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Research Article

EFFECT OF PLASMA CUTTING PARAMETERS UPON SHAPES OF BEARING CURVE OF C45 STEEL SURFACE

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ABSTRACT

The article presents the results of studies on the effect of plasma cutting technological parameters upon the shape of bearing curves and the parameters of the curve. The topography of surface formed by plasma cutting were analyzed. For measuring surface roughness and determining the bearing curve the appliance T8000 RC120 – 400 by Hommel-Etamic was used together with software.

Keywords: plasma cutting, bearing curve, surface, roughness.

INTRODUCTION

Cutting is the first operation, starting the process of manufacturing the parts. A wide range of cutting techniques has been applied in metal and machine industry. These are: plasma cutting, laser cutting, abrasive water jet cutting and oxygen cutting.

Plasma cutting was introduced into industry in the 1950's, to prevent difficulties with cutting machined stainless steel and non-ferrous metals. In plasma cutting, an inert gas is blown with high speed out of a nozzle, at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of the gas into plasma. The plasma melts the material being cut and moves blowing molten metal away from the cutting zone. The advantages of this method of cutting are: high efficiency, low costs and possibility of cutting materials which are thicker (approximately 150 mm). Plasma cutting has the following disadvantages: very high level of noise, risk of electric shock, the plasma arc radiation and a large amount of smoke and gas [3]. Plasma cutting has been used in cutting of all the conductive materials such as: aluminum, steel, cast iron, copper. There is also a possibility of cutting non-ferrous materials (for example: plastics, glass, rubber) with the head of an independent arc (internal) [5].

The assessment of the state of surfaces and edges is accomplished by means of the following standard PN – EN ISO 9013. This standard concerns the following characteristic parameters, describing the quality of material surface after thermal cutting:

- tolerance of perpendicularity or inclination – u,
- average shape height – $Rz5$,
- dimension Δa (reduction of thickness),
- cutting line deflection – n,
- partial melting of the upper edge – r,
- possible presence of slag or a metal drop adhering to the lower cutting edge [9].

Providing a large amount of heat and deflection of beam from intended path during cutting causes the formation of discrepancies on the surfaces and edges of the cut [11]. Discrepancies should mean irregularities or deviations from a specific shape or position of the shearing line. The source of the resultant discrepancies is only plasma cutting process, but not including negative effects, which result from the external stresses or strain. The following groups of discrepancies can be distinguished:

- discrepancies on cutting edges,
- discrepancies on surfaces,
- fractures,
- cinder,

and other discrepancies (for example incomplete cut, over the width of the kerf) [11].

The geometrical structure of the surface after plasma cutting should be classified as an anisotropic mixed structure. The surface resulting from cutting reveals a parallel direction and sometimes two directions. Rz parameter for the surface after cutting varies from 150 μm to 250 μm. Geometrical structure can be determined as practically untreated. The negative effect of this technology is a possible presence of slag or a metal drop adhering to the lower cutting edge [8].

According to PN – EN ISO 9013: 2008, quality of surface after the plasma cutting S700MC steel and S 690QL can be classified according to area 4 – 1, which corresponds to the tolerance range (0.05 + 0.003a) ÷ (0.8 + 0.02a) and surface roughness Rz5 (10 + 0.6a) ÷ (0.8 + 0.02a), where a is thickness sample in mm. The surface roughness occurring after cutting process was Rz = 10 μm for both materials. The perpendicularity deviation of S690QL steel was 0.5 mm and for S 700MC 0.82 mm [2].

In this paper [1] the authors presented the influence of current parameters of plasma cutting system upon geometric structure. The following results were obtained: surface roughness Ra for samples OH18N9 steel ranged from 20.2 ÷ 27.7 μm and for S355E steel: 2.95 ÷ 13.1 μm. The lowest surface roughness was achieved at current intensity 60 ÷ 70 A.

Węglowski et al. [6] conducted comparative studies on the influence of the cutting technology upon the accuracy and surface roughness. The perpendicularity tolerance and surface roughness for plasma cutting samples equaled 0.16 mm, Rz5 = 14.08 μm, for laser cutting 0.12 mm, Rz5 = 28.28 μm and for oxygen cutting 0.25 mm Rz5 = 21.34 μm.

