

SURFACE ROUGHNESS IN LASER BEAM CONTOUR CUTTING

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ABSTRACT: In the industrial engineering field, there are several methods able to be applied in order to materialize a cut contour. Not in all cases, the removable rate of material and cutting accuracy are satisfactory and the costs are sufficiently low. In such situations, some nonconventional processing methods could ensure a fast and appropriate solution for cutting workpieces. Knowing that the surface roughness is a parameter of real interest in almost cases when the accuracy is considered, definitely it will decide the chosen manufacturing process. Due to its influence on the surface properties and on the number of subsequent machining operations, the required roughness value could be taken into consideration when selecting the cutting process. Among distinct nonconventional processes which can be applied, in the present paper, the laser beam procedure was established as being the right choice in order to accomplish certain objectives. A theoretical analysis showed that some of input factors for laser beam process are able to affect the sizes of the surface roughness parameters and could be represented by cutting speed, pressure of the gas sent to the processed area, the power developed in the contact area between the laser beam and workpiece, the process efficiency and the frequency of the laser beam. An experimental research was designed and developed, in order to highlight the influence exerted by the above mentioned factors on the size of the Rz surface roughness parameter. Using the experiments planning, it was developed a series of experiments, in order to show the intensity of effects exerted on the surface roughness by the process input factors.

KEY WORDS: surface roughness, contour cutting, laser beam machining, influence factors.

1. INTRODUCTION

In the current conditions of materials processing using modern techniques and equipment, a problem that could be formulated refers to the way in which one could select an innovative process of manufacturing and a classical one, respectively. As it is known, the cutting processes are widely spread among the mechanical machining processes applied in mechanical industry. This fact is due to several situations established by economic and productivity criteria. Additionally, sometimes there are situations when the complexity of the machined surfaces, in association with the high accuracy imposed to machined parts, require special conditions of processing [1]. Other reason which establishes the limits of an applied cutting process is based on the necessity of taking into consideration the mechanical properties of the workpiece material.

In usual cutting processes like milling, turning etc., separation of a part from workpiece represents a problem easily solved. Although not in all the cases, the right solution could be adopted. Depending on the workpiece complexity, the chosen cutting technology may consist of classical or nonconventional cutting processes. For this reason, first point of view for solving the problem is the analysis of the main advantages and disadvantages

specific to each cutting process which could be applied, in order to solve the technological problem.

Thus, in certain situations, a cutting process could be considered as an inefficient, especially in detriment of a nonconventional one. In such a case, a classic cutting process could be replaced by a nonconventional one. Of course, in certain conditions, the nonconventional process could ensure higher accuracy conditions to the resulted surfaces. In case of this study, when the geometry of workpiece and the imposed accuracy are restricted to certain dimensional intervals, the proposed solution was to use a nonconventional cutting technology. As a consequence, a simple way to replace the milling process by a laser beam cutting process for detaching a part with a certain contour from the workpiece was taken into consideration.

2. GENERAL ASPECTS

Laser beam machining process is a part of the group of machining methods based on erosion by means of radiation. The laser concept refers to that technology which uses the light amplification obtained by stimulated emission of radiation [3]. Basically, as physical phenomenon, a laser light is produced

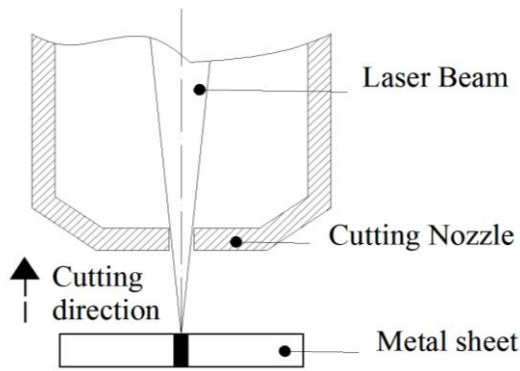


Figure 1. Laser cutting scheme

imposing certain changes in some state parameters of the photons as frequency, phase and wavelength in order to obtain a laser beam light, with high power density, directed and focused on the workpiece surface. As it is well known, essentially the laser device consists of an active environment, which can be solid, liquid or gas, closed into an optical cavity and which uses an external energy to produce an amplified radiation. The thermal processes succeeding the radiation include material melting, vaporization of a small quantity of workpiece, certain chemical reaction and finally a solidification phenomenon [3] Figure 1. Within the radiation machining processes, other machining methods are the electron beam machining and the ion beam machining.

