TECHSUPPORT #16

Thermal Cutting of Hardox and Strenx

Cutting of Hardox and Strenx

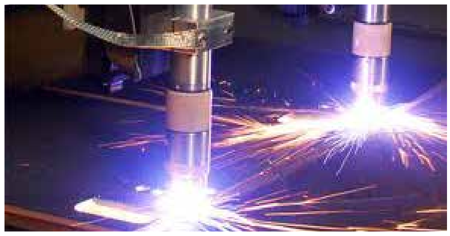
Hardox and Strenx can be cut by using all thermal cutting methods, including oxy-fuel cutting, plasma cutting as well as laser cutting. Of course, it is also possible to use cold cutting processes.

The recommendations in Tech Support #16 are mainly associated with the thermal cutting processes and are divided into three sub-chapters, i.e. oxy-fuel cutting, plasma cutting and laser cutting.

The cold cutting methods, shearing and punching, are limited to the softer Hardox grades (400 and 450) and all Strenx grades up to 10 mm in plate thickness. Abrasive Water Jet (AWJ) cutting is a cold cutting method that enables all Hardox and Strenx grades to be cut independent of thickness.

Figure 1. Oxy-fuel cutting

Laser cutting.



Plasma Cutting

Figure 2. Photograph of AWJ (Courtesy of Stahl-Contor, Zürich, Switzerland).

Thermal cutting Hardox and Strenx is as simple as cutting regular mild steel, although some attention is needed while cutting thick plates of Hardox due to the risk of cut edge cracking. Since Strenx and Hardox belong to the family quenched and tempered steels, they also respond to thermal cutting differently than e.g. mild steel. QT steels are susceptible to softening due to thermal cutting and some QT-steels are susceptible to cut edge cracking.

By following the recommendations and guidelines given below, both Hardox and Strenx can be thermally cut with conventional equipment.

Further information can be found in the Welding Handbook published by SSAB.

SSAB

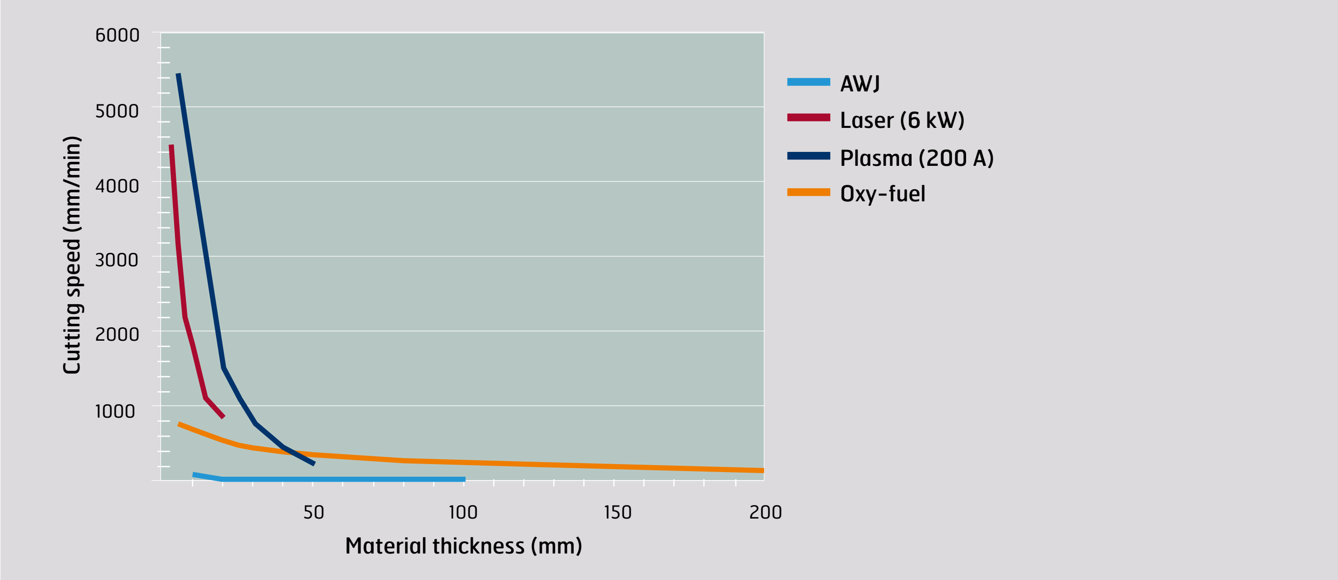


Figure 3. Cutting speed as a function of material thickness for different cutting processes.

