

IMPROVEMENT OF CUTTING CONDITIONS USING OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.

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ABSTRACT

In this research a flame of CNC cutting machine was used. It works manually only in straight line cut. All experiments had been done to reach a proper ultimate processing conditions for clean cut. The dwell time of preheating, piercing and the speed of cutting are variables - in addition to gas pressure - control the cutting process. The target was to improve cutting conditions of carbon steel metal of thickness arranged from (10–15) mm, then to design a written program to be fed with the final readings to the CNC machine to produce a complex frame having sections of straight lines, curves and right angles with tolerance of 0.1mm. The value of cut width which was (2) mm would be shifted toward the core dimensions according to the program. By this technique, it is capable to produce complex shapes such as gears, in particular big components having a clean and even cut for applications require less accuracy.

الخلاصة:

في هذا البحث تم استخدام ماكينة قطع معادن رقمية تعمل وفق برنامج، كما تعمل الماكينة يدويا إذا كان القطع بخط مستقيم. ان جميع التجارب التي أجريت هدفها الوصول إلى ظروف تشغيل نهائية ملائمة تتحكم في نظافة القطع. إن المتغيرات التي تتحكم في عملية القطع هي زمن التسخين المسبق، زمن ثقب القطع وسرعة حركة المشعل بالإضافة إلى ضغط الغاز، إن الهدف كان تحقيق أفضل ظروف تشغيلية لقطع نظيف لمعدن الحديد الكربوني ذو سمك (10 - 15) ملم، ومن ثم تصميم برنامج مكتوب لتغذيته إلى الماكينة الرقمية لإنتاج إطار معدني معقد يحتوي قطوع مستقيمة و أقواس وزوايا قائمة وفق سماحة 0.1 ملم. إن عرض القطع البالغ (2) ملم ستكون محسوبة- وفقا للبرنامج- على المقطع الداخلي و ليس الاطار. إن هذه التقنية قابلة لتصنيع أشكال معقدة كالتروس مثلا، وخاصة الاشكال الكبيرة بقطع نظيف و مستوي في حدود تطبيقات تتطلب دقة قليلة .

KEY WORDS: HAZ, ignition temperature, kerf, correction factor, piercing, ESSI

INTRODUCTION:

Flame cutting technology is still the principal process for cutting metal plate for most metal processors. This process uses gases, propane, and oxygen to produce a controlled flame. Applications are limited to carbon and low alloys steel. These materials can be cut economically. This process is the best choice for end-users requiring inexpensive cutting of carbon steel and most alloys. But, Flame cutting

creates a heat affected zone (HAZ) around the cut that may need to be removed by additional machining. (Peter. Hould Groft 1990). In oxy-fuel cutting: a cutting torch is used to heat metal to kindling temperature. A stream of oxygen then trained on the metal combines with the metal which then flows out of the cut (kerf) as an oxide slag.

The Process

Flame cutting consists of a number of cutting processes used to cut metals by means of the chemical reaction of oxygen with the base metal at elevated temperatures. The required temperature is maintained by via a flame obtained from the combustion of a specified fuel gas mixed with pure oxygen. A jet of pure oxygen is directed into the preheated area instigating a chemical reaction between the oxygen and the metal to form iron oxide or slag, which the oxygen jet blows away. (Peter. Hould Groft 1990). Propane is volatile and boils at - 42 °C. Vaporization is rapid at temperatures above the boiling points. Propane is preferred to achieve higher vapor pressure at the given temperature. It is a great deal heavier and runs much better through a low-pressure injector torch with a setting from a few ounces to about two pounds per square inch when cutting. Slightly along its passage. This allows the compressed oxygen to expand as it leaves, forming a high-velocity jet that spreads less than a parallel-bore nozzle, allowing a cleaner cut. These are not used for cutting by hand since they need very accurate positioning above the work. Their ability to produce almost any shape from large steel plates gives them a secure future in industries. The propane flame is bright orange, and with a minimum of black soot, and the base should just sit on the tip and not ride away from. Steadily add oxygen. Sometimes at this point the flame will pop out. This could be due to old gas in the hose, and by flushing some oxygen and propane through the set up will quickly solve this. When everything is properly lit, there should be a blue flame with white blue flames from the holes around the center of the torch tip. (Mikell. Groove 1996, Peter. Hould Groft 1990)

The track burner will help making very clean straight cuts with very little slag, if it is set up right. Propane does not burn as hot as acetylene in its inner cone, and so it is rarely used for welding. Propane, however, has a very high number of BTUs per cubic foot in its outer cone, and so with the right torch (injector style) can make a faster and cleaner cut than acetylene, and is much more useful for heating and bending than acetylene. (Mikell. Groove 1996).

