

DILLINGER

DILLIMAX690E



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# DILLIMAX & DILLIDUR

Ultra-high strength and wear resistant plates

Photos

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# DILLIMAX AND DILLIDUR – ULTRA-HIGH STRENGTH AND WEAR RESISTANT PLATE FROM DILLINGER

DILLIMAX and DILLIDUR plates have been an established force in bearing ultra-high loads and resisting abrasive wear for the last half century. Plate production potentials have evolved greatly since the market launch of these steels, and it is now possible to achieve ever higher mechanical strength and to produce ever thicker plates. The cleanness and toughness of quenched and tempered steel plate from Dillingen have been systematically further developed to meet maximum safety needs.

## What drives this trend?

**Lightweight construction is cost-efficient:** Ever thinner and thus lighter plates with ever higher mechanical strengths are used to reduce moving loads for resources-efficiency reasons. Lighter, more slender structures can be fabricated with fewer welds and thus require less welding time.

**Ultra-heavy loads:** Lifting equipment and mining machinery have evolved into giants. Ultra-high forces demand ever higher mechanical strengths, but also extremely high plate thicknesses.

**Safety:** Ultra-high safety standards apply in applications that are, both

economically and ecologically, extremely sensitive, such as offshore oil and gas production. The demands made on the plates used in terms of toughness reserves and internal cleanness are then enormous. These plates need not only mechanical strength, but also extreme toughness and thus extreme safety against fracture.

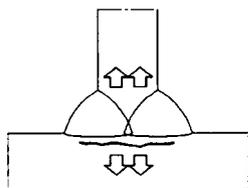


*DILLIMAX: Bearing ultra-high loads*

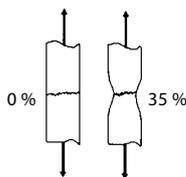


*DILLIDUR: Dumper in service under rough conditions at Dillingen*

## Steel plant



**Stresses in the plate thickness direction caused by welding**



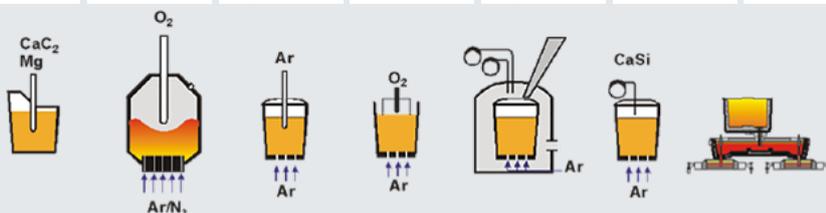
**Z-test: Assuring deformation capability in the plate centre**

The foundation stone for high quality heavy plate is laid in the Dillinger steel plant. Due to their high safety needs, our customers are increasingly demanding plates incorporating ultra-high toughness and extremely homogeneous properties. They therefore order our so-called Z grade, in which the plate possesses special deformation properties in the thickness direction at the most challenging point, the plate centre.

High strength DILLIMAX and wear resistant DILLIDUR steels are degassed under vacuum. This treatment, in combination with sophisticated secondary (or “ladle”) metallurgy reduces undesirable “tramp element” contents (impurity), such as sulphur, to a minimum. A high quality plate, particularly the larger thicknesses, also requires sufficiently thick and homogeneous feed material. Dillinger can continuous-cast so-called slab feed material in up to record thicknesses of 450 mm.



Hot metal desulphurisation	Oxygen-blowing in the converter	Argon bubbling process	Heating	Degassing-process	CaSi treatment	Casting
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**Ultra-clean steel (ultra-low sulphur contents ...)**



**Slabs in thicknesses up to 450 mm, ingots up to 60 t**

## Z grade

High stresses in the plate thickness direction occur due to the cooling and shrinkage of deposited materials in welded structures - even when not under load. Mechanical properties in the plate thickness direction are bindingly specified in Z grades in conformity to EN 10164 or ASTM A770.

Z 35 in accordance with EN 10164, for example, signifies that a round specimen taken in the plate thickness direction will contract by not less than 35% before fracture. This is achieved by means of special treatment of the steel. This capacity for deformation means: safety. Designers can specify the Z grade for their designs, using EN 1993-1-10, for example.

## Rolling mill

The feed material – a slab or an ingot – is rolled to produce the plate. Extraordinarily high rolling forces of up to 108 MN (around 11,000 t) are applied in the rolling mill at Dillingen. The decisive factor is the rolling pass schedule, i.e. the temperature-dependent sequence of rolling operations: rolling is performed in the largest possible “steps”, so-called “rolling passes”. This “high shape rolling” deforms not only the surface but also the centre of the plate. This centre deformation generates the most homogeneous possible plate, from the surface down into the centre.

