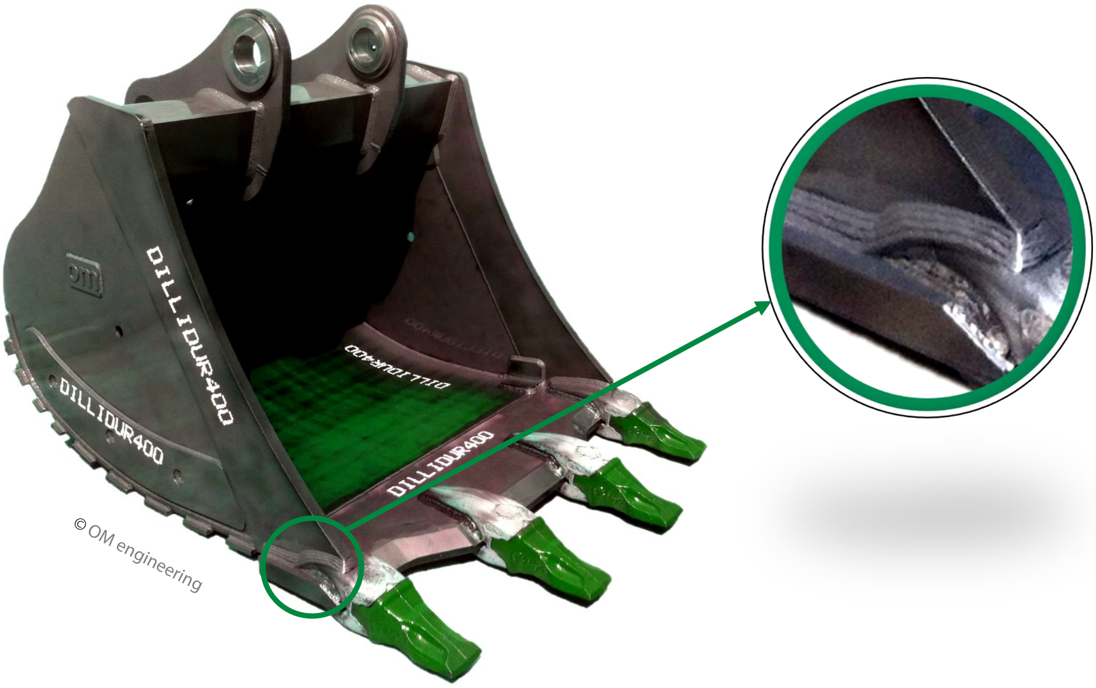
Processing information

Welding

DILLIDUR

Welding

Wear resistant DILLIDUR is highly suitable for processing due to its exceptional homogeneity as well as its cleanness. Increasing hardness requires increased amounts of alloy components and careful treatment of the plate, especially in the case of heat input during welding. DILLIDUR is suitable for welding with all common welding methods.



The information on DILLIDUR welding has been developed in accordance with Dillinger's best knowledge and experience. It is intended to support manufacturers in developing their own processing procedure for DILLIDUR.

The wide variety of welding conditions, the construction and the consumables used have a significant effect on the quality of the welded joints. Optimum mechanical properties of the weld seams as well as welds without defects are achieved by observing the entire process chain and creating suitable welding conditions.

General rules of welding technology as well as the processing recommendations according to EN 1011 must be observed, taking into account the high alloy contents and strong hardenability, especially for DILLIDUR 325 L, DILLIDUR 550 and DILLIDUR 600. During processing, the necessary safety measures must be taken.

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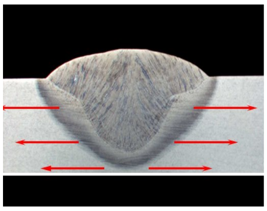
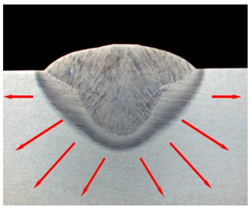
Overview of welding parameters

Heat input (effective)	Q
Voltage [V]:	U
Current [A]:	I
Welding speed [mm/min]:	v
Power P [Watt]: Voltage · Current	(U · I)
Heat input E [kJ/mm]: Power / speed (P / v):	(U · I) / v · (60/1000)
Efficiency-> Radiation Effective heat input Q:	E · k (k =Thermal efficiency factor see EN 1011)

Two– and three-dimensional heat flow



2 D at t = 20 mm



3 D at t = 35 mm

The heat energy applied during the welding process flows off perpendicularly or parallel to the plate surface. Especially with plate thicknesses < 20 mm, the heat input must be limited to prevent slow cooling of the weld. The transition from two- to three-dimensional heat flow is influenced by the temperature and heat input for large plate thicknesses.

