International Institute of Welding Commission I Documents

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DOC.1-743-83/OE/IE-021-83

—Waterjet Cutting by C Bolt Anderson,
The Danish Welding Institute

Summary

High pressure water jets at 1400 to 3500 bar and small diameter 0.12 to 0.5 mm have been effectively used for cutting such materials as polymers, plastics, leather, corrugated boards, textile and other non-metal materials.

Though theoretically and experimentally it has been proved that metals can be cut with waterjets at pressure in excess of 10,500 bar, equipment capable of producing such pressures is not considered commercially viable.

Given below are the sample cutting speeds of some of the materials reported in this document :

Materials	Thickness	Speed
Corrugated board	6.4 mm	3050 mm/s
Rubber	25.4 mm	130 mm/s
Plywood	6.4 mm	2030 mm/s
Plywood	12.7 mm	250 mm/s
Paper	25.4 mm	100 mm/s
Granite	6.4 mm	250 mm/s
Aluminium	1.3 mm	2.5 mm/s

Advantages

It is a process capable of cutting in all directions, with minimal kerf loss of material, with little or no air-borne dust, with no problem of dulling of cutting tool or heating/deformation of cut material or fire or explosion hazard and the process is clean for food/medical applications.

Comparison with other processes

The process can compete with other methods such as nibbling, punching and CO_2-laser cutting for non-metal materials.

The process is not comparable to thermal cutting process—only factors that may be compared are width of kerf and width of heat affected zone.

High Velocity Abrasive Waterjet Cutting

Abrasive jet machining is presently used for surface finishing and removing thin layer of metals. The capabilities of this technique are limited by slow removal rates and required close proximity of the nozzle to the work-piece, inefficiency in terms of power consumption and possibility of severe fire hazard.

High velocity abrasive waterjet cutting combines conventional waterjet cutting and abrasive-jet machining techniques.

1981 annual report of British Hydrodynamic Research Association published for the first time, a brief report on the process claiming capability of cutting 12 mm thick steel plates.

Flow Industries Inc. USA are conducting proprietory investigation and have brought out a commercial cutting system in the market the 'PASER' (Particle Stream Erosion equipment) with claimed capability of cutting a variety of metals and such non-homogeneous materials as steel reinforced concrete, metal laminates and advanced metal-reinforced composites. 200 mm deep cut can be made with narrow kerf in one pass through a slab of reinforced concrete.

The process is capable of cutting exotic materials without changing metallurgical properties and without inducing thermal or deformation stresses. Cutting can be carried out without fire or explosion hazard.

IE—029—83/DOC.I—744—83/OE

Standard for Geometric Quality Classification of Thermally Cut Metal Surfaces<100 mm Thickness

Prepared by : S C I Members

Issued by : Fred Goldberg

Revised : March 1983

Scope — Proposal covers quality of cut surfaces in metals upto 100 mm thickness cut by process such as oxy-fuel gas, plasma and laser.

Quality factors and quality classification—Following factors are considered :

(i) Surface smoothness 'h'—the maximum depth of striations on the cut surface measured in mm.

(ii) Flatness 'u'—the out of flatness value 'u' is the maximum deviation of the actual cut surface plane perpendicular to the intended surface plane.

(iii) Edge 'c'—Top and bottom corner deviation 'c' in mm is the distance between theoretical sharp corner and the real corner.

The above three factors are considered in conjunction with slag adherence 's' and plate surface condition 'p' in quality classification number composed of five digit grade number in the order given above.

Following characteristics of the cut surface, though not covered under quality classification are defined below :

Notch or Crater — A defect in the cut surface causing an irregular deep striation not to be considered in measuring 'h'.

Drag — Draglines are created by oxygen jet and are measured by drag angle between these lines and bottom surface plane of the plate.

Quality Classification Grades

Surface Smoothness 'h' — Altogether 5 grades from 'Superfine' 'O' to 'No requirement' '4' are covered as given in table below :

Grade	Thickness 1 — 100 mm
0	<0,03 mm
1	<0,05 mm
2	<0,15 mm
3	<0,25 mm
4	no req.

Flatness 'u'

There are two proposals. The first one by Dr Goldberg, the second one in line with DIN 2310(3) and NF A 87000. There is better agreement in favour of second proposal.

