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ABREX™ Guidelines for Bending
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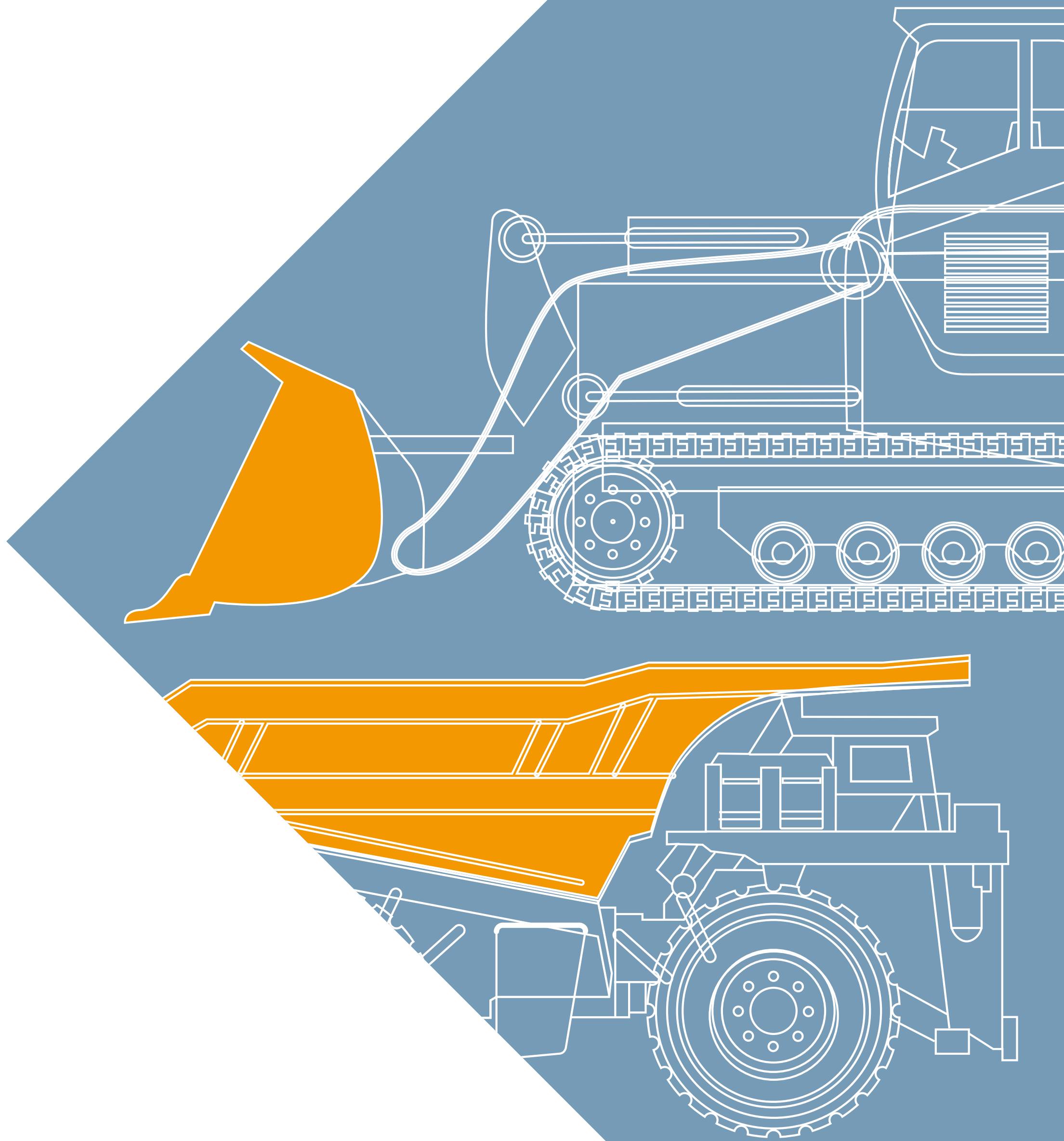
NIPPON STEEL

Steel Plates

ABREX™

Guidelines for Bending



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The abrasion-resistant steel plate “ABREX™ Series” from NIPPON STEEL enjoys broad support as an abrasion-resistant material for construction equipment and many other types of industrial machinery.

