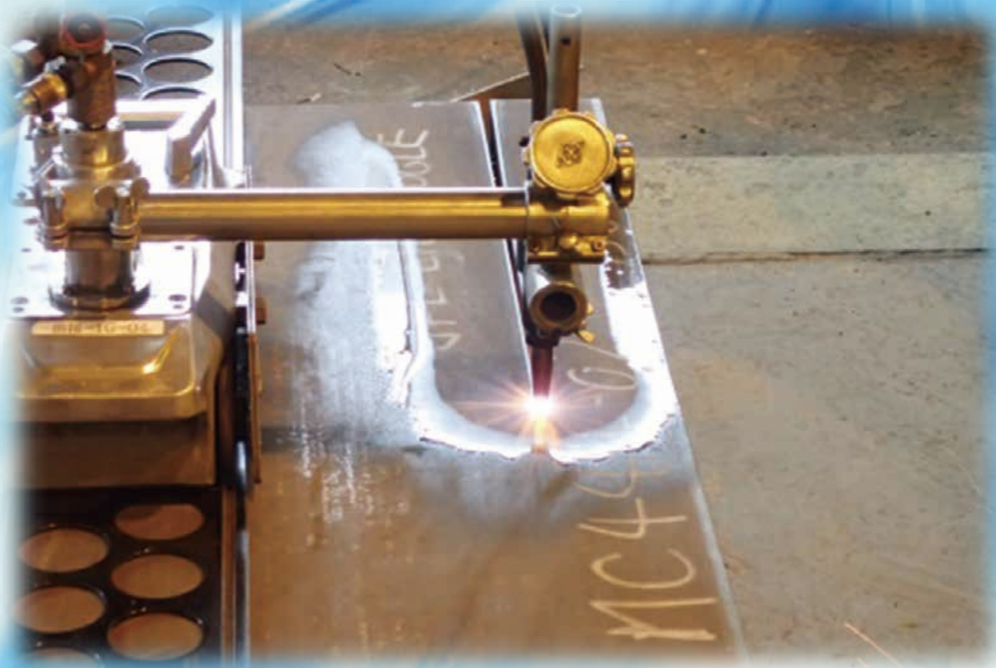
Guidelines for fabrication
JFE's Abrasion-Resistant Steel Plate
EVERHARD™

- Thermal Cutting -

EVERHARD™
JFE's Abrasion-Resistant Steel Plate
Reliable Forever



JFE Steel Corporation

Contents

Guidelines for Fabrication of JFE's Abrasion-Resistant Steel Plate EVERHARD: Thermal Cutting

JFE Steel began manufacturing abrasion-resistant steel plates in 1955 before any other company. Since then, these products, trade-named EVERHARD, have been used in a wide range of applications, beginning with industrial machinery and also including civil engineering and construction equipment, mining equipment and agricultural machinery.

Today, EVERHARD is recognized as an indispensable product that ensures complete customer satisfaction.

This brochure, "Guidelines for fabrication of JFE's Abrasion-Resistant Steel Plates EVERHARD: Thermal Cutting," is prepared so that all customers can enjoy the outstanding performance of EVERHARD effectively and with full confidence. We hope that the information contained herein would contribute to customer’s business.

Thank you for using EVERHARD, and we look forward to continuing to serve you in the future.

■ Features of EVERHARD

Type	Features	Brand name
C (Standard Series)	General purpose EVERHARD products. Economical alloy design with priority on hardness of steel plates. Strict range of surface hardness and reduced variations in formability.	**EVERHARD-C340**
		EVERHARD-C400
		EVERHARD-C450
		EVERHARD-C500
		EVERHARD-C550
		EVERHARD-C600
C-LE (High Toughness Series)	Guarantees low temperature toughness at -40°C (-40°F). Full line of abrasion-resistant performance up to Brinell hardness 500 grade. Alloy design which considers internal hardness.	**EVERHARD-C400LE**
		EVERHARD-C450LE
		EVERHARD-C500LE
SP (Super Abrasion-Resistant Series)	Product that out-performs even the EVERHARD series. Provides abrasion resistance exceeding Brinell hardness 500 grade.	**EVERHARD-SP**

All information contained in this catalog assumes use of EVERHARD based on a basic understanding of correct thermal cutting and within the range of the business experience of JFE Steel Corporation. JFE Steel Corporation cannot accept responsibility for compatibility with individual cases; however, in case of problems, please feel free to consult with this company.