Types of Flame

The neutral flame is the flame most generally used when welding or cutting. The neutral flame is used as the starting point for all other flame adjustments because it is so easily defined. This flame is attained when welders, as they slowly open the oxygen valve on the torch body, first see only two flame zones. At that point, the gas is being completely burned in the welding oxygen and surrounding air. The flame is chemically neutral. The two parts of this flame are the light blue inner cone and the darker blue to colorless outer cone. The inner cone is where the gas and the oxygen combine. The tip of this inner cone is the hottest part of the flame. It is approximately (3300 °C) – for acetylene- and provides enough heat to easily melt steel. The unburned carbon insulates the flame and drops the temperature to approximately (2800 °C). (Serope. Kalpatjian 1996) The flame is not intended to melt the metal, but to bring it to its ignition temperature. The torch's trigger blows extra oxygen at higher pressures

OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.

down the torch's third tube out of the central jet into the workpiece, causing the metal to burn and blowing the resulting molten oxide through to the other side. The ideal kerf is a narrow gap with a sharp edge on either side of the workpiece; overheating the workpiece and thus melting through it causes a rounded edge. Cutting is initiated by heating the edge or leading face (as in cutting shapes such as round rod) of the steel to the ignition temperature (approximately bright cherry red heat) using the pre-heat jets only, then using the separate cutting oxygen valve to release the oxygen from the central jet . The oxygen chemically combines with the iron in the ferrous material to instantly oxidize the iron into molten **iron oxide**, producing the cut. Initiating a cut in the middle of a work piece is known as piercing. The hottest part of the flame is the short points of the blue white flame--that is the part that should be riding along the surface of the steel.(R.S Parmar1995, Peter.Houl Gcroft1990)

CNC Cutting Machine (SATO):

The research was done through (SATO) type (Fig. 1). This machine achieves cut processing automatically. All coordinates moves by servomotor. Data are fed through manual data input panel. Language of program is (ESSI). The machine depends on incremental dimension programming. The torch has a sensor adjusting the distance between the torch and work piece. This machine has three types of modes:

1. NC mode
2. coordinate mode (action with no cut)
3. manual mode .This machine cuts thicknesses range between (8 – 60) mm depending on nozzle type, for carbon steel and alloy steel.



Fig. 1 – CNC cutting machine

EXPERIMENTAL PROCEDURES:

Following procedures were essential prior to - and during - cutting process.

- The meal pieces were cleaned of rust and moisture.
- The torch tip was appropriate for the steel to be cut.

- Moving a track burner up and taking it out for a test run on the piece that was going to be cutting before It was lighted.
- Making sure the burner wasn't going to topple over fall off something during cutting...
- Adjustments had been made by turning propane gas on first at a time and light it with a striker, then turning the oxygen on gently to avoid a popping noise, then making balance till the right flame was gotten.
- Samples were cut manually by CNC machine to get proper cut conditions prior to application of programming cut by robotic machine.
- Preheating along the cut to be made to drive out the moisture from the steel, as well as lessen the shock of the cutting heat. I didn't need to get the whole cut cherry red. Just warm it up a little with a few passes.
- Starting the cut at the edge of the steel.

RESULTS AND DISCUSSION:

Results:

The workpieces :are carbon steel of hardness = **187** (Vickers)
 Thicknesses are between **(10-15)** mm.
 The experiments were done at the following constant pressures:
 Preheating pressure (bar) = **4.5**
 Holing pressure (bar) = **5.5**
 The experimental work was done at two stages to approach ultimate readings for clean cut with little slag in order to start feeding a program of complex engineering shape to CNC cutting machine :

1st stage:

Tests were applied to approach ultimate preheating and holing dwell times (**table 1**):
 No. of attempts for each case = (**2 – 3**) passage

Table 1: presents the preheating and holing periods for many samples of carbon steel.

<u>Preheating time (sec)</u>	<u>Holing time (sec)</u>
------------------------------	--------------------------

50	4
50	5
50	7
50	9
45	5
45	7
40	5

OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.

