# EXPERIMENTAL DETERMINATION OF CUTTING SPEED INFLUENCE ON CUTTING SURFACE CHARACTER IN MATERIAL LASER CUTTING

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In industrial practice the material laser cutting is extensively used for rather accurate and high-quality cutting of both metal and non-metal materials. The objective of the submitted paper is to point out direct relation between influence of cutting speed and surface character of material cut by laser. Cutting speed ranks among the most significant technological parameters in laser cutting and represents important parameter for the productivity of production process. The results of experimental measurements can be applied in practice.

**KEYWORDS**

*laser, surface roughness, sheetmetal, cutting speed*

## 1 INTRODUCTION

Laser cutting represents the technology which is employed in case of laser machinable material and usually in production sector and shall be applied by schools. At the same time it has gained popularity in small businesses. Material laser beam cutting is highly efficient method controlled by a computer [Murcinkova 2013]. Consequently, the material melts, burns, vapours or is dragged by gas flow leaving high-quality machined surface [Gaspar 2013, Halko 2013]. The industrial laser cutters are used for machining of material flat surfaces as well as of pipeline structures [Novakova 2008, Mascenik 2014a].

***Advantages of laser cutting in practice can be summed up as follows:***

- suitable for cutting of material with thickness of up to 10 mm, max. 15 mm,
- particularly suitable for cutting of soft steel and steel alloys, aluminium and aluminium alloys,
- high cutting speed, possibility of mechanization and propagation of technological process,
- high-quality cutting of cutting surfaces (smooth, homogenous surface),
- high geometrical and shaping accuracy of cutting materials,
- minimal heat effect upon cutting material (HAZ) is expressed only in hundredths or tenths of millimetres,
- laser can be applied in case of highly efficient equipment and repeated mass production with guaranteed technical parameters of the process and products resulting from the cutting process,
- less energy-intensive per production unit contrary to comparable thermal technological production processes,
- work with laser device is rather sophisticated and disposes of high added value.

***Disadvantages of laser cutting in practice can be characterized as follows:***

- high initial costs related to provision of technical equipment,
- high initial costs related to installation of technology into production equipment,
- demand of constant gas acquisition out of the laser device,
- radiation emissions of the laser beam,
- demand of continual supply of technical fluids and gases,
- working place requiring extreme maintenance,
- higher requirements for level of education of staff working at laser working place,
- demand of minimally two shift operation with high level of time fund at working place due to economic cost of laser technology.

Suitability of application of the selected technological cutting of material according to material thickness and requirement regarding the accuracy of produced parts is shown in the figures [Litecka 2010, Mascenik 2014b].

**Types of Lasers**

According to the type of applied active medium the following types of laser can be distinguished: solid-state, liquid, gas, plasma and semiconductor. For instance, industry applies a ruby laser, YAG (yttrium-aluminium-garnet) or so-called filamentary laser in case of which active medium is composed of optical fibre. Concerning the gas lasers mainly $CO_2$ is used. Moreover, semiconductor lasers (known as the diode ones) are also widespread. According to time regime the lasers are classified into two categories – the continuous and the impulse ones, which emit radiation in gleams lasting for just a one-hundred-millionth of a second. In direction from the source towards working head the beam is usually emitted by optical fibres [Novakova 2008, Mascenik 2014a].

**Application of Lasers**

In industry, the laser function is to create the beam of radiation and to emit the beam to the desired spot in which the processed material can be thus heated. The material melts, vapours or burns or gets dragged by the gas flow [Mascenik 2012].

The cutting surface is of a high quality. Laser is suitable for cutting the materials with thickness of up to 10 – 15 mm, which is the case of soft steel, steel alloys, aluminium and aluminium alloys. The cutting process is highly efficient and accurate and controlled by a computer. Owing to negligible diameter of a beam the heat-affected zone is minimal as well. In comparison with other cutting technologies the economic and operational intensity is higher [Bicejova 2013a,b, Mascenik 2011].

