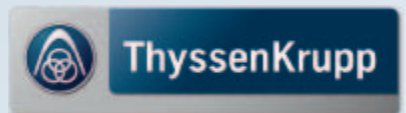




TBL hardenable boron steels
Wear protection for agricultural
machinery and concrete mixer
trucks

ThyssenKrupp Steel Europe
Thinking the future of steel



Fine-grain hardenable special structural steels

TBL and TBL PLUS



Wear is a major cost factor in many applications. That's why manufacturers of agricultural machinery and many other types of equipment have long used wear-resistant steels. The fine-grain boron-alloyed special steels TBL and TBL PLUS combine good processing properties with high wear resistance. In the as-delivered condition, TBL steels have excellent forming properties and good weldability. For use in agricultural machinery, the steels are usually hardened after processing. As a result of alloying with boron, TBL grades can be hardened without difficulty in water, oil or polymer dispersion. TBL and TBL PLUS are therefore particularly suited to structures which require high wear resistance, e.g. in harrows, packers and plows.

Depending on steel grade and heat treatment conditions, different mechanical properties can be obtained. The maximum achievable hardness after hardening is 560 HBW (55 HRC) for TBL PLUS and 500 HBW (51 HRC) for TBL.

TBL steels from ThyssenKrupp Steel Europe have also proven themselves in the special wear conditions encountered in concrete mixing equipment. In these applications, subsequent heat treatment can even be dispensed with. The finely balanced microstructure ensures outstanding wear resistance, as proved recently by rubber friction wheel tests (Fig. 1). The wear tests using fine quartz sand showed wear properties for the TBL steels which are comparable with a hardened 400 HBW steel, both in dry test conditions and in combination with wet wear. TBL grades from ThyssenKrupp Steel Europe therefore offer a cost-effective alternative to hardened wear steels in applications involving fine abrasion particles (such as in concrete and cement mixing

equipment). The good wear properties are made possible by the microstructure, which is characterized by the simultaneous presence of hard and soft microstructure components. The microstructure, which is set during rolling, offers an ideal combination to counter friction wear by small particles.

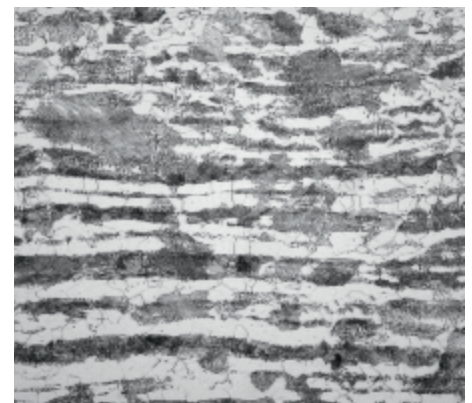
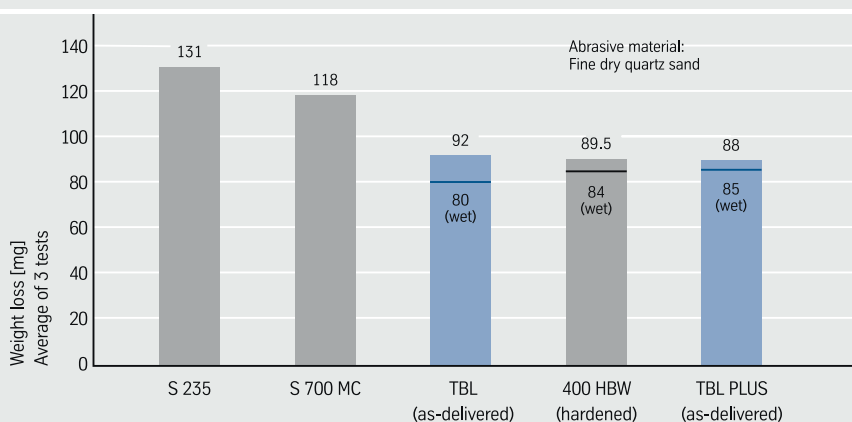
Mechanical properties

TBL and TBL PLUS are both supplied in the normalized or normalized-rolled condition, with the grades differing mainly in terms of their carbon content (Table 2).