ABREX™ is a steel material with excellent abrasion resistance and a certain level of bendability at ordinary temperatures. As it is high-hardness steel, you are asked to use this material only after fully understanding its properties and performance. Improper bending of this steel material may cause cracking and other problems. We hope you will find these guidelines useful for proper and efficient use of ABREX™.

This brochure is provided for reference only for bending to be performed by the users of ABREX™ steel plate, in order to describe typical bending methods and other related information. Although NIPPON STEEL has made every effort to ensure that the information in this publication is correct, it is furnished without any warranty, express or implied, as to its accuracy, completeness or fitness for any particular use, or with respect to the results that may be obtained by any person using it. Accordingly, the use of any information provided herein is at the reader's own risk, and it is the reader's responsibility to determine whether it is suitable for the reader's intended application. The information in this publication is subject to change without notice. Nothing in this brochure is intended as a recommendation to use any product, method or process in violation of any intellectual property rights governing such product, method or process. NIPPON STEEL DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION WARRANTIES OF MERCHANTABILITY AND FITNESS FOR ANY PARTICULAR PURPOSE RELATED TO ANY INFORMATION PROVIDED HERIN.

Preparations before Bending

Precautions for Bending

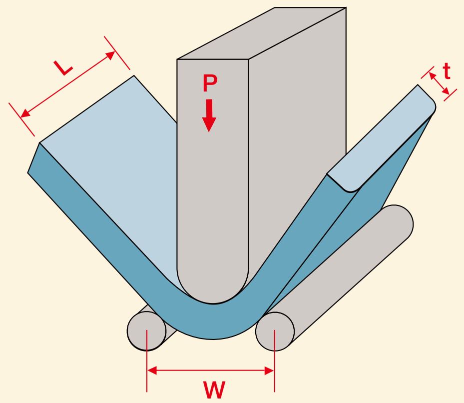
1. Bending Force Prediction (Bending Machine Selection)

The rough estimates of required bending forces can be obtained using the following formula. After calculating an appropriate bending force for a specific operation, the best bending machine will be selected.

$$P_{[ton]} = 2.0^{*1} \times \frac{L \times t^2 \times \sigma_B}{W \times 9800}$$

*1 The value of this coefficient varies depending on the friction between the bending dies and the steel plate, the rotational smoothness of the dies, the diameter of the dies, and other factors. The 2.0 is a value slightly larger than needed, on the assumption that the dies will not rotate. It is recommended to run test bending to make sure the value of this coefficient is appropriate.

Denotations



- P : Bending force [ton]
- L : Bending length [mm]
- t : Steel plate thickness [mm]
- σ_B : Tensile strength [N/mm²]
- W : Distance between the dies [mm]

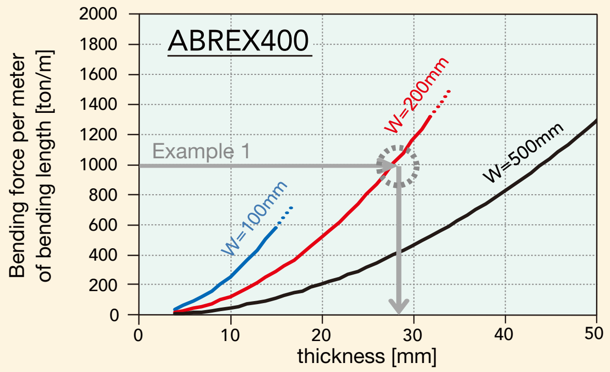
In this case, the diameter of the dies is set at zero for ease of calculation.

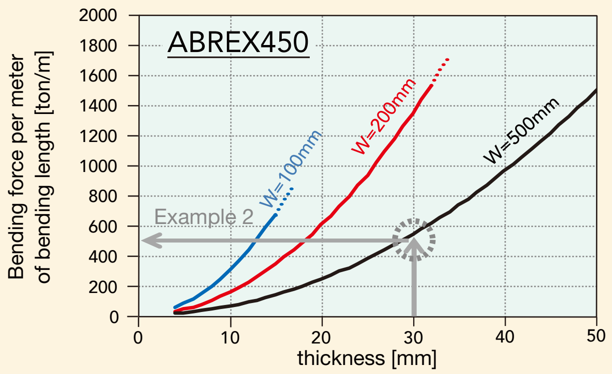
σ_B : Value examples
- ABREX400 (25mm) : 1259 [N/mm²]
- ABREX450 (25mm) : 1469 [N/mm²]
- ABREX500 (25mm) : 1552 [N/mm²]