## 2 EXPERIMENTAL PART

### 2.1 Applied Devices

The experimental part of the paper deals with detection of surface roughness of materials with diverse thickness in case of laser cutting. The samples were cut by Laser Durma HD F 3015 (Fig. 1). The laser devices by the company of Laser Durma are classified into two categories marked as the HD and HD- F series. The HD series of $CO_2$ laser machines allow high quality cutting of both thin and strong materials [Bicejova 2016a,b]. It offers maximal performance with minimal operational expenses.

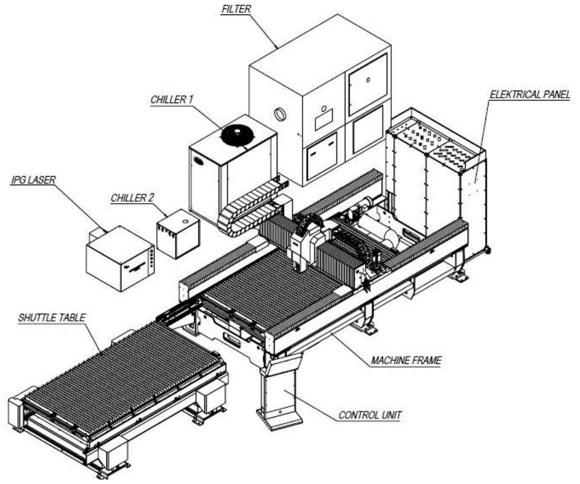


**Figure 1.** Laser DURMA HD – F 3015

In case of laser cutting speed change the surface roughness was detected by contact profilometer Surftest SJ400 (Fig.2) by the company of Mitutoyo.

**Figure 2.** Profilometer MitutoyoSurfest SJ400

The device is characterized by the parameters shown in tab. 1.

**Table 1.** Parameters of profilometer MitutoyoSurfest SJ400

| | |
|---|---|
| measurement speed | 0.05; 0.1; 0.5; 1.0 mm/s |
| return speed | 0.5; 1.0; 2.0 mm/s |
| measurement direction | backwards |
| positioning | ± 1.5° (angle bevel), 10 mm (upwards/downwards) |
| range/resolution of measurement | 800/0.01 µm; 80/0.001 µm up to 2400 µm |
| measurement method | s/without footing |
| radius of footing curvature | 40 mm |
| type of connection | net adapter |
| data output | interface RS-232C/SPC |
| assessed parameters | P (primary), R (roughness), W (filtered waviness), digital filter 2CR, PC75, Gauss |

**Accessories of device MitutoyoSurftest SJ400 designed for roughness measurement:**

- digital measuring apparatus with LCD touching screen,
- sliding unit holder for measuring stand,
- sliding measuring unit,
- special jig for a measured unit fastening.

### *2.2 Preparation of Experimental Samples*

The applied material is steel 11 375 according to STN standard marked also as S235JRG2 according to EN 10025/90+A1/93standard (Fig. 3). Thickness of steel is of 3 mm, 4 mm, 6 mm, 8 mm and 10 mm. Laser performance was changed with the individual values of thickness.

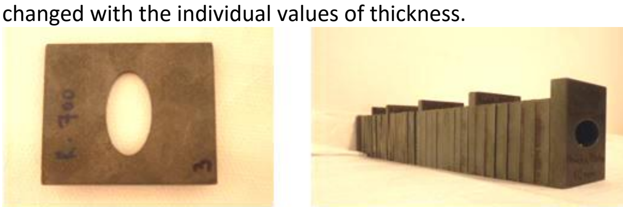

**Figure 3.** Experimental samples

### *2.3 Roughness Measurement Procedure*

Prior to measurement the samples were thoroughly cleaned. Impurities were removed with the application of technical benzine. The samples were arranged according to machining order of the measured surfaces. After switching the measuring device on, the measuring sample was fastened with a special jig. The device contains a tiny body fixed on the top of a holder of a sliding unit for the measuring stand [Puskar 2012, Puskar 2013]. In clockwise rotation the measuring unit slid downwards. In anticlockwise rotation the measuring unit slid upwards. The rotation continued until the stylus of the measuring unit leant against the measuring unit.

