PLASMA, OXYFUEL AND LASER
Which Cutting Method Is Right For You?

By Kat McQuade

There are many different ways to cut metal using a thermal cutting process. Laser, oxyfuel, and plasma are the three major processes, each viable depending on the cutting needs of the business.

Oxyfuel cutting uses a chemical (exothermic) reaction between the oxygen and the steel to generate sufficient heat to melt the steel which is blown out of the gap by the gases used. It is only used for cutting carbon steel and is typically used to cut plate thicker than 2 inches. Oxyfuel is not effective on stainless steel or aluminum.

Plasma cutting uses a high-temperature, electrically-conductive gas to cut through any material that is electrically conductive. Plasma is suitable for ferrous and non-ferrous material, metal that is in any condition (rusted, painted, grated), and covers thicknesses ranging from gauge to 2 inches.

Laser cutting uses a high power laser beam to heat and then partially melt and vaporise the material. A laser is suitable for all types of metal, although the material surface does need to be in good condition (no rust). Laser is typically used for very thin plate (gauge to 1/4 inch), although it can be used on metals up to an inch thick. To cut thick plate with laser, one would need a high powered laser and a table capable of handling thick plate.

The process you choose depends very much on business needs and what areas are most critical, e.g. cut quality, productivity, operating costs, profitability, and flexibility.

Cut Quality Comes First
Depending on downstream processing of the cut parts, the cut quality may be of lesser or greater importance. There are a number of different aspects to cut quality.

<u>Angularity</u>. Each process produces different edge quality in terms of angularity. This is measured by looking at the edge deviation, or how large the angle is as a deviation from a straight edge (see ISO-9013). Laser cutting will typically give the lowest edge deviation, followed by plasma and oxyfuel, in that order.

<u>Kerf</u>. Kerf is the width of the material that is removed during the cutting process. For laser, this typically varies between 0.006 to 0.020 of an inch depending on the thickness of the plate. Note that while the kerf is very small, it is wider at the top of the cut. Plasma cutting produces a kerf in the range of 0.053 to 0.340 of an inch, depending on the thickness of the plate. Oxyfuel kerfs are in excess of this.

<u>Metallurgical changes on cut face</u>. All three processes will produce some heat-affected zone (HAZ) on the edge of the cut. Laser gives the smallest depths (0.004 to 0.008 of an inch); oxyfuel produces the largest, and plasma is in the middle. HAZ is generally related to speed, which explains why the slower oxyfuel process produces the largest HAZ. For both laser and

plasma, the hardness levels are somewhat dependent on the gases used. Nitrogen gas produces the hardest, most brittle edge, while oxygen gas produces the least.

Dross. All three processes can produce a certain amount of dross or slag. Oxyfuel produces the most, and since it is the slowest of the three processes, it is often the hardest to remove. As dross is formed, it melts and re-solidifies, welding itself back to the metal. It adheres most easily to hot surfaces, which means processes that have the largest heat-affected zone, such as oxyfuel, produce the greatest amount of dross, or slag. Both laser and plasma offer virtually dross-free cutting up to certain thicknesses, beyond which some dross is produced. With plasma, dross is typically easy to remove, first of all because there is less of it, and second because plasma produces a narrower heat-affected zone with less hot surface area for the metal to adhere to.

Tolerances. Tolerances are largely dependent on the accuracy of the cutting machine, but there are many other variables (skill of the operator, thickness of plate, speed, torch height to name a few) that do have an impact on tolerances. The figures below provide some general guidance only; actual tolerance levels can be larger or smaller. In general, laser will produce tolerances typically between +/-0.006 to 0.015 of an inch. Plasma tolerances range from +/- 0.015 to 0.030 and oxyfuel ranges from +/- 0.020 to 0.030.

Productivity is More than Speed

Productivity is defined as how many parts are produced in a given time period. One factor that is critical to the number of parts produced is cutting speed: there are many additional factors to consider, such as time spent waiting for preheat, delays associated with piercing, any necessary secondary operations, and any other productivity enhancers such as automated features. Figure 1 provides speeds for three selected thicknesses that can be cut by all three processes.

