DECREASING THE SURFACE ROUGHNESS OF THE SEATING SURFACES OF BALL VALVES

Vaclav MUSIL [1], Marek SADILEK [1], Robert CEP [1], Lenka CEPOVA [1], Jiri KRATOCHVIL [1], Lukas KUSNIR [1]

[1]*VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU*
vaclav.musil@vsb.cz

Abstract

The article deals with the evaluation of the functional surfaces of the ball valve body. It deals with the finishing methods when machining parts of the ball valve assembly. Above all, it is good practice to achieve a reduced roughness of the machined seating surfaces and areas where a special sealing element will be used. From the offered variants of surface finish machining methods, emphasis is placed on turning technology, so called fine turning. Experimental machining is aimed to achieve the required surface roughness (parameter Ra less than 0.2μm) directly after the finishing operation.

Keywords: Ball valves, roughness, finishing methods, surface finish, machining, cermet

1. INTRODUCTION

A cryogenic ball valve is a shut-off valve that serves to fully open or close the flowing medium, see **Figure 1**. The flowing mediums are either non-aggressive or aggressive liquids or gases without mechanical impurities within the temperature range of -42 ° C to -273 ° C. When working under these conditions, there is a clear requirement for a long service life whilst keeping regular service checks to a minimum. Such service intervention on the equipment may stop the entire piping system. Most leaks occur due to wear of the sealing elements. In order to achieve the highest possible service life, high emphasis is placed on reducing the surface roughness of the contact surfaces to minimize the abrasive wear of the sealing elements.

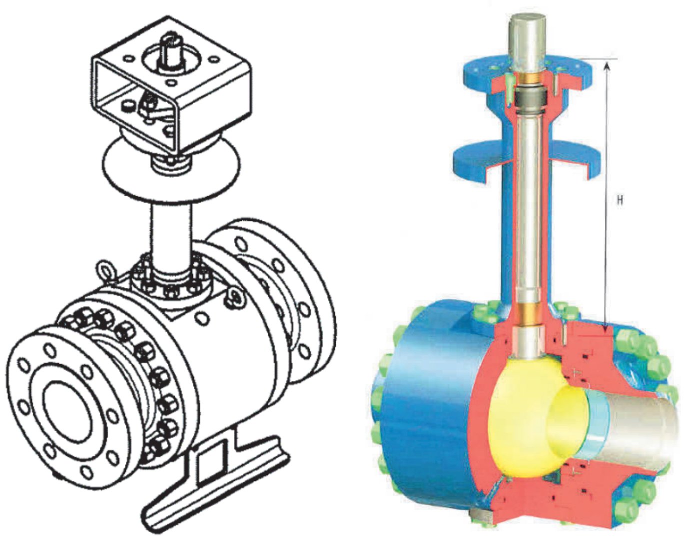


Figure 1 3D View of the K92 type ball valve assembly for cryogenic use

The ball valve assembly consists of a number of standardized parts and the following parts that need to be machined, such as: body, lid, bottom pin, attachment, STEM control pin, stuffing box, stuffing lid, seating and ball. Said components are machined in a conventional manner, however the bearing surfaces of the body, lid, bottom pin and ball valve attachment require a higher quality of their machined surfaces. See cross section in **Figure 2**. These surfaces require further finishing to achieve the roughness within the parameter Ra = 0.1 to 0.2 µm as opposed to the original roughness after machining of Ra = 1 µm [1].

