Application of CO2 High Power Laser to Cutting of Thick Steel Plates

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Abstract

CO_2 laser had enabled accurate and effective cutting. But its application has been limited to thin and small parts. Development of a high power oscillator and oscillator built-in cutting machine have realized cutting of thick and large steel parts. This machine brings also possibility of fully automated cutting systems to practical steel parts such as for construction machinery.

1. INTRODUCTION

CO_2 laser cutting machines become very popular in the thin metal plate cutting field. But they have not been used in the fields to cut thick and large plates such as in construction machinery manufacturing, bridge fabricating, ship building. These industries had been using oxyfuel and/or plasma arc cutting.

These industries in Japan were very much interested in application of CO_2 laser to cut thick plates. Because they have had requirements of "automatization," "labor saving" and "cutting accuracy improvement" on manufacturing facilities under the recent circumstances of chronic lack of skilled labor due to the change of the social environment.

An "oscillator built-in cutting machine" was released in July 1990. This machine mounts a high power laser oscillator on its machine body which travels on the track. Thus thick and large plates became possible to be cut. See PHOTO 1 below for the outlook of the machine.

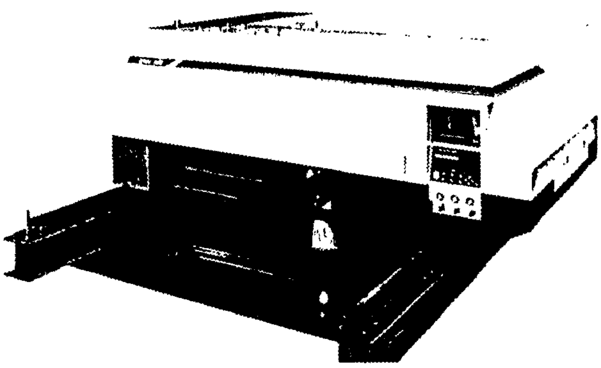


PHOTO 1 Outlook of Oscillator Built-In Cutting Machine

Laser cutting has many advantages such as higher cutting accuracy, better cutting quality, easier possibility of fully automated operation, less influence to working environment, etc., and is rapidly penetrating even into the industries to cut thick and large plates.

The recent model of the laser cutting machines can realize high quality cutting of 22 mm thick plates thanks to its built-in 3 kW CO_2 oscillator. And fully automated systems integrating a number of laser cutting machines start to practical operation.

PHOTO 2 shows an example of a fully atuomated laser cutting plant using with six units of oscillator built-in laser cutting machines.

This paper introduces and explains the present situation of thick and large plate cutting with oscillator built-in cutting machines.

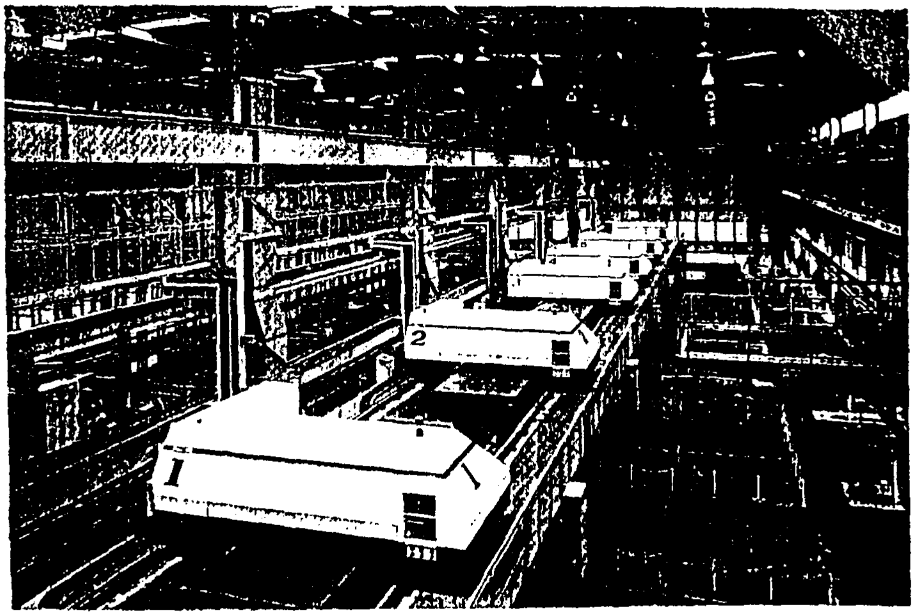


PHOTO 2 fully Automated Laser Cutting Plant

2. FEATURE OF LASER CUTTING FOR THICK PLATES

2.1 Comparison of Cutting Processes

The three thermal cutting processes are used to cut mild steel plates. TABLE 1 compares features of each cutting process with typical cutting equipment used practically.

