SSAB OXELÖSUND

Bending/shearing

WELDOX®
STRUCTURAL STEEL PLATE

HARDOX®
WEAR PLATE

This publication deals with free bending and shearing of HARDOX® wear plate and WELDOX® structural steel plate. In these steel grades, we have combined high strength with high purity, and we maintain close tolerances on thickness, which makes the steels eminently well suited for cold bending.

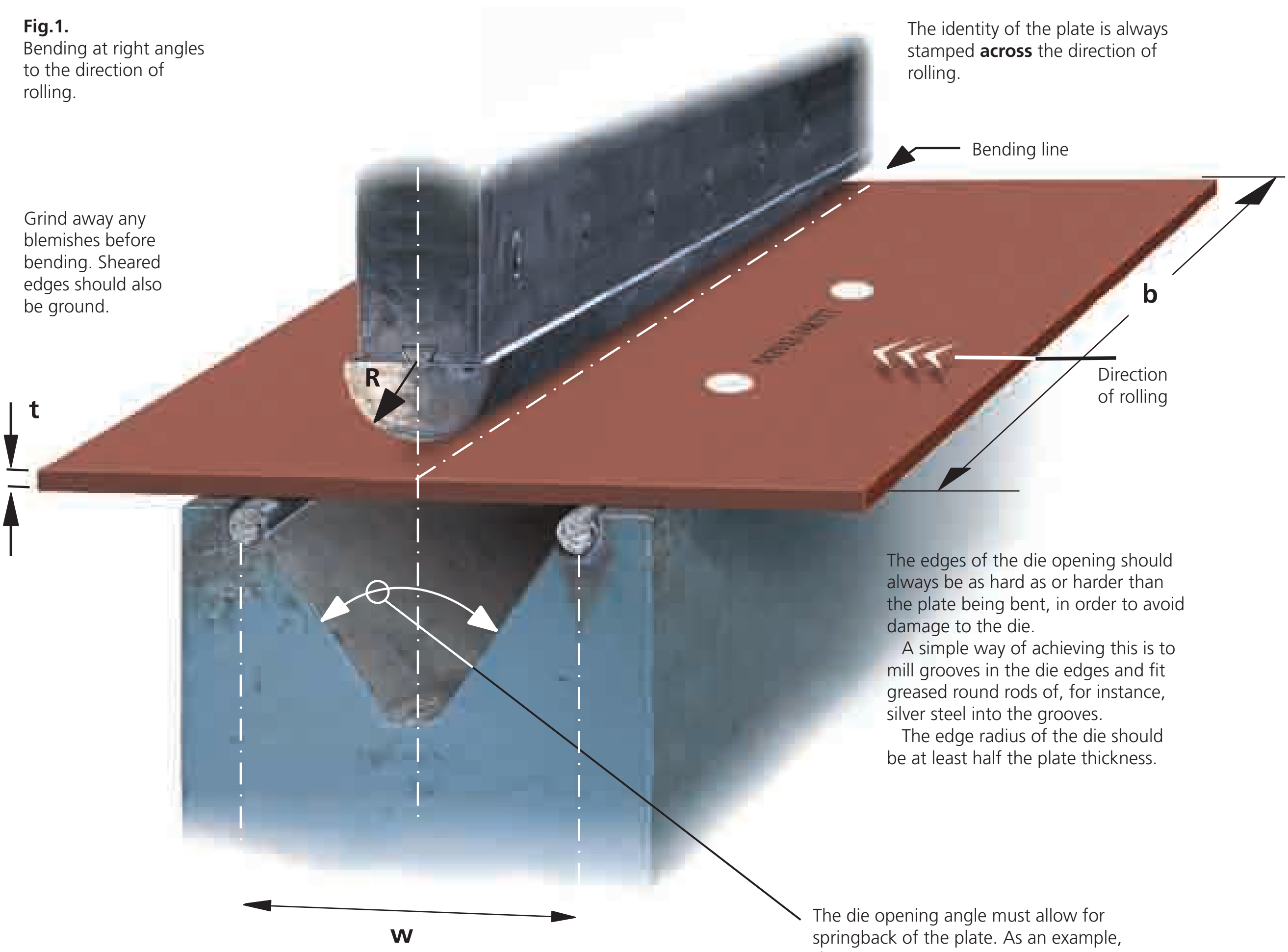
Our recommendations for best results when bending and shearing our wear resistant and high strengths steels are outlined below.

