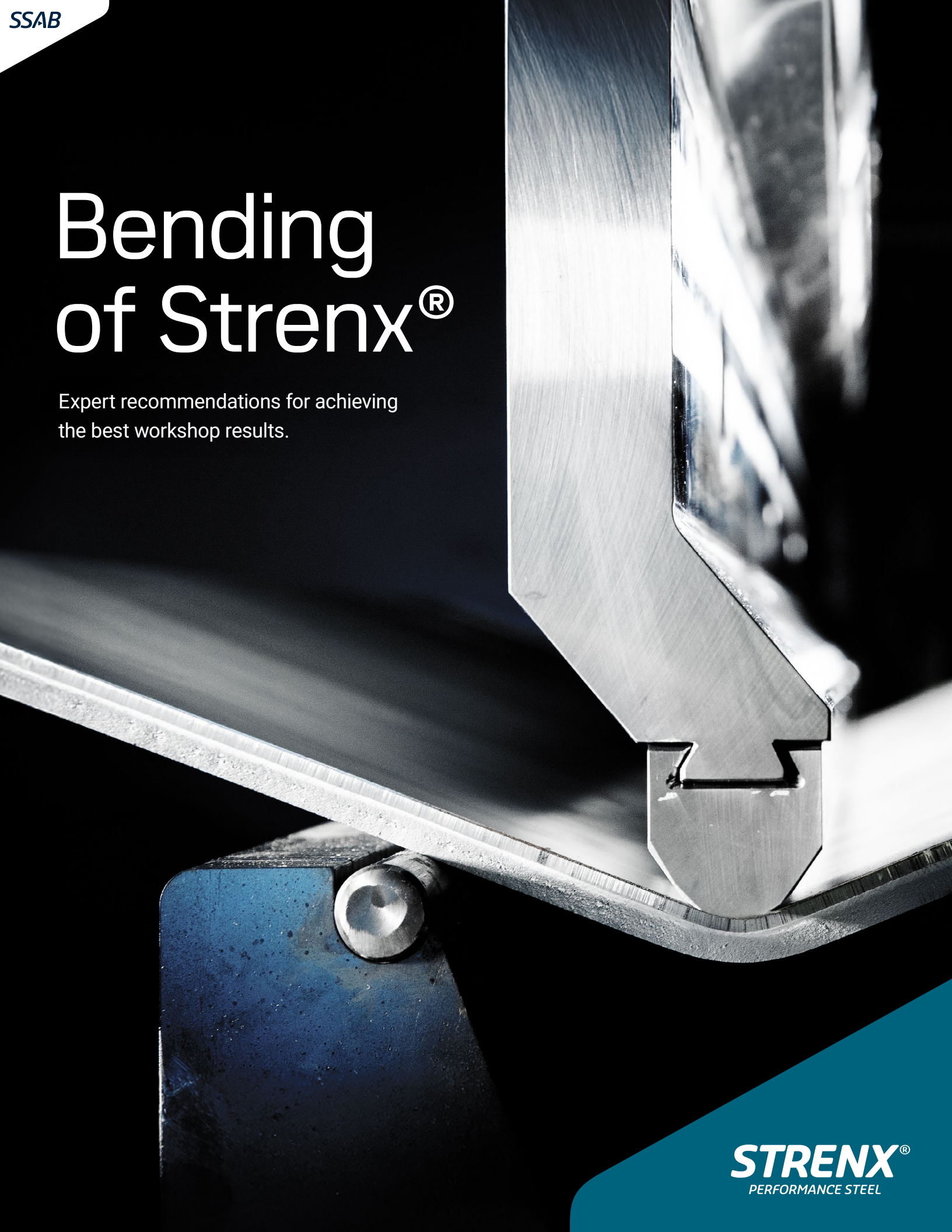