A simply classification of the lasers could be [4] take into consideration:

- nature of the active environment (solid, liquid or gas);
- emission power;
- wavelength of the radiation emitted;
- function mode (continuously or by impulses).

The laser beam technology can be considered as a nanotechnology process, because it could use a certain kind of energy (light energy) to remove very small quantities of material or to obtain very small surfaces. In fact, the laser beam process represents a technical evolving from the maser radiation (Microwaves Amplification by Stimulated Emission of Radiation). In industry, the laser beam machining (LBM) can be considered as a good substitute of a

conventional cutting processes, such are milling, drilling and marking machining. It is also used in order to develop activities in other fields, such are metrology, spectroscopy, nuclear fusion etc. In mechanical engineering, the laser processing is used for marking, engraving, heat treating, cutting etc.

A wide range of materials, varying from metals to non-metals, as plastics, glass and others can be processed by means of the laser beam. As main parameters used in the LBM processes, one can mention the focal distance (determining distance between the laser head and workpiece, position of focal point, nozzle diameter, type and the pressure of the cutting gas, laser power, cutting speed etc.

The actual performances corresponding to the laser beam processes allow cutting steel metal sheets with thicknesses varying between 1 to 6 mm, or stainless steel from 0.5 to 4 mm, aluminum from 3 to 15 mm, with cutting speeds between 0.3 to 4 m/min and leads to obtain roughness (*Ra* parameter values) between 0.03 to 0.8 μm , depending on the processed material [6].

The research objective presented in this paper was to obtain a cutting contour in a metal workpiece using laser beam technology. In order to obtain a cut contour with special characteristics, supposed as having distinct values of roughness parameters, some machining parameters as cutting speed, gas pressure, laser power, laser efficiency and laser frequency were carefully set. The output parameter studied was represented by the surface roughness parameters.

In the case of thermal cutting with oxygen and laser beam, small quantities of samples made of low carbon steels were locally heated by the laser beam and a part of melted or vaporized material was removed by the jet of oxygen. Thus, the kinetic energy produced by the gas pressure released into the work area drains melted material and slag generated by the cutting process. It should be noted that, by oxidizing, the iron from material could emit an additional amount of energy that ensure conditions for the increase of cutting speed.

In the technical literature several approaches

Table 1 Chemical composition and mechanical characteristics of the S355JR (after the producer indications)

Chemical composition (%)							Mechanical Characteristics			
	C	Mn	Si	S	P	Al	As	Tensile Strength (N/mm ²)	Yield Tensile Strength (N/mm ²)	Ductility (%)
S355JR	0.18	1.48	0.014	0.008	0.014	0.044	0.003	0.019	462	507

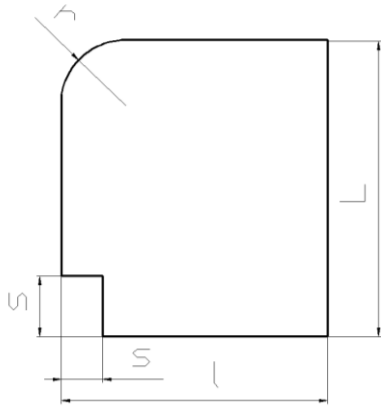


Figure 2. Test piece shape

concerning the laser beam machining process applied to different workpieces shape and materials can be found. Among these works, the study made by Chen [2] presents the effects of the high pressure of the assistant gas flow, using a high power of the laser beam. The author justifies the significance of the assistant gas by means of its properties such as humidity and purity, suggesting that such a gas offers a high quality of manufactured products. Yilbas [6] studied some aspects concerning the laser cutting quality with reference to the roughness and the thermal implications of the laser in this process. He remarked significant differences between the laser processes made by using distinct cutting speed values, if the roughness parameters are considered. One of the conclusions was that a higher cutting speed diminishes the value of the surfaces roughness parameters.

