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Reviewing the paper on Comparison between Laser & Plasma Cutting

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ABSTRACT

This review paper deals with analyzing different papers published on the topic of comparison of Plasma & Laser cutting processes. Finding the best cutting system fulfilling an overall need in terms of economical and efficiency point of view. Paper consists of working principle in detail, comparison of these two processes based on a parameter such as cutting speed, head generation, surface finish, torch standoff distance, etc. factors. It is critically important to possess a sound knowledge of factors affecting quality to obtain a better quality cut. The advantages and disadvantages of both cutting systems may alter the area of the application completely.

Keywords: - cutting speed, Torch standoff, cut, laser, plasma.

1. INTRODUCTION

Rapid advances in technology can make it quite difficult to decide which cutting method is the most beneficial research and your practical applications. Hopefully, the following paper can be used as a guide to help you decide which is a better cutting process comparing two against material type, thickness, accuracy, cutting speed, operating cost, and capital investment for each process. Although the different thermal cutting processes plasma cutting and laser cutting all have their advantages within their specific areas of application, new technological developments have led to the extension and some overlapping of these areas of application. Which process the user will choose in the end, depends not only on the material and the cutting task at hand, but of course also on the investment and operating costs. First of all, we will see detailed working of both processes, then we will going to read review on paper published by respected authors. Then we will conclude the comparison.

1.1 Brief Introduction to Laser Cutting Process

Laser technology melts through materials using the heat generated from a concentrated light beam. With a focal point of 0.05 cm, a 4 kW laser develops an intensity of 2.1 MW/cm2. Though best suited for cutting steel, stainless and aluminum, lasers can also cut a variety of other materials that fall generally in thicknesses of 1 in or less. A good to excellent surface finish can be achieved with a small HAZ.

The most popular laser technologies are solid state and CO2 in power ranges from 1.5 kW to those that use powerful 6 kW resonators. Lasers achieve good to excellent fine feature cutting with very small kerf. Also, a small amount of dross may be present, meaning secondary operations often are not required. Cutting speed is fast to very fast on material thickness less than ¼ in, especially steel.

Lasers are limited in their ability to cut thick material. For example, they can cut mild carbon steel up to 1.25 in, stainless steel up to 1 in and aluminum up to 0.75 in. They also experience process limitations due to their reflective and thermal conductive properties when cutting aluminum, brass, copper and titanium. A capital investment in this technology can run from around $400k to over $1 million for a typical cutting tolerance of .001 in to .003 in.

1.2 Working Principle of Laser Cutting Process

Laser cutting can be:

• **Sublimating** — the material is removed primarily by evaporation due to the high intensity of the laser radiation in the cut area;

• **Melting** — the material is melted by a laser beam in the cut area and blown away by an auxiliary gas. Mainly metallic materials are cut using this process;

• **Burning**— a laser beam heats the material to its ignition temperature, so it can then burn in an exothermic reaction with the reactive gas (e.g., oxygen), and the slag is removed from the cutting area by an auxiliary gas. Titanium, low carbon, and corrosion-resistant steel can be cut this way.

Laser cutting, the most established laser material processing technology, is a method for shaping and separating a workpiece into segments of desired geometry. The cutting process is executed by moving a focused laser beam along the surface of the workpiece at a constant distance, thereby generating a narrow cut kerf. This kerf fully penetrates the material along the desired cut contour.

The absorbed energy heats and transforms the prospective kerf volume into a state (molten, vaporized, or chemically changed) that is volatile or can be removed easily. Normally, removal of the material is supported by a gas jet that, impinges coaxially to the laser beam. This cutting gas accelerates the transformed material and ejects it from the kerf. This process is successful only if the melt zone completely penetrates the workpiece.

Laser metal cutting is therefore generally restricted to thin sections. While cutting has been reported through 100 mm sections of steel, the process is more typically used on metal sheets 6 mm or less in thickness.

