LASER CUTTING OF STAINLESS STEEL

Laser inert gas cutting is the most applicable process type used for cutting of stainless steel. Laser oxygen cutting is also applied in cases where the cut face oxidation is not a critical matter. Laser cutting of stainless steel with inert gas (nitrogen) and active gas (oxygen) as assisting gases are discussed. The workplace safety concerns for both processes are also discussed.

Laser inert gas cutting of stainless steel

During the laser inert gas cutting process (also called laser fusion cutting), the laser beam is the only heat source and the high-pressure inert gas jet provides the mechanical force for melt ejection. Stainless steels have relatively low thermal conductivity, which enables them to be cut at relatively high rates since energy remains at the cutting front rather than being dissipated into the material ahead of the cutting front. The nickel present in austenitic grades of stainless steel affects energy coupling and heat transfer limiting the thickness that can be cut with a given laser beam power.

Nitrogen is the most commonly used assist gas for this cutting technique because of its low chemical activity and its cheapness compared with truly inert gases such as argon. Cutting with nitrogen produces cut edges of a high quality but the cutting speed is usually lower than when cutting with oxygen. Dross adhesion to the bottom edge of the material due to the high viscosity of the molten material may be a problem in nitrogen cutting but it is generally addressed by using very high assist gas pressures. A high pressure nitrogen gas jet is used when cut edge quality is of greater importance than cutting speed. Figure 1 is a schematic of the cut zone when laser cutting stainless steel, there is adherent dross on the bottom edge of the sheet.

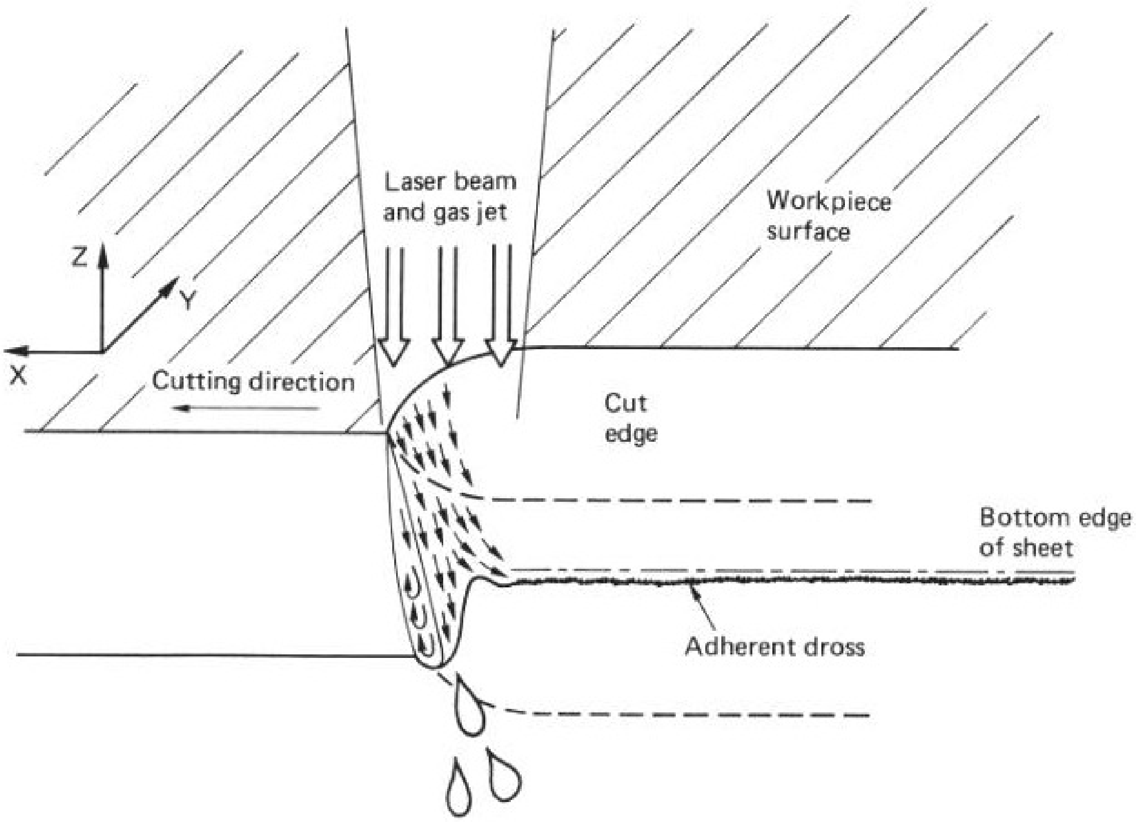

Figure 1: A schematic of the cut zone when laser cutting stainless steel.

