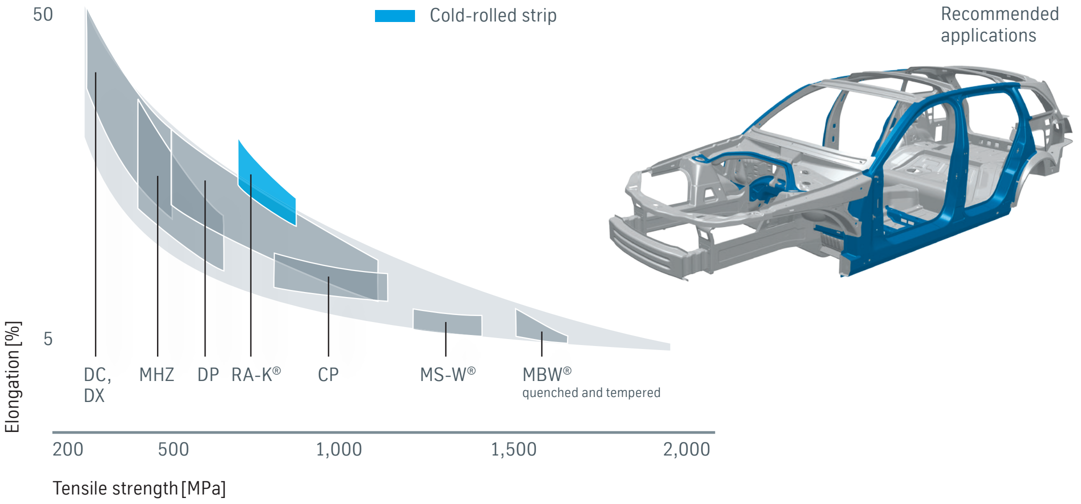
Overview of steel grades



Content

01 Areas of application
02 Material characteristics
03 Technical features
05 Surfaces
06 Notes on applications and processing
10 Available dimensions
11 Sample application

Areas of application

The retained-austensite steels RA-K® developed by thyssenkrupp are modern, multi-phase steels which are characterized by the “TRIP” effect when worked. Compared with dual-phase steels, these steels offer further improved cold formability and hardening accompanied by increased strength. This property combination is achieved through metastable austenite components in a ferritic-bainitic microstructure matrix. Working transforms a large proportion of the retained austenite to martensite, thus ensuring high component strengths. Retined-austenite steels are characterized by a high unitary elongation and a stain hardening capacity that remains intact up to high levels of elongation.

Cold-rolled retained-austenite steel RA-K® by thyssenkrupp is particularly suitable for forming extremely complex components involving a large degree of stretch forming and deep drawing. Due to the high component strengths that can be achieved, as well as the good energy absorption capacity at high rates of deformation, retained-austenite steel is also ideal for use in crash-relevant components. This results in an extensive range of applications for complex strength-relevant structural elements such as body reinforcements, side members, windshield cross-members, and pillars.

Due to their special chemical composition, RA-K® steel grades are not generally suitable for batch galvanizing.

Steel grade designations and surface refinements

To DIN EN

	DIN EN 10346, 10152, 10338	Surface refinements					
		UC	EG	GI	GA	ZM	AS
Steel grade	Standard designation						
🔵 RA-K® 400Y690T	HCT690T	●		●			

Steel grade designations and surface refinements

To VDA

	VDA 239-100	Surface refinements					
		UC	EG	GI	GA	ZM	AS
Steel grade	Standard designation						
🔵 RA-K® 400Y690T	CR400Y690T-TR	●		●			

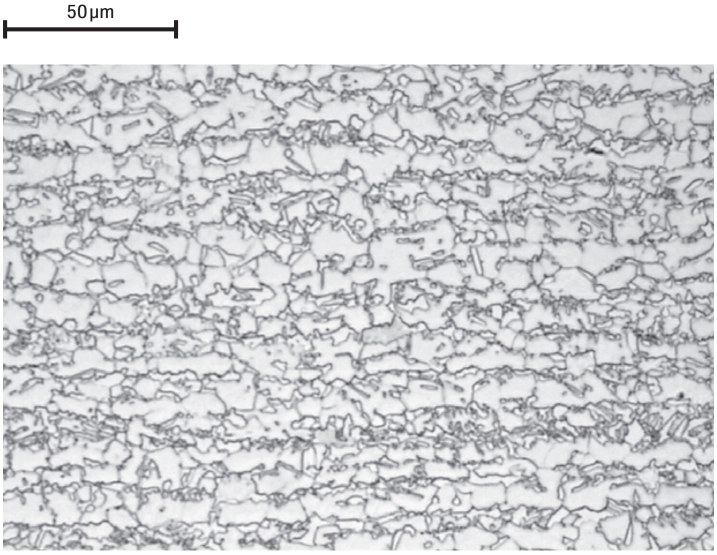
🔵	Cold-rolled strip
●	Serial production for interior parts
UC	Uncoated
EG	Electrogalvanized zinc coating
GI	Hot-dip zinc coating
GA	Galvannealed
AS	Aluminum-silicon coating