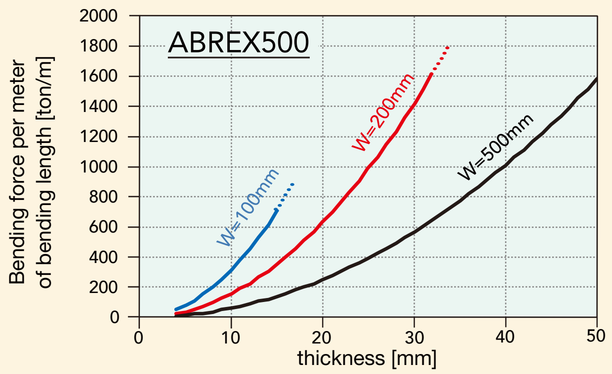
The following figures show the results of bending force calculations using the above formula. These figures will be handy when estimating the maximum thickness of ABREX™ that you can possibly bend on your bending machine.

Example 1: If your bending machine has a bending capacity of 1000ton/m and W (distance between the dies) is set at 200mm, you can bend ABREX400 with a thickness of up to about 28mm.

Example 2: When W (distance between the dies) is set at 500mm, the capacity of your bending machine required to bend 30mm-thick ABREX450 should be about 540ton/m or more.





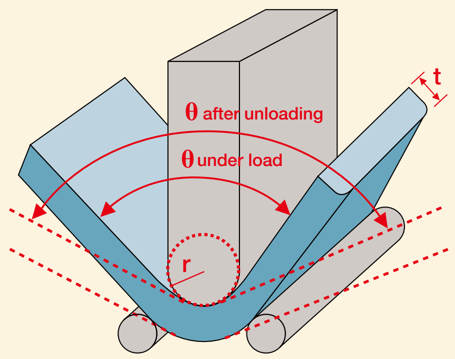


2. Springback Amount

The amount of the elastic deformation released after bending (springback) can be roughly estimated using the following formula.

$$\triangle\theta_{[degrees]} = \theta_{after\ unloading} - \theta_{under\ load} = 3.4 \times \frac{\sigma_B \times r}{E \times t}(180 - \theta_{under\ load})$$

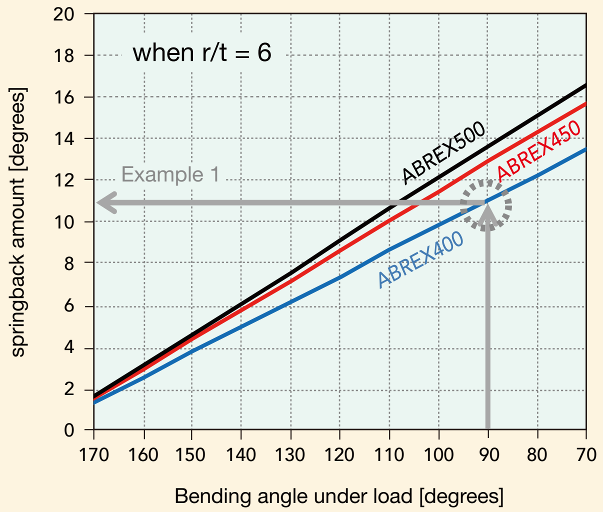
Denotations

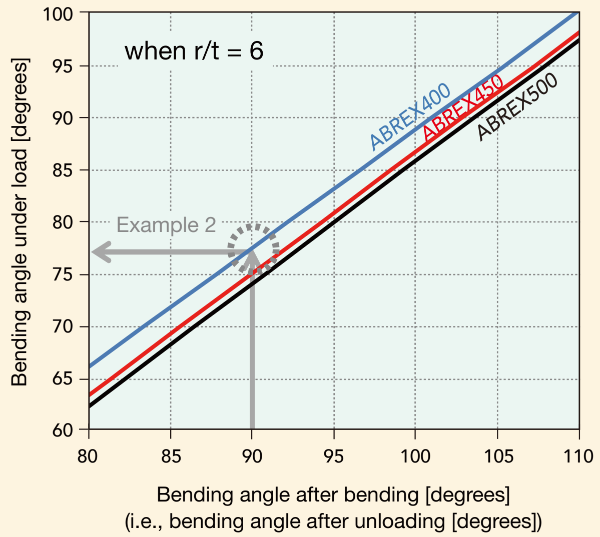


- $\Delta\theta$: Change in bending angle due to springback
- r : Bend radius [mm]
- E : Young's modulus of steel plate (210,000N/mm²)
- t : Steel plate thickness [mm]
- σ_B : Tensile strength [N/mm²]