The surface roughness after plasma cutting depends, to a large extent, on the cutting speed. An increase of cutting speed occurs with increase in surface roughness. The highest surface roughness was achieved for maximum cutting speed. It is due to the formation of the threshold at the lower edge of the sheet. The strongest influencing parameters are the type of plasma gas, environment of cutting and nozzle standoff height. The change of position nozzle ±20% does not influence upon surface roughness. According to standard ISO 9013 it is possible to obtain high quality surface of construction sheet, first class, with respect to geometrical features independent of the type of plasma gas and cutting environment [4].

An important problem in industrial practice is measuring and evaluating the geometric structure after plasma cutting. The traditional ways of presenting surface roughness and waviness using horizontal and amplitude parameters preventing presentation of a lot of additional important information, for example the state mating elements. The objective of the currently presented studies was to determine the effect of plasma cutting technological parameters upon the shape and parameters of Abbott-Firestone curve.

METHODS

In the experimental studies we used a rectangular prism of dimensions: 4×15×100 mm made of C45 steel. The plasma cuts were performed with the use of plasma cutting system supplied by Kjellberg HiFocus 80i, unit level of work 10 ÷ 80A and equipped with stay table with dimension 3000×1500 Eckert company. Plasm cutting was performed with the cutting parameters shown in Table 1. Studies were conducted with nitrogen as plasma gas.

Measurements of surface roughness, topography and bearing curve parameters were performed with the use of Hommel-Etamic T8000 RC120-400 appliance and the software which is compatible with it. The measurements were performed perpendicularly to the treatment traces. The length of the elementary section was lr = 2.5 mm. As the parameters of Abbott-Firestone curve the following were determined: Rk – depth of roughness body, that is a part of the profile, excluding the distinguishable elevations and deep hollows, Rpk – reduced height of elevations [7, 10]. Figure 1 shows the graphic interpretation of bearing curve for the roughness profile.

Table 1. The technological parameters of cutting process

<table>
<tr><th>Lp.</th><th>Cutting speed [mm/min]</th><th>Gas pressure [bar]</th><th>Current intensity [A]</th></tr>
<tr><td>1</td><td>800</td><td rowspan="4">8</td><td rowspan="4">80</td></tr>
<tr><td>2</td><td>1200</td></tr>
<tr><td>3</td><td>1800</td></tr>
<tr><td>4</td><td>2500</td></tr>
<tr><td>5</td><td rowspan="4">1800</td><td rowspan="2">8</td><td>70</td></tr>
<tr><td>6</td><td>60</td></tr>
<tr><td>7</td><td>6</td><td rowspan="2">80</td></tr>
<tr><td>8</td><td>10</td></tr>
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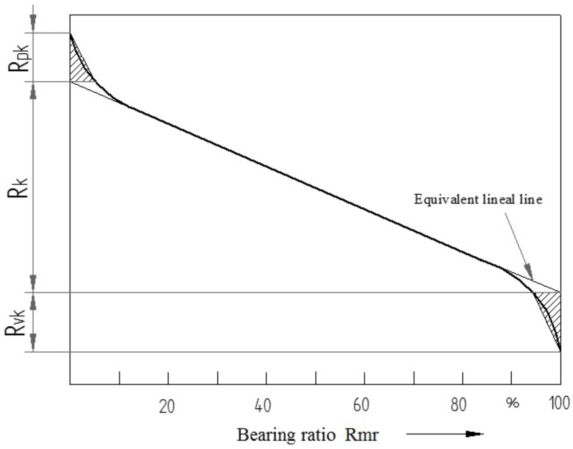