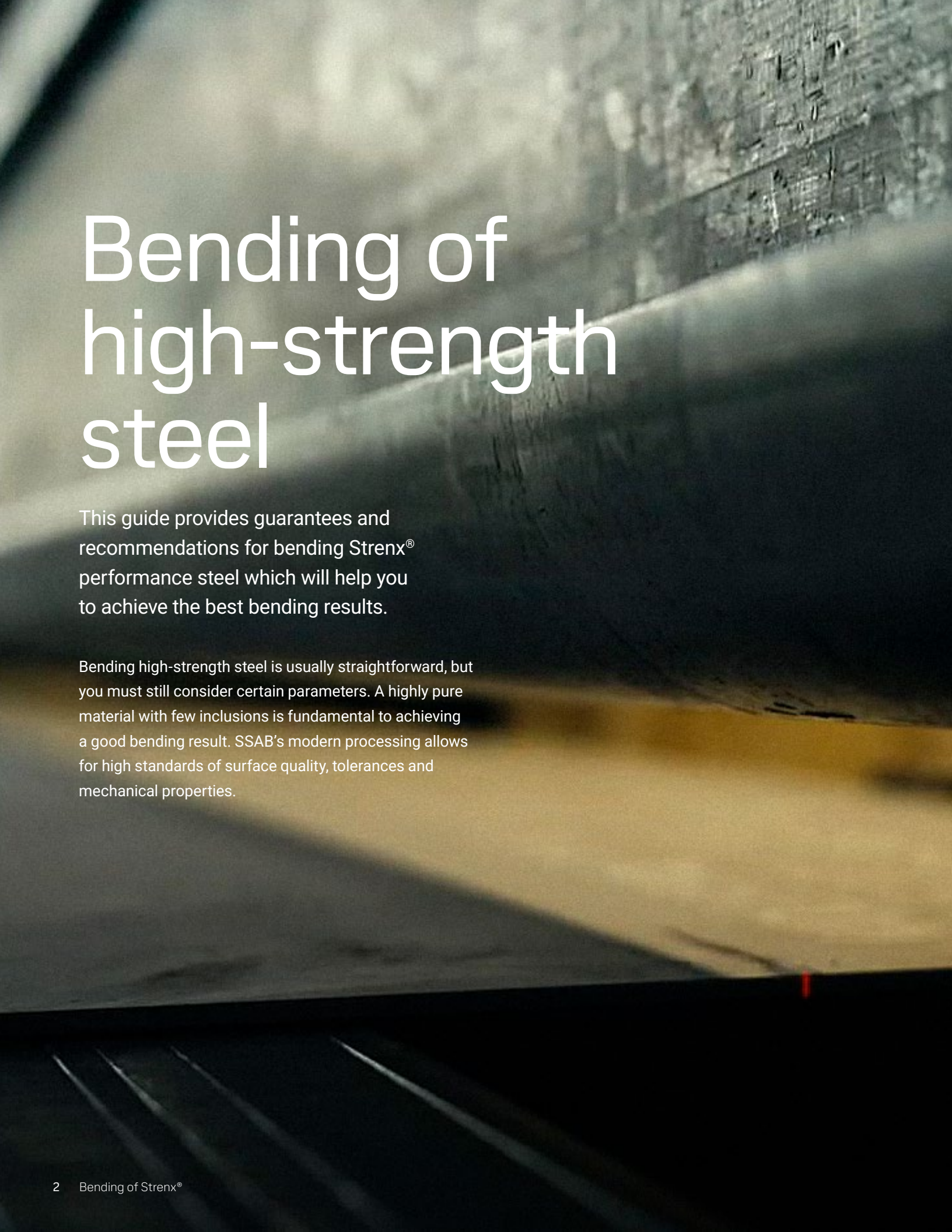