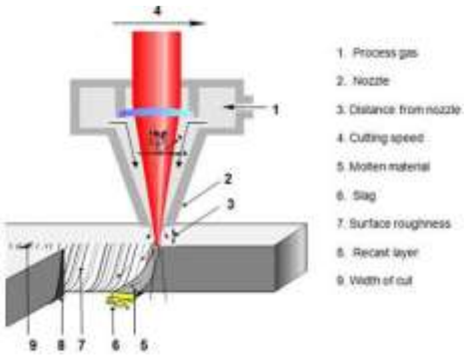


Fig No. 1 Laser Cutting Process

1.2 Brief Introduction to Plasma Cutting Process

Plasma is called the fourth state of matter which is produced when substantial heat is added to a gas and is the term used to describe a mass of gas in which enough atoms are ionized. Fig. 1 shows a schematic representation of the plasma arc cutting process. The basic plasma cutting system consists of a power supply, an arc starting circuit, and a torch . Torch comprises nozzle and electrode assembly with shielding and retaining cap.

In this process, the electrode has a negative polarity and the workpiece a positive polarity so that the majority of arc energy used is approximately two-thirds for cutting . There are two modes of operation of this process transferred arc mode and non-transferred arc mode. In transferred arc mode the pilot arc is formed between the electrode and the nozzle which is transferred to the workpiece for cutting, whereas in non-transferred mode the arc is formed between electrode and nozzle, which is used for cutting. When the plasma gas flow is increased, deep penetration of plasma arc is obtained which cuts through the material and removes the molten material from the kerf generated.

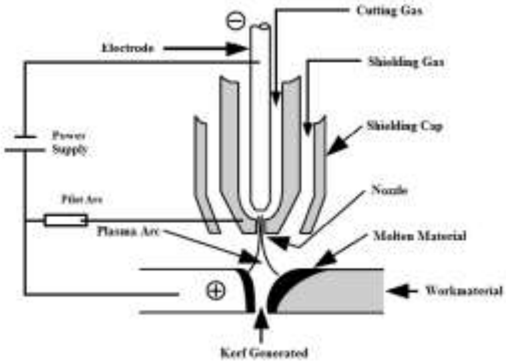


Fig. No.2 Schematic Representation of Plasma Arc Cutting Process

In the conventional system using a tungsten electrode, the plasma is formed using either argon or nitrogen. However, the inert or non-reactive plasma forming gas can be replaced with oxidizing gas like air but this requires a special electrode of hafnium or zirconium mounted in a copper holder . Quality of cut and dimensional accuracy produced by plasma arc cutting process can be accessed by measuring kerf width, bevel angle (conicity), heat affected zone (HAZ), surface finish and, material removal rate, etc. Following Fig. 2 shows quality characteristics of plasma cutting.

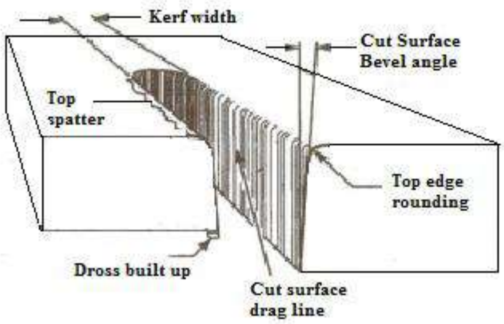


Fig. No. 3 Quality Characteristics of Plasma Arc Cutting Process

During the process of plasma cutting the magnetic field is generated around the arc because of the flowing current through it. There may be a difference in a magnetic field along the length of the arc because of variation in pressure from the electrode to the workpiece, which produces a resultant force on ionized particles of gas. This resultant force blows the arc in opposite direction to the concentration of the magnetic field. Not all the arc blow is disadvantageous. Sometimes a small amount of arc flow can be used for benefit, help to form the bead shape, control molten slag, and control penetration. When arc blow is causing defects such as undercut, inconsistent penetration, beads of irregular width, porosity, wavy beads, and excessive spatter, it must be controlled.