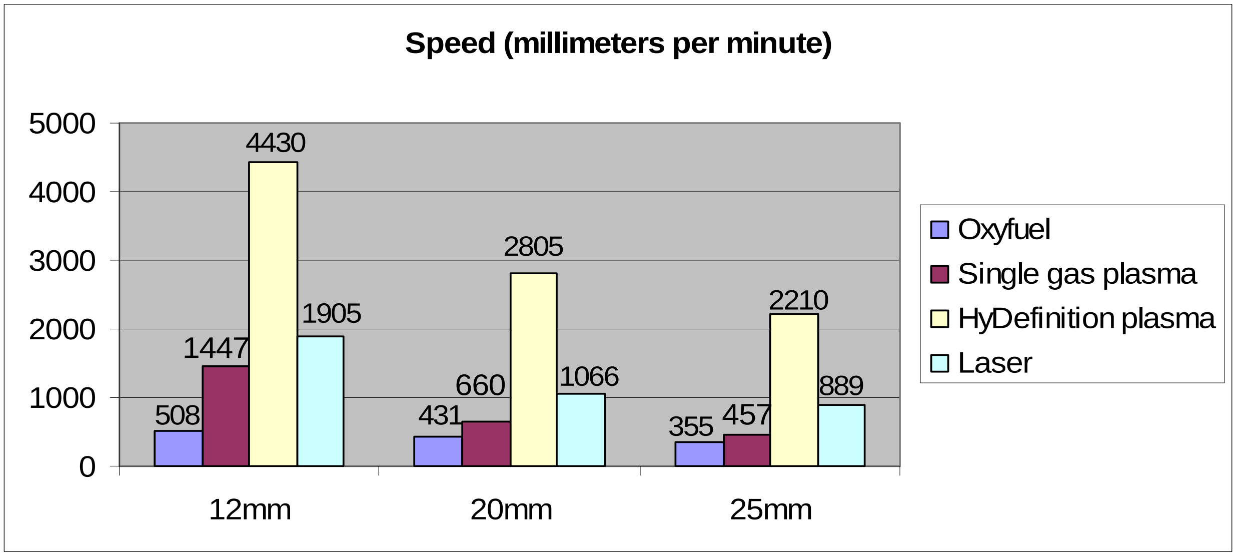

Fig 1 Comparison of cutting speeds for optimum cut quality

Speed comparisons can be used to easily calculate the number of parts produced per hour, provided the linear length to cut is known. For instance, if a part to be cut is a 12 by 12 inch square, the linear length is 48 inches or 4 feet (12 inches times 4 sides). This generates the number of parts per hour as shown in table 1.

	SPEED (inches per minute)	x 60 = LINEAR INCHES	÷ 12 = FEET CUT PER HOUR	PARTS PER HOUR (feet cut per hour ÷ size of part in feet)
Oxyfuel	20	1,200	100	25
Single gas plasma	57	3,420	285	71.25
HyDefinition plasma	170	10,200	850	212.5
Laser	75	4,500	375	93.75

Table 1 Productivity comparison

HyDefinition plasma produces the greatest number of parts per hour (212.5 parts). However, there are other factors that contribute to productivity. The example given does not take into account any delays for preheat or piercing, which are commonly associated with oxyfuel. This will further reduce the part count if using the oxyfuel process. Laser also has pierce delays, although these are shorter than oxyfuel. Of the three, plasma has the shortest amount of time associated with pierce delays because there is no need to preheat before piercing. The amount of energy transferred to the plate is so large, piercing can occur very quickly. All three processes do use some type of method to automatically control gas flow. This removes the variability common with different operators trying to adjust the gas flows for each process.

<u>Secondary operations</u>**.** If cut quality is a concern, additional time may be required for secondary operations, such as dross removal. This will cause a further reduction in part count especially when using oxyfuel.

Operating Cost Impacted by Many Factors
A third factor is operating cost, or how much will it cost you to operate the machine. Many factors—consumables, power, gas, and spare parts—impact the overall operating cost.

- Consumables make up the largest portion of operating costs when cutting with plasma. However, long lasting consumables are now available to help keep operating costs low.
- Power costs are negligible for oxyfuel, a small expense with plasma, and a bit higher for laser.
- Gas is the largest cost associated with laser due to high flow rates.
- Spare Parts are mainly a consideration for laser. While items such as lenses and mirrors are not frequently changed, they do fail and can be costly to replace, in terms of both the cost to purchase and the downtime involved to replace them. Therefore, you should include a portion of this cost when calculating your daily operational expense.