Rajaram et al. [5] referred to the quality of surfaces obtained by CO₂ laser beam cutting.

3. EXPERIMENTAL SET-UP

The experimental research was performed using a Mazak Super Turbo Mk II, with an installed power of 1.8 kW; the system was equipped with a CNC module. The specified device was cooled by means of CO₂ and assisted by oxygen and azote gas. Among the technical characteristics of the mentioned equipment, one can specify: 24 m/min speed along the X-Y axes, 25 m/min along Z axis, precision positioning of ± 0.01 mm/500 mm along X-Y axes, ± 0.01 mm/100 mm along Z axis, cutting head with a working length of 50 mm and which admitted 2 MPa pressure, allowing cutting steel samples characterized by widths ≤ 12 mm. The cut samples had the dimensions $L= 35$ mm, $l= 25$ mm, $s_1= 10$ mm, $s_2= 5$ mm, $r= 12$ mm and they were separated of a S355JR steel plate. The workpiece/sample profile used in this study could be seen in the Figure 2. In order to measure the surface roughness of the cut contours, an apparatus

Table 1. Influence of the assistant gas and cutting speed on the values of surface roughness parameter Ra

Cutting speed, mm/min	Surface roughness parameter Ra [μm] when using oxygen as assistant gas	Surface roughness parameter Ra [μm] when using azote as assistant gas
2000	6.58	1.25
4000	4.94	0.84
4300	5.43	0.86
4600	5.69	0.78

Table 2. Influence of the assistant gas and gas pressure on the values of surface roughness parameter Ra

Gas pressure [MPa]	Surface roughness parameter Ra [μm] when using oxygen as assistant gas	Surface roughness parameter Ra [μm] when using azote as assistant gas
0.6	0.445	0.073
1	0.41	0.065
2.5	0.49	0.074

Table 3. Influence of the assistant gas and gas laser frequency on the values of surface roughness parameter Ra

Laser radiation frequency [Hz]	Surface roughness parameter Ra [μm] when using oxygen as assistant gas [Hz]	Surface roughness parameter Ra [μm] when using azote as assistant gas
150	0.71	0.8
350	0.66	0.82
1000	0.56	0.69

Table 4 Influence of the assistant gas and laser radiation efficiency on the values of surface roughness parameter Ra

Laser radiation efficiency [%]	Surface roughness parameter Ra [μm] when using oxygen as assistant gas	Surface roughness parameter Ra [μm] when using azote as assistant
75	0.79	0.71
85	0.65	0.66
95	0.78	0.56

Surtronic 25 from Taylor-Hobson was used. This apparatus allows determining a large range of roughness parameters values, in certain conditions of measurement. In this case, only the values of Ra surface roughness parameter were measured, considered it as main responsible for characterizing the cut surface roughness. It is expected that the characteristics of the used assistant gases could have a significant influence on the roughness parameter.

The chemical compositions for the laminated steel sheets used in the research are presented in Table 1. As assistant gas, the oxygen with a high purity (99.95%) and azote were used. Some of the experimental results correspond to the use of the oxygen gas and the others were obtained in the case of using azote. Some machining parameters have been kept constant in order to highlight the influence exerted by an input factor on the evolution of the surface roughness parameter Ra. The parameters maintained constant in the case of studying the

influence exerted by the cutting speed were: nozzle diameter: 1.5 mm, focal distance: -1 mm, laser frequency: 1000Hz, gas pressure: 4 bar; laser efficiency: 100 %; laser power: 1800 W. As process input parameters, the followings were used the cutting speed v [mm/min], the cutting pressure gas p [bar], the laser beam power P [W], the frequency laser f [Hz]. A schematic representation of the cutting process was presented in Figure 1. The test sample profile used in this study was shown in Figure 2.