TABLE 1 Features of Three Thermal Cutting Processes

	Laser Cutting CO2 2 kW	Plasma Arc Cutting 230A Oxygen	Oxyfuel Cutting
Energy source	Light	Plasma arc	Oxidation reaction
Power density	High *	Medium	Low
Applicable material	Mild, low alloy, * stainless steels, non ferrous metal, non metal such as ceramics, Wood, cloth, etc.	Mild steel, low alloy steel, stainless steel, aluminium	Mild steels, low alloy steels
Cutting speed	Medium	High	Low
When cutting of 12 mm	1,000 mm/min	2,700 mm/min	500 mm/min
Kerf width	Small *	Large	Medium
When cutting of 12 mm	0.5 to 0.8 mm	2.5 to 3 mm *	1.5 mm
Dimensional accuracy	Good * less than 0.2 mm	Normal 0.5 to 1 mm	Bad 1 to 2 mm
Cut kerf inclination	Good *	Bad	Good *
Cut surface roughness	Normal	Good *	Normal
Upper edge melting	Very good *	Bad	Normal
Multi-torch cutting	Very difficult	Maximum about 4	more than 20 *
Automation easiness	Very suitable *	Normal	Normal
Environmental pollution	Good *	Bad (dust/fume)	Normal
Investment	High	High (including dust collector)	Low *

Note: * marked items are superior to the others.

Fig. 1 shows cutting capacity and thickness range of the three cutting processes. Plates of which thickness is in the range of 6 to 20 mm can be applied to cut them with any of three cutting process. TABLE 1 and Fig. 1 suggest that laser cutting has many advantages.

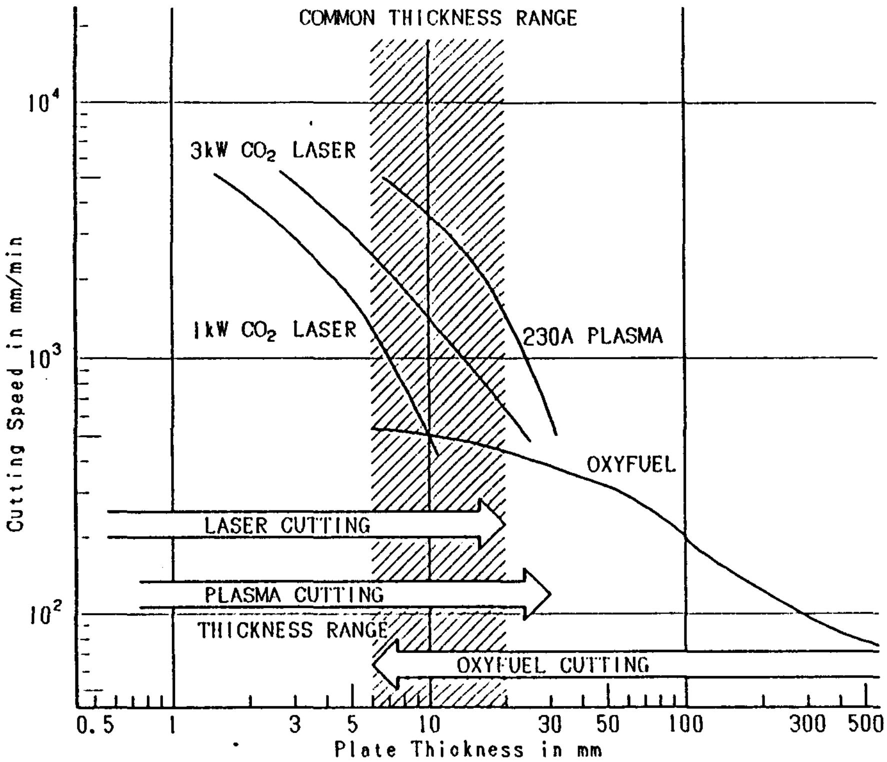


Fig. 1 Comparison of Cutting Speed

2.2 Application of Laser Cutting

In the selection of cutting facilities in fabrication industries, the most important point used to be economical efficiency such as cutting capacity, cutting cost, etc. In such simple estimation, the most advantageous process was clearly the way which has fastest cutting speed, that is, plasma cutting was the best. However, considering the circumstances around the production industries, the following items become important to plan optimum production facilities.