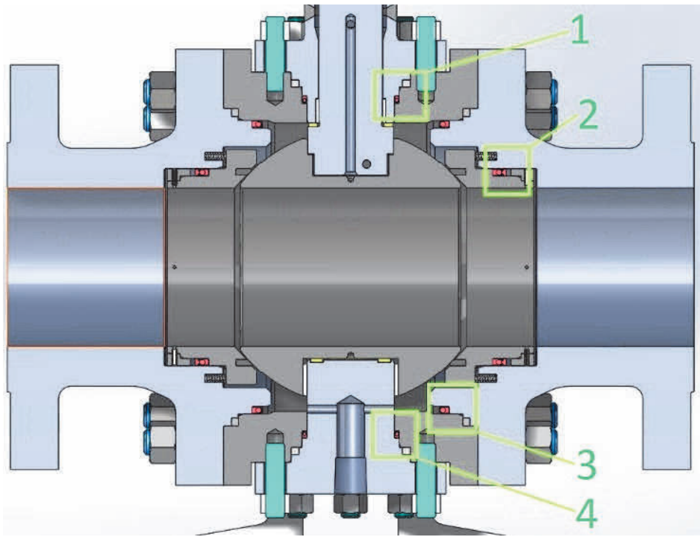


Figure 2 A spherical valve cross section with construction nodes
(1st area - attachment / body; 2nd area - seating / lid; 3rd area - lid / body; 4th area - lower pin / body)

The core part of the assembly is a ball valve body on which there are a total of 4 surfaces to be machined with the surface roughness criterion Ra of 0.1 to 0.2 µm. The machined surfaces are shown in **Figure 3**. The required roughness does not need to be adhered to within 2 mm from the start or end of the runout.

Area	Required diameter	Required surface roughness
1	$\emptyset 61.2$ H11	Ra 0.1 ÷ 0.2 µm
2	$\emptyset 185^{+0.2}_{+0.1}$	Ra 0.1 ÷ 0.2 µm
3	$\emptyset 61.2$ H11	Ra 0.1 ÷ 0.2 µm
4	$\emptyset 185^{+0.2}_{+0.1}$	Ra 0.1 ÷ 0.2 µm

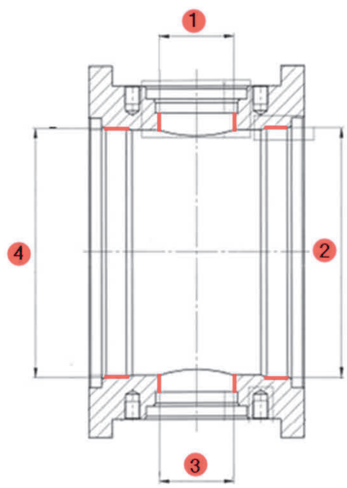


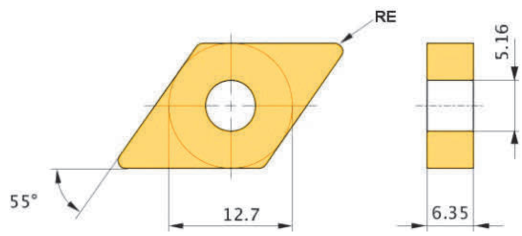
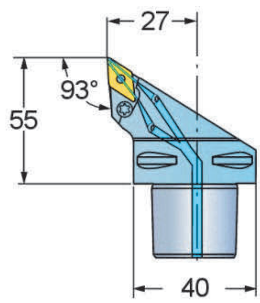
Figure 3 Detail of the required machining on the ball valve body

The theoretical shape of roughness serves only for the basic orientation in surface formation and is of little practical significance because surface roughness is influenced by a number of factors occurring during the machining process e.g.: plastic deformation in the area of chip formation, dynamic phenomena - vibrations arising within the machine-tool-workpiece - lubricant system, creating edges on a minor cutting edge, friction of the cutting tool edge against the machined surface.

In summary, the following aspects influence the roughness of the machined surface during the machining process: cutting conditions (especially feed rate, cutting depth, cutting speed), tool wear, machinery used (dynamics), securing of the workpiece (positioning) - (causing vibration), cutting tool alignment (causing vibration).

In general, fine machining can be achieved with a roughness parameter of Ra of 0.4 to 0.8 μm and IT of 4 to 6. It involves the use of cubic nitride of boron, ceramics or diamond cutting tools, together with high cutting speed. However, the authors of the article try to achieve a better roughness after machining, namely Ra 0.1 to 0.2 μm [2, 3].