2. COMPARISON TABLE FOR PLASMA & LASER CUTTING

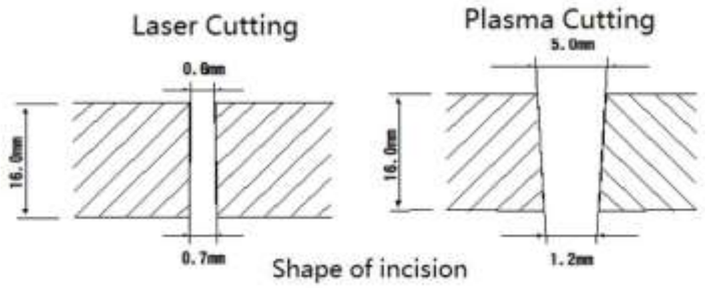
Sr. No.	Parameters	Laser cutting (CO2 laser 4kW)	Plasma cutting (O2 plasma 230A)
1	**Cuttable materials**	Metal: carbon steel, low alloy steel, stainless steel, high alloy steel, aluminum, copper alloy etc; Nonmetal: ceramics, plastics, rubber, wood, leather, cloth, paper, 묷□lm etc.	High alloy steel such as carbon steel, low alloy steel and stainless Steel. Other non-metallic high viscosity materials (rubber, 묷□lm, etc.), brittle Materials (ceramics, glass, etc.) cannot be processed.
2	**Max. cutting thickness**	25mm(mild steel)	150mm (S.S., M.S.)
3	**Slot Width**	Narrow	Very Wide
		Around 0.6mm for 16mm mild steel cutting	Around 0.5mm for 16mm mild steel cutting
4	**Cutting size precision (cut off deformation)**	Very Good	Normal
		Error ± 15mm	Error ± 0.5 ∿ 1mm
5	**Advantage**	･Capable of high precision Machining.	･Portable
6		･There is very little thermal Deformation.	･High speed cut off with low cost
7	**Disadvantage**	･With the increase of plate thickness, the hole drilling Time increases sharply.	･Short service life of the electrode and nozzle (2 changes per day)
		･The state of the material surface determines the Processing quality.	･Wide incision and big deformation.
		･The difference in the composition of the material affects the quality of the cut surface.	･The width and shape of the incision are changed due to the consumption of the nozzle and electrode.
			･The noise is loud when cutting & Large amount of dust production
			･Big hole dia.(φ12mm-16mm)
			･Cannot cut easily magnetized Material.
8	**The cutting slot comparison for laser cutting and plasma cutting**		

Table No. 1 Comparison Table for Plasma & Laser Cutting Processes

2.1 Comparison Regarding Cut Quality

Cutting range: When comparing the cutting range it is evident that plasma covers a larger range of material thicknesses than laser. For process-related reasons the limits of laser cutting are at approx. 40 mm material thickness. The maximum sheet thickness that can be cut with the laser cutting is around 25 mm (mild steel) and 20 mm (stainless steel). In contrast, plasma cutting can be used for materials with up to 160 mm thickness.

Fig. No. 4 Cutting samples stainless steel; left: 150 mm, centre: 100 mm, right: 80 mm