- counterplan for skilled labor famine trend
- sharp rationalization on manufacturing system
- improvement of processing accuracy

Under the above circumstances, the philosophy to select good cutting facilities should be based on the best application of advantages of each cutting process considering more overall aspects than it used to be.

The advantages of laser cutting can be summarized to higher cutting accuracy under the present tendency of automatization and labor saving and more flexible functions as a tool responding to manufacturing variety.

3. LASER CUTTING MACHINE

3.1 Requirement for Machine

The customers' requirements on a laser cutting machine to cut thick and large parts are as follows:

- Large effective cutting area: larger than 2.5 x 6 m
- Thicker cutting thickness: at least 20 mm for mild steel
- Improved cutting quality: easy adoption of automatic processing at subsequent stages
- High degree automatization: sharp labor saving on cutting stage
- Clean environment: removal of hard, dirty and dangerous works on thermal cutting
- Economical facilities: lower costs for investment and operation

3.2 Features of Oscillator Built-in Cutting Machine

The conventional laser cutting machines aim to cut thin material and do not fulfill the requirements of larger cutting area and thicker cutting thickness among those on section 3.1.

An oscillator built-in cutting machine is developed to solve these problems by mounting the high power laser oscillator on the cutting machine body. (Refer to PHOTO 1.)

The machine features the following points:

A) Effective cutting area

This oscillator built-in cutting machine realizes the following large cutting area, solving the problem of different cutting quality depending on point where the cutting head is due to beam path length variation on non-built-in machines.

- Effective cutting width: 4 to 5 meters
- Effective cutting length: more than 30 meters

B) Cutting thickness

A high power laser oscillator is necessary to cut thicker plates. The oscillator built-in cutting machine mounts the oscillator of 2 kW or 3 kW output. The cutting machine equipped with 3 kW oscillator enables to cut 22 mm thick plates with good quality.

C) Advantages

The oscillator built-in cutting machine features mainly to cut thick and large parts. However the machine also has the following advantages:

- Higher material yield and cutting efficiency by cutting of large parts.
- Flexible cutting thickness and cut profiles.
- Better cut accuracy and quality on parts which are difficult to cut by oxyfuel or plasma arc.
- Superior total productivity:
  * by process automatization at subsequent production stages.
  * by high operation efficiency applying two alternative work areas.
  * by high substantial cutting speed with common cutting lines.
  * by multiple processing of cutting, marking and drilling with a machine
  * by stable automatic operation due to few obstacles to cutting.
- Easy realization of clean working environment with low level dust, heat, noise, light, etc.

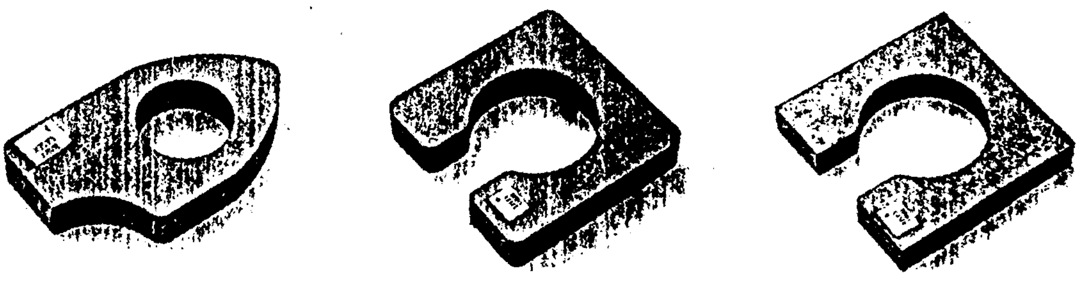
4. CUTTING OF THICK MILD STEEL PLATES

4.1 Characteristics of Thick Plate Cutting

In mild steel cutting of thick plates using oxygen as assist gas, cutting speed decreases as plate thickness increases, and oxidation of assist gas interacts more than laser beam energy, also when plate thickness increases.

