REFERENCES

1. Сварка разнородных металлов и сплавов /В.Р.Рябов, Д.М.Рябкин, Р.С.Курочко, Л.Г.Стрижевская.- Москва.: Машиностроение, 1984.- 239 с.

2. Хасуи А., Морикаки О. Наплавка и напыление. - Москва.: Машиностроение. 1985. – 240 с.

3.Vishniakas I.. The Structure of Welded Austenitic and Non-austenitic Steel Joints //

Materials Science/ Medžiagotyra. ISSN 1392-1320. 2003. Vol 9, No. 2. p. 174 – 177.

4. Vishniakas I..Influence of Structure of Welded Connections from a Heat Resistant Steel on their Reliability// Materials Science/ Medžiagotyra. ISSN 1392-1320. 2004. Vol 10, No. 3. p. 206 – 210.

5. Vishniakas I.. Analysis of Chemical Elements Distribution in Carbon Steel Layer Welded by Austenitic Electrods. ISSN 1392-1207. MECHANIKA. 2004. Nr.4(48). p. 64-67.

6. Shrier L., Jarman R.A., Burstein G.T., Corrosion. University of Cambridge. 1994. 2 Volumes. 1408 p.p. ISBN 07 506 L 1077 8.

7. Арзамасов Б.Н. и др. Материаловедение: 3-ое издание исправленное и дополненное. Москва.: Издательство МГТУ им. Баумана. 2002.- 648 с.

8. Винокуров В.А. и др. Сварные конструкции. Механика разрушения и критерии работоспособности. – Москва.: Машиностроение. 1996.- 576 с.

9. E.E. Lewis. Introduction to Reliability Engineering. John Wiley & Sons Inc. New York, 1996, 435 p.

10. Patric D.T. O`Connor. Practical Reliability Engineering. John Wiley & Sons, Inc. Chichester, 1998, 431 p.

11. H. Medeškas. Gaminių kokybė ir patikimumas. Kaunas.: Technologija 2001.- 280 p.

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THE BEST CUTTING METHOD FOR METALS

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INTRODUCTION

Plasma cutting can improve productivity and lower cutting costs. By 95%

metal plates the material is carbon steel, by carbon steel plates 90% is less than 25 mm thick. In this field, the plasma cutting is the best cutting method. The plasma cutting process is a highly productive method of cutting and is experiencing rapidly growing application. It does not require a preheat cycle, cuts any metal that conducts electricity, minimizes the heat affected zone, and yields a cut with a small kerf. Today, it is used on nearly all types of conducting engineering metals, such as: carbon steels, stainless steels, aluminum, copper, brass, cast metals, and exotic alloys. Although favorable economically, mild steel was seldom cut with this process. Cuts can be made from thick foil thickness up to 250 mm thick plate. Plasma units also can gauge, pierce, bevel, cut holes, and trace shapes. The high investment costs is one limiting factor for application of the plasma cutting machines.

Plasma cutting was developed in the 1950's for severing steel sheet and plate. The plasma jet generated by conventional "dry" arc constriction techniques was introduced in 1957. The dual flow plasma cutting was developed in 1963. Air plasma cutting was introduced in 1963 for cutting mild steel. Water shield plasma cutting was introduced in 1965, and water injection plasma cutting was introduced in 1968. In 1972, was introduced the water muffler and the water table pollution control systems. Underwater plasma cutting was introduced 1977, and law-amp air plasma cutting was introduced in 1980. Oxygen plasma cutting was introduced in 1983, and oxygen injection plasma cutting was introduced in 1985. Deep water plasma cutting was introduced in 1989, and high density plasma cutting was developed in 1990.

PLASMA CUTTING

Plasma cutting is a process where an open arc can be constricted by passing through a small nozzle from the electrode to the workpiece. It utilizes electrically conductive gas to transfer energy from an electrical power source through a plasma cutting torch to the metal being cut. Plasma cutting is shown in figure 1.

