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PARAMETERS INFLUENCE OF CO_2 LASER ON CUTTING QUALITY OF POLYMER MATERIALS

VLIV PARAMETRŮ CO_2 LASERU NA KVALITU ŘEZU POLYMERNÍCH MATERIÁLŮ

Abstract

The article deals with evaluating of the resulting surface state of the three plastic materials and identification of suitable conditions for laser cutting with CO_2 tube. As representative were chosen polypropylene, polymethylmethacrylate and polyamide. When cutting these types of materials it could melt eventually their re-sintering. A suitable combination of parameters is possible to achieve of sufficient quality of the cut. The samples were cut at different feed speed and laser power. Then they was compared on the basis of the measured roughness parameters Ra a Rz by using a portable touch roughness Hommel-Etamic W5 and dates was processed according to ČSN EN ISO 4287. Cutting of samples was realized at the Department of Machining, Assembly and Engineering Metrology, VŠB-TUO.

Abstrakt

Článek se zabývá vyhodnocením výsledného stavu povrchu tří plastických materiálů a vytipování vhodných podmínek pro řezání laserem s CO_2 trubicí. Za představitele byli vybráni poplypropylen, polymetylmetakrylát a polyamid. Při řezání těchto typů materiálů může dojít k roztavení popř. k opětovnému spojení. Vhodnou kombinací parametrů je možno docílit dostatečné kvality řezu. Uvedené vzorky byly nařezány za různých rychlostí posuvu a výkonů laseru. Vzorky byly následně porovnány na základě měřených parametrů drsnosti Ra a Rz s využitím přenosného dotykového drsnoměru Hommel-Etamic W5 a data byla zpracována dle (ČSN EN ISO 4287). Řezání vzorků probíhalo na pracovišti Katedry obrábění, montáže a strojírenské metrologie, VŠB-TU Ostrava.

Keywords

Laser technology, surface roughness, polymer materials.

1 INTRODUCTION

Currently, the production puts the high requirements, which regarding lifetime, wear of components and economics. We meet with methods, which reach better results for shorter time, e.g. unconventional methods – laser technology. Laser cutting of plastic material is lifted in many industries, where is possibility to achieve better quality of product in connection with higher process reliability. The quality of the cut depend on settings operational parameters.

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Principle of laser machining is releasing of potential energy of electrons of the atom element, which is contained in small amounts in basic substance. Mechanical properties of material don't have influence on speed and performance. The material needn't be harder and stronger than machined material. The use of laser technology in polymer area is suitable in terms of speed, accuracy and flexibility of the whole process. Laser process provides quality surface treatment, which is incomparable with other processes. Laser cutting enables machining of complex shapes small width of cut and use of full automation. [1, 2]

2 LASER CUTTING OF POLYMER MATERIAL

A fundamental role in the quality of the surface after cutting polymers plays parameters. The laser beam causes integrity crushing of the material and the heat generated during cutting may cause in inappropriately chosen parameters melt the material or its re-sintering.

Caiazzo et al. [3] presents the cutting of thermoplastic materials by laser technology and he states that the best processing had polycarbonate (PC). The aim is to optimize the quality of the surface and to achieve the desired dimensions with right combination of power and the feed speed of the laser. With increasing feed speed come about deterioration in the surface roughness. This statement applies for both dry and cooling. Laser power has influence on the surface roughness and the parabolic waveform. [4, 5]

Effect on the final quality of the cut has a gas pressure, where better results are secured with a low frequency. Effects of laser power and the cutting speed are different for polymeric materials compared also J.P. Davim et al. [6]. Best workability was PMMA, which showed little HAZ with minimal running off the edge.