Better quality cutting of thick plates requires sufficient consideration on the parameters such as cutting speed, assist gas pressure, nozzle orifice, distribution of focused laser beam, etc. which govern oxidation and/or molten oxide flow.

PHOTO 3 shows an example of thick plate cutting and PHOTOs 3 and 4 explain cut surface of thick plates.



Mild steel 16 mm thick | Mild steel 22 mm thick | Zinc primer painted steel 16 mm thick

PHOTO 3 Samples of Thick Plates Cut by Laser

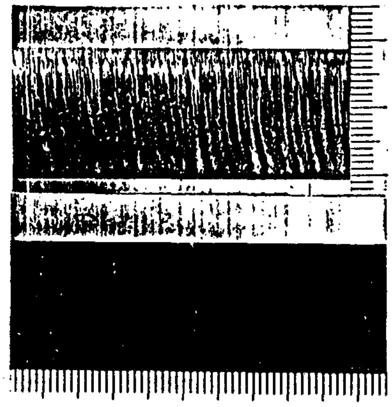


PHOTO 4 Cut Surface of 19 mm Thick Plate

Material:	JIS SS400 mill scale
Laser power:	3.0 kW, pulse
Cutting speed:	700 mm/min
Kerf width:	0.7 mm
Surface roughness (Rz):	40 microns (upper part)
	45 microns (middle part)
	40 microns (lower part)

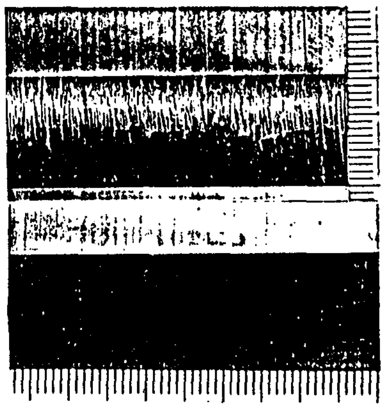


PHOTO 5 Cut Surface of 16 mm Thick Plate

Material:	JIS SS400 mill scale
Laser power:	3.0 kW, pulse
Cutting speed:	800 mm/min
Kerf width:	0.65 mm
Surface roughness (Rz):	32 microns (upper part)
	32 microns (middle part)
	27 microns (lower part)

4.2 Laser Power

Fig. 2 shows typical cutting speed using 2 and 3 kW oscillators. Thicker plate cutting requires higher laser power as understood from this figure.

FIG. 3 shows relation between laser power and cutting performance when cutting of 19 mm thick plates. Higher laser power contributes to raise *maximum* cutting thickness and to improve cut surface quality, but does not contribute to increase cutting speed, as suggested in Fig. 2 and 3.

On the other hand, eccessive high power may lower cut surface quality and occur self burning in thick plate cutting. Appropriate power is important in thick plate laser cutting.