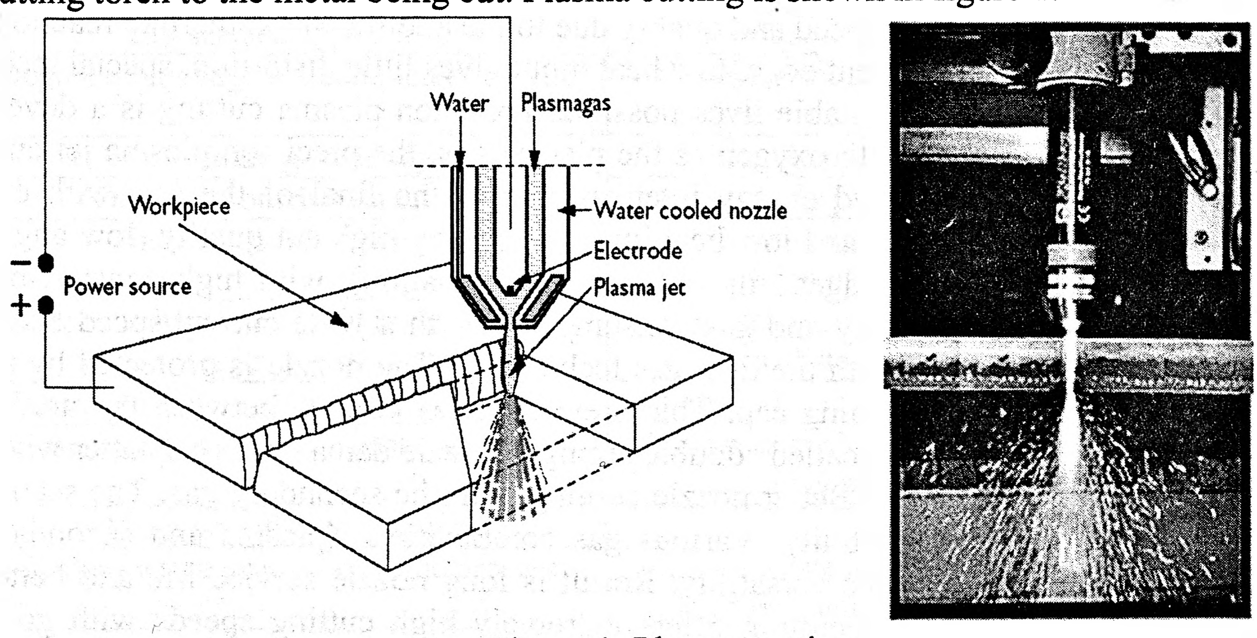

Figure 1. Plasma cutting

Plasma cutting is a melting process. A gas jet in the plasma melts and expels the material from the kerf. During the process an electric arc burns between an electrode and the workpiece. The electrode tip is placed in a water or air cooled gas nozzle in the torch. The plasma gas is conducted through the nozzle. The arc and the plasma gas are forced to pass through a very narrow orifice in the tip of the nozzle. The gas is heated and ionised. The concentrated plasma jet which is formed has a temperature of up to 30000°C together with a high velocity. When the plasma jet hits the workpiece the heat is transferred due to recombination (the gas reverts to its normal state). The material melts and is expelled from the kerf by a flow of gas. To initiate the process, and ionise the gas, a pilot arc must be generated. The pilot arc heats the plasma gas and ionises it. Since the electrical resistance of the main arc is lower than that of the pilot arc, the main arc ignites and the pilot arc automatically extinguishes.

There some variations of plasma cutting process. Process variations for dry plasma cutting are: $Ar/H_2/N_2$ plasma cutting, N_2 plasma cutting, Air plasma cutting, O_2 plasma cutting (conventional), precision plasma cutting. Process variations for under-water plasma cutting are: N_2 plasma cutting and O_2 plasma cutting.

By $Ar/H_2/N_2$ plasma cutting. Argon/hydrogen mixtures are used as a plasma gas for cutting high alloyed materials, aluminium, copper, titanium, zinc and their alloys. Generally nitrogen is used as a third gas component for materials under 10 mm thick. N_2 plasma cutting is used on the same materials as the $Ar/H_2/N_2$ technology when cutting thin sheets. Air plasma cutting is mainly used for mild steel. It is characterized by: good cutting quality, high cutting speed and low heat input (little thermal distortion).

Nitriding of the cut surface can cause problems in subsequent operations. Under certain circumstances can lead to porosity when welding (heavily oxydized cut surface with CrNi plates). O_2 plasma cutting is mainly used for mild steel. It is characterized by: high cutting speed and quality due to the additional exothermic reaction, very low hardening of the cut edge, low heat input gives little distortion, special technologies make long consumable lives possible. Precision plasma cutting is a development of dry plasma. With oxygen as the plasma gas, the precision plasma jet cuts the material: with increased energy intensity due to the final of the arc, with extremely narrow kerf width and low heat input, with very high cut quality (low angularity, clean, precise cut edges, little or no slag formation), with high consumable lives, with minimum energy and gas consumption, with a wide current/speed band. Precision plasma works with the dual gas technology. The nozzle is protected by an electrically insulated shielding cap. This prevents short circuits between the nozzle and the workpieces, the so-called "double arcing". Nozzle damage from splatter when hole piercing is prevented. Better nozzle cooling with the secondary gas. The secondary gas increases arc stability. Various gas combinations (plasma and secondary gases) help the applications versatility. Result is long nozzle service life and better cut quality. Water plasma cutting offers extremely high cutting speeds with good nozzle and electrode lives due to the additional temperature increase of about 5C000K.