Figure 2 shows a typical good quality cut edge produced by high pressure inert gas cutting of 5mm thick stainless steel using a CO_2 laser with the employed gas pressure of 14 bar, cutting speed of 1.1 m/min and a laser power of 1.4 kW

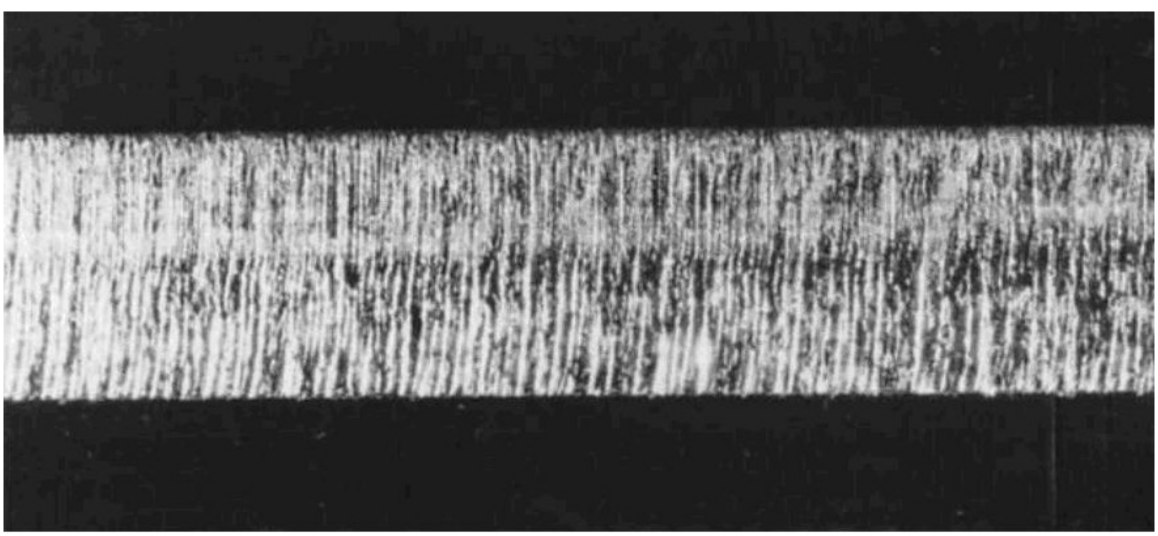

Figure 2: The stainless steel cut edge produced by high-pressure nitrogen cutting.

A comparison of maximum cutting speeds for nitrogen assisted laser cutting of stainless steel (AISI 304) with the CO_2 laser and fiber laser are shown in figure 3. Higher cutting speeds are achieved with the fiber laser.