3 EXPERIMENTAL PROCEDURE

The experimental work has been proposed to assess the cut quality of polymeric materials on influence of laser beam of CO_2 laser. The test materials were selected three representatives (see fig. 1) - polypropylene PP-C natur, polymethylmethacrylate and polyamide (PA6). These materials have high hardness, toughness and strength (PMMA, PA6), good weldability and strength (PP-C natur). [2] The individual mechanical and thermal properties of the materials are given in table 1. Samples were cut from plates with dimensions (500x100x10) mm. The issue is that cross-section with a width of 20 mm (see fig. 2b). [7, 8]

Fig. 1 Samples

Tab. 1 Properties of materials

Parameters	Polypropylene (PPC natur)	Polyamid (PA6)	Polymetylmetakrylát (PMMA)
Density	0,92 g·cm^{-3}	1,15 g·cm^{-3}	1,19 g·cm^{-3}
T_{mp}	163 °C	220 °C	160 °C
Strength	29 MPa	80 MPa	73 MPa

We used laser with CO_2 tube – E 4060, which is available at the Department of Machining, Assembly and Engineering Metrology, VŠB - TUO. CO_2 tube ensures cutting / engraving all materials including metals with using special paste. In table 2, there are technical parameters of the machine. Laser E4060 see fig. 2a.

Tab. 2 Technical parameters of laser E 4060

Technical parameters	Value
Min. / max. dimensions engraved area	(1,5 × 1,5) mm / (400x600) mm
Possibility of engraving rotational figures	yes
Laser power	40 W / 60 W
Laser type	CO_2
Engraving speed	0 – 1000 mm·s^{-1}
Feed speed	0 – 600 mm·s^{-1}
Max. cutting depth	Acryl 0 – 10 mm
Repetition accuracy	0.01 mm
Water cooling	yes

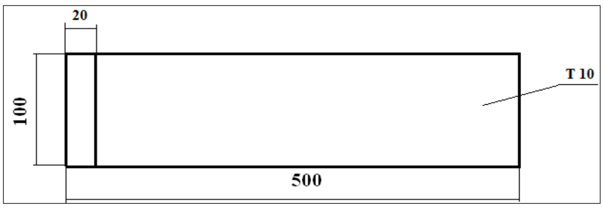

Fig. 2a) Laser E4060; **2b)** Cut layout

Selected materials were cut at the given conditions, which are shown in table. 3. For each material was set feed speed v_f, which was in the range (1;2;5;10) mm·s^{-1} and the laser power P (100;75;50) %. The correct combination of these parameters ensures sufficient quality of the cut. Not all materials could be cut at all propose conditions due to sintering of the material during high speeds, respectively re-sintering at lower speeds.

Tab. 3 Cutting conditions [7]

Feed speed vf [mm·s^{-1}]	1	2	5	10	1	2	5	10	1	2	5	10
Laser power P [%]	100	100	100	100	75	75	75	75	50	50	50	50

However, there are different quality characteristics, which describe the laser cut quality. Because of its impact on several functional attributes and overall performance of end product, surface roughness in laser cutting is of great importance, and hence it was selected as performance measure. Quality control of laser cutting was evaluated according to measured surface roughness parameters. They were evaluated with using Hommel - Etamic W5. The roughness device evaluates data according to standard EN ISO 4287. For each cut carried out five measuring of parameter *Ra* and *Rz* [μm]. The individual measuring were evaluated by the standard deviation and the average value was recorded in graphs. [8, 9]

4 EVALUATION OF THE CUTS

Correct settings of parameters influences whole process and it has noticeable effect on final state. After laser cutting were measured the values of roughness parameter *Ra* and *Rz* (see fig. 4, 5). Figure 3 shows example of the cut for material PMMA – power 100% and feed speed $v_f = 10\ mm \cdot s^{-1}$, $v_f = 1\ mm \cdot s^{-1}$.