Table 1 Technological parameters of the cutting process [5, 6]

Machine	DMG MORI NLX2500MC/700	
Control system	Mitsubishi M730BM	
Material of workpiece	F 304L (EN 10088-3: 1.4307)	
Clamping	Three-jaw chuck Kitagawa 10”	
Tool - inserts	Producer: Mitsubishi Materials DNMG1506-04 (RE = 0.4 mm) DNMG1506-08 (RE = 0.8 mm) DNMG1506-12 (RE = 1.2 mm)	
Tool holder	Producer: Sandvik C4-PDJNR-27055-15HP 	

2. EXPERIMENT DESCRIPTION

The experiment was designed for a DMG MORI NLX2500MC / 700 machine. Detailed information about the machine is given in **Table 1**. The machined material is chromium-nickel austenitic steel F304L marked 1.4307 according to EN 10088-3. Based on previous experience, CERMET's specifically-designed DNMG1506 series interchangeable cutting inserts manufactured by Mitsubishi Materials were the most suitable tool material. The cutting inserts differed only in the radius of the tool tip (RE). The detailed proposed experimental conditions are shown in **Table 2** [4].

Table 2 Cutting conditions of finishing milling operation

Experiment no.	Tool	Radius of the tool tip RE [mm]	Cutting speed v_c [m·min^{-1}]	Feed per revolution f_n	Axial cutting depth a_p
1	DNMG1506-04	0.4	200	0.05	0.3
				0.07	
				0.09	
			275	0.05	
				0.07	
				0.09	
			350	0.05	
				0.07	
				0.09	
2	DNMG1506-08	0.8	200	0.05	0.3
				0.07	
				0.09	
			275	0.05	
				0.07	
				0.09	
			350	0.05	
				0.07	
				0.09	
			425	0.03	
				0.04	
				0.05	
			500	0.03	
				0.04	
				0.05	
3	DNMG1506-12	1.2	200	0.05	0.3
				0.07	
				0.09	
			275	0.05	
				0.07	
				0.09	
			350	0.05	
				0.07	
				0.09	
			425	0.06	
				0.07	
				0.08	
			500	0.06	
				0.07	
				0.08	

3. MEASURING RESULTS

The resulting surface roughness measurement was carried out using the HOMEL device, which was clamped directly into the head of the machine tool (see **Figure 4**). Detailed technical data for the measurements are given in **Table 3**. Each resulting machined area was measured five times and the average mean roughness of the surface was then calculated. The resulting roughness parameters are shown in the graphs below.

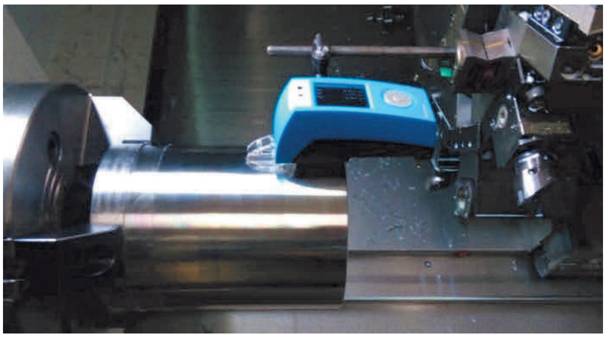


Figure 3 Picture of the surface roughness parameters measurement

Table 3 Conditions of measurement [7]

Device name	Wavelength limit lc [mm]	Base length lt [mm]	Feed speed vt [mm·s^{-1}]	Alignment L [mm]
HOMEL	0.8	4.8	0.5	175