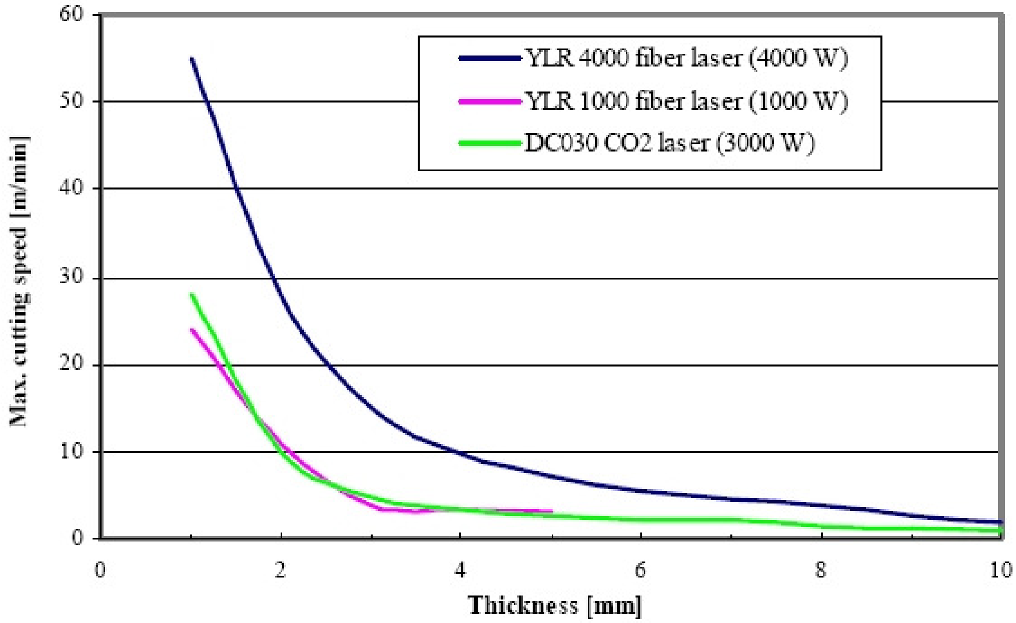

Figure 3: Comparison of maximum cutting speeds with different lasers (The material is stainless steel AISI 304, Nitrogen assisted laser cutting)

Laser oxygen cutting of stainless steel

During oxygen assisted cutting of stainless steel, chromium that has the greatest affinity for oxygen of all the alloying elements present is oxidized preferentially readily forming oxides with a high melting temperature. These oxides do not dissolve in the molten material but form a seal that limits the exothermic reaction in the upper part of the cutting front. The high surface tension of the oxide leads to dross formation and a rough cut surface. The residual oxide layers left on the cut edge have a higher chromium content than the base material and the solidified melt underlying the oxidized edge has a depleted chromium level. Other alloying elements can also create problems when they react with active gases. Figure 4 shows a schematic of the changes in chemistry across the cross section of the stainless steel cut edge and the typical cut quality obtained is shown in figure 5.

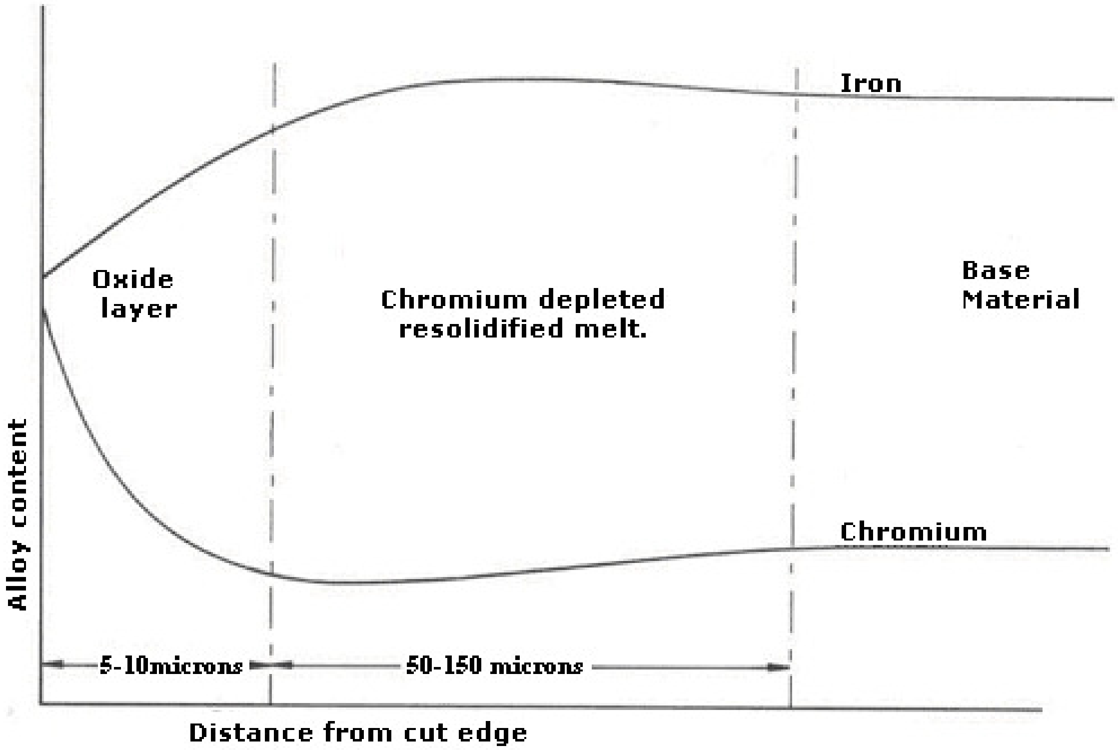

Figure 4: A schematic of the changes in chemistry across the cross section of stainless steel cut edge.

