Quard®

VERSCHLEISSFESTER STAHL

Quend®

HOCHFESTER FEINKORNBAUSTAHL

COLD FORMING

NLMK Europe – Plate

If you want to calculate the optimal parameters for your operations on Quard and Quend, download our **Q Calculator** app!

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1. Introduction

Quard ®, abrasion resistant steel, and **Quend** ®, high yield strength steel, are designed for optimal cold forming performance. Requirements regarding steel cleanliness, consistent thickness properties, surface finish, low residual stresses and narrow thickness tolerances, promote an accurate, close and safe bending to be performed.

In plate thickness from 8 mm and below, special attention has been paid to the design of Quard and Quend steel grades in order to reach outstanding bending performance.

The competitive strength of Quard and Quend, comprising of narrow thickness tolerances, excellent surface finish and flatness, promotes the cold forming capability of the steel.

Outstanding surface finish	**Increased crack integrity :** Reduces crack initiation points along the bend line
Narrow thickness tolerances	**Increased reproducibility :** Secures a constant spring back when bending
Flatness	**Increased reproducibility :** Improves shape tolerance when bending

2. Bending

Cold forming of plates involves plastic deformation, or stretching, of the plate surface on the outer tension side of the bend. The extent to which plastic deformation can occur, without exceeding the limits of the material ductility, controls the minimum radius of a bend which can be used for a specific operation.

The main factors determining the formability of steel, or the capacity to plastically deform without failure, have been listed under points A to E below :

A. The type of steel :

Low strength steel is generally more ductile than higher strength steel and is therefore capable of being bent to a narrower radius. In general, a low carbon content is a prerequisite for good formability, thus being able to use a lean composition to manufacture high-strength Q&T steel benefits the cold forming capability. The higher the steel strength and hardness the larger the spring back, the higher the punch force and the larger the tool radius required.

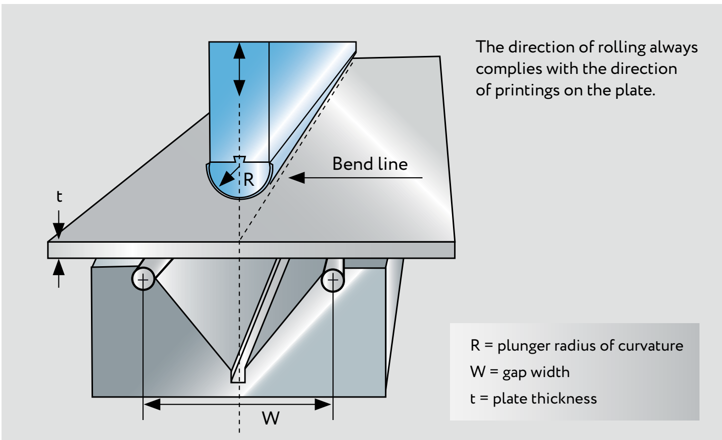
B. Direction of rolling :

Due to the rolling practice applied during the manufacturing process of steel plates, the plate properties will differ depending on the orientation relative to the rolling direction. In the transverse direction to rolling, the microstructure will be oriented in a more favourable way, thus the ductility, as well as the bending properties, are enhanced if the bending line is oriented transverse to rolling.

C. Condition of plate edge and surface:

Poor quality in the plate edges of the bending line or poor surface conditions along the bending line may act as crack initiation points, limiting the bending performance of the plate. For this reason, smoothening and/or removal of sharp corners/edges and slivers on sheared edges, gouge marks, dross formation on flame-cut edges, scratch marks and loose flaked mill scale along the bending line should be considered prior to bending. Always position the plate surface and/or edges of poorest quality on the inside/compressed side of the bend.

The bending machine.



D. Friction :

To lower the friction between the die edges and plate it is recommended to equip a die with freely-rotating steel rods. A further lowering of friction can be obtained by spraying lubricants in the contact zones between the die edges and plate.

The width of the die opening should be adapted to best suit the bending operation. By increasing the die opening width, the spring back will increase and the bending force will be reduced.

E. Punch tool :

When bending Q&T steels, the punch tool radius should have the same radius or somewhat larger radius than the targeted final radius of the plate being formed.

The radius of the tool should be chosen in such a way to accurately comply with the minimum R/t ratio given in the Quard and Quend bending recommendations in Tables 1 and 2.

To secure a proper plate to punch tool contact throughout the entire forming operation, the radius of the punch tool head should run 180°.

Caution

When cold forming high-strength Q&T steel, very high forces are in operation. With a risk of failure of either the plate or the press break, staff operating close to the machine must always follow the safety instructions, whereby they do not stand too close to, or in front of the machine, when bending.

3. Bending recommendations

A. Punch radius :

Minimum recommended punch radius, R (mm), when bending to an angle of 90° in the transverse and longitudinal direction to rolling.

Table 1. Quard abrasion resistant steel.

