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THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS ON THE USE OF PLASMA ARC INSTALLATIONS IN CUTTING DIFFERENT TYPES OF MATERIALS – PART 1

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Abstract*: The aim of this study is to assess the proper technological parameters of plasma cutting in different materials. By measuring the outcome surface roughness values, it was assessed both the influence of technological process parameters and the type of plasma cutting device upon the cutting speed and cut surface quality. By carrying out the experiments using ANOVA method (used for mathematical models testing) and The Response Surface Methodology, the present study has conducted to the following final benefits: practical recommendations concerning the optimization of the technological parameters; decrease of the costs and increase of the consumable items life-time. Upon these results, a data base will be achieved and implemented to extend the technological capabilities of the existing plasma-cutting plants.*

Keywords*: Plasma,Measurements, Roughness, Surfaces, RSM*

1. INTRODUCTION

Among the unconventional cutting processes, the Plasma Arc Cutting process is a significant one. In such cases, particularly when the processes of cutting shear can not be applied because of the relatively large thickness of the half-finished material, the range of procedures likely to remain sufficiently profitable, in terms of cost and productivity is significantly reduced (Popa, 2003), (Westkamper, et al., 2001).

CNC. The level of control within CNC machines is achieved bylinking all parameters of a plasma unit to the same CNC unit that instructs the motion of the head, which allows the controller to compute all factors that might affect the quality of a cut (Popa, 2003).

2. RESEARCH ON PLASMA ARC CUTTING FOR DIFFERENT TYPES OF MATERIALS

2.1 Plasma ArcCutting of stainless steel and aluminum

The systems used for Plasma Arc Cutting – PAC were as follows: Water Injection Plasma - WIP, Conventional Dual-Gas - CDG, High Precision Plasma – HPP (The Hypertherm Inc, 2000).Corrosion resistance, high strength/weight ratio, thermal properties and aesthetics of stainless steel and aluminum make these materials more attractive for many applications.Most samples were cut from stainless steel, alloy 5NiCr180 according to Romanian STAS Standards, equivalent to 1.4301/EN 10088 or ASTM 304, and aluminum alloys, AlMg1SiCu.Experimental purposes are:

• Characterization of thermal and chemical changes that occur in aluminum alloys and stainless steel during plasma cutting;
• Recommendation of alternative process to improve the aesthetics and the quality of the cutting areas, the forming and manufacturing of such materials;
• Minimize the Heat Affected Zone (HAZ).

2.2 Summary of tests

5NiCr180 austenitic stainless steel alloy. Plasma cutting of stainless steel alloys is producing a Heat Affected Zone (HAZ) which is characterized by a thin layer of resolidified metal joining the cut edge. The resolidified metal layer thickness generally falls between 10 to 30 µm. *Aluminum alloy **AlMg1SiCu.*** Cut edges with a heat affected zone, are characterized as a solid state transformation and a resolidifiate metal layer. The surface of aluminum alloy cut edges are rough, and show intergranular cracks and pores. The presence of surface oxides may affect the ability to weld both stainless steels and aluminum alloys. *Heat Affected Zone.*

- HAZ varies with speed and power. The extent of the HAZ in mild steel is related to process variables, such as cutting speed and power, as well as material thickness.
- Faster cutting produces less HAZ. Decreasing the time required to perform a cut by using high amperage and high-speed conditions reduces the HAZ.

3. RSM – RESPONSE SURFACE METHODOLOGY

Response Surface Methodology - RSM has become widely used in many fields from experiments performed by industrial statisticians.Most applications of RSM are in particular situations in which it is suspected that several input variables influence the size of performance or quality characteristics of a process. The size of performance or quality characteristics is called *response*. Input variables are sometimes called *independent variables*, being the control tools of the engineer.

3.1 ANOVA

An important component of the response surface method is dispersion analysis (ANOVA). Through this analysis it is possible to verify whether a particular variable should, or should not be a part of the model analyzed by RSM.

4. DESCRIPTION OF EXPERIMENTAL INSTALLATION AND MATERIALS USED

As Hyperthem, Kjellberg occupy the forefront of the plasma generators manufacturers' field.The main advantages of the HiFocus 160i generator are (Făgărăşan, 2009), (The Hypertherm, 2000): minimum spatter quantity, a high cut surface precision and excellent precision for contour parts,input heat quantity received by the piece is reduced, small deformation,longer consumables-life by the existence of the assistant gas supplies,operating costs and initial investment required, much lower compared to a laser cutting facility,high flexibility for different CNC systems,automatic monitoring for the main processes (torch cooling, cutting time etc.).

5. EXPERIMENTS PLANNING

Next it is described the method of experiments planning and how to reach them using the Finite Element Method based on Response Surface Methodology. Themethodology for determining the mathematical models is describing the relationship between quality characteristics (roughness of the cutted surface) and process variables (intensity value, the voltage and cutting speed). Thus, the requested mathematical models can be written in the general form:

$$Ra = f(v,U,I)\,, \quad (1)$$
$$t = f\ (v,U,I)\,, \quad (2)$$

Where: *Ra* [μm] is the average cut surface roughness;*t*[s] – cutting time; *v* [mm/min] – cutting speed;*U* [V] – plasma generatordirect current voltage;*I* [A] – plasma generatordirect current intensity.*Design Expert* is a software designed to assist in the design and interpretation of multifactorial experiments. PAC can use this program to design an experiment to see how a parameter, e.g. cutting speed, affects the quality of cut surface.