Material characteristics

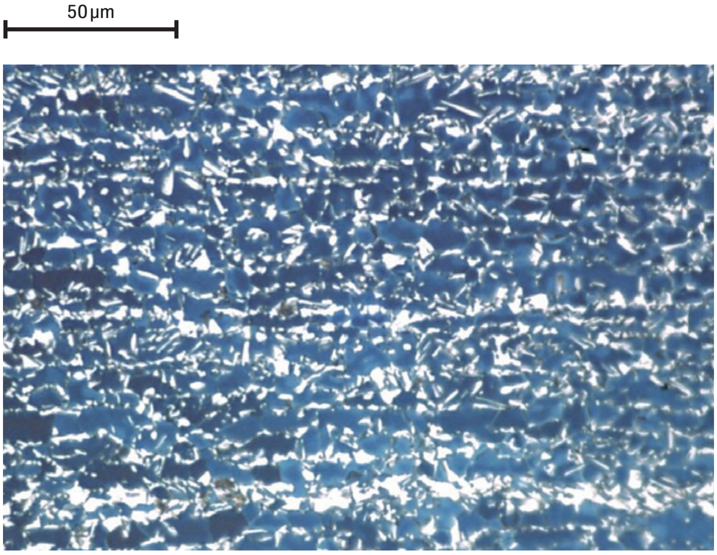
With retained-austenite steels, the working process converts the retained-austenite to martensite. This is accompanied by substantial elongations with high tensile strength. Retained-austenite steels are suitable for both stretch forming and deep drawing. The material's behavior is characterized in particular by strong strain hardening in areas with major shape changes, as well as a high potential for bake-hardening, especially after pre-forming. RA-K® steels have a high energy absorption capacity in case of dynamic loading. The microstructure consists mainly of a ferritic-bainitic matrix, in which retained-austenite is stored. The ferrite content including bainitic ferrite is up to 90%; martensitic components can exist.

The structure of the grain boundaries can be seen in the picture on the left. The picture on the right shows the ferrite grain surfaces and the bainitic ferrite surfaces in brown or blue hues. Retained-austenite and metastable martensite are white.

Micrograph of cold-rolled RA steels



Typical microstructure of cold-rolled RA steels. Microstructural contrasting through nital etching.



Typical microstructure of cold-rolled RA steels. 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.	Al [%] total	Ti + Nb [%] max.	Cr+Mo [%] max.	V [%] max.	B [%] max.
To DIN EN										
Steel grade										
● RA-K® 400Y690T	0.24	2.00	2.20	0.080	0.015	0.015 – 2.00	0.20	0.60	0.20	0.005

Chemical composition

Mass fractions in ladle analysis	C [%] max.	Si [%] max.	Mn [%] max.	P [%] max.	S [%] max.	Al [%] total	Ti + Nb [%] max.	Cr+Mo [%] max.	B [%] max.
To VDA									
Steel grade									
● RA-K® 400Y690T	0.24	2.00	2.20	0.080	0.015	0.015 – 2.0	0.20	0.60	0.005

● Cold-rolled strip

Mechanical properties

	Yield strength	Tensile strength	Elongation		Strain hardening exponent	Bake-Hardening
Test direction in rolling direction	$R_{p0.2}$ [MPa]	R_m [MPa] min.	A [%] min.	A_{80} [%] min.	$n_{10\text{-}UE}$ min.	BH_2 [MPa] min.
To DIN EN						
Steel grade						
● RA-K® 400Y690T	400–520	690	–	23	0.19	40