Bending

This section deals with free bending, although roll bending can obviously also be employed.The bending results are dependent on a number of factors which we have grouped here under three headings:
the plate, the tools and the procedure. These factors are discussed on pages 3 and 4, where a couple of worked examples are also given.

Typical physical properties of the materials are given in Table 4 on the last page.

Fig.1.
Bending at right angles to the direction of rolling.



The results of a bending operation are affected by the plate, the tools and the procedure employed:

THE PLATE

– Steel grade

Note that the bending force and springback increase with the plate strength. (For typical tensile strength values, see Table 4.)

So the stronger and harder the plate,
– the higher the necessary bending force
– the greater will be the springback
– the larger the punch radius needed
– the larger the punch radius needed

– Plate surface

Our recommendations apply to shotblasted and anti-corrosion painted plate. Surface damage and rust on the side of the plate which is under tension during bending may greatly reduce the bendability. In critical cases, such defects must be ground away.

– Plate edges

Cut and sheared edges should be deburred and rounded with a grinder.

– Plate thickness (t)

As a general rule, thinner plate can be bent to smaller radii. SeeTable 1.

– Direction of rolling of the plate

The plate can be bent to a smaller radius at right angles to the direction of rolling than in the direction of rolling. See Figure1 and Table 1.

– Bend length (b)

If the bend length (see Figure 1) is less than 10 times the plate thickness, the plate can often be bent to a smaller radius than the values given in Table 1.

THE TOOLS

– Punch radius (R)

The right punch radius is the most important factor when bending HARDOX and WELDOX. (See Figure 1.)

For the softer steels – up to and including WELDOX 500 – a punch radius which is equal to or somewhat smaller than the required bending radius is recommended.

For stronger steels, a punch radius which is equal to or somewhat larger than the required bending radius is recommended.

Table 1 gives the minimum recommended punch radius that will avoid cracking when the plate is bent to 90°.

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Table 1.
Minimum recommended punch radius (R) and die opening width (W) for plate thickness (t) when the plate is being bent to 90° along the direction of rolling and at right angles to the direction of rolling – and also the corresponding springback.

	Thickness [mm]	At right angles R/t	Along R/t	At right angles W/t	Along W/t	Springback [°]
S 355 acc to EN 10025		2,5	3,0	7,5	8,5	3-5
WELDOX 700	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	1,5 2,0 3,0	2,0 3,0 4,0	7,0 7,0 8,5	8,5 8,5 10,0	6-10
WELDOX 900/960	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	2,5 3,0 4,0	3,0 4,0 5,0	8,5 8,5 10,0	10,0 10.0 12,0	8-12
WELDOX 1030	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	3,0 3,5 4,5	3,5 4,5 5,5	9,0 9,0 11,0	10,0 11.0 13,0	10-32
WELDOX 1100	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	3,5 4,0 5,0	4,0 5,0 6,0	10.0 10,0 12,0	10,0 12,0 14,0	11-18
WELDOX 1300	**t** < 6 6 ≤ **t** < 10	3,5 4,0	4,0 5,0	10,0 12,0	12,0 14,0	12-45
HARDOX 400	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	2,5 3,0 4,5	3,0 4,0 5,0	8,5 10,0 12,0	10,0 10,0 12,0	9-13
HARDOX 450	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	3,5 4,0 5,0	4,0 5,0 6,0	10,0 10,0 12,0	10,0 12,0 14,0	11-18
HARDOX 500	**t** < 8 8 ≥ **t** < 20 **t** ≥ 20	4,0 5,0 7,0	5,0 6,0 8,0	10,0 12,0 16,0	12,0 14,0 18,0	12-20

Care should be taken during all bending – due to the high strength of the plate and the high bending force necessary. If the plate should crack, fragments of the materialmay fly off. During bending, the operator and other personnel must therefore <u>not stand in front of the machine – they should move to the side</u>.

THE TOOLS (cont'd)

– Die opening width (W)

Table 1 specifies the minimum recommended die opening for minimizing the springback. If the width is increased, the bending force and impression marks will admittedly be reduced, but at the expense of increased springback.
Note that the opening angle must be so small that it will allow a sufficient amount of over-bending. (See Figure1 and Table 1.) In roll bending, the springback will be much larger than the tabulated values.

BENDING PROCEDURE

– Friction

The die edges must be clean and undamaged. The bending force needed and the risk of cracking can be reduced by using round rods free to rotate as die edges and/or by lubricating the die edges.

– Bending angle

The recommendations in Table 1 relate to bending to an angle of 90 degrees.