Table 3 shows an overview of typical mechanical properties in the as-delivered condition.

1. Wear behavior of different steels

Results of wear tests by the rubber friction wheel method



The microstructure of TBL PLUS displays both hard pearlitic (dark) and soft ferritic (bright) components.

2. Chemical composition [%]

Steel grade	C	Si	Mn	P	S	Cr	B
TBL	0.25 – 0.30	≤ 0.4	1.10 – 1.30	≤ 0.040	≤ 0.040	≤ 0.50	0.0008 – 0.0040
TBL PLUS	0.31 – 0.38	≤ 0.4	1.20 – 1.50	≤ 0.040	≤ 0.030	≤ 0.50	0.0008 – 0.0040

3. Typical mechanical properties in as-delivered condition

Steel grade	Plate thickness [mm]	R _e [MPa]	R _m [MPa]	A [%]
TBL	15	400	580	18
TBL PLUS	8	420	620	18

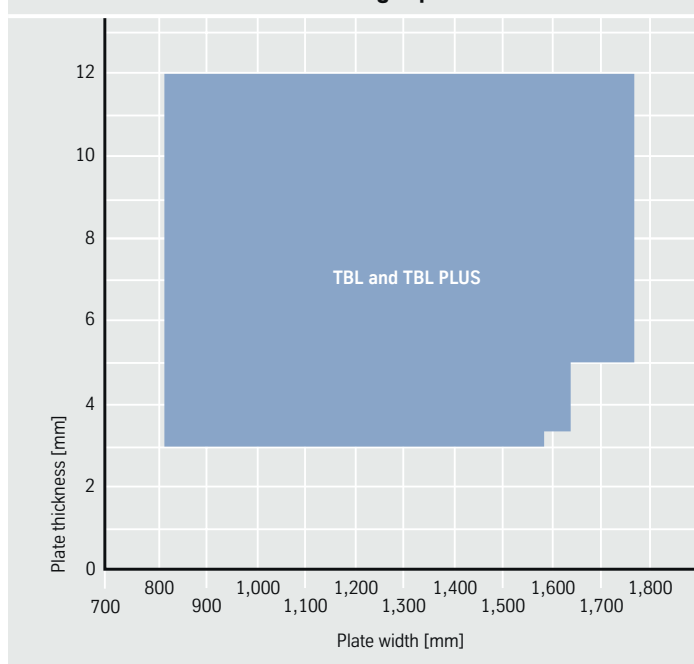
Available sizes for TBL and TBL PLUS

TBL plate is available in thicknesses of 3 – 100 mm and TBL PLUS plate in thicknesses of 3 – 12 mm.

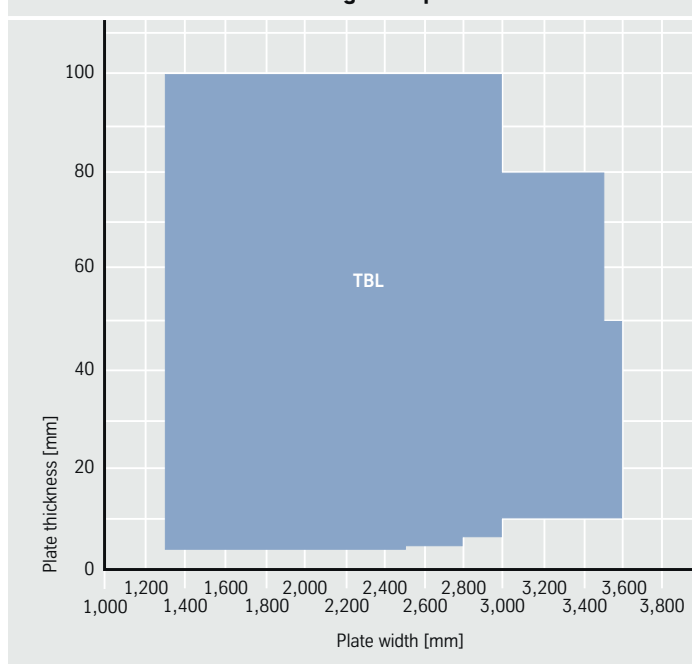
TBL and TBL PLUS are available as heavy plate cut from hot-rolled strip in widths up to 1,770 mm. TBL is also available as four-high mill plate in thicknesses of 4 – 100 mm and widths up to 3,600 mm.