Fig. 1. Graphic interpretation of bearing curve for the roughness profile

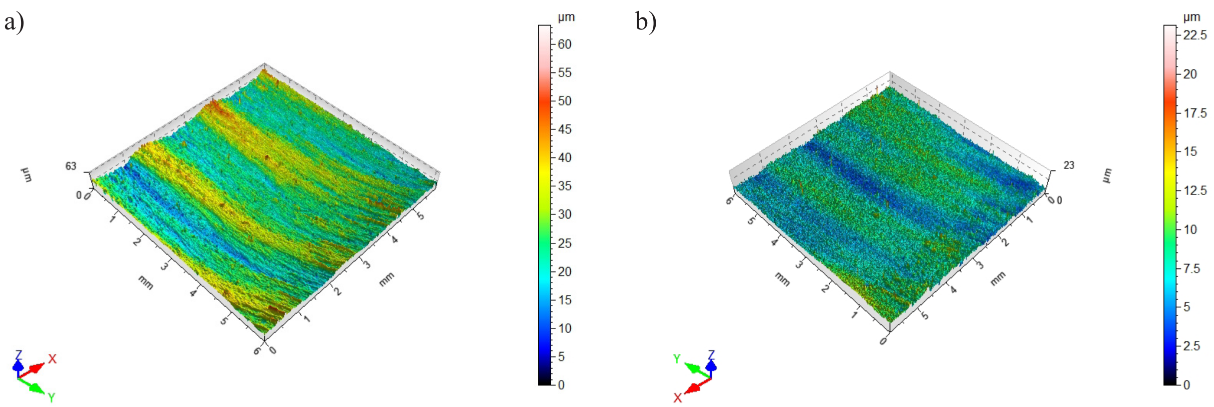
RESULTS

Figure 2 shows the surface topography after plasma cutting. The topography is characterized by uniform, undulating system of striae, which are formed on the cut surface as a result of plasma gas fluctuation. At the lower edge there are noticeable curvilinear striae, deviated from the intended track of plasma beam relocation. This indicates that the material is "slipping away" from the kerf. The geometrical structure should be qualified as an unidirectional parallel. The change cut conditions influence upon topography. These are visible changes in high elevations and cavings (Fig. 2b).

In the aspect of the two surface mating with each other, an important criterion is surface roughness. Parameters, allowing the assessment of ability mating in pairs are the parameters of Abbott-Firestone curve. Figure 3a presents the effect of cutting speed upon the Ra parameter. The increased cutting speed causes surface quality deterioration. It may be caused by shorter duration of plasma beam with workpiece, the consequence of which is a rapid melting process. On the surface there appear micro-irregularities, which have larger elevations and cavings. Considering the effect of cutting speed upon bearing curve parameters (fig. 3b) an increase of parameters can be noticed, together with the increased cutting speed. The Rpk parameter for maximum speed *v* = 2500 mm/min increased by 31%, compared to minimum value obtained for *v* = 1200 mm/min. Rk and Rvk parameters respectively rose up to 113% and 103%.

Increasing the current intensity causes the formation of a lot of elevations and cavings, which is translated into higher surface roughness (fig. 4a). The surface profile presents sharp vertexes and depression, which contributes to increased bearing curve parameters. The Rk parameters, characterized load capacity, increased more than 2 times, Rpk about 44% and Rvk 89%.

Considering the effect of gas pressure upon surface roughness (fig. 5a) and parameters of Abbott-Firestone curve, improved quality can be observed. The increased gas pressure causes faster ejection from the kerf. The shorter contact of liquid metal with the cutting surface prevents adsorption of thin film liquid metal by the workpiece. The Rk parameters, for pressure p = 10 bar, is reduced approximately by 60% compared to the value for pressure p = 8 bar. The parameter Rpk, maintained during surface lapping, is 1.8 time smaller for pressure p = 10 bar. That may lead to the improving resistance of that surface to abrasive wear (attrition). The highest value of Rvk parameter obtained for pressure p = 6 bar



Sa = 4.93 µm, St = 63.4 µm, Sp = 37.6 µm, Sv = 25.8 µm

Sa = 1.26 µm, St = 21.3 µm, Sp = 14.4 µm, Sv = 6.89 µm

Fig. 2. Surface topography after plasma cutting: a) *v* = 1800 mm/min, I = 80A, p = 8 bar (standard parameters); b) *v* = 1800 mm/min, I = 80A, p = 10 bar

a) b)