1. Cutting Methods for EVERHARD (Thermal Cutting)

1.1 Gas Cutting

Thermal cutting by the gas cutting method (also called the oxy-fuel or oxy-gas method) is performed by blowing a preheating flame of combustion gas (preheating mixed gas) and cutting oxygen from the tip of a nozzle (burner), causing an oxidation reaction between the oxygen and steel at a high temperature at or above the ignition point of the steel, and blowing the molten metal and oxide (slag) out of the cut with the cutting oxygen jet (Fig. 1). In principle, cutting is possible in the range that can be reached by the oxygen, making this is an effective cutting method for thick objects. It is possible to cut extra-heavy plates with thicknesses exceeding 100 mm.

As in welding, the area around the thermal cutting point is heated to a high temperature. Because EVERHARD has extremely high strength and high hardness in comparison with general steel, care must be taken to avoid cold cracking when performing thermal cutting, in the same manner as when welding EVERHARD.

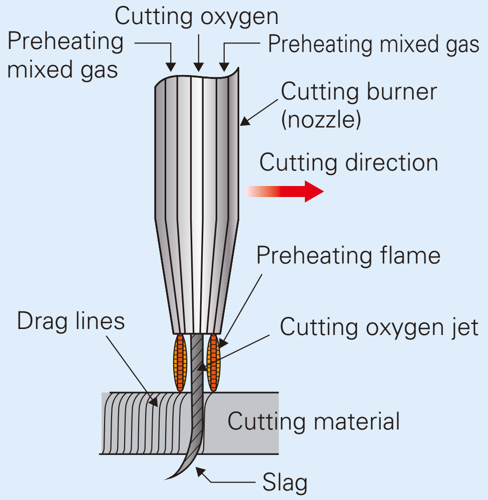


Fig. 1 Schematic Diagram of Gas Cutting

1.2 Plasma Cutting

In the plasma cutting method, the electrical energy of an arc discharge is used. The maximum cutting thickness is smaller than that by gas cutting. Because the hydrogen source is small, the possibility of cold cracking is low because lesser hydrogen is absorbed in principle. However, care is necessary to prevent absorption of hydrogen due to moisture on the steel plate surface, cutting under high humidity environments, etc.

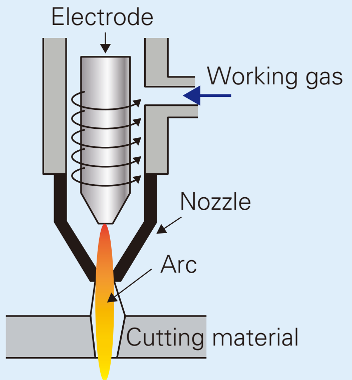


Fig. 2 Schematic Diagram of Plasma Cutting

1.3 Laser Cutting

Laser cutting is the newest cutting method in the field of thermal cutting. When this method was developed, laser output was small, and this method was applied to cutting of thin plates and sheets that could not be cut by the conventional technologies of gas cutting and plasma cutting. However, laser cutting can now be applied to plates with a maximum thickness of about 25 mm.

Oxygen is also used as the cutting gas in laser cutting. The possibility of cold cracking is small because the gas does not contain hydrogen. However, as in the case of plasma cutting, care is necessary to avoid absorption of hydrogen.

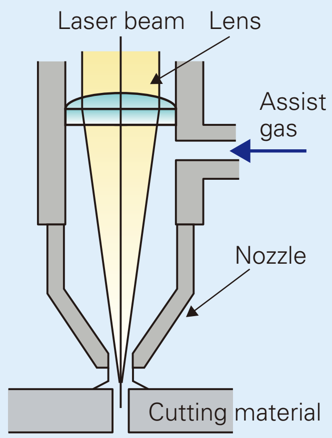


Fig. 3 Schematic Diagram of Laser Cutting

2. Points in Gas Cutting

2.1 Recommended Gas Cutting Conditions

2.1.1 Preheating and Post-Cutting Heat Treatment

Preheating and post-cutting heat treatment (post-heating) are effective for preventing cold cracking as in welding.

Table 1 shows the recommended minimum preheating and post-heating temperatures for gas cutting of EVERHARD. Although the ideal preheating method uses a furnace to heat the entire plate to be cut, sectional heating with a gas burner or electric heater is also applicable. In this case, it is important to check the temperature at multiple points along the cutting line. In addition, because the temperature can only be measured at the surface, it is important to check that the center has also reached the specified temperature by observing the temperature change after the surface reaches the specified preheating temperature, and to begin cutting immediately after the temperature becomes stable. If preheating is not possible, post-heating should be performed. The effect of this technique is improved by performing post-heating immediately after gas cutting.

