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INFLUENCE OF CUTTING PARAMETERS ON HEAT AFFECTED ZONE AFTER LASER CUTTING

VLIV ŘEZNÝCH PARAMETRŮ NA VELIKOST TEPELNĚ OVLIVNĚNÉ OBLASTI PO LASEROVÉM ŘEZÁNÍ

Abstract

The contribution deals with method about the thermal cutting of materials specifically with the laser technology. In the theoretical part is described its principle, capabilities and use of the laser in the process of machining mainly procedure of cutting the material using a laser bunch. The experimental part is focused on cutting the cobalt alloy by continuous laser CO_2 and the influence of technological parameters during the cutting on final quality of the cutting area. Based on metallographic analysis was determinate suitable technological parameters, have been achieved the lowest heat influence material.

Abstrakt

Příspěvek se zabývá metodou tepelného dělení materiálu, konkrétně laserovou technologií. V teoretické části je popsán její princip, funkce, možnosti a využití laseru při obrábění, především postup řezání materiálu pomocí laserového svazku. Experimentální část je zaměřena na řezání kobaltové slitiny kontinuálním CO_2 laserem a vliv technologických parametrů při řezání na výslednou kvalitu řezné plochy. Na základě metalografické analýzy byly stanoveny vhodné technologické parametry, při kterých bylo dosaženo nejmenší tepelné ovlivnění materiálu.

1 INTRODUCTION

Although the development of laser from historical viewpoint was starting very slowly, today we are accompanied directly or indirectly with lasers at every steps. In 1917 Albert Einstein began by describing of theoretical foundations of simulated emission of radiation. He pointed out the possible existence of spontaneous but also stimulated emission. Until the mid 20th century managed to construct facilities that generate and amplify electromagnetic radiation on the principle of stimulated emission of radiation, marked with Maser. About 10 years later, Theodore H. Maiman in the U.S. formed the first working LASER (Light Amplification by Stimulated Emission of Radiation). Since then, development of laser has come a long way (changes, progress) and the laser is started (technology generation and amplification of electromagnetic radiation started) to penetrate into various areas of science and human activities. [1]

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2 LASER PRINCIPLE

The quality of a surface needs to be understood as an integral characteristic of a machine part. A laser is a device that emits light through a process of optical amplification based on the stimulated emission of photons. During stimulated emission, a photon meets an excited atom or molecule and stimulates the electron to pass into the low energy level. Here, it transmits another photon. However, the prerequisite is that the incoming photon should have the energy required for this process. It is said to have the required energy when this energy corresponds to the difference in energy between the excited level and the lower level. [7]

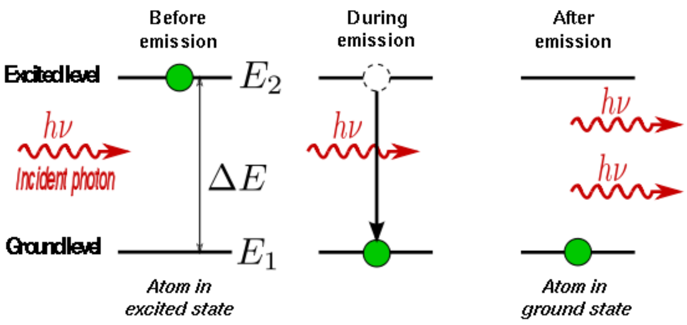

Fig. 1 Stimulated emission [6].

After the stimulated emission, the new photon has exactly the same frequency and the same phase position as the first photon and moves in the same direction. The light beam has increased. Where there was only one photon previously, two of the same kind, are on route now. If these photons meet the excited atoms again, they generate more photons and the light beam increases further. [7]

Bunch of laser beams is the source with high density of energy, the radiation comes from a laser in the form of little spread, monochromatic (single wavelength) beam and coherent electromagnetic waves in a wide range of wavelengths from the ultraviolet through visible light, infrared region further to the border of millimeter waves. [4]

3 LASER CUTTING TECHNOLOGY

Placing the laser beam during machining is one of the most progressive methods, which be replaced slowly by conventional machining technology. Nowadays is laser technology thanks for its massive expansion most widely used laser in industrial production. Technological use of laser presents mainly machining and processing of materials, based on the ability to use powerful lasers concentrate optical energy radiation in space, in time and spectral interval and 16in which no material removal due to the use of mechanical work, but uses physical, chemical processes or their combination. As a result, generated only minimal deformation in the actual process of division, even after its termination. [2], [3]

