



PROTAC

CUTTING

PROTAC steel grades are classified as high-strength steels. Given their relatively high CEV value, it is essential to take special care into account when cutting the plates into final parts. We recommend three cutting methods.

WATERJET CUTTING

Waterjet cutting is the preferred cutting method for PROTAC plates of all thicknesses. No heat is applied to the material during waterjet cutting, so no HAZ is present on the plate. When cutting with WJS, please check the quality of the cut edge and ensure the striated cutting lines are removed from the cut edge.

LASER CUTTING

Laser cutting is a thermal cutting method that creates a HAZ up to 2 mm wide. Due to microstructural changes and increased hardness, this area must be removed before further processing. There are also elevated hydrogen levels in the cut edge area. Due to all these factors, special attention is required, as cut edge cracking can occur. These cracks can appear a few hours or even several weeks after cutting.

OXYFUEL OR PLASMA CUTTING

This method is less advisable. Gas cutting generates an even wider HAZ. The large temperature differences raise the risk of cracking, which increases with the thickness of the plate.

HOW TO PREVENT CUT EDGE CRACKING

The best way to reduce the risk of cut edge cracking is by preheating before cutting. Preheating reduces the temperature difference and thus lowers the risk of cracking. Preheating temperatures above 200 °C (150 °C for PROTAC 650) should be avoided, as they can lead to a decrease in hardness. Additional controlled cooling of the plates is also recommended – if possible, it is best to cool the plates by piling.

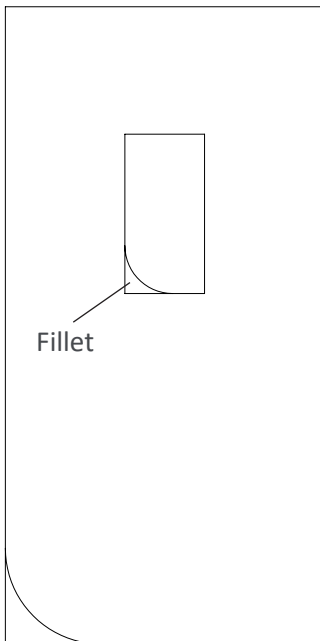
Table: Minimum recommended preheat temperature [°C]

Steel grade	Thickness [mm]			
	6–15	15.01–25	25.01–30	30.01–40
PROTAC 500	Room temp.	125	125	175
PROTAC 550	150	150	180	180
PROTAC 600	150	150	180	180
PROTAC 650	120	120	-	-

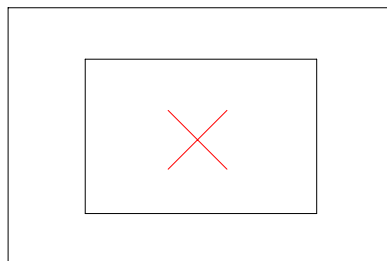
Another, but less reliable way, of avoiding cut edge cracking is to lower the cutting speed.

DESIGN

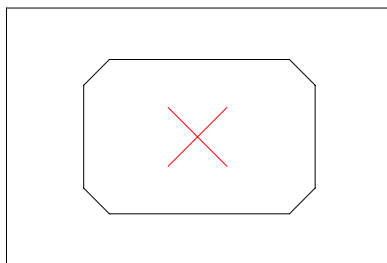
When cutting shapes out of plates, it is advisable to avoid sharp corners and use fillets instead. As shown in the figure, cutting fillet corners in slots is much more advisable than cutting sharp corners, as they do not have a notch effect. Moreover, it is also recommended to avoid chamfered slot corners and use circular slot corners instead.



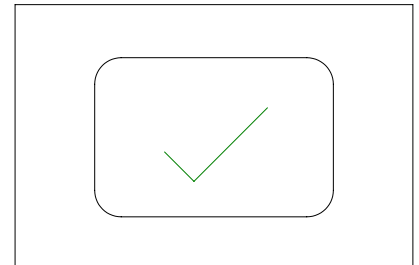
Avoid sharp corners



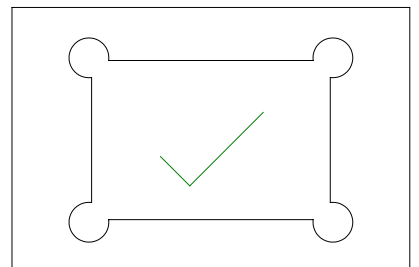
Slot sharp corners



Slot chamfer corners



Slot fillet corners



Slot circular corners

The cutting machine parameters should be adjusted to prevent striations on the cut edge. If striations do appear, the edge must be ground after cutting.