When using preheating or post-heating, it is important to note that the hardness of EVERHARD will decrease if the preheating or post-heating temperature exceeds 200°C even once. In preheating, strictly maintain a temperature limit of 200°C or less. The recommended post-heating temperatures are the same as the preheating temperatures shown in Table 1, and the limit of 200°C must also be maintained when performing post-heating.

■Table 1 Recommended Minimum Preheating/Post-Heating Temperatures

<table>
<tr><th rowspan="2">Brand name</th><th colspan="21">Thickness (mm)</th></tr>
<tr><th colspan="2">10</th><th colspan="2">20</th><th colspan="2">30</th><th colspan="2">40</th><th colspan="2">50</th><th colspan="2">60</th><th colspan="2">70</th><th colspan="2">80</th><th colspan="2">90</th><th colspan="2">100</th><th>160</th></tr>
<tr><td>EVERHARD-C340</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="8">75℃</td><td colspan="7">100℃</td></tr>
<tr><td>EVERHARD-C400</td><td colspan="6">25℃</td><td colspan="4">50℃</td><td colspan="10">75℃</td><td></td></tr>
<tr><td>EVERHARD-C450</td><td colspan="4">25℃</td><td colspan="6">75℃</td><td colspan="10">100℃</td><td></td></tr>
<tr><td>EVERHARD-C500</td><td colspan="2">25℃</td><td colspan="2">75℃</td><td colspan="6">125℃</td><td colspan="10">150℃</td><td></td></tr>
<tr><td>EVERHARD-C400LE</td><td colspan="6">25℃</td><td>50℃</td><td colspan="5">75℃</td><td colspan="8">100℃</td><td></td></tr>
<tr><td>EVERHARD-C450LE</td><td colspan="4">25℃</td><td colspan="3">75℃</td><td colspan="3">100℃</td><td colspan="6">175℃</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C500LE</td><td colspan="2">25℃</td><td colspan="2">75℃</td><td colspan="2">125℃</td><td colspan="4">150℃</td><td colspan="6">175℃</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C550</td><td colspan="6">175℃</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C600</td><td colspan="5">175℃</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-SP</td><td colspan="4">75℃</td><td colspan="9">150℃</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

2.1.2 Cutting Speed

In cases where preheating and post-heating cannot be performed, the gas cutting speed should be reduced. Table 2 shows the recommended maximum cutting speeds. Reducing the cutting speed within the range where a notch does not occur at the gas cutting plane is recommended. In the case of heavy gauge plates of hardness HB450 or higher it may not be sufficient to reduce the cutting speed; therefore, preheating or post-heating is recommended in such cases.

■ Table 2 Recommended Cutting Speed When Preheating is Not Performed (mm/min)

<table>
<tr><th rowspan="2">Brand name</th><th colspan="21">Thickness (mm)</th></tr>
<tr><th colspan="2">10</th><th colspan="2">20</th><th colspan="2">30</th><th colspan="2">40</th><th colspan="2">50</th><th colspan="2">60</th><th colspan="2">70</th><th colspan="2">80</th><th colspan="2">90</th><th colspan="2">100</th><th>160</th></tr>
<tr><td>EVERHARD-C340</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="6">200</td><td colspan="9">150</td></tr>
<tr><td>EVERHARD-C400</td><td colspan="6">No Restrictions</td><td colspan="6">200</td><td colspan="8">150</td><td></td></tr>
<tr><td>EVERHARD-C450</td><td colspan="4"></td><td colspan="6">200</td><td colspan="10">Preheating</td><td></td></tr>
<tr><td>EVERHARD-C500</td><td colspan="2"></td><td colspan="2">250</td><td colspan="4">200</td><td colspan="2">150</td><td colspan="10">Preheating</td><td></td></tr>
<tr><td>EVERHARD-C400LE</td><td colspan="6"></td><td colspan="6">200</td><td colspan="8">Preheating</td><td></td></tr>
<tr><td>EVERHARD-C450LE</td><td colspan="4"></td><td colspan="6">200</td><td colspan="6">Preheating</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C500LE</td><td colspan="2"></td><td colspan="2">250</td><td colspan="4">200</td><td colspan="2">150</td><td colspan="6">Preheating</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C550</td><td colspan="7">200</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-C600</td><td colspan="5">200</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>EVERHARD-SP</td><td colspan="6">250</td><td colspan="2">200</td><td colspan="2">150</td><td colspan="3">Preheating</td><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