Note that the bending angle has a lesser effect on the force needed and the springback than the die opening width and steel grade.

Springback can be compensated by over-bending by the same number of degrees.

– Bending force (P)

The bending force necessary can be estimated using the formula below. The force is obtained in tonnes (1 tonne corresponds to 10 kN), with an accuracy of ±20%, provided that all dimensions used are in mm. For symbols used, see Figure 1. The tensile strength R_m of the plate can be obtained from Table 4.

$$P = \frac{1{,}6 \times b \times t^2 \times R_m}{10000 \times W}$$

If the radius of the punch used for bending is much larger than that specified in Table 1, the force needed may be higher than the value obtained from the formula, unless the die opening width is increased correspondingly.

Example 1:

A certain edging press is only just capable of bending a 20 mm thick EN10025 – S355 steel plate in a die with a 150 mm wide opening.

If the same die is used and the bend length is the same, how thick will be the HARDOX 400 plate that the machine is capable of bending?

The bending forces should be same, and only the plate thickness (t) and tensile strength (R_m) will differ. Substituting in the above formula and simplifying:

$20^2 \times 550 = t^2 \times 1250$

The thickness (t) of the HARDOX plate will be 13.3 mm.

The W/t ratio for HARDOX 400 plate will then be 150/13.3 = 11.3 which, according to Table1, is satisfactory.

Example 2:

A 2000 mm long bracket is to be produced by bending plate. The choice lies between using:

a) 10 mm thick plate of EN10025 – S355 with a typical tensile strength of 550 MPa, or

b) 7 mm thick plate of WELDOX 700 with a typical tensile strength of 860 MPa

In both cases, an existing die with a 100 mm wide opening is to be used. What press force will be needed for each steel grade?

For EN10025 – S355:

$$P = \frac{1{,}6 \times 2000 \times 10 \times 10 \times 550}{10000 \times 100} = 176 \text{ tonnes}$$

For WELDOX 700:

$$P = \frac{1{,}6 \times 2000 \times 7 \times 7 \times 860}{10000 \times 100} = 135 \text{ tonnes}$$

Since the plate thickness has a greater influence than the strength, the force needed for bending WELDOX-plate in this particular case is lower.

	Plate thicknesses, mm			
S 355 – EN 10025	10	20	30	60
WELDOX 700	8	16	24	48
WELDOX 900 / 960	7	14	21	42
HARDOX 400	6	13	19	38
Bending force per metre [tonnes]	120	240	330	660
... at a die opening width (W) [mm]	75	150	240	480

Table 2
Plate thicknesses that require the same bending force per metre of bend length, with the die opening widths (W) shown in the table.

Shearing in power shears

High strength steels can also be sheared. As a general rule, the higher the tensile strength, the higher the shearing force needed. Tool wear also increases with increasing tensile strength, and shearing WELDOX 1100, HARDOX 450 and higher strength steels is therefore inadvisable.

Satisfactory results in shearing high strength plate pre supposes good tools and correct setting of the shearing parameters. Note that our setting suggestions are only *general recommendations*. In practice, the choice is dictated by the machine stability and the condition of the blades.

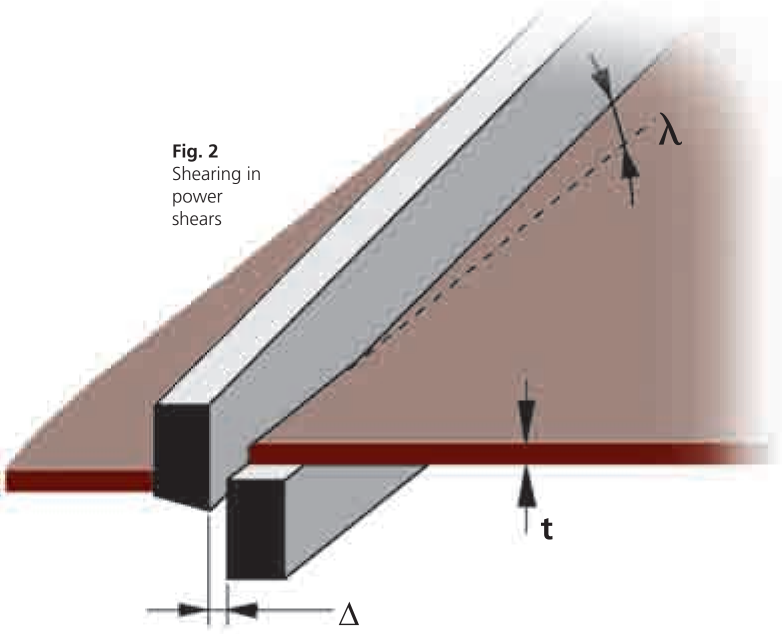
Blades
The blades should be hard and sharp, with slightly rounded edges.