Cut edge cracking

Cut edge cracking is a phenomenon that is closely related to hydrogen cracking in welds and occurs when thermal cutting methods are used. If cut edge cracks should occur, they will become visible between 48 hours and up to several weeks after the cutting. So, cut edge cracking can be regarded as delayed cracking. The risk of cut edge cracking increases with the steel hardness and plate thickness. How to reduce the risk of cut edge cracking is described below.

Cut edge cracking is closely related to the hydrogen content and residual stresses in the steel plate. It is therefore of interest to reduce the hydrogen content as well as the residual stresses, which can be done in different ways:

1. Preheating the plate
2. Post heating
3. Reduced cutting speed
4. Combination of preheating, post heating and reduced cutting speed together with a prolonged cooling process of HAZ

Preheating

One method to avoid hydrogen cracking when oxy-fuel cutting, is to preheat the material. Regarding plasma cutting and laser cutting, preheating is not recommended due to its negative effect of the cut edge quality.

Depending on the situation, either part of the plate or the entire plate can be heated. The way to do this can be:

- Heating furnace
- Preheating lances
- Electrical mats

Heating in furnaces is the best way to preheat due to that it results in an even temperature of the entire plate. Preheating lances can also be applied for preheating of Hardox and Strenx plates see figure 4. It is of importance that the lances are in motion so that the temperature of the plates does not exceed maximum preheating temperature. Further, the preheating temperature is measured on the opposed side of where the preheating procedure is applied.

Figure 4. Preheating lances.

Electrical mats is a slow preheating method, so to preheat to 150-200 °C a good practice is to preheat overnight and begin the cutting operation the next morning.

Post heating

Post heating is the most reliable method in order to avoid cut edge cracking. This can either be done in a furnace or with torches. The easiest method is to use torches since they are widely spread in industry, furnaces are not so common. It is important that the post heating process takes place as soon as possible after the part has been cut out. The maximum time is 30 minutes between start of cutting and start of post heating procedure.

In the case of post heating it is of importance not to heat the material too much. Using furnaces the temperature should be 200 °C and the plate has to stay in the furnace until it reaches this temperature. Depending on the thickness of the plate the time will vary, but as a general rule of thumb the time of post heating should be at least 5 minutes for every mm of plate thickness (i.e. 50 minutes for a 10 mm thick plate).

By using torches, figure 5, it is of importance not to overheat the cut edge. The temperature of the cut edge shall not exceed 700 °C, preferentially 300 to 500 °C. Normally post heat treatment using torches is done manually and in this case it is of importance to know how to control the temperature. By looking at the color of the cut edge just behind the torch, it should be blood red or dark sherry. If the color is bright sherry or dark orange the temperature is too high and the post heating will not be successful.

Figure 5. Manually post heating.

Reduced cutting speed

When cutting speed is reduced, the material heats up around the cut front and the heat affected zone will be wider. This affects the residual stresses in such a way that the risk of cut edge cracking reduces. One should though bear in mind that reduced cutting speed is not as reliable as preheating or post heating and should only be used as a substitute if, for instance, the workshop does not have appropriate pre/post heating equipment

Slow cooling

Regardless of whether or not preheating of the cut parts is employed; a slow cooling rate will reduce the risk of cut edge cracking. Slow cooling can be achieved if the parts are stacked together while still warm from the cutting process, and are covered with an insulating blanket. Allow the parts to cool slowly down to room temperature.

Oxy-fuel Cutting

Hardox and Strenx are easily cut by the oxy-fuel cutting process. Oxy-fuel cutting has almost no limitations when it comes to material thickness, i.e. material thicknesses from 1 up to 1000 mm can be cut. Although it is possible to cut relatively thin materials, the main thickness is above 20 mm. Generally features for oxy-fuel cutting can be seen in table 1.

Cutting method	Kerf width	HAZ	Dim. tolerances
Oxy-fuel cutting	2-5 mm	4-10 mm	± 2.0 mm

Tabel 1. General features for oxy-fuel cutting.

Hardox

The preheat recommendations for oxy-fuel cutting can be seen in table 2.

Grade	Plate thickness	Minimum preheating temp. (°C)	Maximum preheating temp. (°C)
Hardox HiTuf	< 90 mm ≥ 90 mm	No preheating 100	300
Hardox 400	< 44.9 mm 45 – 59.9 mm 60 – 80 mm > 80 mm	No preheating 100 150 175	225
Hardox 450	< 39.9 mm 40 – 49.9 mm 50 – 69.9 mm ≥ 70 mm	No preheating 100 150 175	225
Hardox 500	< 25 mm 25 – 49.9 mm 50 – 59.9 mm 60 – 103 mm	No preheating 100 150 175	225
Hardox 550	10 – 19.9 mm 20 – 65 mm	No preheating 150	225
Hardox 600	12 – 65 mm	175	225
Hardox Extreme*	8 – 25 mm	100 + reduced cutting speed	100

Table 2. Preheat temperatures for oxy-fuel cutting of the Hardox grades.

