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DEVELOPMENT IN MACHINING TECHNOLOGY

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Edited by
Wojciech Żebala
Ildikó Maňková

Cracow University of Technology

This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.



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PREFACE

Machining is one of the most popular technique to change shape and dimensions of the objects. Machining operations can be applied to work metallic and non-metallic materials such as ceramics, composites, polymers, wood.

Cutting tools have been used since ancient times to remove excess material from forgings and castings. Nowadays, metal cutting became one of the primary manufacturing processes for finishing operations. In the last few years we have observed a rapid development in automation of manufacturing processes, especially in automatic control systems. Progress in cutting stimulates a significant increase in the metal removal rate and achieving high accuracy in terms of dimensions and shape of machine parts. New materials, which play the key role here, are used to produce cutting tools.

To meet today's high demands concerning accuracy and efficiency of the manufacturing process of machine parts, it is necessary to use computer methods for designing of technological processes.

This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.

Wojciech Zębala

PART 3

Non Traditional Machining

Chapter 3.3

LASER CUTTING OF COMPLEX PROFILE IN LOW CARBON AND STAINLESS STEEL PARTS

Zębala W., Matras A., Kowalczyk R.
Cracow University of Technology, Poland

Abstract: The chapter presents examples of laser cutting of complex profile in two kinds of steel (low carbon and stainless steel). The measurements results of the surface topography and deviations of measured contour from its theoretical shape were described. Additionally, the influence of the cutting speed on the angle between the formed and theoretical surfaces of the work piece was determined.

Keywords: *laser cutting, carbon steel, stainless steel, profile, surface roughness*

1. Introduction

In industry the laser technology is used for laser cutting, laser welding, laser marking in vehicle production, searching elements of marked and many different branches of industry [1, 2, 4].

Laser cutting is nowadays the most significant application of laser in materials processing in terms of market share. The low alloy steel, stainless steel and aluminium are commonly laser cut in industries such as car production and ship manufacturing. Economical criteria affecting the choice of a suitable laser system for a particular laser cutting application is now very important. High cutting speed is used for maximization of productivity, attainment of high cut quality so that rework of cut pieces can be eliminated, and cutting reproducibility. Increased process efficiency, quality, and flexibility help to reduce cost [1, 3, 5].

2. Structure of laser device

The following components form parts of a laser beam source, Fig. 1: laser-active medium, resonator, excitation and cooling. [4].

Laser-active media are materials that send out part of the emission energy in the form of laser radiation. When processing materials using laser radiation,

these media are predominantly carbon dioxide as part of CO₂ gas lasers and a fluorine/halogen or chlorine/halogen mixture in excimer gas lasers. In solid-state laser, the laser-active medium is a doped crystal such as an yttrium-aluminium-garnet (crystal) enriched with neodymium or, if applicable, with ytterbium in Nd:YAG and Yt:YAG lasers. Diode lasers consist of numerous lasers diodes that are excited by electrical energy in a semiconductor. The rather new fibre laser is another example of a solid-state laser. In this laser, an element from the “rare earths” group, e.g. ytterbium, is embedded in the centre of an optical fibre as a laser-active medium [4].

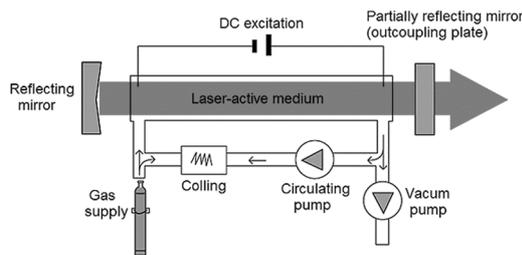


Fig. 1. Design of laser device [4]

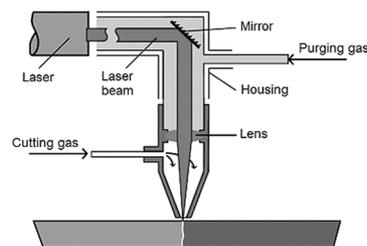


Fig. 2. Principle of laser cutting [4]

3. Principles of laser cutting

If a laser beam is used on a work piece, the material heats up so much that it melts or evaporates. The cutting process begins if it has penetrated the work piece completely. The laser beam moves along the part contour and melts the material continuously, Fig. 2. It is blown from the kerf with the help of a gas current. A narrow kerf between the part and the waste grid occurs. The cutting gas current exits the nozzle with the laser beam [6].

