

ESTIMATE OF CUTTING DATA BY LASER CUTTING, ABRASIVE WATER JET CUTTING AND PLASMA CUTTING

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Abstract

Cutting plate is a difficult and time consuming task, especially when the job calls for a tight tolerance or an unusual shape. In those cases, can choose advanced cutting processes such as laser cutting, abrasive water jet cutting and plasma cutting. For advanced contour cutting processes of the greater importance is determining of cutting data, especially feed rate. One possibility to estimate of cutting data is using the cutting rate. In this paper is done an estimate of cutting data by laser cutting, abrasive water jet cutting and plasma cutting using the cutting rate.

Keywords: laser cutting, abrasive water jet cutting, plasma cutting, cutting data, cutting rate.

INTRODUCTION

The efficient manufacture of high-quality plate components is quite difficult task. Mechanical processes for contour cutting thin sheets, such as punching, shearing, and sawing, are characterized by the need for rigid clamping of the part, difficulty in handling hardened or brittle material, cut edge deformation or burring and the need for constant sharpening and replacement of the cutting tool. One of the easiest methods of contour cutting steel is oxy-fuel cutting. With respect to oxy-fuel cutting, laser cutting, abrasive water jet cutting, and plasma cutting are new attractive advanced processes for contour cutting of plate. They have numerous advantages, namely, a narrow cut, a proper cut profile, smooth and flat edges, minimal deformation of a workpiece, the possibility of applying high feed rates, intricate profile manufacture and fast adaptation to changes in manufacturing programs.

ADVANCED CONTOUR CUTTING PROCESSES

Advanced contour cutting processes are: laser cutting, abrasive water jet cutting, and plasma cutting.

Laser cutting, Fig.1, is an attractive process for contour cutting of plate. Laser cutting is thermal cutting method. It is based on applying

a highly concentrated light energy obtained by laser radiation that is used for material cutting by melting or evaporation. Laser is generator of light beam. Laser light is produces by passing electrical energy through a lasing medium. In CO₂ laser, carbon dioxide is mixed with helium and nitrogen to make the lasing medium. In Nd:YAG laser, yttrium-aluminum-garnet crystals containing neodymium ions are used as the medium. Laser beam is a high intensity beam of light. It can be focused into a very small spot (0.1-0.2 mm in diameter) on the workpiece surface by a lens or focusing mirror. The intensity of the focused laser beam for cutting steels typically is 10⁷-10⁸ W/cm². The high power density in the spot of the focused laser beam melts or vaporizes almost any material in a fraction of a second. In laser cutting, the aim is to melt and vaporize the material as quickly as possible and to produce as narrow a heat-affected zone as possible with minimum distortion of the workpiece. In the laser cutting operation, in addition to the heat obtained by focusing the laser beam, the assist gas is used for removing the molten material from the cutting zone, to protect the lenses from evaporation and to aid the burning process. In cutting of metals, laser cutting with assist gas is normally applied. Assist gas is fed through the coaxial nozzle to blow away the molten and evaporaten material. The gas type

can be oxygen, inert gas (nitrogen, helium, argon), or air depending on material type and quality requirements. Oxygen and nitrogen are frequently used as laser assist gases. The gas blowing increases the feed rates for as much as 40%. The useful power can be increased in the case that the process gas is oxygen due to the exothermic reaction. Thus this energy presents a greater part of the energy used for melting the material. Laser beam works without contact, free of wear and without exerting forces on the workpiece. Laser cutting produce the most precise cut with the smallest heat affected zone. The workpieces have cut edges of highest quality. Cutting quality permits production of finished component parts.