Mechanical properties

	Yield strength	Tensile strength	Elongation			Strain hardening exponent	Bake-Hardening
Test direction in rolling direction	$R_{p0.2}$ [MPa]	R_m [MPa] min.	A [%] min.	A_{50} [%] min.	A_{80} [%] min.	$n_{10\text{-}20/Ag}$ min.	BH_2 [MPa] min.
To VDA							
Steel grade							
● RA-K® 400Y690T	400–520	690–800	–	25	24	0.19	40

●	Cold-rolled strip

$R_{p0.2}$	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 $A_g < 20\%$
BH_2	Increase in yield strength between a reference condition after 2% plastic pre-strain and the condition obtained after heat treatment

Surfaces

Surface refinements, hot-dip zinc coating

Hot-dip zinc coating

Designation	Specification	Minimum coating mass on both sides [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]
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	–

Surface finishes and surface qualities

Products	Finish type	Surface quality	
Cold rolled flat products	Uncoated	A	Normal surface
		U	Unexposed (interior parts)
Hot-dip coated flat products	Hot-dip zinc coating	B	Improved surface
		U	Unexposed (interior parts)

A / B as per DIN EN
U as per VDE 239-100

Surface treatments

Type of surface treatment		UC	EG	GI	GA	ZM	AS
O	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

Retained-austenite steels RA-K® are especially suitable for forming technically demanding parts with high deep-drawing and stretch-forming components, especially in the automotive industry, to create complex, strength-relevant structural parts with high energy absorption capacity. Retained-austenite steels achieve plasticity gains through the deformation-induced conversion of retained-austenite to martensite. This leads to very good strain-hardening behavior, expressed as a correspondingly high n value. Retained-austenitic steels thus exhibit high resistance to local constriction, as larger area of material is involved in the deformation zone due to greater strain-hardening.

Due to the very high n values, an RA-K® 400Y690T , for example, has similarly good stretch working capabilities to a DC05 grade deep-drawing steel. However, the strain hardening-promoting conversion of retained-austenite to martensite also leads to pronounced edge hardening during mechanical cutting and significantly reduces the good forming potential around the cut edges. This must be taken into consideration for engineering design, e.g., in case of through-hole extensions or the height of drawn flanges in corner areas.

Small bending and drawing radii relative to the respective sheet thicknesses should thus be avoided. Under high shear stress, retained-austenite steels react much more sensitively than high-strength microalloyed steel grades. Plasticization must be designed to be as homogeneous as possible in order to improve the dimensional accuracy of the worked components. This can be achieved, e.g., through improved processing conditions. The presses should have high pressing and hold-down force potentials. As a guideline, the tensile strength level should be considered here, compared with known materials.

Particular attention must be paid to the design of the cutting and forming tools. Tool requirements are exacting, especially in cutting. In addition to a sufficient hardness of > 60 HRC, it is important to select suitable tool materials to simultaneously ensure high ductility, thus preventing premature breaking of the cutting edges. The cutting gap must be designed to match the fracture behavior of the material taking the sheet thickness into account, and should be (as a guideline) >10% of the sheet thickness. A sufficient supporting hardness must be achieved for the forming tools. A segmented structure of the forming tools is common today. In addition, tool coatings such as CVD (TiC-TiN coating) can minimize tool wear.

Processing instructions for joining

Retained-austenite steels are suitable for welding in both same-grade joints and hybrid joints with other common steel grades. The precondition is welding parameters matched to the material.

Resistance spot welding

For welding retained-austenitic steels, the same equipment can basically be used as for welding unalloyed deep-drawing steels. Given the same thickness, the welding current setting range tends to be narrower, as is also observed with other high-strength steel grades; however, this can be largely offset by increasing the electrode forces and/or welding currents. Extending the welding time also has a positive effect on the welding current setting range. Similarly, multi-pulse welding can be used in accordance with DIN EN ISO 18278-2. To minimize shear fractures, welding with a reheating pulse has proved useful, improving the ductility of the weld nugget through a tempering effect on the brittle martensite. Compared to lower-strength steels, retained-austenite steels have a lower electrical conductivity; lower welding currents are thus required for spot welding electrodes with the same force. In resistance spot welding of galvanized sheets, the welding currents must be increased due to the higher conductivity of the coating compared with the base material (substrate). In addition to this, increasing the electrode force and welding time has a favorable effect on the welding zone. Depending on the sheet thickness and the spot diameter achieved at the welding application point d_w, high bond strengths can be realized in different directions of stress.