Carbon equivalents

$CEV = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15$
$CET = C + (Mn+Mo)/10 + (Cr+Cu)/20 + Ni/40$

Preheating temperature T_0 according to EN 1011-2 method B[1)] to avoid hydrogen cracks

$$T_0 = 700\,CET + 160\tanh(t/35) + 62\,HD\,\exp 0.35 + (53\,CET - 32)\,Q - 330$$

Depending on:
Carbon equivalent CET; plate thickness t; hydrogen content HD; effective heat input Q

Recommendations for calculation of the welding parameters mentioned and preheating temperature can be found in Dillinger E-Service on the basis of the actual analysis and further data.

1) Further details can be found in EN 1011-2.

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Weld seam including weld seam preparation

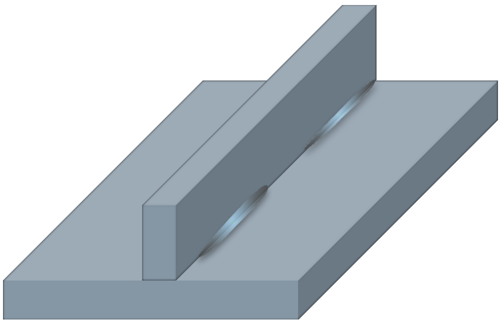
The weld preparation can have a significant effect on the quality of the weld achieved.

Edge-milled plates

The weld edge can be prepared by machining or by thermal cutting. At the beginning of welding, the edge must be bright, dry and free of flame cutting slag, rust, scale, paint and any other impurities.
Any protective primer previously applied to the plate must be removed (Note: some primers can be welded over - see Dillinger's brochure "Raincoat included").

Weld seam

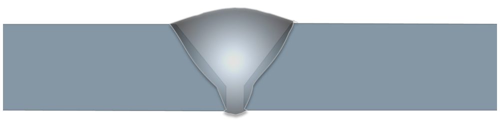
Tack weld

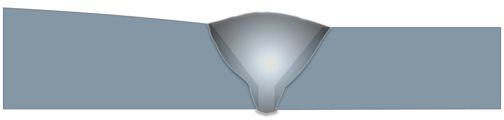


The minimum length of the welding bead should be 50 mm.

The tack weld should not start directly at the outer edge. The tack welds can also be made with soft filler metals.

Butt joint





Butt joints of parts with unequal cross sections positioned in one direction can be aligned with an inclination of less than 1:4.

The weld seam differs from the standard technical heat treatment due to its

- high heating rate
- high maximum temperature (1,350 °C)
- short dwell time
- high cooling rate

Weld seam with different heat input

GSMAW - 0.65 kJ/mm

MMA - 1.8 kJ/mm

MMA - 3.5 kJ/mm

Prevention of cold cracking

Prevention of cold cracking: Like all hardened wear resistant steels, DILLIDUR steels can under unfavourable conditions also tend to form cold cracks in the hardened structure at the weld.
The hazard is that these cracks may not appear until 48 hours after welding. This must be taken into account when inspecting for cracks.
Deposits of molecular hydrogen at the grain boundaries of the weld metal structure and on the fusion line are the main causes of cracking. The hydrogen enters the weld through impurities, moist weld fillers, films of moisture on the weld edges or the atmosphere surrounding the arc. It can be avoided by selecting suitable weld fillers, keeping them dry in storage and, above all, by cleaning and reheating the component to be welded.
The higher temperature leads to a delay in the cooling of the component after welding, which means that the hydrogen has enough time to diffuse out. This phenomenon mainly takes place in the temperature range between 300 °C and 100 °C.
In gas-shielded metal arc welding, only comparatively small amounts of hydrogen are introduced to the weld metal (<2 ml/100 g), so that preheating can often be dispensed with for the DILLIDUR 400 and DILLIDUR 450 series when using welding wires of a lower strength.