The extraordinary mechanical strength or wear resistance of Dillingen plates are then generated in tempering systems.

The plate is firstly cooled extremely rapidly using water under controlled conditions. This generates a hardened microstructure uniformly across the entire surface of the plate. It is precisely this hard microstructure which assures the high wear resistance of the DILLIDUR 400 to 550 grades.

Our customers also make maximum demands on the toughness of DILLIMAX steels. A further heat treatment operation, so-called tempering, therefore follows. This “relaxes” the microstructure inside the plate. Plate hardness and mechanical strength are adjusted to precisely the required values simultaneously, and toughness raised to an extremely high level.



A rolling stand exerting up to 108 MN rolling force

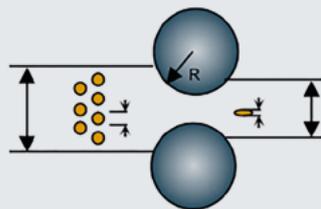
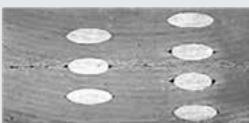
## Heat treatment of DILLIDUR and DILLIMAX

### Water quenching from the austenitising temperature (>Ac3 ≈ 900 °C)

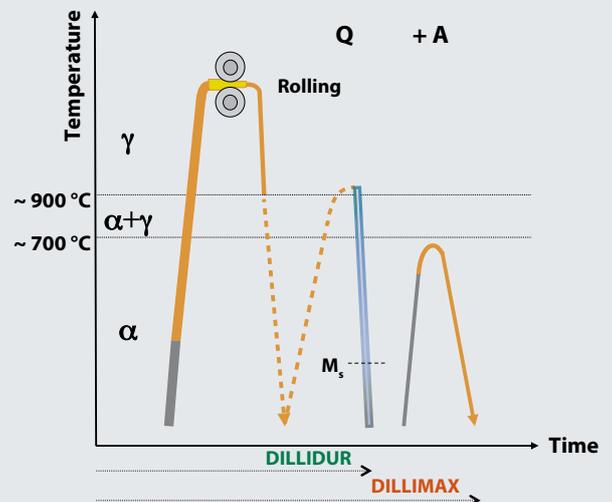
= Q (quenched), e.g. DILLIDUR 500

### + Additional tempering

= Q + A or Q + T (quenched + tempered), e.g. DILLIMAX 965 E



Centre deformation achieved via “high shape factor” rolling: Porosity is eliminated



### With a raincoat if needed

Further production operations, such as marking, the adjustment of demanding flatness requirements on leveling presses, and/or blasting and coating, follow downstream, depending on customers' specific requirements. Temporary corrosion-protection (shop primer) is specified for many applications, in order that the plates arrive

free of corrosion at the customer's site and can, if necessary, be stored in the open there temporarily. In other cases, such corrosion-protection is not desired, for welding reasons, or is just not necessary, because the plates will anyway be blasted. So you decide "with or without". We do the work you need.



*Blasting and coating to meet the customer's wishes*

# DILLIMAX AND DILLIDUR – BRAND NAMES FROM DILLINGER

Dillinger is known around the world as the market leader in thick plates. Our standard supply range of demanding ultra-high strength and wear resistant grades extends to plate thicknesses up to 255 mm and plate widths up to 4,500 mm. The maximum suppliable plate weights of above 35 t permit dimensions that match the customer's wishes.

**DILLIDUR:**  
**Wear resistant steel from Dillinger**  
**for more than 50 years**

For more than 50 years, excavators, demolition and recycling equipment, and also gigantic machines for mining of mineral resources, have been successfully supplied using DILLIDUR. We manage, with our wear resistant DILLIDUR to combine otherwise contradictory properties: ultra-high wear resistance plus simple and reliable processibility.

A graduated range of steel grades up to a hardness of 550 Brinell is available for your special applications.

The basic DILLIDUR 400 grade convinces when ease of working and welding is needed in combination with good wear resistance. This grade, with a nominal hardness of 400 Brinell, is notable for its extremely low carbon contents, assuring extremely good flame-cuttability and

weldability at cost-effective low pre-heat temperatures – or even without any time-consuming and costly pre-heating.

Despite its extremely high nominal hardness of 500 Brinell and its extremely high wear resistance, DILLIDUR 500 can be reliably and cost-efficiently welded and fabricated using the welding and fabrication notes supplied by Dillinger.