The cutting process is based on the interaction of laser beam cutting gas and cut material. Make use of a high concentration of the energy produced by laser radiation, that allows to share all technical materials, regardless of their thermal, physical and chemical properties of high-speed which ensures high productivity. It is especially useful for materials with low thermal conductivity. The effort is to evaporate the material as quickly as possible while maintaining a minimum the area affected by thermal effects. This results in high quality cutting edge. Cutting with laser has a wide range of uses for small-lot production as well as for large-scale production in batches. Laser cutting technology offers a major advantage in speed, quality, accuracy burnouts and achieving low manufacturing costs and minimizes the amount of waste, which is associated with the best possible use of the materials and energy. [2], [3]

4 EXPERIMENT

Ever increasing demands for quality, durability and accuracy in the production of metal parts for aircraft and cremation turbine engines require new application materials. These are mainly products of stainless steel and special alloys (aluminum, nickel, cobalt and titanium). These new materials used have high requirements for processing. Such material is Haynes 188 alloy used for our experiment.

With the entering of laser technology came the possibility of thermal cutting of virtually any type of material, including electrically non-conductive material and with extremely high affinity to oxygen or nitrogen. Laser as an advanced technology enables the processing of difficult weldable materials, hard to machine materials, high strength materials or high-heat resistant, because in this case don´t play the role mechanical properties of material, strength, hardness and toughness.

4.1 Haynes 188 alloy

Haynes 188 alloy is a cobalt-nickel-chromium-tungsten alloy that combines excellent high temperature strength with very good resistance to oxidizing environments up to 1095°C for prolonged exposures, and excellent resistance to sulfate deposit hot corrosion. It is readily fabricated and formed by conventional techniques, and has been used for cast components. Haynes 188 alloy has good forming and welding characteristics, but for its strength, low thermal conductivity not easily machining this alloy. [8]

Tab. 1 Physics and mechanical properties [8].

Density [$g.cm^{-3}$]	Melting range [°C]	Modulus [GPa]	Tensile strength Rm [MPa]	Yield strength Re [MPa]	Elongation [%]
8,98	1315-1410	232	945	465	53

Tab. 2 Chemical composition [8].

Co [%]	Ni [%]	Cr [%]	W [%]	Fe [%]	Mn [%]	Si [%]	C [%]	La [%]	B [%]
39*	22	22	14	3*	1.25	0.35	0.1	0.03	0.015*

* - max

4.2 Laser system

Cutting samples was carried out on a laser machine tool Delta Winbro. Delta can be configured with up to four different types of laser sources to meet the requirements of specific applications of laser technology (cutting, drilling, welding). For our purpose was used a source Rofin DC 020, which consists of Winbro Delta gas CO_2 laser operating in continuous mode. 5-axis machines Winbro Delta system enables production of complicated parts with an accuracy of 0.015 mm and repeatability 0.010 mm. [5]

Fig. 2 Laser system [5].

4.3 Laser cutting of samples

Samples were cut from the sheet with a thickness of 1,27 mm from the above-mentioned alloy. The cutting process was affected by changing certain parameters of the laser power. It was the cutting parameters, namely the size of the output laser power and feed rate, which gradually changed during cutting as necessary and achieved cut quality. Other parameters that also affect the quality of the cut were constant.

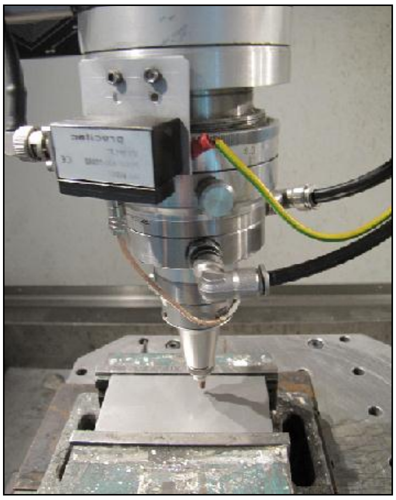

Fig. 3 Laser cutting.