The laser beam must first penetrate the material at a certain point, before a contour can be cut. The piercing can be done quickly using complete laser power or slowly using a so-called power ramp. When creating a start hole in the ramp mode, the laser output is gradually increased, then it is held constant until the start hole has been formed and finally the output is again slowly reduced. The choice of piercing gas or cutting gas depends on which material is being machined and level of quality needed for the work piece. Usually either oxygen, nitrogen, argon or simply air is used as a cutting gas [6].

Pittings in stock and burrs formed on edge of new kerf belong to basic features of quality, treated as criteria of opinion of surface after laser cutting. Several different burrs can be formed:

- right from crumbly slag residue,

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- sharp metallic burr,
- firmly stuck to the lower side of the edge [6].

The quality of laser cutting can be defined as value of roughness or the perpendicularity between the formed surface and the upper cutting edge or the lower cutting edge. [6]

The cutting speed must be adapted to the type of material, the material thickness and the power of laser beam. An erroneous cutting speed can lead to roughness, burr formation or pits in the cut contour [6].

4. Experimental researches

Research of laser cutting was performed on the cutting laser device Trumpf (Fig. 3) of maximum power $P = 3200$ W. Laser parameters:

- work range: X-axis 3000mm, Y-axis 1500mm, Z-axis 115mm,
- max. material thickness with TruFlow 3200: mild steel 20mm, stainless steel 12mm, aluminium 8mm,
- max. axis speed simultaneous: 85m/mm,
- dimensions: length 9300mm, width 4600mm, height 2000mm,
- weight: 11500 kg [4, 7].

Work pieces in the form of special designed shapes (see Fig. 5) with thickness 6 mm were made of low carbon steel (steel of P265GH, 0.2%C, 0.8-1.4%Mn, 0.015%S, 0.012%N, 0.3%Cu, 0.02%Nb, 0.03%Ti, 0.04%Si, 0.025%P, 0.02%Al, 0.3%Cr, 0.08%Mo, 0.3%Ni, 0.02%Vi) and stainless steel (11%Cr, 11%Ni, 0.8%Si, 2%Mn). Stainless steel differs from carbon steel by the amount of chromium present, which prevents further surface corrosion and block corrosion from spreading into the metal's internal structure.



Fig. 3. Cutting laser device Trumpf TruLaser 3030 [4]

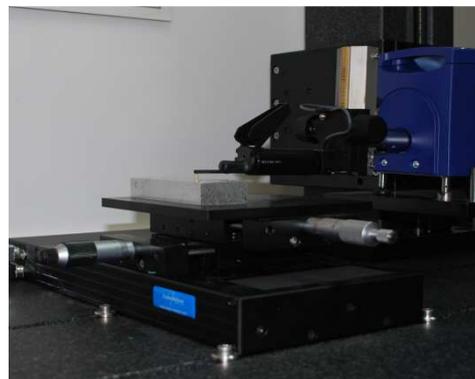


Fig. 4. Device for measurement of contour and surface topography

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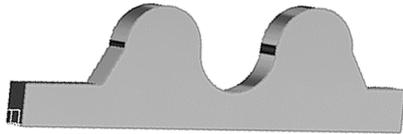


Fig. 5. Shape of the work piece designed in Catia software

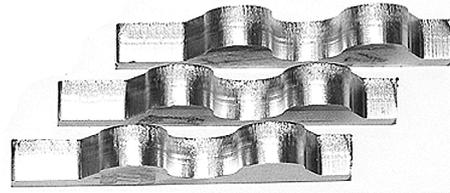


Fig. 6. Laser cutting work piece

Taylor-Hobson profilometer was applied for contour and roughness measurements and surface texture analysis 2D/3D (surface roughness, waviness and primary profile 2D/3D), Fig. 4. Laser cutting speed was changed during researches, Table1.

