durostat®

Wear-resistant sheets made of hot-rolled steel strip

Thanks to their high hardness values ranging between 250 and 500 HB, the martensitic durostat® steels of voestalpine can be used wherever abrasive wear requires high resistance. This manifests itself either as **sliding abrasive wear**, as **impact abrasive wear**, or as a combination of both.

Several different lab tests are used to represent different wear mechanisms in comparing steel materials with regard to wear behavior. Care must be taken, however, to determine how well the lab tests reflect industrial-scale tribological systems and conditions.

The use of durostat® can significantly extend the service life and associated service intervals of components such as excavator buckets, tipper surfaces, conveyor chutes, wear surfaces in freight and bulk railcars, containers and concrete mixers.

Convincing advantages:

» High wear resistance, low abrasion
» Longer service life and maintenance intervals
» Light-weight applications resulting from higher strength

greentec steel

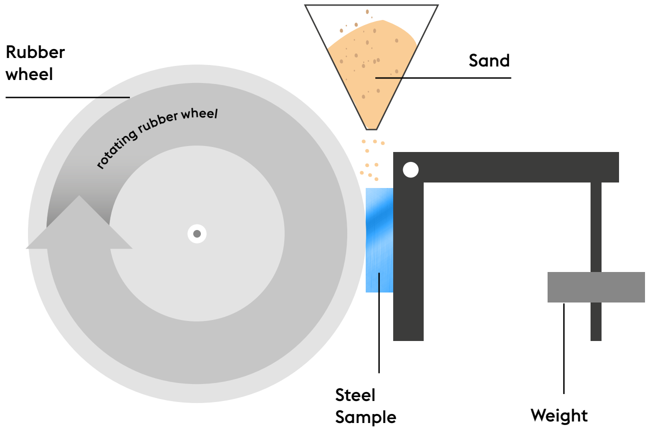
Premium quality
with reduced carbon footprint

durostat®
greentec steel

The results in this document are from the independent testing institutes Technical University in Clausthal, Germany, and the Tampere Wear Center in Finland.