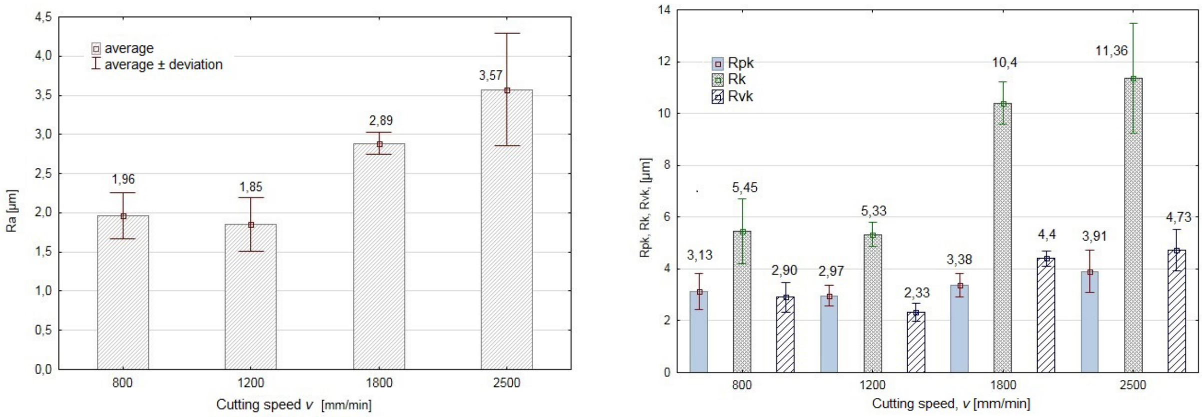


Fig. 3. Effect of cutting speed onto: a) surface roughness Ra, b) parameters bearing curve

a) b)

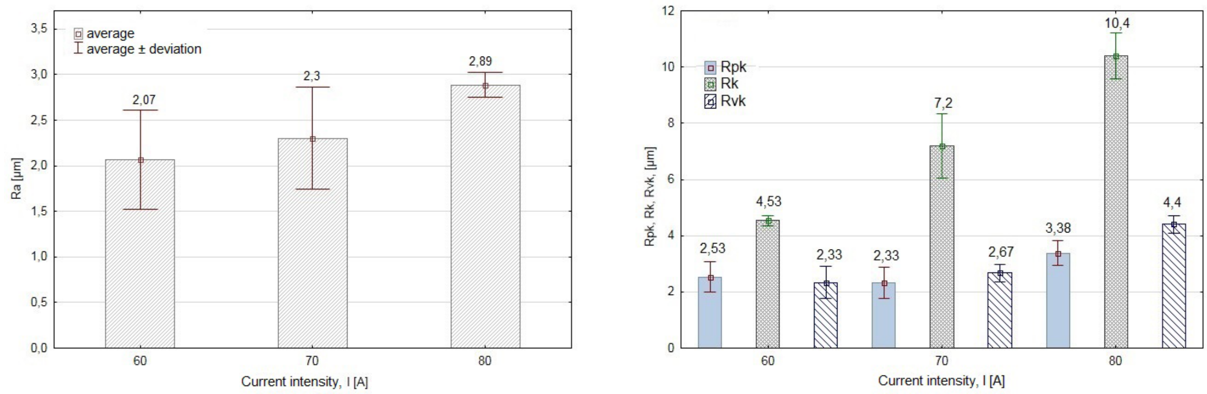


Fig. 4. Effect of current intensity onto: a) surface roughness Ra, b) bearing curve parameters

a) b)