The type of cutting kerf makes water plasma suitable for medium to large cut-outs and for stripping.

Table 1. Characteristics of plasma cutting

Method of imparting energy	Gas transmitter
Source of energy	DC power supply
How energy is transmitted	Electrically charged gas
How cut material is expelled	Gas jet
Distance between nozzle and material and maximum permissible tolerance	0.25 to 5 mm
Physical machine set-up	Working area, shop air and plasma torch
Typical process uses	Cutting
3D material cutting	Not applicable to this process
Materials able to be cut by the process	All metals can be cut
Material combinations	Materials with different melting points
Sandwich structures with cavities	Not possible for this process
Cutting materials with limited or impaired access	Rarely possible due to small distance and the large torch head
Properties of the cut material which influence processing	Material hardness is a key factor
Material thickness at which cutting or processing is economical	3 to 10 mm
Common applications for this process	Cutting of flat sheet and plate of greater thickness
Parts that will wear out	The cutting nozzles and electrodes
Average energy consumption of complete cutting system	300 amp Plasma Electrical power use: 55 kW
Minimum size of the cutting kerf width	0.05 mm
Cut surface appearance	Cut surface will show a striated structure
Degree of cut edges to completely parallel	Fair, will demonstrate non-parallel cut edges with some frequency
Processing accuracy	Approximately 0.5 mm
Degree of burring on the cut	Only partial burring occurs
Thermal stress of material	Deformation, tempering and structural changes may occur in the material
Forces acting on material in direction of gas or water jet during processing	Gas pressure poses problems with thin work-pieces, distance cannot be maintained
Personal safety equipment requirements	Protective safety glasses
Production of smoke and dust during processing	Does occur; plastics and some metal alloys may produce toxic gases
Noise pollution and danger	Medium
Cutting waste produced by the process	Cutting waste is mainly in the form of dust requiring vacuum extraction and filtering

Water plasma cutting can be carried out under water easily (in practice the water level is about 60 mm above the plate surface) which brings a number of advantages: noise reduction to values well below 80 dB, prevention of dazzle from UV light, retention of the cutting dusts in the water, no thermal distortion as plate temperature remains consistent, the nitrogen oxides rising out of the water can be extracted upwards and removed from the workplace. N_2 plasma cutting is used for: mild steels, high alloy materials, aluminium and its alloys. An oxide free cut edge is achieved with high-alloy steels. The cut quality displays a certain sensitivity to high silicon and sulphur contents in the material and to the use of fine grained steels. A tendency to nitriding of the cut edge, which can lead to porosity when welding, is particularly noticeable with mild steels. O_2 plasma cutting is used for mild steels. It is characterized by: high cutting speeds through the additional exothermic reaction, no porosity with subsequent welding, little or no slag formation (any slag formed is also easily removed), additional stabilisation of the arc in the underwater range with an air muffler (compressed air is blown around the arc with reduced pollutant generation). High current cutting is an additional application for the water plasma cutting torch. For this the water level is lowered to below the material .

Ar/H_2 is used as the cutting gas to enable the cutting of thicker CrNi steels. To do so the torch is operated with up to 1000 A to permit the cutting of material up to 150 mm thick. The injection water is no longer also used to constrict the arc but only serves to cool the nozzle. Characteristics of plasma cutting is shown in table 1.

PLASMA CUTTING MACHINE

Plasma cutting machines are product of high technology. They present complex hardware and software equipment. The basic plasma cutting machine consists of a plasma power supply, an arc starting circuit and a cutting torch. At figure 2 are shown components of plasma cutting machine. These system components provide the electrical energy, ionization capability and process control that is necessary to produce high quality, highly productive cuts on a variety of different metals.