Detailed size ranges are shown in Figs 4a and 4b.

4a. Available sizes for cut-to-length plate



4b. Available sizes for four-high mill plate



Hardenability

For many applications, TBL and TBL PLUS are hardened/heat-treated after processing. If forming is planned, the ideal solution is a combination of hot forming followed by quenching in a suitable medium. Hot forming of TBL and TBL PLUS is usually carried out at temperatures between 900°C and 1,050°C. Typical quenching agents are water, oil or polymer dispersion, each of which are associated with different cooling rates. Depending on component geometry, cooling in air may also be sufficient to achieve the desired final hardness.

Achievable final hardness

The achievable hardness of TBL and TBL PLUS depends to a large degree on chemical composition (Tables 5 and 8) and the cooling rates achieved in the hardening process. The hardness values (HV 10) which can be expected can be estimated based on the following TTT diagrams (Figs 6 and 9).

Tempering after hardening is normally not necessary. The influence of tempering on mechanical properties is shown in Figs 7 and 10.

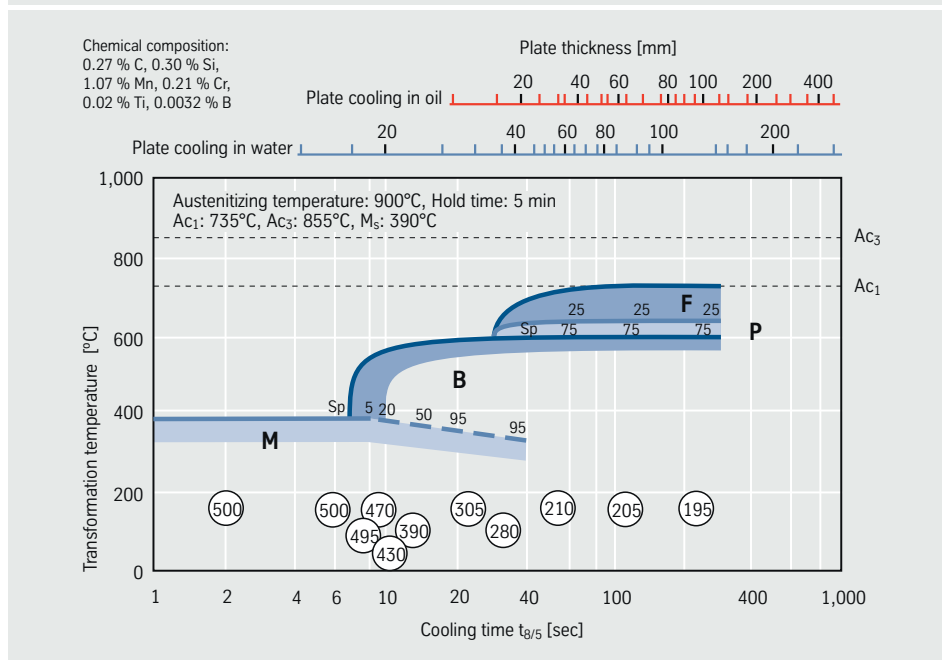
TBL

The recommended austenitizing temperature is 900°C. The material temperature at the start of quenching in water should be between 860°C and 910°C. If quenching is carried out in oil, the temperature at the beginning should be between 900°C and 950°C.