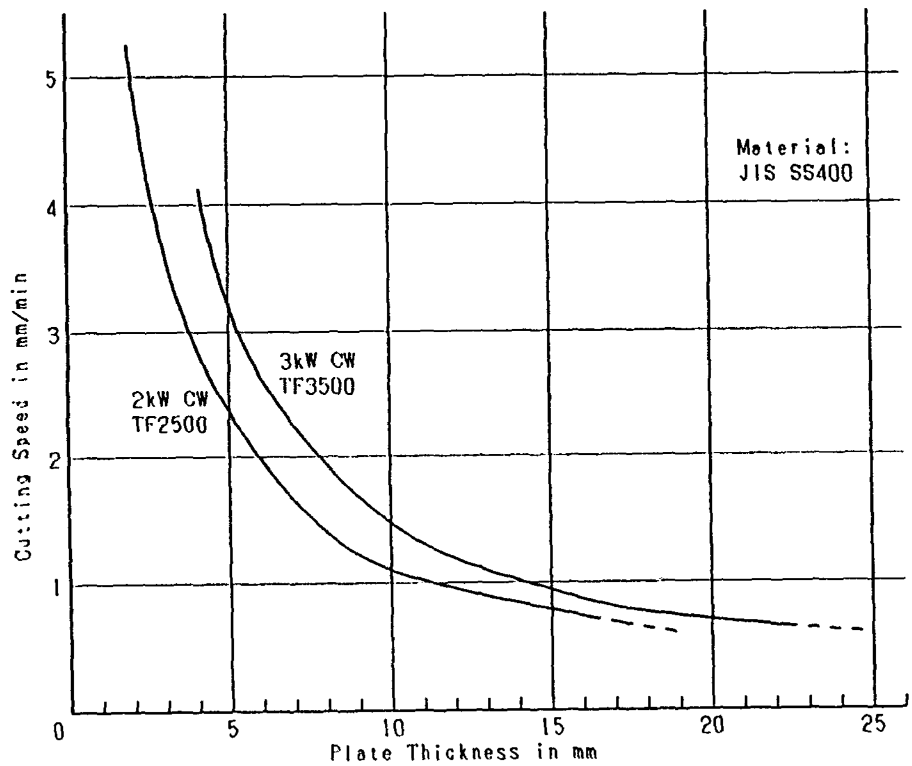


FIG. 2 Cutting Speed of Typical Mild Steel Plate

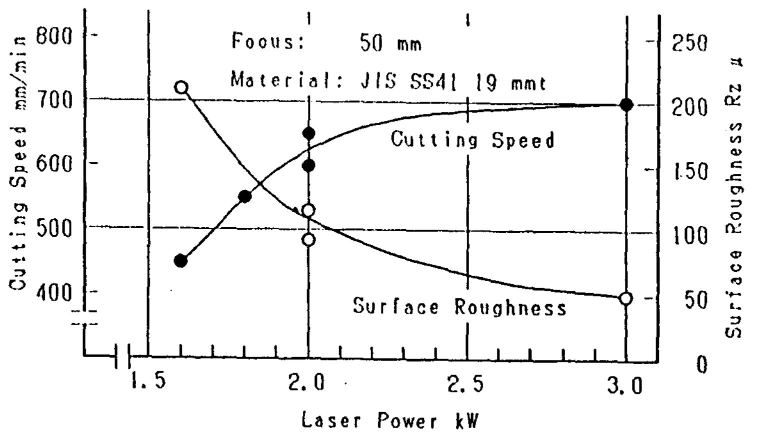


FIG. 3 Relation between Laser Power and Cut Surface Quality

4.3 Piercing Time

Piercing time increases exponentially as plate thickness increases, thus it affects to total operation time when cutting of plates having many piercing points.

To solve this problem, a new technique of laser beam power control is developed. This system can largely shorten piercing time. For instance, it took about two minutes to pierce 19 mm thick plate with the conventional way, but the new system enables to complete a piercing within 20 seconds.

4.4 Cutting of Primer Painted Plates

Many painted plates are cut for parts of large structures. Cutting speed and quality are important to cut painted plates.

Many kinds of primers are used for various applications but zinc rich primer is most used among them. Zinc rich primer coating decreases cutting speed and quality proportionally to zinc content and coating thickness. Plates coated with presently used primers can, however, be cut, if appropriate cutting parameters are selected.

4.5 Stable Cutting

The oxidation reaction relates very much to cutting of thick plates as stated on section 4.1. And setting range of parameters such as cutting speed, laser power, assist gas pressure, etc. is narrower than those in cutting of thin plates. Cutting stability is one of the most important factors to realize fully automated cutting systems.

So the following countermeasures are necessary for stable cutting of thick plates unlike when cutting of thin plates:

- Special cutting technique to prevent self burning at cutting start points and profile corners
- Minimization of deviation of beam focusing characteristics depending on variation of beam path length.
- Measure to fluctuation of piercing time caused by variation of cutting material and parameters, for instance, by using sensors which detect completion of a piercing.

There may be technical subjects to cut thick plates and to realize fully automated systems other than the above, and rapid improvement of technology are expected as thick plate laser cutting becomes popular.

4.6 Cutting Accuracy

Dimensional accuracy of cut parts is mainly affected with machine traveling accuracy and heat distortion of plates during cutting.

The modern thermal cutting machines travel sufficiently accurately in dimension thanks to numerical control and precision machine structure. Thus the most effective factor to determine cutting accuracy is heat distortion. Heat distortion is generated with heat expansion of material and lowered yielding point to plastically deform material both due to heat given to material. In laser cutting, heat input to material is much less than the case of plasma arc or oxyfuel cutting. TABLE 2 shows comparison of heat input.