Typical properties of a resistance spot weld

	Sheet thickness t	Welding zone ΔI	Cross tensile strength for $d_{w\ min}$	Shear tensile strength for $d_{w\ min}$	Mean hardness HV 0.1	
	[mm]	[kA]	[kN]	[kN]	Base material	Weld nugget
Steel grade						
● HX340LAD+Z	1.5	2.0	9.9	13.7	165	330
● RA-K® 400Y690T+Z140	1.5	1.0	6.6	17.7	200	440
● RA-K® 400Y690T-GI60	1.5	1.0	6.6	17.7	200	440

Test results as per SEO 1220-2; in case of equivalent concept projected from DIN EN grade to VDA grade.

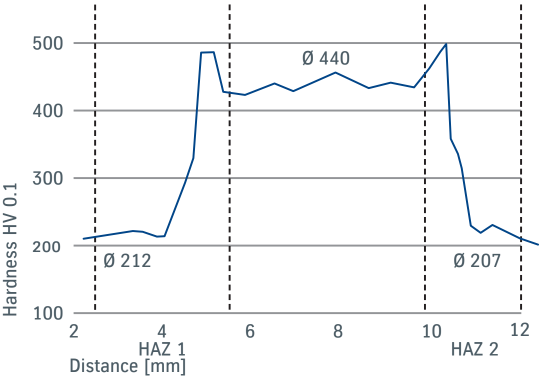
●	Cold-rolled strip
t	Sheet thickness of test specimens
$d_{w\ min}$	Welding spot diameter of $4\sqrt{t}$

MHZ 340

RA-K® 400Y690T

Accurate welded joint.

Hardness profile of the weld nugget in an RA-K® 400Y690T



Normal hardness increase compared to the base material.

MIG arc brazing

Information sheet DVS 0938-2 “Arc brazing” describes brazing of steels up to a tensile strength of approximately 500 MPa. As the material described here is above this tensile strength, it is advisable to check the component-specific suitability for brazing with Cu-based fillers.

MAG welding

Standard steel fillers with increased resistance can be used for MAG welding of RA-K® steels according to E SEP 1220-5, e.g., in line with DIN EN ISO 14341 G 46 4 M G4Si1 (formerly “SG3”), in combination with conventional mixed gases (Ar/CO2 82/18, 92/8). If a technical zero gap exists at fillet welds in the lap joint, the use of shielding gases with a higher active gas component is recommended for galvanized RA-K® steels, as this can help to counteract increased risk of pore formation. In case of repair, it is advantageous to grind off the surface coating.