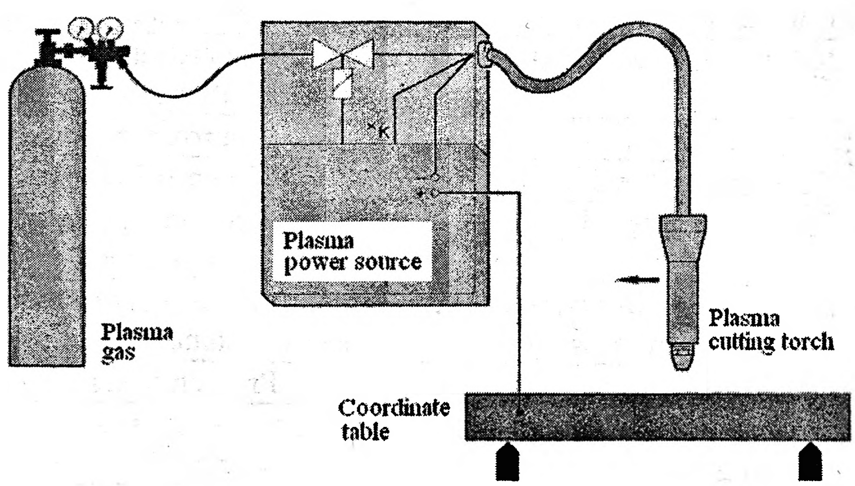

Figure 2. Components of plasma cutting machine

The power supply is a constant current power source. The output current (amperage) of the power supply determines the speed and cut thickness capability of the system. The main function of the power supply is to provide the correct energy to maintain the plasma arc after ionization. The arc starting circuit is high frequency generator circuit that produces an voltage of 5 000 to 10 000 V, at approximately 2 MHz. This voltage is used to create a high intensity arc inside the torch to ionize the gas, thereby producing the plasma. The torch serves as the holder for the consumable nozzle and electrode, and provides cooling (either gas or water) to these parts. The nozzle and electrode constrict and maintain the plasma jet. The power source and arc starter circuit are connected to the torch via interconnecting leads and cables. These leads and cables supply the proper gas flow, electrical current flow and high frequency to the torch to start and maintain the process.

Plasma cutting machine has high quality cutter table with automatically controlled exhaust sections and high load capacity. Guide engine with maintenance-free linear guides is mounted separately from the cutter table - eliminating thermal or mechanical effects. High dynamics DC servo motors, and perfectly tuned drive system ensure extremely high precision and allow extremely small radius cuts using current plasma technology. Laser-like cuts provide users of plasma cutting machine an cost-effective alternative to other cutting methods. At figure 3 are shown plasma cutting machine.

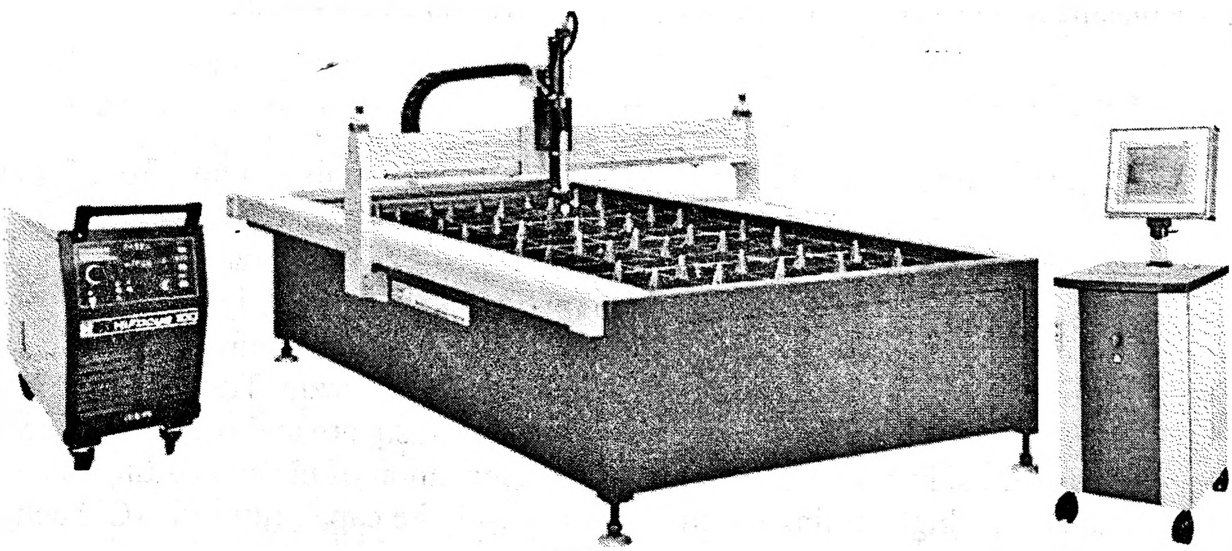

Figure 3. Plasma cutting machine (Knuth)

There are many manufacturers of plasma power source and plasma cutting machines. In table 2 are shown some manufacturers of plasma cutting machines.