Besides these expenditures, the amount of time spent on secondary operations should also be considered when figuring out the cost to operate your system. Table 2 shows the estimated hourly cost for each cutting method based on manufacturer specifications.

COST OF CUTTING	OXYFUEL	SINGLE GAS PLASMA	HYDEFINITION PLASMA	LASER
Consumables	$0.06	$5.89	$16.77	$0.00
Power	$0.00	$0.89	$4.00	$5.90
Gas	$6.20	$0.01	$7.90	$37.43
Spare parts	$0.00	$0.00	$0.00	$3.50
Operating cost / hour	**$6.26**	**$6.79**	**$28.67**	**$46.83**

Table 2 Cost estimates come from manufacturer specifications, actual costs may vary

While the operating cost for oxyfuel appears quite low at $6.26 per hour, it isn't neccessarily the most economical system to operate. This is because the above table only looks at operating cost per hour when the real cost to consider is cost per part. A system that costs $20 per hour to operate, but only produces 2 parts per hour, is not nearly as efficient as something that costs $20 per hour but produces 100 parts.

To determine cost per part, divide the operating cost per hour by the number of parts produced per hour.

- Oxyfuel produced 25 parts per hour, bringing the cost per part to 25 cents.
- Single gas plasma produced 71.3 parts per hour for a cost of 40 cents per part.
- HyDefinition plasma produced 212.5 parts per hour which equals 13 cents per part.
- Laser produced 93.8 parts for a total per part cost of 50 cents.

Although the operating cost per hour for HyDefinition plasma is in the middle, fast cutting speeds make it the most economical system to operate. This is further accentuated when capital costs are factored in.

Calculating Investment Worth

What if you discover that it would make more sense to use a different cutting method? Should you just go out and purchase a new cutting system? Not necessarily. You'll first want to figure out if the particular system you are considering is worth the investment. To do this, multiply profit per part and parts per hour. To make the calculations easy, let's assume $1 profit per part.

- Oxyfuel produced 25 parts/hour for a profit of $25/hour or $200 profit per 8-hour work day.
- Single gas plasma produced 71.3 parts/hour for a profit of $71.30/hour or $570.40 per day.
- HyDefinition plasma produced 212.5 parts/hour, for a profit of $212.50/hour or $1,700 profit per day.
- Laser produced 93.8 parts per hour for an hourly profit of $93.80 and a daily profit of $750.

Now, take the cost of the system you are considering and divide that by your expected daily profit. We will assume secondary operations are not needed to keep the math simple. This will give you the amount of days needed to recoup your investment as shown in Table 3.

	Capital Cost **(see note below)**	Daily Profit	Days to Recoup Investment
Oxyfuel	$50,000	$200	250
Single gas plasma	$35,000	$570.40	61
HyDefinition plasma	$100,000	$1700	59
Laser	$300,000	$750	400

Table 3

Note: capital costs are estimates based on the following specifications:

- Oxyfuel, 5 x 10 cutting machine with 1 oxyfuel torch, PC based control, oxyfuel height control and nesting software
- Single gas plasma, 5 x 10 cutting machine with single side drive, roller ball, and single gas plasma system
- HyDefinition Plasma, 5 x 10 precision cutting machine with PC based control, arc voltage torch height control, nesting software, 130 Amp HyPerformance Class plasma
- Laser, 2.5 kw system, 5 x 10 precision cutting machine, CNC control, nesting software

Flexibility

The final factor to consider is the amount of flexibility your particular situation requires. Plasma is considered the most flexible of the three cut methods because of its ability to cut a wide range of metal types and thicknesses, and its ability to mark, and gouge in addition to cutting.

Summary

Oxyfuel, laser and plasma cutting are all well established thermal processes used for cutting steel. Each has advantages and shortcomings, dependent on specific business needs.

- Laser is often used when cutting thin plate (less than 1/4 inch), and in cases where tight tolerances are required, however, capital costs and overall operating costs are high.
- Oxyfuel has the lowest capital and operating cost, though the costs per part in the end are higher due to slow cutting speeds and lower cut quality which often requires more secondary operations. Oxyfuel is primarily used for cutting only thick carbon steel (greater than 2 inches) when cut quality is not a requirement.
- Plasma provides a good balance in terms of capital cost and an optimal mix of cut quality, productivity and operating costs. It has significant thickness range and material flexibility and provides the highest cutting speeds.

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