40	7
35	5
35	6
30	5
20	5
15	5
10	5
5	5

2nd stage:

Holing time = 5 second

Pressure of preheating = 4.5 bar

Pressure of holing = 5.5 bar

Table 2: The relationship between torch speed and preheating time indicates at start point area.

<u>No. of attempts</u>	<u>Preheating time (sec)</u>	<u>Torch speed (mm/min)</u>					
7	35	137	200	250	300	350	400, 450
5	30		200	230	250	300	450
5	25		200	230	250	300	450
4	20		200	230	250	300	
3	15		200	230	250		

Discussion:

The experimental work depended on trial and error, because many variables controlled cutting process It was worth to refer to several notes in cutting technique:.

- The oxygen flow rate was critical, so, too little would make a slow ragged cut; too much would waste oxygen and produce a wide concave cut.
- The oxygen cutting pressure should match the cutting tip oxygen orifice. The oxidation of iron by this method was highly exothermic. Once started, steel could be cut at a surprising rate, faster than if it was merely melted through. At this point, the pre-heat jets were there purely to reach ignition temperature. The rise in temperature was obvious by the intense glare from the ejected material, even through proper goggles

- CNC oxy-propane cutters almost use a high-speed divergent nozzle. This procedure uses an oxygen jet that opens slightly along its passage. This allows the compressed oxygen to expand as it leaves, forming a high-velocity jet that spreads less than a parallel-bore nozzle, allowing a cleaner cut.
- A nozzle size 0 – for a low thicknesses - is the smallest. The size of the tip is how large the center oxygen hole is the surrounding holes evenly heats up the area with a combination of oxygen and propane mixed in the barrel of the torch, the center hole forces air through the melted steel, giving a nice cut. If the center hole is not clean, the air will not be forced out with the correct pressure or in the right direction relative to the heated area. That's why thicknesses of metal between (10 – 15) mm were chosen for the experiments looking for ultimate results, then, we used a thickness of samples equal to 15 mm for the NC cutting.
- The way to make the kerf smooth and even was to find experimentally proper cutting conditions, for this reason we used the guide to be a mark to check on the kerf.
- Other considerable notes were: If moving way was too slow, the slag would fill back into cut. If moving way was too fast, the cut wouldn't go all the way through. It was nice to travel with the torch tilted a little ahead of the cut, so the leading edge of the flame would preheat the cut a bit, but in line with the cut so that there wasn't any unwanted beveling. According to all previous notes, a large number of cut processing had done taking into consideration changing cut conditions to approach ultimate readings capable of giving very clean, smooth cut, with little slag. The ultimate conditions obtained by the two stages of experiments have been expressed through the improvements took place on the samples as the following curves and pictures show.

Table 1:

- *preheating dwell time more than (25 sec) leads to more slag on the slot of the cut, also, less than 15sec may not enough to start next step.
- * holing dwell time was 5sec. for clean cut. less may not make a hole.
- * proper holing dwell time was done at 5 sec.

Table 2:

- * preheating dwell time between (15 – 20) second was enough to start holing for smooth cut. Out of this rang may not lead for clean cut or even no cut.

OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.

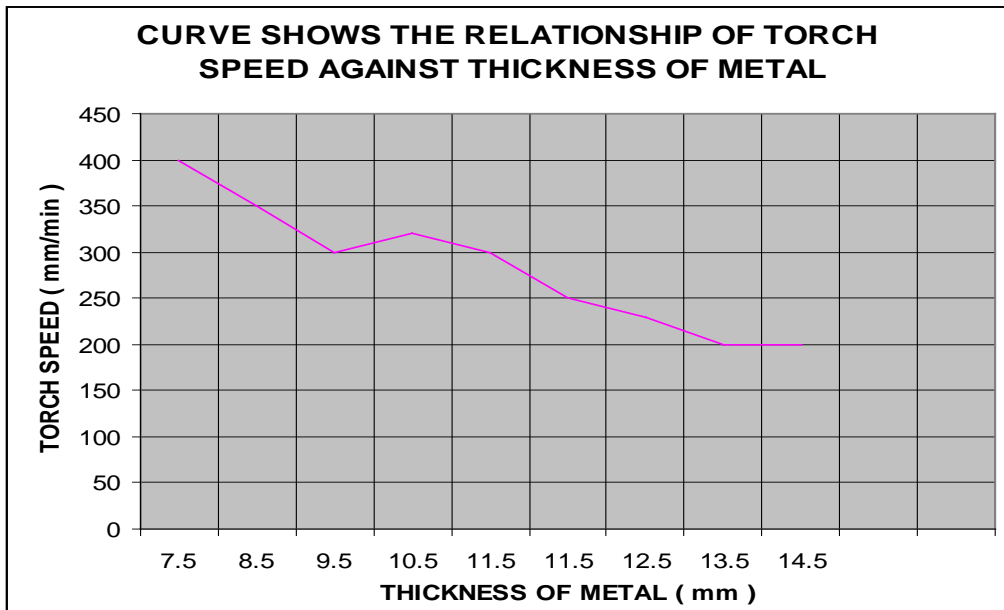


Fig. 2: speed of torch depends on a certain range of thickness to give a clean cut