6. THE TESTS METHODOLOGY AND RESULTS ANALYSIS

The following are the results of Plasma Arc Cuttingexperiments of studied materials (carbon steel, aluminum and stainless steel) and those obtained by using mathematical models (Făgărăşan, 2009).To understand the influence of voltage, electric current intensity and cutting speed, the material properties investigated in this study were analyzed:

• The quality of the resulting cut surface roughness expressed by the outcome values of *Ra* [μm];

• Time *t* [s] necessary for the cutting process, following the given parameters;

6.1 Graphical optimization procedure

Graphical representation by curves of constant value is a technique for three-dimensional graphics display areas within a two-dimensional form by marking some sections of constant value of objective/requested functions (Lăzărescu et al., 2008).

It can be seen in graphical optimization representations, the link of voltage on one axis (X) with the time values on the other axis (Y), while the intensity parameter is always contained within an certain interval: forthe material Al99,5, all thicknesses, I Є [70 A, 100A] for carbon steel S235JR and stainless steel 5NiCr180thickness of 3 mm, I Є [65 A, 95A] and for stainless steel20 mm thick, I Є [150 A, 170A].

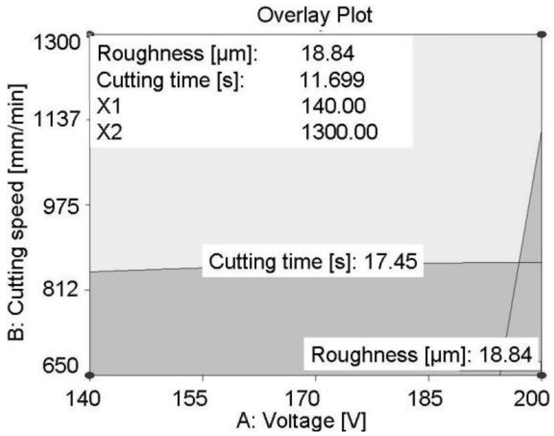

Fig. 1. Graphical optimization by requiring two independent variables limits – 5NiCr180 thickness 3mm

Constant value curves can be used to establish thevoltage and cutting speed fields, which will ensure that a certain limit for the cut surface roughnessvalues, will not be exceeded. For example if it's desired to obtain a roughness less than 18,84 μm, it should not descend below the speed values marked by constant curve corresponding for roughness of 18,84μm, as shown in Fig.1. For cutting time *t*,the values have been limited for the amount indicated by the curve t=17,45 s. The independent variablesfield, in this case is:

U Є [140 V, 200 V], v Є [650 mm/min, 1300 mm/min] and I Є [65 A, 95 A], so that Ra ≤ 18,84 μm and t ≤ 17,45 s.

It is assumed further that we want to obtain a roughness with values between 18, 22μm and 18, 84μm, simultaneously with cutting time range16, 44– 17, 45 s. The independent variables field is:

U Є [140 V, 200 V], v Є [650 mm/min, 1300 mm/min] and I Є [65 A, 95 A], so that 18, 22 μm <Ra ≤ 18, 84 μm and 16, 44 s <t≤ 17, 45 s. These regions of the independent variables can be set also for other required values of surface roughness and necessary cutting time.

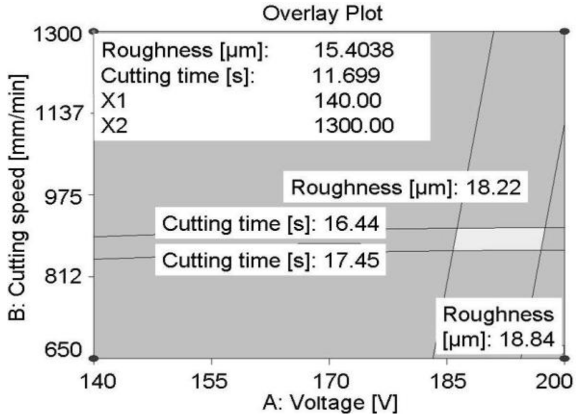

Fig.2. Graphical optimization by requiring four independent variables limits - 5NiCr180 thickness 3mm

To determine the working domain, there were represented curves of constant value related to the fourlimits, as in Fig. 2. This domain is limited by the intersection of the four curves.

7. CONCLUSIONS

It can be concluded that the material having a cut surface of the highest quality is undoubtedly steel grade S235JR.Acceptable values of roughness (e.g. Ra = 5÷15μm) were found for stainless steel (5NiCr180). Aluminum Al99.5 describes the higher values of roughness which is interpreted as a poor cut surface quality. The mathematical models were tested using the ANOVA method, and by graphical comparison it was demonstrated that the solutions fits sufficiently precise the experimental results.

The results obtained in this paper enable the developmentfor future research in the already addressed direction, such: process optimization using RSMfor other cutting processes or unconventional technologies, the use of other materials and other thicknesses for studying their properties and behavior during the plasma cutting process, and also determine theinfluence of process variables on quality characteristics.

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