Laser beam welding

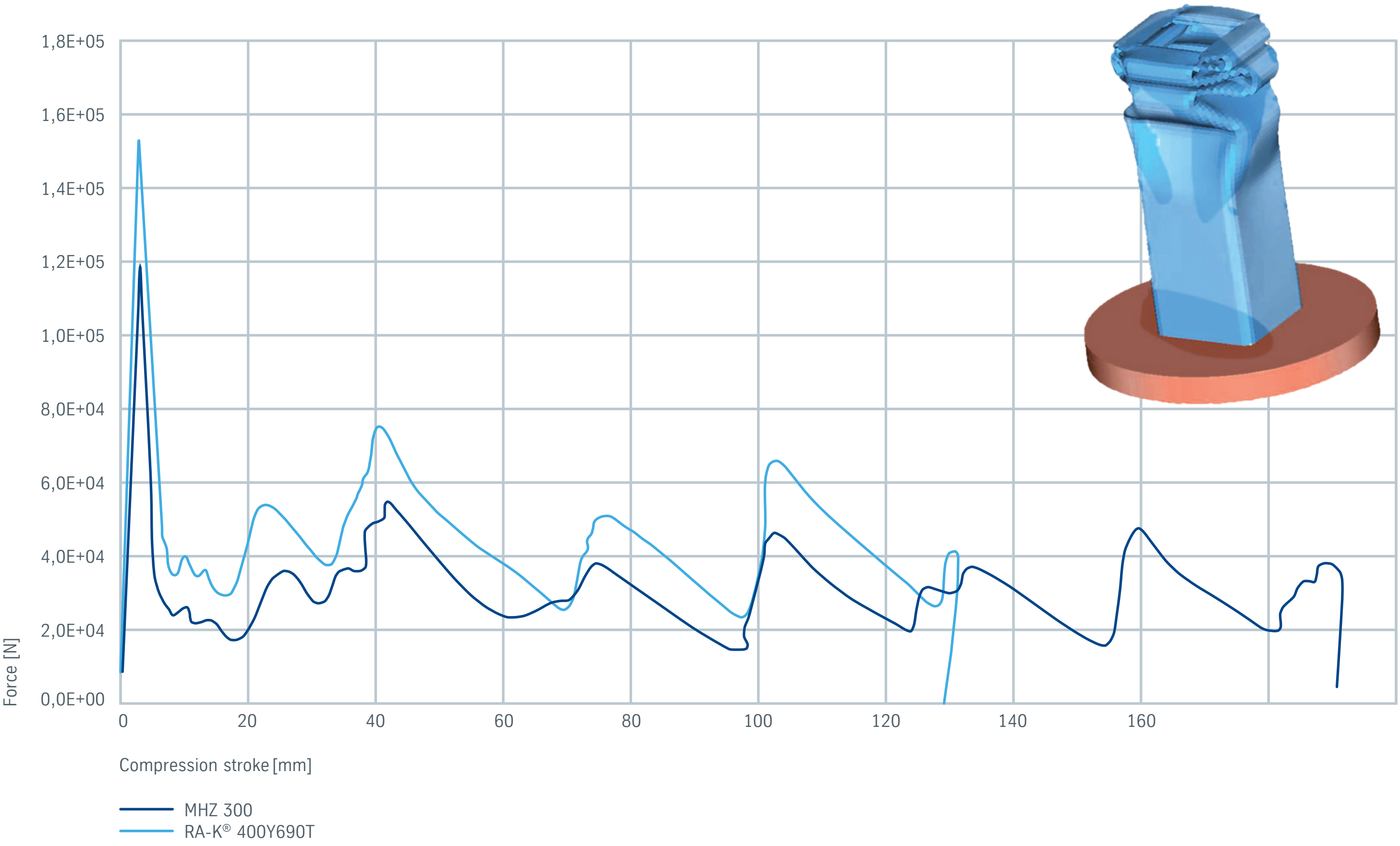
Laser beam welding of RA-K® steels is possible with both CO_2 and solid state lasers. Welding with CO_2 lasers is performed using typical shielding gases. Increased hardening is observed in the melt zone. Where a technical zero gap exists in lap joints of galvanized RA-K® steels, zinc degasification must be ensured by appropriate measures, in order to avoid pore formation and an uneven weld appearance.

Fatigue strength and crash performance

Retained-austenite steels are characterized in particular by the fact that the existing austenite can be converted to martensite by deformation. These structural transformations produce very stable strain hardening. In case of subsequent stresses, i.e., in use under operating conditions, this hardening is not impaired. When assessing the component life, it is thus important to consider that reductions in the sheet thickness can be compensated for by this strain hardening. In addition to this form of tensile strain hardening, solid solution and bake hardening (BH effect) also occur. Simple cold hardening processes, which are essentially characterized by a simple increase in the etch pit density, should be ignored in structural durability considerations from a conservative perspective.

