Measurement of titanium surface roughness created by non-conventional cutting technology

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Abstract

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The paper evaluates the surface roughness quality of the titanium samples created by abrasive waterjet (AWJ) and by CO_2 laser beam cuttings. The introduction describes the principle of the mechanical (contact) method as well as the roughness parameters used for the experiment results evaluation. The following parts summarise the experimental conditions and the measurement methodology. The emphasis of this work is laid on the comparison of machined surfaces final quality for the selected traverse speeds.

Keywords: surface properties; metrology; titanium alloy; roughness measurement

The surface quality control is a very important part of the surface preparation in all types of technologies that are used for their creation (Valíček et al. 2009). Since 1930, when topography meters were invented, great progress has been made in both the methods and measuring equipment. The digital methods implemented in 1960s have enabled the surface evaluation by 3D method (Bumbálek et al. 1989).

MATERIAL AND METHODS

The standardisation of the surface roughness is both a technical and an economic task. Thus, its importance is increasing with the requirements for the precision, efficiency and reliability of the machine components and equipment. All the requirements mentioned depend on many parameters of roughness, mechanical characteristics of the functional surfaces

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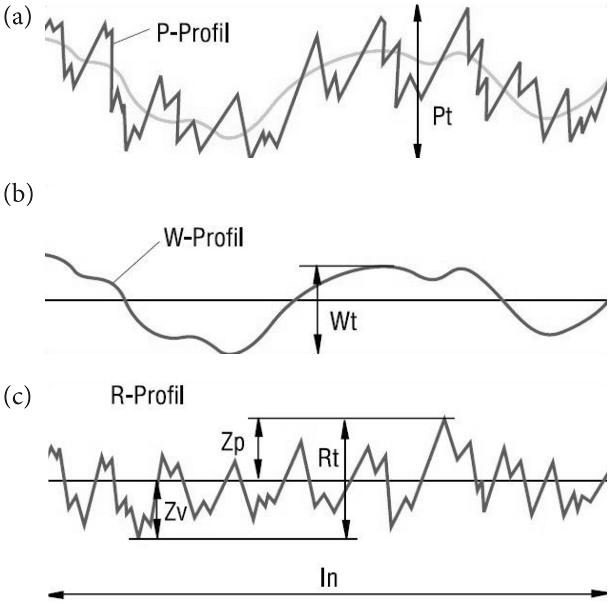

Fig. 1. The profiles according to ČSN EN ISO 4287 (1999) (a) *P* – profile, (b) *W* – profile, (c) *R* – profile

and the method of assembling. The main reason is to improve the lifetime and operational characteristics of the engineering products (Bumbálek et al. 1989).

According to the ČSN EN ISO 4287 (1999) standard, the following surface profiles are distinguished; the basic surface profile *P* (Fig. 1a), the surface waviness profile *W* (Fig. 1b) and the surface roughness profile *R* (Fig. 1c). The basic profile is an ideal smooth surface. The waviness profile is characterised by low frequencies and high amplitudes of the surface roughness. The roughness profile is characterised by high frequencies and low amplitudes of the surface roughness.

The middle arithmetic aberrance of the *Ra* profile is the primary parameter of the surface roughness. It is the average arithmetic value of absolute profile aberrances in the length range. It reflects the time and dimensional dependence of the surface roughness and is determined by the following Eq. 1:

$$Ra = \frac{1}{l_p}\int_0^{l_p}\left|y(x)\right|dx \quad \text{or} \quad Ra \approx \frac{1}{n}\sum_{i=1}^{n}\left|y(x_i)\right| \qquad (1)$$

where

l_p – measured length (m)
$y(x)$ – profile dependence (Bumbálek et al. 1989)
$y(x_i)$ – coordinates of *n* points (Bumbálek et al. 1989) in the length range, $i = 1, 2... n$

The mechanical (contact) method is currently the most used method mainly in engineering (Fig. 2). Its advantage is the direct measurement and the possibility of its use for all surface types (Hlaváček et al. 2009). The analogue recording of the surface topography which is the result of this method can be transformed into digital recording. The values measured by this method are also used in other types of methods (for comparison, etc.). The method also allows measuring the geometric profile of the surface repeatedly and identically (Zeleňák et al. 2009). However, the pressure generated on the prick sensor causes elastic and plastic deformation in the surface layer. The total deformation depends on the surface hardness. Thus, the prick sensor damages the measured surface which influences not only the evaluated surface but also the whole measuring.

As the initial material for the experimental purposes, unalloyed titanium was used with the specification ASTM B265-99 (1999), supplied in the annealed condition. The chemical and mechanical parameters of the titanium are given in Table 1.

Fig. 3 illustrates the cutting heads of the abrasive waterjet (AWJ) and CO_2 laser beams. The technological parameters for the cuttings are given in Table 2.

The surfaces created by AWJ and CO_2 laser beam cutting technologies were measured with a contact profilometer Surftest SJ 401 (Mitutoyo America Corporation, Aurora, USA) (Fig. 4). Each sample was measured in 19 depth traces. The results of the surface irregularities from each trace were obtained, analysed and statistically processed. The measurement was performed on five consecutive fundamental lengths (l_r = 2.5 mm) and the average value of the surface profile roughness *Ra* was determined from the results obtained.