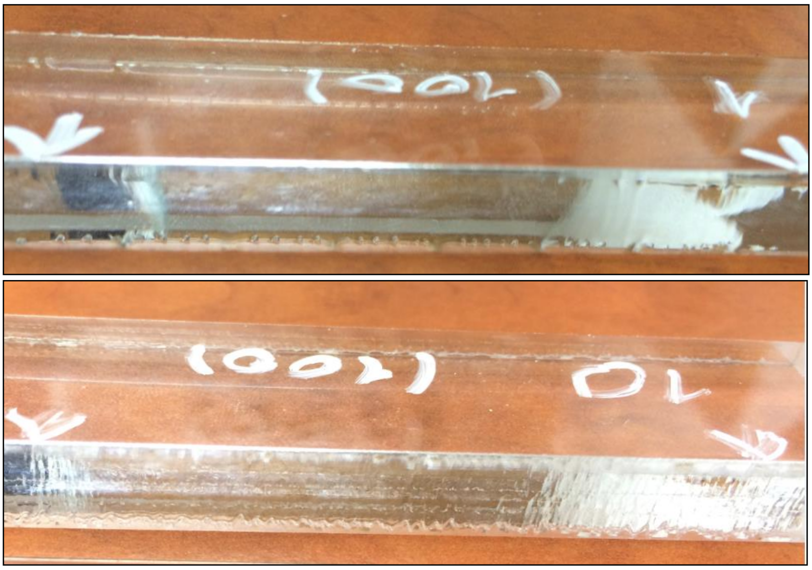

Fig. 3 Section PMMA – P = 100%, v_f = 10 mm·s^{-1}, v_f = 1 mm·s^{-1}.

The course of the measuring under the given cutting conditions indicates that laser cutting the samples no. 1 – PMMA came out the best (see fig. 3). The lowest value *Ra (0,1±0,01) μm* a *Rz (0,3±0,05) μm* was achieved due to the low feed speed 1 mm·s^{-1} and the highest laser power 100%. Increasing value of feed speed and constant power the value rising. The laser cutting of 50% and 75% power has similar character. Final surface was very smooth and didn’t show any unevenness.

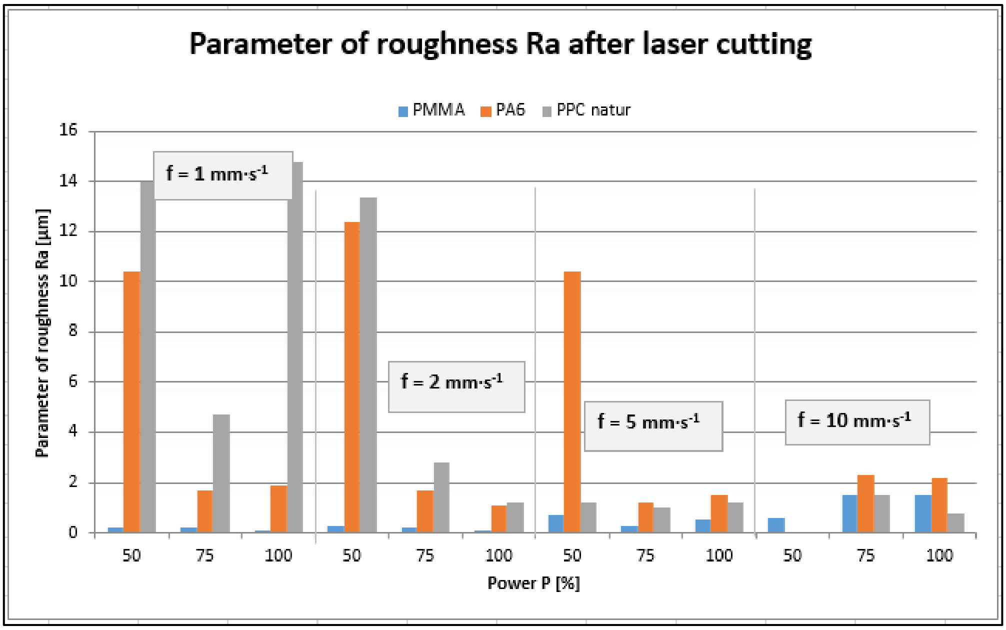

Fig. 4 Dependence of parameter Ra on laser power for different feed speed

Final cut for polyamide PA6 – sample 2 came off best for the highest power and feed speed 2 mm·s^{-1}. By contrast low power and rising feed speed cause deteriorated surface. The quality of surface was un-sufficient for used parameters 50 % and 10 mm·s^{-1} and it caused sintering of material. Due to the measuring wasn't realized (N/A). Samples – fig. 6.