First Proposal

Surface flatness 'u' grades are defined for the following applications :

Grade 0 : Superhigh quality for machine parts to be used without further treatment such as teethed wheels or similar.

Grade 1 : High quality edges required as edge preparation for some specific welding methods (for instance butt-welding of deckplates with submerged arc welding in one pass which permits a gap of 0,6 mm between plates).

Grade 2 : Normal quality required for welding of T-joints or V-joints.

Grade 3 : Outer edges on beam-flanges that are not being welded and therefore left exposed.

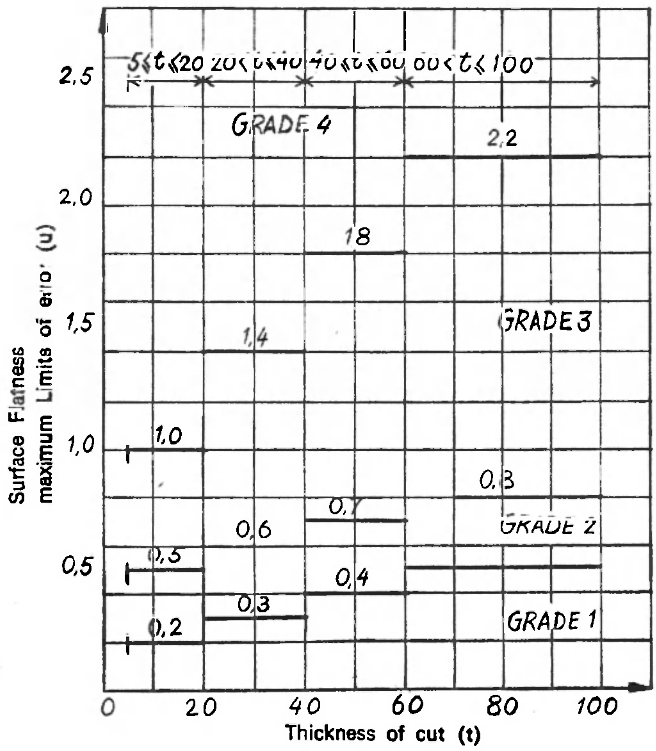
Grade 4 : No requirements.

Grades	Thickness	
	0 — 30 mm	31 — 100 mm
0	0,1	0,2
1	0,3	0,01xt
2	1,0	0,03xt
3	2,0	0,07xt
4	no req.	no req.

t=plate thickness in mm

Second Proposal—In line with DIN 2310(3) and NFA 87000

Table 1



Corner deformation 'C'

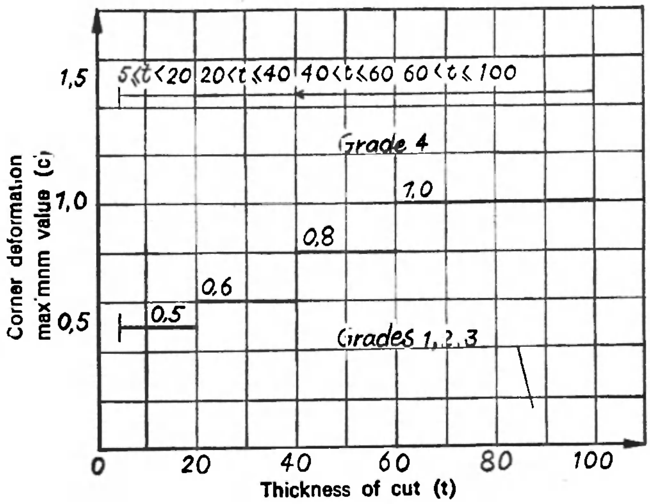
Here again there are two proposals—second one having a better agreement.

First Proposal

Grades	C
0	<0,1 mm
1	<0,5 mm
2	<1,0 mm
3	<3,0 mm
4	no req.

Second Proposal

Table 2



Slag Adherence 'a'

Grade 0 : No slag.
Grade 1 : Slag easy to remove
Grade 2 : Slag which breaks away with hard scraping.
Grade 3 : Slag fused to workpiece and can only be removed with mechanical equipment.