RESULTS AND DISCUSSION

The comparison of the roughness parameters obtained by the AWJ and CO_2 laser cutting technologies (Fig. 5) shows that the AWJ technology achieved five times lower *Ra* values than were those obtained with CO_2 laser cutting, thus indicating that the AWJ

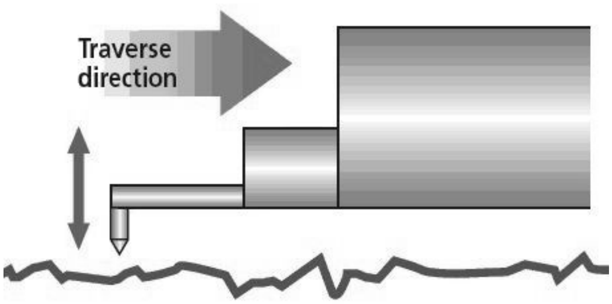

Fig. 2. The principle of sensor contact profilometer

Table 1. Chemical a mechanical parameters of ASTM B265-99

Fe	C	O	H	N
0.2% max	0.08% max	0.18% max	0.015% max	0.03% max
Yield strength 0.2%		Yong's module	Elongation %	
172–310 MPa		103 GPa	25–37	

Table 2. Experimental parameters of abrasive waterjet (AWJ) and CO_2 laser beam cuttings

AWJ				CO_2 laser			
Technological parameter	Sign	Unit	Value	Technological parameter	Sign	Unit	Value
Liquid pressure	p	MPa	370	pressure of inert gas	p_g	MPa	1.7
Water orifice diameter	d_o	mm	0.3	power	P	W	3,500
Focusing tube diameter	d_f	mm	0.8	traverse speed	v	mm/min	350, 450, 550
Focusing tube length	l_a	mm	76	standoff distance	z	mm	1.5
Abrasive mass flow rate	m_a	g/min	250	diameter of beam	d	mm	2
Standoff distance	z	mm	4	output speed of gas	v_p	mm/min	800, 500, 500
Traverse speed	v	mm/min	350, 450, 550	type of inert gas	N_2	–	nitrogen
Abrasive size	–	MESH	80	frequency	f	Hz	0

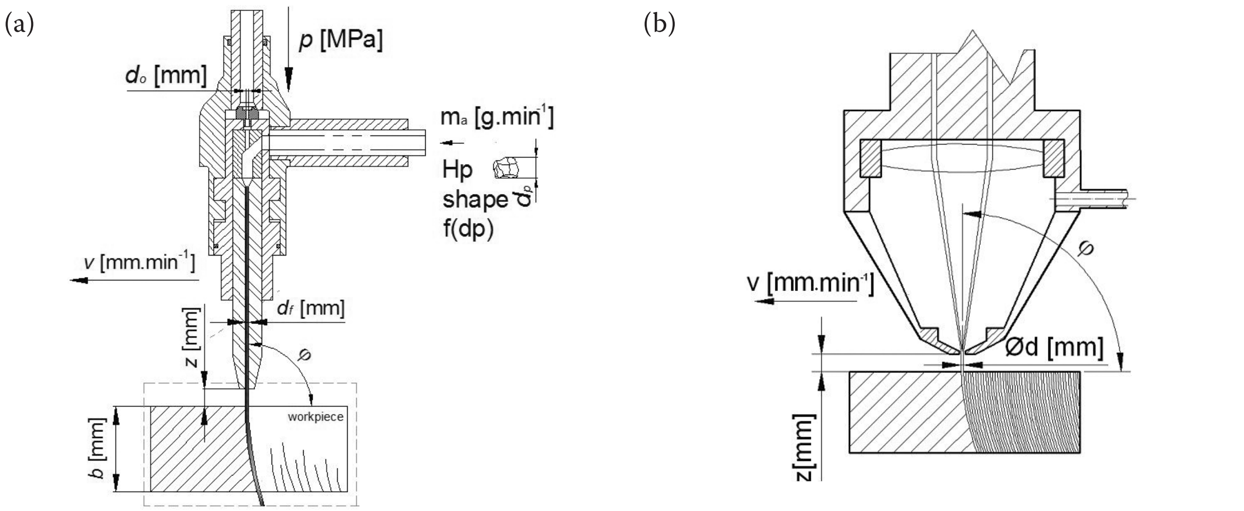

Fig. 3. Details of the cutting head with the target material (a) abrasive waterjet cutting (b) CO_2 laser beam cutting