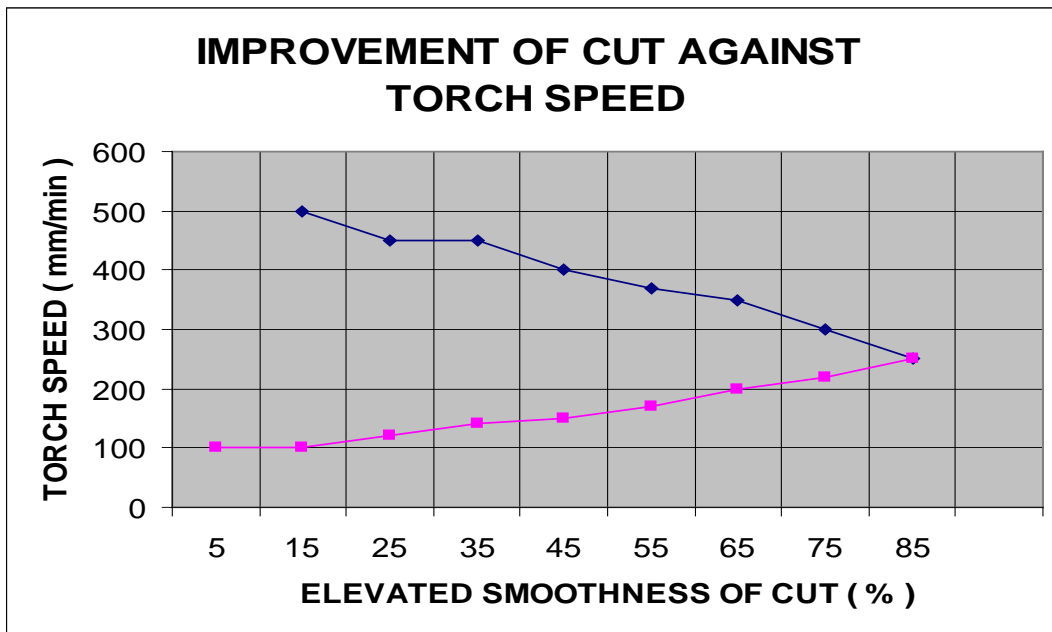


Fig 3: improvement of cut increases at speed ranges of torch between (200-300)