Bending of Strenx[®]

Expert recommendations for achieving
the best workshop results.





Bending of high-strength steel

This guide provides guarantees and recommendations for bending Strenx® performance steel which will help you to achieve the best bending results.

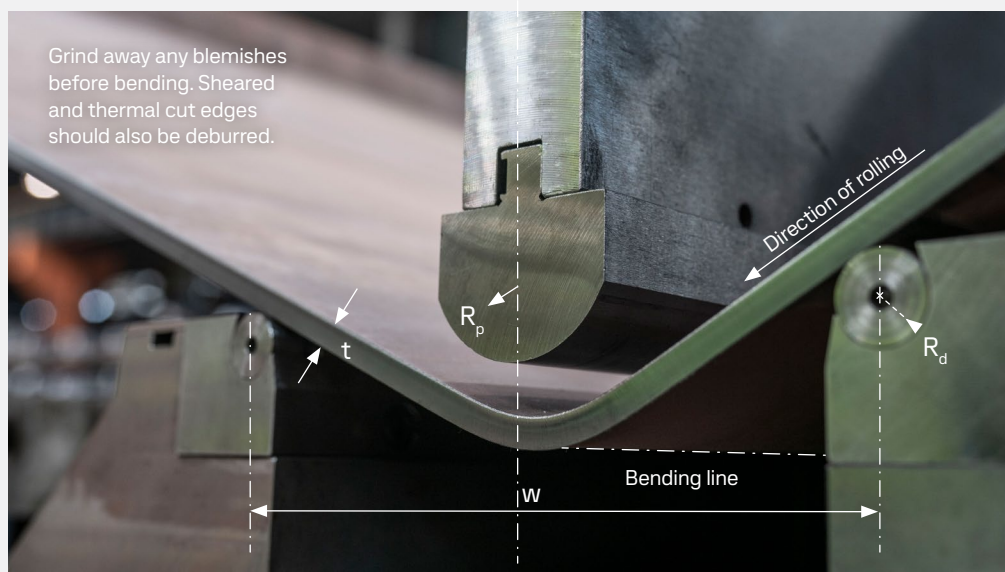
Bending high-strength steel is usually straightforward, but you must still consider certain parameters. A highly pure material with few inclusions is fundamental to achieving a good bending result. SSAB's modern processing allows for high standards of surface quality, tolerances and mechanical properties.

Preparation before bending

- Check the rolling direction of the plate. If possible, orient the rolling direction perpendicular to the bend line. The plate can often be bent tighter this way than with the bend line parallel to the rolling direction. See Figure 1.
- Check the surface quality of the plate. Surface damage can worsen bendability as it can be the cause of fractures. For heavy plates, defects on the plate such as scratches and rust can often be removed with careful grinding. Grinding scratches shall preferably be placed perpendicular to the bend line.
- Thermally cut and sheared edges should be deburred and rounded with a grinder.
- Check the condition of your tools, making sure they are not worn beyond tolerance and that surfaces are smooth.
- To avoid excessive tool wear, tooling should be harder than the workpiece.
- Check that the tools and tool setup are in line with the recommendations given in this brochure.

FIGURE 1

Bending transverse to the rolling direction.



Check the rolling direction of the plate. If possible, orient the rolling direction perpendicular to the bend line. The plate can often be bent tighter this way than with the bend line parallel to the rolling direction.

Check the condition of your tools. To avoid excessive tool wear, tooling should be harder than the workpiece. Check that the tools and tool setup are in line with the recommendations given in this brochure.