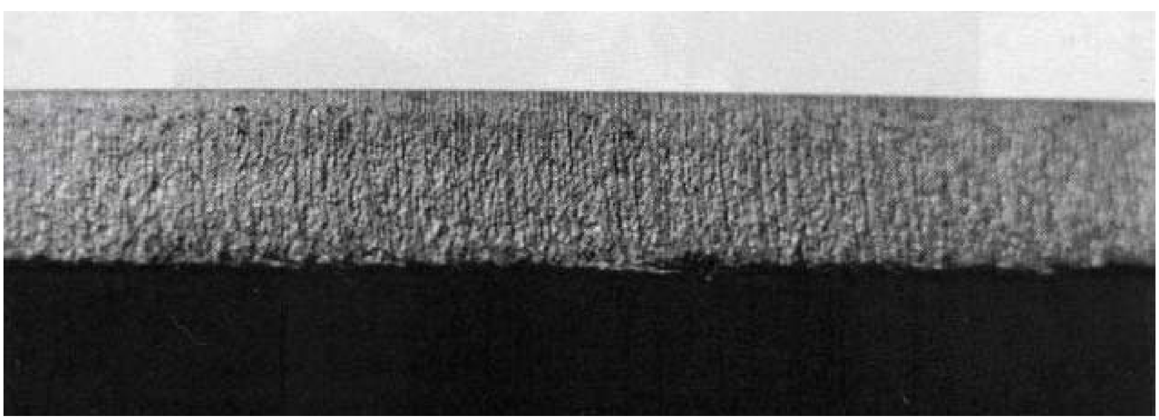

Figure 5: A typical example of a stainless steel cut edge (4 mm thick) produced by oxygen cutting.

The oxidation of stainless steel during cutting is more complex than the mild steel case because the reaction involves the formation of three oxides (Fe_2O_3, Cr_2O_3 and NiO) rather than two (FeO and Fe_2O_3) in mild steel cutting. The formation of the three oxides generates more heat than the simple oxidation of iron to FeO. Therefore, this cutting process is characterized by higher cutting speeds than in fusion cutting. The cutting speed decreases greatly with increase in material thickness and higher laser powers are required to cut thicker materials (see figure 6).