After cutting is completed, it is important to ensure the quality of the edge. It is advisable to grind the edge to remove any imperfections that could cause cracking.

Photo: Same plate, big difference. Sharp corners (left) result in a notch effect and cracking after bending. Slot fillets (right) allow for bending without cracking.



BENDING

PROTAC steels are bendable, however, certain parameters and rules, described below, must be considered. The following recommendations help end-users to achieve high-quality bent plates, avoid cracking and increase safety. Bending PROTAC 650 is not recommended.

One of the most important parameters when performing bending is the correct **bending radius**. The table below shows the correct radius in relation to plate thickness for different PROTAC steel grades. If the bending radius is lower than recommended, the possibility of cracking increases. If possible, the bending should be done in the **transverse direction** to the plate rolling direction, as indicated in the picture. The bending angle should be kept as low as possible, especially with increasing hardness.

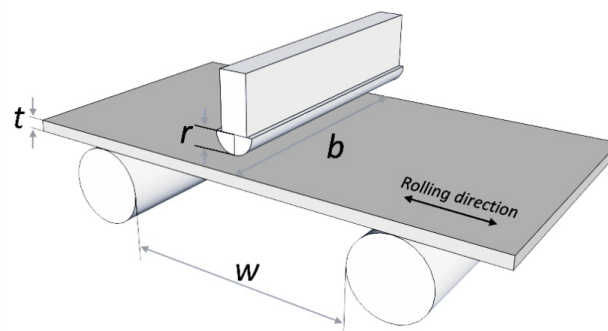


Figure: Schematic representation of bending, with indicated bending parameters (b – bending line, t – plate thickness, r – punch radius and w – die opening width).

Table: Recommended punch radius, die opening width and maximum angle.

Steel grade	Thickness [mm]	r/t Transverse	r/t Longitudinal	min. w Both directions	max. angle [°] Both directions
PROTAC 500	≤ 8	6	7	$w = 2r + 5t$	90
	8.01–15	7	8		90
	15.01–22	8	9		90
PROTAC 550	≤ 10	15	16		20
PROTAC 600	≤ 10	15	16		20
PROTAC 650	bending PROTAC 650 is not recommended				

Users are advised to use **low punch speed** with intermediate stops (multi-stop) during the bending. This will reduce the stresses accumulated in the workpiece, reduce the risk of cracking and increase safety.

An important factor to consider during the bending is the **springback effect**, which occurs due to the relaxation of elastic stresses in the material. The material should be bent to 10 to 15° more than the required final angle. The higher the yield strength, the higher the springback angle (PROTAC 500 < PROTAC 550 < PROTAC 600).

Workshop **temperature** also affects the bending process. To ensure optimal bending, plates shall not be cold – a plate temperature of at least 20 °C (room temperature) is recommended. This is especially important in the winter period and areas with lower temperatures. On the other hand, heating over 200 °C is not allowed, as it degrades the mechanical and workshop properties, including the bendability.

Edge preparation before bending is crucial, as it represents a possible weak area for crack initiation. Plate edges must be free of imperfections originating from cutting. We recommend grinding the plate edges and the tensile side of the plate, directly under the puncher. By grinding the plate edges, the heat-affected zone (laser, oxy-fuel, plasma) from cutting is removed, reducing the possibility of cracking. Grinding the tensile side (bending line) of the plate also reduces the chance of cracking, as it represents the area with the greatest stress accumulation.

Part **design** also affects the bending process. Bending over crack initiators, such as sharp edges, corners, and cutouts, is not advised and should be minimized, if possible. The higher the hardness, the more critical these spots turn out to be.

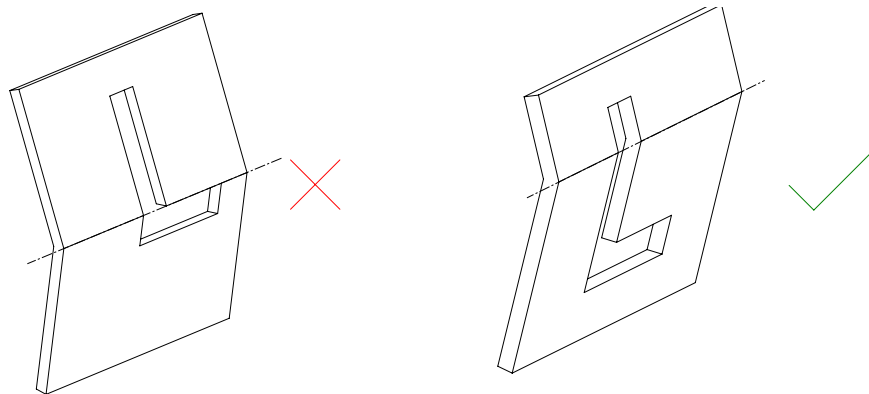


Figure: Schematic representation of bad (left) and good (right) practice when bending PROTAC steel.