**Table 2.** Cutting parameters related to sheetmetal with thickness of 3 mm with cutting speed change

| Cutting pressure (mm/min) | 700 | 1200 | 1700 | 2200 | 2700 | 3200 | 3700 | 4200 |
|---|---|---|---|---|---|---|---|---|
| Gas pressure (bar) | 0,7 | 0,7 | 0,7 | 0,7 | 0,7 | 0,7 | 0,7 | 0,7 |
| Laser performance (W) | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| Distance of a nozzle (mm) | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 |
| Frequency (Hz) | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 |
| Cutting width (mm) | 0,28 | 0,28 | 0,28 | 0,28 | 0,28 | 0,28 | 0,28 | 0,28 |
| Gas type | $O_2$ | $O_2$ | $O_2$ | $O_2$ | $O_2$ | $O_2$ | $O_2$ | $O_2$ |
| Load (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Acceleration (%) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |

To assure correct measurement the LCD display showed the most suitable approximation of the stylus. When the position had been reached, the measurement was triggered using the START button. The stylus of the measuring unit slid along the measured sample. The measured values Ra and Rz were read directly from the LCD display and consequently recorded. The measurement was discontinued by pressing the STOP button. Consequently, the sample was removed from the measuring device. The anticlockwise rotation of a tiny body on the holder of the sliding unit caused upward sliding of the stylus of the measuring unit. Afterwards the sample was removed from the jig in which it was fastened. The measurement procedure remained unchanged for all samples.
Part of the measuring device SURFTEST 400 Fig.2 is a printer of the measured values. Pressing the PRINT button the individual values were printed which were applied in further analysis. Drawback of the device rests in a limited memory – 5 samples

only. As the number of samples exceeded 5, the values were recorded into the table in fives to prevent interruption of the measurement and to assure printing of the values which can be recorded as well. The interruption would considerably prolong the measuring period

### 2.4 Processing of the Measured Values

Laser parameters in production of the samples during cutting speed change are shown in tab.2. With cutting material thickness of 4, 6, 8, and 10mm the monitored speed during laser cutting of the material is plotted into the graph only. Other technological parameters of the device remain constant.

### 2.5 Assessment of the Measured Values

Following table 3 shows the measured surface roughness for the cutting material thickness of 3 mm and other measured roughness values with thickness of 4, 6, 8 and 10 mm are plotted into the graph only.

**Table 3.** Measured roughness of the cutting surface during cutting speed change with material thickness of 3 mm

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Roughness Ra (μm) | 14,5 | 11,46 | 5,22 | 1,1 | 0,39 | 0,26 | 2,93 | 11,13 |
| Roughness Rz (μm) | 50,9 | 38 | 22,3 | 5,1 | 2,2 | 1,5 | 14,3 | 42,3 |

The following figures 4-8 show graphical relations between the influence of laser cutting speed change and surface character, which are defined by values Ra and Rz with Ra referring to a mean arithmetical deviation of the profile[μm] and with Rz referring to the peak unevenness value [μm] [Krenicky 2011, Krenicky 2015].