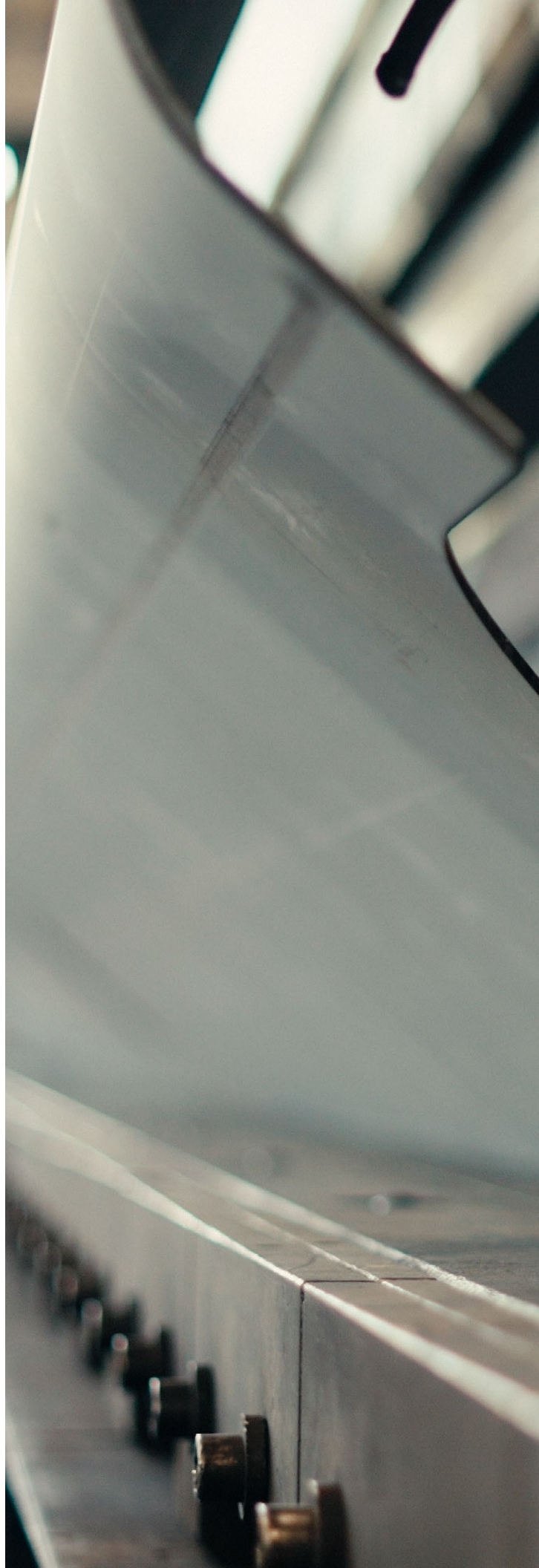
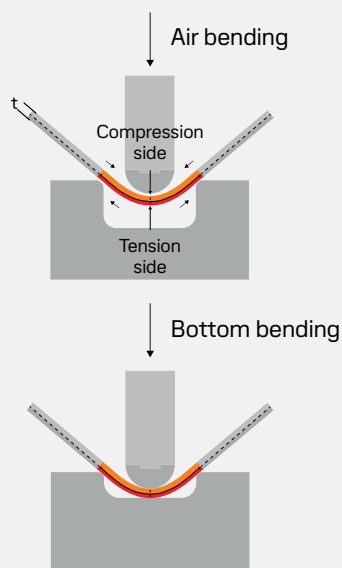
R_d = Die entry radius
 R_p = Punch radius
 W = Die width
 t = Thickness

To consider

- Always take safety precautions and follow local safety regulations. Only qualified people may be by or in the vicinity of the machine. When high-strength steel is being bent, nobody should stand in front of the press brake.
- Make sure the punch and workpiece do not bottom out in the die. See Figure 2.
- Consider springback. Avoid rebending to correct the profile angle. The exposure of a material to previous forming processes reduces its bendability to a great extent.
- Bending force, springback and, in general, minimum guaranteed inner radius increase with the strength of the steel.
- In many Strenx® plate products, the identity of the plate is stamped perpendicular to the rolling direction. Avoid placing the bend line over the stamp due to the risk of cracking.
- Excessive blast cleaning can have a negative effect on bendability. Recommendations for Strenx® plate products are based on tests with blast cleaned and painted surfaces.
- High strain rate may cause a local temperature increase in the bend. This could have an adverse impact on the bendability, especially for thicknesses above 0.787 in. If possible, reduce the punch speed in order to decrease the temperature difference within the workpiece.

FIGURE 2

The difference between air bending and bottom bending.





Tools

Die width

Springback increases with die width, while bending force is reduced. Make sure that the opening angle and depth of the die allow for over-bending without bottoming out, to compensate for springback. An increased die opening width can in many cases lower the strain level in the bend. Also, make sure that there is enough room for the chosen punch together with the workpiece in the die during bending, without deforming the die. The minimum recommended die opening widths are shown in Tables 2 and 3.

The die edge radius should be at least half the plate thickness. Alternatively, the die width should be increased in order to minimize pressure on the die edge radius, and consequently reduce the risk of die marks.