The values of output speed and cutting feed samples were selected for full capacity utilization range of the laser. Gradually, the output power was increased and changed as needed speed cutting machines. Due to the increasing cutting speeds during the experiment at the bottom of the specimens began to appear more and more tricked slag as a burr. On the contrary, at high output power and low feed rate cut occurred at the cutting edge to the emergence of highly heat-affected area, which had an impact on its final quality. As for us wasn´t the size and amount of slag tricked evaluation parameter, we chose with increasing output power is always higher feed rate. In this way, it was gradually created 34 samples.

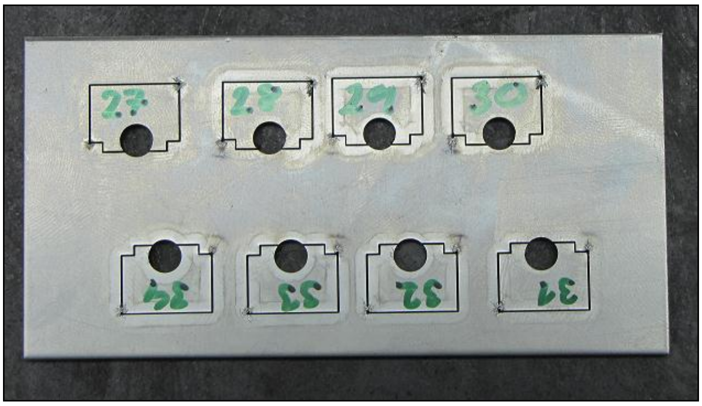

Fig. 4 Cut samples.

5 MEASUREMENT AND EVALUATION

For a measurement and evaluation of the width of the heat-affected area of the samples was necessary to metallographic analysis. Samples were embedded into tablets, grinded, polished and etched to selected etching agent. After reaching the specular gloss and visibility of individual structural components were observed individual surfaces a light microscope. The purpose was to determine the macroscopic nature of the cut surface, and this tour several times (20x) enlarged sample.

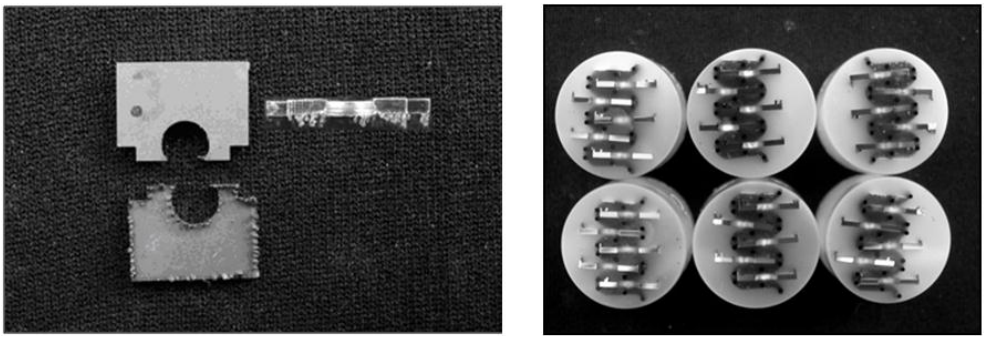

Fig. 5 Samples.

The essence of the evaluation was to find suitable performance parameters during laser machining alloy HS 188. The aim was to achieve the best possible cutting surfaces with different combination of values of output power and feed rate with respect to the full potential of the laser. Due to the large number of samples and cut the amount of processed data in the evaluation were based on visual inspection of quality of cut selected samples that present working range of laser parameters, see table.

Tab. 3 Cutting parameters for sample No. 1.

Performance parameters of the machine		Process parameters of the machine	
Output power [W]	600	Jet distance [mm]	0.9
Feed rate [mm.min^{-1}]	700	Pressure of assistance gas [MPa]	1.2
Excitaction frequency sources [Hz]	5000	Focus position [mm]	1.9