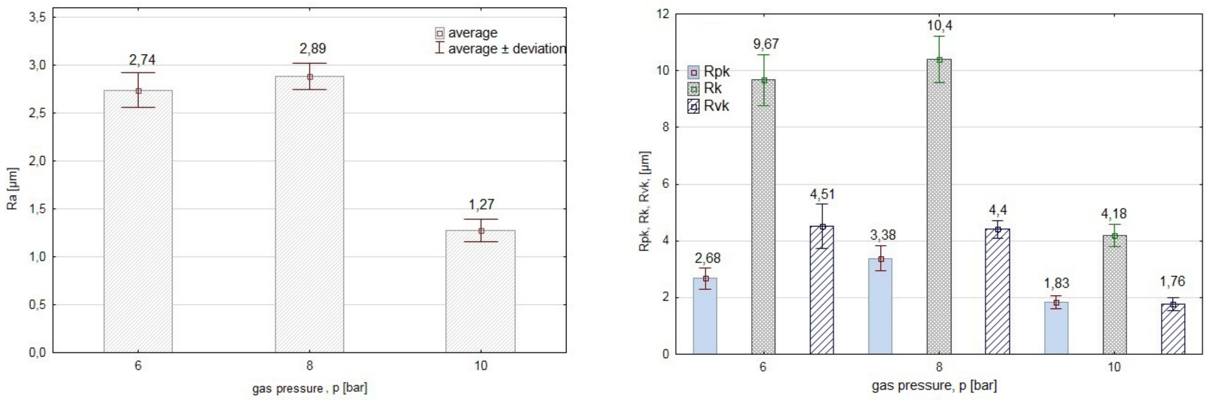


Fig. 5. Effect of gas pressure onto: a) surface roughness Ra, b) bearing curve parameters

that may suggest that the surfaces have greater oil maintenance capacity.

The shape of Abbott-Firestone curve contains information about the operational suitability of such a surface. The curve after plasma cutting is classified as degressive curve and in the same cases degressive-progressive curve. It is described as a curve with a large angle of inclination, representing a surface with sharp vertexes. The profile of such a surface with small bearing is called z curve with a "thin centre" [7].

CONCLUSIONS

In this paper we examined the effect of technological parameters of plasma cutting upon the surface roughness and bearing curve parameters. On the surface there appeared an undulating, par-

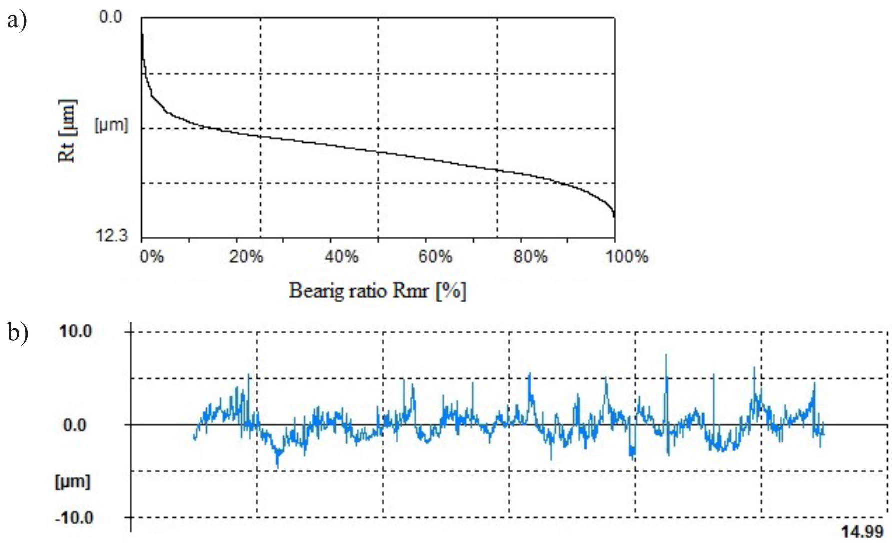


Fig. 6. Bearing curve and surface profile after plasma cutting (*v* = 1800 mm/min, I = 80 A, p =10 bar)

allel structure. At the lower edge there are noticeable curvilinear striae, deviated from the intended track of plasma beam relocation. This indicates that the material is "slipping away" from the kerf.

The technological parameters affect the surface roughness and parameters of Abbott-Firestone curve. The increasing cutting speed and current intensity cause surface quality deterioration and increased bearing curve parameters. The advantageous surface quality and low values Rpk, Rk, Rvk were obtained for higher pressure of the plasma gas.

The Rpk parameter was from 1.83 µm to 3.91 µm, depth of roughness body Rk: 4.18 µm ÷ 11.36 µm and Rvk: 1.76 µm ÷ 4.73 µm, for cutting technological parameters. The lowest surface roughness and bearing curve parameters were obtained for cutting speed: v = 1200 mm/min, current: I = 60 A and gas pressure: p = 10 bar.

The Abbott-Firestone curve is a degressive curve, in some cases degressive-progresive, that indicate low operating properties parts after plasma cutting. The obtained bearing curve parameters satisfy the need for surface finishing treatment after plasma cutting in the aspect of cooperation with some other surface.

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