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QUALITY ASPECTS OF STEEL PARTS AFTER LASER CUTTING

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Summary

The paper presents the problem of a complex shape laser cutting in the elements made of stainless and carbon steel. Brief characteristics of the laser device and experiment method are presented too. The results of measurements of the surface topography of workpieces after laser cutting are described. To estimate the quality of the surface after cutting, the selected parameters of the surface roughness were chosen. In addition, the paper presents the results of the measurements of deviations of the measured profile in the relation to the designed shape of the workpiece.

Keywords: laser cutting, quality, steel, surface topography, shape errors

Aspekty jakości stalowych części po wycinaniu laserowym

Streszczenie

W artykule przedstawiono zagadnienie wycinania laserowego otworów o złożonych kształtach w elementach wykonanych ze stali nierdzewnej i stali konstrukcyjnej (węglowej). Przedstawiono krótką charakterystykę urządzenia laserowego i sposobu przeprowadzenia doświadczeń. Wykonano pomiary topografii powierzchni próbek po obróbce laserowej. Do oceny jakości powierzchni obrobionych wytypowano wybrane parametry chropowatości powierzchni. Dodatkowo w pracy przedstawiono wyniki pomiarów odchyłek zmierzonego profilu w porównaniu z zaprojektowanym kształtem przedmiotu obrabianego.

Słowa kluczowe: wycinanie laserowe, jakość, stal, topografia powierzchni, błędy kształtu

1. Introduction

Laser technology such as laser cutting, laser welding, laser marking is using in many branches in industry [1-3]. 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 aluminum are commonly laser cut in industries such as car production and ship manufacturing. Cost reduction of laser cutting depends, among others on process efficiency and flexibility [1, 4-6].

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Economical criteria affecting the choice of a suitable laser system for a particular laser cutting application is very important. Manufactures using laser cutting are particularity interested in high cutting speeds for maximization of productivity. Figure 1 presents components (laser-active medium, resonator, excitation and cooling) which form parts of a laser beam source [3]. Laser-active media are materials that send out part of the emission energy in the form of laser radiation. The laser beam (which heats up the material) moves along the part contour and melts the material continuously (Fig. 2 [3]).

Burrs and pittings (e.g. sharp metallic burr, firmly stuck to the lower side of the edge) formed on the edge belong to the basic features of quality, treated as criteria of opinion of surface after laser cutting. The quality of laser cutting can be defined as value of roughness or the perpendicularity between the formed surface and the upper or lower cutting edge [2, 7, 8]. The wrong value of cutting speed, v_f can lead to the high surface roughness, burr formation or shape errors of the cut contour. The cutting speed mainly depends on the material type and its thickness (and also the laser power).

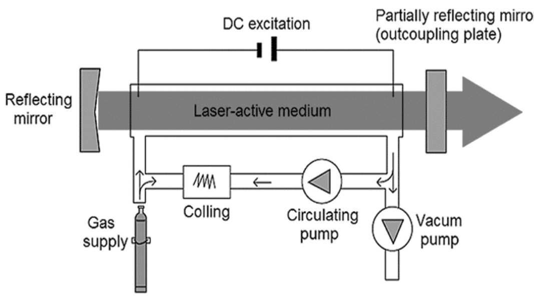


Fig. 1. Design of laser device

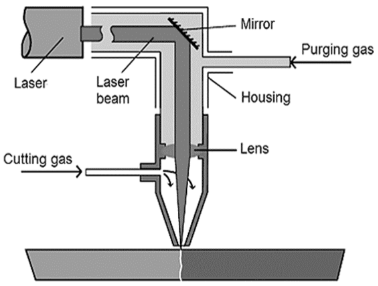


Fig. 2. Main principle of laser cutting

2. Experimental researches

Researches of laser cutting were performed on the cutting laser device [8] of maximum power P = 3200 W. Workpieces in the form of special designed shapes (Fig. 3) with thickness 6 mm were made of low carbon steel (0.2% C, 0.8-1.4% Mn, 0.015% S, 0.012% N, 0.3% Cu) 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. Workpieces after laser cutting are presented in Fig. 4.