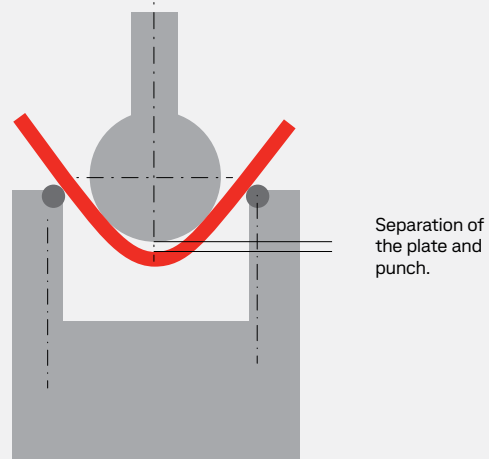
Punch

The suitable punch radius, along with the die width, is the most important parameter when bending Strenx®. The final inner radius often becomes somewhat smaller than the radius of the punch. See Figure 3. When there is low friction between plate and tools, the phenomenon becomes more obvious.

For a steel with a yield strength over approximately 87 ksi, a punch radius that is bigger than the desired remaining inner radius should be used. Tables 2 and 3 on page 11 show the recommended initial punch radius when bending to 90°, along with the minimum guaranteed inner radius. Use the recommended initial punch radius to test the achievable inner radius for your specific tools.

FIGURE 3

Separation of the plate during bending.



Condition of tools

Due to the increased contact pressure between plate and tools when bending high-strength steel, wear on the tools increases somewhat. Check regularly that the punch radius and die edge radius are both constant. For bent material that has cracked during manufacturing of a component or part, the crack has in many cases propagated from the compression side of the bend. This can often be attributed to poor punch condition. The edges of the die should remain clean and undamaged.

Machine stability

The forces are often high when bending high-strength steel. The force from the punch acts on the surface of the steel and the friction between the steel and the tools will affect the bending result and the required force.

The static friction coefficient is typically higher than the kinetic friction coefficient. This can cause the plate to lock over the edge of one die edge radius, and at the same time slide over the other one. In this way, the workpiece swings down into the die in a discontinuous way during the bending process. This phenomenon, called stick-slip, can result

in higher strains over the bend. Use a stable machine and steady tool fastening. Lubrication of the die edge or use of a rotating die edge radius can be helpful, avoiding stick-slip and also lowering the bending force.

Crowning

Crowning compensates for the elastic deflection of the bending machine under load. See Figure 4. The central parts of the punch and die deflect the most. By crowning, the deflection (C) can be compensated for, thus achieving the same bending angle along the entire blank length. If the bend profile becomes curved along the bend line (B), this cannot be compensated for by crowning.

After unloading, compressive stresses arise on the stretched side at the same time as tensile stresses appear on the compressed side. See Figure 2. The stress distribution over the plate thickness causes longitudinal stresses. It is those stresses that tend to curve the profile. The magnitude of curvature depends mainly on the flange height and the profile stiffness.

Additional considerations have to be made when setting the crowning at stepwise bending of long profiles.