DILLIDUR	Plate thickness <sup>a</sup>	Nominal hardness [Brinell]	Special features
550	10 - 51 mm 0.4 - 2 in.	550	
500	8 - 100 mm 0.3 - 4 in.	500	
450	8 - 100 mm 0.3 - 4 in.	450	
400	8 (6) - 150 mm 0.3 (0.25) - 6 in.	400	
IMPACT	40 - 150 mm 1.6 - 6 in.	340	Assured toughness for ultra-high resistance to cracking
325 L	6 (5) - 50 mm 0.25 (0.2) - 2 in.	325	Air hardened for higher working temperatures and hot forming

<sup>a</sup> Larger plate thicknesses available on request



**DILLIDUR: Mining excavator in service under rough conditions**

**DILLIDUR:**  
For special applications

Air hardened DILLIDUR 325 L is available with a nominal hardness of 325 Brinell for special applications at elevated service temperatures up to around 500 °C and for hot formed wear parts. The special feature of this grade is that, thanks to its alloying concept, it automatically retains its hardness even when cooled slowly in air. The properties stated in the data sheet thus return automatically after normalising – for hot forming, for example.

Thick-walled and, possibly, welded wear parts, such as the cutting edges of high-capacity shovels for use under adverse conditions in mines, for example, require special resistance to cracking. DILLIDUR IMPACT in plate thicknesses from 40 mm to 150 mm and with assured Charpy-V notch toughness is the solution for such applications.

Special grades with hardnesses of 400 and 500 Brinell are available for applications requiring extra-thick plates with special requirements for properties at the plate centre.

**DILLIMAX:**  
For slender structures

Around the world, ever more enormous machines, as well as conveying, handling and lifting systems, are coming into use. Such machines are required to move ultra-heavy loads cost-efficiently while having the lowest possible deadweight. This necessitates ever higher mechanical strengths in the steels used for the load-bearing structures, even in extremely thick plates. Extremely good toughness to assure safety margins under extreme loads are vital in the case of thick-walled and welded structures, and are therefore specified in codes such as EN 1993-1-10, for example.

DILLIMAX, with nominal yield strengths of up to 1100 MPa, better the standardised mechanical strength requirements, in some cases significantly, and with genuine toughness data well above the requirements of such standards, even at ultra-low temperatures of -60 °C. The grade designation – “DILLIMAX 690 B/T/E”, for example – states the nominal yield strength (690 MPa in this case) and the temperature down to which the toughness specifications are guaranteed (**Basis**: -20 °C, **Tough**: -40 °C and **Extra tough**: -60 °C). For DILLIMAX 690 B/T, Dillinger warrants 60 J/40 J (longitudinal/transverse) instead of only 30 J/27 J according to EN 10025-6.

**Selecting the right DILLIDUR grade**

Grade	DILLIDUR				
	550/500	450	400	IMPACT	325 L
Abrasive wear	+++	++	+	+	+
Weldability	-	0	+	++	-
Cold formability	-	0	+	+	--
Hot formability	-	-	-	0	+
Service at elevated temperatures	-	-	-	0	+
Crack resistance	-	0	+	++	-
Chip-removing machining	-	0	+	+	+
Nitriding	-	-	-	+	+

## The special performer

Our range of long-term proven ultra-high strength DILLIMAX grades includes, inter alia, DILLIMAX 690 in plate thicknesses up to 255 mm and an extremely broad selection of dimensions. As specialists in out-of-the-ordinary project requirements, we are also pleased to go beyond the limits set down in the data sheets, in cooperation with our partners: one example is DILLIMAX 965, which can also be supplied in plate thicknesses up to 150 mm to meet out-of-the-ordinary customer specifications.

## DILLIMAX: Cost-efficient

The extremely high mechanical strengths of DILLIMAX enable designers to reduce plate thickness to the necessary minimum. The composition of DILLIMAX steels is optimised to permit the assurance of low carbon equivalents. Despite its high mechanical strength, DILLIMAX can thus nonetheless be cost-efficiently welded at only moderate preheat temperatures.



**DILLIMAX: For offshore applications**

### Carbon equivalent - Why?

Carbon equivalents provide simple and rapid information on weldability. The CE(V) or CET carbon equivalents can be used in combination with EN 1011-2 to calculate preheat temperature: The lower the values, the lower the preheat temperature. The US welding standard AWS D1.1. uses  $P_{cm}$ .

$$CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40$$

$$CE(V) = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

$$P_{cm} = C + Si/30 + (Mn + Cu + Cr)/20 + Mo/15 + Ni/60 + V/10 + 5 \cdot B$$

The EN 10025-6 materials standard specifies maximum values for carbon equivalent CEV for ultra-high strength steels. Lower figures, and thus more cost-efficient preheat temperatures, are specified for DILLIMAX.

As standard, a homogenous internal property is guaranteed ex works: All DILLIMAX plates are delivered according to the ultrasonic class S<sub>1</sub>E<sub>1</sub> or even higher customer requirements.