σ_B : value examples
- ABREX400 (25mm) : 1259 [N/mm²]
- ABREX450 (25mm) : 1469 [N/mm²]
- ABREX500 (25mm) : 1552 [N/mm²]

The following figures show the results of springback amount calculations using the above formula.
These figures will be handy when estimating the resulting bending angle.
Note that the formula provides only a rough estimate.
It is recommended to make sure in advance of accuracy of the formula.





Example 1: When you bend ABREX400 at r/t=6 and a bending angle under load of 90 degrees, the amount of springback is estimated to be around 11 degrees.

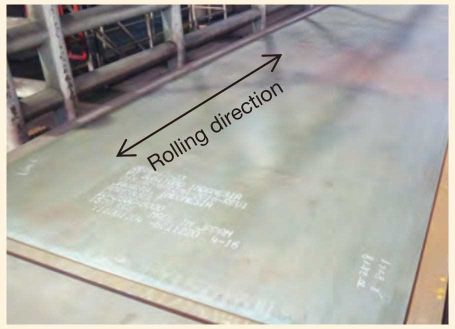
Example 2: If you want to bend ABREX400 at r/t=6 to a resulting bending angle of 90 degrees, you need to set the bending angle under load at around 77 degrees, taking the amount of springback into account.

3. Precautions for Bending

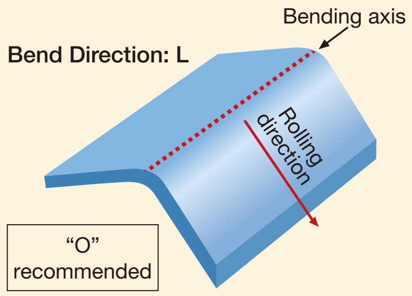
Because of its lower elongation value than that of common steel, abrasion-resistant steel must be carefully handled to prevent cracking. In accordance with the precautions listed below, you are asked to make sure that all the bending requirements are satisfied, such as bend radii, bending direction, the quality of steel plate cut edges, etc.

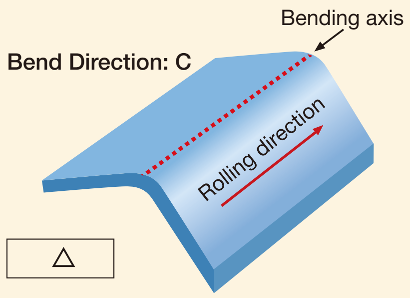
1) Bending Direction

A bend radius can be minimized by bending the steel plate around an axis perpendicular to the rolling direction. This is because cracks tend to propagate along any linear inclusion that was produced during the plate hot rolling process. It is therefore recommended that your product be designed, if possible, to make the steel plate bend around a "bending axis" perpendicular to the rolling direction. The following photos describe the definition of the rolling direction.