Clearance Δ
This is the most important parameter for achieving good results. The clearance between the moving and stationary blades should be increased with increasing tensile strength (see Table 3). Incorrect clearance will result in poor sheared surfaces and may give rise to cracking when the plate is subsequently welded or bent.

Rake angle λ
The larger the rake angle, the lower the shearing force, although the risk will be greater of the plate sliding sideways or the piece of plate that has been sheared off deforming (twisting). As a general rule, the rake angle should be increased when shearing high strength plate. See Fig. 2 and Table 3 below.

Shearing force P
For a given rake angle, the shearing force increases linearly with increasing strength of the plate. See Fig. 3 and Table 4.

Fig. 2
Shearing in power shears



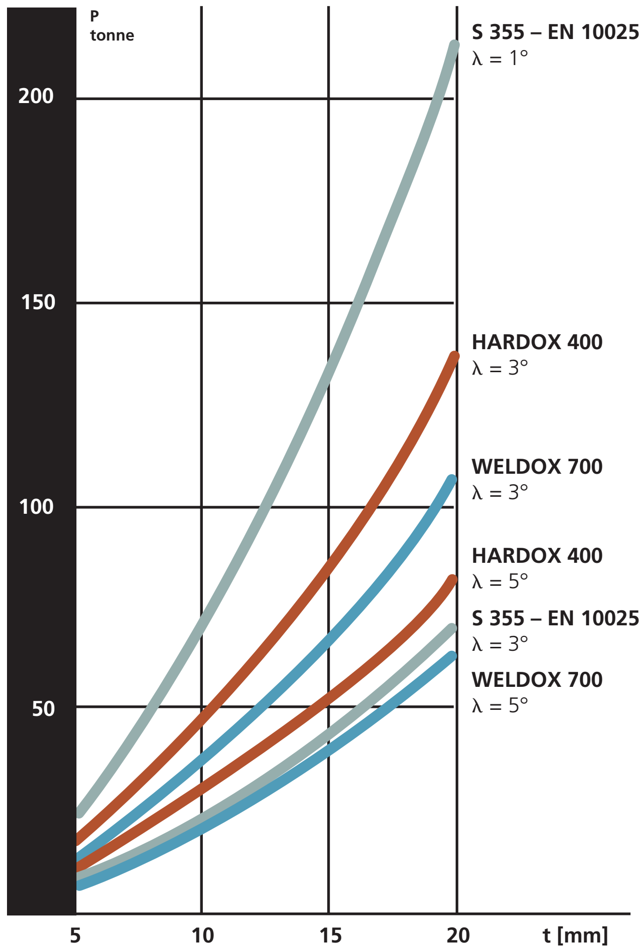


Fig. 3. Shearing force as a function of the thickness and rake angle λ

Table 3. Clearance and rake angle settings for different plate grades

	Clearance, Δ in % of t	Rake angle, λ [°]
S 355 – EN 10025	8-10	1-5
WELDOX 700	12-15	3-5
WELDOX 900	14-16	3-5
WELDOX 960	14-16	3-5
HARDOX 400	16-18	3-5

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Table 4.
Typical physical properties

	Tensile strength R_m [MPa]	Elongation A_5 [%]	Hardness [HBW]
S 355 acc to EN10025	550	28	~ 180
WELDOX 700	860	17	~ 270
WELDOX 900	1030	15	~ 330
WELDOX 960	1070	15	~ 340
WELDOX 1030	1340	11	~ 430
WELDOX 1100	1440	11	~ 460
WELDOX 1300	1540	10	~ 490
HARDOX 400	1250	10	~ 400
HARDOX 450	1440	9	~ 450
HARDOX 500	1550	8	~ 500

For further information, please get in touch with ourTechnical Customer Service Department.

The *Bending/shearing* brochure is included in a series of publications intended to give advice and guidance on using HARDOX and WELDOX plate. The *Welding* and *Machining* brochures are also included in this series. Requisition them through our Market Communications Department.

SSAB OXELÖSUND

SSAB Oxelösund AB
SE-613 80 Oxelösund
Sweden

Tel: + 46 155 25 40 00
Fax: +46 155 25 40 73
www.ssabox.com