DETERMINING THE SURFACE QUALITY OBTAINED AFTER THERMAL CUTTING

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Abstract. *The measurement of deviations from planeness, rectilinearity and parallelism of plane surfaces is a set of measuring tools (instruments, devices, high performance measuring means, etc.) and the conditions under which the measurements are made (temperature mode, way of basing during the measurment, stability or non-stability of the measured quantity in the measurement process, etc.), which implies that the method of measurement is a complex concept, i.e. a set of signs and conditions that accompany the measurement process.*
The present work determines the surface quality obtained after air plasma cutting of 41Cr4 steel by standard methodologies for measuring its parameters. For this purpose, a methodology is used to measure the shape and configuration as well as a methodology for measuring the profile of the surface.

1 Introduction

Post-processing surfaces of workpieces are not perfectly smooth. They contain convexities and concavities of a certain height and shape situated in a certain order or randomly at a relatively small step, known as roughness.
Roughness is caused by various factors related to the type of surface treatment, the shape of the plasma jet, the modes of operation, the type and microstructure of the material under treatment, etc.

Roughnes of the surface of workpieces has a strong influence on their functional purpose. Studies have been conducted to determine the effect of air plasma cutting on different materials on the shape and size of the roughness, i.e. on the exploitation properties of the workpieces and to establish optimal criteria for assessing the roughness of the surfaces. For this reason, standards have been developed and validated, which regulate the roughness evaluation parameters, their numerical values and the marking of roughness requirements. In accordance with the introduced standards, methods and means have been developed for controlling the roughness of the surfaces [1,2,3].

2 Air-plasma cutting of medium carbon alloy steels

The main task of this study is to determine the surface quality obtained after thermal cutting of steel 41Cr4 (BDS EN10083-3); 40X (GOST 4543-71). Determination of the possibilities for immediate arc welding of the cut edges without removal of a layer of metal [4].

Tables 1 and 2 show respectively the chemical composition and mechanical properties of the studied steel [5], [8].

Table 1. *Chemical composition of alloyed machine-tool steel,%*

Steel grade	**C**	**Si**	**Mn**	**Cr**	**Ni**	**Cu**	**S**	**P**
41Cr4	0,36÷ 0,44	0,17÷ 0,37	0,50÷ 0,80	0,80÷ 1,10	<0,3	<0,3	<0,025	<0,025

Table 2. *Mechanical characteristics of steel, %*

Steel grade	**Temperature, °C**		**RA**	**Rm**	**A5**	**Ψ**	**KCU [MJ/m²]**
	tempering	**relieving**	**[MPa]**		**[%]**		
41Cr4	860(oil)	500	785	980	10	45	0,59

Fig.1 *Outlook of plasma cutting equipment for metals*

The outlook of the plasma cutting equipment is shown in Fig. 1, consisting of the following basic systems [6,7]:

- plasma cutting current source, type - REDCO, PLASMA 60/2;
- compressor for plasma generating gas (air), type – ABAC 50 Hp2,5;
- machine plasmatron, type – AUTOCUT P S75;
- NC Cutting Machine, Type - Portable NC Cutting Machine (Steel Cut L);
- ventilation system, type - Vetraflex.

The cutting of steel grade 41Cr4 takes place in the following modes:

- maximum current power (Duty Cycle=60%) - 60A;
- maximum cutting thickness - 12 mm;
- compressed air consumption - 8÷10 dm^3/min;
- air pressure in the plasmatron - (3,5÷ 5,5)$*10^5$ MPa;
- plasma arc ignition mode - oscillator;
- cutting speed - 2÷3 m/min;
- voltage - 100÷110V;
- nozzle diameter - 1.4mm;
- width of the cut – 1,8÷2,0 mm.

Figure 2 shows a photo of sample after air plasma cutting which shows the shape of the relief.

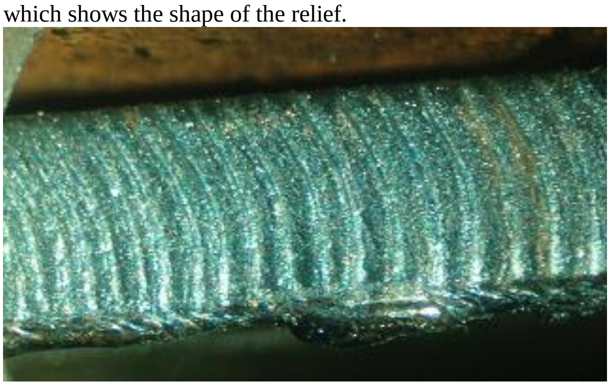


Fig. 2 *Relief of the cut walls.*

3. Surface geometric parameters study by experimental methods and means of measurement.

The accuracy of the shape of the real plane surface is best characterized by the complex indicator called deviation of planeness, and the accuracy of the shape of the surface profile - by the indicator called deviation of the rectilinearity [8,9,12].