Table 1. Values of laser cutting speed v_f

No	Low carbon steel	Stainless steel
1	1800 mm/min	1020 mm/min
2	2400 mm/min	1360 mm/min
3	3000 mm/min	1700 mm/min
4	3300 mm/min	

The next part of the chapter (Fig.7-13) presents the results of work piece contour measurements for laser cutting speeds according to table1.

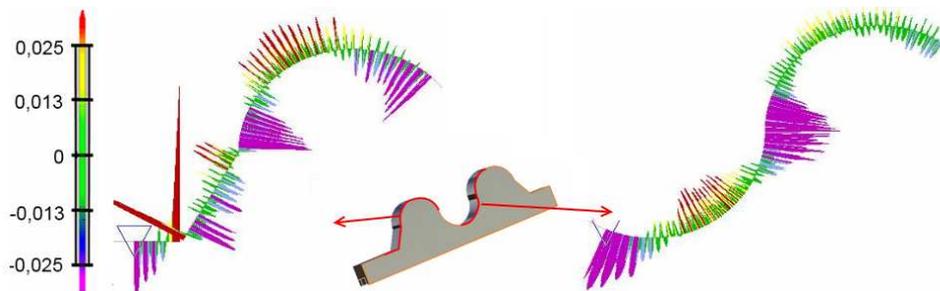


Fig. 7. Theoretical and real work piece profile comparison
- Low carbon steel, $v_f = 1800$ mm/min

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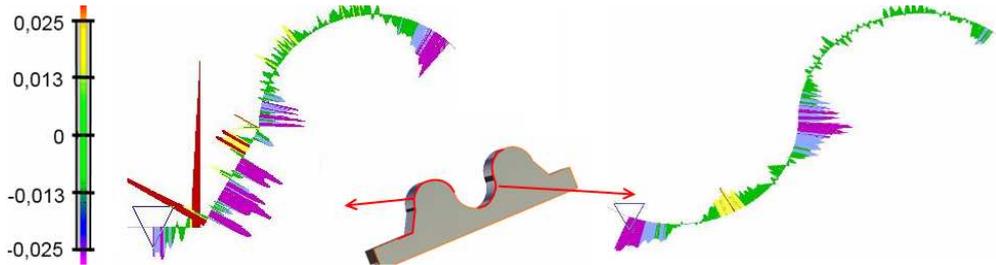


Fig. 8. Theoretical and real work piece profile comparison
- Low carbon steel, $v_f = 2400$ mm/min

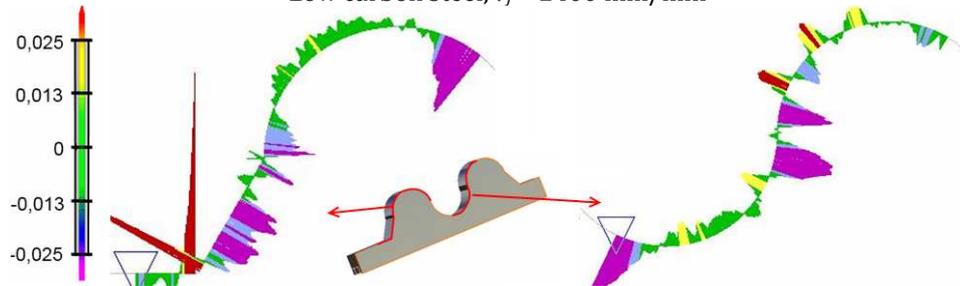


Fig. 9. Theoretical and real work piece profile comparison
- Low carbon steel, $v_f = 3000$ mm/min