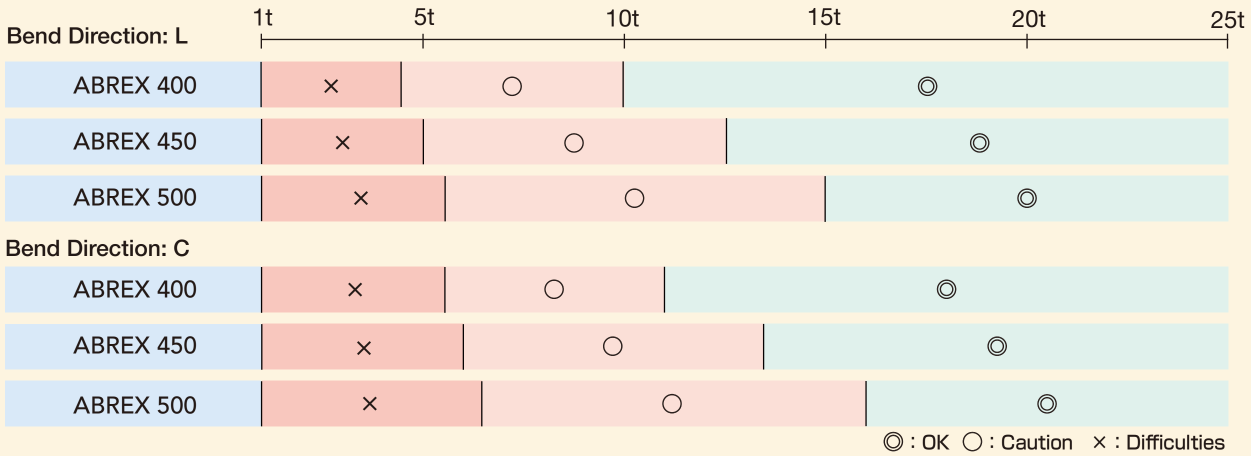


The rolling direction with respect to the stencil markings





2) Guidelines for Minimum Bend Radii

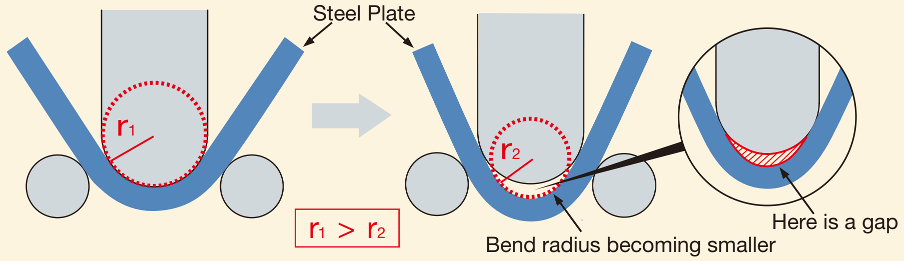


How to interpret the above figure: For L-direction bending of ABREX 400, its bendability is rated as "O" for a radius of 4.5t or more. Here, 4.5t means 4.5 x t (plate thickness). For example, a guideline for the minimum bend radius on 10mm-thick ABREX 400 is 4.5 x 10mm = 45mm.

Minimum bend radii vary depending on the bending conditions (such as ambient temperatures, bending machines, and plate edge treatments), and the above figure should be used as just a guideline.

ABREX 600 is not recommended to be bent.

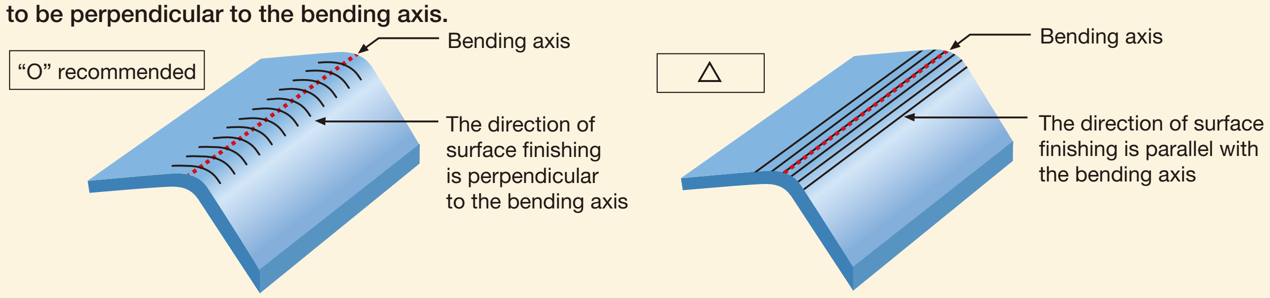
During deformation, when the friction coefficient between the dies and the steel plate becomes lower, the bend radius (r) becomes smaller than the radius of the punch (r1). In this case, a larger bend radius (r) must be designed.