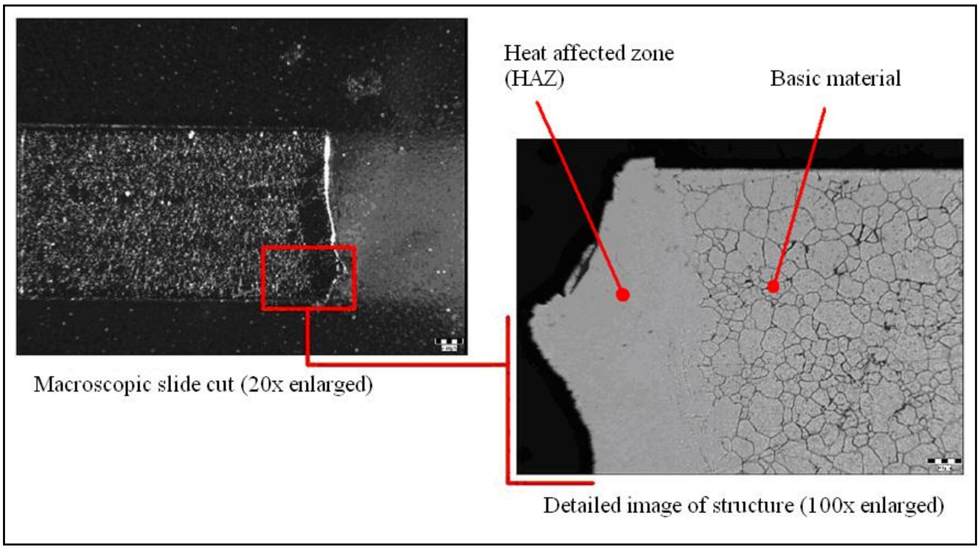

Fig. 6 Sample No. 1.

Tab. 4 Cutting parameters for sample No. 2.

Performance parameters of the machine		Process parameters of the machine	
Output power [W]	800	Jet distance [mm]	0.9
Feed rate [mm.min^{-1}]	3000	Pressure of assistance gas [MPa]	1.2
Excitaction frequency sources [Hz]	5000	Focus position[mm]	1.9

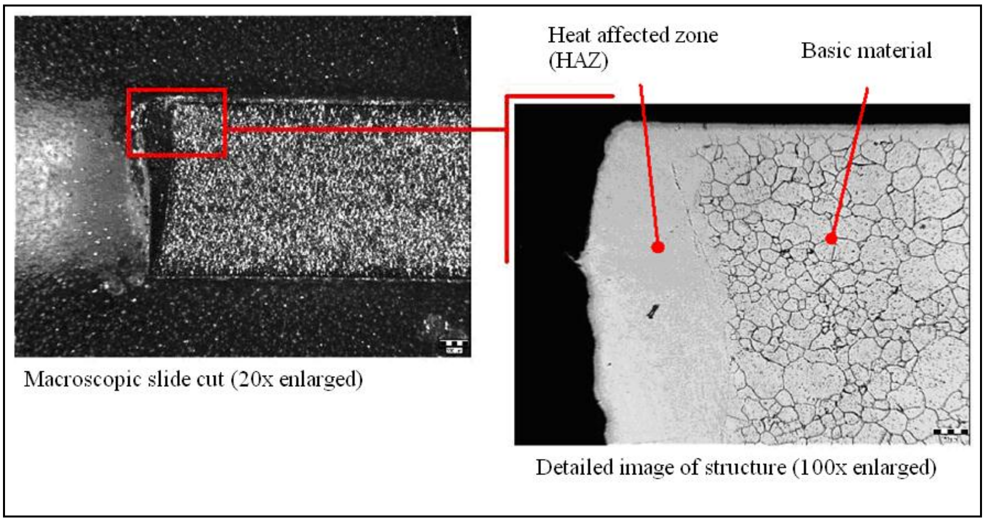

Fig. 7 Sample No. 2.

Tab. 5 Cutting parameters for sample No. 3.

Performance parameters of the machine		**Process parameters of the machine**	
Output power [W]	1800	Jet distance [mm]	0.9
Feed rate [mm.min^{-1}]	1000	Pressure of assistance gas [MPa]	1.2
Excitaction frequency sources [Hz]	5000	Focus position[mm]	1.9