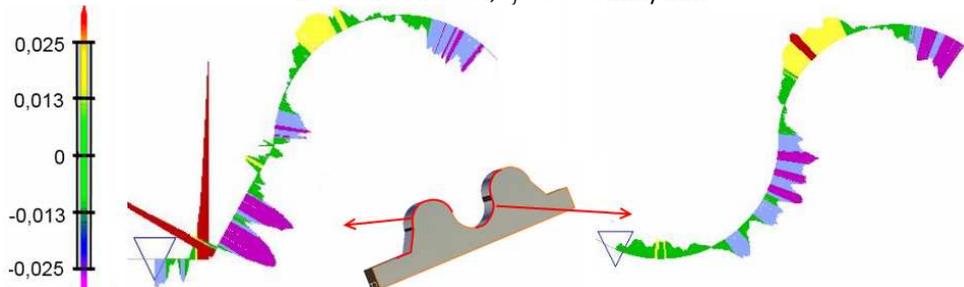


Fig. 10. Theoretical and real work piece profile comparison
- Low carbon steel, $v_f = 3300$ mm/min

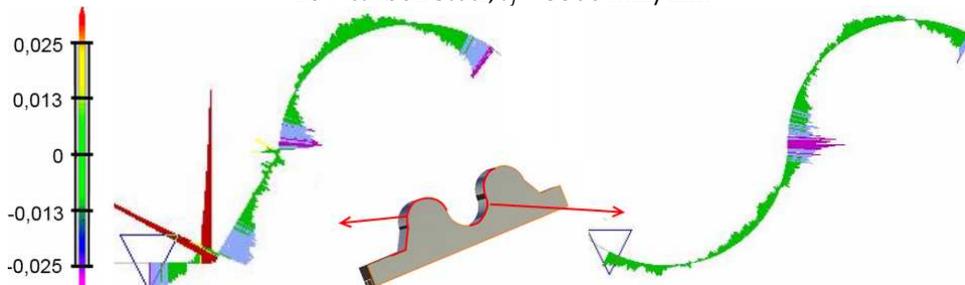


Fig. 11. Theoretical and real work piece profile comparison
- Stainless steel, $v_f = 1020$ mm/min

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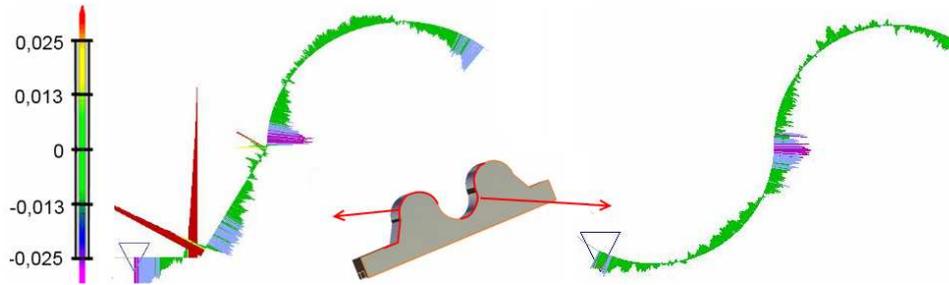


Fig. 12. Theoretical and real work piece profile comparison
- Stainless steel, $v_f = 1360$ mm/min

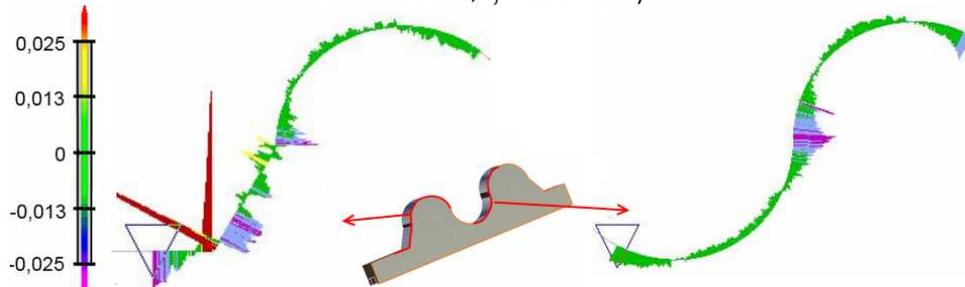
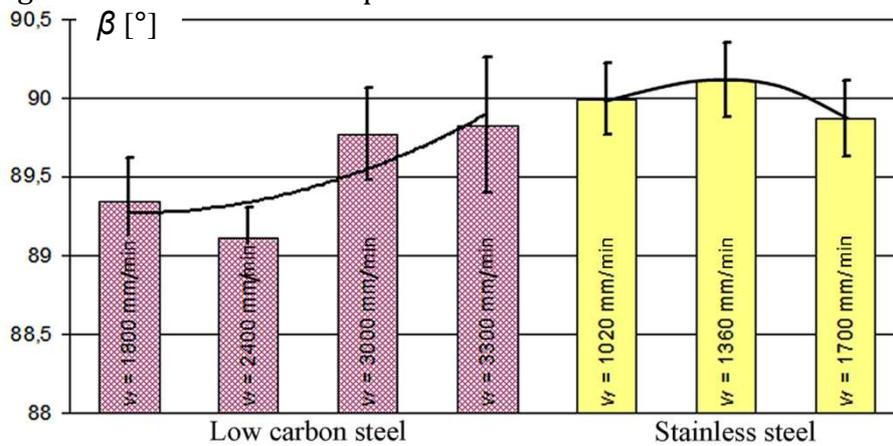