Plate Thickness, mm	Direction of bending vs. rolling	Bending radius, R (mm)			
		Quard 400	Quard 450	NEW Quard PRO	Quard 500
t < 8.0	Transverse Longitudinal	2.5 x t 3.0 x t	3.5 x t 4.0 x t	3 x t 3.5 x t	3.5 x t 4.5 x t
8 ≤ t < 20	Transverse Longitudinal	3.0 x t 4.0 x t	4.0 x t 5.0 x t	3.5 x t 4.5 x t	4.5 x t 5.0 x t
t ≥ 20	Transverse Longitudinal	4.5 x t 5.0 x t	5.0 x t 6.0 x t	/	6.0 x t 7.0 x t

For cold forming recommendations regarding Quard 550, please contact your local representative.

Table 2. Quend high yield strength steel.

Plate Thickness, mm	Direction of bending vs. rolling	Bending radius, R (mm)			
		Quend 700	Quend 900/960	Quend 1100	NEW Quend 1300
t < 8.0	Transverse Longitudinal	1.5 x t 2.0 x t	2.5 x t 3.0 x t	3.0 x t 3.5 x t	3.0 x t 3.5 x t
8 ≤ t < 20	Transverse Longitudinal	2.0 x t 3.0 x t	3.0 x t 4.0 x t	3.0 x t 3.5 x t	3.0 x t 3.5 x t
t ≥ 20	Transverse Longitudinal	3.0 x t 4.0 x t	4.0 x t 5.0 x t		

B. Die opening:

The minimum recommended die opening (W/t - ratio), when bending Quard and Quend, should be taken according to the following tables.

Table 3. Quard abrasion resistant steel.

Plate Thickness, mm	Direction of bending vs. rolling	Die opening, W (mm)			
		Quard 400	Quard 450	NEW Quard 500	Quard 500
$t < 8.0$	Transverse Longitudinal	8 x t 10 x t	10 x t 10 x t	10 x t 12 x t	10 x t 12 x t
$8 \leq t < 20$	Transverse Longitudinal	10 x t 10 x t	10 x t 12 x t	12 x t 14 x t	12 x t 14 x t
$t \geqslant 20$	Transverse Longitudinal	12 x t 12 x t	12 x t 14 x t	16 x t 18 x t	16 x t 18 x t

Table 4. Quend high yield strength steel.

Plate Thickness, mm	Direction of bending vs. rolling	Die opening, W (mm)			
		Quend 700	Quend 900/960	Quend 1100	NEW Quend 1300
$t < 8.0$	Transverse Longitudinal	8 x t 9 x t	9 x t 10 x t	10 x t 10 x t	10 x t 10 x t
$8 \leq t < 20$	Transverse Longitudinal	8 x t 9 x t	9 x t 10 x t	10 x t 12 x t	10 x t 12 x t
$t \geqslant 20$	Transverse Longitudinal	9 x t 10 x t	10 x t 12 x t		

C. Spring back :

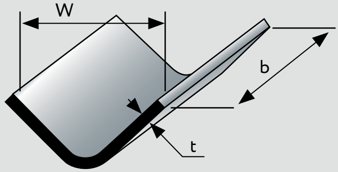
Estimated spring back when bending to 90°.	
Steel grade	**Typical spring back**
Quard 400	8-12°
Quard 450	10-14°
NEW Quard PRO	12-16°
Quard 500	12-18°
Quend 700	6-10°
Quend 900/960	8-12°
Quend 1100	10-12°

The spring back increases with :

- **Increasing plate hardness and strength ;**
- **Increasing width of die opening ;**
- **Increasing punch tool radius.**

4. Calculation of bending force

Energy required for bending.



$$F = C \cdot \frac{R_m \cdot b \cdot t^2}{W}$$

R_m = tensile strength, (MPa)
t = plate thickness, (mm)
C = constant (1.5)
b = lenght to be bent, (mm)
W = width of the V groove, (mm)

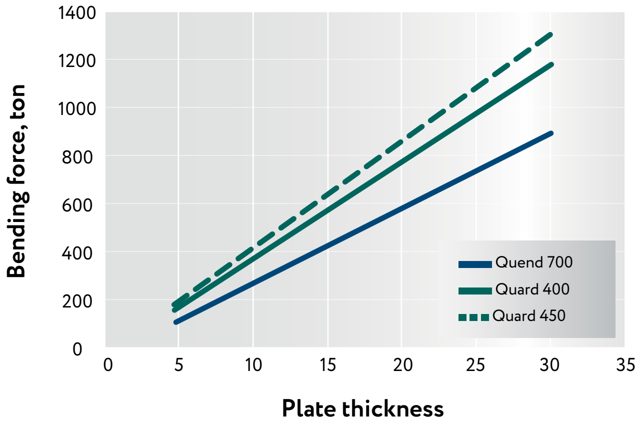
Example:
Quard 400:
R_m: 1,250 MPa;
plate thickness (t) = 10 mm;
bending length (b) = 2,500 mm;
Die width (W): 120 (W = 12 x t).

Calculation of bending force:

$$F\ (\text{Newton}) = 1.5 \times \frac{(1{,}250 \times 2{,}500 \times 10^2)}{120}$$

F = 3906250 Newton / 10,000
= 391 ton, (see graph)

Bending force required when bending Quard 400, 450 and Quend 700 plates in lengths of 2,500 mm shown in plate thickness.



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NLMK Europe – Plate

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