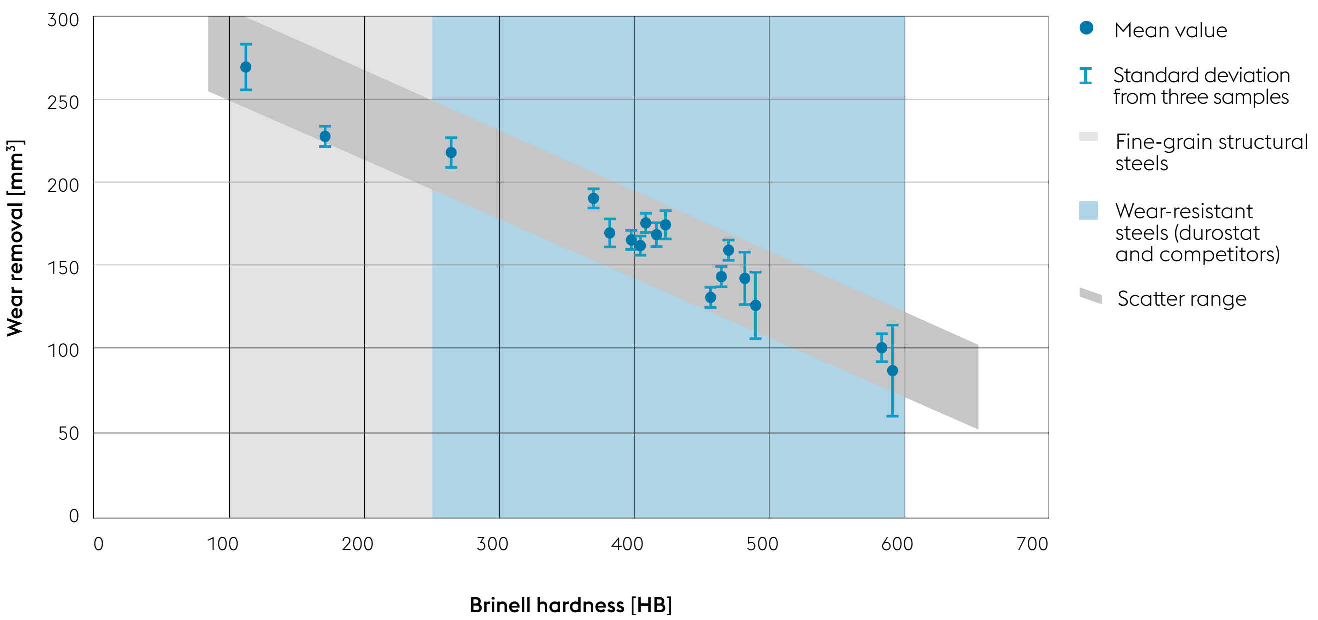
Sliding abrasive wear

Friction wheel tests were carried out pursuant to ASTM G65, in which dry or moist quartz sand is used as an abrasive between a rubber wheel and the sample to investigate the sliding abrasive wear of durostat® steels. The test describes the classic 2-body wear that occurs when rock materials slides off tipper surfaces, conveyor chutes or excavator shovels.