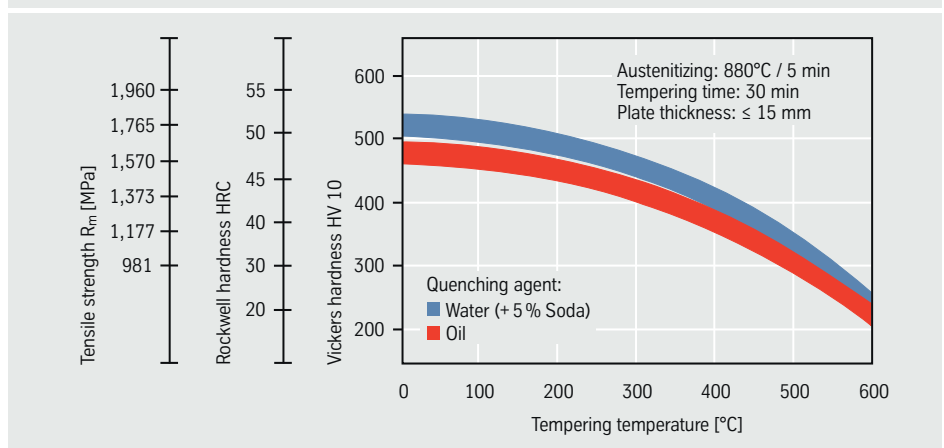
5. Chemical composition (typical)

Steel grade	Heat analysis [%]					
	C	Si	Mn	Cr	Ti	B
TBL	0.28	0.25	1.15	0.45	0.03	0.003

6. Time-temperature-transformation diagram for TBL



7. Tempering diagram for TBL



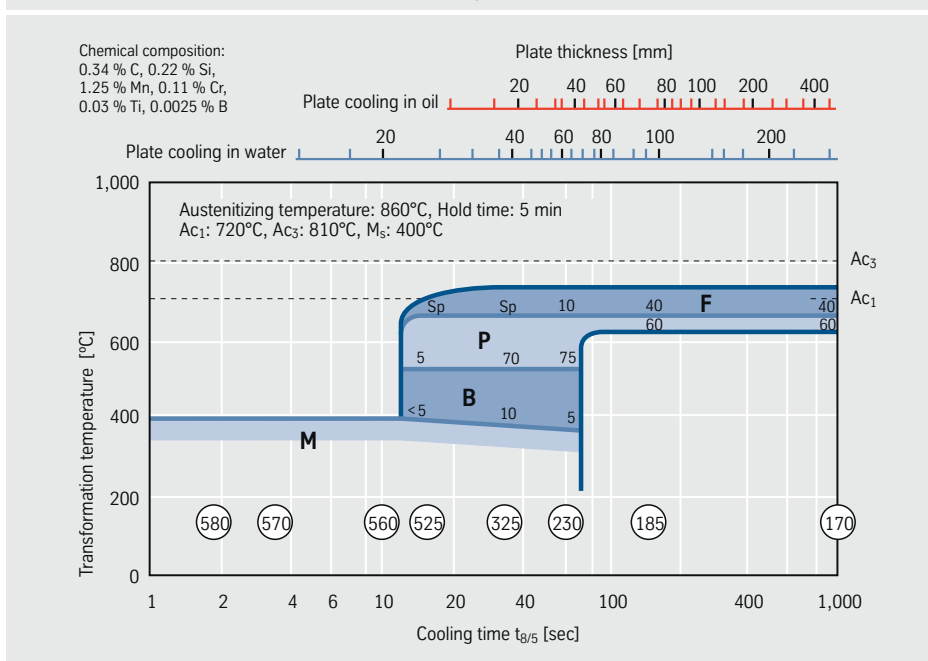
8. Chemical composition (typical)

Steel grade	Heat analysis [%]					
	C	Si	Mn	Cr	Ti	B
TBL PLUS	0.35	0.25	1.30	0.14	0.03	0.0030