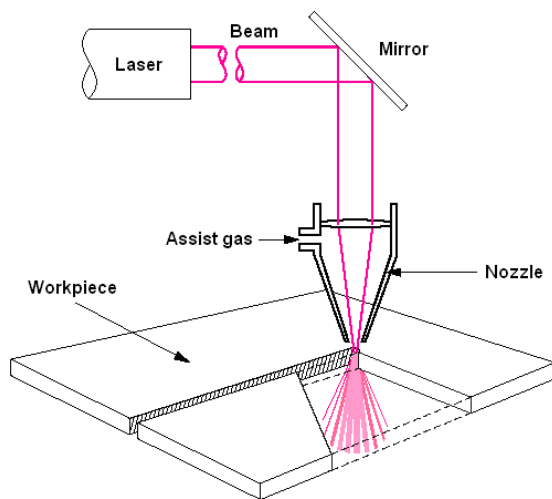


Fig.1. Laser cutting

Laser cutting is suited for high-precision cutting of various materials, from metals up to non-metals. Many materials, hard, soft, ferrous or non-ferrous can be precisely cut with a laser beam. Laser beam is capable of cutting steel, stainless steel, super alloys, copper, aluminum, and brass. Carbon and low-alloy steels can be cut quickly and with an excellent edge finish. Stainless steels, nickel, chromium and aerospace alloys sometimes show slag or dross at the bottom of the cut. Aluminum and copper tend to reflect the laser light unless coated or anodized to improved absorption. In addition, there are usually burrs on the bottom of the cut, which must be removed. Laser beam also cut non-metallic materials such as ceramic, quartz, plastic, wood, vinyl and easily-deformed materials like rubber. Laser cutting offers rapid cutting, cutting accuracy of 0.1 mm or better, minimal kerfs (0.25 mm) and heat affected zones

(0.2 mm), clean, straight-sided cuts with minimum loss, no part distortion, no tool wear, efficient part nesting capability, fast inexpensive prototyping, rapid design changes, intricate part cutting ability, cost competitive due to low fixture costs, high feed rates, multi-axis capability and minimal downtime. Consumables usage is less than with plasma cutting.

Abrasive water jet cutting, Fig.2, uses a mix of water and a fine abrasive for cutting materials. Mix abrasives with high pressure water give an effective tool to cut metals and nonmetals materials. The cutting process is like grinding, except that abrasives are moved through the material by water rather than by a solid wheel. Most theories explain abrasive water jet cutting as a form of micro erosion. Abrasive water jet cutting is the most suitable process for very thick, highly reflective or highly thermal-conductive materials, laminates and composite materials. Abrasive water jet can cut a wide range of thickness. Typical thickness are 100 mm for stainless steel, 120 mm for aluminum, 140 mm for stone, 100 mm for glass, but not limited. The abrasive water jet makes it possible to cut random contours, very fine tabs and filigree structures. Abrasive water jet cutting is a very precise technique. Tolerances of ± 0.1 mm can be realized in metal cutting. The workpiece is not heat-stressed. Materials cut by abrasive water jet have a smooth, satin-like finish, similar to a fine sandblasted finish. Abrasive water jet cut material at room temperatures. As a result, there are no heat-affected zones or structural changes in materials. Abrasive water jet can cut hardened metals and materials with low melting points. No heavy burrs are produced by the abrasive water jet. Parts can often be used directly without additional machining. By abrasive water jet cutting the high pressure pump produces the required pressure up to 400 MPa. A high pressure supply line directs the pressurized water from the pump to the cutting head. High pressure water passes through an orifice - water nozzle in the cutting head, creating a high velocity jet that induces a vacuum in a tiny mixing chamber located downstream of the orifice. A precisely metered flow of abrasive material is fed into the mixing chamber. Water jet stream, now including the abrasive, is re-focused by a focusing tube - abrasive nozzle which is typically from 0.7 to 1.0 mm in

diameter. The focusing tube is 50 to 70 mm in length, aligned concentrically with the orifice. Mix abrasives with high pressure water give an effective tool to cut metals and nonmetals materials.

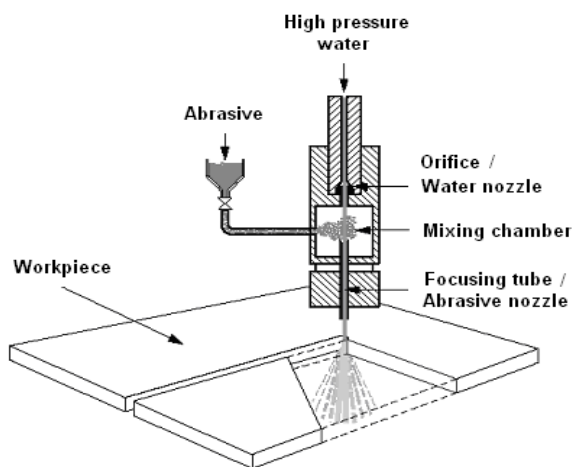


Fig. 2. Abrasive water jet cutting

Abrasive water jet does not produce the hardened edges of heat cutting methods or create structural changes in the workpiece. Abrasive water jet cutting produces very little lateral force, reducing or eliminating the need for fixturing to hold the workpiece. Toxic fumes, recast layers, edge hardening, slag and thermal stress are also totally eliminated.