Preheating temperature

The basis for calculating the preheating temperature is the actual chemical analysis shown on the corresponding certificate. Reference values can be found under the following table:

Thickness [mm]	t = 20 CEV (CET) typical [%]	t = 60 CEV (CET) typical [%]	t = 100 CEV (CET) typical [%]	t = 150 CEV (CET) typical [%]	Maximum temperature
DILLIDUR 325 L	0.77 (0.44)	-	-	-	500 °C
DILLIDUR IMPACT	-	0.63 (0.38)	0.66 (0.39)	0.66 (0.39)	500 °C
DILLIDUR 400	0.41 (0.3)	0.63 (0.36)	0.63 (0.36)	0.67 (0.37)	250 °C
DILLIDUR 450	0.44 (0.33)	0.66 (0.39)	0.66 (0.39)	-	200 °C
DILLIDUR 500	0.45 (0.38)	0.56 (0.41)	0.62 (0.43)	-	200 °C
DILLIDUR 550	0.56 (0.46)	0.75 (0.49)	0.75 (0.49)	-	200 °C
DILLIDUR 600	0.63 (0.50)	0.63 (0.50)	-	-	180 °C

CEV = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15
CET = C + (Mn+Mo)/10 + (Cr+Cu)/20 + Ni/40

Preheating temperatures for welding are shown in the following table. They show, as an example, the preheating temperatures (°C) for manual arc welding as a function of the plate thickness and thus of the carbon equivalent CET with a hydrogen content of 2 ml/100g and a heat input of 1.5 kJ/mm.

<table>
<tr><th>Thickness [mm]*</th><th><10</th><th>≤ 15</th><th>≤ 20</th><th>≤ 25</th><th>≤30</th><th>≤ 35</th><th>≤ 40</th><th>≤ 45</th><th>≤50</th><th>≤ 55</th><th>≤ 60</th><th>≤ 65</th><th>≤ 70</th><th>≤ 75</th><th>≤ 80</th><th>≤ 85</th><th>≤ 100</th><th>≤ 200</th></tr>
<tr><td>DILLIDUR 325 L</td><td>100</td><td colspan="2">125</td><td colspan="2">150</td><td colspan="2">175</td><td colspan="2">180</td><td colspan="9">200</td></tr>
<tr><td>DILLIDUR IMPACT</td><td colspan="6"></td><td colspan="12">150</td></tr>
<tr><td>DILLIDUR 400</td><td colspan="3"></td><td>50</td><td>75</td><td colspan="2">100</td><td colspan="5">125</td><td colspan="6">150</td></tr>
<tr><td>DILLIDUR 450</td><td colspan="2"></td><td>50</td><td colspan="3">100</td><td colspan="4">130</td><td colspan="8">150</td></tr>
<tr><td>DILLIDUR 500</td><td></td><td>60</td><td colspan="2">100</td><td colspan="5">160</td><td colspan="4">180</td><td colspan="4">200</td><td></td></tr>
<tr><td>DILLIDUR 550</td><td></td><td>150</td><td colspan="15">200</td><td></td></tr>
<tr><td>DILLIDUR 600</td><td></td><td colspan="10">180</td><td colspan="7"></td></tr>
</table>

*Temperatures [°C]: typical values for Q=1,5 kJ/mm, HD = 2 ml/100g

The selected welding consumables should be as soft as possible, provided the construction and wear conditions of the welded joint allow for it.
When using soft austenitic filler materials, the preheating temperature can be significantly reduced.

Heat control:
- Heating of the weld seam area at the beginning of the welding process
- Adherence to calculated minimum temperature throughout the whole welding process (interpass temperature)
- The maximum interpass temperature should not exceed the maximum permissible temperature of the single steel grades

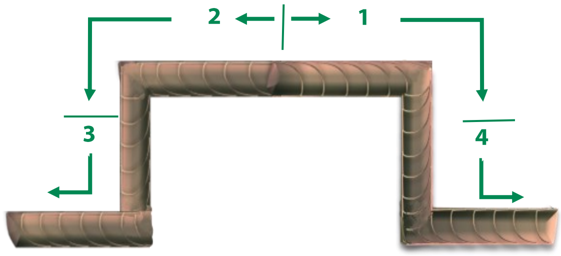
At the beginning of the welding process, the whole length of the seam must have reached the preheating temperature. A zone of about 100 mm width (or at least 4 times the plate thickness) on both sides of the weld must have reached the preheating temperature as well. For multiple layer welding, preheating temperature must also be considered as a minimum interpass temperature.
The risk that cracks may occur in welded joints as a result of residual stresses is particularly high when the seam volume is only partly filled. Therefore, cooling below the prescribed interpass temperature must be avoided during the whole welding process. In the interest of lower residual stresses, harsh cross-sectional transitions and concentrations must be avoided.