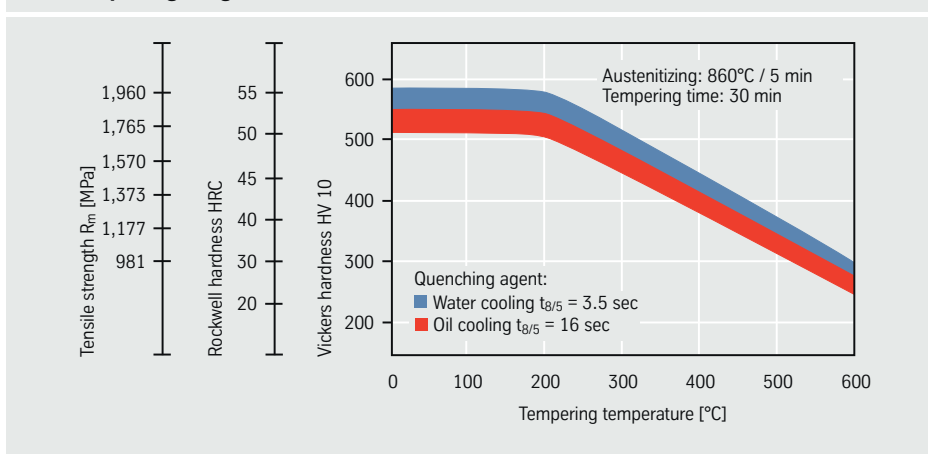
TBL PLUS

The recommended austenitizing temperature is 860°C. The material temperature at the start of quenching in water should be between 815°C and 870°C. If quenching is carried out in oil, the temperature at the beginning should be between 860°C and 910°C.

9. Time-temperature-transformation diagram for TBL PLUS



10. Tempering diagram for TBL PLUS



Processing

Cold forming

TBL and TBL PLUS are suitable for cold forming to a limited extent in the as-delivered condition. If more than light forming operations are planned, they should be carried out at normalizing temperature.

The main forming processes are cold bending on three-roll bending machines and bending in 90° vee dies on press brakes.

In the hardened condition cold forming is only possible to a limited extent, and the minimum bending radii must be significantly increased. The increased force resistance and the higher springback must be taken into account. Bending force should be as low as possible and can be achieved by good lubrication of the die edges and by increasing the die opening.

Machining

TBL and TBL PLUS are readily machinable. In the hardened or heat treated condition, the use of cemented carbide tools is recommended. Holes with a diameter of more than 16 mm can also be made with indexable insert drills in special drilling machines. The following conditions must be observed when drilling hardened sheet/plate:

- Vibrations must be avoided
- Clamp part as close as possible to drilling point
- Part and drill head must be as close as possible to machine column
- Use short drills in short machine spindles

When countersinking/counterboring hardened material, pilots should be used to prevent straying of the tool and ensure good cooling.

Boron steels are also suitable for tapping.

Before carrying out the above machining processes, we recommend you contact a tool manufacturer.



Thermal cutting

The preferred thermal cutting processes for TBL and TBL PLUS are oxyfuel cutting, plasma cutting and laser beam cutting. Laser beam cutting has become more prominent recently as it often permits significantly higher cutting speeds than oxyfuel cutting.

To avoid cracks during oxyfuel cutting, the preheat temperatures shown in Fig. 11 should be observed.

11. Preheat temperatures for oxyfuel cutting

Steel grade	Plate thickness [mm]														
	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 45	≤ 50	≤ 55	≤ 60	≤ 65	≤ 70	>70
TBL	without				100°C				125°C				150°C		
TBL PLUS	without														

Welding

The hardenable boron steels are suitable for welding and can be welded by all popular processes both automatically and manually.

The sensitivity to cold cracking of a steel can be estimated based on its chemical composition. Especially suited to this is the carbon equivalent CET, which is derived from extensive cold cracking tests. The corresponding tests by ThyssenKrupp Steel Europe AG into avoiding cold cracks have been incorporated into EN 1011-2 as the CET concept (Fig. 12).

The risk of cold cracks occurring in the weld deposit can be minimized by using austenitic filler metals. With steel thicknesses up to 30 mm, preheating can be generally dispensed with.