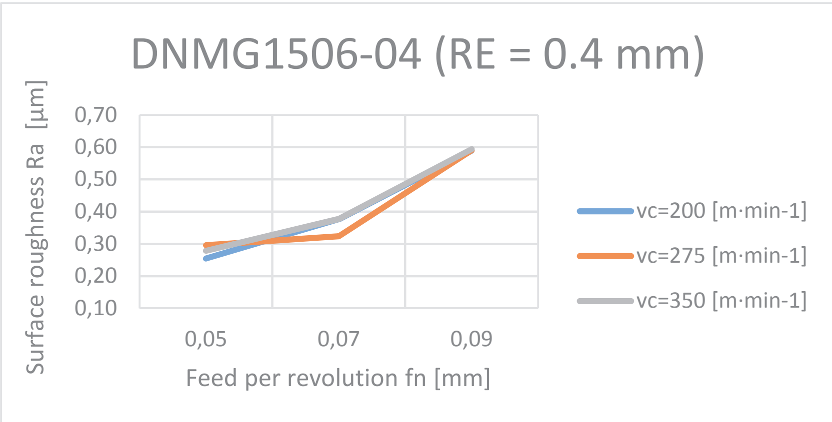


Figure 4 Final roughness of surface for DNMG1506-04 insert

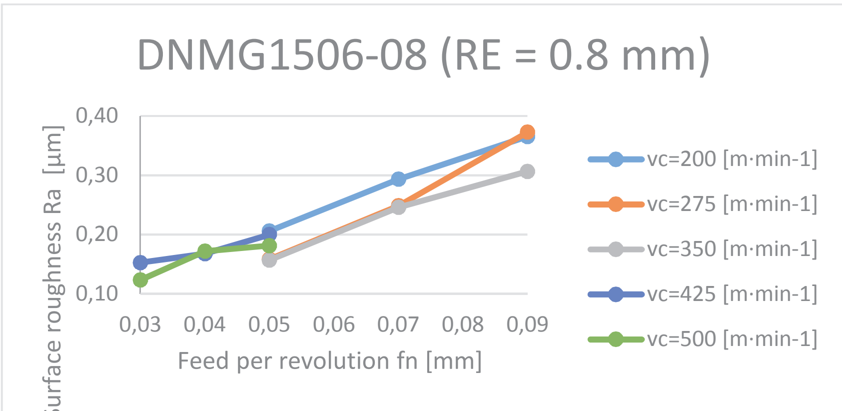


Figure 5 Final roughness of surface for DNMG1506-08 insert

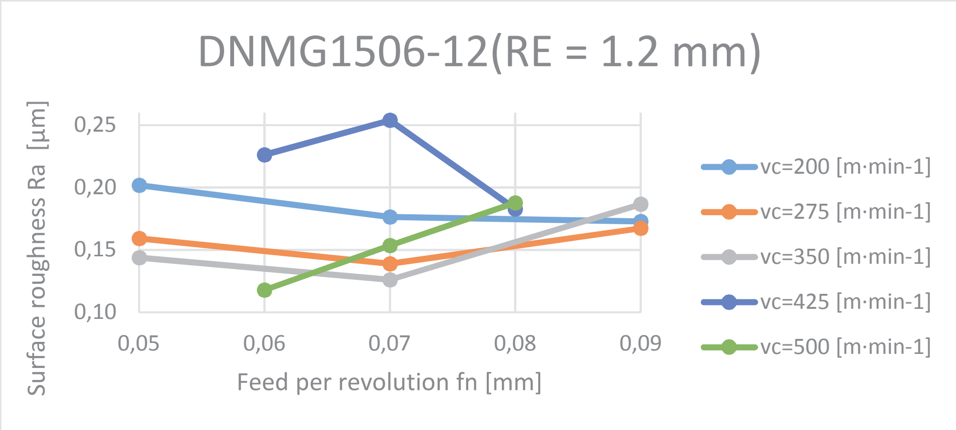


Figure 6 Final roughness of surface for DNMG1506-12 insert

4. CONCLUSION

The experiment disproved the theoretical assumption that machining would only achieve a maximum surface roughness of Ra = 0.4 µm. The experiment proved that the desired roughness parameter Ra = 0.1 ÷ 0.2 µm can be achieved by choosing a suitable cutting tool and operating within ideal cutting conditions. Initially, an experiment was performed using the DNMG1506-04 Interchangeable cutting insert with a Radius of RE = 0.4 mm. This experiment failed to achieve the required surface roughness. For the second experiment, a DNMG1506-08 interchangeable cutting insert with a radius of RE = 0.8 mm was used. At a lower cutting speed (v_c = 200 ÷ 350 m·min^{-1}) and a higher feed rate, the resulting surface roughness was in the range of 0.157 ÷ 0.373 µm. With these cutting parameters, the required roughness was achieved, but the process was unstable. For this reason, the cutting speed was increased to a value of v_c = 500 m·min^{-1} and the feed rate was reduced. When selecting these cutting parameters, the surface roughness Ra of 0.123 ÷ 0.2 µm was achieved. These cutting parameters were judged to be satisfactory because the resulting roughness surface was always of the required quality. The third experiment was performed with a DNMG1506-12 interchangeable cutting insert with a radius of RE = 1.2 mm. With a lower cutting speed (v_c = 200 ÷ 350 m·min^{-1}) and a change in feed rate, there was a minimal change in the resulting surface roughness, and the whole process was stable and resulting roughness of the surface within the desired quality. The lowest surface roughness was achieved using the cutting speed of v_c = 500 m·min^{-1} and feed of f = 0.06 mm. However, as the feed rate increased, the surface roughness deteriorated significantly.