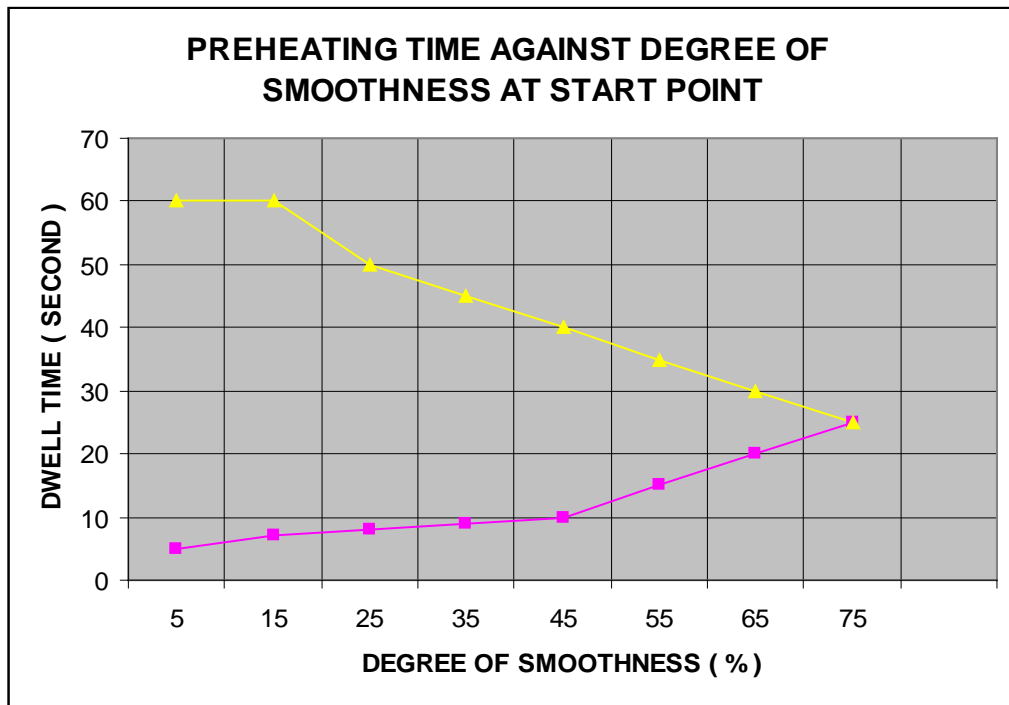


Fig. 4: Preheating dwell time at start point (edge of metal) for (10-15)mm thickness requires (20 – 30) second to produce a clean cut.



Fig. 5: shows gradual improvement on cut - from left to right – starting with (50) second preheating time (left) to (15) second (right picture). The process curve shown in fig. 4.

OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.

Low Carbon steel of thicknesses equal to (15mm)

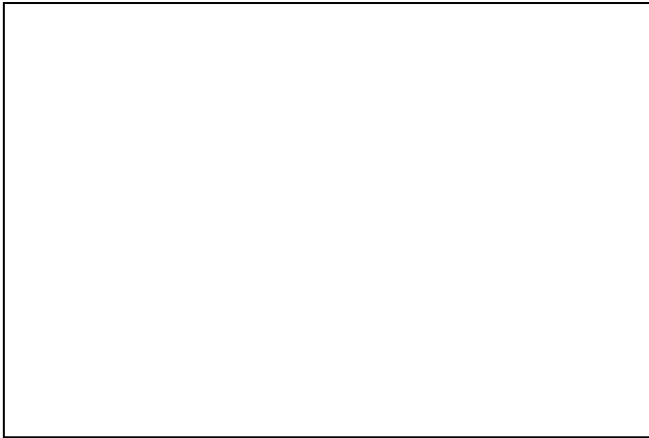
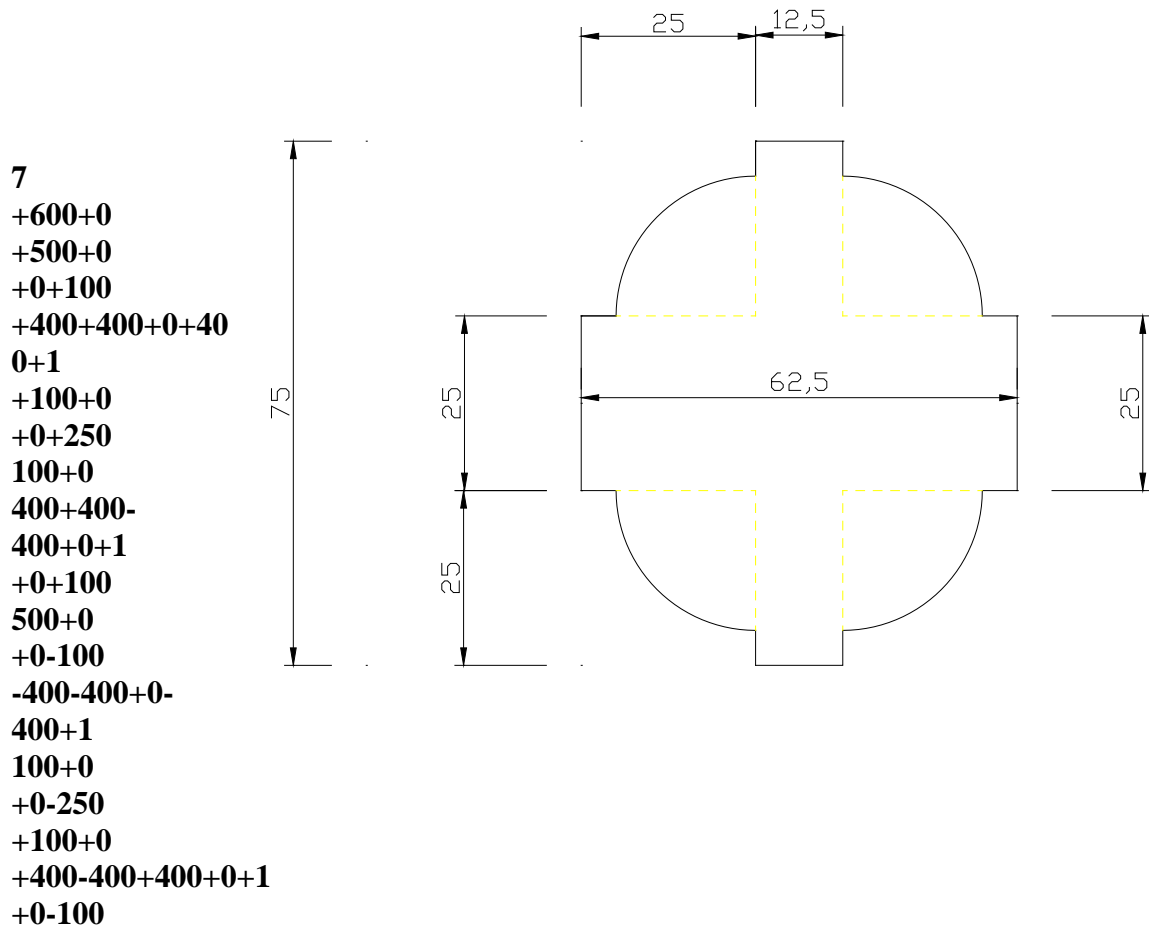