In principle, cold cracking can be prevented, if appropriate precautionary measures are taken during welding:
- Minimize the hydrogen in the weld metal
- Give the hydrogen enough time to diffuse out
- Avoid any impurities and humidity in the weld seam
- Take the hardening in the heat affected zone into account (can only be partially controlled)
- Minimize residual stresses with suitable welding sequences
- Avoid harsh cross-sectional transitions and concentrations of welds

Weld sequences:

The welding sequence should be chosen in such a way that the individual components can shrink freely for as long as possible. This helps to reduce residual stresses.

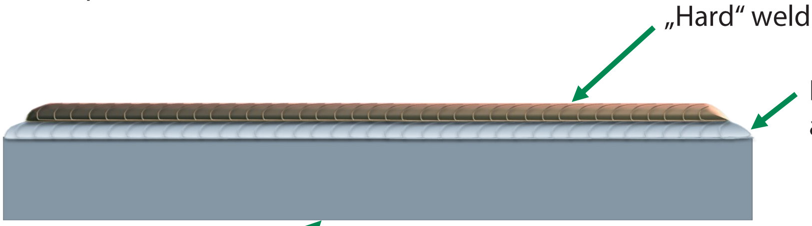
Example of a favourable weld sequence:



Hard facing

Components which are subject to extreme local wear load can be additionally protected by hard facing through weld overlays. Application of welded wear protection layers is possible for all DILLIDUR steels. It must be taken into account that weld overlay changes the original properties of the plate within the heat-affected zone.

When the layer has been worn away, the softened base material may then wear faster than in its original condition. Hence the weld overlay should be observed regularly to avoid loss of wear protection. For information about suitable weld fillers for hard facing, we recommend to consult the respective manufacturers.



Filler metals and consumables

The filler metals must be selected according to the required mechanical properties. In most cases it is sufficient to use a “soft“ weld filler with a low strength and hardness (yield strength ≤355MPa). However, this is only practical if the welds can be designed to be in areas that are subject to less wear, so that the wear of the weld does not have a negative effect on the service life of the component.
The following table shows some examples of "soft" welding consumables, classified according to standard and welding procedure.

Method	EN	(SFA) AWS
Manual arc welding	EN ISO 2560-A: E 42*	SFA/AWS A5.1: E70*
Gas-shielded arc welding	EN ISO 14341-A: G 42*	SFA/AWS A5.18: ER70*
	EN ISO 17632-A: T 46*	FA/AWS A5.20: E71*
	EN ISO 14171-A: S 46*	
Submerged arc welding	EN ISO 14171-A: S 46*	SFA/AWS A5.17: F7*

*Allows selection of one or more characters

The base layer should be welded "soft" in any case to enable it to yield to fully occurring stresses.

For welds subject to extreme wear, we recommend carrying out the final pass with special hard facing electrodes. For such applications, the following table shows some examples of "hard" filler metals, classified according to standard and welding process.

Method	EN	Possible hardness depending on selected filler metal
Manual arc welding	EN 14700: E Fe*	from 350 HBW up to 650 HBW
Gas-shielded arc welding	EN 14700: S (T) Fe*	

*Allows selection of one or more characters

You should take into account that a high degree of hardness in the weld increases the risk of cold cracking.

In manual arc welding, basic coated rod electrodes are always used to reduce the risk of cracks. It is essential to carry out redrying and storage according to the instructions of the consumable manufacturer because base coatings absorb air humidity.

Where austenitic electrodes or electrodes on a nickel base are used, preheating may not be required.

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.

This information is updated at irregular intervals. The current version is relevant. The latest version is available from the mill or as download at www.dillinger.de.

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