Fig. 3. Shape of the workpiece designed in Catia software

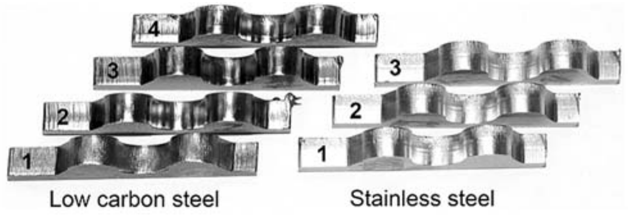


Fig. 4. Workpieces after laser cutting

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. 5b. Contour of machined workpieces were measured along the lines between the marked points (A – B and C – D) (Fig. 5a). Microscope pictures were made in the place marked by letter “E”. Laser cutting speed, v_f was changed during researches (Table 1).

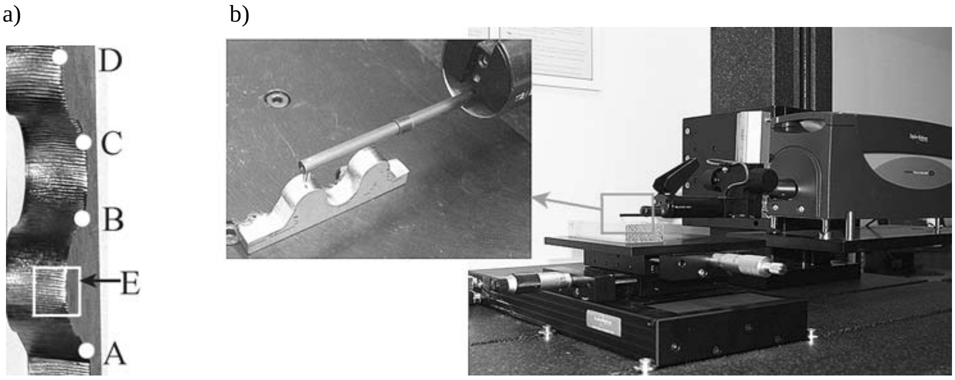


Fig. 5. Research setup of contour and surface topography measurements: a) view of machined workpiece with marked places of measurements, b) profilometer during measurements

Table 1. Values of laser cutting speed v_f

No	**Laser cutting speed, mm/min**	
	Low carbon steel	Stainless steel
1	1800	1020
2	2400	1360
3	3000	1700
4	3300	

The next parts of the paper (Fig. 6-12) presents the results of workpieces contour measurements. Diagrams in Fig. 6-9 present the deviation of measured contour from the theoretical (design) shape for low carbon steel workpieces and in Fig. 10-12 can be seen the deviations for the stainless steel workpieces.

Surface roughness images as a map of grey intensity are presented in Fig. 13-14 (for carbon steel) and Fig. 15-16 (stainless steel).

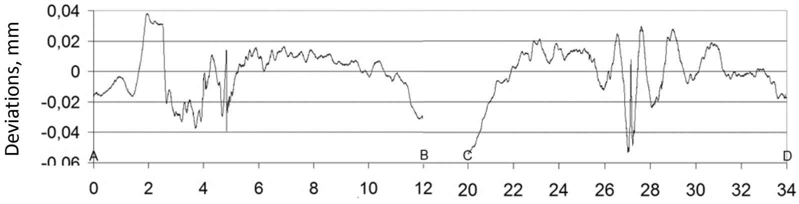


Fig. 6. Deviations of measured contour from the theoretical (design) shape.
Low carbon steel, v_f = 1800 mm/m

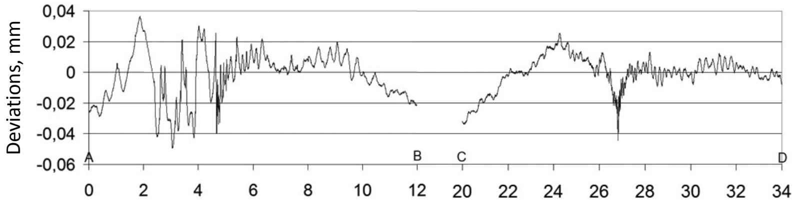


Fig. 7. Deviations of measured contour from the theoretical (design) shape.
Low carbon steel, v_f = 2400 mm/m

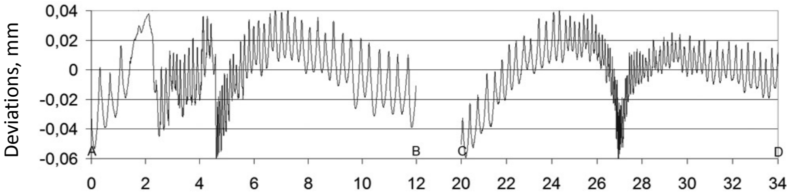


Fig. 8. Deviations of measured contour from the theoretical (design) shape.
Low carbon steel, v_f = 3000 mm/m