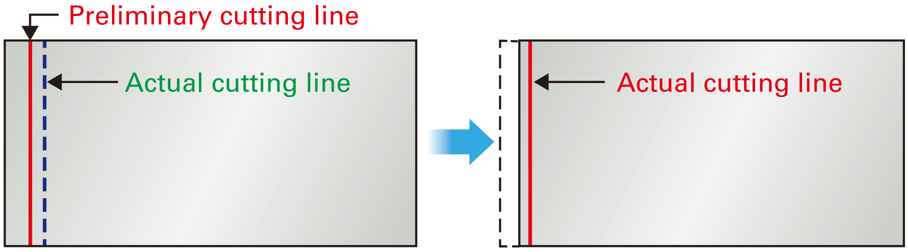
2.1.3 Other Recommended Method

The same effect as preheating can also be obtained by performing double cutting.

Double cutting is a method in which precutting is performed near the planned cutting line, and actual cutting is performed immediately thereafter (Fig. 4), and the preheating effect of precutting in the area near the actual cutting line is used.

Since the preheating effect will be lost if the temperature of the material being cut decreases after precutting, actual cutting should be performed as quickly as possible after preheat cutting.

The precutting position should be adjusted so that the temperature in the vicinity of the actual cut is the same as the minimum preheating/post-heating temperature shown in Table 1.

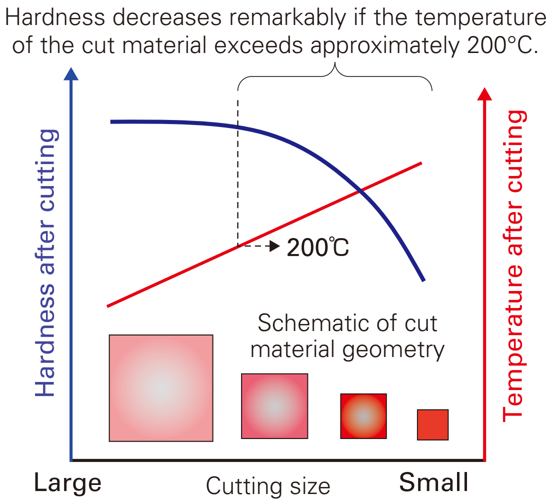


■Fig. 4 Double Cutting Method

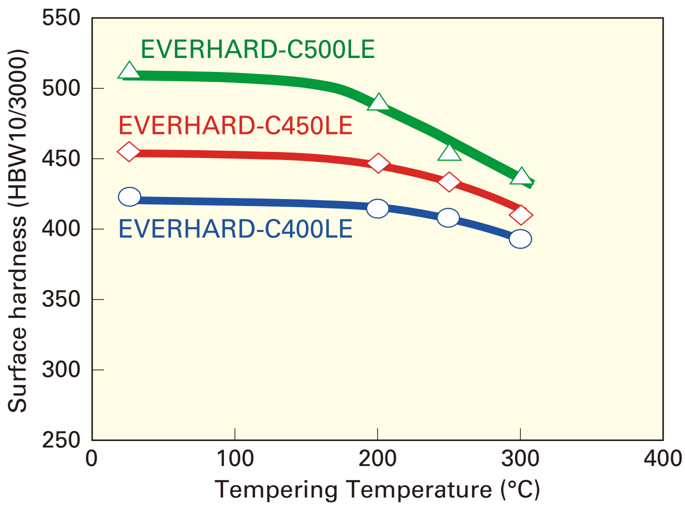
2.1.4 Precautions When Cutting Small Material

In thermal cutting of small material, the hardness of the material can easily decrease due to the rise in the temperature of the cut material. As shown schematically in Fig. 5, temperature rise becomes larger and hardness easily decreases as the size of the material being cut becomes smaller. When cutting small samples, it is necessary to check the degree of temperature rise in advance. Figure 6 shows the relationship between the heating temperature and surface hardness of EVERHARD-C400LE, C450LE and C500LE, respectively.

In case the temperature of the cut material is supposed to exceed 200°C, be sure that the temperature does not exceed 200°C by using an appropriate cutting method (plasma cutting, laser cutting, etc.) in place of gas cutting, increasing the cutting speed, changing the cutting order, etc.