Plate Surface Condition

Grade 0 : Shot-blast or cleaned to similar standard.
Grade 1 : Primed with iron oxide.
Grade 2 : Primed with zinc-components.
Grade 3 : Light mill scale or rust <0.5 mm thick
Grade 4 : Heavy scale or rust>0.5 mm thick.

IIW-QCS (IIW—Quality Classification System)

This consists of a three or five digit number within bracket following the wording QCS. The digits representing 'h', 'u' 'c', 's' & 'p' in the order mentioned.

Examples — QCS (12200)
or QCS (332)

IIW Document IE.024-83, March '83

—Technique for piercing in oxygen cutting machines
by Dr Fred Goldberg

Normally oxygen cutting is started from the edge of a plate, but on many occasions because of the design of the component, starting has to be done inside a plate by piercing a hole by oxygen cutting. However, even when component design is not a constraint, cut may be started by piercing a hole instead of starting from the edge with a view to minimising distortion by restricting the movement of cut shape/scrap.

In the second case, piercing can be avoided and operation can be started from the edge with a 'scrap lock' technique (*see Fig.* 1).

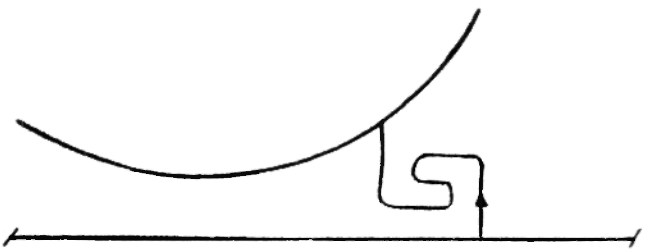


Fig. 1. "Scrap-lock" cutting procedure from edge.

Piercing in plate thickness < 100 mm

Selection of Gases

(1) Acetylene—Gives the fastest preheat but has the disadvantage of being more prone to backfire under the arduous piercing condition due to reflected heat and slag. In spite of this drawback, Acetylene can be successfully used for piercing upto 100 mm thick plate using proper technique. In lower thickness involving many piercing operations, it has the distinct advantage of reducing preheat time by approx. 50%.

(2) Propane, MAPP, Natural Gas & other hydrocarbons—These gases have the advantage of being more resistant to backfire.

Selection of cutting nozzles

(1) High speed cutting nozzle—Convergent-divergent orifices of high speed cutting nozzles are very sensitive against wear and spatter and not recommended for piercing operation.

(2) Nozzle with parallel bore—suitable for piercing.

(3) For acetylene, nozzle mixing type blowpipe preferred compared to injector-type because of better backfire resistance.

(4) Propane and other hydrocarbons—Injector type is good enough and more economical compared to nozzle-mix type.

Piercing Techniques

(1) Retract-Piercing (RP piercing method)

(a) Position cutter with ignited flame on the plate and wait till surface sparks start flying off preheated surface.

(b) Raise cutter approximately 5 cm, introduce cutting oxygen and simultaneously move cutter forward slowly. Slowly bring down the cutter height to normal operating height by the time piercing is complete. During the movement of the cutter till piercing is complete, slag moves away from the cutter and slag spray may be thrown upto 5-10 m distance. Operator should therefore position himself away from slag spray.

(2) Pressure controlled piercing (PCP method)

In this method, the blowpipe is not retracted and after the preheating is completed, a gas control system slowly increases the cutting oxygen pressure simultaneously with the blowpipe moving forward till piercing is through.

PCP is best suited for automatic piercing in plate thickness < 50 mm.

(3) Wire Insertion method (WI method)