FIGURE 4
Crowning

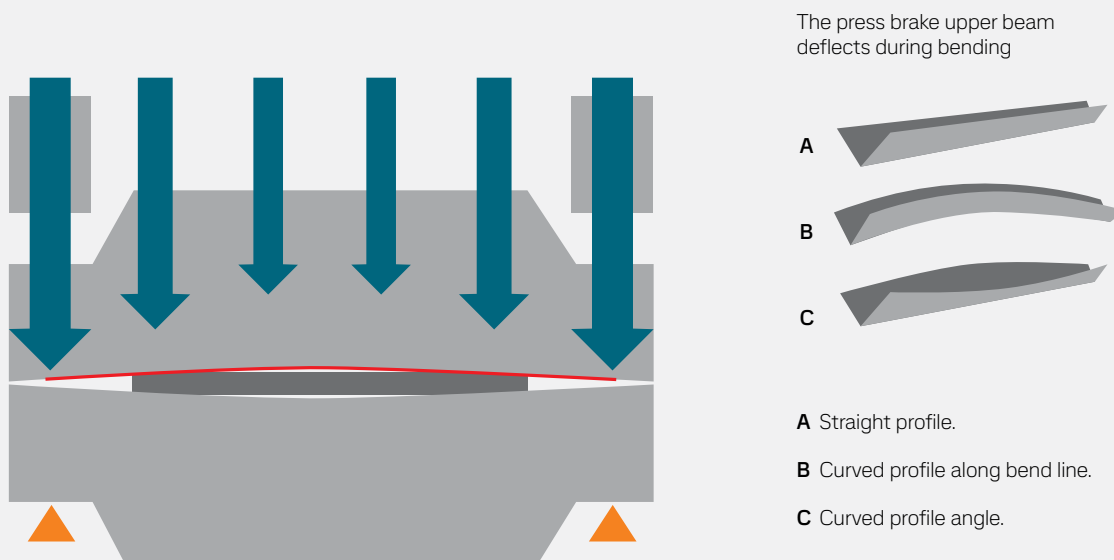






TABLE 1

Typical tensile strength values to calculate bend force.

Grade	Typical tensile strength (ksi)
Strenx® 100	122
Strenx® 100 XF	116
Strenx® 110 XF	123
Strenx® 700 E/F	123
Strenx® P700	123
Strenx® 700 OME	123
Strenx® 900 E/F	148
Strenx® 960 E/F	154
Strenx® 1100 E/F	206
Strenx® 1300 E/F	220
Strenx® 600MC D/E	106
Strenx® 650MC D/E	116

Grade	Typical tensile strength (ksi)
Strenx® 700MC D/E	123
Strenx® 700MC Plus	119
Strenx® 700 CR	158
Strenx® 900MC	155
Strenx® 900 Plus	151
Strenx® 960MC	161
Strenx® 960 Plus	158
Strenx® 960 CR	174
Strenx® 1100MC	191
Strenx® 1100 CR	203
Strenx® 700 HR W	126
Strenx® 700 CR W	158
Strenx® 960 HR W	167

Bending force

To estimate the force needed during bending, consider not only the bend length, plate thickness, die width and tensile strength, but also the changing moment arm during bending.

The peak load is assumed to be reached at a bend opening angle of 120° with normal friction (no lubrication). Trial tests are always recommended.

$$P = \frac{b \times t^2 \times R_m}{2 \times (W - R_d - R_p)}$$

P = Bend force, US short tons-force
(1 US short ton-force = 2,000 lbf)

t = Plate thickness, in.

W = Die width, in. (Figure 1)

b = Bend length, in.

R_m = Tensile strength, ksi (Table 1)

R_d = Die entry radius, in.

R_p = Punch radius, in.

SSAB



SSAB BendCalc

To get the correct bending settings for Strenx®, please consult SSAB's BendCalc – the first software that predicts springback and punch depth. It's free and available at ssab.com.

Based on the steel characteristics, die and tool symmetry, final bend shape, and friction conditions, the BendCalc app gives you the result in seconds:

- Maximum bend force
- Springback
- Punch depth
- Opening angle during maximal stroke
- Minimum flange height

You can save the results and share the report as a PDF.

Springback

Springback increases with steel strength and the ratio between die width and plate thickness (W/t). Material yield strength has the biggest influence.

When bending, a varying residual stress distribution is achieved over the bend cross section. The plastic strain level and the distribution of these stresses will control the tendency for springback. All springback is fully elastic.

To compensate for springback, the die should be shaped to allow overbending without coining the material.

It is very difficult to accurately predict the springback of a material when bending, since this depends to a large extent on each unique tool setup. That is one reason why trials are recommended. For thinner plate or sheet ($t < 0.394$ in.), you can estimate the material's springback by dividing the tensile strength (ksi) by 14.5.

A precondition is that the die width meets our recommended minimum die opening width.

Parameters that affect springback:

- Yield strength of the material – higher yield strength causes greater springback.
- Punch radius – increased punch radius will cause greater springback.
- Die width – larger die width causes greater springback.
- The strain hardening of the material.