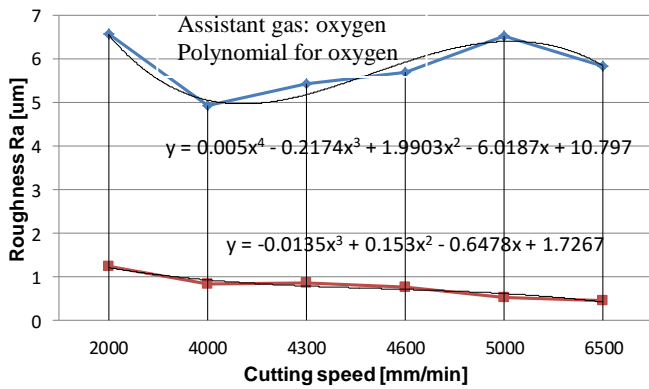


Figure 3. Graphical representation of influence exerted by cutting speed on the values of the surface roughness parameter Ra

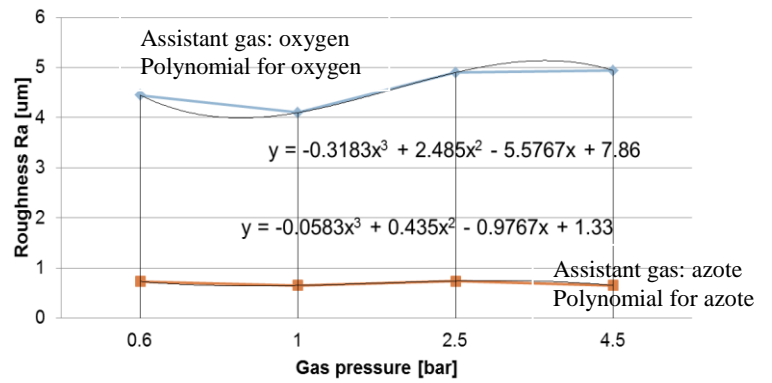


Figure 4. Graphical representation of the influence exerted by gas pressure on the values of surface roughness parameter Ra

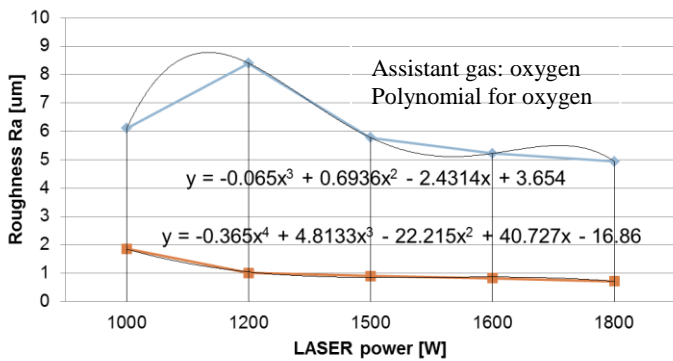


Figure 5. Graphical representation of influence exerted by laser radiation power influence on the value of the surface roughness parameter Ra

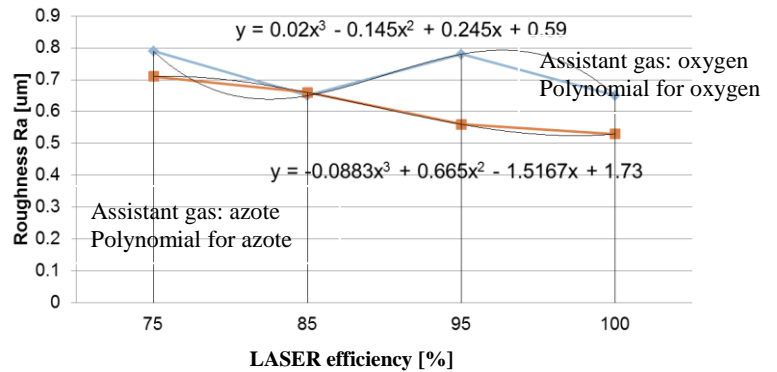


Figure 6. Graphical representation of influence exerted by laser radiation efficiency on the values of surface roughness parameter Ra