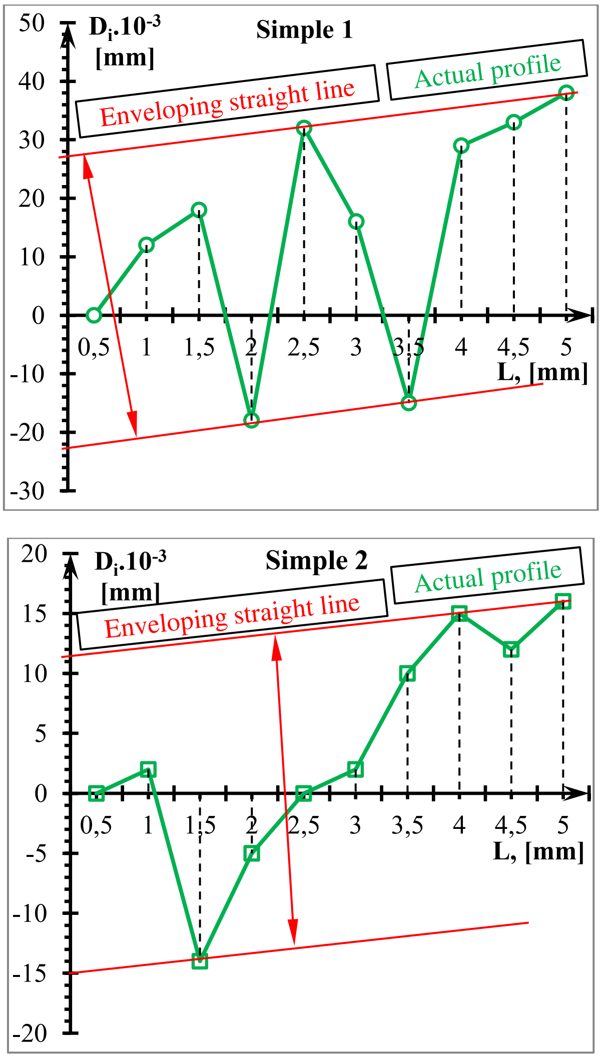
The accuracy of the studied thermal cut samples and the quality of the surfaces are determined after removal of the slag and the growths obtained after the air plasma cutting [10,11].

Measurements of the experimental samples are carried out on a check plate with a MITUTOYO electronic measuring clock firmly fixed on a stand. The clock shown in Figure 3 reads the deviation in the shape and position.

Measurements are made on the thermal cut samples by measuring 10 points at equal distances, the results of the deviation from the profile are shown in Table 3.

Fig.3. Experimental installation for reading the deviations in the shape

On the basis of the measured deviations from the profile, a graphical representation is made of the surfaces of the two samples Figure 4.



a)

b)

Fig.4. Graphical representation of the surface: a) Probe 1; b) Probe2.

Table 3. Deviation from the profile of plane surfaces

Samples	Di.10^{-3} mm	Length of measurement L, mm									
		0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
Sample of 41Cr4	Probe 1	0	12	18	-18	32	16	-15	29	33	38
	Probe 2	0	2	-14	-5	0	2	10	15	12	16

The graphs show the real profile of the surface that separates the body from the environment. The estimation of the deviation from rectilinearity is performed with respect to the mean line determined by the function of the least squares method against which is constructed the enveloping straight line (ESL). It is a geometric straight line, tangent to the actual profile (AP) outside the workpiece material and it is positioned is such a way that the largest distance between the ESL and the AP has the smallest of the possible values.

From the graphical relationships in Fig. 4 we can read the deviation from planeness, rectilinearity and parallelism of the surface for the 2 different experimental samples shown in Table 4.

Table 4. Results of the deviation in the shape and configuration

Sample of 41Cr4	Deviation from rectilinearity, µm	Deviation from parallelism, µm	Deviation from planeness, µm
Probe 1	5,29	6,32	4,68
Probe 2	5,13	6,88	4,87

The readings indicate that the largest deviation from the profile is obtained in sample 1 because after the plasma cutting the surface at the end of the sample has some distortion resulting from the leakage of the molten metal. The profile obtained has a conical shape. In the cross-section, the surface has a convex shape, as there is a slight bevel of the edges of the sample due to the high temperature.