Plasma cutting, Fig.3, is practical alternative to laser cutting and abrasive water jet cutting. Plasma cutting was developed primarily for cutting stainless steel and aluminum. Plasma is often described as the fourth state of matter. If energy is added to a gas, it can be shown that its physical properties change drastically. A highly ionized, hot gas is formed composed up of ions, electrons and neutral particles – plasma. Many of the laws of electrical current flow through a metal can also be applied to the plasma arc. High temperature of the plasma arc is used with its kinetic energy for plasma cutting. The plasma cutting process, as used in the cutting of electrically conductive metals, utilizes electrically conductive gas to transfer energy from an electrical power source through a plasma cutting torch to the material being cut. It uses a high-velocity jet of electrically charged gas to cut metal at up to 50.000 degrees Kelvin.

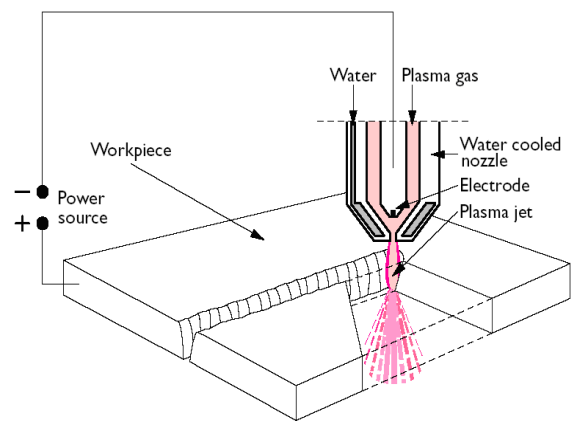


Fig. 3. Plasma cutting

The basic plasma cutting system consists of a power supply, an arc starting circuit and a torch. These system components provide the electrical energy, ionization capability and process control that is necessary to produce high quality, highly productive cuts on a variety of different materials. Plasma cutting can be used to cut plate to 180 mm thick. Plasma cutting is less expensive than laser cutting. Nitrogen based systems are well suited for high performance materials such as stainless steel, aluminum and nickel. Oxygen based systems are better for carbon steels and leave no nitride deposits, which complicate further processing. Plasma consumables can be short lived depending on gas selection, operator proficiency and water selection. Heat affected zones appear in the area surrounding the cut. Dross can occur. Under water cutting helps reduce the size of the heat affected zone. Fine plasma cutting (high tolerance plasma arc cutting) is used for cutting metals from 5 to 10 mm thickness. This system uses a nozzle with a smaller orifice diameter so the flow rate of the spinning plasma gas is much higher. The cut quality is nearly as good as laser cutting, but at a lower cost.

ESTIMATE OF CUTTING DATA

Technological problems related to the application of contour cutting process are in absence of sufficiently reliable practical cutting data. Cutting data can estimate using cutting rate, R

$$R = v \cdot s \quad (1)$$

Where are: v -feed rate, s -material thickness.

On the basis of the cutting rate R , can estimate:

Feed rate, v

$$v = \frac{R}{s} \quad (2)$$

Time to make the cut, t_g

$$t_g = \frac{\ell}{v} = \frac{\ell \cdot s}{R} \quad (3)$$

Material removal rate, Q

$$Q = R \cdot w \quad (4)$$

Specific power consumption, P_s

$$P_s = \frac{P}{Q} = \frac{P}{R \cdot w} \quad (5)$$

Where are ℓ -length of cut, w -width of cut, P -power of source.

Values of cutting rate have done in Table 1 for laser cutting, in Table 2 for abrasive water jet cutting, and in Table 3 for plasma cutting.

Table 1. Cutting rate of laser cutting

Method	Laser power P (W)	Cutting rate R (cm ² /min)
Laser oxygen cutting	3000	120-160
	4000	170-190
	5000	200-240
Laser nitrogen cutting	3000	80-100
	4000	110-130
	5000	110-160
Material of workpiece: mild steel		

Table 2. Cutting rate of abrasive water jet cutting

Material	Cutting rate R (cm ² /min)
Special steel	10-20
Titanium	10-25
Copper	15-30
Brass	20-50
Aluminum	20-50
Lead	80-120
Glass	100-200
Plexiglas	120-300
Rubber	200-400
Fiberglass	120-300
Ceramics	100-300
Natural stone	50-300

Table 3. Cutting rate of plasma cutting

Current I (A)	Cutting rate R (cm ² /min)
40	70-120
60	120-160
100	180-190
200	250-280
300	350-400
400	440-520

CONCLUSION

For contour cutting plates we can apply advanced cutting processes. For concrete workpiece it is necessary to select the right process. Each of contour cutting processes has its own specific strengths and weaknesses. Laser cutting and plasma cutting can make a cut in a particular type of material. Abrasive water jet cutting is a very versatile process by which can cut almost any material. Technological problems related to the application of contour cutting process are in absence of sufficiently reliable practical cutting data. Cutting data can estimate using cutting rate.

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