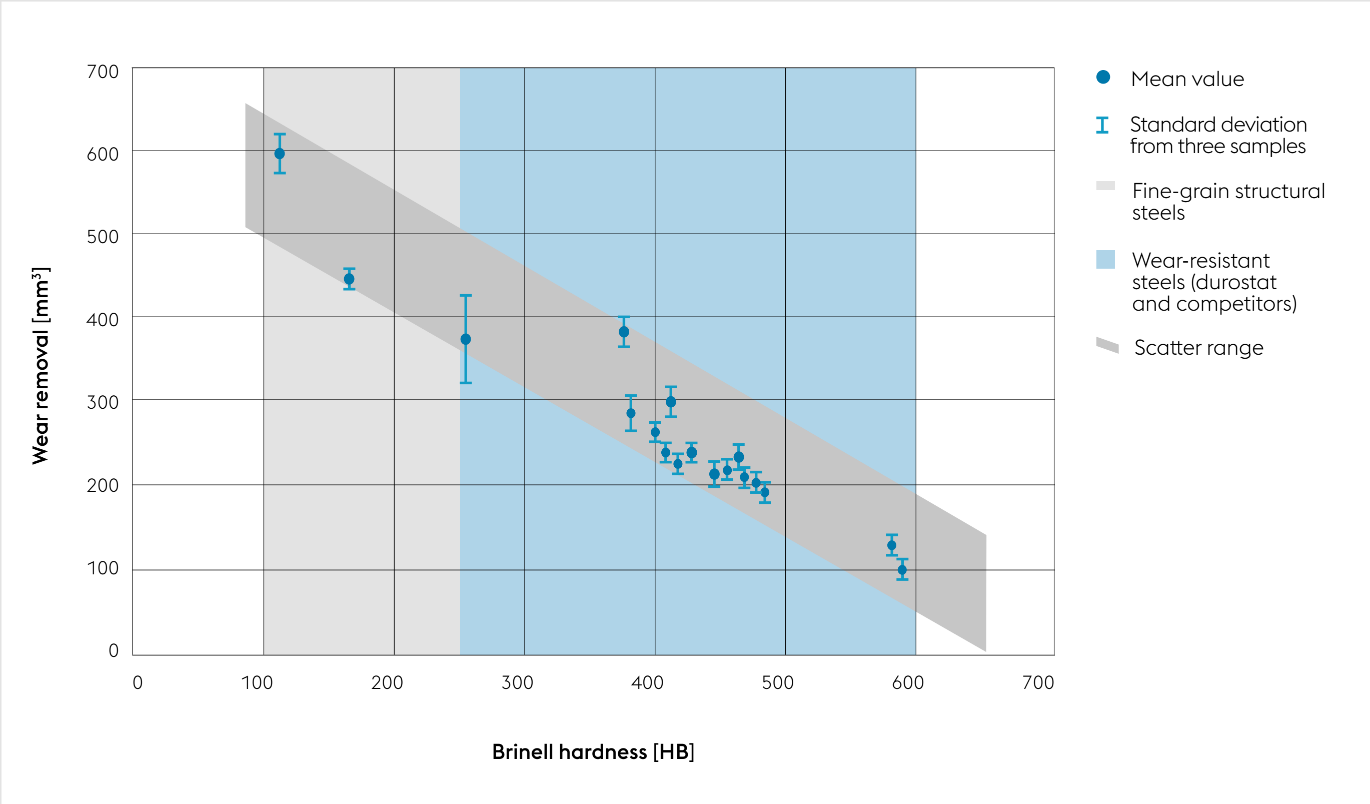


Experimental setup, ISAF Institute, Technical University of Clausthal, Germany

Friction wheel test ASTM 65 with dry sand



Friction wheel test ASTM 65 with wet sand



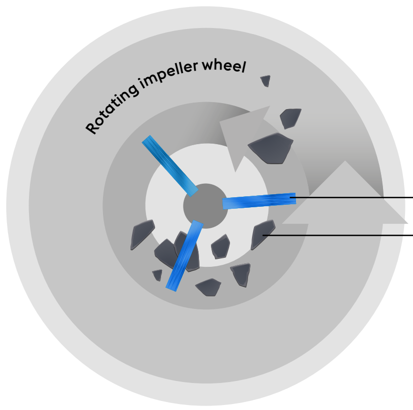
Significantly reduced sliding abrasive wear

The results show that the main factor influencing sliding abrasive wear behavior is hardness. Martensitic steels such **as durostat® made by voestalpine** have a significantly higher resistance to sliding abrasion than classic structural steels or microalloyed steels.

Impact wear

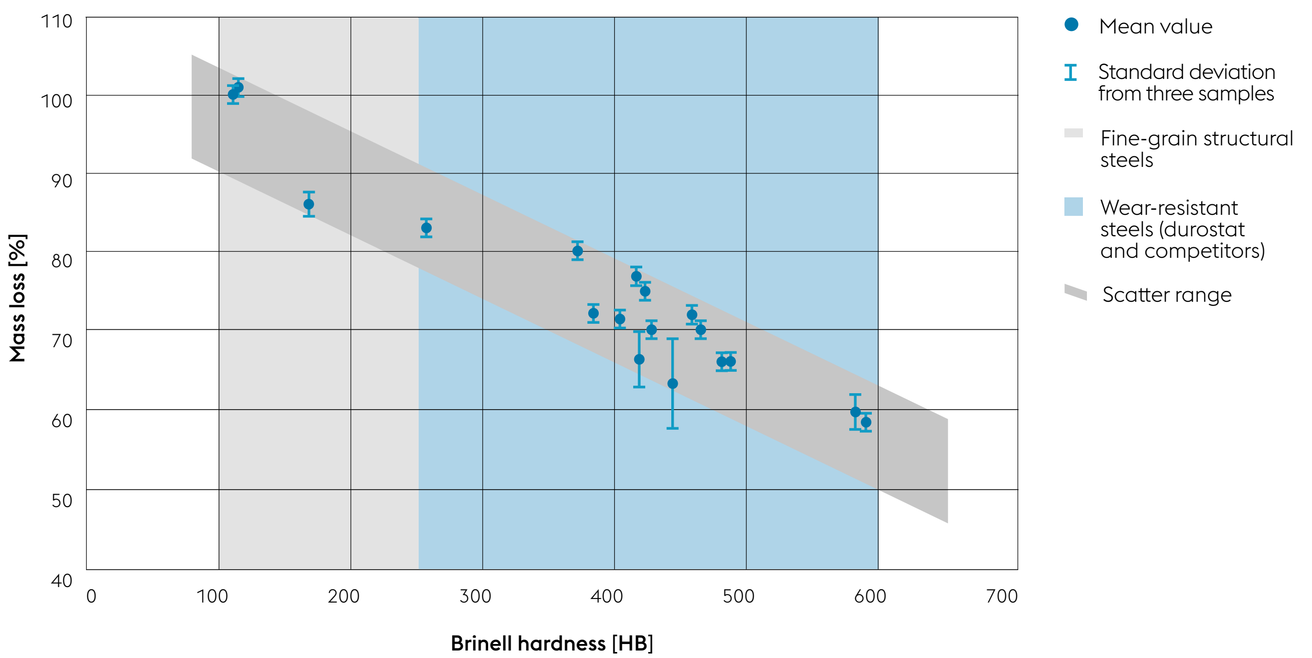
Impeller tumbler tests were performed to characterize the impact wear (Institute at Tampere University, Tampere Wear Center). An external paddle wheel (tumbler) transports the material (here: Kuru granite in 10 to 12.5 mm grain size) slow speed (30 rpm); material to be tested on the fast rotating impeller (impeller with 700 rpm) that crushes the granite by means of impact energy.