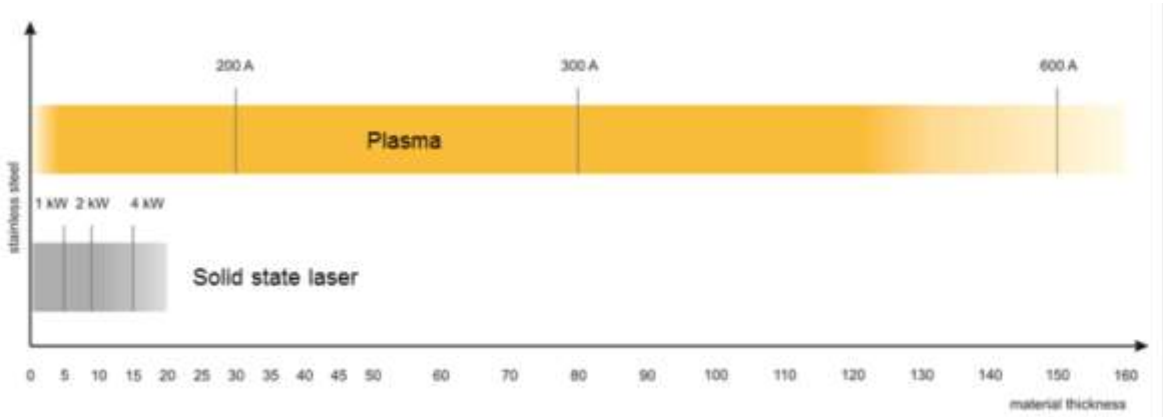


Fig. No. 5 Cutting range for stainless steel, above: plasma, below: laser

Cut surface: The tests within the mentioned cutting range demonstrated that especially the laser-cut samples with material thicknesses of 10 mm and more show a much higher roughness than the plasma-cut samples with the same material thicknesses. The samples cut with plasma technique showed the lowest average surface roughness. The following tables show the comparison of the three cutting systems using 10 mm mild steel and 10 mm stainless steel as examples.

Cutting Parameters:				
Cutting system	Plasma Cutting		Solid state laser	
Material thickness	10 mm			
Cut surface				
Cutting current / Cutting power	70 A	90 A	2 kW	4 kW
Cutting Speed	800 mm/min	1600 mm/min	1000 mm/min	2100 mm/min
Roughness Rz*	40 µm	9 µm	66 µm	35 µm

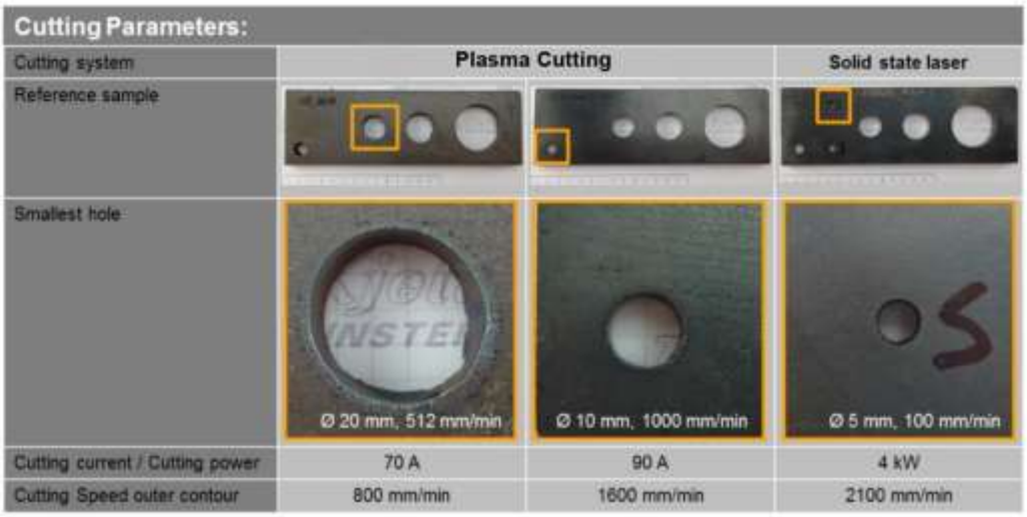
Fig. No. 6 Comparison of cutting processes – cut surface mild steel, 10 mm

Cutting Parameters:				
Cutting system	Plasma Cutting		Solid state laser	
Material thickness	10 mm			
Cut surface				
Cutting current / Cutting power	70 A	130 A	2 kW	4 kW
Cutting Speed	800 mm/min	1400 mm/min	300 mm/min	600 mm/min
Roughness Rz*	78 µm	10 µm	105 µm	90 µm

* Measuring range: 2.5 mm x 5, sample centre (cut surface).
For process-related reasons the samples cut as examples in the laboratory may show some variations (influence of the guiding system, variations in the material etc.)

Fig. No. 7 Comparison of cutting processes – cut surface stainless steel, 10 mm

Quality of holes: Whereas Plasma and solid-state laser allow very precise hole cutting, the cost-efficient plasma cutting process showed a low preciseness and contour accuracy. Often the holes were non-circular and showed a slightly conical shape. Up to a material thickness of 10 mm the solid-state laser could cut holes with a hole diameter to material thickness ratio of 0.5: 1. Then the ratio changed to 1: 1. Where plasma was concerned, there were differences between the materials. Whereas the holes in mild steel of all material thicknesses could be cut with a hole diameter to material thickness ratio of 1 : 1 (minimum hole diameter = 5 mm), the ratio concerning all stainless steel samples was 2 : 1 (minimum hole diameter = 10 mm).