ACKNOWLEDGEMENTS

Article has been done in connection with projects Education system for personal resource of development and research in field of modern trend of surface engineering - surface integrity, reg. no. CZ.1.07/2.3.00/20.0037 financed by Structural Founds of Europe Union and from the means of state budget of the Czech Republic and by project Students Grant Competition SP2018/150 and SP2018/136 financed by the Ministry of Education, Youth and Sports and Faculty of Mechanical Engineering VŠB-TUO.

REFERENCES

[1] STANCEKOVA, D., KURNAVA, T., SAJGALIK, M., NAPRSTKOVA, N., STRUHARNANSKY, J., SCOTKA, P. Identification of machinability of ceramic materials by turning. In. *Manufacturing Technology*, Žilina: Žilinská univerzita, Strojnícka fakulta, 2014, pp. 91- 97.

[2] SADÍLEK, M., ČEP, R., SADÍLKOVÁ, Z., VALÍČEK, J., PETŘKOVSKÁ, L. Increasing tool life during turning with variable depth of cut. *Materials and Technology*, 2013, vol.47, no.2, pp.199-203.

[3] STĘPIEŃ, K. In situ measurement of cylindricity-Problems and solutions. *Precision Engineering*, 2014, vol. 38, no. 3, pp. 697-701.

[4] MRKVICA, I., KONDERLA, R., FAKTOR, M. Turning of Inconel 718 by Cemented Carbides. In MORGAN, M. M., SHAW, A., MGALOBLISHVILI, O. Precision Machining VI. *Key Engineering Materials*, 2012, vol. 496, p. 112-141.

[5] SANDVIK COROMANT. General Turning. 2014. [Online] [q. 2015-05-10]. Available from WWW: https://www.sandvik.coromant.com/cs-cz/knowledge

[6] DMG MORI. CNC univerzální soustruh (universal CNC machine lathe) NLX 2500MC/700. [Online].[q. 2015-04-24]. Available from WWW: <http://cz.dmgmori.com/products/lathes/universal-lathes/nlx/nlx2500+700>

[7] MICIETOVA, A., NESLUSAN, M., CILLIKOVA, M. Influence of surface geometry and structure after non-conventional methods of parting on the following milling operation. *Manufacturing Technology*, 2013, vol. 13, no. 2, pp. 199-204.