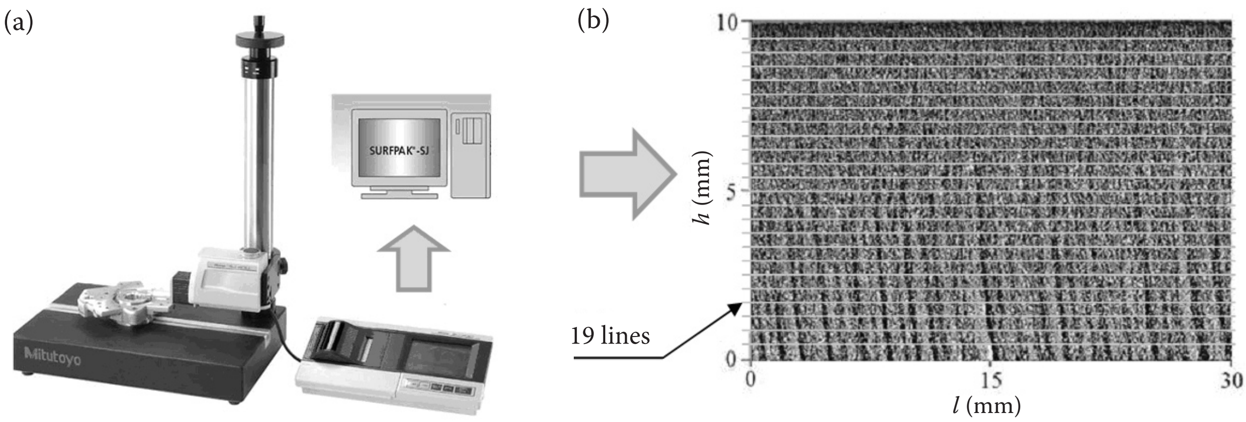

Fig. 4. (a) Contact profilometer SURFTEST SJ 401, (b) photo of the surface measured in 19 lines

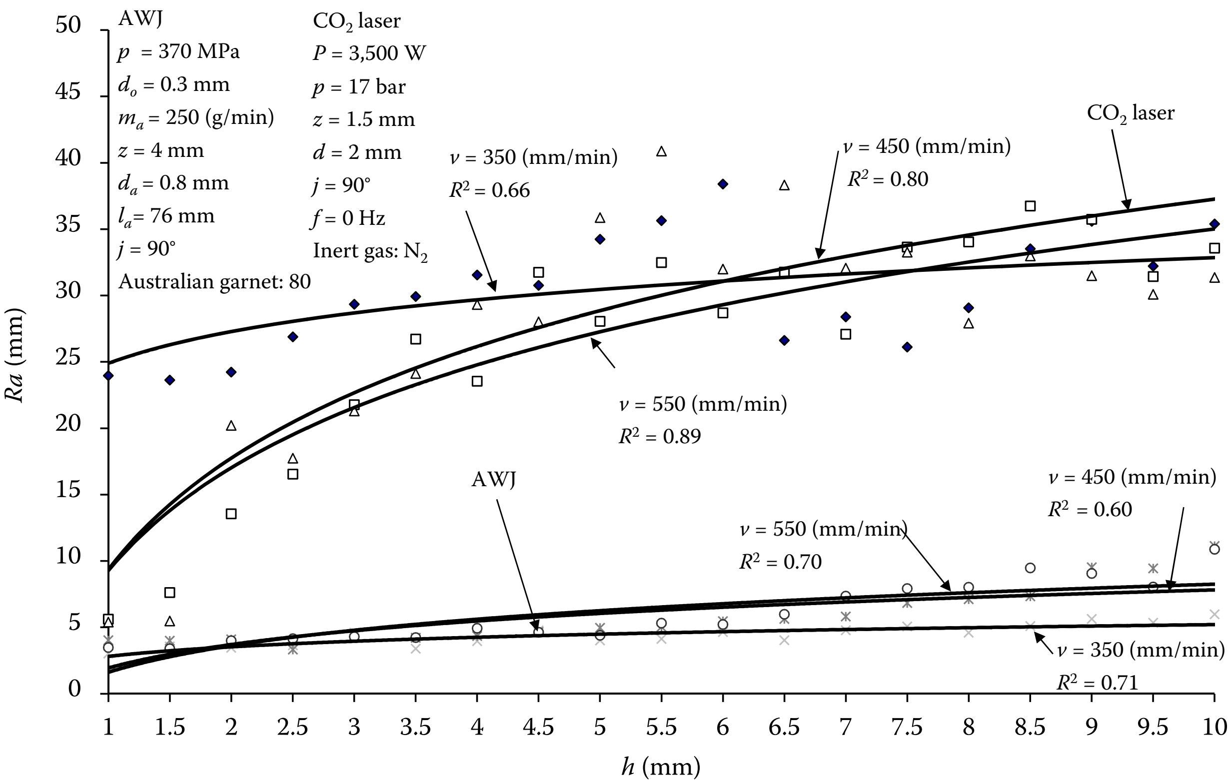

Fig. 5. The dependence of the surface roughness parameter Ra on the depth of cut h for AWJ and CO_2 laser beam cuttings

technology provides a significantly higher quality of the machined surfaces. The CO_2 laser beam cutting technology shows significant differences in the curve behaviour as compared to AWJ technology.

According to Fig. 5, the surface roughness increases with the increasing traverse speed. The behaviour of the curve in AWJ technology shows minimal differences and smooth behaviour at particular speeds, which indicates good optimisation of the cutting process and an appropriate setup of the input.

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