This results in the formation of furrows and troughs on the samples. These strongly deformed areas can further be removed by blasting with abrasive particles. Practical example Earth work: agricultural cultivators, disc harrows; loading tippers, freight cars, bulk railcars.



Experimental setup, Institute, Tampere Wear Center in Finland

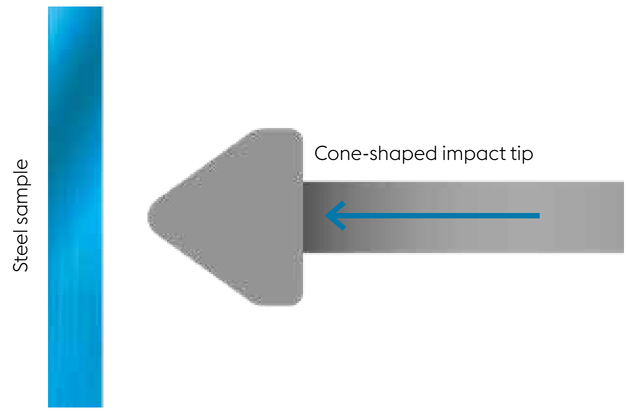
Impeller tumbler results relative to reference [%]



Significantly reduced impact wear
Martensitic durostat® steels also exhibit excellent performance with respect to impact wear.

Impact test

Tests were carried out in an impact simulator in order to test extreme loads on the material when tipper bodies are loaded with large pieces of rock, scrap or the like. A sled with a cone-shaped impact tip is fired with a defined energy at the sample. The resulting dent depth is measured on the test plate.



The following materials were tested:

Materials	Material thickness
S355MC	10 mm
durostat 250	7 mm
durostat 400	5 mm
durostat 450	4 mm