Cutting Parameters:			
Cutting system	Plasma Cutting		Solid state laser
Reference sample			
Smallest hole	Ø 20 mm, 512 mm/min	Ø 10 mm, 1000 mm/min	Ø 5 mm, 100 mm/min
Cutting current / Cutting power	70 A	90 A	4 kW
Cutting Speed outer contour	800 mm/min	1600 mm/min	2100 mm/min

Fig. No. 8 Comparison of cutting processes – holes mild steel, 10 mm

Kerf width: As expected, the kerf width of the tested solid-state laser cuts was smaller than the plasma-cut samples, so that also smaller and filigree contours can be cut with laser. With laser, kerf widths between 0.2 mm and 0.7 mm were achieved with sheet thicknesses ranging between 3 mm and 20 mm. With plasma, the kerf widths were between 1.7 mm and 3.9 mm with sheet thicknesses ranging between 3 mm and 25 mm. However, it turned out that such a narrow kerf achieved with laser can also have an adverse effect as the inner contours often did not fall out without problems because the molten metal could not completely be driven out of the narrow kerf.

Cutting Parameters:			
Cutting system	Plasma Cutting	Solid state laser	
Material	Mild Steel – 1.0037		
Kerf width			–
Cutting current / Cutting power	90 A	4 kW	–
Cutting Speed	1600 mm/min	2100 mm/min	–
Material	Stainless Steel		
Kerf width			–
Cutting current / Cutting power	130 A	4 kW	–
Cutting Speed	1400 mm/min	600 mm/min	–

Fig. No. 9 Comparison of cutting processes – kerfs, 10 mm

3. CONCLUSIONS

Each of these methods has its advantages and shortcomings and which one to choose depends only on the specific business needs. The well - chosen cutting technology clearly affects the inputs and outputs of the entire production process. From the preceding case study it is evident that each process has a different significant cost set associated with it. The comparison show that all processes have their areas of application and their special advantages. While the conventional plasma cutting achieves the lowest costs per cutting metre, a lower cut quality in the form of rougher cut surfaces, imprecise contours and limitations regarding the cutting range have to be accepted. The high-end plasma cutting system convinced in the tests with a good cut quality and reasonable costs, especially for material thicknesses from 3 mm and 5 mm. Where thinner sheets with a thickness of up to 10 mm were concerned, the laser cutting system could cut small contours and achieved a good cut quality.

Thick materials can be cut with laser only at relatively low speeds. Depending on the material, the costs per cutting metre increase considerably for laser oxy-fuel cutting from 20 mm and for laser fusion cutting from 15 mm because the cutting speeds decrease and the gas consumption increases significantly especially during laser fusion cutting. A combination of plasma and laser cutting makes it possible to use the special advantages of each process: laser works quickly and precisely where thin sheets and small contours are concerned, whereas plasma cutting is suitable for cutting thicker materials with high quality and at low costs. From an economic point of view, when combining the two systems and depending on the cutting task at hand, it is recommendable to use laser cutting for sheets with a thickness of up to 5 mm and plasma cutting for sheets with a thickness from 3 mm.

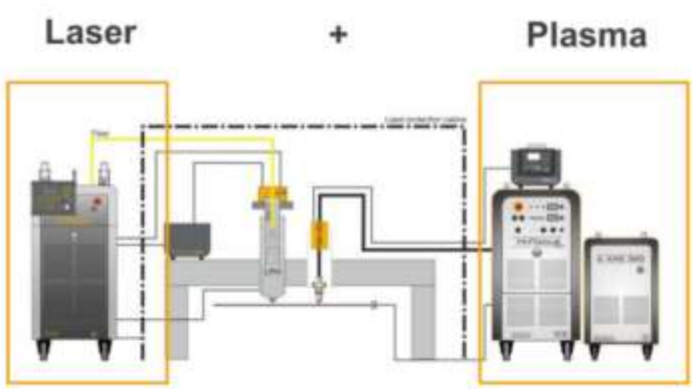


Fig. No. 10 Combination of plasma and laser on guiding system

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