WELDING

PROTAC steel plates are produced with the chemical composition necessary to achieve high hardness and ballistic protection. PROTAC plates can be welded using all conventional arc welding processes. Heat input during the welding shall be as low as possible to minimise the softening in the HAZ, thus preserving high hardness and ballistic resistance.

Using GMAW as the most preferable welding process will result in a very low hydrogen content in the weld metal and hence a very low cold cracking susceptibility.

GTAW is also preferable due to the very low heat input into the weld joint and very low hydrogen content.

MMAW is only allowed when the welding electrodes are properly dried as per the electrode manufacturer's recommendations.

PROTAC can be welded to any other structural steel. When PROTAC steel plates are part of the structure, the welding technology is always prepared according to the PROTAC steel plates.

WELD EDGE – Safe structures require perfect alignment of the plates along the weld joint line. Additionally, all impurities, such as scale, anti-corrosion painting, rust, grease oils and moisture, shall be removed from the weld area. Weld edges on the plates shall be prepared mechanically by milling or grinding.

TACK WELDING – Tack welds are used to align plates in a structure before the main welding job. Due to the high cooling speed of tack welds, take care to minimize the risk of cold cracking. Each tack weld should be at least 50 mm long. Pay attention to welding arc settings to prevent crater cracking, especially when using austenitic electrodes.

MINIMUM PREHEAT AND INTERPASS TEMPERATURES [°C]

Steel grade	Thickness [mm]			
	6–10	10.01–16	16.01–22	> 22
PROTAC 500	60	125	150	175
PROTAC 550	120	140	175	175
PROTAC 600	140	175	175	175
PROTAC 650	120	120	120	120

MAXIMUM PREHEATING AND INTERPASS TEMPERATURE

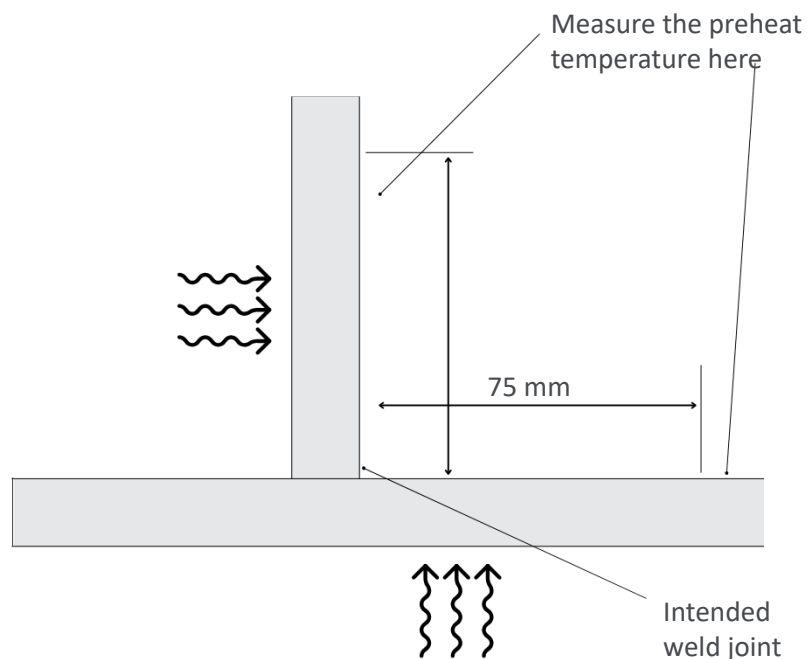
Maximum preheating and interpass temperature shall be carefully controlled to avoid the softening effect of the steel.

Steel grade	Max. temperature [°C]
PROTAC 500	190
PROTAC 550	190
PROTAC 600	190
PROTAC 650	150

PREHEATING METHOD AND TEMPERATURE CONTROL

Several methods are available for preheating the weld areas before welding. The open flame preheating method is typically used due to the complexity of the welded structures made of PROTAC steels.