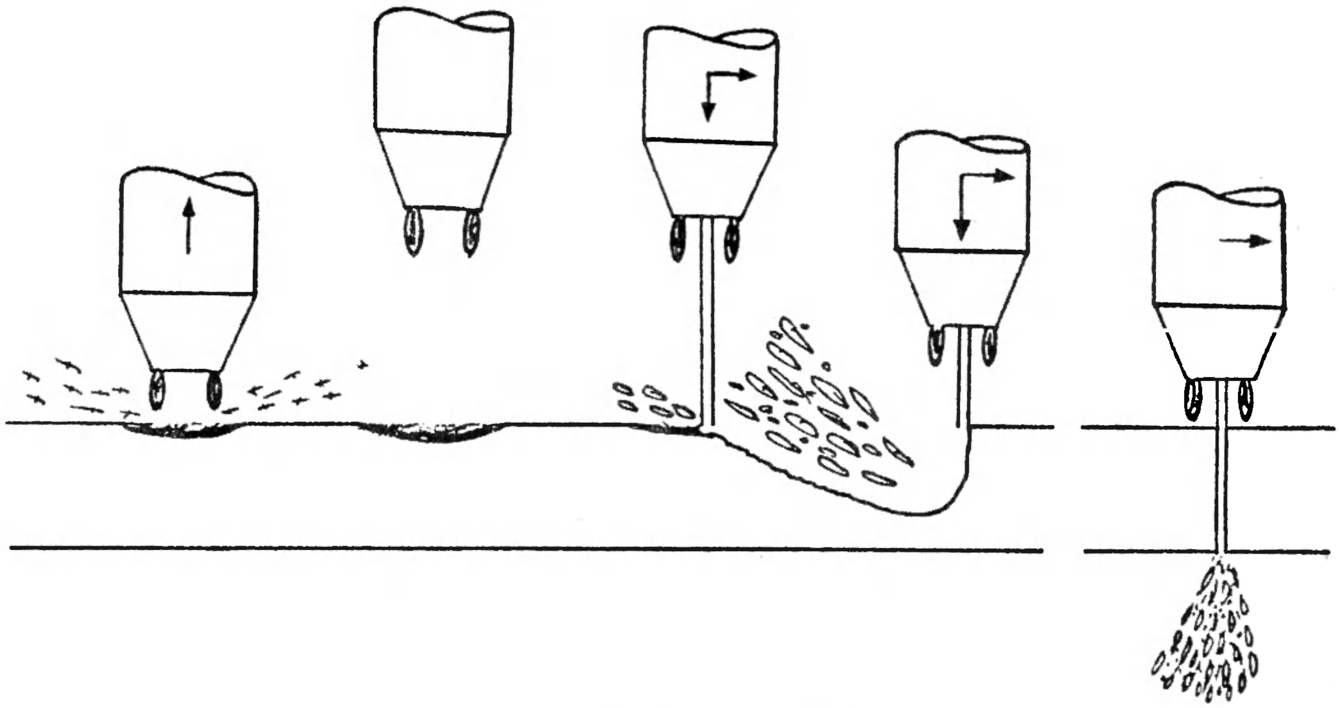


Fig. 2. The RP Piercing method

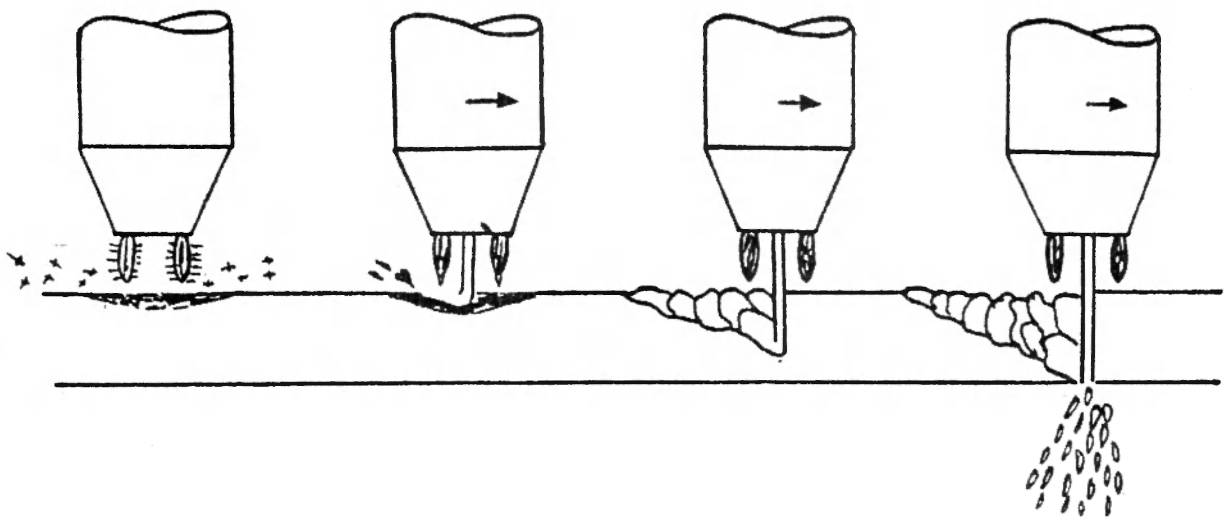


Fig. 3. The PCP Piercing method

It is a Japanese method designed to minimise pre-heating time.