Fig. 6-A: shows improved samples of clean cut after removing HAZ only (no surface machining). **Fig. 6-B:** shows more improvement on cut at 15 second preheating time, 230 mm/min torch speed.

The program (ESSI language):

The designed program was fed to CNC cutting machine to produce a complex shape. This design has a curve, an angle and straight line details. The cut process had been done according to table 1, table 2 taking into consideration that the cut wide would be a correction factor which was at least (2mm) in this research. The direction of torch travel was counterclockwise. The following data were fed to CNC machine in addition to the program to produce – for same program – a frame and a core each has its requirements when designing the program

Torch speed	Piercing (holing) time	Preheating time	Preheating pressure
Piercing 230 mm/min	5 second.	(15-20) second	4.5 bar
bars			5.5



8

Fig. 7: profile of the designed program

OXY – PROPANE FLAME THROUGH CNC CUTTING MACHINE.



Fig. 8 Manual and robotic clean cut



Fig. 9: Engineering shape product



Fig (10A)

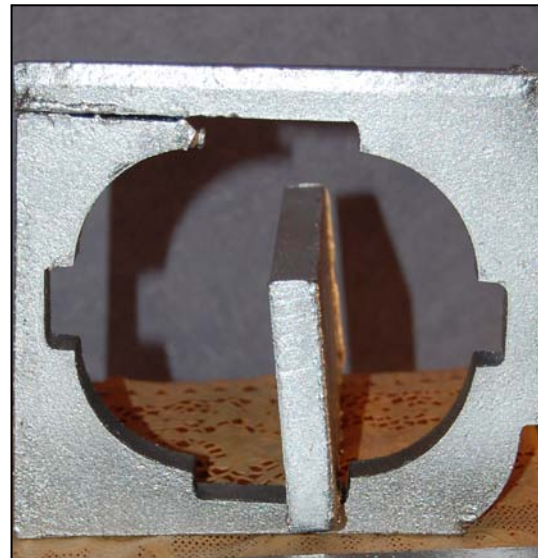


Fig (10B)

Frames & Cores which were produced according to data fed to the CNC cutting machine, having a clean cut, without machining (only removing HAZ traces). Samples of product are seen in Fig (9), Fig 10 (A&B)

CONCLUSIONS:

At chosen pressures using low carbon steel with thickness of **(10-15)** mm:
The improved conditions - which led to smooth clean cut of **(2)** mm width – were:

Preheating dwell time = **(15- 20)** second.
Holding dwell time = **(5 – 6)** second.
Torch speed = **(200 – 250)** mm/min.

The following results represented the proper conditions to produce a complex shape through designed program to be fed to robotic cutting machine (see fig . **9, 10**) using carbon steel of **(15)** mm, the flame was used oxy – propane:

Torch speed (mm/min) = **230**

Conditions	Preheating	Piercing	Notes
Pressure (bar)	4.5	5.4	clean cut, the width was not less than
2mm			Dwell time (sec) 15
5			

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