4. Study of the parameters characterizing the roughness after plasma cutting.

In the world practice, two roughness assessment systems are available - the system of the mean line of the profile (system M) and the system of the enveloping line of the profile (system E) [8,9,13].

By filtering the primary profile, the mean line that depicts the corrugation is calculated. The deviation of the actual surface from the center line corresponds to the roughness.

In accordance with the standard, for this type of heat treatment and sample thickness, a roughness of Ra = 0,5-0,8 mm is prescriped. For this roughness, we choose a base length of the surface equal to 8mm.

The initial experimental samples were measured with the installation shown in Figure 5 in two adjacent cross-sections after air plasma cutting to as to cover the entire area under study.

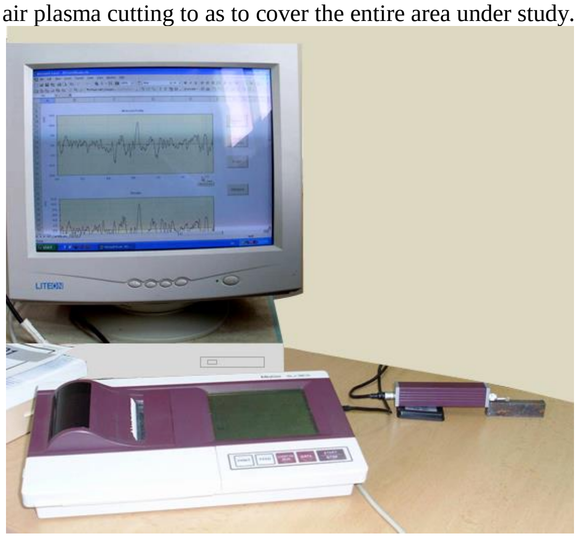


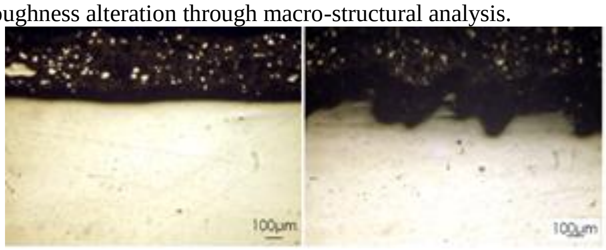
Fig. 5. Installation for measuring the roughness Mitutoyo Surftest SJ301

The profilegrams obtained are a set of roughnesses that shape the surface relief obtained before and after the air plasma cutting and are evaluated in an area that does not contain shape and corrugation deviations.

The drawback of the contact profilemeter is that the parameters can only be calculated for a part of the surface, i.e. they are calculated from a two-dimensional cross-section of the profile, although the surface is three-dimensional. This part of the surface depends on the distance between the traces of treatment nd the size of roughness [13].

The obtained parameters measured with the Mitutoyo Surftest SJ 301 contact profilemeter [13] are presented in Table 5, and the profilegram of the surface, in Fig. 7, for the initial and the thermally cut samples.

From the sample in Figure 2 it can be seen that the roughness of the relief is different in height of the cut-off parent metal. The height is the smallest at the top of the cut walls and becomes maximum at the bottom. Figure 6 (a) and (b) shows the effect of roughness alteration through macro-structural analysis.



a) b)

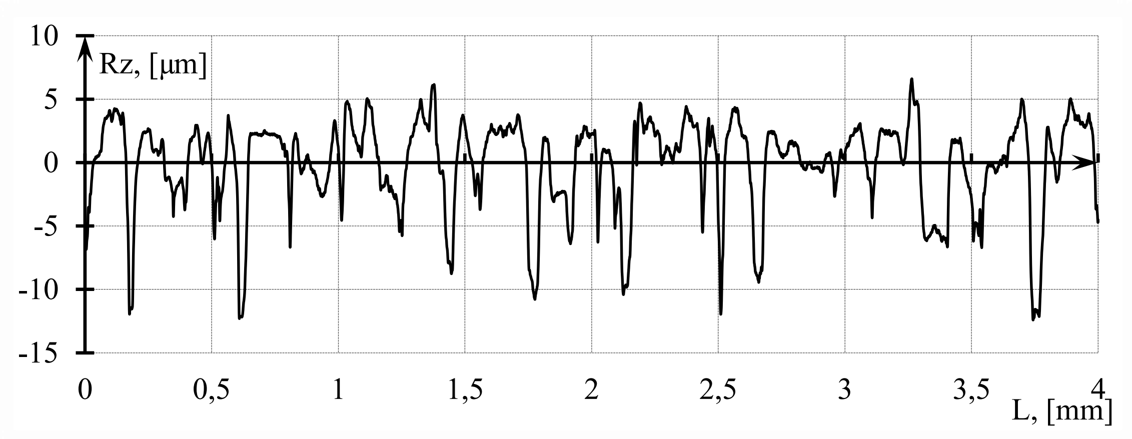
Fig. 6. *Macrosection with an increase of 63 times: a) roughness at the top of the cut walls;b) roughness at the bottom of the cut walls*.