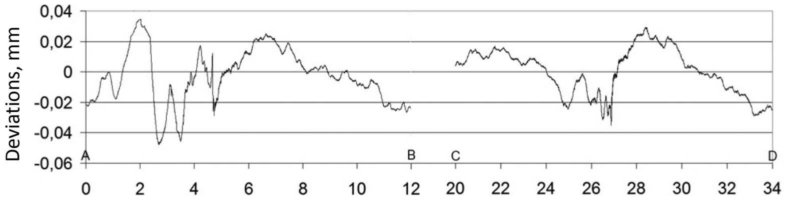


Fig. 9. Deviations of measured contour from the theoretical (design) shape.
Low carbon steel, v_f = 3300 mm/m

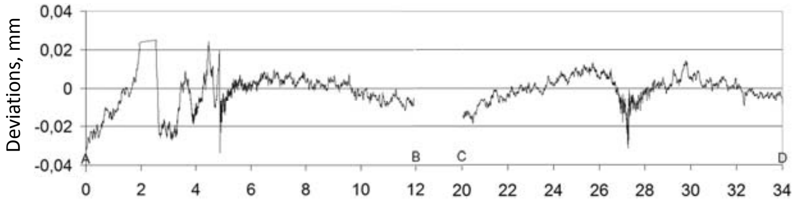


Fig. 10. Deviations of measured contour from the theoretical (design) shape. Stainless steel, v_f = 1020 mm/m

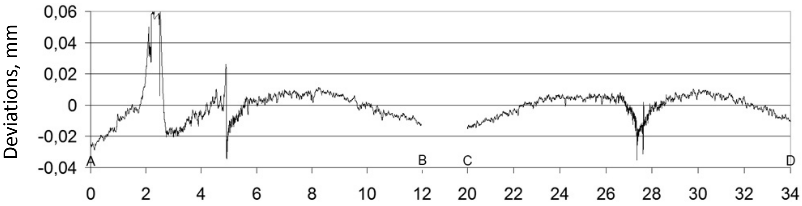


Fig. 11. Deviations of measured contour from the theoretical (design) shape. Stainless steel, v_f = 1360 mm/m

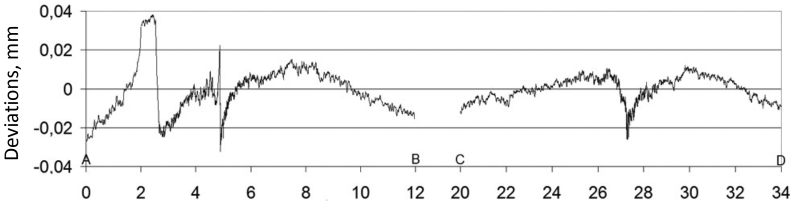


Fig. 12. Deviations of measured contour from the theoretical (design) shape. Stainless steel, v_f = 1700 mm/m

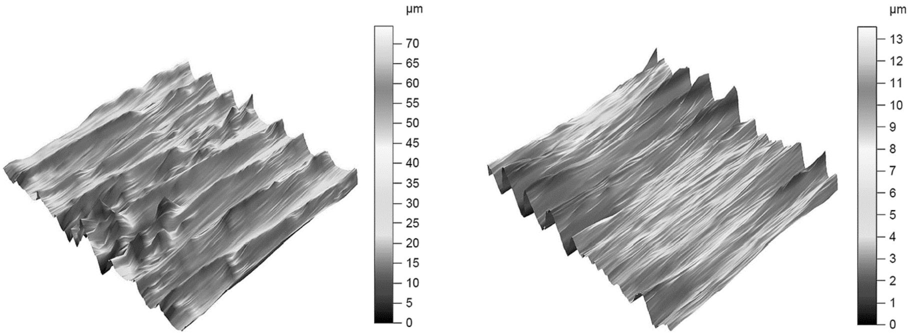


Fig. 13. Surface roughness images as a map of grey intensity. Low carbon steel, *Lc* = 0,8 mm (measured area = 1mm x 1mm): a) v_f = 1800 mm/m, b) v_f = 2400 mm/m