(a) Position blowpipe 5-10 cm above piercing point with both preheating flame and cutting oxygen on.

(b) Insert a wire under the nozzle. The ignition of wire enables immediate piercing action despite the high position of nozzle. The time to ignition is only a few seconds and piercing is done without moving the machine. This method is very practical for multi-blowpipe operation. Piercing is completed one after another without moving the machine. All the cutters are then simultaneously brought down and cutting operation started. Not recommended above 30 mm thickness.

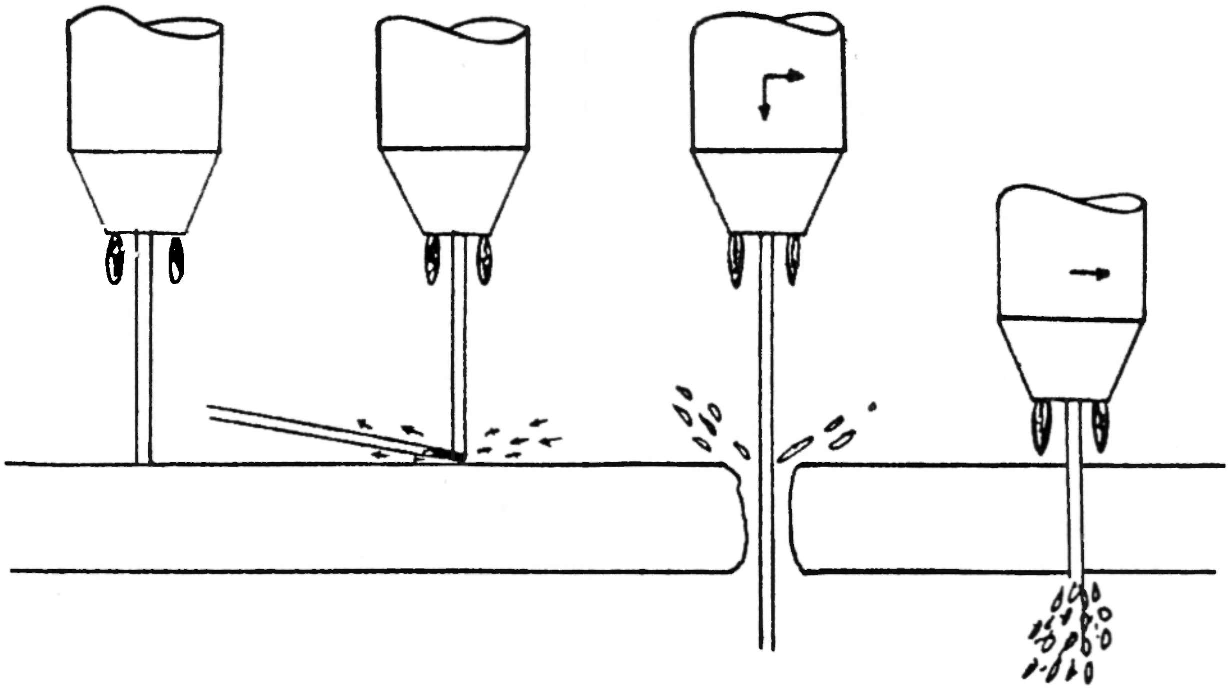


Fig. 4. The WI Piercing method

Piercing heavy plate thickness >100 mm

The only practical method is RP method, however, with a risk of damaging the nozzle which should better be replaced after piercing before cutting operation starts. A convenient approach is to have two torches—one for piercing and the second one for cutting. The nozzle used for piercing can be reused for subsequent piercing operation if not badly damaged.

Acetylene as a fuel gas should be avoided for heavy piercing.

Piercing with Oxygen Lance before cutting

For very heavy plate, hole may be pierced by oxygen lancing using packed lances.