From the analysis of the roughness of the surfaces, it can be seen that in the plasma cutting of the 41Cr4 steel the roughness is not high.

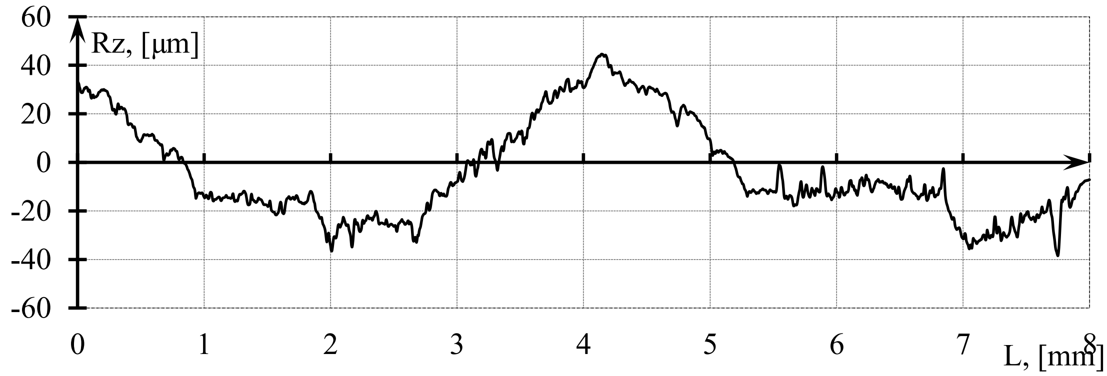
Further research should continue in the direction of: optimizing cutting parameters to reduce surface roughness and shorten the final surface treatment technology.

5 Conclusion

1. Air-plasma cutting was carried out of alloyed machine-building steel 41Cr4 with thickness 12mm;
2. The parameters of the plasma cutting mode of steel 41Cr4 were determined;
3. By using a methodoly for determination of the shape and configuration deviation were determined the deviations in the cut edge after air-plasma cutting of the 41Cr4 steel;
4. By using a methodoly for determination of the roughness parameters after air-plasma cutting were determined the standard parameters of roughness before and after the cutting in the area of the cut.



(a)



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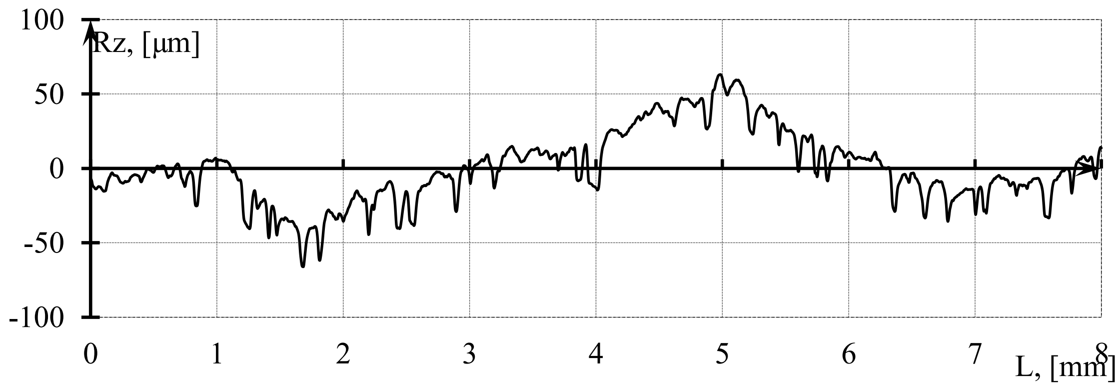

(c)

Fig. 7. *Profilegram of the surface: (a) initial sample; (b) thermally cut sample 1; c) thermally cut sample 2.*

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