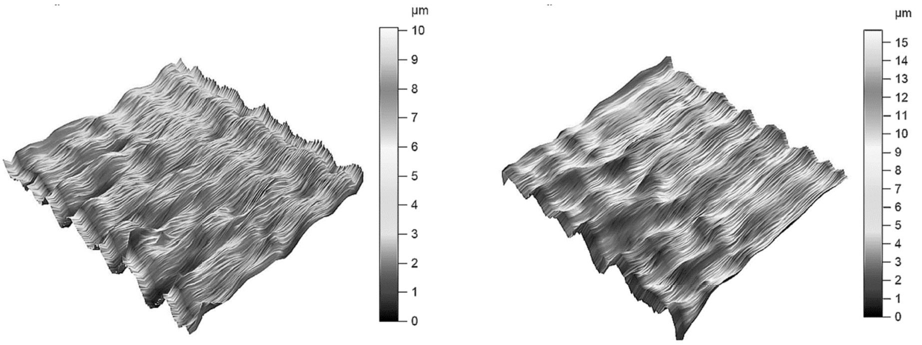


Fig. 14. Surface roughness images as a map of grey intensity. Low carbon steel, *Lc* = 0,8 mm (measured area = 1mm x 1mm): a) v_f = 3000 mm/m, b) v_f = 3300 mm/m

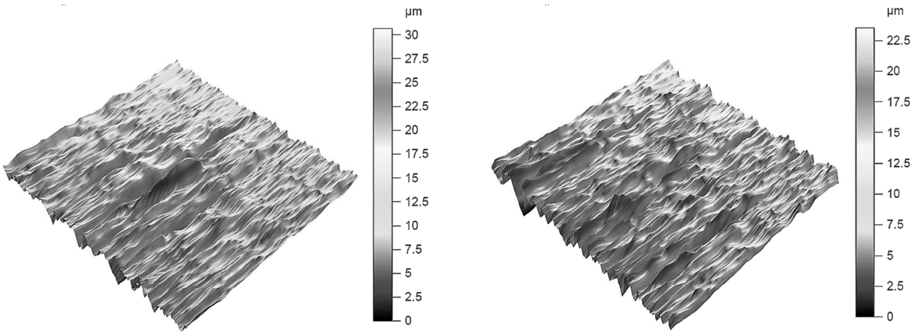


Fig. 15. Surface roughness images as a map of grey intensity. Stainless steel, *Lc* = 0,8 mm (measured area = 1mm x 1mm):: a) v_f = 1020 mm/m, b) v_f = 1360 mm/m

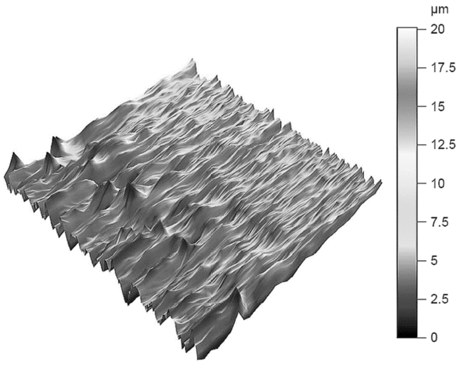


Fig. 16. Surface roughness images as a map of grey intensity. Stainless steel, *Lc* = 0,8 mm, v_f = 1700 mm/m (measured area = 1mm x 1mm)

3. Conclusions

Laser cutting as an effective technology for metal cutting of sheet is frequently used. During the tests, workpiece profiles with high dimensionally repeatability were obtained. Shape deviations did not exceed the value of ± 0.03 mm for low carbon steel (Fig. 6-9) and ± 0.02 mm for stainless steel (Fig. 10-12).

Influence of the cutting speed on the dimensionally accuracy of the cut profile was small. Figure 17 presents the influence of the cutting speed on the angle between formed surface and the surface layer of the workpiece. Workpieces machined with speed 2400 mm/min (low carbon steel) and 1700 mm/min (stainless steel) have the minimum values of this angle. Microscope pictures made in place marked by letter “E” in Fig. 5a for this case is presented in Fig. 18a. The maximum values of this angle can be found for speed 3300 mm/min (low carbon steel) and 1360 mm/min (stainless steel). Figure 18b shows the Microscope pictures for case of maximum values of this angle.