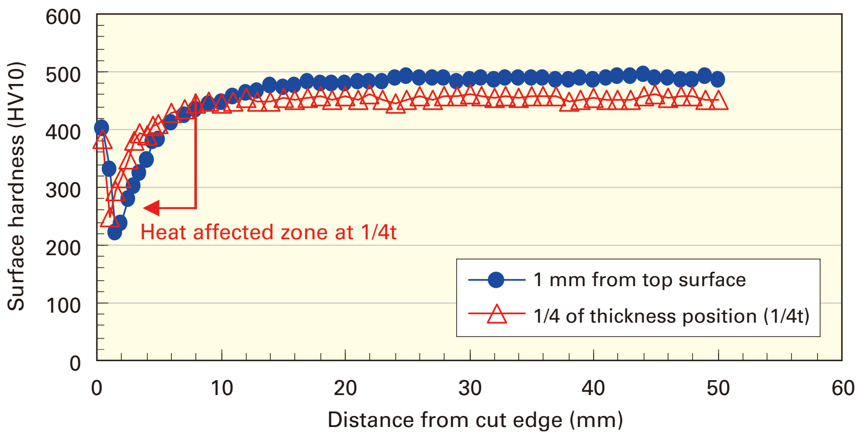
■Fig. 5 Relationship of Size of Cut Material, Hardness After Cutting and Temperature Rise of Material (Schematic Diagram)



■Fig. 6 Relationship of Heating Temperature and Hardness

3. Heat Affected Zone at Cut edge

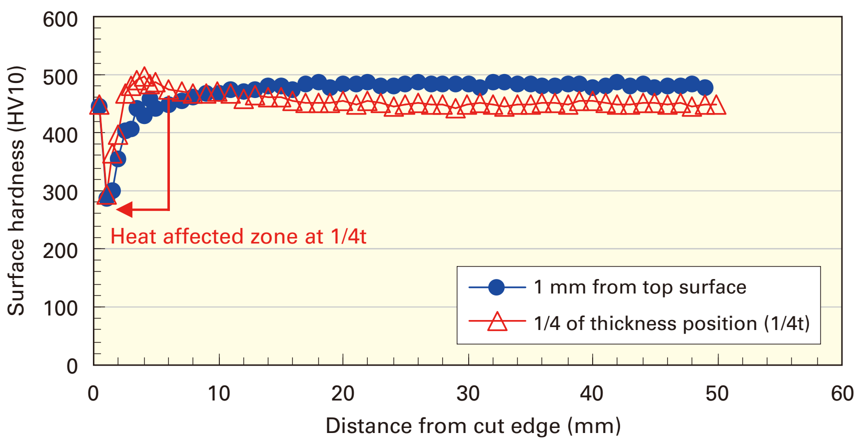
Figures 7 to 9 show the hardness distribution from the cutting plane when thermal cutting is performed by the gas, plasma and laser cutting methods, respectively. Hardness decreases in the area near the cut edge, which is affected by heat, in other words, the heat affected zone. Please select the most appropriate cutting method based on the characteristics of these methods.



EH-C450LE
Thickness: 20 mm

Oxygen gas pressure: 0.30-0.35 MPa
Propane gas pressure: 0.02-0.03 MPa
Cutting speed: 475 mm/min

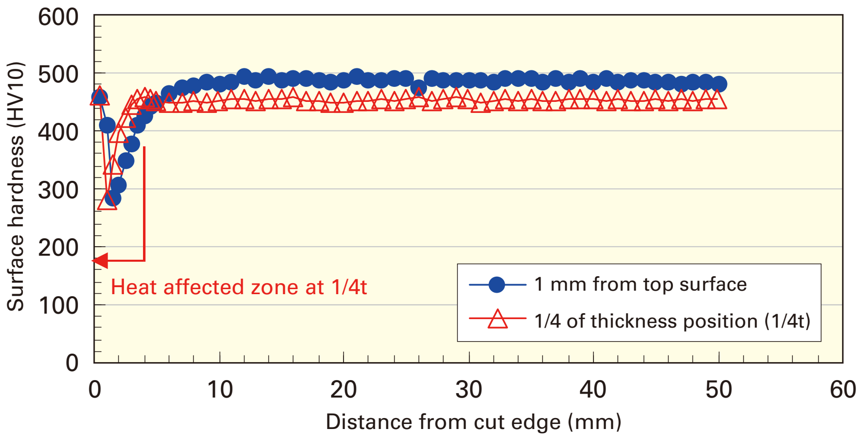
■Fig. 7 Comparison of Hardness Distribution of Gas Cutting