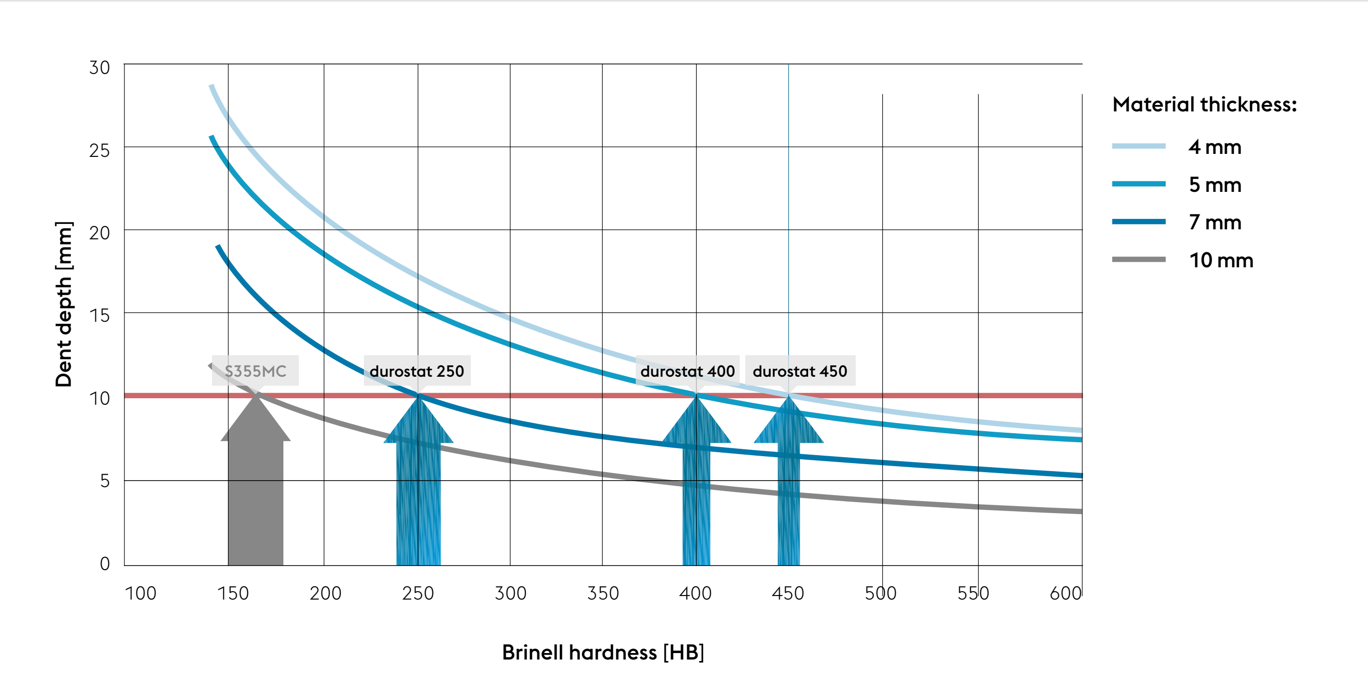
Results

As material hardness increases, the material thickness required for the same dent depth decreases (red line in the diagram). This creates possibilities for lightweight applications. As the hardness of the materials increases, the dent depth decreases at the same material thickness (curves in the diagram). This means that even more resistant components and component groups can be achieved.

durostat® material performs best in the impact test.

Example

A material thickness of 10 mm would be required for S355MC to achieve a dent depth of 10 mm, while only 4 mm is required for durostat 450 to achieve the same depth. This allows lighter components and component assemblies to be produced with the same resistance to deformation, thus making it possible to economically manufacture sustainable end products with less material and fuel consumption and less CO_2, yet with increased payloads.



GOOD WELDABILITY BASED ON LOW CARBON CONTENT

Sheets made of durostat® exhibit good welding characteristics when using any conventional fusion welding technique. This is because of their chemical composition. The heat-affected zone of the welded joints is characterized by both the occurrence of temper softening and a lack of hardness increase as compared to the direct-quenched base material.

Material	Typical values				Classification according to ISO/TR 15608
	Carbon content [%]	CET [1] [%]	CEV [2] [%]	PCM [3] [%]	
durostat 400	0,11	0,35	0,54	0,26	3.2 [4]
durostat 450	0,15	0,39	0,58	0,30	3.2 [4]
durostat 500	0,19	0,43	0,61	0,34	3.2 [4]

[1] CEV=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15
[2] CET=C+(Mn+Mo)/10+(Cr+Cu)/20+Ni/40
[3] PCM=C+Si/30+(Mn+Cu+Cr)/20+Ni/60+Mo/15+V/10+B·5

[4] Delivered in hardened condition

TECHNICAL RECOMMENDATIONS FOR WELDING

Temper softening
The extent of temper softening is directly dependent on the cooling time ($t_{8/5}$). The effects of temper softening on the tensile properties across the weld are dependent on the relative width of the soft zone (ratio of soft zone width to sheet thickness) and the tensile properties of the weld metal.

No hardness increase
Maximum hardness in the heat-affected zone (HAZ) does not exceed the hardness of the base material because of the purely martensitic microstructure. Hardness depends exclusively on carbon content. The carbon equivalent therefore only has an effect on transformation behavior and a decrease in maximum hardness as the $t_{8/5}$ time increases. Vickers (HV) is used to determine the hardness values in welded joints. The hardness values in Brinell (HB) or tensile strength (Rm) can be estimated using the conversion table pursuant to EN ISO 18265, Table A.1.