Bending guarantees and recommendations

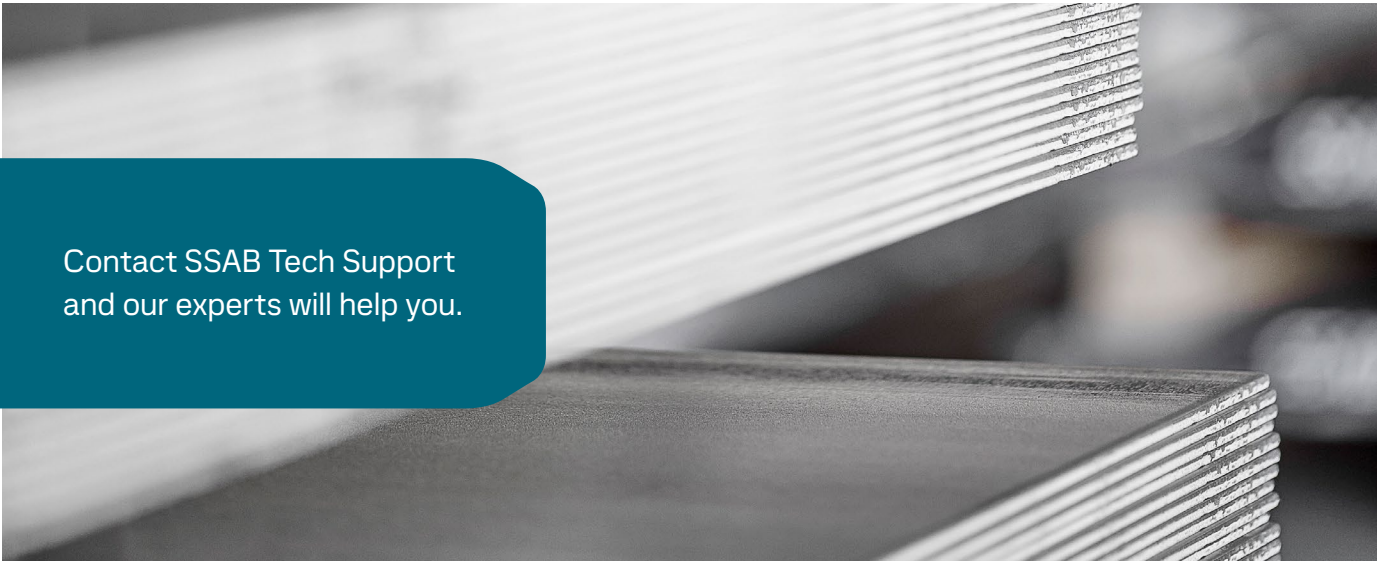
Since SSAB's products are developed and specialized for different types of use, bend tests and evaluation of these vary somewhat.

The guaranteed minimum inner radius is shown in Tables 2 and 3. There are also values for the recommended initial punch radius, which is a starting point for determining the achievable inner radius with the specific tools and setup.

These bending guarantees and recommendations are based on bend tests of one step to 90° after unloading. Die opening widths are guidelines and may vary somewhat.

For information about other materials and more technical information, please contact Tech Support or visit www.ssab.com.

Strenx® is delivered with guaranteed bending performance according to the Strenx® guarantee. For more information, contact your local SSAB representative.



Contact SSAB Tech Support
and our experts will help you.

TABLE 2 STRENX® PLATE, BENDING GUARANTEES AND RECOMMENDATIONS

The bending guarantees and recommendations for Strenx® plate are based on dies with rolls and normal friction (no lubrication). R/t stands for radius (R) divided by plate thickness (t).