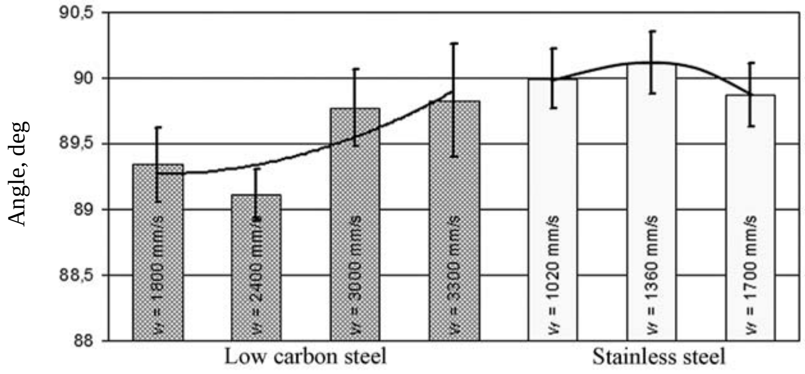
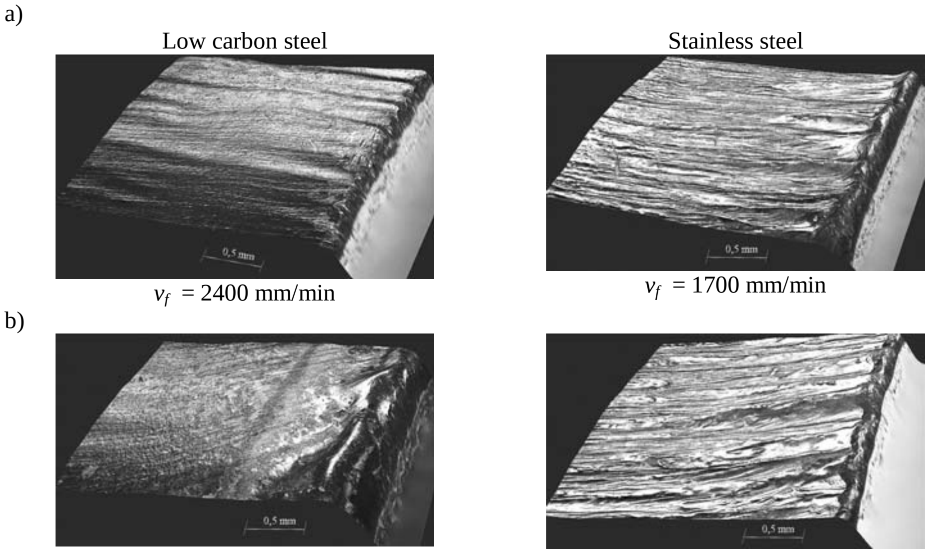


Fig. 17. The influence of the cutting speed on the angle between formed surface and the surface layer of the workpiece

Results of studies indicate the impact of cutting speed on the machined surface roughness (Fig. 13-16). It was observed that the values of the selected surface roughness parameters decreases with increasing of the cutting speed. The values of selected surface roughness parameters for different cutting speeds are shown in Fig. 19.



v_f = 2400 mm/min v_f = 1700 mm/min

v_f = 3300 mm/min v_f = 1360 mm/min

Fig. 18. Microscope pictures of workpiece's surface after laser cutting in the place marked by letter "E", see Fig. 5a, for the case of: a) minimum, b) maximum values of the angle between formed surface and the surface layer of the workpiece

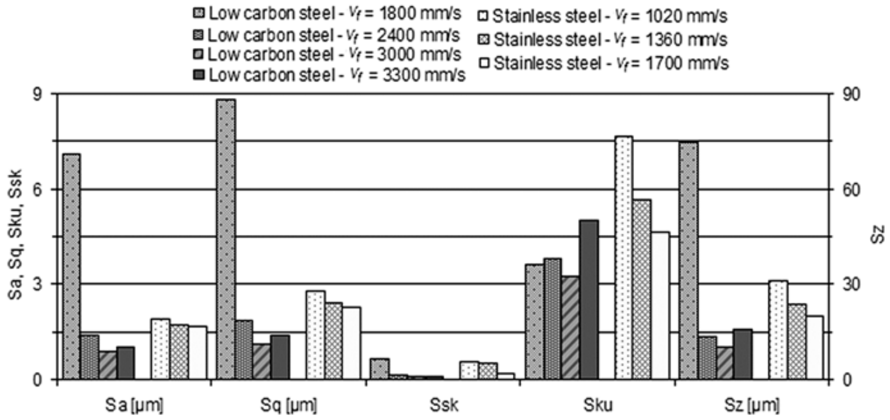


Fig. 19. The values of selected surface roughness parameters for different cutting speeds

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