DILLIMAX	Nominal minimum yield strength [MPa] (ksi)	Charpy-V notch toughness at [°C] (°F)	Plate thickness [mm] (in.)	Designation EN 10025-6
1100	1100 (160)	-40 (-40)	8 - 40 (0.3 - 1.6)	—
965	960 (140)	B/T/E -20/-40/-60 (-4/-40/-76)	6 - 120 <sup>a</sup> (0.25 - 4.7)	S960 Q/QL/—
890	890 (130)		6 - 255 <sup>b</sup> (0.25 - 10)	S890 Q/QL/QL1
690 B/T/E	690 (100)			S690
550	550 (80)		6 - 200 <sup>c</sup> (0.25 - 8)	S550
500	500 (72)			S500

<sup>a</sup> Larger plate thicknesses available on request <sup>b</sup> DILLIMAX 690 E: up to 200 mm (8 in.) <sup>c</sup> DILLIMAX 500 T/E and DILLIMAX 550 T/E: up to 150 mm (6 in.)

### DILLIMAX: High precision

Every kilogram counts in weight-sensitive applications, such as the booms of mobile cranes. Only minimal deviations in thickness can therefore be tolerated. DILLIMAX TL assures precisely the tight thickness and flatness tolerances for such tasks.

In the case of large machined components – for use in mechanical engineering, for example – every extra millimetre of thickness causes expensive machining time and enormous costs. To reduce extra thickness, DILLIMAX plates in thicknesses up to 200 mm can be ordered in accordance with the DIPLAN specification, which assures flatness within extremely tight tolerance bands across the entire surface of the plate.

### Certified quality for offshore applications

Particularly sensitive applications for ultra-high strength steels, in the offshore sector, for example, necessitate an exceptionally high level of safety. For this reason, exceptional requirements are also made here on the reserve capabilities of the steel used. These may, specifically, take the form of

- high requirements for mechanical strength properties, even in extremely thick plates;
- high requirements for Charpy-V notch toughness at extremely low temperatures and, possibly, also in the plate centre and
- requirements in the through-thickness direction (Z grades).

Specially developed and modified steels in the 690 MPa yield strength class are available up to plate thicknesses of 210 mm for such applications. These steels can be supplied in accordance with the Dillinger DI-RACK material data sheet, as grades approved under offshore rules such as ABS and DNV, for instance, and in accordance with project specifications.



*High quality work: Our employees are perfectly satisfied.*



*Jack-up rigs for offshore applications*

# REFERENCES

## Material data sheets

([www.dillinger.de](http://www.dillinger.de)):

DILLIMAX 1100, 965, 890, 690, 550, 500: High strength fine grained structural steel, quenched and tempered  
DILLIDUR 550, 500, 450, 400, IMPACT: Wear resistant steel  
DILLIDUR 325 L: Air hardened wear resistant steel  
DI-RACK: High strength fine grained structural steel for racks and chords of jack-up rig legs

## Special specifications

([www.dillinger.de](http://www.dillinger.de)):

DILLIMAX TL: High strength fine grained structural steels for telescopic crane booms  
DIPLAN: Heavy steel plates with improved flatness tolerances over the entire plate dimension

## Technical Information

([www.dillinger.de](http://www.dillinger.de)):

DILLIMAX: Make savings with high strength steel  
DILLIDUR: The concept to combat wear and tear

## Further information

([www.dillinger.de](http://www.dillinger.de)):

Delivery program heavy plate  
Shot blasted and primer coated heavy plates

## Standards and rules – Steel grades, tolerances, processing, design:

EN 10025  
Hot rolled products of structural steels  
– Part 1: General technical delivery conditions

– Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition

EN 10163

Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections  
– Part 1: General requirements  
– Part 2: Plate and wide flats

EN 10164

Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions

EN 10029

Hot-rolled steel plates 3 mm thick or above – Tolerances on dimensions and shape

EN 1011

Welding – Recommendations for welding of metallic materials  
– Part 1: General guidance for arc welding  
– Part 2: Arc welding of ferritic steels

CEN/TR 10347

Guidance for forming of structural steels in processing

EN 1993

Eurocode 3: Design of steel structures  
– Part 1-9: Fatigue  
– Part 1-10: Material toughness and through-thickness properties  
– Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S700

## Further standards and rules:

ASTM A6/A6M

Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

ASTM A514/A514M

Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding

ASTM A770:

Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications

AWS D1.1

Structural Welding Code – Steel

## Disclaimer:

The information and data provided concerning the quality and/or applicability of materials and/or products constitute descriptions only. Any and all promises concerning the presence of specific properties and/or suitability for a particular application shall in all cases be deemed to require separate written agreements.



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