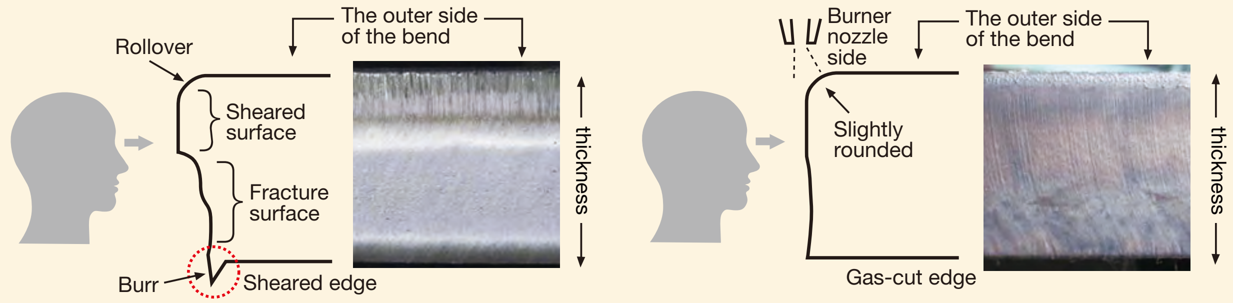
point The most effective way to prevent cracking is to make the bend radius larger. You are asked to choose a bend radius in the range of "O" or larger as shown in the above guidelines for minimum bend radii.

3) Steel Plate Edge and Surface Treatments

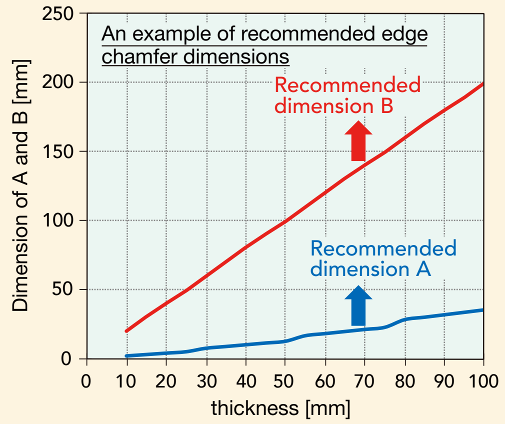
In accordance with the guidelines for minimum bend radii described in Section 2), if the steel plate is bent with a bend radius in the range of "O," particularly when it is closer to the range of "X," it is recommended to be appropriately treated on the edges and surface. Surface imperfections such as scratches and rust on the steel plate serve as stress concentration points, which may cause cracking. Before bending, these surface imperfections must be removed using a grinder or the like. In this case, the grinding direction is recommended to be perpendicular to the bending axis.

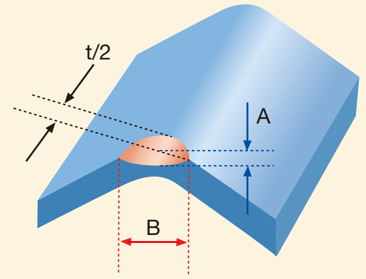


Surface imperfections such as notches on cut edges, burrs on sheared surfaces, and hardened layers on gas-cut surfaces can cause cracking. It is therefore recommended to remove them and smoothen these areas using a grinder or the like. If the removal of these surface imperfections is difficult, it is recommended to face the burner nozzle side of the gas-cut surfaces, or the rollover side of the sheared surfaces, face the outer side of the bend.



Another effective way to avoid cracking is to chamfer the edge on the outer side of the bend before bending. The figure below shows the recommend size of the chamfer.





4) Other Instructions

- **Shot blasting hardens the surface of the steel plate, making it more susceptible to cracking. It is therefore recommended that shot blasting be applied after bending.**
- **Multiple bending at the same location or reverse bending must be avoided.**
- **If the steel plate is bent at a place where its temperature may go down to 0°C or below, it is recommended to preheat the steel plate up to around 20°C.**

*Be careful not to preheat the plate to a temperature over 200°C, which may affect the hardness of the material.

point
* The level of tensile strain becomes the highest on the outer side of the bend, where a crack is likely to start developing. A sharper surface scratch or a rougher cut edge surface is more susceptible to stress concentration, serving as a crack initiator. What is most important to obtain high quality bends is to remove and smoothen sharp scratches on the outer side of the bend and rough surfaces on the cut edges.
* The harder the steel plate is, the more susceptible it becomes to cracking. After bending, the steel plate becomes harder due to work hardening. It is therefore recommended that the steel plate be bent in a single operation if possible.