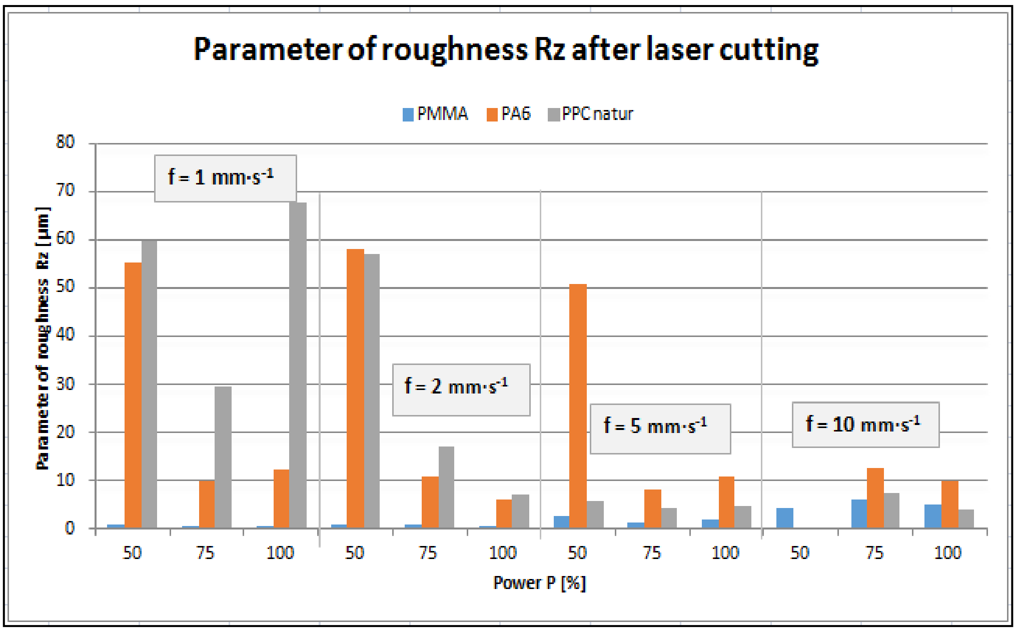

Fig. 5 Dependence of parameter Rz on laser power for different feed speed

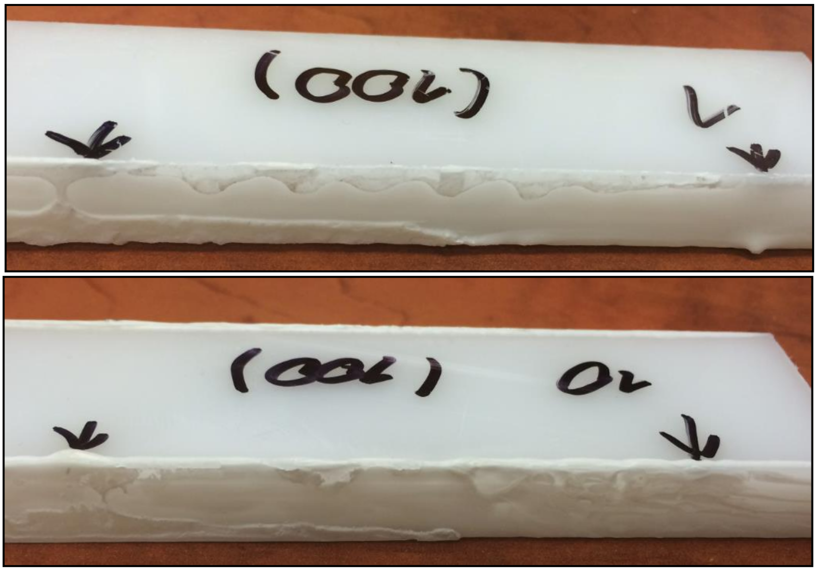

Fig. 6 Section PA6 – P = 100%, $v_f = 1\ mm \cdot s^{-1}$, $v_f = 10\ mm \cdot s^{-1}$

Material PP – C natur showed inverse values like previous examples. The lowest values was measured with using laser power 100% and $v_f = 10\ mm \cdot s^{-1}$. Poor-quality surface was made by cutting laser power 50 % and feed speed 10 $mm \cdot s^{-1}$. The value wasn't measured – N/A. The surface of the cut with rising feed speed and constant 100 % laser power came about improvement surface state. Samples – fig. 7.