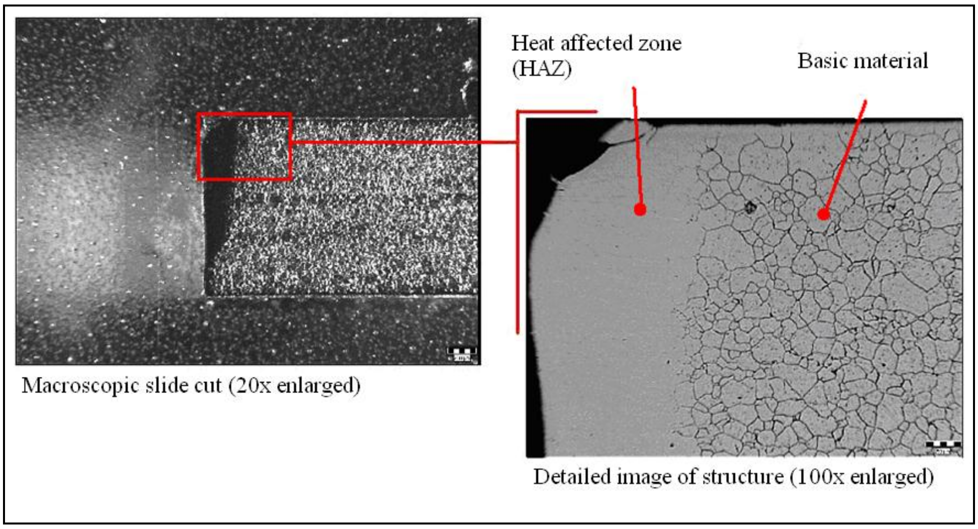

Fig. 8 Sample No. 3.

Tab. 6 Cutting parameters for sample No. 4.

Performance parameters of the machine		**Process parameters of the machine**	
Output power [W]	1800	Jet distance [mm]	0.9
Feed rate [mm.min^{-1}]	3000	Pressure of assistance gas [MPa]	1.2
Excitaction frequency sources [Hz]	5000	Focus position[mm]	1.9

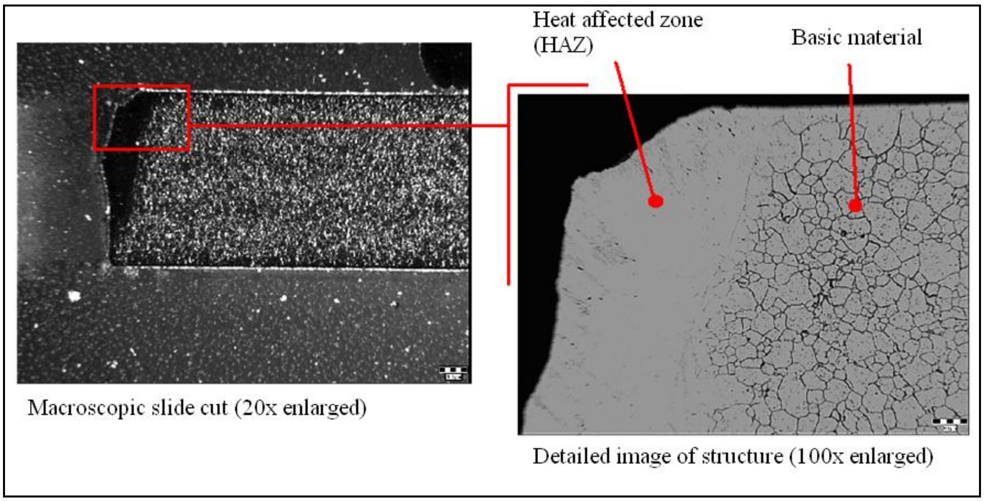

Fig. 9 Sample No. 4.

Tab. 7 Cutting parameters for sample No. 5.

Performance parameters of the machine		Process parameters of the machine	
Output power [W]	1800	Jet distance [mm]	0.9
Feed rate [mm.min^{-1}]	5000	Pressure of assistance gas [MPa]	1.2
Excitaction frequency sources [Hz]	5000	Focus position[mm]	1.9