Fig. 13. Theoretical and real work piece profile comparison
- Stainless steel, $v_f = 1700$ mm/min

The influence of the laser cutting speed on the dimensionally accuracy of the cut profile was small. The Fig. 14 presents the influence of the cutting speed on the angle between the formed surface and the theoretical designed surface of the work piece.



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Fig. 14. The influence of the laser cutting speed on the angle between the formed and theoretical design surfaces of the work piece

Results of studies indicate the impact of cutting speed on the machined surface roughness. It was observed that the values of the selected surface roughness parameters decrease with increasing of the cutting speed. The values of selected surface roughness parameters for different cutting speeds are shown in Fig. 15.

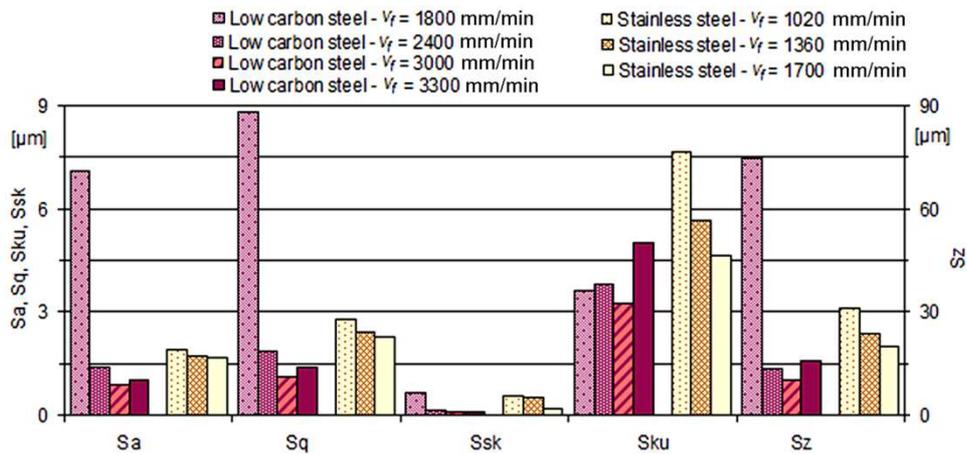


Fig. 15. The values of selected surface roughness parameters for different laser cutting speeds

5. Example of “Mechanical Faculty” logo, cut by laser beam

According to the previous research, described in section 4, an example of part in the form of “Mechanical Faculty” logo was created, Fig. 16. Stainless steel plate (5 mm thick) was machined with laser cutting speed $v_f = 1700$ mm/min. Right side of this figure presents the 3D surface topography image. Profiles measured in different places, according to Fig. 17 are shown in next Fig. 18-23.