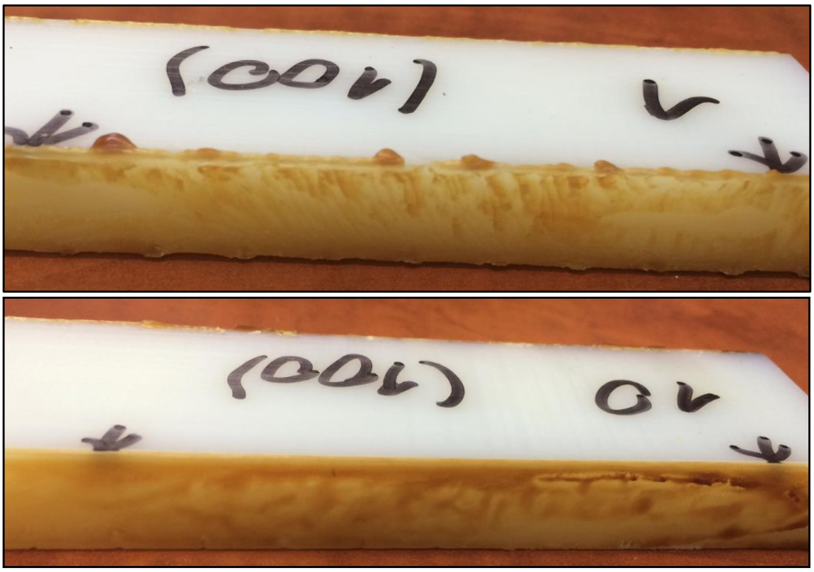

Fig. 7 Section PP – C natur – P = 100%, $v_f = 1\ mm \cdot s^{-1}$, $v_f = 10\ mm \cdot s^{-1}$

5 CONCLUSION

Experimental activity was realized in order to determine the cut quality of polymer materials on effect laser beam CO_2 laser. There were evaluated adjustment material parameters, laser power and feed speed. Different combinations of these parameters caused different surfaces. Implementation of experiment was achieved the best – the smoothest cut surface. Each sample had different mechanical and thermal properties and final measured values. The quality of cutting edge is not only dependent on the cutting process and setting parameters, but also on the cutting depth. The final surface didn’t show any signs further necessary processing. The cutting speed, laser power and focus position are the main parameters influencing the surface roughness.

Of three material which were used for experiment (PMMA, PA6, PP – C natur) preferably showed sample no. 1 – PMMA (plexiglass XT). Measured values achieved only tenth microns and final surface was smooth without evident unevenness. It confirmed suitability application of laser for this material. For the highest feed speed 10 $mm \cdot s^{-1}$ was necessary to cut through sample multiple times, because high feed speed didn’t allow to cut through material at one track. Then the final surface roughness can appear distortedly. With increasing feed speed and constant laser power roughness, values are rising. For this material is recommended to select very small feed speed and maximum laser power.

Sample no. 2 – polyamide PA6 is suitable for application laser technology too. The material was adaptable for cutting with maximum laser power and low feed speed again. For this material is not recommended to cut during low laser power (50 % and 75 %). After application these parameters, the cuts had deteriorated quality of surface. Samples, which were cut by high feed speed and low power, they sintered again.

The material no. 3 (PP – C natur) showed the worst machinability by CO_2 laser. During laser cutting material sintered, it was necessary to cut through sample multiple times. For conditions feed speed 1 $mm \cdot s^{-1}$ and power 100 % we cut sample at once, but quality of final surface wasn’t satisfactory and it was seen traces of beam. For this material is applied high feed speed and maximum laser power, which ensures low values of surface roughness.

Generally, we can say that for these materials we can choose low feed speed and maximum or as the case may be 75 % laser power. Material is possible to cut through at once and samples won’t sinter. The above mentioned ratio reduces life of the machine and with their using we can achieve sufficient surface quality.

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