Preheating not necessary
Preheating is generally not required up to a sheet thickness of 6 mm.

This applies under the following conditions:
» Use of welding consumables that lead to a very low hydrogen content in the weld metal (HD < 5 ml/100 g weld metal). Compliance with the manufacturer's instructions on storage and re-drying is mandatory.
» Sheets must be kept clean, dry and free from coatings, rust and scale in the area of the joint.

In cases of deviation, the preheating temperature should be estimated based on EN 1011-2, C.3, Method B or SEW 088. Depending on atmospheric conditions (temperature below dew point, condensation of humidity), edge drying is recommended at least 80 °C immediately before welding.

The dew point and preheating temperature can also be estimated using tools such as the voestalpine welding calculator.

Shielded metal arc welding (111) and gas-shielded metal arc welding (MAG, 135)

The strength properties across the weld are influenced among other factors by the strength characteristics of the selected welding filler metal.

Welding consumables

Material	Strength level/hardness of the filler metal or the pure weld metal Conversion according to DIN EN ISO 18265, Table A.1	HB ~ 0,30 x R_m	HB ←→ HV, HRC		Welding Consumables Filler rod SMAW (111)	Solid wire GMAW (135)	Flux cored wire FCAW (136, 138)
	R_m ≥ 500 MPa	HB ≥ 148	HV ≥ 156	-	e.g. **BÖHLER FOX EV 50, ...** AWS A5.1: E7018-1H4R EN ISO 2560-A: E 42 5 B 4 2 H5	e.g. **BÖHLER EMK 6, UNION K 52, ...** AWS A5.18: ER70S-6 EN ISO 14341-A: G 42 4 M21 3Si1	-
	R_m ≥ 530 MPa	HB ≥ 156	HV ≥ 164	-	e.g. **BÖHLER FOX EV 60, ...** AWS A5.5: E8018-C3 H4R EN ISO 2560-A: E 46 6 1Ni B 4 2 H5	e.g. **BÖHLER EMK 8, UNION K 56, ...** AWS A5.18: ER70S-6 EN ISO 14341-A: G 46 4 M21 4Si1	e.g. **diamondspark 52 MC, BC, RC, ...** AWS A5.36: E71T15, E70T5, E71T1 EN ISO 17632-A: T 46 4 M, T 46 4 B, T 46 4 P
durostat 400 HB 360 - 440	R_m ≥ 690 MPa	HB ≥ 204	HV ≥ 215	-	e.g. **BÖHLER FOX EV 75, ...** AWS A5.5: E10018-G H4R EN ISO 18275-A: E 62 6 Mn2NiCrMo B 4 2 H5	e.g. **UNION NiMoCr, ...** AWS A5.28: ER100S-G EN ISO 16834-A: G 69 6 M21 Mn4Ni1,5CrMo	e.g. **diamondspark 620 MC, RC, ...** AWS A5.36: E101T15, E101T1 EN ISO 18276-A: T 62 4 Z M, T 62 4 Mn1,5Ni P
durostat 450 HB 410 - 490 **durostat 500** HB 460 - 540	R_m ≥ 760 MPa	HB ≥ 224	HV ≥ 236	HRC ≥ 20	e.g. **BÖHLER FOX EV 85, ...** AWS A5.5: E11018-G H4R EN ISO 18275-A: E 69 6 Mn2NiCrMo B 4 2 H5	e.g. **BÖHLER NiCrMo 2,5-IG, UNION X85, ...** AWS A5.28: ER110S-G EN ISO 16834-A: G 69 6 M21 Mn3Ni2.5CrMo G 79 5 M21 Mn4Ni1,5CrMo	e.g. **diamondspark 700 MC, BC, RC, ...** AWS A5.36: E111T15, E110T5, E111T1 EN ISO 18276-A: T 69 6 Mn2NiCrMo M, T 69 6 1Mn2NiCrMo B, T 69 6 Z P
	R_m ≥ 940 MPa	HB ≥ 277	HV ≥ 291	HRC ≥ 29		e.g. **BÖHLER X90-IG, Union X90, ...** AWS A5.28: ER120S-G EN ISO 16834-A: G 89 6 M21 Mn4Ni2CrMo	e.g. **diamondspark 900 MC, BC, ...** AWS A5.36: 131T15, E130T5 EN ISO 18276-A: T 89 5 ZMn2NiCrMo M, T 89 4 Mn2Ni1CrMo B
	R_m ≥ 980 MPa	HB ≥ 289	HV ≥ 304	HRC ≥ 30		e.g. **UNION X96, ...** AWS A5.28: ER120S-G EN ISO 16834-A: G 89 5 M Mn4Ni2,5CrMo	e.g. **diamondspark 960 MC, ...** EN ISO 18276-A: T 89 4 ZMn2NiCrMo M