*SSAB recommends AWJ cutting. If only oxy-fuel cutting is available follow the recommendations in table 2.

As mentioned in the cut edge cracking section, it is preferable to use post heating of the cut edge in order to minimize the risk of cut edge cracking. In the case of post heat treating in a furnace, use the temperatures (maximum) given in table 2. Let the plate/part stay in the furnace until the core temperature has reached the accurate temperature (table 2).

If the post heating is done with a torch, make sure that the temperature does not exceed 700 °C. In practice this means that the color of the cut edge just behind the torch should be blood red or dark sherry, see schematic figure 6.

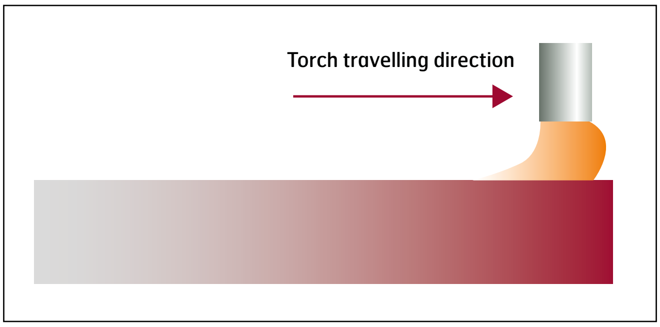


Figure 6. Color of the cut edge behind the post heating torch.

It is also important that the post heat treatment takes place as soon as possible after finished cutting operation. Maximum 30 minutes between the start of the cutting operation and the start of the post heating operation.

Strenx

Most Strenx grades have a high enough resistance to hydrogen cracks that it is unnecessary to take additional steps, such as preheating, to remove hydrogen from HAZ. However, if preheating is applied should the preheat temperatures not exceed the ones mentioned in table 3.

Material	Max preheating temp. (°C)
Strenx 700	300
Strenx 900	300
Strenx 960	300
Strenx 1100	150
Strenx 1300	150

Table 3. Recommended maximum preheat levels.

Regarding post heat treatment of Strenx, see post heat treatment of Hardox above.

Plasma Cutting

Hardox and Strenx are easily cut by the plasma cutting process. Plasma cutting has a limitation when it comes to material thickness and the main thickness to be cut is below 50 mm (plasma cutting machine dependent). Generally features for plasma cutting can be seen in table 4.

Cutting method	Kerf width	HAZ	Dim. tolerances
Plasma cutting	2-4 mm	2-5 mm	± 1.0 mm

Tabel 4. General features for plasma cutting.

Figure 7 shows general cutting speeds for different plasma power sources.