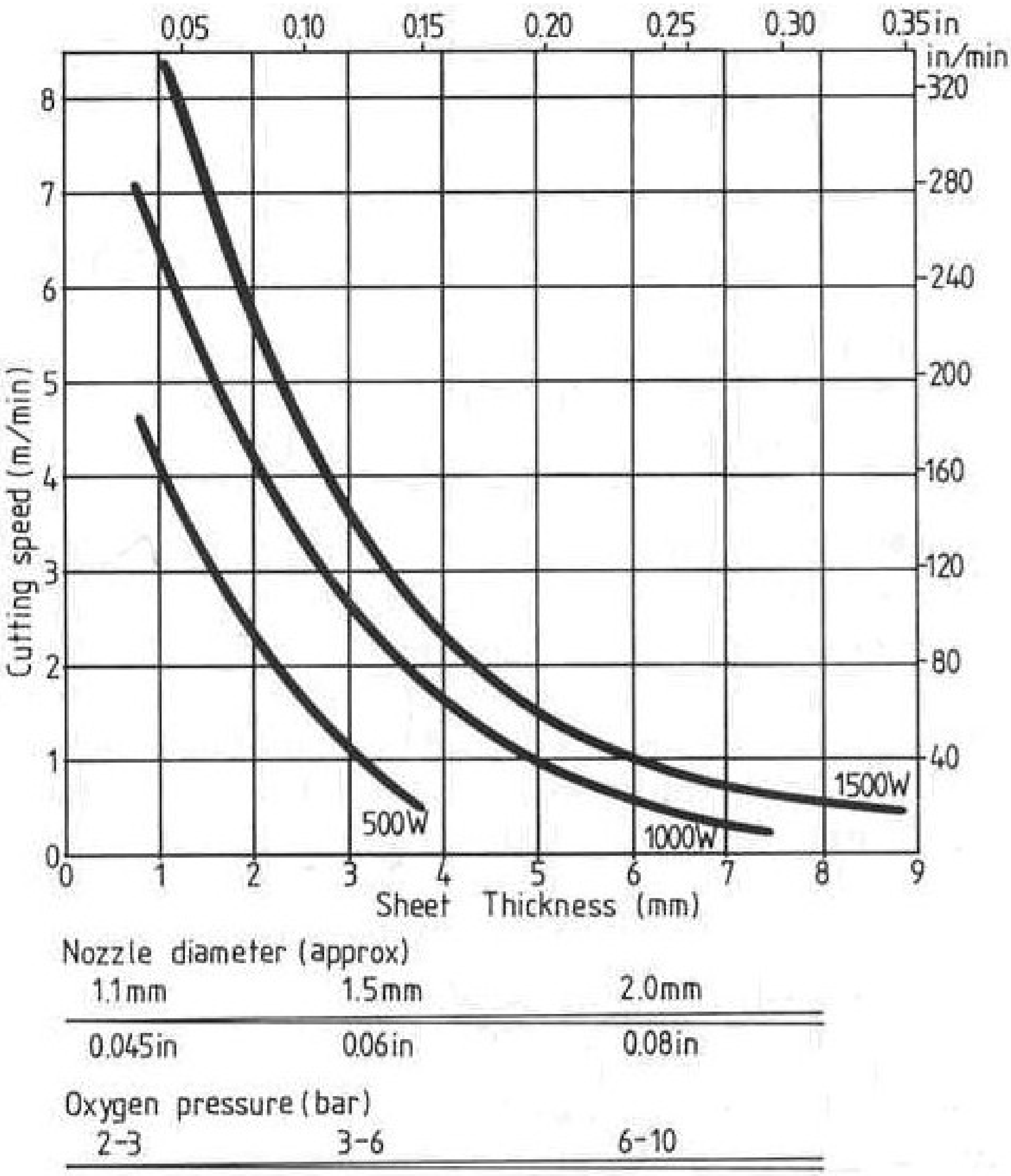

Figure 6: Typical cutting speeds for oxygen-assisted cutting of stainless steels with CO_2 laser.

While chromium oxide in small concentrations protects the base material, the chromium oxides formed under laser cutting with even small concentrations of oxygen usually cause corrosion. Therefore, any oxidation of the cut surface must be avoided in order to preserve the corrosion resistance. Cutting of stainless steel with inert gas is often favored because it avoids the dross problem caused by the formation of high melting point oxides of chromium when stainless steel is cut with oxygen gas.

Workplace safety during laser cutting of stainless steel

Although, the gases used for laser cutting stainless steel are not toxic, they can be potentially hazardous and the hazards associated with these gases include fume, gas properties and pressure. Precautions must be taken to avoid inhalation of chromium vapour that is generated when cutting stainless steels.

The increasing focus on workplace safety has led to assessment of the hazards associated with fume generation from the laser cutting process. Fume extraction is a requirement of laser cutting and most systems are equipped with integral fume extraction systems. The cutting of stainless steel provides an example of how the choice of assist gas can affect the levels of fume generation. An analysis of cutting fume was carried out by Gabzdyl to determine fume formation rates, chemical composition of the fume and the particle size distribution. The results showed that the amount of fume generated by oxygen cutting was 100 times greater than that produced by nitrogen cutting. The particle size and distribution of the oxygen generated fume was smaller, predominantly in the less than 6μm range, a size that is considered to be the most problematical hygienically while the particle size of the fume generated by nitrogen assisted cutting was found to be significantly larger. The chemical analysis of the fume generated by both processes showed that the percentage of chromium (VI), a known carcinogen, in the fume was lower when cutting with nitrogen.

There is a danger to human life if ambient oxygen concentrations fall below 18% while conditions of oxygen enrichment make many materials susceptible to combustion. Operation of the high pressure nitrogen cutting in a confined area causes a risk of oxygen depletion therefore good ventilation around the laser cutting area is essential as even oxygen and nitrogen can be potentially hazardous. Nitrogen cutting that usually utilizes high pressure requires pipelines and equipment that are suitable for the pressure.