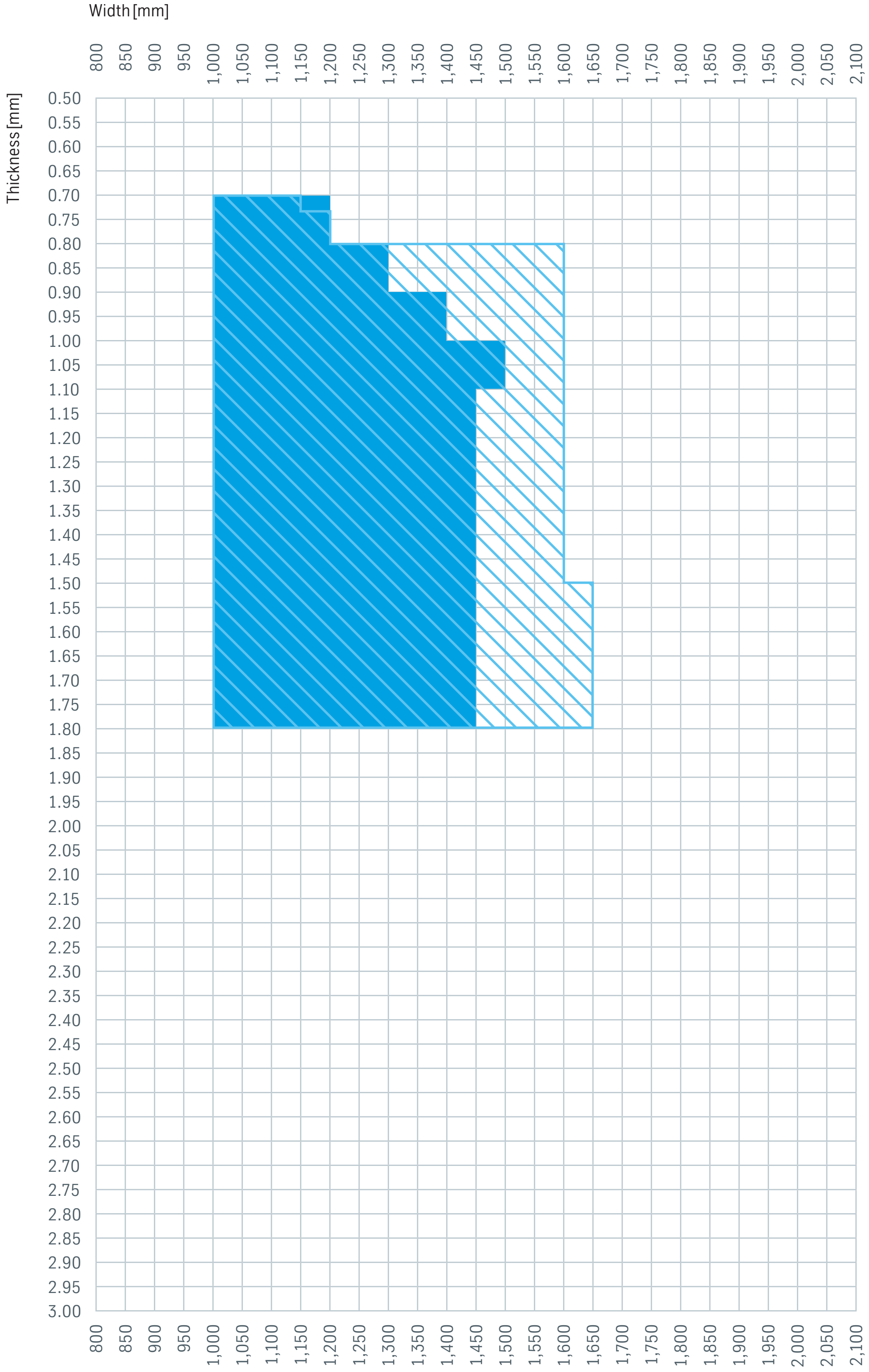
The crash-relevant key features of retained-austenite steels such as yield point (yield strength) and tensile strength indicate the potential of this group of materials whenever excellent crash-energy absorbing properties are required. For components that need to exhibit high resilience to deformation in a crash scenario, complex-phase and martensitic steels are better suited than retained-austenite steels.

Simulation results on square profile



Available dimensions

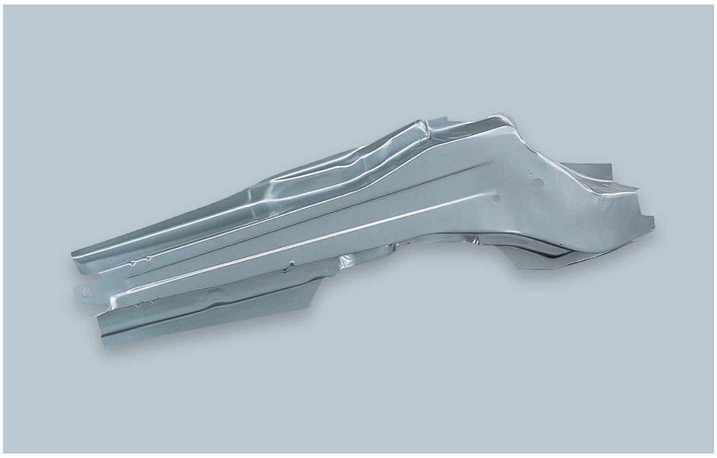
RA-K® 400Y690T



GI	Hot-dip zinc coating
▨	GI trimmed
■	Uncoated with mill edge

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

Sample application



Front side member made of RA-K® 400Y690T.

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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 information