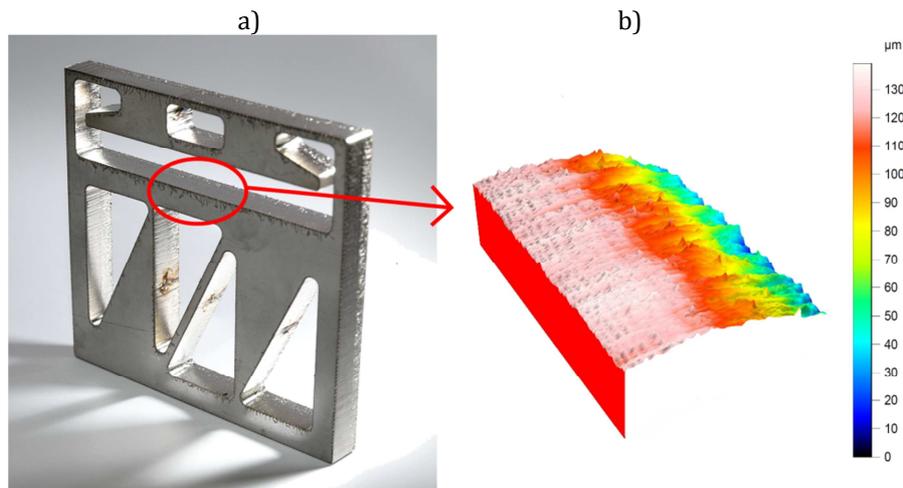


Fig. 16. "Mechanical Faculty" logo (a) and 3D surface topography image (b) of marked area

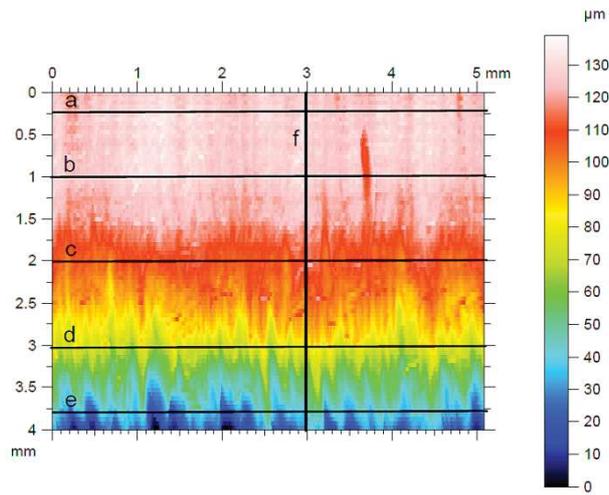


Fig. 17. 2D surface topography image of the area (4mmx4mm) marked in Fig. 16 with 6 lines (a,b,c,d,e,f) defining the measured profiles

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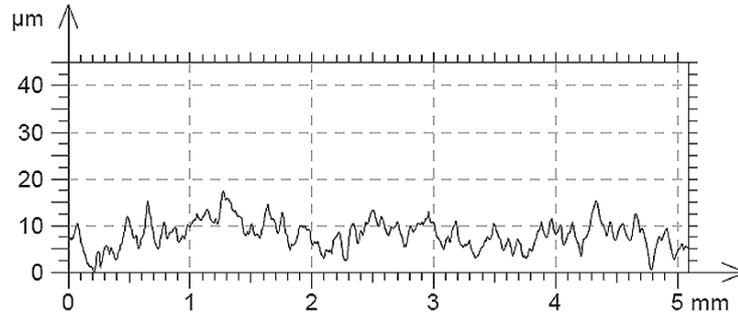