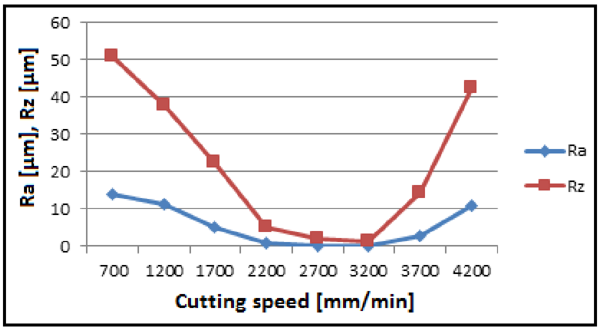


**Figure 4.** Graphical plotting of sheetmetal surface roughness with thickness of 3 mm during cutting speed

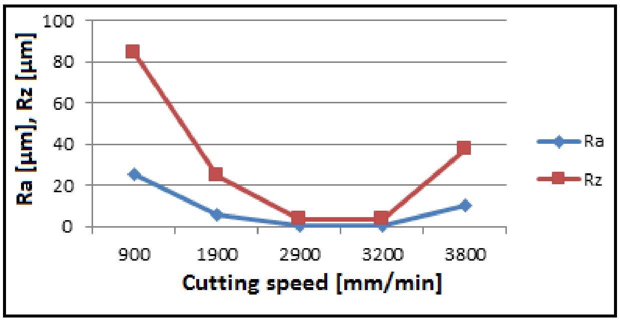


**Figure 5.** Graphical plotting of sheetmetal surface roughness with thickness of 4 mm during cutting speed

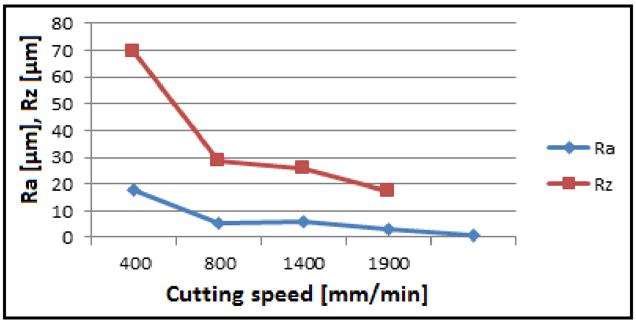


**Figure 6.** Graphical plotting of sheetmetal surface roughness with thickness of 6 mm during cutting speed

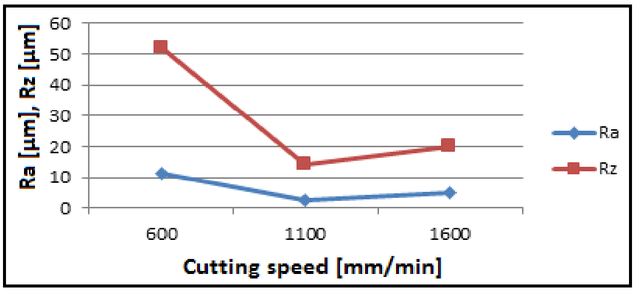


**Figure 7.** Graphical plotting of sheetmetal surface roughness with thickness of 8 mm during cutting speed

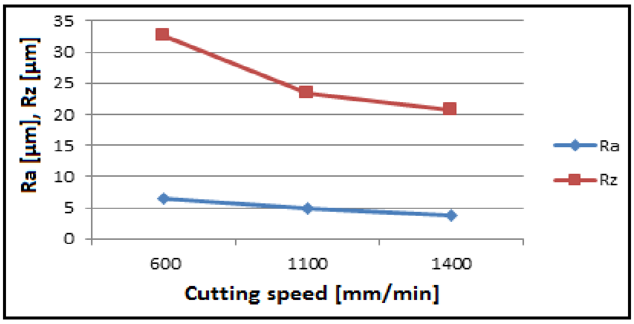


**Figure 8.** Graphical plotting of sheetmetal surface roughness with thickness of 10 mm during cutting speed

## 3 CONCLUSION

On the basis of experimental measurements it can be stated that with the cutting speed change the individual surface roughness values change as well. Graphical relations show the curves which indicate the individual surface roughness values during laser cutting speed change.

With sheetmetal thickness of 3 and 4 mm a parabola occurs and surface roughness character decreases from speed of 2000mm/min up to speed of 3200 mm/min. Consequently, the roughness character tends to increase and with sheetmetal thickness of 6 mm the parameters were changed within the range from 400 – 1900 mm/min. In this case the decrease occurs from value of approximately 1400 mm/min and continues up to the last selected value. With sheetmetal thickness of 8 and 10 mm the surface roughness increases from value of 1400 mm/min. The decrease can be observed from value of 1100 mm/min. It can be assumed that in the event of application of the identical cutting speed change the curves would appear to be developing in a like manner. The results of the experimental measurements can contribute to further applications of unconventional technology of material laser cutting in practice.

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