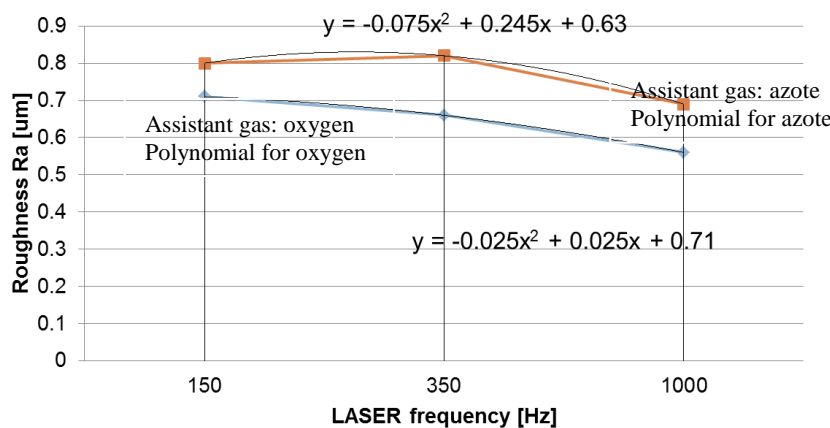


Figure 7. Graphical representation of influence exerted by laser radiation frequency on the values of the surface roughness parameter Ra

Table 5 Influence of the assistant gas and laser radiation power on the values of surface roughness parameter Ra

Laser radiation power [W]	Surface roughness parameter Ra [μm] when using oxygen as assistant gas	Surface roughness parameter Ra [μm] when using azote as assistant
1000	6.1	1.86
1200	8.4	1.01
1500	5.78	0.9

Other settings referred to the focal distance, which has been established taking into consideration the producer indications, as it is the distance between the nozzle and the workpiece (that was chosen as depending on the nozzle diameter at a distance of 10 mm).

The surface roughness parameter Ra was chosen as output parameter because it was considered as depending on the cutting conditions. The experimental results allowed elaboration of graphical representations able to highlight the influence exerted by the process input factors on the values of the surface roughness parameter Ra.

The experimental data were presented in tables 1 - 6. The figures 3 - 7 highlight the influence exerted by the process input factors on the values of the surface roughness parameter Ra..

4. CONCLUSIONS

The graphical representations allow concluding that:

- The values of surface roughness parameter Ra are directly influenced by the cutting parameters (as it was showed in the graphical representations); also, on could consider that the type of chosen assistant gas could generate an increase of the machining cost;
- if an inappropriate gas pressure is used, it is possible to obtain high values of the surface roughness parameter Ra, due to less controlled flow of melted material;
- the gas pressure (having a certain purity and humidity) exerts a significant influence on the values of the roughness parameter Ra of the cut surfaces; as it was presented, the studies developed in this field shows that the level of impurities conducted to a cutting speed reduction (for 1% impurities, results a 30% decrease of cutting efficiency);

- the cutting speed represents a parameter which exerts a direct influence on the roughness of the cut surfaces and of course, on the productivity of the process;

- even the effect of the laser power on the machining cost is relatively low, it has a significant influence on the values of the surface roughness parameter Ra;

- a high value of the laser efficiency determines low values of the surface roughness parameter Ra;

- a high frequency of the laser beam determines small values of surface roughness parameter Ra.

- the oxygen gas allows using high cutting speeds and the azote offers a high quality of the cut surfaces.

In the future, there is the intention to establish empirical mathematical models able to highlight the simultaneous influence exerted by the process input factors on the values of the surface roughness parameter Ra.

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