EH-C450LE
Thickness: 20 mm

Voltage: 220 V
Cutting speed: 1000 mm/min

■Fig. 8 Comparison of Hardness Distribution of Plasma Cutting



EH-C450LE
Thickness: 20 mm

Output: 6 kW
Cutting speed: 1250 mm/min

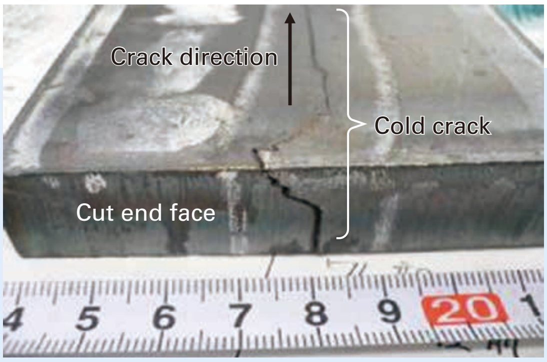
■Fig. 9 Comparison of Hardness Distribution of Laser Cutting

4. Cold Cracking (Commentary)

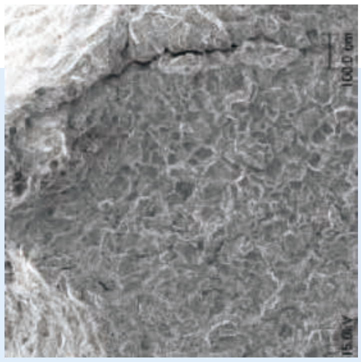
4.1 What is Cold Cracking?

If steel contains diffusible hydrogen, it is known that cracks occur in a given conditions. These cracks are called cold cracks (also called delayed cracks or delayed fracture). Although generally associated with welding, this phenomenon also occurs in gas cutting when a source of hydrogen exists.

As the name suggests, cold cracks do not occur immediately after cutting, but occur after some time has passed. If microscopic cold cracks occur, they may lead to accompanying macroscopic brittle fracture in some cases. Photo 1 shows an example of this. Fracture surface of cold crack shows a “quasi-cleavage” fracture surface, which is a characteristic feature of hydrogen embrittlement (Photo 2).



■Photo 1 Example of Appearance of Cold Crack after Gas Cutting



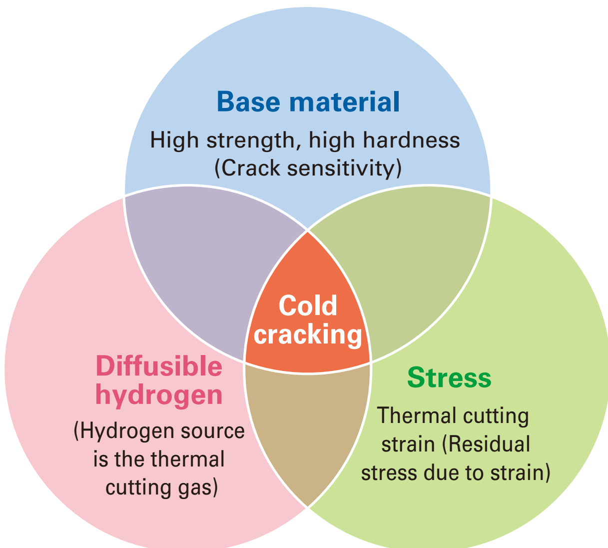
■Photo 2 Facture Surface of Cold Crack (Quasi-Cleavage Fracture Surface)

4.2 Factors in Cold Cracking

In gas cutting, cold cracking occurs by the same mechanism as cold cracking after welding (see EVERHARD Guideline - Welding - No. C1E-012). Accordingly, the factors that cause cold cracking are also the same. These are the three factors listed below:

(1) Crack sensitivity of the material (property of the base material)
(2) Diffusible hydrogen content
(3) Tensile residual stress

As abrasion-resistant materials, products in the EVERHARD Series are designed to have high strength and high hardness, and for this reason, (1) Crack sensitivity is higher than that of conventional high strength steels. Therefore, please note that cold cracking may occur in EVERHARD even under cutting conditions (certain diffusible hydrogen content and residual stress) that do not lead to cold cracking in conventional high strength steels.