Fig. 18. Profile measured along the line **a**

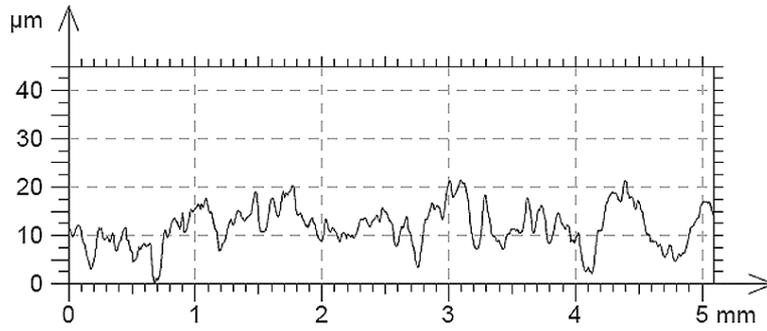


Fig. 19. Profile measured along the line **b**

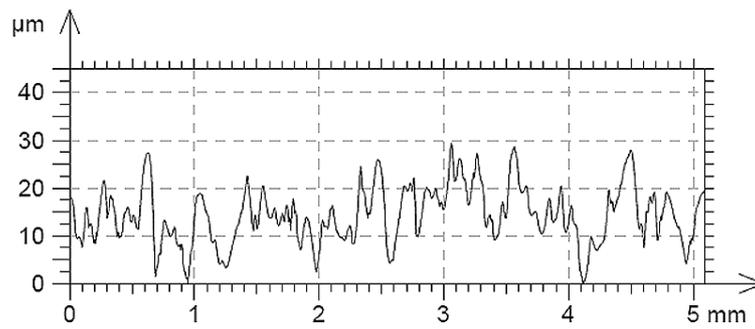


Fig. 20. Profile measured along the line **c**

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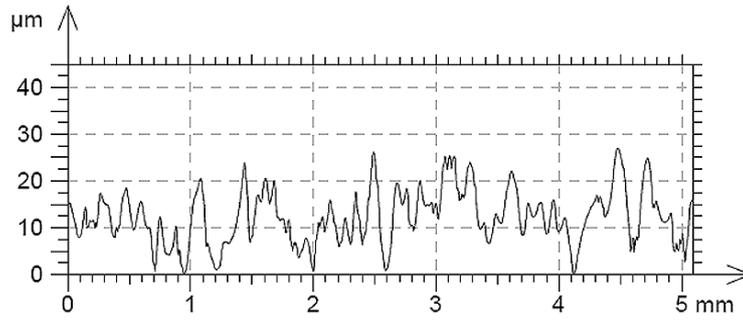


Fig. 21. Profile measured along the line **d**

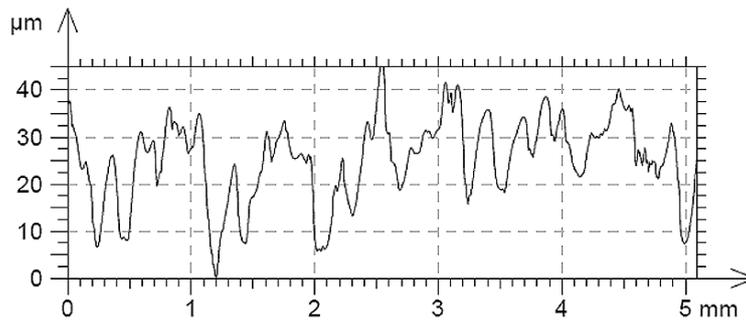


Fig. 22. Profile measured along the line **e**

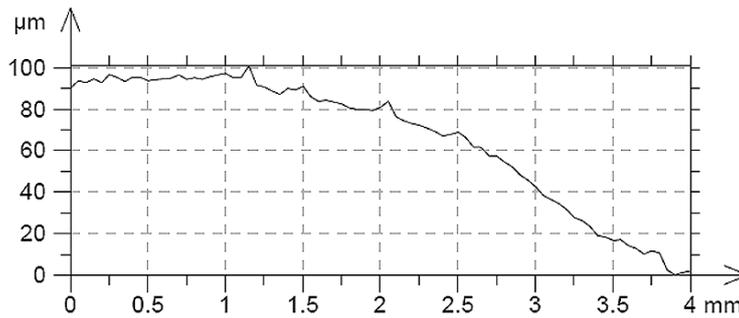


Fig. 23. Profile measured along the line **f**

6. Conclusion

Laser cutting as an effective technology for cutting of metal sheet is frequently used. During the tests, work piece profiles with high dimensionally repeatability were obtained. Shape deviations did not exceed the value of ± 0.03 mm for low carbon steel (Fig. 7-10) and ± 0.02 mm for stainless steel (Fig. 11-13). It was also observed, that the values of the selected surface roughness parameters decreases with increasing of the cutting speed. As the laser beam sinks into the steel material during machining its deviation occurs. It changes the dimension of the machined part of about 100 mm over a distance of 4 mm (Fig. 23). The machined surface maintains its linearity for a distance of about 1.2 mm.

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