Industry leaders of manufacturers of plasma power source and plasma cutting machines are: Hypertherm Plasmatechnik GmbH, Kjellberg Finsterwalde Elektroden & Maschinen GmbH, Messer Cutting & Welding GmbH, Esab-Hancock GmbH, Germany, and Cebora, Italy.

Table 2. Manufacturers of plasma cutting machines

Manufacturers	Web-site
Hypertherm	www.hypertherm.com
Kjellberg	www.kjellberg.de
Messer	www.messer-cw.de
Esab	www.esab.de
Cebora	www.cebora.it
Selco	www.selco-it.com
Miller	www.millerwelds.com
Knuth	www.knuth.de
Innerlogic	www.innerlogic-inc.com
MicroStep	www.microstep-group.com

Pricing example of plasma cutting machine for Plasma-Jet 3000 x 1500 (Knuth Werkzeugmaschinen GmbH, Germany), including PC control, software, colour monitor, automatic arc high control, with plasma power source Fine-Focus 450 (Kjellberg) is 72.500 EUR; with plasma power source Hi-Focus (Kjellberg) is 80.900 EUR; and with plasma power source Powermax (Hypertherm) is 54.310 EUR.

Conclusion

Plasma cutting is capable of cutting virtually all metals ranging from 3 mm to 250 mm. It may be used to cut any conductive material. Precise cut with square kerf, clean face and dross free enables plasma cutting to be finish machining operation. Advantages of plasma cutting are: relatively square cuts at high cutting speeds; smooth, clean cut face; dross free cuts on most metal including mild steel; increased nozzle life since the ceramic bottom piece insulates the nozzle. The cut angle on the high quality side will usually be within two degrees of square and will seldom require machining or finishing. The most widespread application of plasma cutting is cutting of mild steel. The high cutting speeds, together with the capabilities of NC machines, enable the user to greatly increase his productivity.

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REFERENCES

1. Eichorn F., Autogen-, Plasma- und Wasserstrahl-verfahren, Inovative Schneidtechnologien, Industrie Anzeiger, August, 1999, pp. 413-414, 2. Parashkevov

S., Some aspects for solving the energy balance equation of electrics arts in low-temperature plasma generator, Journal "IMK-14, Research and development", year X, No 18-19, 1-2/2004, pp. 15-18, 3. Colt J., Matters of the fourth state, Cutting technology, American machinist's, september/october 2002, 4. Colt J., How to compare plasma cutting costs, Forming & Fabricating-4/2002, pp. 27-31, 5. Plasma arc cutting – process and equipment considerations, TWI information, 6. Schwarz H., Rudaz A., Plasma: a welding and cutting technique with a future, www.pwsweld.com, 7. Plasma cutting history, www.hypertherm.com.

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CUTTING PROCESS OF THE FUTURE

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INTRODUCTION

Abrasive water jet cutting has become a highly developed industry technology. Its development has been favored by the fact that abrasive water jet cutting can be used in practically all areas in which solids are processed – stone, glass, plastics, composite materials and metals. Abrasive water jet technology was first introduced in 1984. The technique uses a mix of water and a fine abrasive for cutting hard materials. Mix abrasives with high pressure water give an effective tool to cut metals and nonmetals materials. Abrasive water jet cutting is the most suitable process for very thick, highly reflective or highly thermal-conductive materials, laminates and composite materials, as well as hard syntetics. The abrasive stream produces a kerf width that is ideal for cutting titanium, armor plate, steel, granite, composites, glass and many other materials. The list includes metals such as aluminium, carbon steel, stainless steel and high nickel alloys, or brittle materials such as marble, reinforced composites, and sandwiched materials. Abrasive water jet can cut a wide range of thickness. Typical thickness are 100 mm for stainless steel, 120 mm for aluminium, 140 mm for stone, 100 mm for glass, but not limited. Abrasive water jet cutting is of great interest for various reasons. Almost any material can be cut. The abrasive water jet makes it possible to cut random contours, very fine tabs and filigree structures. Abrasive water jet cutting is a very precise technique. Tolerances of ±0.1 mm can be realized in metal cutting. The workpiece is not heat-stressed. Materials cut by abrasive water jet have a smooth, satin-like finish, similar to a fine sandblasted finish. Abrasive water jet cut material at room temperatures. As a result, there are no heat-