If ferritic fillers are used for reasons of cost, MAG welding should be preferred. It offers considerable advantages due to the relatively low hydrogen content in the weld deposit. In addition, a mild, unalloyed weld material (yield strength below 500 MPa) should be preferred which displays good forming capabilities. This applies in particular to comparatively thin material or fillet welds because here the composition of the weld deposit is affected by the higher-alloyed base metal.

For butt welds and multipass fillet welds, an increased yield strength in the weld areas of wear-resistant parts is sometimes desired. In such cases, a medium-alloyed filler metal (yield strength in weld metal 500 to 700 MPa) should be used for the filler and cover passes (Fig. 13).

In the interests of preventing cold cracking, the hydrogen content of the weld metal should be as low as possible. Measures should be taken to ensure that hydrogen input into the weld metal is as low as possible, e.g. by cleaning and drying the weld grooves, setting a stable shield gas stream in MAG welding and using re-dried basic electrodes in manual arc welding. The welding sequence should be designed to minimize residual stress.

Preheating is an effective means of avoiding cold cracks. Fig. 14 shows recommended preheat temperatures for the MAG welding of TBL steels with ferritic fillers and a heat input of 1 kJ/mm as a function of the thickest sheet in the weld area.

12. Carbon equivalent

Steel grade	Product	CEV, typical [%]	CET, typical [%]
TBL	cut-to-length plate	0.58	0.43
TBL	four-high mill plate	0.51	0.40
TBL PLUS	cut-to-length plate	0.60	0.49

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15} \quad CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

13. Classification of wire electrodes for MAG welding

Wire electrodes MAG welding	Product	Classification
austenitic	EN 12072	G 18 8 Mn (1.4370)
ferritic, $R_e < 500$ MPa	EN 440	G 46 4 M G4Si1 G 46 4 M G2Mo G 50 5 M G3Ni1
ferritic, $R_e = 500 - 700$ MPa*	EN 12534	G 62 5 M Mn3Ni1Mo G 69 5 M Mn4Ni1,5CrMo

* not recommended for welding prior to hardening

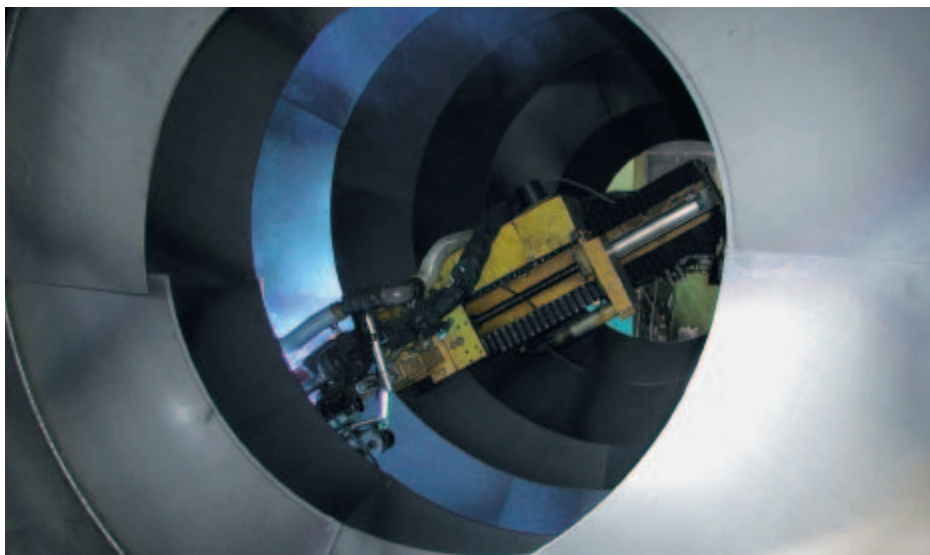
14. Preheat temperatures MAG welding with ferritic fillers

Heat input $Q = 1,0 \text{ kJ/mm}$, hydrogen content $HD = 2 \text{ ml/100 g}$

Steel grade	Plate thickness [mm]										
	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 45	≤ 50	> 50
TBL	-	75°C	100°C		125°C			150°C			175°C
TBL PLUS	100°C	125°C	150°C								

For applications in which hydrogen content and heat input differ significantly from those assumed here, preheat temperatures can be calculated using the computer program ProWeld (Fig. 15), which we will be pleased to supply free of charge on request.