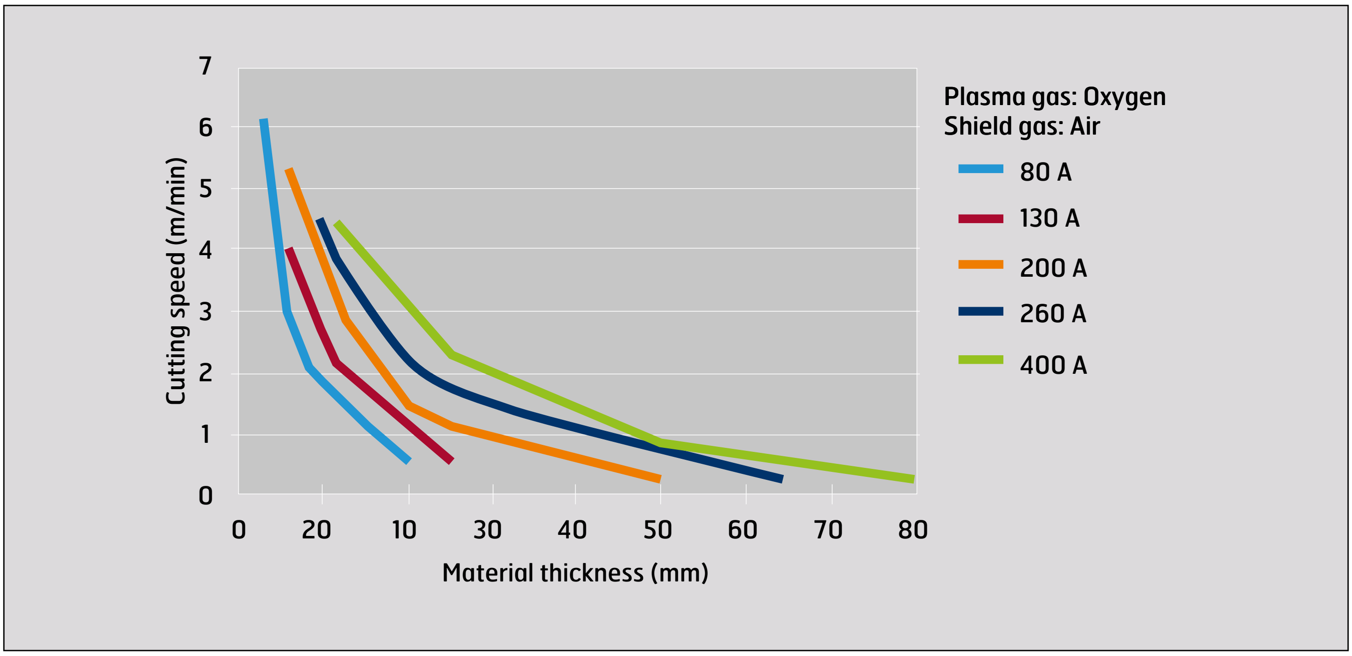


Figure 7. Cutting speeds for different plasma power sources.

Hardox and Strenx

It is no difference to plasma cut Hardox and Strenx compared to ordinary mild steel, i.e. use the same process parameters.

Preheating or post heating to enhance hydrogen migration from HAZ is not required during plasma cutting of most Hardox and Strenx grades. Hardox 600 and Hardox Extreme have to be either preheated or post heat treated in order to avoid cut edge cracking, see recommendations for oxy-fuel cutting.

Laser Cutting

Laser cutting of Hardox and Strenx can easily be done by using the normal processing parameters for the given material thickness. The maximum thickness is approximately 25 mm depending on the laser cutting equipment. Most commonly to cut is thicknesses below 15 mm. Generally features for laser cutting can be seen in table 5.

Cutting method	Kerf width	HAZ	Dim. tolerances
Laser cutting	< 1 mm	0.2-2 mm	± 0.2 mm

Tabel 5. General features for laser cutting.

One of the benefits with laser cutting is the high cutting speed that can be used. Figure 8 shows cutting speed as a function of material thickness and laser power.

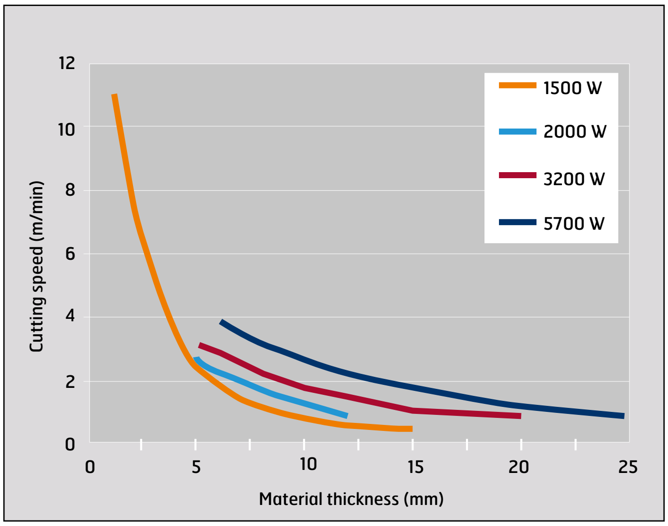


Figure 8. Laser cutting speeds.

Due to the relatively thin thicknesses, preheating to enhance hydrogen migration from HAZ is not required during laser cutting of Hardox and Strenx grades. Preheating is instead detrimental to the cut edge quality.

Hardox

It is no difference to laser cut Hardox compared to ordinary mild steel, i.e. use the same process parameters. The primer reduces the cutting speed, but this can be solved by first vaporize the primer and then cut the contour.

Strenx

As in the case of Hardox, most of the time it is possible to use the same laser cutting parameters as when cutting mild steel. Sometimes it is necessary to first vaporize the primer in order to achieve highest possible cutting speed, otherwise reduced cutting speed is the alternative.

Hardness properties in HAZ

The properties of HAZ depend on:

- Whether or not the steel was tempered during manufacturing, and if so, how it was carried out
- The chemical composition of the steel
- The impact of the thermal treatment from the cutting process

The width of HAZ increases with increasing thermal impact from the cutting process. For instance, cutting with the same power and reduce the cutting speed leads to a wider HAZ. Different thermal cutting processes have different thermal impact, resulting in wider or narrower HAZ. Oxy-fuel cutting has the highest thermal impact followed by plasma cutting and laser cutting. Figure 9 shows a schematic figure of HAZ for Strenx 1100 – Strenx 1300 and Hardox 400 – Hardox Extreme.