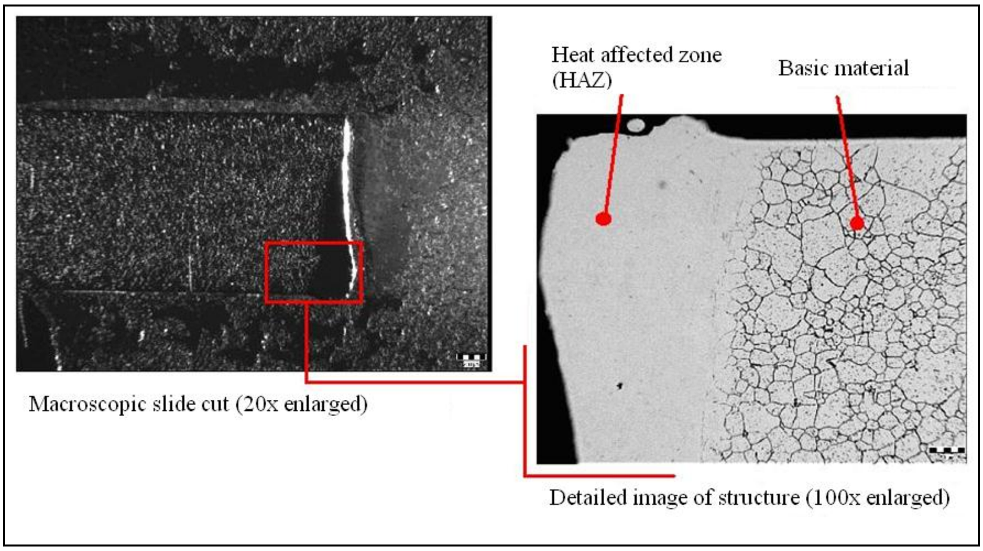

Fig. 10 Sample No. 5.

The images obtained in the field of laser cutting visible heat affected zone (hereinafter HAZ). HAZ ranges of wide, according to the theoretical assumption depend on the parameters of cutting tools, especially on the speed of the laser beam displacement. Therefore, the width HAZ studied depending on the quantity. HAZ was created by short but very intense action of the thermal energy of the laser beam. In some ways HAZ marked change in structure and material properties, which is undesirable. There may be accompanied by an increase in turbidity of the hardness and brittleness, cracking. In choosing the appropriate parameters When selecting the appropriate size parameters can be remelted layer and to some extent HAZ influence, but completely prevent their occurrence can´t. Increasing feed rate cutting should ensure that the basic material in the cut is not enough warm up. Thus, the total amount of heat input into the cutting area will be smaller and thus less HAZ. Since the width is HAZ irregular cuts for all individual samples were collected at the place where the greatest heat affected material. Larger values were always achieved in the upper section, which was subsequently measured by its width, see figure 11.

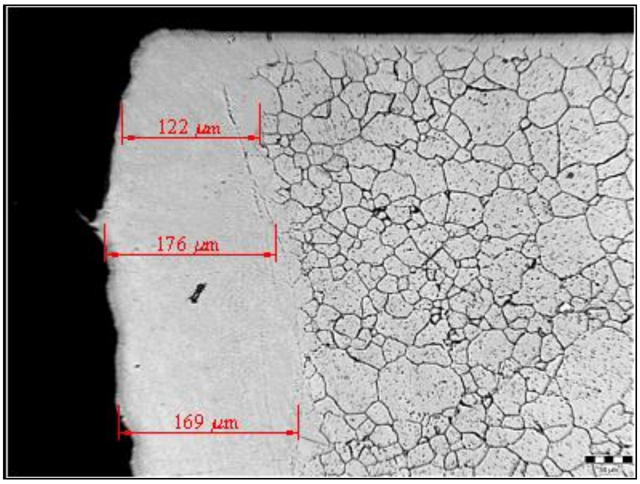

Fig. 11 Width of the HAZ of sample No. 2.

The measured values of the width HAZ samples ranged from 122 to 293 micron. The smallest width HAZ, where the maximum width value does not exceed 176 m, was achieved in sample No. 2, the cut was made output power of 800 W and a feed rate of 3000 mm.min^{-1}. In contrast, the largest thermal influence of the material occurred in the sample No. 5, where the output power was 1800 W and 5000 mm.min^{-1} speed. Although the evaluation was used in only five samples, the course of the experiment showed an indirect dependence on the velocity widths HAZ feed. We can say that when using a continuous CO_2 laser is a measure of the thermal influence of the material depends not only on the feed rate, but more factors.

6 CONCLUSIONS

The work was focused on the use of laser technology in machining, the use of which is the world's long-term increases and improves. This is due to increasing demands for quality, durability and precision production, which requires a new application of machined materials. For these so-called special alloys, a significant decrease in their machinability, because in many cases be replaced by non-conventional machining technology conventional. Laser technology is currently one of the most progressive technologies and engineering for the last time experiencing an incredible boom.

The contribution doesn´t deal only with known facts, but also trying to determine the possible influence of processing parameters, especially the output power and feed rate on the quality of cutting surface. In the course of the experiment was observed width of the thermal influence of the material, where no evidence of direct dependence on feed rate. The evaluation follows, therefore, that when properly selected combination of performance parameters of the laser can achieve very good results as the quality of the cut surface, the size of the heat affected zone.

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