The properties in the heat-affected zone of the weld change as a result of the temperature-time cycle during welding. The temperature-time cycle is dependent on the welding conditions, characterized by the cooling time $t_{8/5}$. This is the time required after welding a bead for the temperature to pass from 800°C to 500°C. Too fast cooling of the weld bead increases the risk of cold cracks in the weld area. Too slow cooling by contrast results in lower hardness in the heat-affected zone and lower toughness near the fusion line.



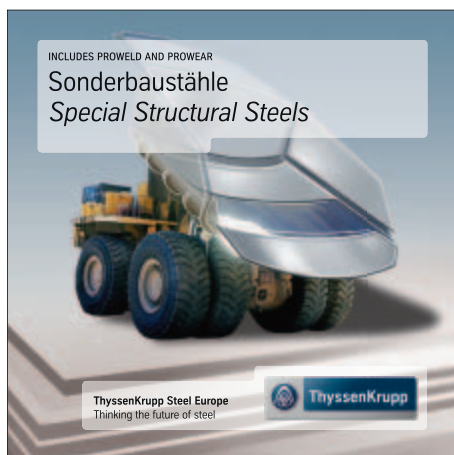
Through selection of suitable welding conditions taking into account necessary preheat and interpass temperatures it must be ensured that the cooling times lie in the range of 6 to 20 seconds. Our ProWeld program can also provide assistance in selecting welding conditions. General recommendations on manual arc welding are contained in EN 1011 Part 1 and Part 2 and in Stahl-Eisen-Werkstoffblatt SEW 088.

15. Calculation possibilities offered by the "ProWeld" computer program



The ThyssenKrupp Steel Europe world of “Special Structural Steels” on CD

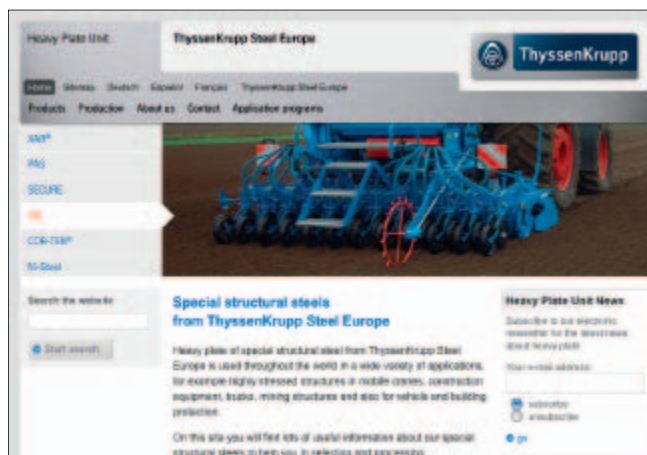
Optimized processing and application of TBL and TBL PLUS steels requires close contact between supplier and customer. A comprehensive technical customer service has therefore been established to provide support in all material processing and design questions. A multilingual compact disc containing information about our special structural steels, including data



sheets, processing recommendations and ProWeld, a computer software developed by ThyssenKrupp Steel Europe for calculating welding parameters, is available free of charge from ThyssenKrupp Steel Europe. All the information is naturally also available in printed brochures. Customers can see the very latest developments on the internet homepage – only a click away from ThyssenKrupp Steel Europe.

ThyssenKrupp Steel Europe – more than just a material supplier

ThyssenKrupp Steel Europe is more than a reliable material supplier. The expansion of our worldwide distribution network is aimed not just at guaranteeing the availability and just-in-time delivery of TBL and TBL PLUS steels to consumers. The close cooperation with first-class steel service centers also makes it possible to offer components which are prefabricated by



means of cutting, cold forming or welding. In this way ThyssenKrupp Steel Europe meets the steadily growing demands of its customers for quality, service and delivery performance.

General note

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