TABLE 2 Heat Input of Three Thermal Cutting Processes

Process	Cutting Speed	Cutting Parameter	Unit Heat Input
Oxyfuel	420 mm/min	Fuel gas flow: 3.4 l/min with 3051#1 tip	22.53 J/mm2
Plasma	2,150 mm/min	Plasma current: 150A	7.33 J/mm2
Laser	900 mm/min	Power: 3 kW in CW mode	4.09 J/mm2

Condition: Cut profile: 100 dia. circle
Material: JIS SS 400 mild steel 12 mm thick

The more heat is given to a plate, naturally the more heat distortion is observed on a thermal cut plate. Because heat input of laser is the least among thermal cutting, heat distortion when cutting with laser is the smallest. FIG. 4 shows comparison of heat distorted values.

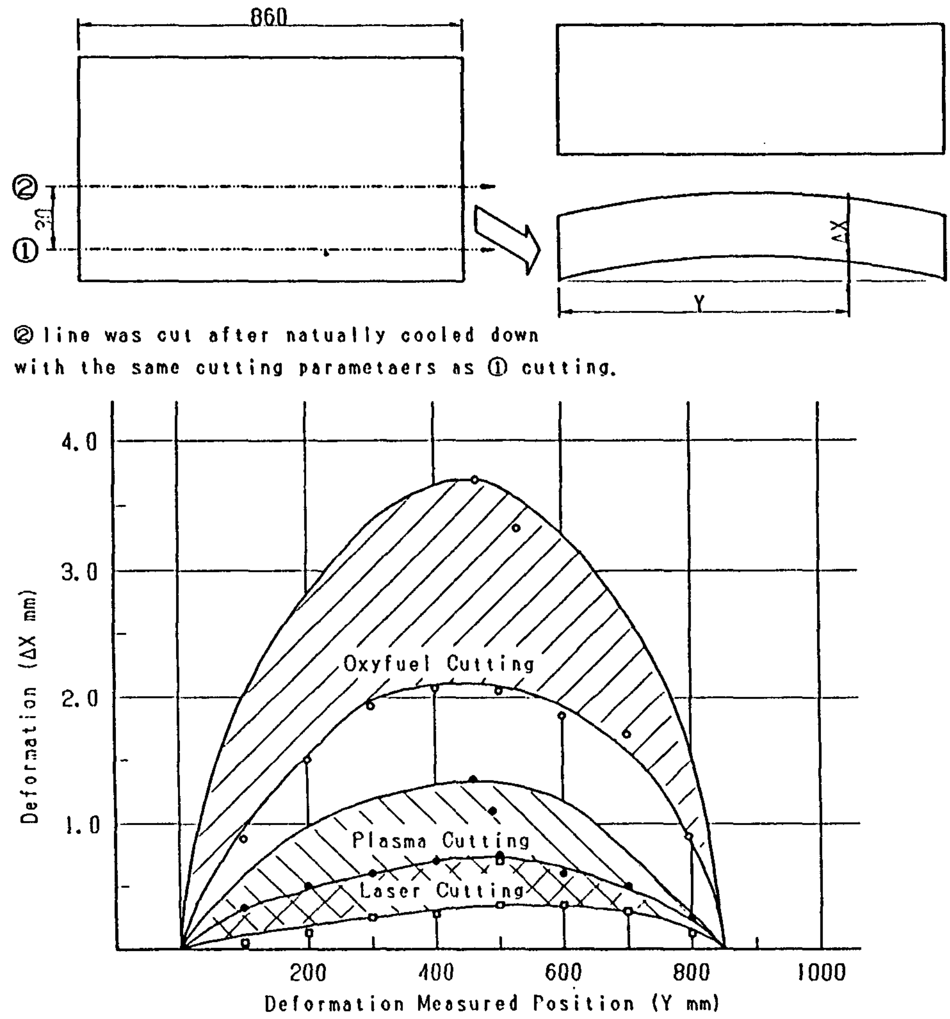


FIG. 4 Comparison of Heat Distortion with Thermal Cutting

5. CONCLUSION

The high power oscillator built-in cutting machine enlarges range of choice as the third thermal cutting process in the field of thick plate cutting where only plasma arc and oxyfuel cuttings exist.

This does not mean only the expansion of plate thickness range which laser can cut, but also gives deep significance to new idea and possibility to a "thick plate processing system" targeting more accurate, economical and flexible cutting, applying many advantages of laser cutting.

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