Grade/Product	Nominal thickness (t) (in.)	Guaranteed minimum final inner radius on plate		Recommended initial punch radius		Recommended die opening width
		R _t /t transverse to rolling direction	R _t /t along rolling direction	R _p /t transverse to rolling direction	R _p /t along rolling direction	
Strenx® 700 E/F	t < 0.315	1.5	1.8	2.0	2.5	10
Strenx® 100	0.315 ≤ t < 0.591	1.5	1.8	2.0	2.5	10
Strenx® P700	0.591 ≤ t < 0.787	1.7	2.1	2.0	2.5	12
Strenx® 700 OME	t ≥ 0.787	2.0	2.2	2.6	2.8	12
Strenx® 900 E/F Strenx® 960 E/F	t < 0.315	2.3	2.5	2.8	3.0	12
	0.315 ≤ t < 0.591	2.3	2.6	2.8	3.2	14
	0.591 ≤ t < 0.787	2.4	2.7	2.8	3.2	14
	t ≥ 0.787	2.8	3.4	3.0	3.5	16
Strenx® 1100 E/F	t < 0.315	2.8	3.3	3.2	3.6	12
	0.315 ≤ t < 0.591	3.4	3.6	3.8	4.0	14
	0.591 ≤ t < 0.787	3.4	3.6	3.8	4.0	14
	t ≥ 0.787	3.7	4.0	4.2	4.5	16
Strenx® 1300 E/F	t < 0.315	3.1	3.8	3.5	4.0	14
	0.315 ≤ t ≤ 0.591	3.6	4.3	4.0	4.5	14

TABLE 3 STRENX® SHEET, BENDING GUARANTEES AND RECOMMENDATIONS

The bending guarantees and recommendations for Strenx® sheet are based on dies with rolls and normal friction (no lubrication). R/t stands for radius (R) divided by sheet thickness (t).

Grade/Product	Nominal thickness (t) (in.)	Guaranteed minimum final inner radius on sheet		Recommended initial punch radius		Recommended die opening width
		R _t /t transverse to rolling direction	R _t /t along rolling direction	R _p /t transverse to rolling direction	R _p /t along rolling direction	
Strenx® 600MC D/E	t ≤ 0.118	0.7	0.7	0.7	0.7	10
	0.118 < t ≤ 0.236	1.1	1.1	1.1	1.1	10
	t > 0.236	1.4	1.4	1.4	1.4	10
Strenx® 650MC D/E Strenx® 100 XF	t ≤ 0.118	0.8	0.8	0.8	0.8	10
	0.118 < t ≤ 0.236	1.2	1.2	1.2	1.2	10
	t > 0.236	1.5	1.5	1.5	1.5	10
Strenx® 700MC D/E Strenx® 110 XF	t ≤ 0.118	0.8	0.8	1.0	1.0	10
	0.118 < t ≤ 0.236	1.2	1.2	1.4	1.4	10
	t > 0.236	1.6	1.6	1.7	1.7	10
Strenx® 700 HR W	0.118 ≤ t ≤ 0.236	1.2	1.2	1.4	1.4	10
	t > 0.236	1.6	1.6	1.7	1.7	10
Strenx® 700MC Plus	0.118 ≤ t ≤ 0.393	1.0	1.0	1.3	1.3	10
	t ≥ 0.394	1.5	1.5	1.8	1.8	10
Strenx® 900MC	0.118 ≤ t ≤ 0.315	3.0	3.0	3.7	4.0	12
	t > 0.315	3.5	3.5	4.0	4.5	12
Strenx® 900 Plus	0.079 ≤ t ≤ 0.315	3.0	3.0	4.0	4.0	12
Strenx® 960MC	0.118 ≤ t ≤ 0.393	3.5	3.5	4.0	4.0	12
Strenx® 960 Plus	0.079 ≤ t ≤ 0.315	3.5	3.5	4.0	4.2	12
Strenx® 960 HR W	0.118 ≤ t ≤ 0.240	3.5	3.5	4.0	4.0	12
Strenx® 1100MC	0.118 ≤ t ≤ 0.315	4.0	4.0	4.7	5.0	14
Strenx® 700 CR Strenx® 700 CR W	0.028 ≤ t ≤ 0.083	2.0	2.0	2.5	2.5	10
Strenx® 960 CR	0.031 ≤ t ≤ 0.083	3.5	3.5	4.5	4.5	12
Strenx® 1100 CR	0.031 ≤ t ≤ 0.083	3.5	3.5	4.5	4.5	14

SSAB is a Nordic and US-based steel company. SSAB offers value-added products and services developed in close cooperation with its customers to create a stronger, lighter and more sustainable world. SSAB has employees in over 50 countries. SSAB has production facilities in Sweden, Finland and the US. SSAB is listed on Nasdaq Stockholm and has a secondary listing on Nasdaq Helsinki.

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