Temperature shall be controlled using melting crayons or contact thermocouples. Temperature shall be measured at least 75 mm from the weld joint area and at least 2 minutes after the heating process. Preheating shall be done as per the guidance of EN ISO 13916.



WELDING CONSUMABLES

Welding of PROTAC steel plates shall be done using consumables with low tensile and yield strength, enabling high toughness of the weld metal. Soft welding consumables with a yield point below 500 MPa will produce weld metal with high cold cracking resistance. As the tensile properties of the weld joint are typically lower than those of base metal properties it is necessary to position the weld joints in the low stress areas.

Weld metal hydrogen shall be controlled below 5 ml/100 g of weld metal. This value can be controlled using solid welding wires and the GMAW or GTAW process. We recommend avoiding using coated electrodes on PROTAC 550, PROTAC 600 and PROTAC 650 steel due to the higher possibility of hydrogen-induced cracking.

Coated electrodes for MMAW shall be stored and dried according to the electrode manufacturer's recommendations.

FILLER METALS

Welding process	Low-alloyed consumables	Austenitic consumables
GMAW	AWS: ER 70 S-6 ISO: G42 5M/C G3Si1	AWS A5.9: ER 307Si ISO: 18/8 Mn 6
GTAW	AWS: ER 70 S-6 ISO: W 42 5 W3Si1	AWS A5.9: ER 307Si ISO: 18/8 Mn 6
MMAW	AWS A-5.1: E7018 EN ISO 2560-A: E 42 4 B 32 H5 AWS A-5.5 E10018-G EN ISO 18275-A: E 69 6 Mn2NiCrMo B 42 H5	AWS A-5.4: E 307-15 EN ISO 3581-A: E 18 8 Mn B 22

DESIGN

Some precautions must be considered when designing parts from high-strength PROTAC steels. **Welding shall not be done directly on the bending line**, as indicated on the figure below. Doing this will increase the risk of cracking, especially for PROTAC 550 and PROTAC 600, as the buildup of stresses on the tensile side of the bend exceeds the critical point, resulting in cracks propagating across the bending line. The correct design alternative would be moving the welding at least 80 mm from the bending line. Another alternative is to add an add-on plate to the bending line and perform the weld on the add-on plate.

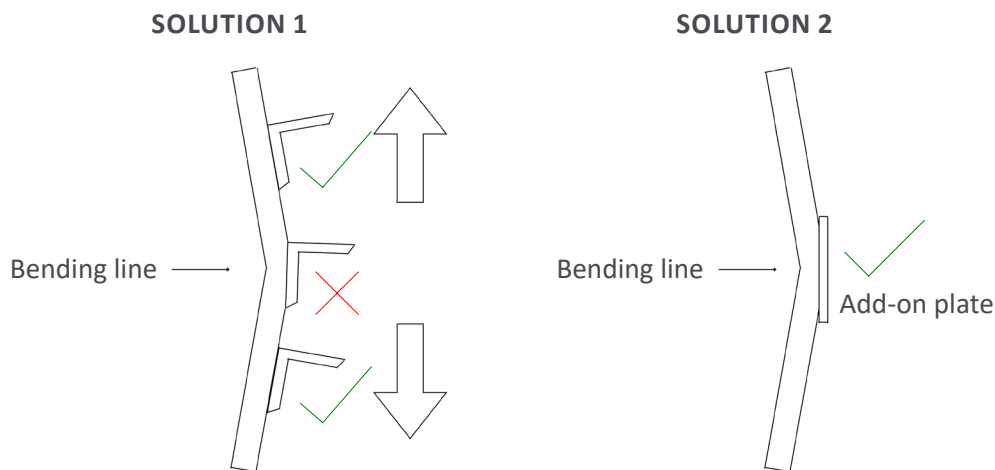


Figure: Schematic representation of possible alternative design solutions to avoid cracking on the bending line after welding.

PROTAC 650 is particularly suitable for use as an add-on plate. We recommend avoiding welding onto the structure.

The information and data in this manual are intended for informative purposes only and may be revised at any time without notice. Presented typical properties and design recommendations are provided only to help readers make their own evaluations and decisions. It is the user's responsibility to adjust the recommendations in this manual to meet the specific needs of their application. SIJ Acroni explicitly disclaims any liability for the suitability of these recommendations for particular applications.