■Fig. 10 Factors in Occurrence of Cold Cracking

4.3 Prevention of Cold Cracking

1 Reduce diffusible hydrogen

In order to prevent cold cracking after gas cutting, it is important to reduce the hydrogen that penetrates into the steel. Hydrogen penetrates from the combustion gas during gas cutting. The following may be mentioned as methods for reducing the amount of this hydrogen.

(1) Perform preheating immediately before cutting.

(2) Perform post-heating immediately after cutting.

(3) Use the double cutting method.

(4) Reduce the gas cutting speed.

All of these methods reduce the cooling rate of a steel plate after cutting. Reducing the cooling rate increases the amount of hydrogen that can be released from the steel during cooling, and as a result, the hydrogen remaining in the steel decreases.

Application of plasma cutting or laser cutting is also effective for avoiding a hydrogen source.

2 Reduce residual stress

Residual stress depends on the size of thermal expansion. In order to reduce thermal expansion as much as possible, heating should be held at minimum. For this, it is necessary to reduce the amount of heat input in cutting. In other words,

(1) Increase the cutting speed.

(2) Use a concentrated cutting heat source.

These conditions can be achieved by applying plasma cutting or laser cutting.

3 Avoid sources of stress concentration

In some cases, cold cracking is caused by the cutting surface quality or a stress concentration acting on an internal defect. To avoid stress concentrations, it is important to eliminate sharp defects (notches, etc.) near the cutting plane.

5. Ensuring Safe, Sound Cutting Work

Cutting work is a high temperature process, as it is performed by using flammable gas, high pressure gas, electricity or laser energy. It also requires handling of heavy materials. So thermal cutting works involves many hidden dangers and factors that may damage the worker's health. Please perform this work properly, remembering the following points for ensuring safe, sound thermal cutting work.

In thermal cutting work

(1) Always maintain a clean, orderly workplace and take care to prevent fires and unexpected accidents.
(2) Put a protective fence and display notices for caution when necessary.
(3) Use appropriate ventilation at the work site.
(4) Wear safety glasses, safety shoes and correct work clothing when performing work.
(5) Persons performing gas cutting must have appropriate qualifications. Follow all applicable laws and ordinances in your country.

References
1) Industrial Safety and Health Act, Article 61 (In case of Japan)
2) Industrial Safety and Health Act, Article 59 (In case of Japan)
3) Introduction: Q&A on Thermal Cutting Processing; Gas Welding and Cutting Division, Japan Welding Engineering Society

Effects of dust and gas on human health

Gas cutting and other thermal cutting methods generate comparatively a little dust and harmful gas. However, because a powerful heat source is used to melt metal, in addition to the dust and fumes generated by melting and vaporizing the metal, these processes also generate gasified substances contained in the cutting material, as well as harmful gases such as ozone, carbon monoxide, carbon dioxide, nitrogen dioxide, etc. from the working gas or the surrounding air. Lead, copper, zinc, tin and other materials coated on the surface of the cutting material also form metal fumes when vaporized, and these may cause a fever called "metal fume fever" or other symptoms. In addition, harmful gases may be generated by thermal decomposition of sealants, paints, lining materials and other plastics in some cases, depending on the type of material.

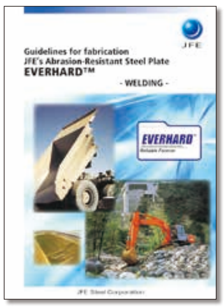
If the particle size of dust is 10 μm or larger, it is discharged from the mouth together with sputum, but if it is smaller than this size, it will remain in the atmosphere for a long time and can cause pneumoconiosis, bronchitis, pulmonary edema, asthma or other medical problems. In particular, dust with a size of 2.5 μm or smaller, or so-called PM2.5, has a serious effect on human health.

Conclusion

In all the products in the lineup of the JFE Abrasion Resistant Steel Plates EVERHARD series, optimum properties are achieved by control of chemical composition and microstructure considering processing at customers to produce abrasion-resistant parts.

We hope that customers will use this Guideline to ensure safe and effective use of the EVERHARD Series. Although this Guideline describes thermal cutting of EVERHARD, JFE Steel has also prepared similar Guidelines for Machining, Welding and Bending of EVERHARD. We hope that you will also use those references.

Machining
(C1E-016)



Welding
(C1E-012)

Bending
(C1E-014)

Cat.No.C1E-018-01

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