Oxyfuel cutting - process and fuel gases

Mechanized oxyacetylene cutting system

The oxy-fuel process is the most widely applied industrial thermal cutting process because it can cut thicknesses from 0.5mm to 2,500mm, the equipment is low cost and can be used manually or mechanized There are several fuel gas and nozzle design options that can significantly enhance performance in terms of cut quality and cutting speed.

Process fundamentals

The cutting process is illustrated in *Fig. 1*. Basically, a mixture of oxygen and the fuel gas is used to preheat the metal to its 'ignition' temperature which, for steel, is 700°C - 900°C (bright red heat) but well below its melting point. A jet of pure oxygen is then directed into the preheated area instigating a vigorous exothermic chemical reaction between the oxygen and the metal to form iron oxide or slag. The oxygen jet blows away the slag enabling the jet to pierce through the material and continue to cut through the material.

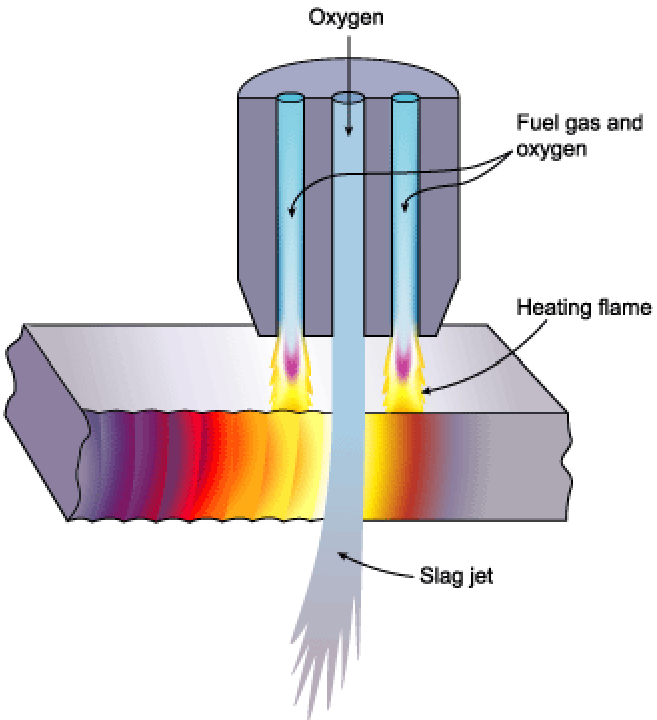

Fig.1. Diagram of oxyacetylene cutting process

There are four basic requirements for oxy-fuel cutting:

- the ignition temperature of the material must be lower than its melting point otherwise the material would melt and flow away before cutting could take place
- the oxide melting point must be lower than that of the surrounding material so that it can be mechanically blown away by the oxygen jet
- the oxidation reaction between the oxygen jet and the metal must be sufficient to maintain the ignition temperature
- a minimum of gaseous reaction products should be produced so as not to dilute the cutting oxygen

As stainless steel, cast iron and non-ferrous metals form refractory oxides; i. e. the oxide melting point is higher than the material, powder must be injected into the flame to form a low melting point, fluid slag.

Purity of oxygen

The cutting speed and cut edge quality are primarily determined by the purity of the oxygen stream. Thus, nozzle design plays a significant role in protecting the oxygen stream from air entrainment.

The purity of oxygen should be at least 99.5%. A decrease in purity of 1% will typically reduce the cutting speed by 25% and increase the gas consumption by 25%.

Choice of fuel gas

Fuel gas combustion occurs in two distinct zones. In the inner cone or primary flame, the fuel gas combines with oxygen to form carbon monoxide and hydrogen which for acetylene, the reaction is given by

$$2C_2H_2 + 2O_2 \rightarrow 4CO + 2H_2$$

Combustion also continues in the secondary or outer zone of the flame with oxygen being supplied from the air.

$$4CO + 2H_2 + 3O_2 \rightarrow 4CO_2 + 2H_2O$$

Thus, fuel gases are characterized by their

- flame temperature - the hottest part of the flame is at the tip of the primary flame (inner cone)
- fuel gas to oxygen ratio - the amount of fuel gas required for combustion but this will vary according to whether the flame is neutral, oxidizing or reducing
- heat of combustion - heat of combustion is greater in the outer part of the flame

The five most commonly used fuel gases are acetylene, propane, MAPP (methyl-acetylene-propadiene), propylene and natural gas. The properties of the gases are given in the Table. The relative performance of the fuel gases in terms of pierce time, cutting speed and cut edge quality, is determined by the flame temperature and heat distribution within the inner and out flame cones.

Acetylene

Acetylene produces the highest flame temperature of all the fuel gases. The maximum flame temperature for acetylene (in oxygen) is approximately 3,160°C compared with a maximum temperature of 2,810°C with propane. The hotter flame produces more rapid piercing of the materials with the pierce time being typically one third that produced with propane.

The higher flame speed (7.4m/s compared with 3.3m/s for propane) and the higher calorific value of the primary flame (inner cone) (18,890kJ/m^3 compared with 10,433 kJ/m^3 for propane) produce a more intense flame at the surface of the metal reducing the width of the Heat Affected Zone (HAZ) and the degree of distortion.

Propane

Propane produces a lower flame temperature than acetylene (the maximum flame temperature in oxygen is 2,828°C compared with 3,160°C for acetylene). It has a greater total heat of combustion than acetylene but the heat is generated mostly in the outer cone (*see Table*). The characteristic appearance of the flames for acetylene and propane are shown in *Figs.2 and 3* where the propane flame appears to be less focused. Consequently, piercing is much slower but as the burning and slag formation are effected by the oxygen jet, cutting speeds are about the same as for acetylene.