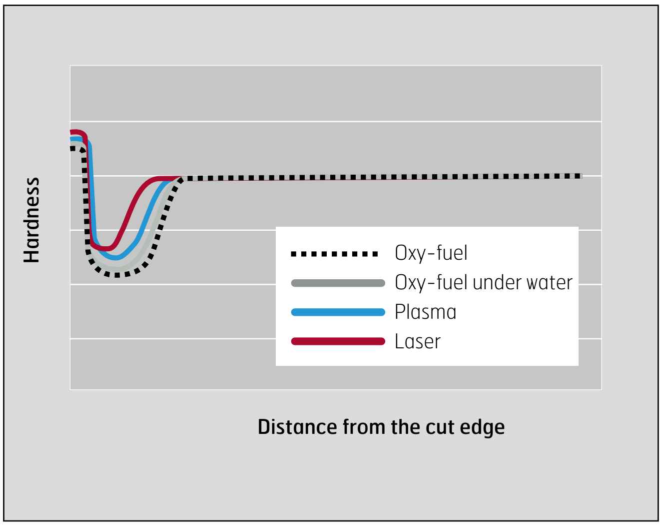


Figure 9. Hardness profiles in HAZ after thermal cutting of Hardox and Strenx with different cutting methods.

Reducing the risk of softening

The resistance of the steel to softening depends on its chemistry, microstructure and the way in which it has been processed.

The smaller the part that is thermally cut, the greater the risk of the whole component being softened. If the temperature of the steel exceeds 200-250 °C, the hardness of the steel will be reduced, according to figure 10 (see also data sheet for each steel grade).

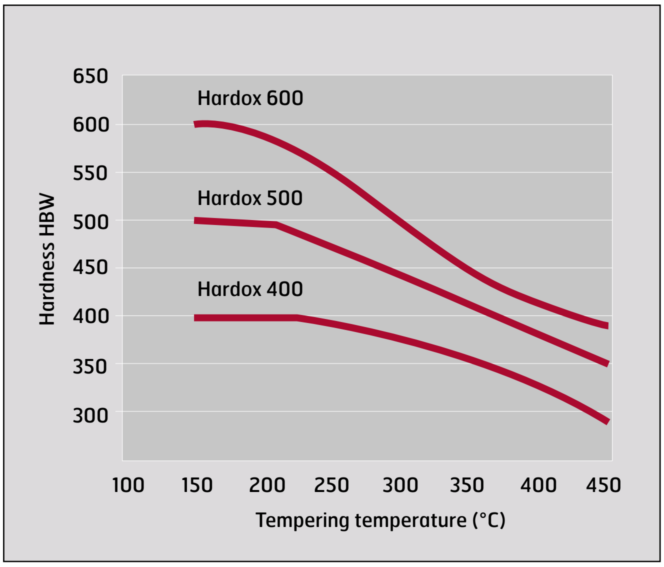


Figure 10. Surface hardness vs. tempering temperature.

Submerged cutting

An effective way of limiting and reducing the extent of the soft zone is to water-cool the plate and the cut surface during the cutting operation. This can be done either by submerging the plate in water (figure 11) or by spraying water on the piece during and after cutting. Submerged cutting can be done both in plasma cutting and in oxy-fuel cutting.

Some advantages offered by submerged cutting are:

- Narrow heat affected zone
- Prevents loss of hardness of the whole component
- Reduced distortion of the cut part
- Parts are cooled directly after cutting
- No fumes or dust
- Reduced noise level

Figure 11. Submerged cutting.

Cutting method

When small parts are cut, the heat supplied by the cutting torch and by preheating will be accumulated in the workpiece. The smaller the size of the cut part the greater the risk of softening. When oxy-fuel is used for cutting 30 mm or thicker plate, the rule of thumb is that there is risk of loss of hardness of the entire component if the distance between two cuts is less than 200 mm.

The best way of eliminating the risk of softening is to use cold cutting methods, such as abrasive water jet cutting. If thermal cutting must be performed, laser or plasma cutting is preferable to oxy-fuel cutting. This is because oxy-fuel cutting supplies more heat and thus raises the temperature of the workpiece.

Avoiding both softening and cut edge cracking when oxy-fuel cutting small parts from thick Hardox plate

When small parts are cut by oxy-fuel from thick Hardox plate, there is risk of softening as well as cut edge cracking. This is best avoided by submerged cutting at low cutting speeds.