Should the respective structure require that welding seams feature the same level of wear resistance as the base material, the cover pass can be carried out using wear-resistant welding consumables.

Material	Strength level/hardness of the filler metal or the pure weld metal Conversion according to DIN EN ISO 18265, Table A.1	R_m ~ 3,39 x HB	HB ←→ HV, HRC		Welding consumables Filler rod SMAW (111)	Flux cored wire FCAW-S (114)	Solid wire GMAW (135)	Flux cored wire FCAW (138)
durostat 400 HB 360 - 440	HB ≥ 250	R_m ≥ 847 MPa	HV ≥ 263	HRC ≥ 24	e.g. **UTP DUR 250, ...** EN 14700: E Fe 1 DIN 8555: E 1-UM-250	e.g. **SK BU-O, ...** EN 14700: T Fe 13 mod. DIN 8555: MF 1-GF-300 P	e.g. **UTP A DUR 250, ...** EN 14700: SZ Fe 1 DIN 8555: MSG 1-GZ-250	e.g. **UTP AF ROBOTIC 250, ...** EN 14700: T Fe 1 DIN 8555: MSG 1-GF-250-P
durostat 450 HB 410 - 490	HB ≥ 350	R_m ≥ 1186 MPa	HV ≥ 368	HRC ≥ 37	e.g. **UTP DUR 350, ...** EN 14700: E Fe 1 DIN 8555: E 1-UM-350	e.g. **SK 242-O, ...** EN 14700: T Fe 1 DIN 8555: MF 1-GF-40-P	e.g. **UTP A DUR 350, ...** EN 14700: SZ Fe 2 DIN 8555: MSG 2-GZ-400	e.g. **UTP AF ROBOTIC 352, ...** EN 14700: T Fe 1 DIN 8555: MSG 1-GF-350-P
durostat 500 HB 460 - 540	HB ≥ 532	R_m ≥ 1845 MPa	HV ≥ 580	HRC ≥ 53	e.g. **UTP DUR 600, ...** EN 14700: E Fe 8 DIN 8555: E 6-UM-60	e.g. **SK 258-O, ...** EN 14700: T Fe 1 DIN 8555: MF 6-GF-55-GT	e.g. **UTP A DUR 600, ...** EN 14700: S Fe 8 DIN 8555: MSG 6-GZ-60-S	e.g. **UTP AF ROBOTIC 600, ...** EN 14700: T Fe 1 DIN 8555: MSG 6-GF-60-GP

Laser welding (521, 522, 523) and laser hybrid welding

As compared to shielded metal arc welding and gas metal arc welding, a lower tendency to temper softening in the heat-affected zone and higher strength in the weld metal are the result of the more concentrated energy input and the associated increased cooling rate.

Please find more detailed information about the voestalpine Welding Calculator at:
www.voestalpine.com/alform/Welding-Calculator

greentec steel

Premium quality with reduced carbon footprint

durostat®

greentec steel

Hot-rolled steel strip – greentec steel Edition
Max. carbon footprint 2.10 kg CO_2e per kg of steel [1]

[1] per EN 15804+A2 (EPD methodology) cradle to gate

All products, dimensions and steel grades listed in each voestalpine supply range are available as greentec steel Edition.

To find out more about durostat®, please visit us at **www.voestalpine.com/durostat**

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