Propane has a greater stoichiometric oxygen requirement than acetylene; for the maximum flame temperature in oxygen, the ratio of the volume of oxygen to fuel gas are 1.2 to 1 for acetylene and 4.3 to 1 for propane.

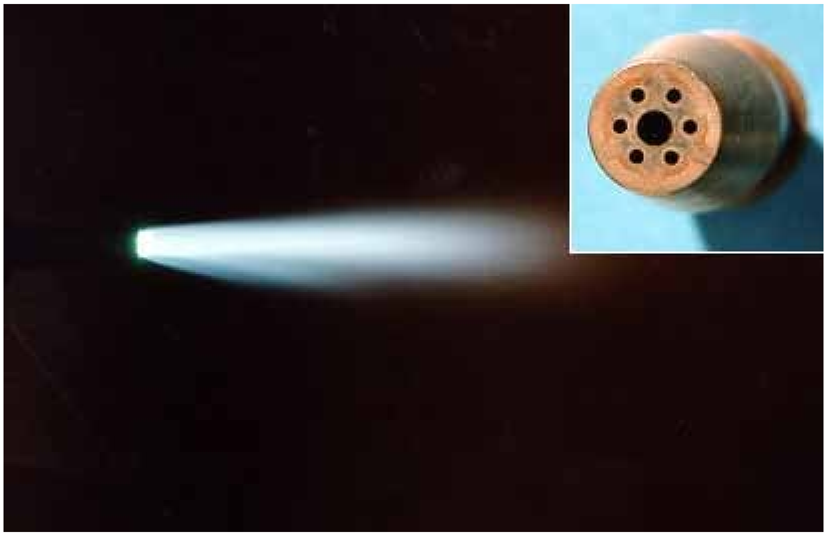

Fig.2. Oxyacetylene gas jet and nozzle design

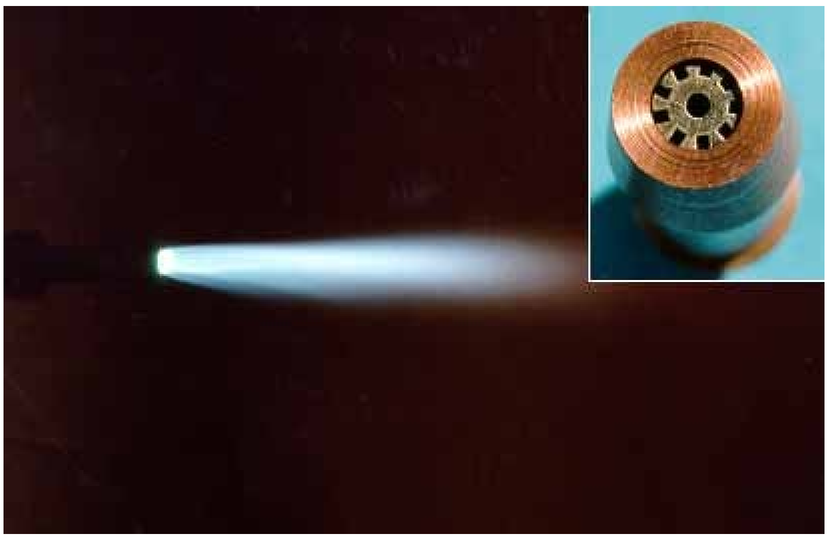

Fig.3. Propane gas jet and nozzle design

MAPP

MAPP gas is a mixture of various hydrocarbons, principally, methyl-acetylene and propadiene. It produces a relatively hot flame (2,976°C) with a high heat release in the primary flame (inner cone) (15,445kJ/m ^{3}), less than for acetylene (18,890kJm ^{3}) but much higher than for propane (10,433kJm ^{3}). The secondary flame (outer cone) also gives off a high heat release, similar to propane and natural gas. The combination of a lower flame temperature, more distributed heat source and larger gas flows compared with acetylene results in a substantially slower pierce time.

As MAPP gas can be used at a higher pressure than acetylene, it can be used for underwater cutting in deep water as it is less likely to dissociate into its components of carbon and hydrogen which are explosive.

Propylene

Propylene is a liquid petroleum gas (LPG) product and has a similar flame temperature to MAPP (2896°C compared to 2,976°C for MAPP); it is hotter than propane, but not as hot as acetylene. It gives off a high heat release in the outer cone (72,000kJ/m ^{3}) but, like propane, it has the disadvantage of having a high stoichiometric fuel gas requirement (oxygen to oxygen ratio of approximately 3.7 to 1 by volume).

Natural Gas

Natural gas has the lowest flame temperature similar to propane and the lowest total heat value of the commonly used fuel gases; e. g. for the inner flame 1,490kJ/m 3 compared with 18,890kJ/m 3 for acetylene. Consequently, natural gas is the slowest for piercing.

Table : Fuel Gas Characteristics

Fuel Gas	Maximum Flame Temperature °F	Maximum Flame Temperature °C	Oxygen to fuel gas Ratio (vol)	Heat distribution kJ/m3	
				Primary	Secondary
Acetylene	5720	3160	1.2:1	18890	35882
Propane	5090	2810	4.3:1	10433	85325
MAPP	5301	2927	3.3:1	15445	56431
Propylene	5202	2872	3.7:1	16000	72000
Hydrogen	5133	2834	0.42:1	-	-
Natural Gas	5018	2770	1.8:1	1490	35770

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